Rules for Building and Classing

Underwater Vehicles, Systems and Hyperbaric Facilities

ABS

January 2025

RULES FOR BUILDING AND CLASSING

UNDERWATER VEHICLES, SYSTEMS AND HYPERBARIC FACILITIES
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Foreword *(2021)*

The 2021 edition of the *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities* incorporates all Rule Changes and Corrigenda items since 2020. Requirements for underwater habitats and complexes have been added.

- 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 ambient pressure submersibles.
- Section 14 provides the specific requirements that are applicable to diving systems.
- Section 15 provides the specific requirements that are applicable to Hyperbaric Facilities.
- Section 16 provides the specific requirements that are applicable to atmospheric diving suits.
- Section 17 provides the specific requirements that are applicable to underwater habitats and complexes.
- Section 18 provides the specific requirements that are applicable to remotely operated vehicles.
- Section 19 provides the specific requirements that are applicable to autonomous underwater vehicles.
- Section20 provides the specific requirements that are applicable to handling systems.
- Section 21 provides the specific requirements that are applicable to dive control stations.
- Section 22 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.

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UNDERWATER VEHICLES, SYSTEMS AND HYPERBARIC FACILITIES

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SECTION 1

Scope and Conditions of Classification

See Chapters 1 and 7 of the separate ABS *Rules for Conditions of Classification (Part 1A)* for the requirements for conditions of classification for underwater vehicles, systems, and hyperbaric facilities.

SECTION 2

Definitions *(2016)*

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.

24 Hyperbaric Diving Simulator *(2021)*

A hyperbaric facility used for simulating diving conditions and intended for one or more of the following applications:

i) Simulating working dives

ii) Training divers

iii) Conducting manned or unmanned tests

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 Underwater Habitat *(2019)*

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 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 *(2021)*

A facility typically comprising of a PVHO or combination of PVHOs, along with the associated systems, equipment and machinery, intended for operation with human occupancy at internal pressure above atmospheric. Based on the intended application, hyperbaric facilities may include additional components such as test chambers, handling systems, etc.

42 Hyperbaric Reception Facility (HRF) *(2021)*

A hyperbaric facility that is capable of accepting and mating with Hyperbaric Evacuation Units (HEUs) in order to facilitate the pressurized transfer of the HEU occupants, and to allow subsequent decompression of those occupants.

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 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 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 14.)

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 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 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 *(2019)*

A complex comprising of any combination of underwater 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 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 *(2020)*

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 8/25.

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 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 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.

5 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.

7 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 NAVSEA Technical Publication T9074-BD-GIB-010/0300; 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 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 4/5.3.1 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 4/5.3.1 TABLE 1.

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)*.

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.

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.	¼ *t*	¼ *t*
Over 12.5 (0.5) to 19 (0.75), incl.	3.2 (⅛)	¼ *t*
Over 19 (0.75) to 38 (1.5), incl.	3.2 (⅛)	4.8 ($^3/_{16}$)
Over 38(1.5) to 51(2.0), incl.	3.2(⅛)	⅛ *t*
Over 51(2.0)	$^1/_{16}$ *t* (9.5 (⅜) max.)	⅛ *t* (19 (¾) 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 5/13 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 27kg/mm^2 (38,000 psi) < Yield Strength ≤ 42kg/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 6/15.

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 *Requirements for Nondestructive Testing (NDT Requirements)*. 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 *NDT Requirements* 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 *NDT Requirements*. 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.)
$1/3\ t$	for t from 19 mm ($3/4$ in.) to 57 mm ($2 1/4$ in.)
19mm ($3/4$ 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 4/3.1.ii are to be taken from 2-5-A1/3.11 TABLE 1 of the ABS *Rules for Materials and Welding (Part 2)*.

9.3.2 Other Alloys and Tempers

Tensile and yield strengths for welded aluminum alloys and/or tempers not listed in 4/3.1.ii, 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 Design Geometry

11.1 Measurements *(2015)*

Upon completion of fabrication and heat treatment, deviations from design geometry are to be measured before and after hydrostatic testing. The procedure for taking the measurements is to be submitted to the ABS Technical Office for review.

The measurements are to be conducted to the Surveyor's satisfaction, and the results are to be submitted to the ABS Technical Office 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 5/13 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 5/13 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 5/13 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 above 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 *(2015)*

Measurements are to be taken at a sufficient number of data points that cover the geometry of the pressure hull or PVHO as determined by the designer and approved by ABS. Additional measurements as required at the discretion of the Surveyor. For conical sections, the measurement locations specified above are to also include those listed in 5/11.3.2.

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.

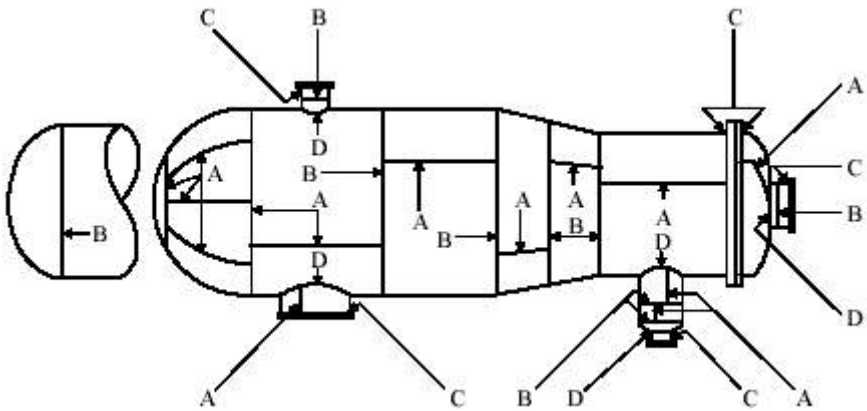
11.9.3 *(2015)*

If repairs are needed to bring the completed pressure hull or PVHO within above requirements, they are to be carried out with any approved process which will not impair the strength of the pressure hull or PVHO. 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 asphere, 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 transitionsin diametr, to nozzles or to communicating chambers.

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

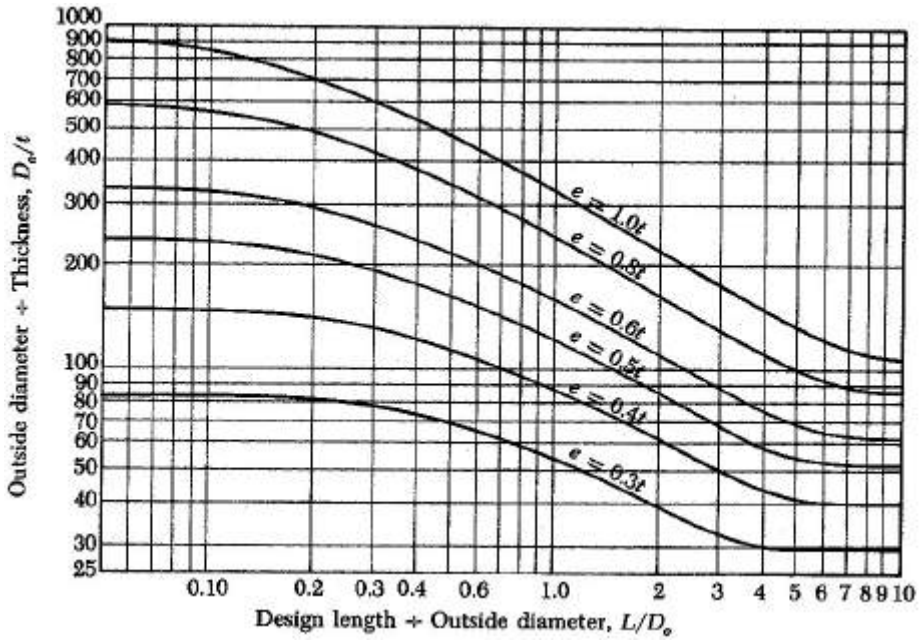


FIGURE 3
Arc Length

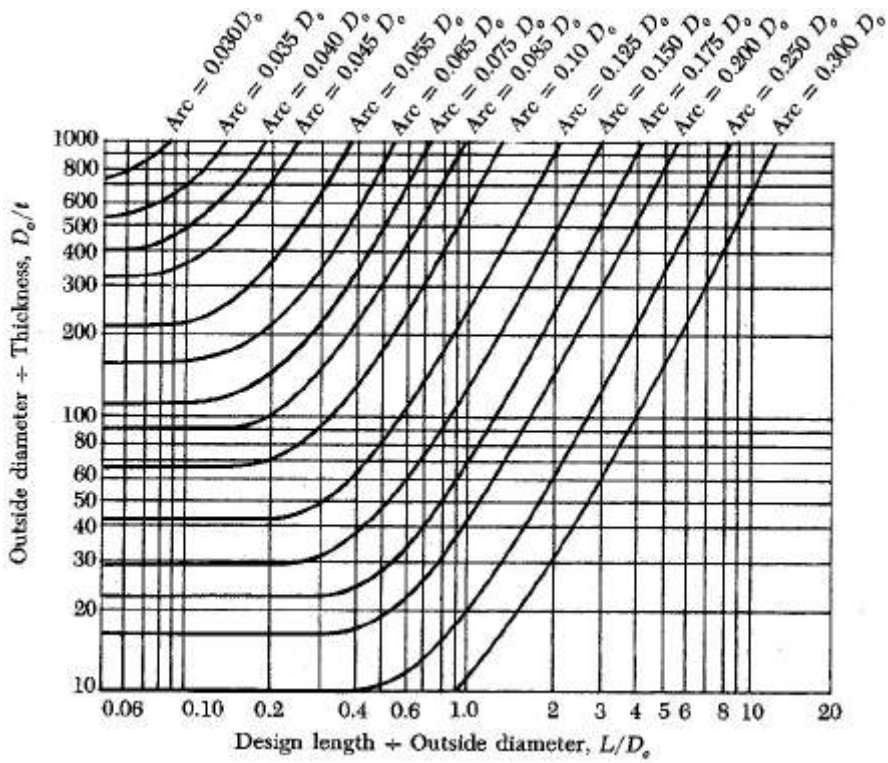
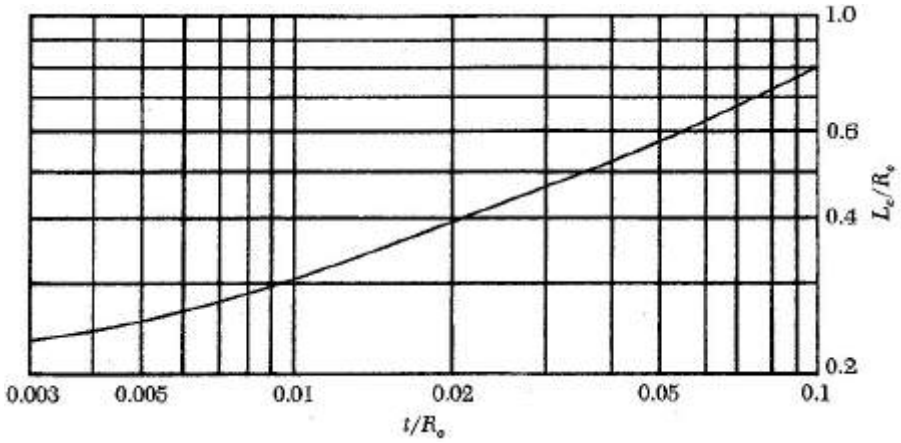


FIGURE 4
Values of Chord Length (L_c) for Out-of-roundness of Spheres



SECTION 6

Metallic Pressure Boundary Components

1 General *(2025)*

Metallic pressure boundary components are to comply with this section.

The design requirements in this section are predicated on compliance with the out-of-roundness and fabrication tolerances specified under Section 5. Where these tolerances are exceeded, the design will be evaluated on a case-by-case basis by ABS Engineering.

A consistent set of units is to be used for the design calculations for metallic pressure boundary components.

2 Design

2.1 Design Pressures and Loads *(2025)*

Metallic pressure boundary components are to be designed for all anticipated pressures and loads that may act on the pressure boundary under normal and emergency operating conditions. These can include, but are not limited to:

i) Internal and/or external pressures

ii) Loads due to external forces and impacts

iii) Mating loads (see 6/2.2 below)

iv) Lifting loads (see 6/2.3 below)

v) Nozzle loads due to external manway/piping connections

vi) Loads due to localized reactions (see 6/2.4 below)

vii) Loads due to discontinuities (see 6/2.5 below)

viii) Loads due to expansion/contraction of pressure boundaries

ix) Deadweight of installed equipment

x) Weight of entrapped water/mud

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

Commentary:

The requirements under Section 6 of these Rules are not intended to address shock loads due to underwater explosions (i.e., UNDEX loads). For UNDEX loads, refer to the requirements of Naval Technical Administrations.

End of Commentary

2.2 Mating Loads

Where pressure hulls and pressure vessels for human occupancy (PVHOs) are used for mating operations, they 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.

2.3 Lifting Loads *(2025)*

Where pressure hulls and pressure vessels for human occupancy (PVHOs) are launched and recovered at sea, their primary lifting lugs and lifting attachments 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.

2.4 Localized Reactions

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

2.5 Discontinuities

Localized stresses resulting from geometric discontinuities are to be analyzed.

2.6 Load Cases *(2025)*

The designer/builder is to develop the load cases for the design analysis of the pressure boundary based on the worst-case pressures and loads that can act independently or simultaneously, as applicable to the underwater unit. The load cases, as well as the assumptions and justification used for developing the load cases, are to be submitted to ABS Engineering for review.

3 Design for Internal Pressure *(2025)*

3.1 Internal Pressure *(2025)*

Metallic pressure boundary components subject to internal pressure are to comply with the requirements applicable to Group I pressure vessels in Part 4, Chapter 4 of the *Marine Vessel Rules*.

3.2 Reinforcement *(2025)*

Penetrations are to be reinforced in accordance with Part 4, Chapter 4 of the *Marine Vessel Rules*. All reinforcement is to be integral with shell and nozzle walls. Reinforcement pads are not to be used.

3.3 Non-Pressure Loads *(2025)*

In addition to internal pressure, metallic pressure boundary components are to be also analyzed for non-pressure loads (see Subsection 6/2 above). The calculated stresses are not to exceed the following limits:

Commentary:

The limits below apply when the pressure boundary is analyzed for non-pressure loads acting independently, or in combination with external pressure and other non-pressure loads.

End of Commentary

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

3.4 Alternative Standards/Codes *(2025)*

As an alternative to compliance with the internal pressure requirements above (see 6/3.1, 6/3.2 and 6/3.3 above), metallic pressure boundary components can comply with recognized national or international pressure vessel standards or codes that are not less effective than the Rules.

4 Design for External Pressure

4.1 External Pressure *(2025)*

Metallic pressure boundary components are to be analyzed for external pressure using the applicable requirements specified under Subsections 6/8 through 6/11 of these Rules.

4.2 Reinforcement *(2025)*

Penetrations are to be reinforced in accordance with Part 4, Chapter 4 of the *Marine Vessel Rules*, except that the reinforcement area need only be 50 percent of that required by these Rules. All reinforcement is to be integral with shell and nozzle walls. Reinforcement pads are not to be used.

4.3 Non-Pressure Loads *(2025)*

In addition to external pressure, metallic pressure boundary components are to be also analyzed for non-pressure loads (see Subsection 6/2 above). The calculated stresses are not to exceed the limits specified in 6/3.3 above.

4.4 Alternative Standards/Codes *(2025)*

As an alternative to compliance with the external pressure requirements above (see 6/4.1, 6/4.2 and 6/4.3 above), metallic pressure boundary components can comply with recognized national or international pressure vessel standards or codes that are not less effective than the Rules.

5 Fatigue *(2025)*

For pressure hulls and pressure vessels for human occupancy (PVHOs), a fatigue analysis in accordance with a recognized national or international pressure vessel standard or code is to be submitted for review.

The fatigue life of pressure hulls and PVHOs is to be documented in the Operations/Maintenance Manuals of the underwater unit.

6 Corrosion *(2025)*

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. Alternatively, protective coatings or sacrificial anodes are to be provided to prevent corrosion of the pressure boundary. (See 4/7.1)

7 Definition and Determination of Yield Point and Yield Strength

7.1 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.

7.3 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.

8 Nomenclature

8.1 General

P Applied External Pressure

η Usage Factor

8.3 Material Properties

E Modulus of Elasticity

ν Poisson's ratio

σ_y specified minimum yield point or yield strength

8.5 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

8.7 Shell Parameters

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

$$Q = \theta/2$$

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

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

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

Note:
Other symbols are defined where used.

9 Cylindrical Shells Under External Pressure

9.1 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

9.3 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

9.5 Inter-Stiffener Strength

9.5.1

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

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

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

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

where

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

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

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

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

$A = A_s(R/R_s)^2$ 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 $\eta = 0.80$

9.5.2

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

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

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

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

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

9.7 Unstiffened Cylinders

Unstiffened cylinders are to be assessed using the inter-stiffener strength expressions given in 6/9.5.1 considering $F = 0$. L is to be taken as L_c (See 6/9.9). The axial length of a conical section adjacent to the cylinder(s) is to be included in the value of L_c (See 6/13.9 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.

9.9 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 6/13.9 FIGURE 2.

9.11 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 6/9.15.2.

9.13 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

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

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

$$A_2 = n^2 - 1$$

The number of lobes, n, expected at failure is a positive integer, 2 or higher (see 6/13.9 FIGURE 4), that results in the lowest P_n.

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

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

9.15 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.

9.15.1 Non-Heavy Stiffeners

9.15.1(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:

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

where

n = number of overall instability lobes

P_n = corresponding buckling pressure as given in 6/9.13

δ = the 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:

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

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

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

9.15.1(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.

9.15.1(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 $\leq 0.9\sqrt{E/\sigma_y}$

9.15.1(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:

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

9.15.2 Heavy Stiffeners

9.15.2(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:

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

where

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

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

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

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

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:

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

9.15.2(b) Stiffener Tripping.

Item 6/9.15.1(b) is likewise applicable to heavy stiffeners.

9.15.2(c) Local Buckling.

Item 6/9.15.1(c) is likewise applicable to heavy stiffeners.

9.15.2(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:

$$I = PD_o L_c {R_s}^2/\left(6E\eta\right) \qquad \text{where } \eta = 0.50$$

The applicable usage factor η is 0.5.

9.15.3 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.

10 Conical Shells Under External Pressure

10.1 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

10.3 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

10.5 General

Conical shells are to have a half-apex angle, α (see 6/13.9 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 *Marine 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 6/13.9 FIGURE 2).

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

10.7 Inter-Stiffener Strength

10.7.1

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

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

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

$$P_{co} = \tfrac{5}{6}P_{yo} \qquad \text{if } P_{mo}/P_{yo} > 3$$

where

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

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

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

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

$A = A_s(R_b/R_{se})^2$ 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 $\eta = 0.72$

Notes:

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 6/8 and 6/10:

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 6/13.9 FIGURE 5.

10.7.2

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

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

where

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

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

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

10.7.3

The same assessment as in Subparagraphs 6/10.7.1 and 6/10.7.2 above is to be followed for each of the remaining bays of the cone.

10.9 Unstiffened Cones

Unstiffened cones (including unstiffened cones whose ends are bounded by heavy members, see 6/10.13) are to be assessed using the inter-stiffener strength expressions given in 6/10.7.1 considering $F = 0$. L is to be taken as the axial length of the cone (see 6/13.9 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 6/9.7.

10.11 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 6/13.9 FIGURE 2.

10.13 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 6/10.17.2.

10.15 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

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

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

$$A_2 = n^2 - 1$$

The number of lobes, n, expected at failure is a positive integer, 2 or higher (see 6/13.9 FIGURE 4), that results in the lowest P_{no}.

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

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

Notes:

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 6/13.9 FIGURE 5.

10.17 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.

10.17.1 Non-heavy Stiffeners

10.17.1(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 6/10.7 for each bay.

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

where

n = number of overall instability lobes

P_{no} = corresponding buckling pressure as given in 6/10.15

δ = the 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:

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

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 $\eta = 0.50$

10.17.1(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.

10.17.1(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 $\leq 0.9\sqrt{E/\sigma_y}$

10.17.1(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 6/10.7) acting with it, is to be not less than I obtained from the following:

$$I = P\left(2R_b + t\right)LR_{so}^2/\left(6E\eta\cos\alpha\right)$$

where

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

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

The applicable usage factor η is 0.50

10.17.1(e) Remaining Non-Heavy Stiffeners.

The same assessment as 6/10.17.1 above is to be followed for each stiffener considered in 6/10.7 for the remaining conical bays.

10.17.2 Heavy Stiffeners

10.17.2(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.

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

where

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

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

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

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

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

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

$A = A_s(R_c/R_{sx})^2$ 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 $\eta = 0.50$

10.17.2(b) Stiffener Tripping.

Item 6/10.17.1(b) is likewise applicable to heavy stiffeners when R_b is replaced by R_c.

10.17.2(c) Local Buckling.

Item 6/10.17.1(c) is likewise applicable to heavy stiffeners.

10.17.2(d) Inertia Requirements.

The moment of inertia for the combined section, consisting of the stiffener attached to the shell and the effective shell length L_e (see Note in 6/10.15) acting with it, is not to be less than that obtained from the following:

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

where

$R_{sc} = R_{sx}$ for external framing

$R_{sc} = R_{sn}$ for internal framing

The applicable usage factor η is 0.50

10.17.2(e) Transitions.

Heavy stiffeners located at cylinder-to-cone transitions are to be in compliance with both 6/9.15.2 and 6/10.17.2.

10.17.3 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.

11 Spherical Shells Under External Pressure

11.1 Shell Geometry

D mean diameter

D_i inner diameter

D_o outer diameter

R_o outer radius

t shell thickness

11.3 General

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

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

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

where

P_{ys} = $2\sigma_y t/R_o$

R_o = the nominal outside radius of the spherical shell

P_{es} = $\left[2/\sqrt{3\left(1-v^2\right)}\right]E\left(t/R_o\right)^2$

The maximum allowable working pressure is given by:

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

11.5 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.

11.7 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 6/13.9 FIGURE 6)

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

11.9 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 6/13.9 FIGURE 6.) The applicable usage factor η is to be taken as 0.67.

11.11 Shape Limitations

The thickness of hemispherical heads is to be such that $0.0002D \leq t \leq 0.16D$, where D is the mean diameter. Shape limits for ellipsoidal and torispherical heads are shown below. (See 6/13.9 FIGURE 6.)

Ellipsoidal: $0.0002D \leq t \leq 0.80D$

$h \geq 0.18D$

$\ell_h \geq 2t$

Torispherical: $0.0002D \leq t \leq 0.80D$

$h \geq 0.18D$

$\ell_h \geq 2t$

$r \geq 0.06D$

$r \geq 2t$

$R \leq D$

12 Fasteners *(2025)*

i) 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.

ii) Design calculations in accordance with recognized standards or recognized engineering methods are to be submitted for review.

iii) Fasteners are to have adequate strength and corrosion resistance suitable for the intended service.

iv) Round bottom and rolled thread profile fasteners are to be used.

v) *High-Strength Steel Fasteners:* Zinc or Aluminum coated fasteners or Cadmium plated fasteners of tensile strength greater than 150 ksi are not to 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. (*Note:* Under wet conditions, these coatings/platings increase the susceptibility of the fasteners to hydrogen embrittlement.)

13 Proof Testing

13.1 Hydrostatic Testing *(2025)*

i) For pressure hulls or PVHOs that are designed for external pressure, external hydrostatic proof testing is to be conducted in the presence of the Surveyor to a pressure equivalent to 1.25 times the design depth for two cycles. This proof testing is to be conducted after the out-of-roundness measurements have been taken.

ii) For pressure hulls or PVHOs that are designed for internal pressure, internal hydrostatic proof testing to 1.3 times the MAWP for one cycle is to be conducted in the presence of the Surveyor, as per 4-4-1/7.11.2 of the *Marine Vessel Rules*.

iii) For the external and/or internal hydrostatic proof testing, the test pressure is to be maintained for a minimum of 1 hour during each test cycle.

iv) Acrylic components are to be pressure tested in accordance with Section 7 of these Rules.

13.3 Strain Gauging

i) During the external proof testing specified in 6/13.1i), 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.

ii) The strain gauge measurements (for the report referenced below) are to be recorded after shakedown effects associated with the initial external pressurization of the pressure hull or PVHO have ceased.

iii) Upon completion of the proof testing, the designer is to submit a report comparing the calculated stresses versus the measured stresses, in order to validate the design of the pressure hull or PVHO. Differences of over 10 percent (between the calculated and measured stresses) are to be supported by appropriate technical justification.

13.5 Waiver of Strain Gauging *(2025)*

i) Hydrostatic proof testing without strain gauges can be accepted for units that are duplicates of a previously tested unit and have a design depth not greater than the tested unit.

ii) 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 pressure vessel standards or codes having an equal or higher design margin (i.e., factor of safety) may be accepted without strain gauging. (*Note:* This does not preclude the use of design standards having a lower factor of safety. Also see 6/13.9 and Subsection 6/1 of these Rules.)

13.7 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.

13.9 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 6/13.3 and 6/13.5. Post-test examination is to be in accordance with 6/13.7, except that the acceptance criteria are to be in accordance with the standard used.

FIGURE 1
Illustrative Hull Components

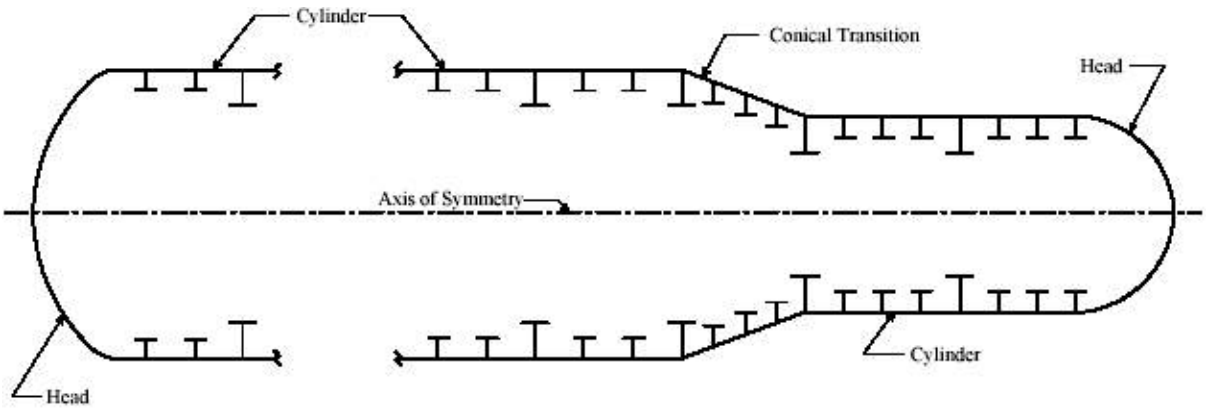


FIGURE 2
Definitions –Compartment Length

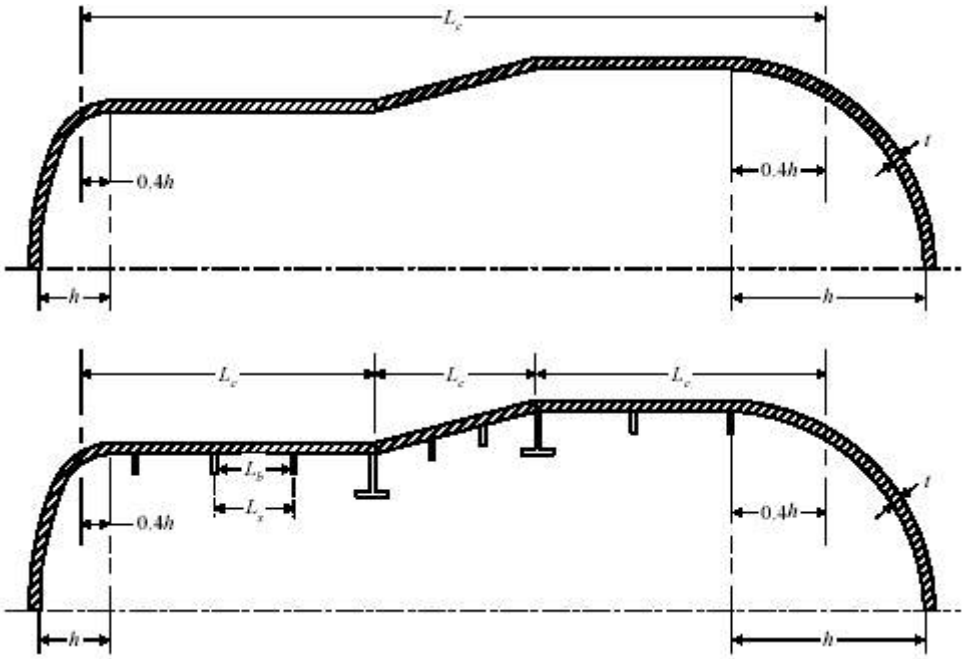


FIGURE 3
Definitions

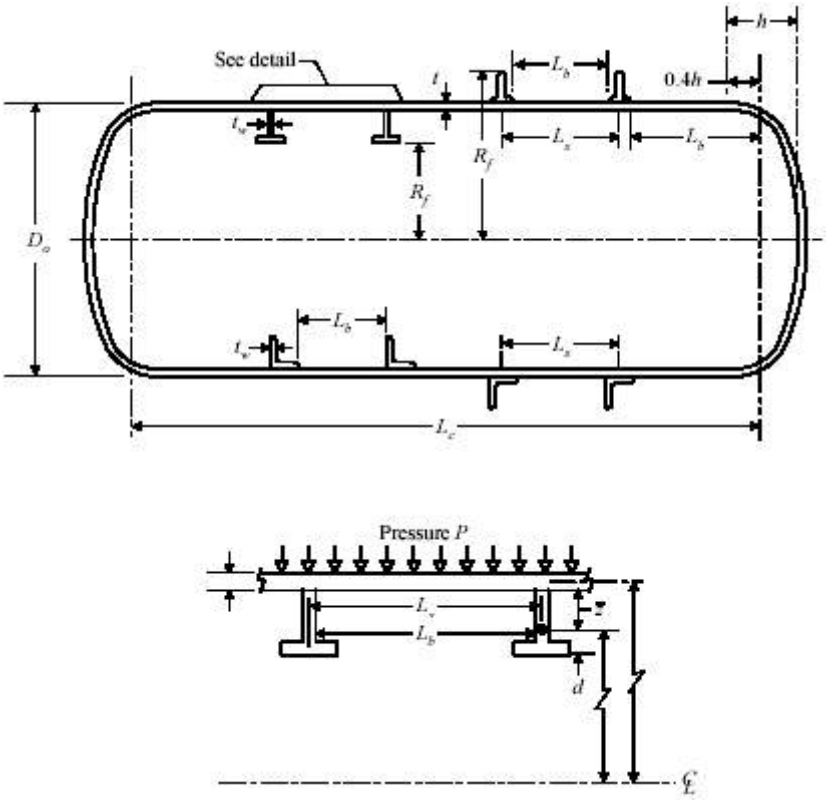


FIGURE 4
Overall Buckling Strength –Lobes Expected at Failure

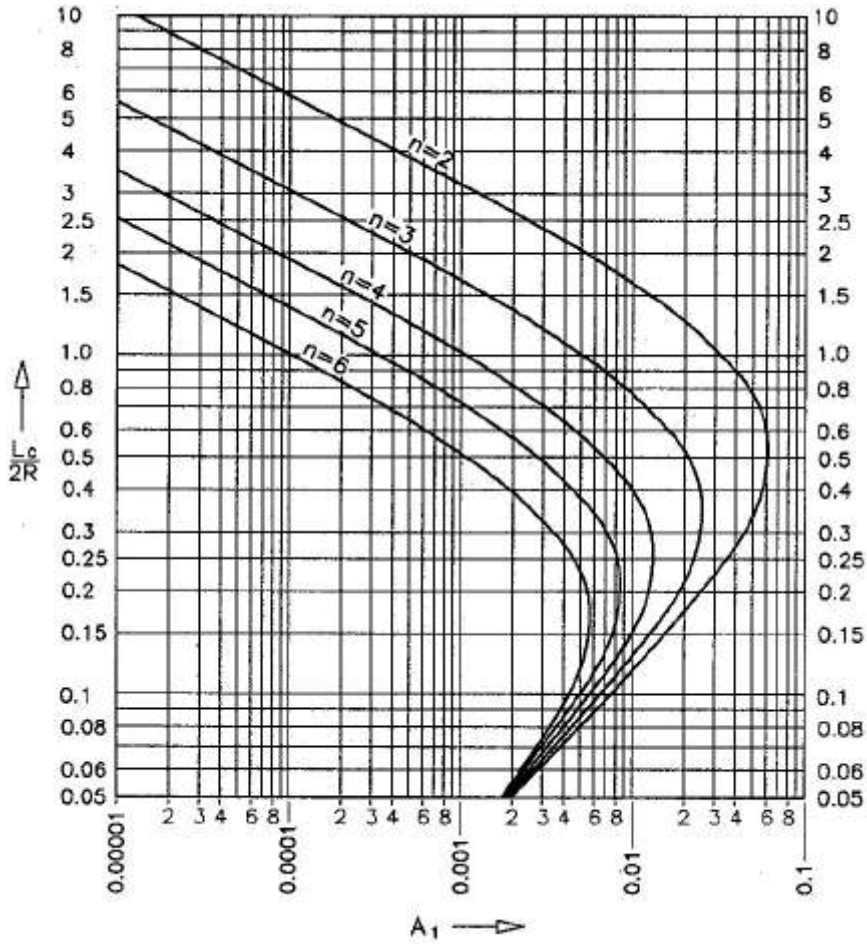


FIGURE 5
Definitions –Cones

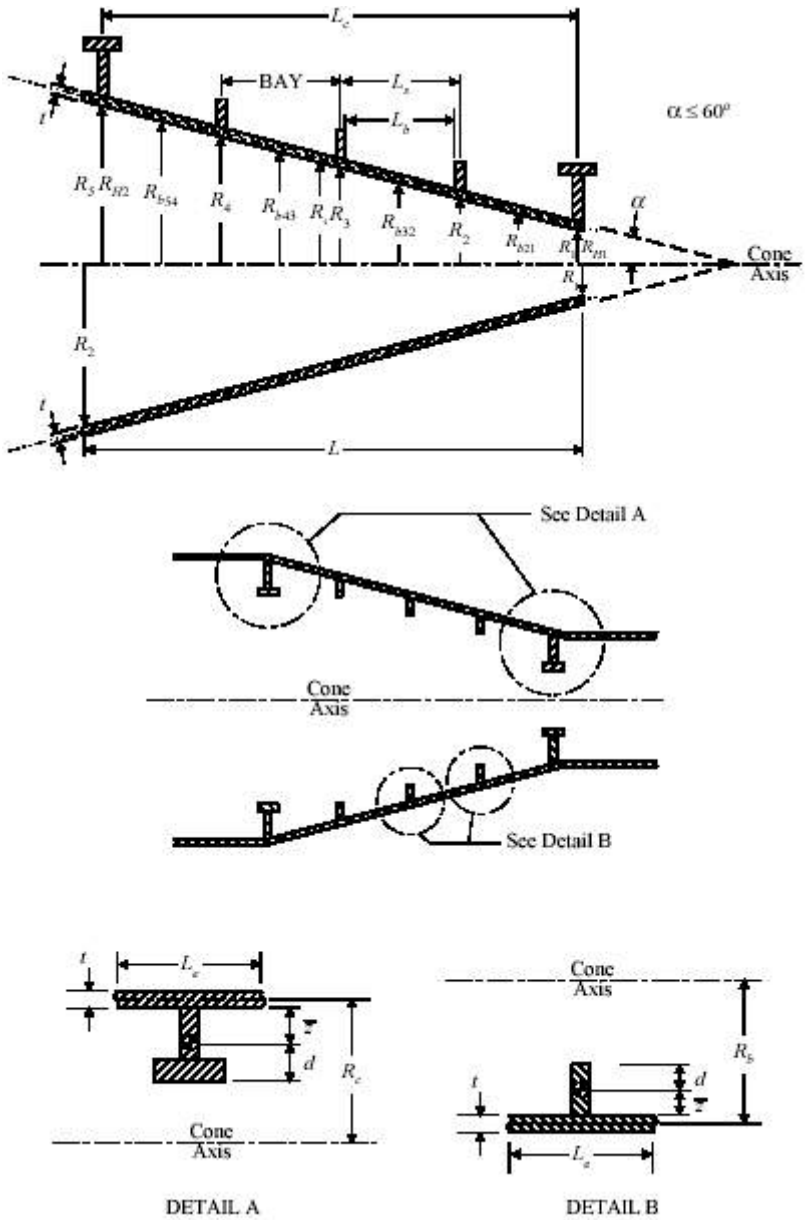
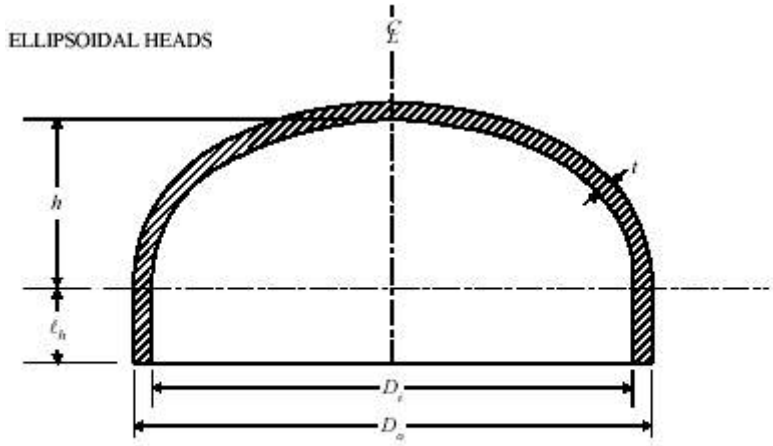
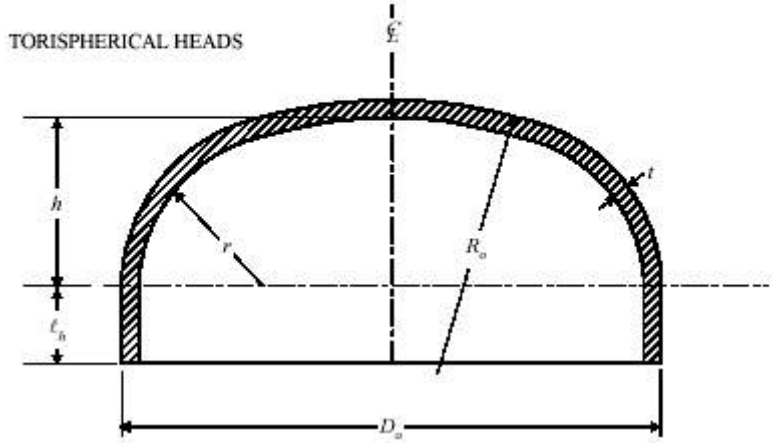


FIGURE 6
Definitions –Heads





14 Leak Testing *(2025)*

After fabrication and completion of all outfitting, pressure hulls and PVHOs designed for internal pressure are to be leak tested to their maximum allowable working pressure (MAWP) for a minimum of four hours 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.

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 *(2025)*

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. It is the responsibility of the designer to determine that these requirements are consistent with the latest edition of the ASME PVHO-1.

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 fluids to which the windows can be exposed are to only include 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 is not to exceed 4 millirads

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.

Design parameters different from the above will be evaluated by ABS Engineering on a case-by-case basis.

Note: See 7/3.1 and 7/3.3 for the definition of the terms "design life" and "service life". Also refer to the ASME PVHO-1 and PVHO-2 standards.

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 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 6/27), 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 14, 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 Section 1A-7-4 of the ABS *Rules for Conditions of Classification (Part 1A)*)

- 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 *(2025)*

Where the design of life support systems is such that the oxygen concentration in personnel compartments can potentially exceed 23 percent by volume, then the increased fire hazard due to elevated oxygen concentration is to be considered. All combustible materials within such personnel compartments (such as paints, lubricants, adhesives, furniture coverings, etc.) are to be investigated for combustibility. As a minimum, the combustibility evaluation is to consider the maximum oxygen concentration, rate of combustion, quantity of material, exposed surface area and proximity to heat sources, and is to demonstrate that the fire hazard has been eliminated or mitigated to a satisfactory level of safety. See Subsection 3/1.

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 8/29.3 and 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 Life Support Piping *(2017)*

11.1 Materials

Material specifications and details of life support piping systems are to be submitted for review.

11.1.1

Life support piping systems are to be fabricated from materials complying with recognized material specifications (such as ASTM, ASME, etc.). Acceptable materials include 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

Aluminum may only be used when adequate precautions are taken to prevent contact with fluorochlorocarbon lubricants and hydroxide based CO_2 absorbents.

11.1.3

Other suitable materials may be considered on a case-by-case basis after evaluation of their material specifications.

11.1.4 Material Restrictions

11.1.4(a) The following materials are not to be used for life support systems:

i) Carbon steel

ii) Cast, ductile and malleable iron piping, tubing and fittings

iii) Plating or coatings with cadmium

11.1.4(b) Components containing the following materials are not to be used on life support systems:

i) Beryllium

ii) Mercury

iii) Asbestos

11.1.5 Castings

Cast components are not to be used for helium service.

11.1.6 Seawater Service

Materials exposed to seawater are to be compatible with seawater.

11.1.7 Soft Goods

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.

11.1.8 Lubricants

The manufacturer's specifications for lubricants used in life support piping systems are to be submitted to the ABS Technical Office for review. Fluorochlorocarbon based lubricants are not to be used on aluminum. See also 8/11.9.2.

11.1.9 Thread Sealants

The manufacturer's specifications for thread sealants used in life support piping systems are to be submitted to the ABS Technical Office for review. See also 8/11.9.2.

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

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

11.5.1 Standard Valves

In general, valves are to comply with a recognized national standard and are to be permanently marked in accordance with the requirements of the standard. For valves not complying with a recognized national standard, see 8/11.5.2 below.

11.5.2 Nonstandard Valves

Valves not manufactured to a recognized national standard are to have a burst strength of at least four times the maximum allowable working pressure (MAWP) of the piping system. They may be accepted on the basis of manufacturer specified pressure and temperature ratings, test data and burst strength ratings.

Nonstandard valves are to be permanently marked with the manufacturer's name or trademark, model/part number as well as their pressure and temperature pressure ratings. As an alternative, this information may be indicated by means of a permanent tag similar to that indicated in 8/11.11.5.

11.5.3 Suitability for Service

Valves are to be suitable for service with the gas at the system's maximum allowable working pressure (MAWP). Valves intended for oxygen and oxygen-enriched service (i.e., gases containing more than 25% oxygen by volume) are to be suitable for service at the maximum flow velocity of the gases.

11.5.4

Valves are to be of materials specified in 8/11.1.

11.5.5

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

11.5.6

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

11.7 Piping/Tubing

11.7.1

Life support piping and tubing are to have a burst strength of at least four times the maximum allowable working pressure (MAWP) of the piping system.

11.7.2

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.

11.7.3

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.

11.7.4

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

11.7.5

See also 9/7.21.

11.9 Oxygen Piping/Tubing

The following requirements apply to piping/tubing used for oxygen and oxygen-enriched service (i.e., gases containing more than 25% oxygen by volume):

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 8/15.1. Oxygen piping is to meet the requirements of 8/11.7.

11.9.2

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

11.9.3

See also 8/11.5.3.

11.11 Hoses

11.11.1

Fire resistant, non-metallic, armored hose may be accepted for use on life support systems up to a maximum allowable working pressure (MAWP) of 5000 psi, on the basis of manufacturer specifications, satisfactory in-service experience for the intended application, and subject to compliance with the following requirements:

i) Hoses are to meet the requirements of 9/7.19.

ii) Hoses are to be compatible with the intended life support system gases at the MAWP of the piping system.

iii) Hoses are to be tested by the manufacturer for overpressure, burst strength and fire resistance. Pressure testing of each individual hose is to be carried out to a pressure of not less than 1.5 times the MAWP of the hose for 1 hour. Burst strength is to be not less than 4 times the MAWP of the hose. Fire resistance of the hoses is to meet recognized national standards (such as ISO 15540 and ISO 15541).

11.11.2

SAE 100-R3 hoses may be used, provided they comply with 8/11.11.1 above.

11.11.3

Hoses intended for oxygen and oxygen-enriched service (i.e., gases containing more than 25% oxygen by volume) are to be suitable for service at the maximum flow velocity of the gases.

11.11.4 Hoses Subject to External Pressure

When hoses are intended for applications where they may be subject to a net external pressure, they are to meet the following additional requirements:

i) The hose construction is to be of a type that is resistant to collapse at the maximum anticipated differential pressure.

ii) The hose end fittings are to be of a type that forms a complete seal at the ends of the hose. Fittings that leave the cut ends of the hose exposed to pressure are not to be used.

iii) The hoses are to be externally pressure tested to a pressure of not less than 1.5 times the maximum anticipated external pressure for 1 hour. At the end of the testing, the hoses are to exhibit no evidence of collapse, either of the casing (outer jacket and reinforcing layer) and liner together, or of the liner separately. Testing is to also confirm flow through the hose while externally pressurized.

iv) The hoses are to be installed in such a manner that minimizes kinks, crushes, etc., so as to prevent premature collapsing of the hoses when subject to external pressure.

11.11.5 Marking

Hoses are to be marked with the manufacturer's name or trademark, model/part number, hose size, as well as their pressure and temperature ratings. This information is to be either permanently printed on the hose or on a permanently attached tag. Tags, when used, are to be attached in such a manner that they do not abrade the hose or prevent the hose from bending or expanding due to pressure.

11.13 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.

11.15 Color Coding

Life support 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 Life Support Instrumentation

13.1 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

13.3 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.

13.5 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).

15 Controls

15.1 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.

15.3 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.

15.5 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.

17 Diving Temperature and Humidity Controls

17.1 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.

17.3 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.

17.5 Electric Water Heaters

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

17.5.1

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.

17.5.2

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.

17.7 Air Conditioning

When air conditioning systems are installed, detailed plans of piping and components are to be submitted for review showing compliance with Sections 14, as applicable.

19 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.

21 Filtration Systems

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

23 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.

25 Mercury

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

27 Gas Reclaim Systems *(2012)*

27.1 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

27.3 Diver Gas Reclaim Systems

27.3.1 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 x RMV liters/minute (SLPM) per diver
Carbon Dioxide production	1/25 x 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.

27.3.2 CO_2 Removal Systems

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

27.3.2(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.

27.3.3 Water Traps

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

27.3.4 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 $\pm$ 6.0 kPa relative to the lung centroid pressure.

27.3.5 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.

27.3.6 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:

27.3.6(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.

27.3.6(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 x RMV as defined in 8/27.3.1 above.

27.3.7 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).

29 Testing *(2025)*

(2014) The test procedures for the testing (pressure testing (see 8/29.1.1), leak testing (see 8/29.1.2) and off-gas testing [see 8/29.3.1] 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 8/29.3.1] 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).

29.1 Breathing Gas Piping Systems

29.1.1 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 confirm that all traces of test gases are removed.

29.1.2 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.

29.3 Pressure Vessels for Human Occupancy and Pressure Hulls

29.3.1 Off-gas Testing

29.3.1(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 8/29.3.1(a) 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 this Section, Table 1 below, regardless of their ACGIH TLV or duration of occupation. (8/29.3.1(b).ii TABLE 2 below does not apply for these four compounds).

TABLE 1
Monochloro/Dichloroacetylene Precursor Compounds *(2018)*

Compounds	*IUPAC Name*	*CAS Number*	*Max. Exposure Limit*
Trichloroethylene	1,1,2-trichloroethene	79-01-6	0.1 ppm
Vinylidene Chloride	1,1-dichloroethene	75-35-4	0.1 ppm
Methyl Chloroform	1,1,1-trichloroethane	71-55-6	0.1 ppm
Acetylene Dichloride	1,2-dichloroethene	156-59-2	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 8/29.3.1(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 8/29.3.1(b) i),ii) or iii) below, as applicable.

29.3.1(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 8/29.3.1(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 8/29.3.1(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 8/29.3.1(b).ii TABLE 2 below. (Linear interpolation for intermediate values is permitted)

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

Duration	F_p
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 8/29.3.1(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.

29.5 Life Support Testing *(2025)*

Life support testing is to be carried out as specified in Sections 11 through 17, as applicable to the underwater unit. (See 11/35.11, 12/39.11.9, 13/39.5, 14/3.13.11, 15/3.15, 16/39.3, 17/5.7.6, and 17/5.21).

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 *Marine Vessel Rules*, to the satisfaction of the Surveyor, except as modified herein. Additionally, life support and engineering systems are to comply with Sections 14 of these Rules.

3 Production Equipment *(2025)*

Equipment for the production of hydrocarbon is to comply with the ABS *Rules for Building and Classing Offshore Units* and the ABS *Guide for Building and Classing Facilities on 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 Section 1A-7-4 of the ABS *Rules for Conditions of Classification (Part 1A)*. 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

Mass produced pressure vessels may be accepted in accordance with 4-4-1/1.11.3 of the *Marine Vessel Rules*.

5.1.3 *(2025)*

Seamless pressure vessels for gases (i.e., gas cylinders) may be accepted in accordance with 4-4-1/1.11.5 of the *Marine Vessel Rules*, provided their application does not violate any restrictions contained in the standard applied.

5.1.4 *(2025)*

The use of fiber reinforced plastic (FRP) pressure vessels will be evaluated by ABS Engineering on a case-by-case basis for applications where they are subject to a net internal pressure.

5.2 Internal Pressure *(2025)*

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

5.3 External Pressure *(2025)*

5.3.1 *(2025)*

Pressure vessels, heat exchangers and heaters subject to external pressure are to comply with Sections 4, 5 and 6.

5.3.2 *(2025)*

As an alternative to 9/5.3.1, pressure vessels, heat exchangers and heaters subject to external pressure can comply with national or international pressure vessel standards or codes that are not less effective than these Rules.

5.5 Pressure Vessel Location *(2025)*

Pressure vessels and heat exchangers are not to be located within the pressure boundary of pressure hulls or pressure vessels for human occupancy unless calculations are submitted showing that the inadvertent release of the contained fluid(s) will not increase the pressure inside the pressure boundary by more than one atmosphere, nor raise the oxygen concentration above 23% by volume at 1 atmosphere (see 8/7.5.2). Additionally, the release of the contained fluid(s) is not to result in a toxic concentration.

5.7 Safety Relief Devices *(2010)*

5.7.1 *(2025)*

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 vessel 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 *(2025)*

If the safety relief devices are mounted outside the pressure boundary of pressure hulls or pressure vessels for human occupancy (PVHOs), 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 Maintenance Manual (See 1A-7-5/3 of the ABS *Rules for Conditions of Classification (Part 1A)*). Where applicable, the designer is to consider the effect of seawater back-pressure acting on the downstream side of the safety relief device.

5.7.4 *(2025)*

If the safety relief devices are mounted within the pressure boundary of pressure hulls or pressure vessels for human occupancy (PVHOs), then it is to be demonstrated by calculations that the release of the fluid(s) contained in the pressure vessel will not increase the pressure within the pressure boundary by more than one atmosphere, nor raise the oxygen concentration above 23% by volume at 1 atmosphere (see 8/7.5.2). Additionally, the release of the contained fluid(s) is not to result in a toxic concentration.

For surface-based systems, the exhaust of safety relief devices can 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 to prevent backflow. The check valve is not to alter the setting or relieving capacity of the safety relief device.

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 *Marine 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 *Marine 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:

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

$$t = 3WR_o/Q_y$$

where

W	=	external pressure
T	=	thickness
E	=	modulus of elasticity
R	=	mean radius
R_o	=	outside radius
v	=	Poisson's ratio
Q_y	=	yield strength
c	=	0.00 for plain-end pipe or tubing
	=	1.27 mm (0.05 in.) for all threaded pipe 17 mm (⅜ in.) O.D. and smaller
	=	depth of thread *h* for all threaded pipe over 17 mm (⅜ 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 1A-7-5/3 of the ABS *Rules for Conditions of Classification (Part 1A)*). 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 *(2025)*

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(s) contained in the pressure vessel will not increase the pressure within the pressure boundary by more than one atmosphere, nor raise the oxygen concentration above 23% by volume at 1 atmosphere (see 8/7.5.2). Additionally, the release of the contained fluid(s) is not to result in a toxic concentration.

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 to prevent backflow. The check valve is not to alter the setting or relieving capacity of the safety relief device.

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 8/11.15.

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. 9/9.1 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 *(2025)*

Manufacturer's specifications and capacities of all pumps, compressors, and associated pressure relief devices are to be submitted for review.

Pressure relief devices installed on pumps/compressors are to relieve and discharge in a manner that will not affect the internal pressure of the pressure boundary or the operational integrity of the piping system. (See 9/7.13.2 and 9/7.13.3 above)

Pumps and compressors are to be functionally tested in the presence of the Surveyor.

15 Heating, Ventilation and Air Conditioning (HVAC) Systems *(2025)*

When HVAC systems are installed, their design details are to be submitted for review.

HVAC systems are to be functionally tested in the presence of the Surveyor.

Refrigerant circuits of air conditioning systems are to be installed outside the pressure boundary of pressure hulls or PVHOs. The use of these refrigerant circuits within pressure hulls or PVHOs will be evaluated by ABS Engineering on a case-by-case basis, provided it is demonstrated that:

i) Additional protective measures are provided to prevent leakage of refrigerant gases within pressure hulls or PVHOs.

ii) Gas monitoring equipment and alarms are installed to warn the pressure hull or PVHO occupants of refrigerant gas leakages.

iii) Discharge of any leaked refrigerant within pressure hulls or PVHOs will not result in a toxic concentration.

17 Equipment *(2025)*

Underwater units 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) For tethered manned underwater units, an internal release device, suitably protected against inadvertent operation, for severing or releasing the umbilical cable.

v) For manned underwater units that employ underwater towing, an internal release device, suitably protected against inadvertent operation, for releasing the towing cable.

vi) Where required by the design, anchors, chains/cables, and winches that are suitable for the intended application.

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 *Marine 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 *(2025)*

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 systems

iii) Life support systems

iv) Environmental monitoring equipment

v) Automatic control systems for essential and emergency services

vi) Computer-based systems (where provided)

vii) 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 *(2025)*

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 systems

iii) Emergency life support system (if electrically powered)

iv) Launch and Recovery System

v) Environmental monitoring equipment

vi) Automatic control systems for essential and emergency services

vii) Computer-based systems (where provided)

viii) 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 so as to maintain 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) Scope (2020)

The requirements of this section apply to rechargeable and non-rechargeable Lithium batteries that are used as the main or emergency source of power. These include, but are not limited to Lithium-ion, Lithium-alloy, Lithium metal and Lithium polymer type batteries, or other Lithium battery chemistries that have the potential for self-sustaining energy release.

11.5.1(b) Exclusions (2020)

Lithium batteries used for portable equipment such as laptops, cellphones, cameras or other portable equipment are not included under the scope of these requirements.

11.5.1(c) Certification (2020)

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

i) Section 38.3, UN Manual of Tests and Criteria

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

iii) 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(d) Quality Assurance (2020)

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

11.5.1(e) Suitability for Marine Applications (2020)

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

11.5.2 Installation *(2025)*

11.5.2(a) (2020)

For manned units, Lithium batteries are to be installed outside the occupied pressure boundary of the PVHO or pressure hull. Alternative arrangements that provide an equivalent level of safety will be considered on a case-by-case basis.

11.5.2(b) (2020)

All installations are to include appropriate means to prevent inadvertent shorting between the terminals of Lithium batteries (such as non-shorting caps).

11.5.2(c) *(2020)*

Prior to installation, a risk analysis shall be carried-out for evaluating and mitigating potential risks associated with the Lithium battery installation, as well as the normal and emergency operating procedures. The risk analysis is to be conducted as per the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* or equivalent recognized national or international standards.

11.5.3 Battery Housings *(2020)*

Lithium batteries may be installed in either a one-atmosphere housing or a pressure compensated housing.

11.5.3(a) General Requirements

All battery installations housing lithium batteries are to meet the following general requirements:

i) The housings are to be installed in locations that are as far away as practicable from sources of heat, compressed gas cylinders and acrylic windows on PVHOs or pressure hulls.

ii) The housings are to be mechanically protected from direct impact loads. For units that are transported while in-service (such as Diving Bells or Submersibles), the battery housing are to be also protected from acceleration shock loads.

iii) The housings are to be provided with means of pressure relief (such as blow-out plugs or vents) in order to relieve any potential pressure build-up within the housing due to malfunctioning batteries. The discharge of the means of pressure relief is to be vented as far away as practicable from sources of heat, compressed gas cylinders and acrylic windows on PVHOs or pressure hulls.

iv) All electrical circuits are to be insulated and isolated from the structural elements of the housings.

v) Battery housings are to be labeled appropriately, and are to be provided with appropriate signs warning personnel against inadvertent abuse.

11.5.3(b) One-Atmosphere Housings

When Lithium batteries are installed in one-atmosphere housings, they are to meet the following additional requirements:

i) The housings are to be designed to permit purging and charging of the internal atmosphere with inert gas, so as to minimize the Oxygen concentration below the flammable limit.

ii) Electrical equipment within the housings is to be of the explosion proof type.

iii) Water intrusion sensors, fire detectors, pressure and temperature sensors, as appropriate, are to be provided within the housings. For manned units, these devices are to activate audiovisual alarms in order to alert the operator at the pilot stand and/or the control station of an adverse event (such as a fire or water leakage) within the housing.

iv) When the battery housings are contiguous with the pressure boundary of the PVHO or pressure hull, then these housings are to meet the “A-60” structural fire protection rating as defined by the IMO International Code for Application of Fire Test Procedures (FTP Code), or equivalent recognized standards.

11.5.4 Battery Management System (BMS) for Rechargeable Batteries *(2020)*

Rechargeable Lithium battery installations are to be provided with an electronic battery management system (BMS).

11.5.4(a) **(2020)**

The BMS is to provide means for:

- Monitoring the State-of-Charge and State-of-Health of the batteries.
- Charge control to prevent overcharging/undercharging and voltage reversal.
- Discharge control to prevent over-discharging.
- Inter-module and intra-module balancing of the cells.
- Overcurrent (short circuit) protection to prevent overcurrent discharge.

11.5.4(b) **(2020)**

The BMS is to provide real-time performance monitoring of the following parameters:

- Voltage (cell or string level and module level)
- Current (cell or string level and module level)
- State-of-Charge and State-of-Health (module level)
- Temperature (module level)

11.5.4(c) **(2020)**

For manned units, audio-visual alarms are to be provided to alert the operator at the pilot stand and/or the control station when the parameters in10/11.5.4(b) above are outside their allowable limits.

11.5.5 Protection for Non-Rechargeable Batteries *(2020)*

Nonrechargeable Lithium battery installations are to be provided with the following:

- Over-temperature protection
- Overcurrent (short circuit) protection
- Voltage reversal protection

11.5.6 Testing *(2020)*

11.5.6(a)

Lithium batteries exposed to ambient pressures exceeding 1 Atmosphere are to be pressure tested to the satisfaction of the Surveyor prior to being placed in-service. The pressure testing is to be carried out to the design depth of the unit and is to demonstrate satisfactory operation of the batteries.

11.5.6(b)

For rechargeable batteries, functional testing of the Battery Management System (See 10/11.5.4 above) is to be carried out to the satisfaction of the Surveyor.

11.5.6(c)

For non-rechargeable batteries, functional testing of the battery protection devices (See 10/11.5.5 above) is to be carried out to the satisfaction of the Surveyor.

11.5.7 Charging *(2020)*

The following requirements apply to rechargeable Lithium batteries:

11.5.7(a) **(2020)**

The charging procedures are to be documented in the Operations and Maintenance Manuals of the unit, and are to follow the battery manufacturer's recommendations and specifications.

11.5.7(b) *(2020)*

Charging is to be carried out using the manufacturer specified battery chargers.

11.5.7(c) *(2020)*

For manned applications, charging of lithium batteries is not to be carried out while the unit is in-service.

11.5.8 Replacement

11.5.8(a) *(2020)*

Lithium batteries (including individual cells) are to be replaced taking the following into consideration:

- Manufacturer's recommendations and specifications
- Visual inspection
- Deterioration of performance

11.5.8(b) *(2020)*

The replacement is to be carried out while the unit is not in service.

11.5.9 Manuals and Records *(2020)*

11.5.9(a)

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

11.5.9(b)

As a minimum, these procedures are to follow the battery manufacturer's recommendations and specifications.

11.5.9(c)

The emergency procedures are to address events such as fires, thermal runaways, short circuits, leaks, hazardous gas build-up, low temperature charging, electrical shocks, stored energy hazards, etc., as applicable.

11.5.9(d)

Any special measures taken for mitigating or eliminating potential risks (see 10/11.5.2(c) above) are to be documented in the operations and/or maintenance manuals.

11.5.9(e)

The operator is to maintain a log to record vital information such as the installation dates and maintenance history of the 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 Industries* or equivalent recognized national or international standards.

13 Motors

13.1 Propulsion Motors Not Subject to External Pressure *(2025)*

Propulsion motors inside the pressure boundary of underwater units are to be suitable for the anticipated operating environment and are to be rated appropriately.

Manufacturer's specifications and test data or satisfactory service experience demonstrating adequacy for intended service are to be submitted for review.

13.3 Propulsion Motors Subject to External Pressure *(2025)*

Propulsion motors located outside the pressure boundary of underwater units and subject to external pressure are to be suitable for the anticipated pressures, temperatures and environmental conditions.

Manufacturer's specifications and test data or satisfactory service experience demonstrating adequacy for intended service are to be submitted for review.

When pressure compensation systems are used, their design details and calculations are to be submitted for review. The air purging procedure for pressure compensation systems are to be included in the maintenance manual of the underwater unit.

13.5 Other Electric Motors *(2025)*

Other electric motors are to be suitable for the intended location and service conditions. Manufacturer's specifications for the motors are to be submitted for review.

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 *(2015)*

Ground detectors or interrupters are to be provided for systems with a line voltage above 7.5 volts AC or 30 volts DC.

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 *(2025)*

Power supply conductors from the same main or emergency power source 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 supply conductors 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 (30 volts or lower) DC applications, special consideration will be given to both the positive and negative power supply conductors from the same main or emergency power source 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 *(2018)*

17.1 General *(2010)*

Cables and wiring are to be in accordance with Part 4, Chapter 8 of the *Marine 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 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.

17.5 Mechanical Protection

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

17.7 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 8/11.13.

17.9 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.

17.11 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.

17.13 Prototype Testing of Electrical Penetrators *(2018)*

Penetrators used for electrical service are to be tested by the manufacturer as indicated below, in the listed sequence of tests.

Gland type penetrators (those for which the electrical cable forms part of the pressure boundary) are to be tested assembled with 1 foot of cable of the type that will be used in the final installation.

For pin type penetrators (those for which the electrical cable does not form part of the pressure boundary), in cases where the method of attachment of the conductors may compromise the penetrator pin sealing arrangement, the ABS Technical Office or Surveyor may require the attachment of 1 foot of conductor to each pin, prior to testing.

The penetrator assemblies are to show no sign of deficiency during and after the testing.

17.13.1

For gland type penetrators, voltage test by applying 1 kV AC plus twice the design voltage for 1 minute to each conductor and armor separately.

For pin type penetrators, voltage test by separately applying 1kV AC plus twice the design voltage for 1 minute across each conductor pin and the penetrator body.

Special consideration will be given to voltage sensitive applications.

There is to be no visual evidence of flashover or insulation breakdown as a result of this test.

17.13.2

Hydrostatic test to a pressure of 1.5 times the unit's design pressure repeated six times. This testing is to be conducted before the penetrator assembly is over-molded / potted. The test pressure is to be applied to the side that will be under pressure in the actual application.

For gland type penetrators, this testing is to be conducted with the cable cut-open. The severed end of the cable is not to be potted and is to be fully exposed to the test pressure.

For pin type penetrators, the pins on the high pressure side are to be fully exposed to the test pressure.

For the first five pressure cycles, the test pressure (1.5 times the unit's design pressure) is to be maintained for at least 5 minutes. For the sixth and final pressure cycle, the test pressure (1.5 times the unit's design pressure) is to be maintained for at least 15 minutes. Between any two consecutive pressure cycles, there is to be at least a 5 minute interval where the penetrator assembly is completely unpressurized.

17.13.3

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

For gland type penetrators, this testing is to be conducted with the cable cut-open. The severed end of the cable is not to be potted and is to be fully exposed to the test pressure.

For pin type penetrators, the pins on the high pressure side are to be fully exposed to the test pressure.

17.13.4

Insulation test demonstrating a result of not less than 10 megohm at the unit's design pressure, when tested at not less than 500 V DC. Special consideration will be given to voltage sensitive applications.

This testing is to be conducted with the ends of the cable (gland type penetrators) or pins (pin type penetrators) sealed from the pressurizing medium. Alternatively, this testing is to be conducted using a non-conducting pressurizing medium (eg. Air).

For gland type penetrators, these tests are to be made between each conductor and armor. For pin type penetrators, these tests are to be made between each conductor pin and the penetrator body.

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.

17.15 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.

17.15.1 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.

17.15.2 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.

17.15.2(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.

17.15.2(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 10/17.15.2(c) shall be taken during the final (6th) pressure cycle.

17.15.2(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).

17.15.3 Non Penetrator Cable Assemblies Subject to External Pressures

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

17.15.3(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).

19 Lighting

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

21 Automatic Control Systems *(2025)*

Where automatic control systems are used for essential or emergency services, they are to meet the following requirements:

21.1 General *(2025)*

i) Automatic control systems are to be designed to maintain the controlled equipment within pre-set parameters under normal or emergency operating conditions.

ii) Automatic control systems are to be of fail-safe design, such that a single failure will not cause unsafe operation or lead to loss of control of the underwater unit.

iii) Automatic control systems controlling multiple functions are to be designed such that a single failure will not affect more than one function.

iv) Automatic control systems are to be self-monitoring. (i.e., monitoring for failures or malfunctioning of the control system)

v) Deviation from pre-defined parameters or malfunctioning/failure of automatic control systems is to initiate an audio-visual alarm and is to automatically transfer the control system to a safe state that is not detrimental to the safety of the underwater unit and its occupants (for manned units). See Subsection 10/24 for alarms.

vi) The design of automatic control systems is to be validated through a failure mode and effects analysis (FMEA) and functional testing. The FMEA is to be conducted as per the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* or equivalent recognized national or international standards.

21.2 Manned Underwater Units *(2025)*

For manned underwater units, the following additional requirements are to be met:

i) Automatic control systems are not to override the human operator's control of the unit.

ii) Manual controls are to be provided for disabling and overriding automatic control systems, and for taking control in the event of an emergency or malfunctioning/failure of automatic control systems.

iii) Means are to be provided to prevent inadvertent/accidental disabling and overriding of automatic control systems.

iv) Instructions for disabling and overriding automatic control systems are to be permanently affixed adjacent to the manual controls.

v) For propulsion, steering, depth control, and life support applications, the sensor input to automatic control systems is to be provided by at least two (2) independent sensors. Where the inputs from these sensors disagree by pre-defined parameters, it is to initiate an alarm and is to automatically transfer the control system to a safe state that is not detrimental to the safety of the underwater unit and its occupants.

Commentary:

For 10/21.2v) above, the disagreement parameters between the sensors would be pre-defined and set by the builder or operator and should be documented in the Operations and Maintenance Manual of the underwater unit.

End of Commentary

21.3 Power Supply *(2025)*

Automatic control systems are to be supplied with power from the main power supply, as well as the emergency power supply. In the event of failure of the main power supply during operation of the unit, changeover to emergency power is to be automatic (see 10/5.7), and is not to cause the control system to reset.

21.4 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.

22 Computer-Based Systems *(2025)*

Where computer-based systems are used for overall operational control of the underwater unit, they are to comply with the requirements of Section 4-9-3 of the *Marine Vessel Rules*, as applicable to underwater units.

i) Unmanned underwater units are to comply with the requirements for Category II computer-based systems in accordance with 4-9-3/Table 1. and 4-9-3/Table 2 of the *Marine Vessel Rules*.

ii) Manned underwater units are to comply with the requirements for Category III computer-based systems in accordance with 4-9-3/Table 1. and 4-9-3/Table 2 of the *Marine Vessel Rules*.

iii) Computer-based systems are to be supplied with power from the main power supply, as well as the emergency power supply. In the event of failure of the main power supply during operation of the unit, changeover to emergency power is to be automatic (see 10/5.7) and is not to cause the computer-based system to reset.

Computer-based systems are to be examined and tested to the satisfaction of the attending Surveyor as per Section 4-9-9 and 4-9-10 of the *Marine Vessel Rules*, as applicable to underwater units.

23 Communication Systems

23.1 Interference and Disturbance *(2025)*

Where required by the design of the underwater unit, means are to be provided to protect communication systems from interference (e.g., electromagnetic or acoustic) or disturbance (e.g., operating mechanical equipment).

23.2 Operational Testing *(2025)*

Satisfactory operation of all communication systems is to be demonstrated during the sea trials.

24 Alarms *(2025)*

Where alarms are provided for monitoring equipment or systems, they are to meet the following requirements:

24.1 Independence of Visual and Audible Alarm Circuits

Where audio-visual alarms are provided, a fault in a visual alarm circuit is not to affect the operation of the audible alarm circuit.

24.2 Audible Alarms

Audible alarms for monitoring equipment or systems are to be distinct from the fire alarm and are to be sufficiently loud to attract the attention of the personnel on duty.

For spaces with unusually high noise levels, a beacon light installed in a conspicuous place is to supplement the audible alarm. This beacon light is to be distinct from beacon lights used for fire alarms.

24.3 Visual Alarms

Visual alarms are to provide a flashing light/visual display when first activated. This flashing light/visual display is to change to a steady light/visual display (i.e., non-flashing) upon acknowledgment.

The steady light/visual display is to remain activated, either individually or in a summarized fashion, until the fault condition is rectified.

24.4 Acknowledgement of Alarms

Newly activated alarms are to be acknowledged by manual means. This means is to mute the audible signal and is to change the flashing light / visual display to a steady light/visual display.

Other alarm conditions occurring during the process of acknowledgment are to be alarmed and displayed. The latter alarm is not to be suppressed by the acknowledgment of the former alarm.

Acknowledgement is to be possible from the local controls (where provided) or from the centralized control station. The muting of an alarm at the local control station is not to automatically mute and steady or acknowledge the same alarm at the centralized control station.

24.5 Alarm Testing

Alarms are to be provided with built-in means of testing that can be operated without disrupting the normal operation of the monitoring system(s).

SECTION 11

Submersibles *(2010)*

1 Scope

This Section, along with 1, 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 Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. 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 11/1 of these Rules.

3 Pressure Hulls *(2025)*

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

Acrylic pressure boundaries of pressure hulls for human occupancy are to meet the applicable requirements of Section 7.

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 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

9.1 Design *(2025)*

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 20/55.1 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

9.2 Welded Connections *(2025)*

All welded connections between exostructures and the exterior of pressure hulls are to be welded so as to minimize local stresses induced in the pressure hull. Inspection of such connections is to be feasible.

9.3 Fasteners *(2025)*

i) Fasteners (including bolts, studs and nuts) employed in the joining of exostructures with the exterior of pressure hulls are to meet a recognized national or international standard for fasteners.

ii) Design calculations in accordance with recognized standards or recognized engineering methods are to be submitted for review.

iii) Fasteners are to have adequate strength and corrosion resistance suitable for the intended service.

iv) Round bottom and rolled thread profile fasteners are to be used.

v) High-Strength Steel Fasteners: Zinc or Aluminum coated fasteners or Cadmium plated fasteners of tensile strength greater than 150 ksi are not to 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. (*Note:* Under wet conditions, these coatings/platings increase the susceptibility of the fasteners to hydrogen embrittlement.)

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.).

11.1 Design *(2025)*

i) 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.

ii) 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.

iii) The allowable stresses for the analysis of external structures are defined in 11/9.1.

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

v) 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.

vi) Consideration is to be given to the height of sills so that a minimum freeboard can be maintained. See Subsection 11/31.

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

11.2 Welded Connections *(2025)*

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

11.3 Fasteners *(2025)*

Fasteners (including bolts, studs and nuts) employed in the joining of external structures with the exterior of pressure hulls are to meet the requirements of 11/9.3.

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 *(2025)*

i) 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 *Marine Vessel Rules* and in accordance with the applicable requirements of Sections 4, 5, and 6 of these Rules.

ii) Their capacity is to be sufficient to compensate for all loading conditions of the submersible.

iii) The quantity of water in the hard ballast tanks, along with their internal pressure, is to be indicated at all times at the pilot stand/control station.

21.3 Soft Ballast Tanks *(2025)*

i) Soft ballast tanks are compartments that are not subject to differential pressures for the majority of their operating cycle. They may occasionally be exposed to relatively minor differential pressures (e.g., during the transition from the submerged to the surfaced condition).

ii) Soft ballast tanks together with their supports, fittings, and openings are to be designed for the anticipated loads which may be imposed on them and are to be constructed following sound engineering practice and in accordance with approved plans.

iii) Venting and blowing of soft ballast tanks is to be achieved using separate piping.

iv) Control of vents on the soft ballast tanks are to be arranged so that failure of one vent valve or control line will not affect the integrity of the rest of the venting system.

v) Soft ballast tanks are to be internally pressure tested to a pressure of not less than 1.1 times the maximum anticipated differential pressure during a dive cycle.

Commentary:

For 11/21.3iii) above, separate piping means that the same line is not be used for both blowing as well as venting.

End of Commentary.

23 Propulsion and Steering Equipment/Systems *(2025)*

23.1 Submission of Drawings and Data *(2024)*

In addition to the plans listed under Section 1A-7-4 of the *Rules for Conditions of Classification (Part 1A)*, the following plans are to be submitted for review:

- Details of the foundations and attachments for propulsion and steering equipment
- Propulsion control system details

23.2 General *(2025)*

i) Submersibles are to be provided with propulsion and steering equipment / systems that are suitable for the intended service.

ii) Propulsion and steering equipment, as well as their associated control systems and supporting structures are to be designed for intermittent as well as continuous service at the intended depths.

iii) The thrust provided by the propulsion equipment / systems is to be sufficient to maintain the minimum speed for maneuvering.

iv) Motor casings exposed to external pressure are to be designed for the intended depths or are to be pressure compensated.

v) Welded connections are to comply with 11/11.

23.3 Propulsion Systems *(2024)*

The following requirements apply to propulsion systems with shafting that penetrates the pressure hull:

23.3.1 Shaft Design *(2024)*

Design calculations are to be submitted to substantiate the suitability and strength of the shaft(s) 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 or standards for shaft designs.

23.3.2 Thrust Bearing, Thrust Plate and Foundations *(2024)*

Calculations substantiating the design of the thrust bearing, thrust plate and foundations in accordance with a recognized method or standard are to be submitted for review

23.3.3 Propeller Design *(2024)*

Calculations substantiating the design of propellers in accordance with a recognized method or standard are to be submitted for review.

23.3.4 Ducted Propellers *(2024)*

When ducted propellers are used, adequate clearance is to be provided between the propeller blade tips and the shroud at all operating depths (of the submersible) and at all operating speeds (of the propulsion system), so as to prevent interference between these components.

23.3.5 Vibration Analysis *(2024)*

Torsional and lateral vibration analysis covering all operating speeds of the propulsion systems is to be submitted for review.

23.3.6 Shaft Seals *(2024)*

Detailed plans of the shaft seals penetrating the pressure hull are to be submitted for review. Tests demonstrating the adequacy of the shaft seals may be required.

23.3.7 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.

23.3.8 Electrical Prime Movers *(2025)*

23.3.8(a) Power Output of < 100 kW (135 hp)

For electrical propulsion motors with an individual power output of less than 100 kW (135 hp), manufacturer's ratings and data indicating suitability of the motors for the intended service, as well as evidence of satisfactory testing or service experience is to be submitted for review.

The manufacturer's data is to include the electrical rating, temperature rise, and class of insulation of the motors.

23.3.8(b) Power Output of ≥ 100 kW (135 hp)

Electrical propulsion motors with an individual power output of 100 kW (135 hp) and over are to comply with 4-8-3/3 of the *Marine Vessel Rules*, as applicable to submersibles.

23.3.9 Non-Electrical Prime Movers *(2025)*

The use of non-electrical prime movers for propulsion (such as internal combustion engines or hydraulic motors) will be evaluated on a case-by-case basis by ABS Engineering.

23.4 Externally Mounted Thrusters *(2024)*

The following requirements apply to externally mounted thrusters with shafting that does not penetrate the pressure hull:

23.4.1 General *(2024)*

For ducted thrusters, adequate clearance is to be provided between the propeller blade tips and the shroud at all operating depths (of the submersible) and at all operating speeds (of the thrusters), so as to prevent interference between these components.

23.4.2 Power Output of < 100 kW (135 hp) *(2025)*

For thrusters with an output of less than 100 kW (135 hp), manufacturer's ratings and data indicating suitability of the thrusters for service at the intended water depths, as well as evidence of satisfactory testing or service experience of the thrusters under design service conditions is to be submitted for review.

The manufacturer's data is to include the electrical rating, temperature rise and class of insulation of the thruster motors.

23.4.3 Power Output of ≥ 100 kW (135 hp) *(2025)*

Thrusters with an output of 100 kW (135 hp) and over are to comply with 4-3-5 of the Marine Vessel Rules, as applicable to submersibles.

23.5 Control Planes and Rudders *(2025)*

Where control planes and/or rudders are installed, the following requirements are to be met:

i) Control planes/rudders, their shafts, and other mechanical components in their actuating mechanism are to be designed for the worst-case loads and moments that are anticipated during the operation of the submersible. Design calculations are to be based on recognized standards or recognized engineering methods.

ii) The design of control planes/rudders is to minimize the risk of entanglement.

iii) Means are to be provided to prevent collisions and descent of the submersible beyond its design depth in the event of a jammed, inoperable or freely flapping control plane/rudder.

23.6 Sea Trials *(2024)*

Propulsion and steering systems/equipment are to be performance tested during the sea trials over their entire operating range and at all operating depths to the Surveyor's satisfaction. The sea trials procedure is to be submitted to the Technical Office for review prior to the testing.

The propulsion tests are to demonstrate that the propulsion equipment/systems are free from excessive vibrations at all speeds within their operating range, and while maneuvering at maximum steering angles.

The testing of the steering equipment/systems is to demonstrate the safe operation of the submersible at the maximum steering angles and corresponding submersible speeds, as defined by the designer or builder.

25 Pilot Stands/Control Stations *(2025)*

25.1 General

Submersibles are to be provided with a pilot stand or control station for centralized monitoring, control, and operation of the submersible.

25.2 Submission of Drawings and Data

The following plans are to be submitted for review:

i) General arrangement

ii) Layout of control stands and consoles

iii) Front view of all consoles and stands together with their installation arrangements

iv) A schematic or logic diagram, with a written description, giving the sequence of events and operating procedures for control of all submersible functions and related operations

25.3 Location and Construction

i) The position of the pilot stand or control station is to provide the pilot(s) with an overview of all systems and activities associated with the operations of the submersible.

ii) Control stands and consoles are to be firmly secured to a solid foundation or internal structure of the submersible.

iii) The installation of pipes carrying fluids in the vicinity of control consoles is to be avoided as far as possible. When such piping runs are unavoidable, care is to be taken so that:

a) Flanges or joints are not located over or near the consoles, unless provision is made to protect the consoles from piping leakages.

b) Provisions are made for protecting consoles from condensation drippings

25.4 Controls, Instrumentation and Displays

Suitable controls, instrumentation, and displays are to be provided to facilitate the centralized monitoring and operation of the submersible from the pilot stand or control station.

25.4.1 Monitored Parameters and Alarms

As required by the subsections listed below, the operational parameters and alarms for the following systems and equipment are to be monitored from the pilot stand or control station:

i) Navigational equipment (see Subsection 11/26)

ii) Communication systems (see Subsection 11/27)

iii) Life support and environmental control systems (see Section 8)

iv) Electrical and control systems (see Section 10)

v) Emergency systems (see Sections 9 and 11)

vi) Stability and ballast systems (see Subsections 11/21 and 11/31)

vii) Propulsion and steering systems (see Subsection 11/23)

viii) Hatches (see 11/5.9)

ix) Fire detection and alarm systems, where applicable (see Subsection 11/33)

25.4.2 Joysticks

Where joysticks or similar devices are provided for propulsion or steering control, they are to meet the following requirements:

i) Joysticks are to be suitable for use in a marine environment. Manufacturer's ratings and service experience data is to be submitted to ABS Engineering for review.

ii) Joysticks are to be hard wired to their control system.

Commentary:

Bluetooth links between joysticks and their control system are not permissible.

End of Commentary.

26 Navigation and Steering *(2025)*

26.1 Field of View *(2025)*

Suitable means or equipment (such as viewports, cameras, or sonars) are to be provided to assist the pilot(s) in navigating and steering the submersible while on the surface, as well as while submerged.

These means are to provide the pilot(s) with an adequate field of view to enable safe navigation and steering of the submersible. The adequacy of the field of view is to be demonstrated to the Surveyor during the sea trials.

Commentary:

The "field of view" may be actual (e.g., via viewports) or virtual (e.g., via sonars).

End of Commentary

26.2 Navigational Equipment *(2025)*

As a minimum, the following navigational equipment is to be provided:

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) Emergency locating devices as per Subsection 11/29

Manufacturer's ratings for the visual and navigational equipment is to be submitted to ABS Engineering for review. (For viewports, see Subsection 11/7)

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 20/55.1 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 11/47 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 8/7; the CO_2 removal system reserve time is to be based on the requirements in 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 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 1A-7-5/1 of the ABS *Rules for Conditions of Classification (Part 1A)*).

35.5.2

The subsurface locating device required as per 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 11/47 below), the life support system is to be tested in the presence of the Surveyor with all the hatches closed. (Also see 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 Section 8 and Section 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 *(2025)*

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.

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 be 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 Section 1A-7-4 of the ABS *Rules for Conditions of Classification (Part 1A)* 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 Section 1A-7-4 of the ABS *Rules for Conditions of Classification (Part 1A)*, 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 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

1 Scope

This Section along with 11 provide the requirements for the design, fabrication and testing of lock-out submersibles.

3 Class Notations *(2024)*

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 Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. 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 Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)* of these Rules.

Where lock-out submersibles comply with this Section and Section 7-11-6 of the ABS *Rules for Survey After Construction (Part 7)*, the class notation **G** (signifying U.S. government service) will be added to the above specified class notations ⊠ **A1 Lock-Out Submersible** or **A1 Lock-Out Submersible**. Example: ⊠ **A1 Lock-Out Submersible G**.

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 Pilot Stands/Control Stations *(2025)*

A pilot stand/control station is to be provided in the Command Compartment, and is to meet the applicable requirements of Subsection 11/25.

7.1 Navigation and Observation *(2025)*

i) 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.

ii) 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 and transport compartments (where provided). Suitable lighting is to be provided in the lock-out and transport compartments to permit observation.

iii) 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.

iv) Navigational equipment is to meet the applicable requirements of Subsection 11/26.

v) Viewports, when installed, are to meet the applicable requirements of Section 7.

7.2 Controls and Instrumentation *(2025)*

i) The required controls and instrumentation for lock-out and transport compartments (where provided) are to be installed in the command compartment. Additional controls and instrumentation may be installed in the lock-out and transport compartments.

ii) Controls and instrumentation for command compartments, lock-out compartments, and transport compartments (where provided) are to be placed on separate control panels.

iii) Suitable means are to be provided in the command compartment for overriding and controlling the breathing, pressure supply, and exhaust piping for lock-out compartments and transport compartments (where provided).

9 Exostructures

Exostructures are to meet the applicable requirements of this Section and 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 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 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 11/15.

17 Emergency Recovery Features

Emergency recovery features are to meet the applicable requirements of 11/17.

19 Entanglement

External appendages susceptible to entanglement are to meet the applicable requirements of 11/19.

21 Ballast Tanks

Ballast tanks are to meet the applicable requirements of 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 11/23.

25 Emergency Locating Devices

Emergency locating devices are to meet the applicable requirements of 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 11/31.

27.1 Change Control *(2024)*

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.

27.2 Partial Flooding of Lock-Out Compartments *(2025)*

Partial flooding of upright lock-out compartments during diver lock-in/lock-out operations (See 12/39.11.5 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 20% of the internal volume of the lock-out compartment. Consideration will be given on a case-by-case basis for lock-out compartments using alternative flooded volumes, subject to a review by ABS Engineering.

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, while the lock-out hatch is closed.

The stability analysis for underwater operations (See 11/31.9) is to also consider partial flooding of lock-out compartments.

27.3 Emergency Surfacing System *(2025)*

a) Lock-out submersibles are to be provided with an emergency surfacing system that complies with 11/31.5.

b) Emergency surfacing systems that are designed to jettison masses [see 11/31.5.i] are to consider the largest single floodable volume other than the command/lock-out compartment or a partially flooded lock-out compartment, whichever is greater.

c) Emergency surfacing systems that are designed to release the personnel compartment [see 11/31.5.ii] are to release the command compartment as well as the lock-out compartment, along with their associated emergency life support systems.

d) As an alternative to the emergency surfacing systems specified under 11/31.5.i or 11/31.5.ii, consideration will be given on a case-by-case basis for the command and lock-out compartment personnel evacuating (i.e., locking-out) through the lock-out compartment hatch, provided the following additional requirements are met:

i) The emergency evacuation is carried-out within a reasonable timeframe, at depths not exceeding the maximum lock-out depth of the submersible.

ii) Each person is provided with self-contained breathing equipment suitable for the emergency evacuation depth.

iii) In addition to the normal ballast system (see 11/31.1), means are provided to prevent uncontrolled descent of the submersible beyond its design depth.

iv) Means are provided or procedures are documented for preventing uncontrolled ascent of the evacuating personnel to the surface.

v) Means of egress (such as hatches, transfer trunks, etc.) are provided between the command compartment and lock-out compartment.

vi) Means of equalizing the pressure between the command compartment, transfer trunk and lock-out compartment (as applicable) are provided.

vii) The pressure hull of the command compartment is not to be exposed to a net internal pressure during the emergency evacuation. Alternatively, the pressure hull of the command compartment is to be designed for the maximum anticipated net internal pressure during the emergency evacuation.

viii) Where the command compartment is exposed to internal pressure during the emergency evacuation, the implodable volumes within this compartment are to be rated for a pressure corresponding to the maximum anticipated internal pressure.

ix) For cases when the evacuation is carried-out through a bottom facing hatch while the submersible is resting on the seabed, the submersible design includes adequate clearance (between the hatch and seabed) to enable the personnel to safely evacuate.

x) The emergency evacuation procedure is documented in the Operations Manual of the lock-out submersible.

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 *(2025)*

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.

37.3 Access Hatches

Access hatches for command compartments are to meet the applicable requirements of Subsection 11/5.

37.5 Communication Systems *(2025)*

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 lock-out compartments, transport compartments, the in-water divers (where appropriate) and the support vessel (where appropriate).

37.7 Fire Fighting *(2024)*

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.

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 pressure 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 is 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 *(2025)*

Lock-out compartments are to be provided with voice communication systems, and are to include a primary, as well as a secondary, communication system.

39.5.1 Primary Communication Systems *(2025)*

i) The primary system is to be arranged for direct two-way communication with the command compartment, transport compartment (where provided), the in-water divers (where appropriate) and the support vessel (where appropriate).

ii) This communication system is to be supplied by two independent sources of power, one of which is to be the emergency source of power.

iii) When mixed gas is used, speech unscramblers are to be provided.

39.5.2 Secondary Communication Systems *(2025)*

i) The secondary system is to be arranged for communication with the command compartment and transport compartment (where provided), and 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.

ii) In case the command compartment, lock-out compartment, and transport compartment (where provided) personnel 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, the lock-out compartment personnel, or the transport compartment (where provided) personnel.

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

39.9.1 General *(2025)*

i) Piping systems for lock-out compartments are to meet the applicable requirements of this section and Section 11.

ii) 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.

iii) 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.

iv) Anti-suction protective devices are to be provided inside lock-out compartments on the openings of exhaust outlet lines.

39.9.2 Under Pressure Protection for Draining Water *(2025)*

Where the design of lock-out compartments is such that a vacuum could be inadvertently drawn while draining water from the compartment, the following additional requirements are to be met:

i) An interlock is to be provided between the drain valve and vent valve, to prevent draining of the compartment while the vent valve is shut.

ii) Means of under pressure protection (such as vacuum breakers) are to be provided.

iii) Means are to be provided to visually indicate the open and shut positions of the drain and vent valve to the operator. These means are to be located above the waterline of partially flooded lock-out compartments.

iv) Fittings (such as grease nipples) for lubricating the drain and vent valves, as well as other associated components (such as operating linkages) are to be conspicuously located and are not to be painted over.

v) The operational procedures for draining lock-out compartments are to be documented in the Operations Manual of the submersible.

vi) The periodic maintenance procedures for the drain and vent valves, as well as other associated components are to be documented in the Maintenance Manual of the submersible.

39.9.3 Under Pressure Protection for Exhausting Breathing Gases *(2025)*

Where the design of lock-out compartments is such that a vacuum could be inadvertently drawn while exhausting breathing gases from the compartment, the following additional requirements are to be met:

i) Means of under pressure protection (such as vacuum breakers) are to be provided.

ii) The operational procedures for exhausting lock-out compartments are to be documented in the Operations Manual of the submersible.

39.9.4 De-Watering *(2025)*

i) Means are to be provided for de-watering partially flooded lock-out compartments under normal, reserve and emergency life support conditions.

ii) These means are to be capable of de-watering lock-out compartments while they are at their maximum lock-out depth, and with 20% of their internal volume filled with water. Consideration will be given on a case-by-case basis for lock-out compartments using alternative flooded volumes, subject to a review by ABS Engineering.

iii) The de-watering can be carried out using power driven pumps or using breathing gases (see 12/39.11.3, 12/39.11.4 and 12/39.11.5).

iv) Under normal and reserve life support conditions, the maximum number of de-watering cycles is to be determined by the designer/builder and is to be suitable for the intended mission.

v) Under emergency life support conditions, the means of de-watering is to be sufficient for a one-time de-watering of the lock-out compartment.

39.11 Life Support and Environmental Control Systems

39.11.1 General *(2025)*

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 pressurization and exhaust rates of the breathing gas systems are to be suitable for the intended diving operation 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/Treatment *(2025)*

39.11.2(a) Decompression/Treatment in Lock-Out Compartments (2025)

When it is intended that diver decompression/treatment be carried out within the lock-out compartments, the following requirements are to be met:

i) A sufficient supply of breathing and pressurization gases required for the maximum decompression periods (in accordance with the applicable decompression table) is to be available for the expected maximum number of divers plus one.

ii) An appropriate supply of pressurization and breathing gases for treatment (in accordance with the applicable treatment table(s)) is to be available for the treatment of divers.

iii) 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.

iv) 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.

39.11.2(b) Decompression/Treatment at Other Sites (2025)

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 for the divers, and that suitable means are provided for transporting and transferring the divers to these facilities.

39.11.3 Normal Life Support System *(2025)*

Lock-out compartments are to be provided with a normal life support system.

i) For untethered submersibles, the breathing gases and the carbon dioxide removal system for normal life support are to be carried on board the submersible.

ii) For tethered submersibles, the breathing gases and the carbon dioxide removal system for normal life support may be surface supplied or carried on board the submersible.

iii) 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).

iv) 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. (Also see 12/39.11.1.)

v) Where de-watering of the lock-out compartment is to be carried-out using breathing gases from the normal life support system, the capacity of the normal life support system is to be also sufficient for the maximum number of de-watering cycles at maximum lock-out depth, when 20% of the lock-out compartment internal volume is filled with water.

Commentary:

For 12/39.11.3v) above, the maximum number of de-watering cycles during normal operations is to be determined by the designer/builder and is to be suitable for the intended mission.

End of Commentary

39.11.4 Reserve Life Support System

Lock-out compartments are to be provided with a reserve life support system.

39.11.4(a) General

The reserve life support system may be an independent system or may be a part of the normal life support system.

For untethered submersibles, the breathing gases and the carbon dioxide removal system for reserve life support are to be carried on board the submersible.

For tethered submersibles, the breathing gases and the carbon dioxide removal system for reserve life support may be surface supplied or carried on board the submersible.

The carbon dioxide (CO_2) removal system for reserve life support is to be capable of maintaining the partial pressure of CO_2 below 0.005 atmosphere absolute (ata).

39.11.4(b) Capacity.

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:

i) *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.

ii) *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 additional requirements below, the above duration may be reduced to the greater of 10% of the design mission duration or 8 hours:

a) The submersible is part of an underwater complex (see Subsection 2/87) having two independent lifting means.

b) Each lifting means complies with the requirements of Section 20 and is capable of independently raising the submersible to the surface.

39.11.4(c) De-watering (2025)

Where de-watering of the lock-out compartment is to be carried out using breathing gases from the reserve life support system, the capacity of the reserve life support system is to be also sufficient for the maximum number of de-watering cycles at maximum lock-out depth, when 20% of the lock-out compartment internal volume is filled with water.

Commentary:

For 12/39.11.4(c) above, the maximum number of de-watering cycles during the reserve duration is to be determined by the designer/builder and is to be suitable for the intended mission.

End of Commentary

39.11.5 Emergency Life Support System (Tethered and Untethered Submersibles) *(2025)*

Lock-out compartments are to be provided with an emergency life support system.

i) 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.

ii) The emergency life support system is to supply the maximum number of occupants (divers) plus one with the appropriate emergency breathing gases and is to provide carbon dioxide (CO_2) removal. 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).

iii) Emergency breathing 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). As an alternative to the dedicated piping system (BIBS), self-contained breathing systems (e.g., rebreathers) can be provided for the maximum number of occupants (divers) plus one.

iv) The capacity of the emergency life support system is to be sufficient for all of the following, as applicable:

a) Capacity that is sufficient to supply the maximum number of occupants (divers) plus one 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.

b) Where emergency de-watering of the lock-out compartment is to be carried-out using breathing gases from the emergency life support system, the capacity of the emergency life support system is to be also sufficient for a one-time de-watering of the lock-out compartment, while it is at maximum lock-out depth and when 20% of its internal volume is filled with water.

c) When the in-water divers are supplied with breathing gases using umbilicals, the capacity of the emergency life support system is to be sufficient to supply each of the in-water 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.

39.11.6 Built-in Breathing System (BIBS) *(2025)*

Where a built-in breathing system is provided for emergency breathing or treatment, the following requirements are to be met:

i) The BIBS gas supply piping is to be independent of the lock-out compartment normal and reserve gas supply piping. The emergency or treatment gas cylinders are not to be used for supplying the lock-out compartment normal and reserve gas supply system.

ii) Breathing masks are to be permanently connected or easily connectable to the BIBS supply piping.

iii) Breathing masks are to be provided with back-pressure regulators to protect against pressure drops on the exhaust side.

iv) 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.

v) Where open circuit systems are used, the effects of increased lock-out compartment pressure are to be considered.

vi) 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.

vii) 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 *(2025)*

Where diver umbilicals are provided, the following requirements are to be met:

i) Diver umbilicals are to be supplied with breathing gases from both the normal life support system as well as the emergency life support system.

ii) 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.

iii) 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.

iv) 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.

v) 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.

vi) 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.

39.11.8 Temperature and Humidity Control

i) 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.

ii) 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)*

i) Life support system testing is to meet the applicable requirements of this section and 11/35.11.

ii) Life support system testing of the command compartment and the lock-out compartments is to be carried out independently.

40 Diver Transport Compartments *(2025)*

Where diver transport compartments are provided, they are to meet the requirements of Subsection 12/39, with the exception of the requirements listed below:

i) Lock-In/Lock-Out Hatches under 12/39.3.

ii) De-watering under 12/39.9.3, 12/39.11.3v), 12/39.11.4(c) and 12/39.11.5iv)b).

iii) Diver Umbilicals and In-Water Divers under 12/39.11.7, 12/39.11.5iv)c) and 12/39.11.8ii).

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 for Personnel Transfer *(2024)*

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 20/55.1 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.

48 Transportation *(2024)*

Lock-out submersibles that are exposed to the ambient environment while being transported on host vessels or submarines are to be designed for the worst-case loads that are anticipated during transportation. The design analysis is to meet the applicable requirements of these Rules and is to include appropriate analysis, test data or other justification for the design loads and load cases.

49 Test Dive *(2025)*

The test dive is to meet the applicable requirements of this Section and Subsection 11/47.

The test dive is to include functional testing of lock-out compartments and transport compartments (where provided) 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

Ambient Pressure Submersibles *(2016)*

1 Scope

This Section along with 1 of these Rules, except as modified herein, provide the requirements for the design, fabrication and testing of ambient-pressure submersibles.

3 Class Notation

New construction ambient-pressure submersibles and ambient-pressure passenger submersibles built under ABS survey are to be assigned the Class notation ⊠ **A1 Ambient-Pressure X Submersible** and ⊠ **A1 Ambient-Pressure X Passenger Submersible**, respectively, subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*.

Note:

'X' represents the words 'Wet', 'Semi-Dry' or 'Dry', depending on the category of the ambient-pressure submersible. For example, an ambient-pressure wet submersible would be assigned the Class Notation ⊠ **A1 Ambient-Pressure Wet Submersible**. See Subsection13/5 below for the definition of these terms.

New and existing ambient-pressure submersibles and ambient-pressure passenger submersibles not built under ABS survey are to be assigned the Class notation **A1 Ambient-Pressure X Submersible** and **A1 Ambient-Pressure X Passenger Submersible**, respectively, subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*.

Note:

The Maltese cross notation (⊠) signifying survey under construction is to be omitted.

5 Definitions

5.1 Ambient-Pressure Submersible

A self-propelled submersible that is capable of carrying personnel and/or passengers while operating underwater or on the surface. Occupants of the submersible are exposed to ambient pressure and may have access to the surrounding environment. Ambient-pressure submersibles include wet, semi-dry and dry submersibles.

5.3 Hull

An enclosure for human occupants.

5.5 Ambient-Pressure Wet Submersible

An ambient-pressure submersible in which the hull is completely flooded with water. The occupants of the submersible remain completely wet due to direct contact with ambient water surrounding the submersible.

5.7 Ambient-Pressure Semi-Dry Submersible

An ambient-pressure submersible in which the hull is partially flooded to a level no higher than the shoulder level of the occupants. The hull has an enclosed upper section that remains dry and is used as an envelope for maintaining a bubble of breathing gases for the occupants.

5.9 Ambient-Pressure Dry Submersible

An ambient-pressure submersible in which the hull is maintained completely dry and is used as an envelope for maintaining a bubble of breathing gases for the occupants. The occupants of the submersible remain completely dry.

5.11 Passenger

See 11/49 for the definition of the term 'Passenger'.

7 Design Depth and Sea-Bed Depth

The design depth of ambient-pressure submersibles is not to exceed the recreational diving limit of 130 FSW (39.6 MSW).

Classification of ambient pressure 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 Section 1A-7-4 of the ABS *Rules for Conditions of Classification (Part 1A)* and Subsection 13/9 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.

9 Operational Parameters

In addition to the required plans, calculations and data in Section 1A-7-4 of the ABS *Rules for Conditions of Classification (Part 1A)*, 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.

vii) When operating in altitudes above sea-level, consideration is to be given to the effect of altitude on decompression

viii) Salinity limits

11 Hull

11.1 General

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

11.3 Emergency Egress

The design of the submersible is to permit emergency egress of personnel while the submersible is in the water column or resting on the sea-bed.

13 Windows

Windows are to be of construction adequate for the function performed, consideration being given to their size and the anticipated loads, including impact loading which may be imposed on them. They are to be constructed following sound engineering practice and in accordance with approved plans.

When acrylic windows are installed on hulls, the window materials are to comply with the material fabrication and material testing requirements of Section 7 of these Rules and the ASME Safety Standard for Pressure Vessels for Human Occupancy (ASME PVHO-1).

15 External Structures

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

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

In order to avoid the detrimental effects of buoyancy on the unit, free-flooding external structures 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 free-flooding external structures are to be provided.

Openings for flooding and venting 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 while in service.

Welded connections between external structures and the exterior of hulls are to be welded so as to minimize local stresses induced in the hull. Inspection of such connections is to be feasible.

17 Nameplates

Ambient-pressure submersibles are to be fitted with a permanent nameplate indicating the design depth, manufacturer's name, serial number and year built. The nameplate is to be of stainless steel or other suitable material and is to be permanently attached.

19 Surface Anchoring, Mooring and Towing Equipment

Surface anchoring, mooring and towing equipment, when provided, are to meet the applicable requirements of 11/15.

21 Emergency Recovery Features

Emergency recovery features are to meet the applicable requirements of Subsection 11/17.

23 Entanglement

External appendages susceptible to entanglement are to meet the applicable requirements of 11/19.

25 Ballast Tanks

Ballast tanks are to meet the applicable requirements of 11/21.

27 Propulsion Systems, Steering Equipment, and Their Control

Propulsion systems, steering equipment and their control systems are to meet the applicable requirements of 11/23.

29 Navigational Equipment

Ambient-pressure submersibles are to be provided with the following equipment:

i) At least one compass or gyro

ii) Means of obstacle avoidance

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

31 Communication Equipment

Ambient-pressure submersibles are to be provided with voice communication systems complying with the applicable requirements of 11/27.

As an alternative to the above, each occupant of the ambient-pressure submersible is to be provided with voice communication equipment to facilitate communication between the occupants as well as the surface/subsurface control station.

33 Emergency Locating Devices

Emergency locating devices are to meet the applicable requirements of 11/29.

An emergency releaseable buoy capable of reaching the surface from the design depth is to be provided. The buoy is to be attached to the submersible with a length of line equal to or greater than 120% of design depth.

35 Buoyancy and Stability

Buoyancy and stability of ambient-pressure submersibles are to meet the requirements of this Section.

35.1 Normal Ballast System

Each ambient-pressure 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.).

35.3 Depth Keeping Capability

Under normal and emergency operating conditions, ambient-pressure submersibles are to be capable of maintaining a constant depth statically and dynamically while submerged.

35.5 Ascent Rate

The maximum ascent rate for ambient pressure submersibles is not to exceed 30 feet per minute.

35.7 Intact Surface Stability

Each ambient-pressure submersible is to have sufficient intact stability on the surface under the worst loading condition and when subjected to the environmental conditions listed in 20/55.1 TABLE 1 for the design sea state.

35.9 Intact Underwater Stability

Adequate static and dynamic stability in submerged condition is to be demonstrated by the tests and calculations required in 13/35.13 below.

Under all conditions of loading, ballast and personnel egress/re-entry, the center of buoyancy is to be above the center of gravity by at least 51 mm (2 in.).

35.11 Changes in Buoyancy, List and Trim

35.11.1

Ambient-pressure submersibles are to be provided with suitable means to compensate for changes in buoyancy, list and trim that may occur when the occupants exit or enter the submersible while underwater. The means are to have sufficient control to counteract the effect of the occupants exiting or entering the submersible in quick succession.

35.11.2

For ambient-pressure dry and semi-dry submersibles, the design of the submersible is to ensure that the bubble of breathing gases within the hull is maintained at a constant volume as the ambient pressure changes during ascent or descent, in order to avoid sudden changes in buoyancy that could lead to loss of control of the submersible.

35.11.3

For ambient-pressure dry and semi-dry submersibles, the design of the submersible is to ensure that the submersible is capable of being maintained in the upright or substantially upright position under all operating conditions, in order to prevent loss of the bubble of breathing gases within the hull.

35.13 Partial Flooding

For ambient-pressure semi-dry submersibles, partial flooding of the hull is to be limited to no higher than the shoulder level of the occupants (See 13/5.7) and to a level that is below the location of any electrical and life support equipment (such as CO_2 scrubbers) within the hull.

35.15 Calculations and Experiments

The following calculations are to be submitted and tests are to be witnessed by the Surveyor:

35.15.1 Detailed Weight and Displacement Calculations

Detailed weight and displacement calculations that include the calculated positions of the 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 weight and balance spreadsheet during design and construction.

35.15.2 Hydrostatic Model

A mathematical model is to be used to calculate the displacement (Δ), the positions of the center of buoyancy (CB) and the metacenter (CM), by computing the hydrostatic properties during design.

35.15.3 Hydrodynamic Calculations

Hydrodynamic calculations are to demonstrate that the submersible is dynamically stable and is capable of preventing uncontrolled behavior at all design speeds.

35.15.4 Deadweight Survey and Lightship Measurement

The location, number and weight of all items listed on the weight and balance spreadsheet are to be physically checked by the Surveyor after construction and outfitting. The completely outfitted submersible is to be weighed and the measured weight is to be then compared with the total spreadsheet weight, compensating for any extraneous weights that were on-board the submersible at the time of testing.

35.15.5 Inclining Experiments

Inclining experiments or equivalent testing is to be carried out on the surface and while submerged in order to fix GM (the distance between CG and the metacenter CM) and GB (the distance between CG and CB). 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.

35.15.6 Scenario Curves

Scenario curves indicating the CB, CG, W, CM, and Δ of the submersible are to be assembled in graphic form for interpretation and comparison with criteria.

37 Ventilation

Ventilation is to meet the applicable requirements of 11/37.

Battery box ventilation air used while charging and/or operations is not to pass through, or come from any other systems.

39 Life Support and Environmental Control Systems

39.1 General

Life support systems are to meet the requirements of this Section and the applicable requirements of Section 8 of these Rules.

Appropriate means for monitoring and performing decompression requirements is to be carried onboard.

For dry and semi-dry submersibles, the O_2 limits within the bubble are to be maintained between a minimum partial pressure of 0.18 ATA and a maximum concentration of 23%. The partial pressure of carbon dioxide (CO_2) within the bubble is to be maintained at or below 0.005 ATA.

For scuba gear/rebreathers, the partial pressure of Oxygen (O_2) is to be kept within the appropriate limits for underwater breathing apparatus (UBA) as specified in the US Navy Diving Manual or equivalent recognized national or international standards.

39.3 Life Support Systems

Life support systems are to consist of normal as well as emergency life support systems.

39.3.1 Normal Life Support System

The normal life support system is to be provided on the submersible. The normal life support system is to be capable of supplying life support for two times the mission duration, but not less than one hour at design depth.

39.3.2 Emergency Life Support System

In addition to the normal life support system, an emergency life support system is to be provided for each occupant of the submersible. This emergency life support equipment must be readily available to each occupant for immediate use.

Each occupant is to be provided with appropriate scuba gear or self-contained re-breathers in order to facilitate their leaving the submersible and ascending to the surface.

An extra (spare) underwater breathing apparatus is to be provided onboard.

The scuba gear or self-contained re-breathers are to be capable of supplying life support for a duration of not less than 150 percent of the time required for ascent of the occupant from the rated depth of the submersible to the surface. (*Note:* The ascent duration is to also include the time required for any decompression stops en route to the surface, as applicable).

39.5 Life Support Testing

Life support testing of the normal life support system is to be carried-out as per the applicable requirements of 11/35.11.

41 Piping Systems

Piping systems are to meet the applicable requirements of Section 8 Section 9.

43 Electrical Systems

The onboard batteries are to be capable of supplying power to all essential systems, including life support systems for the same duration as specified in 13/39.3.1

45 Equipment

Ambient-pressure submersible equipment is to meet the applicable requirements of Subsection 11/41.

47 Access to Vital Equipment

Access to vital equipment is to meet the applicable requirements of Subsection 11/45.

49 Test Dive

A test dive is to be conducted as per the applicable requirements of Subsection 11/47.

51 Additional Requirements for Ambient-Pressure Passenger Submersibles

Ambient-pressure passenger submersibles are to meet the applicable requirements of 11/49.5, 11/49.7 and 11/49.11.

53 Operations and Training

Submersible operations and training is solely the responsibility of the Owner/Operator (See Section 1A-7-6 of the ABS *Rules for Conditions of Classification (Part 1A)*).

The Owner/Operator must ensure that all occupants are appropriately trained (including being a certified scuba diver).

The Owner/Operator is to consider the provision of emergency recompression capabilities when decompression obligation dives are performed.

SECTION 14

Diving Systems *(2010)*

1 Scope

This Section, along with Sections 1 through 10 and Sections 19 and 20, 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 14/2 TABLE 1 above and the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*.

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 Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*.

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 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 14/11.3.20.

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 20/55.1 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 14/3.3.1.

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 20.

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 14/3.3.1.

3.3.3(b) The lifting lugs/attachments of PVHOs other than those in 14/3.3.3(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 20/55.1 TABLE 1.). Mating systems for HEUs are to be designed to facilitate 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 20/55.1 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 Section 8 and Section 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 Section 8 and Section 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) (2017) BIBS exhaust systems are to be provided with a back-pressure regulator and a secondary means to prevent pressure differential to the diver using the mask, if the back pressure regulator were to fail.

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 CO2 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 *Marine 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 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 4-8-3/3.15.2 through 4-8-3/3.15.11 of the *Marine 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 Administration of the dive support vessel/offshore facility. Alternatively, they are to meet the requirements specified in 14/3.15.5(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 14/3.19.1(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 14/3.7.

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 (3.0 m^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 14/7.3

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 14/3.3.1.

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 14/3.3.1.

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 14/3.3.1.

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 14/3.7.

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 14/3.5. 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 14/3.9.

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 A1).

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 A1). 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 litres/minute or 1.5 actual cubic feet/minute (acfm) per diver for the lock-out divers under heavy work conditions and 62.5 litres/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 litres/minute or 0.42 actual cubic feet/minute (acfm) per diver for average rest conditions and 22.5 litres/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:

¾ inch NPT (female) - for hot water

½ 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) *(2020)*

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 and for recovery of the bell does not to exceed the time equivalent to the capacity of the diving bell's onboard emergency life support system.

7.31.1(e) *(2020)*

The positive buoyancy of the diving bell (without ballast weights, and with fully flooded trunk(s)) is not to exceed 5 % of the displacement of the fully loaded bell. Alternative arrangements that provide an equivalent level of safety will be considered on a case-by-case basis.

7.31.1(f) *(2020)*

The angle of inclination of the bell in the substantially upright position is not to exceed 5 degrees with the vertical.

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 20.

7.31.2(c) (2011) In addition to 14/7.31.2(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 *(2020)*

Life support system tests are to be conducted as per the applicable requirements of Section 8.

7.33.2 Functional Tests *(2020)*

In-shop functional testing of diving bells is to be conducted. 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 Stability Tests *(2020)*

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 Test Dive *(2020)*

Prior to commencement of diving operations, an unmanned test dive of the diving bell to its design depth is to be conducted in the presence of the Surveyor.

For this test dive, the diving bell is to be loaded to its maximum weight. When internally pressurized diving bells are used, the bell is to be pressurized to its design depth using compressed air or breathing gases.

The test dive is to be conducted by increasing the submergence of the diving bell in increments until design depth is reached. Once at design depth, constant depth is to be maintained and functional testing of the bell systems and equipment is to be carried-out as per the manufacturer's instructions.

The test dive is to demonstrate satisfactory operation of the diving bell systems, equipment, as well as the handling system. The test dive is to also include emergency recovery of the diving bell from the design depth using the handling system's emergency means of recovery (such as the guide wire system).

Upon completion of the test dive, the following is to be carried-out on the surface:

i) Visual examination of the welded joints, penetrations, viewports and hatches of the diving bell, as well as the bell systems and equipment.

ii) Functional testing of the diving bell systems and equipment, as per the manufacturer's instructions.

The test dive may be a single dive as described above, or a series of dives to accomplish the same purpose. Where the depth of water available is less than the design depth, the test dive may be conducted to the rated depth (i.e., depth reached during the test dive). For such cases, both the rated depth, as well as the design depth of the diving bell are to be indicated in the Record. The rated depth may be subsequently increased by performing a test dive to a greater depth, not exceeding the design depth of the diving bell, in the presence of the Surveyor.

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 20.

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 14/7.1.

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 14/3.3.1 and

14/3.3.3(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 14/3.3.1.

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 litres/minute or 1.5 actual cubic feet/minute (acfm) per diver for the working divers under heavy work conditions and 62.5 litres/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 litres/minute or 0.42 actual cubic feet/

minute (acfm) per diver for average rest conditions and 22.5 litres/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 *(2020)*

Life support system tests are to be conducted as per the applicable requirements of Section 8.

9.21.2 Functional Tests *(2020)*

In-shop functional testing of open bells is to be conducted. 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 Test Dive *(2020)*

Prior to commencement of diving operations, an unmanned test dive of the open bell to its design depth is to be conducted in the presence of the Surveyor.

For this test dive, the open bell is to be loaded to its maximum weight.

The test dive is to be conducted by increasing the submergence of the open bell in increments until design depth is reached. Once at design depth, constant depth is to be maintained and functional testing of the open bell systems and equipment is to be carried-out as per the manufacturer's instructions.

The test dive is to demonstrate satisfactory operation of the open bell systems, equipment as well as the handling system. The test dive is to also include emergency recovery of the open bell from the design depth using the handling system's emergency means of recovery (such as the guide wire system).

Upon completion of the test dive, the following is to be carried-out on the surface:

i) Visual examination of the open bell structure, systems and equipment.

ii) Functional testing of the open bell systems and equipment, as per the manufacturer's instructions.

The test dive may be a single dive as described above, or a series of dives to accomplish the same purpose. Where the depth of water available is less than the design depth, the test dive may be conducted to the rated depth (i.e., depth reached during the test dive). For such cases, both the rated depth, as well as the design depth of the open bell are to be indicated in the Record. The rated depth may be subsequently increased by performing a test dive to a greater depth, not exceeding the design depth of the open bell, in the presence of the Surveyor.

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 20.

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 14/9.1. For operations exceeding 300 FSW (91.46 MSW), see 14/7.1.

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 14/3.3.1 and 14/3.3.3(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 14/3.3.1.

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.

10.12 Test Dive *(2020)*

Prior to commencement of diving operations, an unmanned test dive of the diving basket to its design depth is to be conducted in the presence of the Surveyor.

For this test dive, the diving basket is to be loaded to its maximum weight.

The test dive is to be conducted by increasing the submergence of the diving basket in increments until design depth is reached, and is to demonstrate satisfactory operation of the diving basket handling system. The test dive is to also include emergency recovery of the diving basket from the design depth using the handling system's emergency means of recovery (such as the guide wire system).

Upon completion of the test dive, the following is to be carried-out on the surface:

i) Visual examination of the diving basket structure and equipment.

ii) Functional testing of the diving basket equipment, as per the manufacturer's instructions.

The test dive may be a single dive as described above, or a series of dives to accomplish the same purpose. Where the depth of water available is less than the design depth, the test dive may be conducted to the rated depth (i.e., depth reached during the test dive). For such cases, both the rated depth, as well as the design depth of the diving basket are to be indicated in the Record. The rated depth may be subsequently increased by performing a test dive to a greater depth, not exceeding the design depth of the diving basket, in the presence of the Surveyor.

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 20.

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 14/17.1.

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 14/5.

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 14/3.3.1.

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 14/3.3.3(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 14/3.5.

11.3.12

Clamping arrangements, when provided, are to meet the applicable requirements of 14/3.9.

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 14/3.7.

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 11/23.

11.3.20 Self-Propelled Hyperbaric Lifeboats (SPHLs) *(2017)*

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", as well as any subsequent amendments to the same.

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 (2017).* 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. (*Note*: In many cases, the HEU gas cylinders will be unable to supply the emergency life support system for an extended duration. For such cases, additional gas supply may be provided by an external Life Support Package. See 14/11.7.2).

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) (2017) An adequate supply of food, water, first-aid equipment, sickness bags, paper towels for not less than 72 hour duration and all necessary operational instructions are to be provided on HEUs before launching at sea. In determining the amount of food and water to be provided, consideration is to be given to the area of operation and the environmental conditions envisaged. (Refer to the table in 8/5.5). Food packages that utilize exothermic chemical means, flames, electrical resistance, or any other heating means that are not approved for hyperbaric environments are not be used.

11.3.22(k) (2017) 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 and are to be capable of preventing accidental spillage during launch, recovery or under rough weather conditions. 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:

¾ in. NPT (female) - hot or cold water

½ in. NPT (female) - breathing mixtures

The connections are to be clearly and permanently marked and suitably protected.

11.3.23 Standardized Interfaces *(2021)*

In order to facilitate interface compatibility between Hyperbaric Evacuation Units (HEUs) and Hyperbaric Reception Facilities (HRFs), it is recommended that HEUs comply with the standardized interface guidelines as outlined by the International Marine Contractors Association (IMCA) in their publication "Hyperbaric Evacuation Systems (HES) Interface Recommendations", IMCA D051. (Note: *The design of standardized mating flanges should also take into consideration geometric dimensioning and tolerancing of these flanges*).

11.3.24 Fire Protection

11.3.24(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.

11.3.24(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.

11.3.25 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.

11.3.26 Electrical Systems

11.3.26(a) HEUs are to be provided with a suitable onboard source of power.

11.3.26(b) The onboard source of power is to be suitable for supplying power for not less than 72 hours.

11.3.26(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.

11.3.27 Stability

11.3.27(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.

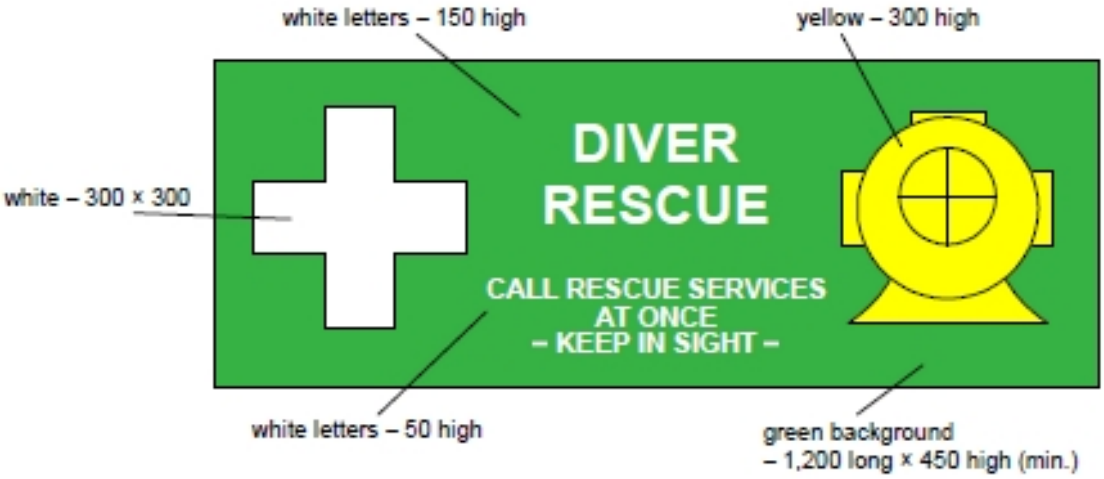
b) *Hydrostatic Model.* A mathematical model is to be used to calculate Δ, the positions of the center of buoyancy (*CB*) and the metacenter (*CM*), by computing the hydrostatic properties during design.

11.3.27(b) HEUs Designed for Underwater Operations. HEUs are to meet the applicable submersible stability requirements of Section 11.

11.3.28 Marking and Additional Information

11.3.28(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.

11.3.28(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.



11.3.28(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

11.3.28(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 attempt to give food, drinks or medical supplies to the occupants; and

4) Do not open any hatches."

11.3.29 Tests

Fully outfitted HEUs are to be subjected to the following tests in the presence of the Surveyor:

11.3.29(a)

Life support system tests as per the applicable requirements of Section 8.

11.3.29(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.

11.3.29(c)

Launch test of the fully loaded HEUs using the dedicated launch systems that are installed on the dive support vessel/offshore facility.

11.3.29(d) *(2020)*

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 an unmanned test dive to its design depth in the presence of the Surveyor.

For this test dive, the HEU is to be loaded to its maximum weight, and is to be pressurized to its design depth using compressed air or breathing gases.

The test dive is to be conducted by increasing the submergence of the HEU in increments until design depth is reached. Once at design depth, constant depth is to be maintained and functional testing of the HEU systems and equipment is to be carried-out as per the manufacturer's instructions. The test dive is to demonstrate satisfactory operation of the HEU systems and equipment.

Upon completion of the test dive, the following is to be carried-out on the surface:

a) Visual examination of the welded joints, penetrations, viewports and hatches of the HEU, as well as the HEU systems and equipment.

b) Functional testing of the HEU systems and equipment, as per the manufacturer's instructions.

The test dive may be a single dive as described above, or a series of dives to accomplish the same purpose. Where the depth of water available is less than the design depth, the test dive may be conducted to the rated depth (i.e., depth reached during the test dive). For such cases, both the rated depth, as well as the design depth of the HEU are to be indicated in the Record. The rated depth may be subsequently increased by performing a test dive to a greater depth, not exceeding the design depth of the HEU, in the presence of the Surveyor.

11.5 HEU Launch Systems

11.5.1 *(2017)*

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 20. 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", as well as any subsequent amendments to the same.

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 20/7 and 20/51).

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 21.

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 *(2020)*

Shipping containers used for housing portable dive control stations are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers* or the ABS *Guide for Certification of Offshore Containers*, based on intended use. 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 or Guide.

15 Utility Vans

15.1 *(2020)*

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* or the ABS *Guide for Certification of Offshore Containers*, based on intended use. 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 or Guide.

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 14/17.1.2 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 *Marine 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 14/17.1.2 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 14/17.1.3 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)* *(2025)*

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 4-1-1/7.7 TABLE 2 of the *Offshore 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 *Marine 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 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 5D-5-3/5.3.1 of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel 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 20/7.3.4).

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 5D-5-3/5.3.6 of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel 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 ABS *Rules for Building and Classing Marine Vessels (Marine Vessel 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 litres/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 ABS *Rules for Building and Classing Marine Vessels (Marine Vessel 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 15

Hyperbaric Facilities *(2021)*

1 Scope

This Section along with Sections 1 through 10 provide the requirements for the design, fabrication and testing of hyperbaric facilities for marine applications, including Hyperbaric Diving Simulators and Hyperbaric Reception Facilities.

The scope of this section does not include the following types of facilities:

- Hyperbaric facilities intended to be used in a clinical setting for medical hyperbaric therapy (e.g., Medical Hyperbaric Chambers)
- Hypobaric facilities for high altitude training (e.g., Altitude Chambers)

See Section 2 for the definition of the applicable terms.

2 Class Notations

New construction hyperbaric facilities that are built under ABS survey and meet the requirements of Subsections 15/3 and 15/4 below are to be assigned the class notation ✠ **A1 Hyperbaric Facility**, subject to the conditions of classification referenced in Section 1 of these Rules. New and existing hyperbaric reception facilities that are not built under ABS survey and meet the requirements of Subsections 15/3 and 15/4 below are to be assigned the class notation **A1 Hyperbaric Facility**, subject to the conditions of classification referenced in Section 1 of these Rules.

New construction hyperbaric diving simulators that are built under ABS survey and meet the requirements of Subsections 15/3, 15/4 and 15/5 below are to be assigned the class notation ✠ **A1 Hyperbaric Diving Simulator**, subject to the conditions of classification referenced in Section 1 of these Rules. New and existing hyberbaric diving simulators that are not built under ABS survey and meet the requirements of Subsections 15/3, 15/4 and 15/5 below are to be assigned the class notation **A1 Hyperbaric Diving Simulator**, subject to the conditions of classification referenced in Section 1 of these Rules.

New construction hyperbaric reception facilities that are built under ABS survey and meet the requirements of Subsections 15/3, 15/4 and 15/6 below are to be assigned the class notation ✠ **A1 Hyperbaric Reception Facility**, subject to the conditions of classification referenced in Section 1 of these Rules. New and existing hyperbaric reception facilities that are not built under ABS survey and meet the requirements of Subsections 15/3, 15/4 and 15/6 below are to be assigned the class notation **A1 Hyperbaric Reception Facility**, subject to the conditions of classification referenced in Section 1 of these Rules.

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

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

Windows are to be provided with appropriate means of protection to prevent mechanical damage.

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 hatches (including the doors, hatch operating and hinge mechanisms) are to take into account all applicable loads.

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.). When hyperbaric facilities are used for diver training or recovery, the hatch opening diameter is not to be less than 711 mm (28 in.) in order to facilitate the recovery of an unconscious diver wearing full diving gear. 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. Interlocks are to prevent accidental opening of the doors while under pressure, and are to prevent pressurization if not fully engaged. Locking mechanisms and interlocks 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 that would prevent personnel ingress or egress.

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, including doors, which use springs or similar assist mechanisms. 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 external working pressures, maximum and minimum rated temperatures, internal and 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.

3.2 External Structures

External structures include all structural members located outside the pressure boundaries of PVHOs. These include members such as support frames, skids and lifting lugs.

The design of each welded connection is to facilitate appropriate inspection. All welds on external welded connections are to be sealed or full penetration welds.

3.2.1 Support Frames / Skids

3.2.1(a)

Support frames/skids of PVHOs 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.

3.2.1(b)

Loads to be considered include applicable loads such as the weight of the fully loaded PVHO (including equipment, supplies and people). Where mating operations are carried-out, the mating loads are to consider a force of not less than twice the weight of the mating PVHO (e.g., Hyperbaric Evacuation Unit). When it is intended to carry out hydrostatic testing of the PVHO with the support frames/skids installed, then the maximum static load due to the hydrostatic testing is to also be considered in the design. Calculated stresses are not to exceed the allowable stresses f_a as obtained from the following equation:

$$f_{\mathrm{a}} = f\mu_{\mathrm{e}}$$

where

f = critical or shear stress for buckling considerations, or

= minimum specified material yield stress

μ_{e} = usage factor as follows:

TABLE 1
Usage Factors

Type of Stress	μ_{e}
Compressive or Shear Buckling	0.8
Axial and / or Bending Stresses	0.8
Shear Stresses	0.53

3.2.1(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 20, "Handling Systems".

3.2.2 Lifting Lugs / Attachments

Lifting lugs/attachments of PVHOs are to be suitable for handling the PVHOs during installation/ demobilization. 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 less.

3.3 Piping Systems

i) Piping systems are to meet the applicable requirements of this Section and Sections 8 and 9.

ii) PVHOs are to be equipped with valves, gauges and other fittings as necessary to control and monitor the internal environments of compartments from the control station of the hyperbaric facility. All interior breathing and pressure supply controls are to be provided with means of overriding and controlling them from the exterior.

iii) A manually operated stop valve is to be provided at each PVHO pressure boundary piping penetration. Additionally, piping exclusively carrying fluids into the PVHO are to have a check valve close to and downstream of the stop valve.

iv) 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. 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. Pressure relief devices are to be capable of preventing the internal pressure from rising more than 10% above the maximum allowable working pressure of the PVHO.

v) 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.

vi) Anti-suction protective devices are to be provided inside PVHOs on the openings of exhaust lines.

vii) All high-pressure piping is to be well-protected and well-supported against mechanical damage.

viii) Piping systems carrying mixed gas or oxygen under high pressure are not to be arranged inside accommodation spaces, machinery rooms or similar compartments.

ix) Flexible hoses, except for umbilicals, are to be reduced to a minimum.

3.4 Life Support and Environmental Control Systems

3.4.1 General

i) Life support systems are to meet the applicable requirements of this Section and Sections 8 and 9.

ii) Hyperbaric facilities 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 with the maximum number of occupants, and 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 occupants. In determining the duration and amount of life support necessary, consideration is to be given to the environmental conditions, the Oxygen (O_2) and mixed gas consumption and Carbon Dioxide (CO_2) generation under such conditions, the heat input or removal and the emergency services that may be available for the decompression of occupants. 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 Carbon Dioxide (CO_2) absorbent required for the hyperbaric operation.

iii) The normal life support system is to be designed so that the partial pressure of Oxygen (O_2) within PVHOs are 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. Carbon Dioxide (CO_2) removal systems are to be designed so that the partial pressure of Carbon Dioxide (CO_2) within PVHOs do not exceed 0.005 atmosphere absolute (ata).

iv) *Life Support Capacity (Normal and Reserve).* At the commencement of operations, the normal breathing gas supply and Carbon Dioxide (CO_2) removal systems of the hyperbaric facility are to have sufficient capacity for the anticipated mission time plus a reserve capacity that is not less than 48 hours.

v) Each compartment of the PVHO is to be provided with two (2) independent gas pressurization systems.

3.4.2 Breathing Gas Systems

3.4.2(a)

Each compartment of the PVHO is to be provided with two (2) independent breathing gas supply systems.

3.4.2(b)

For decompression / recompression applications, each applicable compartment of the PVHO is to be provided with the following:

i) One (1) gas exhaust system

ii) One (1) Built-in Breathing System (BIBS) with breathing masks (See 3.4.2(i) below)

3.4.2(c)

Where pure Oxygen (O_2) or gases containing more than 25% Oxygen (O_2) by volume is being supplied, a separate piping system is to be provided for this purpose.

3.4.2(d)

The design pressurization and exhaust depressurization rates for hyperbaric operations are to be determined by the designer and are to be consistent with the rates specified in the US Navy Diving Manual or equivalent recognized national or international standards. For treatment recompression applications, 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.

3.4.2(e)

The gas supply and exhaust systems are to be arranged to provide even mixing of the gases.

3.4.2(f)

Gas system valves are to be arranged so that valve leakage does not lead to inadvertent mixing of pure Oxygen (O2) or gases containing more than 25% Oxygen (O_2) by volume with other breathing gases. Intersections between Oxygen (O_2) and non- Oxygen (O_2) systems are to be isolated by two shut-off valves with a vent valve in between.

3.4.2(g)

Filters and automatic pressure regulators are to be arranged so that they can be isolated without interrupting vital gas supplies.

3.4.2(h)

The discharge from relief devices, vents and exhausts are to be vented away from sources of ignition, personnel or any area where the presence of the discharged gases could be hazardous.

3.4.2(i) Built-in Breathing Systems (BIBS)

For decompression/recompression applications, each applicable compartment of the PVHO is to be provided with a Built-in Breathing System (BIBS) to supply emergency/treatment gas. The BIBS is to comply with the following:

i) The BIBS is to supply emergency/treatment gas through a dedicated piping system to breathing masks (either full-face masks or oral-nasal masks). Breathing masks are to be suitable for the intended application and are to be permanently connected or easily connectable to the BIBS supply piping.

ii) Compartments that serve as living facilities are to be provided with BIBS masks corresponding to the maximum number of occupants for which the compartment is rated plus one. Compartments that serve as transfer locks are to be provided with BIBS masks corresponding to the maximum number of occupants that may simultaneously transfer through the lock plus one. All other compartments are to be provided with at least two BIBS masks.

iii) The BIBS supply piping is to be independent of the normal gas supply piping to the compartment.

iv) The emergency and treatment gas cylinders are not to be used for supplying the normal gas supply system of the compartment.

v) The capacity of the emergency/treatment gas supplies is to be sufficient for the safe conclusion of the hyperbaric facility's operation.

vi) The system is to be designed such that the partial pressure of Carbon Dioxide (CO_2) in the gas being inhaled does not to exceed 0.015 atmosphere absolute (ata).

vii) 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.

viii) BIBS exhaust systems are to be provided with a back-pressure regulator and a secondary means to prevent pressure differential to the diver using the mask, if the back pressure regulator were to fail.

ix) 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.

x) Where open circuit systems are used, the effects of change in the compartment pressure and oxygen concentration are to be considered.

xi) The exhaust sides of masks intended for oxygen service are to be connected to an external dump or the BIBS is to be of closed-circuit type. When closed-circuit type systems are used, consideration is to be given to the change in oxygen concentration resulting from operational procedures.

3.4.3 Carbon Dioxide (CO_2) Removal Systems

i) Each compartment of the PVHO is to be provided with means for Carbon Dioxide (CO_2) removal.

ii) Carbon Dioxide (CO_2) removal systems used for normal operation are to be provided with full redundancy to maintain the CO_2 concentration within acceptable limits.

3.4.4 Emergency Life Support System

i) In addition to the normal breathing gas and Carbon Dioxide (CO_2) removal systems, an emergency life support system is to be provided. The emergency life support system is to be independent of the normal life support system.

ii) Emergency breathing gas is to be supplied to either full-face masks, oral-nasal masks or self-contained re-breathers suitable for the intended service. One mask per occupant of the PVHO is to be provided.

iii) Where open circuit systems are used for emergency life support, the effects of increased compartment pressure are to be considered.

iv) The emergency life support system is to be designed so that the partial pressure of Carbon Dioxide (CO_2) in the gas being inhaled does not exceed 0.015 atmosphere absolute (ata).

v) The capacity of the emergency life support system is to be sufficient to permit evacuation of the compartment during events such as a contaminated atmosphere, as per the emergency operating procedures of the hyperbaric facility.

3.4.5 External Environmental Control Units (ECUs)

i) External Environmental Control Units (ECUs), when fitted, are to be capable of providing heating/cooling, humidity control and Carbon Dioxide (CO_2) removal services.

ii) 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 so as to maintain the life support parameters within the allowable limits.

iii) 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.

iv) Sizing calculations for flow-fuses are to be submitted for review. In addition, means are to be considered for resetting flow-fuses.

3.5 Electrical Systems and Equipment

3.5.1 General

i) Electrical systems and equipment are to meet the applicable requirements of this Section and Section 10.

ii) Electrical systems and equipment installed within PVHOs are to be limited to those necessary for the safe operation of the PVHO and the monitoring of its occupants.

iii) Electrical systems and equipment, 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 PVHO.

iv) The electrical systems and equipment within the PVHO are to be suitable for hyperbaric applications and are to be rated for the maximum anticipated pressure within the PVHO. These systems and equipment are to be such that repeated pressurization and depressurization will not cause damage.

3.5.2 Normal Power Supply

At the commencement of each operation, the normal power supply of the hyperbaric facility is to have sufficient capacity for the anticipated mission time plus a reserve capacity that is not less than 48 hours.

3.5.3 Emergency Power Supply

i) In the event of failure of the normal source of electrical power to the hyperbaric facility, an independent emergency source of electrical power is to be available. The emergency source of power is to have sufficient capacity for 150% of the time required for safe termination of operations of the hyperbaric facility, while supplying the emergency equipment (such as life support equipment, communication equipment and internal lighting).

ii) The emergency source of electrical power is to be located as far apart as practicable from the normal source of electrical power.

3.5.4 Generators

Generators that are part of the classed hyperbaric facility, and are used for supplying normal or emergency power, are to comply with the following:

i) Generators of 100 kW (135 hp) and over, are to be certified for compliance with the appropriate provisions of Section 4-8-3 of the *Marine Vessel Rules*.

ii) Generators of less than 100 kW (135 hp), 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 4-8-3/3.15.2 through 4-8-3/3.15.11 of the *Marine 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.

3.6 Communication Systems and Equipment

3.6.1

Hyperbaric facilities are to be provided with voice communication systems and equipment. These communication systems and equipment are to be arranged for direct two-way communication between the control station of the hyperbaric facility and the following as applicable:

- Each compartment of the hyperbaric facility's PVHOs
- Where mating operations are carried-out, the unit (e.g., Hyperbaric Evacuation Unit) that is mating with the hyperbaric facility's PVHO

3.6.2

The control station is to have the capability to initiate communication without action from the occupants.

3.6.3

i) Communication systems are to consist of a primary and secondary system.

ii) 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.

iii) The secondary system is to be fully independent of the primary system. It may consist of a sound-powered telephone or other means that are capable of operating in the event of main and emergency power failure.

3.7 Fire Fighting and Fire Detection

3.7.1 Internal Fire Extinguishing Systems for PVHOs

3.7.1(a) General

i) Each compartment of a PVHO is to be provided with suitable means for fire fighting. This may include fixed fire extinguishing systems or portable hyperbaric fire extinguishers.

ii) The means of fire fighting are to be suitable for operation at all internal pressures, up to the maximum operating pressure of the PVHO.

iii) 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.

iv) The capacity of extinguishing systems using gaseous propellants is to be such that complete discharge of the extinguishing system will not result in a toxic concentration.

v) Consideration is to be given to the increase in compartment pressure resulting from the discharge of the extinguishing agents/propellants.

3.7.1(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) Fixed fire extinguishing systems are to be suitable for operation at all internal pressures up to the maximum operating pressure of the PVHO.

iii) Means are to be provided to actuate fixed fire extinguishing systems from within and outside the PVHOs. Suitable safeguards are to be provided to prevent inadvertent actuation.

iv) The extinguishing agent is to be fresh water or other liquid agents suitable for use in manned compartments.

v) Fixed fire extinguishing systems are to be capable of recharging without the need for depressurizing the PVHOs.

vi) Fixed fire extinguishing systems are to have the capability to stop and reactivate their discharge from within and outside PVHOs.

vii) Fixed extinguishing systems are to be functionally tested in the presence of the Surveyor over the full range of internal pressures, until the maximum operating pressure of the PVHO.

3.7.1(c) Portable Hyperbaric Fire Extinguishers

i) When PVHOs are not provided with fixed fire extinguishing systems, the fire extinguishing means is to consist of portable hyperbaric fire extinguishers.

ii) Hyperbaric fire extinguishers are to be suitable for operation at all internal pressures up to the maximum operating pressure of the PVHO.

iii) 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 hyperbaric services.

iv) The extinguishing agent is to be distilled water or other non-conductive liquid agents suitable for use in manned compartments.

3.7.2 Internal Fire Detection and Alarm Systems for PVHOs

i) Each compartment of the PVHO is to be provided with automatic fire detection and alarm systems.

ii) The fire detection and alarm systems are to be suitable for operation under hyperbaric conditions. Where such systems are unsuitable, consideration will be given to alternate arrangements.

iii) Faults (*voltage failure, breakage in the detection loops, earth faults, etc.*) in the fire detection and alarm systems are to be indicated at the control station of the hyperbaric facility by means of visual and audible signals.

3.8 PVHO Layout and Outfitting

3.8.1 General

i) Hyperbaric facilities 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.

ii) Each compartment of the PVHO is to be provided with means of visual monitoring of the internal occupants from the outside. At least one viewport is to be provided for each compartment.

iii) 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. A general interior illumination level of at least 270 lumens/m2 (25 foot-candles) is to be provided, with 540 lumens/m2 (50 foot-candles) provided over bunks and in work areas under normal operating conditions.

iv) PVHOs are to be provided with suitable means of heating, cooling and controlling humidity, to maintain a comfortable temperature and humidity level for the occupants. The heating, cooling and humidity control systems are to have full redundancy.

v) PVHOs or PVHO compartments that serve as living facilities and other compartments that may be used for decompression are to be provided with suitable medical/equipment locks. See Subsection 15/3.9.2 below.

vi) All compartments of PVHOs are to be provided with gas circulation systems. The circulation systems are to have the capability to maintain homogenous gas mixtures and avoid stratification of gas layers within the compartments.

3.8.2 Continuously Occupied PVHOs

When PVHOs are continuously occupied for 12 hours or longer, they are to be provided with the following features:

3.8.2(a)

PVHOs 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.

3.8.2(b)

The viewports/windows for PVHOs that serve as living facilities are to allow the bunks to be seen as much as possible over their entire lengths from the outside.

3.8.2(c)

PVHOs 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.

3.8.2(d)

PVHOs or PVHO compartments that serve as transfer locks are to have internal dimensions sufficient to allow the simultaneous transfer of at least two persons. The floodable volume is not to be less than 105 ft^3 (3.0 m^3).

3.8.2(e)

Toilet, hand washing, and shower arrangements are to be provided and are to be installed outside the living facilities in separate compartments. These arrangements are to comply with the following:

i) *Flush Type Toilets*

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 safe and sufficient pressure above the internal pressure of the PVHO at the time of flushing.

iv) Flushing systems are to require two positive manual actions for operation.

v) Flushing systems are to have means to limit the volume of gas exhausted with each flushing operation.

vi) Effluent drain from the toilets is to be routed to an external holding tank. An interlock is to be provided in order to prevent inadvertent chamber depressurization.

vii) Means for communicating with the control station are to be provided in the vicinity of flush type toilets.

ii) *Hand Washing and Shower Systems*

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 safe and sufficient pressure above the internal pressure of the PVHO at the time of washing or showering.

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. They are to be fitted with anti-suction devices.

v) Means are to be provided to limit the volume of gas exhausted with each drainage operation.

iii) *Holding Tanks*

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 PVHO pressure during operation of the flushing/drainage systems or during decompression.

ii) Pressure gauge for indicating the tank pressure.

iii) A means for flushing/cleaning the holding tank is to be considered.

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.

v) Where multiple toilets are connected to a common holding tank, means are to be provided to prevent inadvertent depressurization of the chambers and backflow to the other compartments.

3.9 PVHO Support Components

3.9.1 Transfer Trunks/Tunnels

i) 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.

ii) Trunks/tunnels are to be capable of allowing the safe transfer of occupants between PVHOs and are to have a minimum internal diameter of 610 mm (24 inches).

iii) Trunks/tunnels are to be provided with an external means for monitoring, venting and equalizing internal pressure with the compartment being serviced or the eternal atmosphere.

iv) Trunks/tunnels exceeding 914 mm (36 inches) in length are to be provided with internal hand and/or footholds.

3.9.2 Medical/Service Locks

i) Where Medical/Service locks are provided, they are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

ii) 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 masks / 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.

iii) 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.

iv) Medical/Service locks are to be provided with an external means for monitoring, venting and equalizing pressure with the compartment being serviced or the external atmosphere.

3.9.3 Mating Systems and Clamping / Closure Arrangements

i) Where mating systems and clamping arrangements are provided, they are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

ii) Mating systems between underwater units (e.g., Hyperbaric Evacuation Units) and the hyperbaric facility's PVHOs are to enable their connection and disconnection easily and securely under the worst-case operating and environmental conditions.

iii) 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, the loads resulting from the mating forces, worst-case environmental conditions, as well as internal and external pressure are to be considered.

iv) Clamping/Closure arrangements are to be provided with a safety interlock in order to prevent inadvertent opening of the clamps/closures while under pressure and to prevent pressurization of the transfer trunks/tunnels if the clamps/closures are not properly closed. Mechanical locking mechanisms are required for hydraulically or pneumatically actuated clamping/closure arrangements. Means are to be provided to visually indicate to the operator complete locking or unlocking of the clamp/closure.

v) 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.

3.10 Control Stations

i) Control stations for hyperbaric facilities are to meet the applicable requirements of Section 21, "Dive Control Stations".

ii) When shipping containers are used for housing the control stations of hyperbaric facilities, they are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers* or the ABS *Guide for Certification of Offshore Containers*, based on intended use. 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 or Guide.

3.11 Utility Vans

When shipping containers are used for housing the machinery, tools, spares, etc., of the hyperbaric facility, they are to meet the applicable requirements of the ABS *Rules for Certification of Cargo Containers* or the ABS *Guide for Certification of Offshore Containers*, based on intended use. 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 or Guide.

3.12 Hyperbaric Evacuation

When hyperbaric facilities are provided with means of hyperbaric evacuation and these means are part of the classed hyperbaric facility, then the means of hyperbaric evacuation are to comply with the applicable requirements of Subsection 14/11, "Hyperbaric Evacuation".

3.13 Diving Bells

When diving bells are part of the classed hyperbaric facility (e.g., for diver training centers), then these bells are to comply with the applicable requirements of Subsection 14/7, "Diving Bells".

3.14 Handling Systems

When handling systems are part of the classed hyperbaric facility, then these handling systems are to comply with the applicable requirements of Section 20, "Handling Systems".

3.15 Testing of Fully Outfitted PVHOs

Fully outfitted PVHOs of the hyperbaric facility are to be subjected to the following tests in the presence of the Surveyor:

3.15.1 PVHO Life Support Qualification Testing

i) All PVHOs of the hyperbaric facility are to undergo life support qualification testing in the presence of the Surveyor.

ii) For hyperbaric facilities incorporating duplicate PVHOs (100% identical, i.e., same dimensions, same outfitting and same life support systems), such testing is only required for one of the duplicate PVHOs.

iii) Life support testing is to be conducted after the PVHO is completely outfitted.

iv) The tests may be conducted at surface conditions (1 ata) or by pressurizing the PVHO to a pressure corresponding to shallow depths.

v) When External Environmental Control Units (ECUs) are provided, they are to be tested independent of the Carbon Dioxide (CO_2) scrubbers within the PVHO.

vi) 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.

vii) The testing is to include the following:

i) A manned test with the maximum number of occupants within the PVHO or a simulated test is to be conducted until equilibrium is achieved by the Carbon Dioxide (CO_2) scrubbers, plus an additional one hour. This test is to be conducted for a minimum of three hours. Where simulation testing is carried-out, the simulation details are to be submitted for review. The following is to be demonstrated during the test:

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

ii) Changing-out of the Carbon Dioxide (CO_2) absorbent can be achieved without exceeding a Carbon Dioxide (CO_2) concentration of 0.015 ata and that the concentration of Carbon Dioxide (CO_2) can be reestablished and maintained at or below 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 Carbon Dioxide (CO_2) scrubber breakthrough, where breakthrough is defined as a Carbon Dioxide (CO_2) concentration of 0.5% by volume referenced to standard temperature and pressure (0.005 ata). The test may be continued beyond a Carbon Dioxide (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 Carbon Dioxide (CO_2) absorbent required to be carried for the hyperbaric facility. Where simulation testing is carried-out, the simulation details are to be submitted for review.

3.15.2 PVHO Functional Testing

Functional tests, wherein satisfactory operation is to be demonstrated for the life support systems, piping systems, electrical systems, communication systems, locks, and other essential systems and equipment of the PVHO. This testing is to be conducted at the maximum allowable working pressure using the normal breathing gas.

4 Interface and Installation Arrangements

4.1 Hyperbaric Facilities Installed on Vessels/Offshore Facilities

When hyperbaric facilities are installed on vessels/offshore facilities, they are to comply with the following requirements:

4.1.1 Installation

4.1.1(a) Hazardous Zones

Hyperbaric facilities are to be installed in safe areas on the 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.

4.1.1(b) Angles of Inclination

For hyperbaric facilities installed on vessels or ship-shaped offshore facilities, the PVHOs, machinery and systems essential for the safe operation of the hyperbaric facility are to be designed for operation under the inclinations specified in TABLE 2 below:

TABLE 2
Design Angles of Inclination

Component / Systems	*Angles of Inclination (Degrees)*			
	Athwartship		*Fore & 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

Component / Systems	*Angles of Inclination (Degrees)*			
	Athwartship		*Fore & Aft*	
	Static	*Dynamic*	*Static*	*Dynamic*
Electrical / Electronic Appliances & Control Systems	22.5 (2)	22.5 (2)	10	10
Emergency Power Installations	22.5	22.5	10	10
Emergency Fire Pumps & their Drives	22.5	22.5	10	10

Notes:

i) Athwartship and fore-and-aft inclinations occur simultaneously.

ii) Up to an angle of inclination of 45 degrees, switches and controls are to remain in their last set position.

iii) 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.

iv) 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 *Marine Vessel Rules*.

For hyperbaric facilities installed on column-stabilized, self-elevating or surface offshore facilities, the PVHOs, machinery and systems essential for the safe operation of the hyperbaric facility are to be designed for operation under the inclinations specified in TABLE 3 below:

TABLE 3
Design Angles of Inclination

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

4.1.1(c) Temperature (2025)

For hyperbaric facilities of unrestricted service that are installed on vessels/offshore facilities, the ambient temperatures specified in TABLE 4 below are to be considered for the selection and installation of PVHOs, machinery and systems. For hyperbaric facilities of restricted or special service, the ambient temperatures appropriate for the intended service are to be considered.

TABLE 4
Ambient Temperatures for Unrestricted Service

Position	*Location*	*Temperature Range (°C)*
In-Air	Enclosed Spaces (1), (2)	0 to +45
	Open Deck (1)	-25 (3) to +45

Notes:

i) Electronic equipment is to be suitable for operation up to 55°C.

ii) 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.

iii) For drilling units, refer to 4-1-1/7.7 TABLE 2 of the *Offshore Rules*.

4.1.1(d)

Hyperbaric facilities and breathing gas storage facilities are not to be installed in machinery spaces that have machinery not associated with the hyperbaric facility.

4.1.1(e)

Hyperbaric facilities are to be installed in spaces or locations that are adequately ventilated and provided with suitable lighting. Hyperbaric facilities are not to be installed in the vicinity of exhausts / ventilation outlets from machinery spaces and galleys.

4.1.1(f)

When any part of the hyperbaric facility 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 support vessel/offshore facility.

4.1.1(g)

In order to minimize deflections and to obtain satisfactory transfer of heavy loads through the deck foundations, it is recommended that hyperbaric facilities be installed in such a way that the underdeck supporting structure of the support vessel/offshore facility is in-line with the deck foundations.

4.1.1(h)

It is recommended that pressure vessels for human occupancy (PVHOs) be arranged in order to minimize the rolling effect on the PVHO occupants.

4.1.1(i)

Approval of hyperbaric facilities is based on the pressures, loads, environmental and operating conditions as specified by the designers / operators. For hyperbaric facilities, these factors may change after the hyperbaric facility is demobilized from one vessel / offshore facility, and is installed on another vessel / offshore facility and mobilized for use. It is the responsibility of the operator to advise ABS of changes to the pressures, loads, environmental and operating conditions due to the transfer of the hyperbaric facility. The plans affected by the changes are to be updated and resubmitted to ABS for approval by the responsible party.

4.1.2 Breathing Gas Storage

i) Breathing gas cylinders for hyperbaric facilities are to be stored on the open deck or in well ventilated enclosed spaces, and away from flammable substances and sources of ignition.

ii) When 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.

iii) When breathing gas cylinders are stored in enclosed spaces, they are to meet the following requirements:

i) The boundaries between enclosed spaces housing the breathing gas cylinders and other enclosed spaces are to be gas tight.

ii) Access doors for these enclosed spaces are to open outwards.

iii) Suitable drainage of the enclosed spaces is to be provided.

iv) 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.

v) 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.

vi) 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. An alarm repeater is to be provided at each entrance to the enclosed space. 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.

iv) 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.

v) Where the 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.

4.1.3 Support Systems Provided by Vessels / Offshore Facilities

4.1.3(a)

Support systems are those systems that are provided by vessels / offshore facilities and are not an integrated part of the hyperbaric facility. 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.*)
- Stability of vessels/offshore facilities

4.1.3(b) (2025)

For hyperbaric facilities installed on ABS classed vessels/offshore facilities, these support systems are to be in accordance with the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)* or the ABS *Rules for Building and Classing Offshore Units (Offshore Rules)*.

Drawings, specifications, data and calculations are to be submitted to ABS for review and approval.

4.1.3(c)

When ABS classed hyperbaric facilities are installed on non-ABS classed vessels/offshore facilities, documentation that these systems have been reviewed and approved by the Society classing the vessel/offshore facility is to be provided. Alternatively, the details may be provided to ABS for review.

4.1.4 Deck Foundations, Fastening Arrangements, and Vessel / Offshore Facility Structures

4.1.4(a) General Requirements

i) Hyperbaric facilities are to be securely attached to the hull structure of vessels/offshore facilities using suitable permanent means of fastening such as welding or bolting. (*Note:* Lashing is not considered to be a permanent means of fastening.)

ii) The design of deck foundations and fastening arrangements are to consider the relative movement between the components of the hyperbaric facility. In addition, the deck foundations and fastening arrangements are to be designed to meet any required survival conditions of the vessel/offshore facility as may be specified by the Flag Administration.

iii) In order to avoid exposing the hyperbaric facility components to excessive deflections, the maximum deflections of the deck structure of vessels/offshore facilities in-way of hyperbaric facilities are to be evaluated. The evaluated deflections are not to exceed the defined acceptable level of deflections for the hyperbaric facility.

4.1.4(b) Design Loads

Deck foundations, fastening arrangements and vessel/offshore facility structures in-way of hyperbaric facilities are to be designed for the following loads:

i) *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 5D-5-3/5.3.1 of the *Marine Vessel Rules*.

ii) *Static Inclination Loads:* Deck foundations and fastening arrangements for hyperbaric facility components are to be designed for a static inclination of 30°.

iii) *Hydrostatic Testing Loads:* When it is intended to carry out hydrostatic testing of PVHOs and other pressure vessels while they are installed on the 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.

iv) *Mating Loads:* When mating operations are to be carried out on the 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 (e.g., Hyperbaric Evacuation Unit).

v) *Handling System Loads:* When handling systems are part of the classed hyperbaric facility, then the design of deck foundations, fastening arrangements and the vessel structure in-way of the handling system are to take into consideration the maximum expected loads due to the handling operations. (See Section 20, “Handling Systems”)

4.1.4(c) 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 facility. For offshore support vessels, the allowable stresses are to be in accordance with 5D-5-3/5.3.6 of the *Marine Vessel Rules*.

4.1.5 Piping Systems

i) Piping systems carrying gases for hyperbaric applications are not to be arranged inside accommodation spaces or engine rooms.

ii) Piping systems carrying breathing gases are to run as far as practicable apart from electrical cable conduits.

iii) Piping systems containing flammable fluids are not to run through enclosed spaces or open deck areas housing breathing gases.

4.1.6 Fire Protection

4.1.6(a) ***Hyperbaric Facilities Installed in Enclosed Spaces***

i) Enclosed spaces on support vessels/offshore facilities housing hyperbaric facilities 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 hyperbaric facility are to be laid in separate structural ducts insulated to the A-60 class standard.

ii) 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.

4.1.6(b) ***Hyperbaric Facilities Installed on Open Decks***

When hyperbaric facilities 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.

4.1.7 Fire Fighting

4.1.7(a) ***External Fire Extinguishing Systems***

i) ***Hyperbaric Facilities Installed in Enclosed Spaces***

i) Enclosed spaces on vessels/offshore facilities are to be provided with manually actuated fixed fire extinguishing systems with a layout that covers the complete hyperbaric facility. 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 hyperbaric facility. 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 litres/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.

ii) ***Hyperbaric Facilities Installed on Open Decks***

i) The deck area where hyperbaric facilities are installed are to be equipped with fire extinguishing systems suitable for the locations and areas concerned. Fire hoses connected to the fire main of the vessel/offshore facility may be considered as providing the necessary protection.

ii) Means are to be provided for cooling the windows of PVHOs installed on open decks.

4.1.7(b) ***External Fire Detection and Alarm Systems***

i) *Hyperbaric Facilities Installed in Enclosed Spaces (2025)*

i) Enclosed spaces on vessels/offshore facilities are to be provided with automatic fire detection and alarm systems suitable for the location and area concerned.

ii) For marine vessels, the fire detection and alarm systems are to comply with the applicable requirements of 4-7-3/11 of the *Marine Vessel Rules*. For offshore facilities, the fire detection and alarm systems are to comply with the applicable requirements of Section 5-2-5 of the *Offshore Rules*.

iii) The loop or group of detectors covering these enclosed spaces is to be independent of those for other spaces.

iv) The fire detection panel is to be located in the vessel's navigation bridge and is to be provided with repeaters at the control station of the hyperbaric facility, as well as the engine control room.

ii) *Hyperbaric Facilities Installed on Open Decks*

The deck area where hyperbaric facilities are installed are to be equipped 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 hyperbaric facility by the control station personnel in-lieu of fire detection and alarm systems.

4.2 Hyperbaric Facilities Installed on Shore-Based Facilities

When hyperbaric facilities are installed on shore, the interface and installation arrangements provided by the shore-based facility (such as the electrical power supplies, piping systems, fire detection systems, fire fighting systems, structural fire protection, ventilation systems and structural support) are to meet the relevant codes and national regulations of the country in which the shore-based facility is located. The owner/operator of the hyperbaric facility is responsible for complying with these codes/regulations, and verification of compliance is the responsibility of the appropriate jurisdictional authorities of that country.

5 Hyperbaric Diving Simulators

Hyperbaric diving simulators are to meet the following requirements as applicable, in addition to the requirements of Subsections 15/1 through 15/4 above.

5.1 Wet Chambers

When hyperbaric diving simulators incorporate wet chambers, they are to meet the following requirements:

i) The interior surfaces of wet chambers are to be adequately protected against corrosion. (See Subsections 3/7 and 4/7)

ii) Wet chambers are to be provided with piping systems for filling as well as draining the chambers. These piping systems are to be designed to function under all internal operational pressures, up to

maximum allowable working pressure of the chamber. The drainage connections are to be located at or near the lowest point of the chamber.

iii) The design of the wet chamber is to take into consideration the internal pressure rise when filling the chamber with water. Appropriate means of over-pressure protection are to be provided.

iv) Where the design of the wet chamber is such that a vacuum could be inadvertently drawn while draining the chamber, suitable means of under-pressure protection (such as vacuum breakers) are to be provided.

v) Wet chambers are to be provided with a water level control arrangement in order to maintain the desired water level throughout the operating pressure range of the chamber. This arrangement is to be designed to prevent the overflow of water into the dry chambers.

vi) Where water partitions are installed, they are to have an access opening that is sized to facilitate the recovery of an unconscious diver wearing full diving gear. This opening diameter is not to be less than 711 mm (28 in.). Larger access openings may be necessary to accommodate divers with emergency life support systems activated.

5.2 Test Chambers

When hyperbaric diving simulators incorporate test chambers, they are to meet the following requirements:

i) The design of the test chambers is to include means for complete isolation from the other PVHOs of the hyperbaric diving simulator, including isolation of the life support systems and piping systems. When test chambers are directly connected to the other PVHOs of the hyperbaric diving simulator, they are to be separated using a double door arrangement.

ii) The design of test chambers is to take into consideration the additional fittings and pressure boundary penetrations for the test equipment, as well as the additional loads imposed by the test equipment.

6 Hyperbaric Reception Facilities (HRFs)

Hyperbaric reception facilities are to meet the following requirements as applicable, in addition to the requirements of Subsections 15/1 through 15/4 above.

6.1 Design

i) The design of the hyperbaric reception facility (HRF) is to take into consideration all arrangements, systems and equipment required for accepting and mating with Hyperbaric Evacuation Units (HEUs). This includes the ability to support the weight of the fully loaded HEU, as well as the ability to fine-tune the alignment of the manway flanges in order to facilitate mating.

ii) In order to facilitate interface compatibility between Hyperbaric Evacuation Units (HEUs) and Hyperbaric Reception Facilities (HRFs), it is recommended that HRFs comply with the standardized interface guidelines as outlined by the International Marine Contractors Association (IMCA) in their publication "Hyperbaric Evacuation Systems (HES) Interface Recommendations", IMCA D051.

Note: The design of standardized mating flanges should also take into consideration geometric dimensioning and tolerancing of these flanges.

iii) HRFs are to comply with 15/3.8.2 irrespective of the length of continuous occupation (i.e., the requirements of 15/3.8.2 apply even when the duration of continuous occupation is less than 12 hours). However, in-lieu of the requirements outlined under 15/3.8.2(a), HRFs may be provided with bunks for 50% of the maximum number of occupants.

iv) HRFs are to have the capability to lock-in/lock-out medical personnel. This may be facilitated by the use of twinlock chambers or the use of separate transfer locks.

v) HRFs are to be provided with medical locks. These locks are to comply with 15/3.9.2.

vi) HRFs are to be provided with mating systems in order to mate with HEUs. These mating systems are to comply with 15/3.9.3.

6.2 Mating Trials

In order to verify interface compatibility between the HRF and HEUs, mating trials are to be carried-out in the presence of the Surveyor.

SECTION 16

Atmospheric Diving Suits (ADS) and Systems *(2014)*

1 Scope

This Section, along with 1, 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 Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*.

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 Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. (*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 16/11.5 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 16/11.5 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_a = 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 16/29.5 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 Section 8 and Section 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 16/25.5 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 16/25.5 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 16/25.5 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 A1).

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 20, “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 21, "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 20, "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 6/15, "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.

SECTION 17

Underwater Habitats and Complexes *(2019)*

1 Scope

This Section along with 1 provide the requirements for the design, fabrication and testing of underwater habitats and complexes that incorporate Pressure Vessels for Human Occupancy (PVHO) type. Other types of underwater habitats and complexes will be considered on a case-by-case basis. See 2/33 for the definition of the term "Underwater Habitat". See 2/87 for the definition of the term "Underwater Complex".

3 Class Notations

New construction underwater habitats or underwater complexes built under ABS survey are to be assigned the class notation ✠ **A1 Underwater Habitat** or ✠ **A1 Underwater Complex**, respectively, subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. New and existing underwater habitats or underwater complexes not built under ABS survey are to be assigned the class notation **A1 Underwater Habitat** or **A1 Underwater Complex**, respectively, subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*.

5 Underwater Habitats

5.1 Pressure Vessels for Human Occupancy (PVHOs)

5.1.1 Metallic Pressure Boundaries

Metallic pressure boundaries are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

5.1.2 Windows and Viewports

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

Windows are to be provided with appropriate means of protection to prevent mechanical damage.

5.1.3 Personnel Access Hatches/Manways

5.1.3(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 any dynamic loads.

5.1.3(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.). 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.

5.1.3(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.

5.1.3(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.

5.1.3(e)

Hatch coaming ways are to be free from obstacles that would prevent personnel ingress or egress.

5.1.3(f)

Hatches are to be provided with a mechanical means for securing in the fully open position.

5.1.3(g)

Means are to be provided to prevent inadvertent operation of hatches, including doors, which use springs or similar assist mechanisms. Fluids used in hatch assist mechanisms are to be compatible with the internal environment of the PVHO.

5.1.4 Nonmetallic Materials

Paints, coatings, insulation and other internal and external materials are to meet the applicable requirements of 3/1.

5.1.5 Nameplates

PVHOs are to be fitted with permanent nameplates indicating the maximum allowable internal and external working pressures, maximum and minimum rated temperatures, internal and 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.

5.3 External Structures

External structures include all structural members located outside the pressure boundaries of PVHOs. These include members such as support frames, skids and lifting lugs.

The design of each welded connection is to facilitate appropriate inspection. All welds on external welded connections are to be sealed or full penetration welds.

5.3.1 Support Frames/Skids

5.3.1(a)

Support frames/skids of PVHOs 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.

5.3.1(b)

Loads to be considered include applicable loads such as the dead-weight of the fully loaded PVHO, environmental loads such as current forces, etc. Mating loads are to be also considered when underwater units such as submersibles or diving bells mate with the habitat's PVHOs. The mating loads are to consider a force of not less than twice the weight of the mating PVHO (i.e., diving bell, submersible, 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 the habitat's 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 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
	=	0.8 for compressive or shear buckling
	=	0.8 for axial and/or bending stresses
	=	0.53 for shear stresses

5.3.1(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 20.

5.3.2 Lifting Lugs/Attachments

Lifting lugs/attachments of PVHOs are to be suitable for handling the PVHOs during installation/demobilization. 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 less.

5.5 Piping Systems

i) Piping systems are to meet the applicable requirements of this Section and Section 8 and Section 9.

ii) PVHOs are to be equipped with valves, gauges and other fittings as necessary to control and monitor the internal environments of compartments from the habitat's control station. All interior breathing and pressure supply controls are to be provided with means of overriding and controlling them from the exterior. The external pressure acting on PVHOs are to be indicated inside the PVHOs.

iii) A manually operated stop valve is to be provided at each PVHO pressure boundary piping penetration.

iv) For systems connected to sea suctions or discharges, an additional stop valve or check valve is to be provided close to and downstream of the stop valve (required as per 17/5.5.iii above).

v) Where PVHOs are used for hyperbaric applications, the piping exclusively carrying fluids into the PVHO is to have a check valve close to and downstream of the stop valve (required as per 17/5.5.iii above).

vi) PVHOs are to be provided with a fixed bilge system capable of draining all spaces inside the PVHO. Where bilge pumps are used for overboard discharging, they are to be provided with a check valve on their discharge side. An audio and visual bilge alarm is to be provided at the habitat's control station for early detection of water accumulation.

vii) 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. 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. Pressure relief devices are to be capable of preventing the internal pressure from rising more than 10% above the maximum allowable working pressure of the PVHO.

viii) Piping systems are to be designed so as to minimize the noise inside the PVHOs during normal operations. For hyperbaric applications, mufflers/silencers are to be provided on blowdown outlets.

ix) Anti-suction protective devices are to be provided inside PVHOs on the openings of exhaust lines.

x) All high-pressure piping is to be well-protected and well-supported against mechanical damage.

xi) Piping systems carrying mixed gas or oxygen under high pressure are not to be arranged inside accommodation spaces, machinery rooms or similar compartments.

xii) Flexible hoses, except for umbilicals, are to be reduced to a minimum.

5.7 Life Support and Environmental Control Systems

5.7.1 General

i) Life support systems are to meet the applicable requirements of this Section and Section 8 and Section 9.

ii) Habitats 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 with the maximum number of occupants, and at the maximum pressure for normal and emergency conditions are provided.

iii) For hyperbaric applications, 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 occupants. In determining the duration and amount of life support necessary, consideration is to be given to the environmental conditions, the oxygen (O_2) and mixed gas consumption and carbon dioxide (CO_2) generation under such conditions, the heat input or removal and the emergency services that may be available for the decompression of occupants. 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 hyperbaric operation.

iv) Where the pressure inside PVHOs is maintained at 1 atmosphere, the normal life support system is to be designed so that the concentration of oxygen within the PVHO will be kept within the limits of 18.0 to 23.0 percent by volume, and the concentration of CO_2 will not exceed 0.5 percent by volume, referenced to standard temperature and pressure.

v) For hyperbaric applications, the normal life support system is to be designed so that the partial pressure of oxygen within PVHOs are 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. CO_2 removal systems are to be designed so that the partial pressure of CO_2 within PVHOs do not exceed 0.005 atmosphere absolute (ata).

vi) *Life Support Capacity (Normal and Reserve).* At the commencement of the habitat's operations, the normal breathing gas supply and CO_2 removal systems are to have sufficient capacity for the anticipated mission time plus a reserve capacity that is consistent with the emergency rescue plan, but not less than 72 hours.

5.7.2 Breathing Gas Systems

5.7.2(a)

Each compartment of the PVHO is to be provided with two (2) independent gas supply systems for normal breathing gas supply.

5.7.2(b)

For decompression/recompression applications, each applicable compartment of the PVHO is to be provided with the following:

i) One (1) gas exhaust system

ii) One (1) Built-in Breathing System (BIBS) with breathing masks (See 17/5.7.2(i) below)

5.7.2(c)

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.

5.7.2(d)

The design pressurization and exhaust depressurization rates for hyperbaric operations are to be determined by the designer and are to be consistent with the rates specified in the US Navy Diving Manual or equivalent recognized national or international standards.

For treatment recompression applications, 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.

5.7.2(e)

The gas supply and exhaust systems are to be arranged to provide even mixing of the gases.

5.7.2(f)

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.

5.7.2(g)

Filters and automatic pressure regulators are to be arranged so that they can be isolated without interrupting vital gas supplies.

5.7.2(h)

The discharge from relief devices, vents and exhausts are to be vented away from sources of ignition, personnel or any area where the presence of the discharged gases could be hazardous.

5.7.2(i) Built-in Breathing Systems (BIBS)

For decompression/recompression applications, each applicable compartment of the PVHO is to be provided with a Built-in Breathing System (BIBS) to supply emergency/treatment gas. The BIBS is to comply with the following:

i) The BIBS is to supply emergency/treatment gas through a dedicated piping system to breathing masks (either full-face masks or oral-nasal masks). Breathing masks are to be permanently connected or easily connectable to the BIBS supply piping.

ii) Compartments that serve as living facilities are to be provided with BIBS masks corresponding to the maximum number of occupants for which the compartment is rated plus one. Compartments that serve as transfer locks are to be provided with BIBS masks corresponding to the maximum number of occupants that may simultaneously transfer through the lock plus one. All other compartments are to be provided with at least two BIBS masks.

iii) The BIBS supply piping is to be independent of the normal gas supply piping to the compartment.

iv) The emergency and treatment gas cylinders are not to be used for supplying the normal gas supply system of the compartment.

v) The capacity of the emergency/treatment gas supplies is to be sufficient for the safe conclusion of the habitat's operation.

vi) The system is to be designed such that the partial pressure of CO_2 in the gas being inhaled does not to exceed 0.015 atmosphere absolute (ata).

vii) 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.

viii) BIBS exhaust systems are to be provided with a back-pressure regulator and a secondary means to prevent pressure differential to the diver using the mask, if the back pressure regulator were to fail.

ix) 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.

x) Where open circuit systems are used, the effects of increased compartment pressure are to be considered.

xi) 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.

5.7.3 Carbon Dioxide Removal Systems

i) Each compartment of the PVHO is to be provided with means for CO_2 removal.

ii) CO_2 removal systems used for normal operation are to be provided with full redundancy.

5.7.4 Emergency Life Support System

i) 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 the normal life support system.

ii) Emergency breathing gas is to be supplied to either full-face masks, oral-nasal masks or self-contained re-breathers suitable for the intended service. One mask per occupant of the PVHO is to be provided.

iii) Where open circuit systems are used for emergency life support, the effects of increased compartment pressure are to be considered.

iv) Where the pressure inside the PVHO is maintained at 1 atmosphere, the emergency life support system is to be designed such that CO_2 levels in the gas being inhaled does not exceed 1.5 percent by volume, referenced to standard temperature and pressure.

v) For hyperbaric applications, the emergency life support system is to be designed so that the partial pressure of CO_2 in the gas being inhaled does not exceed 0.015 atmosphere absolute (ata).

vi) The capacity of the emergency life support system is to be sufficient to permit evacuation of the compartment during events such as a contaminated atmosphere, as per the emergency operating procedures of the habitat.

5.7.5 External Environmental Control Units (ECUs)

i) External Environmental Control Units (ECUs), when fitted, are to be capable of providing heating/cooling, humidity control and CO_2 removal services.

ii) 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.

iii) 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.

iv) Sizing calculations for flow-fuses are to be submitted for review. In addition, means are to be considered for resetting flow-fuses.

5.7.6 PVHO Life Support Testing

i) All PVHOs of the habitat are to undergo life support testing in the presence of the Surveyor.

ii) For habitats incorporating duplicate PVHOs (100% identical, i.e., same dimensions, same outfitting and same life support systems), such testing is only required for one of the duplicate PVHOs.

iii) Life support testing is to be conducted after the PVHO is completely outfitted.

iv) The tests may be conducted at surface conditions (1 ata). For PVHOs intended for hyperbaric applications, these tests may be conducted by pressurizing the PVHO to a pressure corresponding to shallow depths.

v) When External Environmental Control Units (ECUs) are provided, they are to be tested independent of the CO_2 scrubbers within the PVHO.

vi) During testing, the O_2 and 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.

vii) The testing is to include the following:

a) 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. The following is to be demonstrated during the test:

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

2) 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 (0.015 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.

b) 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 the habitat.

5.9 Electrical Systems and Equipment

5.9.1 General

i) Electrical systems and equipment are to meet the applicable requirements of this Section and Section 10.

ii) Electrical systems and equipment installed within PVHOs are to be limited to those necessary for the safe operation of the PVHO and the monitoring of its occupants.

iii) Electrical systems and equipment, 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 PVHO.

iv) For PVHOs intended for hyperbaric applications, the electrical systems and equipment within the PVHOs is to be suitable for hyperbaric applications and is to be rated for the maximum anticipated pressure within the PVHO. These systems and equipment are to be such that repeated pressurization and depressurization will not cause damage.

5.9.2 Normal Power Supply

At the commencement of each habitat operation, the normal power supply is to have sufficient capacity for the anticipated mission time plus a reserve capacity that is consistent with the emergency rescue plan, but not less than 72 hours.

5.9.3 Emergency Power Supply

i) In the event of failure of the normal source of electrical power to the habitat, an independent emergency source of electrical power is to be available. The emergency source of power is to have sufficient capacity for 150% of the time required for safe termination of the habitat's operation, while supplying the emergency equipment (such as life support equipment, communication equipment and internal lighting).

ii) The emergency source of electrical power is to be located as far apart as practicable from the normal source of electrical power.

5.9.4 Generators

Generators that are part of the Classed habitat, and are used for supplying normal or emergency power, are to comply with the following:

i) Generators of 100 kW (135 hp) and over, are to be certified for compliance with the appropriate provisions of Section 4-8-3 of the *Marine Vessel Rules*.

ii) Generators of less than 100 kW (135 hp), 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 4-8-3/3.15.2 through 4-8-3/3.15.11 of the *Marine 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.

5.11 Communication Systems and Equipment

5.11.1

Habitats are to be provided with voice communication systems and equipment. These communication systems and equipment are to be arranged for direct two-way communication between the habitat's control station and the following, as applicable:

i) Each compartment of the habitat's PVHOs

ii) Surface support for the habitat (such as a support vessel, etc.)

iii) Where lock-out operations are carried-out, divers in water, except scuba divers

iv) Where mating operations are carried-out, the unit (such as a submersible, diving bell, etc.) that is mating with the habitat's PVHOs

5.11.2

5.11.2(a)

Communication systems are to consist of a primary and secondary system.

5.11.2(b)

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.

5.11.2(c)

The secondary system is to be fully independent of the primary system. It may consist of a sound-powered telephone or other means that are capable of operating in the event of cable/umbilical failure or loss of main and emergency power.

5.13 Fire Fighting and Fire Detection

5.13.1 Internal Fire Extinguishing Systems for PVHOs

5.13.1(a) General

i) Each compartment of a PVHO is to be provided with suitable means for fire fighting. This may include fixed fire extinguishing systems or portable fire extinguishers.

ii) For PVHOs intended for hyperbaric applications, the means of fire fighting, including any portable hyperbaric fire extinguishers, are to be suitable for operation at all internal pressures until the maximum operating pressure of the PVHO.

iii) 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.

iv) 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.

v) Consideration is to be given to the increase in compartment pressure resulting from the discharge of the extinguishing agents/propellants.

5.13.1(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) For hyperbaric applications, the fixed fire extinguishing systems are to be suitable for operation at all internal pressures until the maximum operating pressure of the PVHO.

iii) 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.

iv) The extinguishing agent is to be fresh water or other liquid agents suitable for use in manned compartments.

v) For hyperbaric applications, the systems are to be capable of recharging without the need for depressurizing the PVHOs.

vi) The systems are to have the capability to discharge less than the total supply of the extinguishing agent.

vii) Fixed extinguishing systems are to be functionally tested in the presence of the Surveyor. For hyperbaric applications, the extinguishing system is to be functionally tested over the full range of internal pressures until the maximum operating pressure of the PVHO.

5.13.1(c) Portable Fire Extinguishers

i) When PVHOs are not provided with fixed fire extinguishing systems, the fire extinguishing means is to consist of portable fire extinguishers.

ii) For hyperbaric applications, the portable fire extinguishers are to be suitable for operation at all internal pressures until the maximum operating pressure of the PVHO.

iii) Portable fire extinguishers, including 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.

iv) The extinguishing agent is to be distilled water or other non-conductive liquid agents suitable for use in manned compartments.

5.13.2 Internal Fire Detection and Alarm Systems for PVHOs

i) Each compartment of the PVHO is to be provided with automatic fire detection and alarm systems.

ii) For hyperbaric applications, the fire detection and alarm systems are to be suitable for operation of the PVHO. Where such systems are unsuitable, consideration will be given to alternate arrangements.

iii) Faults (voltage failure, breakage in the detection loops, earth faults, etc.) in the fire detection and alarm systems are to be indicated at the habitat's control station by means of visual and audible signals.

5.15 PVHO Layout and Outfitting

5.15.1 General

i) Each compartment of the PVHO is to be provided with means of visual monitoring of the occupants from the control station. At least one viewport is to be provided for each compartment.

ii) 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. A general interior illumination level of at least 270 lumens/m^2 (25 foot-candles) is to be provided, with 540 lumens/m^2 (50 foot-candles) provided over bunks and in work areas under normal operating conditions.

iii) PVHOs are to be provided with suitable means of heating, cooling and controlling humidity, to maintain a comfortable temperature and humidity level for the occupants. The heating, cooling and humidity control systems are to have full redundancy.

5.15.2 Habitats used for Hyperbaric Applications

Habitats used for hyperbaric applications are to comply with the following:

i) PVHOs or PVHO compartments that serve as living facilities and other compartments that may be used for decompression are to be provided with suitable medical/equipment locks. See 17/5.19.3 below.

ii) All compartments of PVHOs are to be provided with gas circulation systems. The circulation systems are to have the capability to maintain homogenous gas mixtures and avoid stratification of gas layers within the compartments.

5.15.3 PVHOs Continuously Occupied for 12 Hours or Longer

When PVHOs are continuously occupied for 12 hours or longer, they are to be provided with the following features:

5.15.3(a)

PVHOs 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.

5.15.3(b)

The viewports/windows for PVHOs that serve as living facilities are to allow the bunks to be seen as much as possible over their entire lengths from the outside.

5.15.3(c)

PVHOs 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.

5.15.3(d)

PVHOs or PVHO compartments that serve as transfer locks are to have internal dimensions sufficient to allow the simultaneous transfer of at least two persons. The floodable volume is not to be less than 105 ft^3 (3.0 m^3).

5.15.3(e)

Toilet, hand washing, and shower arrangements are to be provided and are to be installed outside the living facilities in separate compartments.

5.15.3(f)

For hyperbaric applications, the toilet, hand washing, and shower arrangements are to comply with the following:

i) Flush-type toilets, when installed, are to be provided with the following:

- ***a)*** An interlock to prevent flushing of the toilet while the user is seated.
- ***b)*** Stand-offs on the toilet seat to prevent the formation of a complete seal between the toilet bowl and the user.
- ***c)*** Water for flushing at a sufficient pressure above the internal pressure of the PVHO at the time of flushing.
- ***d)*** Flushing systems are to require two positive manual actions for operation.
- ***e)*** Flushing systems are to have means to limit the volume of gas exhausted with each flushing operation.
- ***f)*** Effluent drain from the toilets is to be routed to an external holding tank.
- ***g)*** Means for communicating with the control station are to be provided in the vicinity of flush type toilets.

ii) Hand washing and shower systems are to be provided with the following:

- ***a)*** A sink for hand washing and a shower head for showering.
- ***b)*** Water at a sufficient pressure above the internal pressure of the PVHO at the time of washing or showering.
- ***c)*** Effluent drain from the hand washing and shower systems is to be routed to an external holding tank.
- ***d)*** Drainage systems may be manual or automatic. They are to be fitted with anti-suction devices.
- ***e)*** Means are to be provided to limit the volume of gas exhausted with each drainage operation.

iii) Holding tanks are to be provided with the following:

- ***a)*** Means (such as pilot and vent valves) to ensure that the tank pressure does not exceed the PVHO pressure during operation of the flushing/drainage systems or during decompression.
- ***b)*** Pressure gauge for indicating the tank pressure.

c) Means to determine the tank level.

d) A means for flushing/cleaning the holding tank is to be considered.

e) 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.

5.17 Diver Lock-Out Compartments

5.17.1 General

i) 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.

ii) 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.

iii) Seating is to be provided for the maximum number of occupants.

iv) Suitable means are to be provided for taking unconscious divers into lock-out compartments.

v) 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.

5.17.2 Piping Systems

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.

5.17.3 Life Support and Environmental Control Systems

5.17.3(a)

For the lock-out compartment, the normal and reserve capacity of the life support system as specified under 17/5.7.1.vi above, is to be sufficient to supply the maximum number of occupants (divers) plus one with the appropriate breathing gases and provide CO_2 removal.

5.17.3(b)

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 Occupants (divers) plus one.

5.17.3(c)

Means for overboard dumping or storage of the lock-out compartment gases are to be provided.

5.17.3(d)

Under normal operating conditions, diver decompression is to be controlled from the control station. Additional decompression controls may be provided in the lock-out compartments for use during an emergency.

5.17.3(e)

An appropriate supply of treatment gases (in accordance with the applicable treatment table) is to be available for the treatment of the occupants (divers).

5.17.3(f)

For the lock-out compartment, in-lieu of the emergency life support system capacity specified under 17/5.7.4.vi above, the capacity of the emergency life support system is to be as follows:

i) *In-Water Divers with Self-Contained Breathing Systems.*

a) 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 decompress to the surface from the maximum operating depth, but not less than 2 hours. A respiratory minute volume (RMV) 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.

b) Capacity that is sufficient to de-water a lock-out compartment filled with 40% water, while at a pressure corresponding to the maximum operating depth.

ii) *In-Water Divers Supplied from Umbilicals.*

a) 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 decompress to the surface from the maximum operating depth, but not less than 2 hours. A respiratory minute volume (RMV) 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.

b) 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 (RMV) 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.

c) Capacity that is sufficient to de-water a lock-out compartment filled with 40% water, while at a pressure corresponding to the maximum operating depth.

5.17.3(g) Diver Umbilicals

i) 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.

ii) Suitable means are to be provided for stowing the diver umbilicals on the habitat. The means of stowing is to consider the minimum bend radius of the umbilical.

iii) 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.

iv) 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.

5.17.3(h) Temperature and Humidity Control

i) 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.

ii) 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.

iii) 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.

5.19 PVHO Support Components

5.19.1 Transfer Trunks/Tunnels

i) Trunks/tunnels incorporated in or created by the coupling of the habitat's PVHOs are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

ii) Trunks/tunnels are to be capable of allowing the safe transfer of occupants between the habitat's PVHOs and are to have a minimum internal diameter of 610 mm (24 inches).

iii) Trunks/tunnels are to be provided with an external means for monitoring, venting and equalizing internal pressure with the compartment being serviced or the eternal atmosphere.

iv) Trunks/tunnels exceeding 914 mm (36 inches) in length are to be provided with internal hand and/or footholds.

5.19.2 Medical/Service Locks

i) Where Medical/Service locks are provided, they are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

ii) 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 masks/helmets, etc., to be safely transferred into/out of the habitat's PVHOs. As far as practicable, the dimensions are to also minimize the loss of gas when the lock is being used.

iii) 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.

iv) Medical/Service locks are to be provided with an external means for monitoring, venting and equalizing pressure with the compartment being serviced or the external atmosphere.

5.19.3 Mating Systems and Clamping/Closure Arrangements

i) Where mating systems and clamping arrangements are provided, they are to meet the applicable requirements of this Section and Sections 4, 5, and 6.

ii) Mating systems between underwater units (such as diving bells, submersibles, etc.) and the habitat's PVHOs are to enable their connection and disconnection easily and securely under the worst expected environmental conditions. (See 20/55.1 TABLE 1).

iii) 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, the loads resulting from the mating forces, worst case environmental conditions, as well as internal and external pressure are to be considered.

iv) Clamping/closure arrangements are to be provided with a safety interlock in order to prevent inadvertent opening of the clamps/closures while under pressure and to prevent pressurization of the transfer trunks/tunnels if the clamps/closures are not properly closed. Mechanical locking mechanisms are required for hydraulically or pneumatically actuated clamping/closure arrangements. Means are to be provided to visually indicate to the operator complete locking or unlocking of the clamp/closure.

v) 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.

5.21 Testing of Fully Outfitted PVHOs

Fully outfitted PVHOs of the habitat are to be subjected to the following tests in the presence of the Surveyor:

5.21.1 Life Support System Tests

Life support system tests as per the applicable requirements of 17/5.7.6 above.

5.21.2 Functional Tests

Functional tests, wherein satisfactory operation is to be demonstrated for the life support systems, piping systems, electrical systems, communication systems, locks, etc. For hyperbaric applications, this testing is to be conducted at the maximum allowable working pressure using the normal breathing gas.

7 Underwater Complexes

7.1 General

Underwater complexes are to meet the requirements specified under 17/5 above.

7.3 Submersibles or Lock-Out Submersibles or Ambient-Pressure Submersibles

Where submersibles or lock-out submersibles or ambient-pressure submersibles are part of the underwater complex, they are to meet the requirements of 13, respectively.

7.5 Diving Bells

Where diving bells are part of the underwater complex, they are to meet the requirements of Section 14.

7.7 Handling Systems

Where handling systems are part of the underwater complex, they are to meet the requirements of Section 20.

9 Installation and Securing Arrangements

9.1 Securing Arrangements

Underwater habitats and/or underwater complexes are to be are to be provided with the appropriate equipment to securely fasten them to the sea floor. This equipment is to meet the applicable requirements of Section 20 or a recognized national/international standard.

9.3 Installation

The installation location of the underwater habitat/complex, as well as the suitability, stability and load-bearing capacity of the sea floor in-way of the underwater habitat/complex, are the responsibility of the owner/operator.

SECTION 18

Remotely Operated Vehicles (ROVs) *(2014)*

1 Scope *(2024)*

This Section, along with 1, as applicable, provides the requirements for the design, fabrication and testing of Remotely Operated Vehicles (ROVs) or Hybrid Remotely Operated Vehicles (HROVs).

3 Definitions

3.1 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.

3.3 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.

3.5 ROV or HROV System *(2024)*

An *ROV or HROV System* includes the vehicle, as well as the associated support systems such as the handling system and the control station.

5 ROV and HROV Categorization *(2024)*

5.1 Class I (Pure Observation) *(2024)*

Pure observation ROVs or HROVs 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.

5.3 Class II (Observation with Payload Option) *(2024)*

Class II ROVs or HROVs include vehicles capable of carrying additional sensors (over and above those carried by Class I ROVs or HROVs) such as data measurement instrumentation, sonar systems, additional video cameras, still cameras, etc. In general, they are somewhat larger than Class I vehicles.

Class II ROVs or HROVs are capable of carrying additional payload without loss of functional capabilities.

5.5 Class III (Work Class Vehicles) *(2024)*

Work class ROVs or HROVs are primarily employed for conducting work while submerged in the water column. In general, these vehicles are larger and more powerful than Class I and II vehicles. 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 or HROV and operated without the need for being separately hardwired through the umbilical.

5.7 Class IV (Seabed-working Vehicles) *(2024)*

Seabed-working vehicles including seabed plows 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 vehicles are larger and heavier than Class III vehicles. These vehicles are configured for special purpose tasks. Such tasks typically include cable and pipeline trenching, excavation, dredging or other seafloor construction work.

5.9 Class V (Prototype or Development Vehicles) *(2024)*

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 vehicles.

7 Approval *(2024)*

7.1 Class I and II ROVs or HROVs [3,4]

Approval Path	*Scope of Approval*	*Approval Tier*[1]
Option A	Product Design Assessment (PDA) only [2]	2
Option B	Type Approval (TA) (*Includes Product Design Assessment (PDA) & Manufacturing Assessment (MA)*)	3

Notes:

1) For approval tiers, see 1A-1-A4 of the ABS *Rules for Conditions of Classification (Part 1A)*.

2) The scope of the design assessment is limited to the vehicle, umbilical and control console, and does not include design assessment for installation and integration on a specific surface vessel, submarine or offshore facility.

3) For Class I & Class II ROVs or HROVs, installation and integration surveys on a specific surface vessel, submarine, or offshore facility, as well as periodic surveys after construction (*See* Part 7, Chapter 11 of the ABS *Rules for Survey After Construction*) are not required.

4) Where the ROV or HROV spread includes a Launch and Recovery System (LARS), the LARS is required to be certified by ABS as per Section 20 of these Rules, and is required to undergo periodic surveys after construction for maintaining certification. (*i.e., Options A or B above do not apply to the LARS*)

7.2 Class III and IV ROVs or HROVs [(2)]

Approval Path	*Components*	*Scope of Approval*
Option A (*I3P Verification with IRC*)	Vehicle, Umbilical & Control Station [(1)]	Detailed design review & issuance of the Independent Review Certificate (IRC)
Option B (*I3P Verification with IRC & CoC*)	Vehicle, Umbilical & Control Station [(1)]	Detailed design review with issuance of the Independent Review Certificate (IRC) and New construction surveys with issuance of the Certificate of Conformity (CoC)
Option C (*Classification*)	Vehicle, Umbilical, LARS & Control Station	Classification[(3)] of the ROV or HROV spread with issuance of the applicable Class Notations

Notes:

1) For the Independent Third Party (*I3P*) verification under Options A or B above:

a) ABS classification of the ROV or HROV spread along with issuance of the Class Notations is not included.

b) The scope of the detailed design review is limited to the vehicle, umbilical and control station, and does not include design review for installation and integration on a specific surface vessel, submarine or offshore facility.

c) Installation and integration surveys on a specific surface vessel, submarine or offshore facility, as well as periodic surveys after construction are not required.

d) See Appendix 2 for sample Independent Review Certificate (IRC) and Certificate of Conformity (CoC).

2) Where the ROV or HROV spread includes a Launch and Recovery System (LARS), the LARS is required to be certified by ABS as per Section 20 of these Rules and is required to undergo periodic surveys after construction for maintaining certification. (*i.e., I3P verification per Options A or B above does not apply to the LARS*).

3) The Classification process for the ROV or HROV spread (*Option C above*) includes design review, new construction surveys, installation, and integration surveys, as well as periodic surveys after construction throughout its life cycle.

7.3 Class V ROVs or HROVs

For prototype or developmental vehicles, the approval path will be determined by ABS on a case-by-case basis.

Designers and builders of such vehicles may apply for an ABS Approval-In-Principle (AIP) during the early conceptual design phase. An AIP demonstrates project feasibility and would confirm that the conceptual design complies with the intent of these Rules and other applicable industry codes / standards subject to a list of conditions. Refer to Part 1D, Appendix 1 of the *ABS Alternative Arrangements, Novel Concepts and New Technologies (Part 1D)* for additional details on the AIP process.

9 Class Notations *(2024)*

The following Class Notation are available for the Classification of Class III and IV ROVs or HROVs and their associated equipment (*Option C above*):

New construction ROVs, HROVs and ROV or HROV Systems built under ABS survey are to be assigned the Class notations ⊞ **A1 ROV, Class X**, ⊞ **A1 HROV, Class X**, and ⊞ **A1 ROV or HROV System, Class X**, respectively, subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. (Note: "**X**" represents the Roman numerals "III or IV", depending on the category of the vehicle (See 18/5). For example, a work class ROV would receive the Class notation ⊞ **A1 ROV, Class III**.)

New and existing ROVs, HROVs and ROV or HROV Systems not built under ABS survey are to be assigned the class notation **A1 ROV, Class X**, **A1 HROV, Class X**, and **A1 ROV or HROV System, Class X** subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. The Maltese cross notation (✠) signifying survey under construction is to be omitted.

11 Pressure Boundary Components

Pressure boundary components are to be certified by the manufacturer as being suitable for the intended service.

13 External Structures

13.1 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.

13.3 Corrosion Protection

Metallic external structures are to be provided with appropriate means to manage/mitigate corrosion, marine growth and galvanic action.

13.5 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.

13.7 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 20/55.1 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_a = 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

13.9 Lifting Lugs/Attachments *(2024)*

The lifting lugs/attachments used for launch and recovery of ROVs or HROVs 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 18/13.7 above.

Removable equipment on ROVs or HROVs are to be provided with lifting lugs/attachments to facilitate their easy retrieval.

13.11 Towing Attachments *(2024)*

For towed ROVs or HROVs, an accessible towing point, appropriately sized for the anticipated conditions is to be provided.

15 Nameplates *(2024)*

ROVs or HROVs 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 vehicle.

17 Emergency Recovery Features *(2024)*

ROVs or HROVs 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 vehicle to the surface, under the heaviest emergency condition following a casualty. The analysis is to include consideration of entrained water, mud and sand.

19 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 18/11 above.

21 Stability *(2024)*

ROVs or HROVs are to have adequate stability while operating underwater or on the surface.

23 Propulsion and Steering Systems

23.1 General *(2024)*

ROVs or HROVs are to be provided with appropriate means of propulsion and steering.

23.3 Thrusters

Thrusters are to be certified by the manufacturer as being suitable for the intended service.

25 Navigational Equipment/Systems *(2024)*

As a minimum, ROVs or HROVs 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 17/25 below)

27 Emergency Locating Devices *(2024)*

ROVs or HROVs 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.

29 Communication Systems *(2024)*

ROVs or HROVs 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.

31 Piping Systems

Piping systems, when provided, are to meet the applicable requirements of this Section and 9.

Piping systems are to be mechanically protected from damage.

33 Umbilicals/Tethers

33.1 General *(2024)*

Umbilicals are to be securely attached to ROVs or HROVs 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 vehicle and is to include extra length for re-termination of the umbilicals.

When the strength member of the umbilical supports the weight of the vehicle, the strength member is to meet the applicable requirements of Section 20, “Handling Systems”.

33.3 Tether Management System (TMS) *(2024)*

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 vehicle 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 18/13. Lifting lugs, when installed, are to meet the requirements of 18/13.9. The TMS frame and lifting lugs are to be designed for lifting the fully outfitted vehicle 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 vehicle 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.

35 Electrical Systems *(2024)*

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 1000 V AC or DC, additional precautions are to be taken to protect personnel (see 10/7.3).

When ROVs or HROVs are intended for operating in hazardous areas, the electrical equipment on the vehicle is to meet the requirements of 10/3.5.

37 Access to Equipment

Adequate access space for maintenance and handling is to be provided around the equipment and tools of ROVs.

39 ROV and HROV Control Boxes or Stations *(2024)*

Each vehicle or vehicle system is to be provided with a control box or control station for monitoring and controlling the vehicle operations, as applicable.

39.1 ROV or HROV Control Boxes *(2024)*

ROV or HROV control boxes are to be provided with sufficient controls and displays to efficiently and reliably control the operations and functioning of the vehicle.

39.3 ROV or HROV Control Stations *(2024)*

i) ROV or HROV control stations, when provided, are to meet the applicable requirements of Section 21, “Dive Control Stations”.

ii) Sufficient controls and displays are to be provided in the control stations to efficiently and reliably control the operations and functioning of the vehicle.

iii) Shipping containers used for housing portable ROV or HROV 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.

41 Handling Systems *(2024)*

Each ROV or HROV System is to be provided with a handling system to ensure safe transportation of the vehicle to and from the subsea work location.

Handling systems for ROV or HROV Systems are to meet the applicable requirements of Section 20, “Handling Systems”.

Handling systems for ROV or HROV 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.

43 Hybrid Remotely Operated Vehicles (HROVs)

HROVs are to also meet the appropriate requirements for AUVs (see Section 19), as applicable to the specific design.

45 Tests *(2024)*

Vehicles or vehicle Systems are to be subjected to the following tests in the presence of the Surveyor:

i) Hydrostatic testing of piping systems (see 9/7) and umbilicals (see 8/11.13)

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) Load testing of handling systems

v) Test dive

vi) Sea trials

SECTION 19

Autonomous Underwater Vehicles (AUV) *(2014)*

1 Scope *(2024)*

This Section, along with 1, as applicable, provides the requirements for the design, fabrication and testing of Autonomous Underwater Vehicles (AUVs) and Hybrid Autonomous Underwater Vehicles (HAUVs).

3 Definitions

3.1 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.

3.3 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.

5 AUV and HAUV Categorization *(2024)*

AUV and HAUV Category	*Criteria*
Micro	• Diameter ≤ 3-inch • Man portable, surface or submarine launched
Small	• Diameter > 3-inch and ≤ 10-inch • Man portable, surface or submarine launched
Medium	• Diameter > 10-inch and ≤ 21-inch • Surface or submarine launched
Large	• Diameter > 21-inch and ≤ 84-inch • Surface or submarine launched
Extra Large	• Diameter > 84-inch • Pier launched

Note: The diameter in the table above refers to the outer diameter of the vehicle. For vehicles with non-circular cross-sections, the maximum cross-sectional dimension of the vehicle may be used in-lieu of the diameter.

7 Approval *(2024)*

7.1 Micro, Small and Medium AUVs or HAUVs[3,4]

Approval Path	*Scope of Approval*	*Approval Tier* [1]
Option A	Product Design Assessment (PDA) only [2]	2
Option B	Type Approval (TA) (*Includes Product Design Assessment (PDA) & Manufacturing Assessment (MA)*)	3

Notes:

1 For approval tiers, see Appendix 1A-1-A4 of the ABS *Rules for Conditions of Classification (Part 1A)*.

2 The scope of the design assessment is limited to the vehicle and control console, and does not include design assessment for installation and integration on a specific surface vessel, submarine or offshore facility.

3 For Micro, Small & Medium AUVs or HAUVs, installation and integration surveys on a specific surface vessel, submarine, or offshore facility, as well as periodic surveys after construction (See Part 7, Chapter 11 of the ABS *Rules for Survey After Construction*) are not required.

4 Where the AUV or HAUV spread includes a Launch and Recovery System (LARS), the LARS is required to be certified by ABS as per Section 20 and is required to undergo periodic surveys after construction for maintaining certification. (i.e., Options A or B above do not apply to the LARS)

7.2 Large and Extra Large AUVs or HAUVs [2]

Approval Path	*Components*	*Scope of Approval*
Option A (*I3P Verification with IRC*)	AUV or HAUV and Control Station [1]	Detailed design review & issuance of the Independent Review Certificate (IRC).
Option B (*I3P Verification with IRC & CoC*)	AUV or HAUV and Control Station [1]	Detailed design review with issuance of the Independent Review Certificate (IRC). and New construction surveys with issuance of the Certificate of Conformity (CoC).
Option C (*Classification*)	AUV or HAUV, LARS and Control Station	Classification [3] of the AUV or HAUV spread with issuance of the applicable Class Notations.

Notes:

1 For the Independent Third Party (*I3P*) verification under Options A or B above:

a) ABS classification of the AUV or HAUV spread along with issuance of the Class Notations is not included.

b) The scope of the detailed design review is limited to the vehicle and control station, and does not include design review for installation and integration on a specific surface vessel, submarine, or offshore facility.

c) Installation and integration surveys on a specific surface vessel, submarine, or offshore facility, as well as periodic surveys after construction are not required.

d) See Appendix 2 for sample Independent Review Certificate (IRC) and Certificate of Conformity (CoC).

2 Where the AUV or HAUV spread includes a Launch and Recovery System (LARS), the LARS is required to be certified by ABS as per Section 20 of these Rules and is required to undergo periodic surveys after construction for maintaining certification. (i.e., I3P verification per Options A or B above does not apply to the LARS)

3 The Classification process for the AUV or HAUV spread (*Option C above*) includes design review, new construction surveys, installation, and integration surveys, as well as periodic surveys after construction throughout its life cycle.

Commentary:

A "spread" is the equipment that is deployed for a specific job (such as a diving spread, an AUV spread, etc.).

End of Commentary

7.3 Prototype or Developmental AUVs and HAUVs

For prototype or developmental vehicles, the approval path will be determined by ABS on a case-by-case basis.

Designers and builders of such vehicles may apply for an ABS Approval-In-Principle (AIP) during the early conceptual design phase. An AIP demonstrates project feasibility and would confirm that the conceptual design complies with the intent of these Rules and other applicable industry codes / standards subject to a list of conditions. Refer to Appendix 1 of the ABS *Rules for Alternative Arrangements, Novel Concepts and New Technologies (Part 1D)* for additional details on the AIP process.

9 Class Notations *(2024)*

The following Class Notations are available for Large and Extra Large AUVs or HAUVs and their associated equipment (*Option C above*):

New construction AUVs and hybrid AUVs built under ABS survey are to be assigned the Class notation ⊞ **A1 AUV, X** and ⊞ **A1 HAUV, X** respectively, subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. **X** represents the AUV categories "Large" or "Extra Large" (See 19/5 above). For example, an extra large AUV would receive the Class notation ⊞ **A1 AUV, Extra Large**.

New and existing AUVs and hybrid AUVs not built under ABS survey are to be assigned the class notation **A1 AUV, X** and **A1 HAUV, X** respectively, subject to the conditions of classification referenced in Part 1A, Chapter 7 of the ABS *Rules for Conditions of Classification (Part 1A)*. The Maltese cross notation (⊞) signifying survey under construction is to be omitted.

11 Pressure Boundary Components

Pressure boundary components are to be certified by the manufacturer as being suitable for the intended service.

13 External Structures

13.1 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.

13.3 Corrosion Protection

Metallic external structures are to be provided with appropriate means to manage/mitigate corrosion, marine growth and galvanic action.

13.5 Mechanical Protection *(2024)*

AUVs or HAUVs are to be provided with adequate mechanical protection to protect the critical components during handling operations and other normal or emergency operations.

13.7 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 20/55.1 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

13.9 Lifting Lugs/Attachments *(2024)*

The lifting lugs/attachments used for launch and recovery of AUVs or HAUVs, 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 19/13.7 above.

15 Nameplates *(2024)*

AUVs or HAUVs 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 vehicle.

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 19/11 above.

19 Stability *(2024)*

AUVs or HAUVs are to have adequate stability while operating underwater or on the surface.

The stability analysis for AUVs or HAUVs is to take into consideration the maximum payload that the vehicle is capable of carrying.

21 Emergency Surfacing System *(2024)*

AUVs or HAUVs 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.

23 Propulsion and Steering Systems

23.1 General *(2024)*

AUVs or HAUVs are to be provided with appropriate means of propulsion and steering.

23.3 Thrusters

Thrusters are to be certified by the manufacturer as being suitable for the intended service.

25 Control Systems

25.1 General *(2024)*

AUVs or HAUVs are to be provided with the appropriate equipment to facilitate autonomous operation of the vehicle under the design conditions.

25.3 Emergency Operations *(2024)*

AUV or HAUV 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.

27 Navigational Equipment/Systems *(2024)*

AUVs or HAUVs 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 19/29 below)

29 Emergency Locating Devices *(2024)*

AUVs or HAUVs 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).

31 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.

33 Electrical Systems

33.1 General *(2024)*

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 or HAUVs are intended for operating in hazardous areas, the electrical equipment on the vehicle is to meet the requirements of 10/3.5.

33.3 Power Supply

The on-board source of power is to have adequate capacity for the mission duration.

35 Hybrid Autonomous Underwater Vehicles (HAUVs)

HAUVs are to also meet the appropriate requirements for ROVs (see Section 19), as applicable to the specific design.

37 Tests *(2024)*

AUVs or HAUVs are to be subjected to the following tests in the presence of the Surveyor:

i) Hydrostatic testing of piping systems (see 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) Test dive

v) Sea trials

SECTION 20

Handling Systems *(2015)*

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 20/1.3), 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 20/7.

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.

1.9 Latching Mechanism *(2015)*

A device used to mechanically connect and support the live load (underwater unit) on the handling system, permitting the ropes to be unloaded.

3 Submission 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 20/5.3.)
- 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 *(2015)*

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:

$F_a = F_y/1.33$ if $F_y/F_u \leq 0.7$

$F_a = (F_y + F_u)/3.25$ 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 20/7.1.3.

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:

$(f_a/F_a') + (f_b/F_b) \leq 1.0$

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 20/7.1.3 for axial stress.

ii) F value as obtained from 20/7.1.11 for buckling.

F_b = allowable compressive stress due to bending as specified in 20/7.1.4.

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:

$$f_a + f_b \leq F_a$$

where F_a is defined in 20/7.1.3.

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 20/7.1.8.

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 1.75 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 Tolerances *(2015)*

For latching mechanism components that are subject to wear while in-service, the designer is to specify the allowable in-service tolerances on the drawings and in the handling system maintenance manual.

9 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.

11 Power Sources *(2015)*

For personnel handling, an independent emergency power source is to be available for supplying power in case of failure of the primary source of power. (See 10/5).

13 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

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 Hooks *(2015)*

Loose gear hooks for launch and recovery of manned underwater units, with the exception of manned submersibles, are to be equipped with a latch that is positively lockable.

19 Winches *(2011)*

19.1 Design

Winches are to meet the applicable design requirements of 20/7.

19.3 Operation

Winches are to satisfactorily operate when handling the rated load at the rated speed.

19.5 Power Drives

Lowering of loads is to be controlled by power drives independent of brake mechanisms.

19.7 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.).

19.9 Spooling

For recovery systems, appropriate means are to be provided to ensure that the rope being recovered is correctly spooled on the winch drum.

19.11 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.

19.13 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.

19.15 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.

21 Latching Mechanisms *(2015)*

i) When latching mechanisms for personnel handling are installed in the primary load path, they are to be provided with a means to visually indicate complete latching to the operator.

ii) Latching mechanisms for personnel handling are to be statically and functionally load tested as per 20/43.3 and 20/45, respectively.

23 Hydraulic Cylinders *(2015)*

23.1 Primary Load Path Cylinders

i) Hydraulic cylinders in the primary load path, regardless of cylinder diameter, are to be designed, fabricated and tested in accordance with Section 4-4-1 of the *Marine Vessel Rules*. Alternatively, the cylinders are to comply with a recognized standard or code for fluid power cylinders or pressure vessels, having factors of safety not less than those specified in the *Marine Vessel Rules*.

ii) In addition to 20/23.1.i above, the hydraulic cylinders are to also meet the applicable structural factors of safety specified in 20/7.1.

iii) Hydraulic cylinders are to be designed for the forces induced by the loads specified in 20/7.3.

iv) Ordinary cast iron having an elongation of less than 12% is not to be used for primary load path cylinders.

v) Certified mill test reports for the hydraulic cylinder materials are to be made available to the Surveyor upon request.

vi) Each individual hydraulic cylinder is to be hydrostatically pressure tested to 1.5 times the maximum allowable working pressure (2 times for cast iron and nodular iron cylinders) by the manufacturer.

vii) *Counterbalance Valves*: Hydraulic cylinders for personnel handling are to be provided with integrally mounted counterbalance valves (lock valves) that are capable of maintaining the position of the cylinder ram in the event of loss of hydraulic power. These valves are to be directly mounted on the cylinders without the use of hoses. The valves are to be capable of closing automatically when the control lever is returned to the neutral position or upon loss of hydraulic power. These valves are to be rated for the maximum pressure induced by the loads specified in 20/7.3.

23.3 Non-Load Path Cylinders

Non-load path hydraulic cylinders are to comply with a recognized standard or code for fluid power cylinders or pressure vessels. Acceptance of these cylinders will be based on manufacturer's certification of compliance and on verification of permanent identification on each cylinder bearing the manufacturer's name or trademark, standard of compliance and the maximum allowable working pressure and temperature.

25 Hydraulic Accumulators *(2015)*

Hydraulic accumulators having operating pressures above 6.9 bar (7 kgf/cm^2 or 100 psi) are to be certified by ABS in accordance with Section 4-4-1 of the *Marine Vessel Rules* as pressure vessels, regardless of their diameter.

Each accumulator which may be isolated from the hydraulic system is to be protected by its own relief valve or equivalent. Where a gas charging system is used, a relief valve is to be also provided on the gas side of the accumulator.

27 In-Air Personnel Rescue *(2015)*

Handling systems for personnel handling are to be provided with emergency means for the recovery of the live load (underwater unit) from any position while in-air. In the event of power failure or control systems failure, the emergency means is to facilitate controlled slewing, luffing or lowering (as applicable), to land the live load safely.

29 Motion Compensation Systems *(2017)*

29.1 General Requirements

29.1.1 Design

i) The manufacturer is to specify the design/operational parameters of the motion compensation system, including any specific operational limitations.

ii) Motion compensation systems are to be designed so that a single failure in the system does not cause loss of control of the load. Compliance with this requirement is to be verified by means of a risk analysis (See 20/29.1.2 below) or equivalent means.

iii) When motion compensation systems subject components (such as the sheaves) and ropes to higher fatigue cycles over the lifetime of the handling system, then the manufacturer is to demonstrate suitability of these components and ropes for the anticipated fatigue cycles. When wire ropes are used, the sheaves and winch drums of motion compensation systems are to have a pitch diameter of not less than 20 times the nominal diameter of the wire rope.

iv) The effect of adding a motion compensation system to the handling system is to be taken into account in the design of the handling system. This could include additional loading on the structural and/or mechanical components of the handling system.

29.1.2 Risk Analysis

For motion compensation systems, a risk analysis is to be carried out for evaluating and mitigating the potential risks associated with the malfunctioning or failure of compensation system components. The risk analysis is to be conducted as per the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* or equivalent recognized national or international standards.

29.1.3 Structural Members, Machinery, Mechanical Components and Systems

i) Passive heave compensation systems are to be designed to operate using stored energy.

ii) When the passive heave compensation system employs hydraulic/pneumatic stored energy, then the pressure retaining components of the system (such as the accumulators, cylinders and piping systems) are to be designed for the maximum pressure corresponding to the worst case anticipated loading on the system, including dynamic loading where applicable.

iii) Passive heave compensation system components that are located in the primary load path (such as in-line hydraulic cylinders) are to be also designed to meet the applicable structural factors of safety of 20/7.1, when subjected to the worst case anticipated loading, including dynamic loading.

iv) Passive heave compensation systems utilizing hydraulic/pneumatic cylinders and accumulators are to have a position indicator in order to provide the operator with visual indication of the position of the system with reference to its operating range.

29.5 Active Heave Compensation Systems

i) Active heave compensation systems are to be provided with two independent control systems and power supplies. Alternatively, they are to be provided with a back-up means (such as a passive heave compensation system or shock absorber system) to prevent shock loading or structural overloading of the handling system in the event of failure of the active heave compensation system.

ii) Active heave compensation systems are to operate when the handling system is in the offboard condition. Appropriate means are to be provided to prevent operation of the heave compensation system when the handling system is in the onboard condition.

iii) Appropriate means are to be provided for continuous monitoring and recording of the handling system load during operation of the active heave compensation system.

iv) Audio-visual alarms are to be provided for warning the operator in the event of equipment failure or abnormal operation of the active heave compensation system.

v) When computer based control systems are used for motion compensation systems, they are to comply with the requirements of Section 4-9-3 of the *Marine Vessel Rules*, as applicable. For the handling of unmanned objects/loads, the motion compensation systems are to comply with the requirements for Category I Systems in accordance with 4-9-3/7.1 TABLE 1. For the handling of manned units (personnel lifting), the motion compensation systems are to comply with the requirements for Category II Systems in accordance with 4-9-3/7.1 TABLE 1.

vi) When active heave compensation systems use synthetic fiber ropes, means are to be provided for monitoring the temperature of the rope. The operating temperature of the rope is to be in accordance with the rope manufacturer's specification. Where there is potential for rope overheating, means are to be provided for cooling the section of rope in-way of the active heave compensation system.

29.7 Testing

Motion compensation systems are to meet the following testing requirements in addition to the requirements of Subsection 20/43:

29.7.1 Manufacturer Testing

Motion compensation systems are to be tested to the satisfaction of the Surveyor in accordance with the manufacturer specified factory acceptance testing requirements.

For active heave compensation systems, the testing is to also include simulated testing (such as by using a simulation program to simulate the sensor feedback to the control system) in order to demonstrate the ability of the heave compensation system to maintain the position of the suspended load with reference to a fixed reference frame, under the worst case operating conditions.

29.7.2 On-Board Functional Testing

After installation of the handling system on the vessel, the motion compensation systems are to be functionally tested to the satisfaction of the Surveyor in accordance with the manufacturer's testing requirements. This testing need not be conducted to the rated load of the handling system.

31 Structural Members

Structural members are not to be less than 6.4 mm (0.25 in.) thick and are to be suitably protected from corrosion.

33 Structural Materials

33.1 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.

33.3 Toughness

For handling systems with design service temperature of -10°C (14°F) and colder, primary structural members such as those listed in 20/35 are to be in conformity with the toughness criteria in 20/37. 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 20/37.

33.5 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.

33.7 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.

33.9 Other Material

Materials other than steel will be specially considered.

33.11 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 20/33.3 or 20/37, 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).

35 Primary Structural Members

The following load-carrying structural members are to meet the requirements of 20/37.

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 20/55.1 TABLE 2

37 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.

37.1 Steels up to and Including 41 kg/mm² (58,000 psi) Yield Strength

Steels up to and including 41 kg/mm²(58,000 psi) yield strength are to meet the following longitudinal CVN requirements:

Yield Strength		*CVN (longitudinal)*		*Test Temperature*
kg/mm²	*ksi*	*kg-m*	*ft-lb*	10°C (18°F) below design service temperature
24–31	34–44	2.8	20	
32–41	45.5–58	3.5	25	

37.3 Extra High Strength Steels above 41 kg/mm² (58,000 psi) Yield Strength

Steels in the 42–70 kg/mm²(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)

37.5 Alternative Requirements

As an alternative to the requirements in 20/37.1 and 20/37.3, 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 20/37.1 and 20/37.3.

iv) Other means of fracture toughness testing, such as Crack Opening Displacement (COD) testing, will be specially considered.

39 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)*.

41 Nondestructive Inspection (NDT) of Welds *(2025)*

Inspection is to be in accordance with the *NDT Requirements* 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.

43 Surveys and Tests During Construction

43.1 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.

43.3 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.

43.5 Original Tests on Handling Systems

43.5.1 Loose Gear

43.5.1(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 20/55.1 TABLE 2.

43.5.1(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.

43.5.1(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.

43.5.2 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.

45 Functional Test *(2015)*

Prior to the system being placed in service, the system is to be tested through its full working range 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.

47 Operation *(2011)*

The complete handling system is to operate satisfactorily when handling the rated load at the rated speed.

49 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.

51 Running Rope Maintenance Program

51.1 Wire Rope Replacement or Ends Exchange *(2021)*

The ends of wire rope are to be exchanged every twelve months and the rope is to be maintained as recommended by the manufacturer. As an alternative to end-to-end exchanging of the rope ends, wire ropes are to be replaced every two years. Records of the replacement or exchange are to be maintained as part of the Record of Certification.

51.3 Annual Testing *(2021)*

Annually, a section is to be removed from the used end of the rope. The length of this 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.

Following each ends exchange, except the first exchange, the testing as referenced above is to be conducted.

51.5 Lubrication of Wire Rope *(2021)*

Where applicable, records of lubrication application as per the manufacturer's recommendations are to be maintained as part of the Record of Certification.

53 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 20/5.
- Certificate for Handling Systems (see 1A-7-2/5 of the ABS *Rules for Conditions of Classification (Part 1A)*).
- Certificates for items of loose gear (see 20/43.5.1).
- Certificates for rope components (see 20/43.5.2).
- Report of tests and surveys during construction (see 20/43.1 and 20/43.3).
- Report of initial tests and examinations to system as a unit (see 20/45).
- Report of tests and examinations following repairs or design modifications (see 20/49).
- Rope maintenance program (see 20/51).
- Report on surveys after construction (see 20/55).

55 Surveys After Construction

55.1 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*		*Significant range of periods, sec.*	*T average period*	*ℓ average wave length*	*Minimum fetch, nmi*	*Minimum duration, hr*
						Average	*Average 1/10 height*					
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	0.6	1.2	0.8-5.0	2.4	20	9.8	1.7 hr
					10	0.88	1.8	1.0-6.0	2.9	27	10	2.4
2, 3	Small waves, becoming larger; fairly frequent white horses.	4	Moderate breeze	11–16	12	1.4	2.8	1.0–7.0	3.4	40	18	3.8
					13.5	1.8	3.7	1.4–7.6	3.9	52	24	4.8
					14	2	4.2	1.5–7.8	4	59	28	5.2
					16	2.9	5.8	2.0–8.8	4.6	71	40	6.6

		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 height					
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	3.8	7.8	2.5–10.0	5.1	90	55	8.3
					19	4.3	8.7	2.8–10.6	5.4	99	65	9.2
					20	5	10	3.0–11.1	5.7	111	76	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	6.4	13	3.4–12.2	6.3	134	100	12
					24	7.9	16	3.7–13.5	6.8	160	130	14
					24.5	8.2	17	3.8–13.6	7	164	140	15
					26	9.6	20	4.0–14.5	7.4	188	180	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	11	23	4.5–15.5	7.9	212	230	20
					30	14	28	4.7–16.7	8.6	250	280	23
					30.5	14	29	4.8–17.0	8.7	258	290	24
					32	16	33	5.0–17.5	9.1	285	340	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	19	38	5.5–18.5	9.7	322	420	30
					36	21	44	5.8–19.7	10.3	363	500	34
					37	23	46.7	6.0–20.5	10.5	376	530	37
					38	25	50	6.2–20.8	10.7	392	600	38
					40	28	58	6.5–21.7	11.4	444	710	42

		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 height					
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	31	64	7.0–23.0	12	492	830	47
					44	36	73	7.0–24.2	12.5	534	960	52
					46	40	81	7.0–25.0	13.1	590	1110	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	44	90	7.5–26.0	13.8	650	1250	63
					50	49	99	7.5–27.0	14.3	700	1420	69
					51.5	52	106	8.0–28.2	14.7	736	1560	73
					52	54	110	8.0–28.5	14.8	750	1610	75
					54	59	121	8.0–29.5	15.4	810	1800	81

		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 height					
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	64	130	8.5–31.0	16.3	910	2100	88
					59.5	73	148	10–32	17	985	2500	101
9	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 21

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 *Marine 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 *Marine 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 22

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)*.

(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 channel B	38.5 ±0.05 kHz 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)

SECTION 2

Sample Certificates for ROVs and AUVs *(2024)*

FIGURE 1
Sample: Independent Review Certificate (IRC)

American Bureau of Shipping

Independent Review Certificate (*IRC*)

IRC No.....

Issuance Date:.....

ABS Project No.:.....

This is to certify that the design plans and data for the underwater vehicle and associated equipment listed below have been reviewed and found to be in compliance with the applicable requirements of the ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, 2021.

Manufacturer's Name	
Address	
Telephone Number(s)	
E-Mail Address(es)	

Equipment Name	Class	Model Number	Serial Number	Design Data
ROV or AUV				
Umbilical				
Dive Control Station				

Drawings and documentation as per the attached list.

.....

Vice President, Engineering

ABS Global Engineering

Electronically Signed by: .....

This certificate is a representation that the structure, item of material, equipment, machinery, or other item covered by this certificate has met one or more of the Rules, Guides, standards, or other criteria of ABS or of a National Administration, and is issued solely for use by ABS, its committees, its clients, or other authorized entities. The validity, applicability and interpretation of this certificate is governed by the Rules and Standards of ABS, and ABS shall remain the sole judge thereof. Nothing contained in this certificate or in any notation made in contemplation of this certificate shall be deemed to relieve any designer, builder, owner, manufacturer, seller, repairer, operator, or other entity of any warranty express or implied.

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American Bureau of Shipping

Independent Review Certificate (*IRC*)

Attachment to IRC No.....

Issuance Date:.....

ABS Project No.:.....

Drawing and Documentation List

Engineering Office:		
Submitter:		
Drawing No.	**Rev. No.**	**Drawing Title**

Scope and Limitations

1. This IRC is issued for the design assessment of the above listed underwater vehicle and associated equipment to the applicable requirements of the ABS Rules. The scope of this design assessment does not include installation and integration of the underwater vehicle and associated equipment onboard any specific vessel or facility.

2. The scope of this IRC does not include surveys for the fabrication of the above listed underwater vehicle and associated equipment, as well as surveys for installation and integration of the underwater vehicle and associated equipment onboard any specific vessel or facility.

Related Correspondence / Previous Approvals

.....

.....

.....

This certificate is a representation that the structure, item of material, equipment, machinery, or other item covered by this certificate has met one or more of the Rules, Guides, standards, or other criteria of ABS or of a National Administration, and is issued solely for use by ABS, its committees, its clients, or other authorized entities. The validity, applicability and interpretation of this certificate is governed by the Rules and Standards of ABS, and ABS shall remain the sole judge thereof. Nothing contained in this certificate or in any notation made in contemplation of this certificate shall be deemed to relieve any designer, builder, owner, manufacturer, seller, repairer, operator, or other entity of any warranty express or implied.

FIGURE 2
Sample: Certificate of Conformity (CoC)

American Bureau of Shipping

Certificate of Conformity (CoC)

CoC No.…… IRC No.……

Issuance Date:…… Issuance Date:……

ABS Project No.:……

This is to certify that the undersigned Surveyor has surveyed the following underwater vehicle and associated equipment and has found the same to be in compliance with the applicable requirements of the ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, 2021.

Manufacturer's Name	
Address	
Telephone Number(s)	
E-Mail Address(es)	

Equipment Name	Category	Model Number	Serial Number	Design Data
ROV or AUV				
Umbilical				
Dive Control Station				

Scope of Survey

……
……
……
……

This certificate is a representation that the structure, item of material, equipment, machinery, or other item covered by this certificate has met one or more of the Rules, Guides, standards, or other criteria of ABS or of a National Administration, and is issued solely for use by ABS, its committees, its clients, or other authorized entities. The validity, applicability and interpretation of this certificate is governed by the Rules and Standards of ABS, and ABS shall remain the sole judge thereof. Nothing contained in this certificate or in any notation made in contemplation of this certificate shall be deemed to relieve any designer, builder, owner, manufacturer, seller, repairer, operator, or other entity of any warranty express or implied.

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American Bureau of Shipping

Certificate of Conformity (CoC)

Equipment Testing Details (*as applicable*)

.....
.....
.....

Drawing or Documentation

.....
.....
.....

Scope and Limitations

1. This CoC is issued for the survey of the above listed underwater vehicle and associated equipment to the applicable requirements of the ABS Rules. The scope of these surveys does not include installation and integration of the underwater vehicle and associated equipment onboard any specific vessel or facility.

Port of Issue:.....

Issued by:..... (ABS Surveyor)

Signature:.....

This certificate is a representation that the structure, item of material, equipment, machinery, or other item covered by this certificate has met one or more of the Rules, Guides, standards, or other criteria of ABS or of a National Administration, and is issued solely for use by ABS, its committees, its clients, or other authorized entities. The validity, applicability and interpretation of this certificate is governed by the Rules and Standards of ABS, and ABS shall remain the sole judge thereof. Nothing contained in this certificate or in any notation made in contemplation of this certificate shall be deemed to relieve any designer, builder, owner, manufacturer, seller, repairer, operator, or other entity of any warranty express or implied.