



RULES FOR BUILDING AND CLASSING

UNDERWATER VEHICLES, SYSTEMS AND HYPERBARIC FACILITIES 2018

**American Bureau of Shipping
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the State of New York 1862**

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ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA**

Rule Change Notice (2018)

The effective date of each technical change since 1993 is shown in parenthesis at the end of the subsection/paragraph titles within the text of each Part. Unless a particular date and month are shown, the years in parentheses refer to the following effective dates:

(2000) and after	1 January 2000 (and subsequent years)	(1996)	9 May 1996
(1999)	12 May 1999	(1995)	15 May 1995
(1998)	13 May 1998	(1994)	9 May 1994
(1997)	19 May 1997	(1993)	11 May 1993

Listing by Effective Dates of Changes from the 2017 Rules

EFFECTIVE DATE 1 January 2018 – shown as (2018)

(based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
8/Table 1	Monochloro/Dichloroacetylene Precursor Compounds	To include the standard IUPAC name, which is commonly used in the industry, and the CAS number of each compound
10/17.13	Prototype Testing of Electrical Penetrators	To update existing testing requirements and acceptance criteria.
10/17.17 (Deleted)	Prototype Testing of Pin Type Penetrators	To update existing testing requirements and acceptance criteria.

Foreword

The 2016 edition of the *Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities* incorporates all Rule Changes and Corrigenda items since 2015. Requirements for ambient pressure submersibles 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 atmospheric diving suits.
- Section 16 provides the specific requirements that are applicable to remotely operated vehicles.
- Section 17 provides the specific requirements that are applicable to autonomous underwater vehicles.
- Section 18 provides the specific requirements that are applicable to handling systems.
- Section 19 provides the specific requirements that are applicable to dive control stations.
- Section 20 provides the requirements for surveys after construction.
- Appendix 1 provides relevant excerpts from IMO Res. A.831 (19) Code of Safety for Diving Systems regarding diving bell emergency locating devices

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

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

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

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



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SECTION 1 Scope and Conditions of Classification

1 Classification (1 January 2008)

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

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

3 Classification Symbols and Notations (1 January 2008)

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

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

3.1 Classed Units (2012)

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

3.3 Classed Systems (2012)

In addition to the Classification of the individual underwater vehicles, underwater facilities, and hyperbaric facilities mentioned in 1/3.1, a system may be classed and distinguished in the *Record* by the symbols **✕ A1** followed by the appropriate notation, such as **Air Diving System (P) or (F), Mixed Gas Diving System (P) or (F), Saturation Diving System (P) or (F)** (See Subsection 14/3), **Underwater Complex**, etc., provided the system has been built to the satisfaction of the ABS Surveyors to the full requirements of these Rules, or their equivalent.

3.4 Support Components for Classed Systems (2012)

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

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

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

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

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

- i) Welding procedures (WPS) and performance qualifications records (PQR)
- ii) NDT records
- iii) Material mill test reports
- iv) All other certificates of past surveys and tests results conducted by the original certifying agency, insofar as such documentation is available and valid
- v) Written test procedures for the tests and trials required to be performed for classification or certification

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

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

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

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

3.7 Other Conditions

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

5 Rules for Classification (1 January 2008)

5.1 Application of Rules (2012)

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

7 Submissions of Plans, Calculations, Data and Test Results

7.1 Submission Schedule and Number of Copies (2011)

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

7.3 Documentation to be Submitted (2010)

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

7.3.1 Design and Operational Parameters (2007)

Design pressures and depths

Design temperatures

Hydrostatic test pressures

Design sea state conditions

Maximum operating depth

Maximum mission time

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

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

Maximum towing speed/towing line tension

Maximum speed while surfaced and submerged

7.3.2 General

General arrangement

Cross-section assembly

Outboard profile

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

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

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

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

Out-of-roundness tolerances

Fabrication tolerances

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

Penetrator sealing arrangements

Hatch sealing arrangements

Nameplate, including nameplate material and method of attachment

Plan showing all hull valves, fittings and penetrations

Exostructure details

Dimensional details of viewport components

Hard ballast tanks design details

Soft ballast tanks design details

Piping systems including pump capacities and pressure relief devices

Ballast piping systems

Layout of control stands

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

Release devices and arrangement for jettisonable weights and equipment

Propeller details including shafting, bearings and seals

Propulsion motors, thrusters and wiring diagram

Steering control system

Electrical distribution system

Battery capacity, arrangement and main feeder scheme

Lifting and handling system

Depth indicating systems

Emergency systems

Fire fighting system

Details for permanently installed pressure vessels

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

List and location of implodable volumes

Materials and dimensions of umbilicals including cross sectional details

Any additional system deemed necessary to the intended operations

7.3.3 Life Support Systems and Equipment

Life support system details, both normal and emergency

Life support system capacities, fluids contained and supply arrangement

Specifications for environmental control systems and equipment including heating, gas analysis (CO₂, CO, CH₄, O₂, etc.), absorption, circulation, temperature control, humidity control, equipment for tracing contaminants

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

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

Lodging facilities and drainage systems in hyperbaric chambers

7.3.4 Procedures

Procedures for out-of-roundness and sphericity measurements

Cleaning procedures for breathing gas systems

Inclining experiment procedures

Functional test procedures

Sea trial procedures for normal and emergency conditions

7.5 Calculations (2002)

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

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

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

7.7 Operational Data

The following operational data are to be submitted:

- Description of operations
- Description of units and intended service

7.9 Test Results

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

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

9 Manuals

9.1 Operating Manual (2007)

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

- System description
- Operation check-off lists (list to include equipment requiring operational status verification or inspection prior to each dive/operation and verification of the existence of appropriately updated maintenance schedule – see 1/9.3)
- Operational mission time and depth capabilities
- Sea state capabilities (see Section 18, Table 1)
- Geographical dive site limitations (such as maximum current, night/limited visibility operation and list of operational and environmental hazards, if any, to be avoided.) as related to the design parameters addressed in Subsection 1/7 and 11/49.3
- Special restrictions based on uniqueness of design and operating conditions
- Life support system description including capacities
- Electrical system description
- Launch and recovery operation procedures
- Liaison with support vessel

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

9.3 Maintenance Manual (2002)

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

9.5 Availability (2007)

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

11 Personnel (2002)

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

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



SECTION 2 Definitions (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.

25 Diving System

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

27 Fire-restricting Materials (2002)

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

29 Fixed Diving System (F) (2012)

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

31 Gas Reclaim System (2013)

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

33 Habitat

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

35 Handling System

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

37 Hyperbaric Evacuation System (2010)

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

39 Hyperbaric Evacuation Unit (2010)

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

41 Hyperbaric Facility

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

43 Launch and Recovery System (2011)

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

45 Light Ship (2002)

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

47 Lock-Out Submersible (2012)

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

49 Manipulator

A remotely operated work arm.

51 No-Decompression Limit (2011)

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

53 Open Bell

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

55 Passenger Submersible (2013)

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

57 Personnel Capsule

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

59 Portable Decompression Chamber

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

61 Portable Diving System (P) (2012)

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

63 Pressure Boundary (2013)

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

65 Pressure Hull (2011)

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

67 Pressure Resistant (2013)

A structure or component that withstands pressure.

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

A vessel or chamber that encloses one or more human beings within its pressure boundary while under internal or external pressure exceeding a differential pressure of 2 psi. (See Section 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 Subsection 2/75, "Remotely Operated Vehicle".

79 Submersible

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

81 Submersible Decompression Chamber

See Subsection 2/23, "Diving Bell".

83 Tethered Submersible

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

85 Umbilical

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

87 Underwater Complex

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

89 Underwater Container

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

91 Underwater System

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

93 Underwater Vehicle

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

95 Unit (2007)

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

97 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 (2015)

1 Nonmetallic Materials

1.1 General

Materials and equipment inside manned compartments are to be such that they will not give off noxious or toxic fumes within the limits of anticipated environments or under fire conditions. Where compliance with this requirement has not been demonstrated through satisfactory service experience, a suitable analysis or testing program is to be performed and submitted. Systems are to be designed and equipped to minimize sources of ignition and combustible materials. See also Subsection 8/25.

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 Subsection 2/27 for the definition of fire-restricting materials.

1.7 External Materials (2002)

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

3 Test Dive (2007)

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

5 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.

7 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.

9 Thermal Protection (2007)

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



SECTION 4 Materials

1 General

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

3 Pressure Boundary Material Specifications

3.1 Plates (2010)

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

- i) *Steel (2008)*: ABS Hull Grades E, EH32, EH36; U.S. Navy Grades HY-80 and HY-100 per MIL-S-16216; ASTM A516 Grades 55, 60, 65, 70; ASTM A537 Class 1 and 2; ASTM A517 Grades, A, B, E, F, J
- ii) *Aluminum*: ASTM B 209 alloy 6061-T6; ASTM B 928 alloys 5083, 5086, 5383, 5456 (see Section 5 of these Rules)
- iii) *Titanium Alloys*: ASTM B265 Grade 5
- iv) *Stainless Steel*: ASTM A240 Type 304 or 316
- v) *Acrylic Plastics* (cast polymethyl methacrylate): ASME PVHO-1 and Section 7 of these Rules

3.3 Bolts, Extrusions, Forgings, and Shapes

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

3.5 Materials Complying with Other Standards

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

5 Testing

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

5.1 Inspection

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

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

- ii) Grid lines are to be measured from the center or one corner of the plate, with an additional path within 50 mm (2.0 in.) of all edges of the plate on the searching surface.
- iii) Where complete loss of back reflection is detected along a given grid line, the entire surface area of the squares adjacent to this indication is to be continuously scanned. The boundaries of areas where complete loss of back reflection is detected are to be established.

5.3 Toughness Testing

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

5.3.1 Charpy Tests

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

5.3.2 Drop Weight Tests

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

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

7 Corrosion and Galvanic Action

Protection against corrosion is to be provided as follows.

7.1 Ferritic Materials

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

7.3 Galvanic Action

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

TABLE 1
Charpy Impact Testing Requirements

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

Notes

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



SECTION 5 Fabrication

1 Material Identification

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

3 Alignment Tolerance

3.1 Butt Weld Alignment

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

Section Thickness in mm (in.)	Offset in mm (in.)	
	Direction of Joints in Cylindrical Shells	
	Longitudinal	Circumferential
Up to 12.5 (0.5), incl.	$\frac{1}{4}t$	$\frac{1}{4}t$
Over 12.5 (0.5) to 19 (0.75), incl.	3.2 ($\frac{1}{8}$)	$\frac{1}{4}t$
Over 19 (0.75) to 38 (1.5), incl.	3.2 ($\frac{1}{8}$)	4.8 ($\frac{3}{16}$)
Over 38 (1.5) to 51 (2.0), incl.	3.2 ($\frac{1}{8}$)	$\frac{1}{8}t$
Over 51 (2.0)	$\frac{1}{16}t$ (9.5 ($\frac{3}{8}$) max.)	$\frac{1}{8}t$ (19 ($\frac{3}{4}$) max.)

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

3.3 Heads and Spherical Vessels

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

5 Joints

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

5.1 Category A and B

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

5.3 Category C and D

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

5.5 Joint Properties

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

<i>Plate Thickness in mm (in.)</i>	<i>Maximum Thickness of Reinforcement in mm (in.)</i>
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/mm² (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/mm² (38,000 psi)

For steel material with a minimum specified yield strength equal to or less than 27 kg/mm² (38,000 psi) a minimum average value of 4.8 kg-m (35 ft-lb) at -20°C (-4°F) is to be attained. Filler metals listed in “Approved Welding Electrodes, Wire-Flux and Wire-Gas Combination” as ABS Grade 3 filler metal or as an equivalent American Welding Society (AWS) Classification are considered to meet the impact requirement.

7.7.2 27 kg/mm² (38,000 psi) <Yield Strength ≤ 42 kg/mm² (60,000 psi)

For steel material with a minimum specified yield strength greater than 27 kg/mm² (38,000 psi) and equal to or less than 42 kg/mm² (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/mm² (60,000 psi)

For steel material with a minimum specified yield strength greater than 42 kg/mm² (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-100 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/mm² (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/mm² (60,000 psi) yield strength or greater is to be conducted at a suitable interval after the welds have been completed and cooled to ambient temperature. The interval is to be at least 72 hours unless specially approved otherwise. At the discretion of the Surveyor, a longer interval and/or additional random inspection at a later date may be required. Further, at the discretion of the Surveyor, the 72 hour interval may be reduced to 24 hours for radiographic or ultrasonic inspections, provided a complete visual and random magnetic particle, liquid penetrant or eddy current inspection are conducted 72 hours after the welds have been completed and cooled to ambient temperature.

7.15.2 Post Hydrostatic Test Examination

Following hydrostatic testing, all pressure boundary welds are to be examined by magnetic particle or liquid penetrant or eddy current method. See also Subsection 6/27.

7.15.3 Radiographic and Ultrasonic Examinations

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

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

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

6 mm ($\frac{1}{4}$ in.)	for t up to 19 mm ($\frac{3}{4}$ in.)
$\frac{1}{3}t$	for t from 19 mm ($\frac{3}{4}$ in.) to 57 mm ($2\frac{1}{4}$ in.)
19 mm ($\frac{3}{4}$ in.)	for t over 57 mm ($2\frac{1}{4}$ 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 ($\frac{3}{16}$ in.)
- iii) Four or more rounded indications in a line separated by 1.6 mm ($\frac{1}{16}$ in.) or less edge to edge
- iv) Ten or more rounded indications in any 3870 mm² (6 in²) 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 ($\frac{3}{8}$ in.) or 10 percent of the weld thickness, the examination may be made by magnetic particle, liquid penetrant method, or eddy current technique.

9 Welding of Non-Ferrous Materials (2002)

9.1 General

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

9.3 Welded Joints in Aluminum

9.3.1 Alloys Listed in 4/3.1ii)

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

9.3.2 Other Alloys and Tempers

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

11 Out-of-Roundness, Sphericity, and Local Departure from 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 Section 5, Figure 2. The lengths, diameters and thicknesses are to be taken in constant units.

11.3.1 Length for Cylinders

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

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

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

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

11.3.2 Length of Cones and Conical Sections

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

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

L_o = overall length of conical section under consideration.

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

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

i) *At large diameter end*

$L = L_e$

$D_o = D_L$

ii) *At the small diameter end*

$L = L_e(D_L/D_s)$

$D_o = D_s$

iii) *At the midlength diameter*

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

$D_o = 0.5(D_L + D_s)$

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

$L = L_e(D_L/D_x)$

$D_o = D_x$

11.3.3 Template

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

11.5 Permitted Deviations of Spheres and Hemispheres

11.5.1 General

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

11.5.2 External Pressure

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

11.7 Thickness

11.7.1

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

- i) For vessels with butt joints, t is the nominal plate thickness less corrosion allowance.
- ii) Where the shell at any cross section is made of plates having different thicknesses, t is the nominal thickness of the thinnest plate less corrosion allowance.

11.7.2

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

$$\begin{aligned} t_e &= \text{effective thickness of conical section} \\ &= t \cos \alpha \\ \alpha &= \text{one-half the apex angle, deg.} \end{aligned}$$

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 5/11.3.2i), ii) and iii).

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.

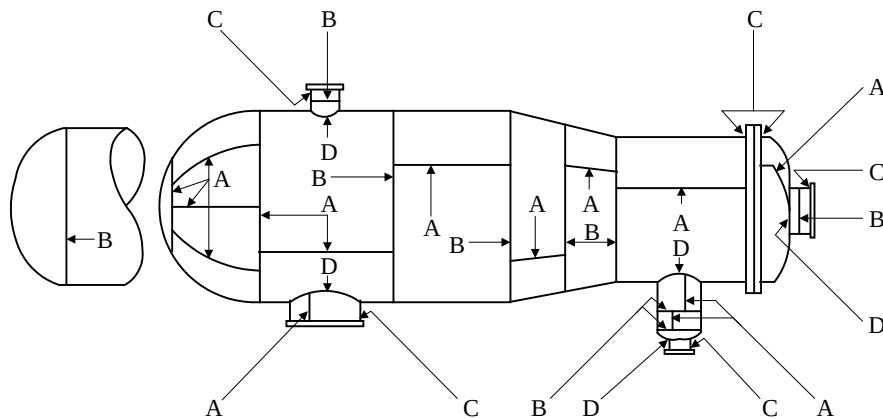
11.9.3 (2015)

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 $6.35 \mu\text{m}$ ($250 \mu\text{in}$) rms. A surface finish of $0.8 \mu\text{m}$ ($32 \mu\text{in}$) is required for O-ring sealing surfaces unless otherwise specified by the manufacturer. Surface finish for viewport flanges is to comply with Section 7.

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



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

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

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

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

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

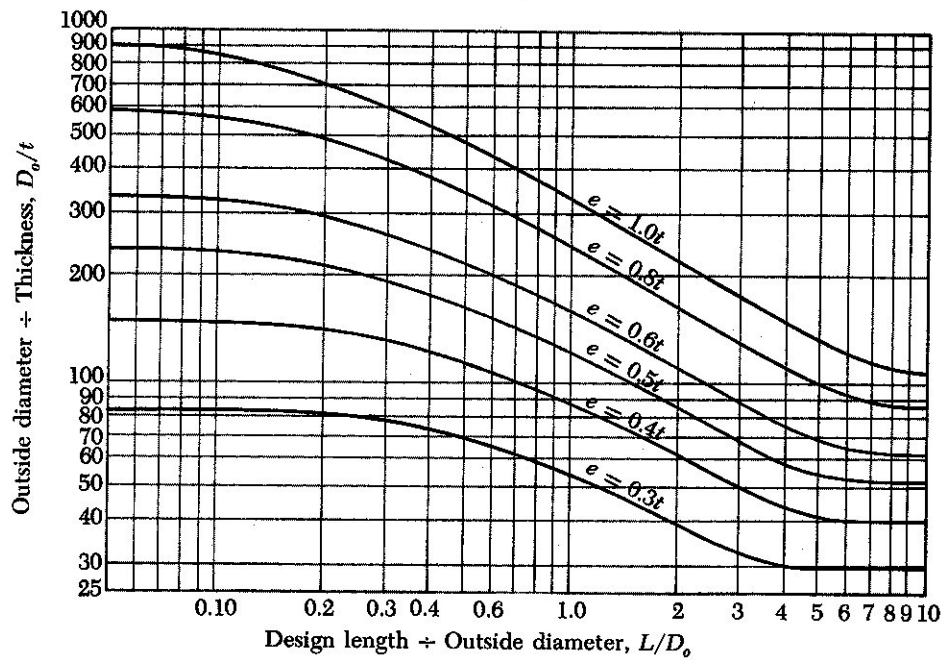


FIGURE 3
Arc Length

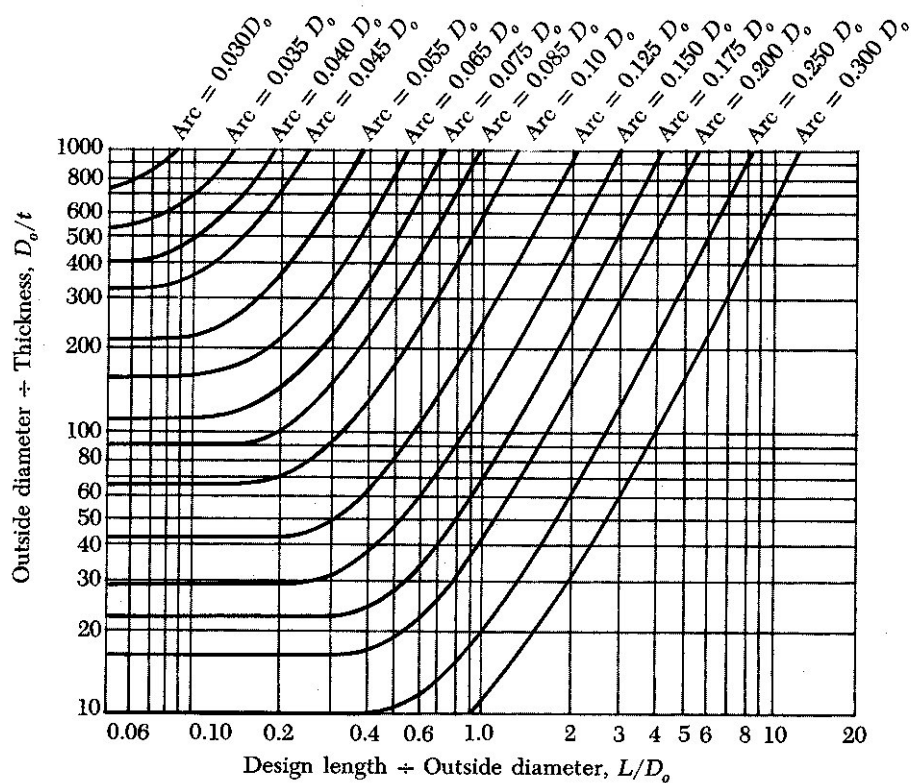
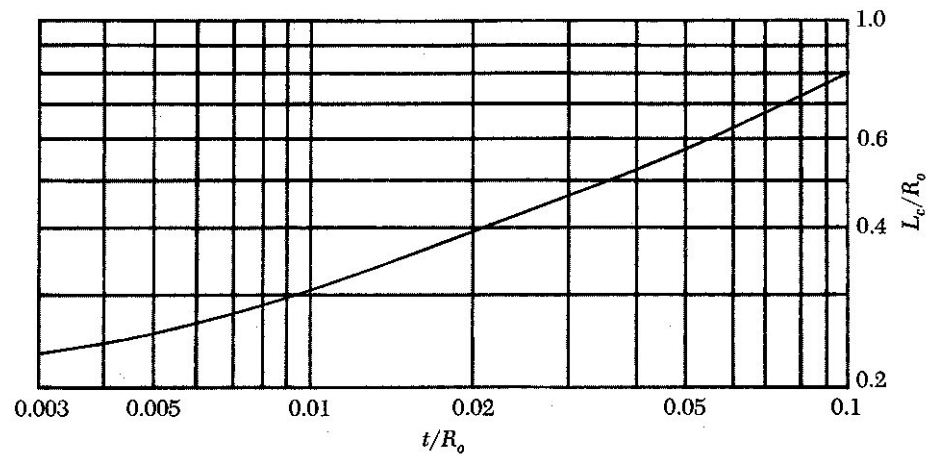


FIGURE 4
Values of Chord Length (L_c) for Out-of-roundness of Spheres





SECTION 6 Metallic Pressure Boundary Components

1 General

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

3 Design for Internal Pressure (2010)

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

5 Design Pressures and Loads (2010)

5.1 General

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

- i) Internal and/or external pressures
- ii) Localized loads due to external forces, impact loads, lifting forces, localized reactions and discontinuities
- iii) Nozzle loads due to external manway/piping connections
- iv) Loads due to expansion/contraction of the pressure boundaries
- v) Deadweight of the installed equipment
- vi) Weight of entrapped water/mud
- vii) Loads due to the environmental conditions including wind loads, wave loads and current forces

5.3 Localized Loads

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

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