Guide for Building and Classing

LNG Regasification Vessels

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GUIDE FOR BUILDING AND CLASSING

LNG REGASIFICATION VESSELS
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Foreword *(2022)*

The industry and ABS share a large and successful body of experience with Liquefied Natural Gas (LNG) carriers.

This Guide provides criteria that can be applied to LNG Carriers and LNG Barges proposed to be classed by utilizing the ABS *Rules for Building and Classing Marine Vessels*, ABS *Guide for Building and Classing Liquefied Gas Carriers with Independent Tanks*, and/or ABS *Rules for Building and Classing Steel Barges* and fitted with regasification systems and components.

Floating storage and regasification units (FSRUs) provide solutions to meet the energy demands of an ever-changing global market. Floating regasification is a flexible, cost-effective way to receive and process shipments of LNG. Floating regasification is increasingly being used to meet natural gas demand in smaller markets, or as a temporary solution until onshore regasification facilities are built. Floating regasification involves the use of a specialized vessel often referred to as an FSRU, which is capable of transporting, storing, and regasifying LNG onboard. An FSRU can be purpose-built or be converted from a conventional LNG vessel by installing a regasification plant.

Regasification plants are installed to vaporize the liquid gas onboard a vessel, this may include self-propelled LNG carriers or Non-Self-Propelled LNG barges. The gas may be delivered to the shore side facility via various arrangements, such as turret system with delivery through an offshore buoy piping system or vessel manifold system to facility on platform, quay or similar.

This Guide is to be used in conjunction with other ABS Rules and IMO Regulations.

This Guide is for the use of designers, builders, owners and operators of liquefied gas carriers/tank barges and specifies the ABS requirements for obtaining the optional classification notation **(LNG) R**.

The December 2021 update outlined how the ABS Modified Tank Entry Program may be used to permit reduced or extended tank entry for FSRU vessels assigned the **(LNG) R** notation when employed in long term employment on a single site. By incorporating features and utilizing alternate means of crediting Surveys normally requiring tank entry while covering all aspects of required Surveys, such alternate programs suitably documented and approved may be considered.

The January 2022 edition replaces the requirements for surveys after construction with a reference to Section 7-9-40 of the ABS *Rules for Survey After Construction (Part 7)*.

This Guide becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

GUIDE FOR BUILDING AND CLASSING

LNG REGASIFICATION VESSELS

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SECTION 1

Scope and Conditions of Classification

1 Scope and Application *(1 May 2018)*

This Guide has been developed to provide guidance for the design, construction, and survey of Liquefied Natural Gas (LNG) vessels utilizing regasification systems. The Guide focuses on systems and arrangements provided for the safe delivery of natural gas by means of regasification systems. The Guide applies to LNG vessel types that fall under the scope of the IGC Code and associated ABS requirements for Vessels Intended to Carry Liquefied Gases in Bulk under Part 5C, Chapter 8 of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*, the ABS *Guide for Building and Classing Liquefied Gas Carriers with Independent Tanks (LGC Guide)*, or the ABS *Rules for Building and Classing Steel Barges (Barge Rules)*.

In general, vessels are to comply with the requirements contained in the ABS requirements for Vessels Intended to Carry Liquefied Gases in Bulk under Part 5C, Chapter 8 of the *Marine Vessel Rules*, the *LGC Guide*, or the *Barge Rules*, as applicable, and the requirements of this Guide to receive the notations listed in Subsection 1/3.

This Guide applies to both new construction and existing vessel conversions, regardless of size, utilizing regasification systems.

3 Classification Notations *(1 May 2018)*

Vessels that comply with this Guide and are intended to operate in a regasification and gas discharge role, are eligible for ABS classification which will be denoted with the additional notation **(LNG) R**, so that the class notation as it appears in the *Record* will be:

✠ A1 Liquefied Gas Carrier, (LNG) R or **✠ A1 Liquefied Gas Tank Barge, (LNG) R**

✠ A1 Liquefied Gas Carrier with Independent Tanks, (LNG) R

5 Definitions

The definitions contained in 5C-8-1/2 of the *Marine Vessel Rules* are applicable. The following definitions are applied to the terms used in this Guide:

Cargo Machinery Spaces. The spaces where cargo compressors or pumps, cargo processing units, are located, including those supplying gas fuel to the engine-room.

Floating Storage and Regasification Unit (FSRU). A vessel that has LNG storage as well as regasification equipment for LNG vaporizing.

Gas Process Unit. Booster pumps, process pressure vessel, regasification plant.

Regasification Plant. All systems and components for removing liquefied gas from the storage tanks, pressurizing, heating and vaporizing liquefied gas and discharge ashore of vaporized gas through an off-loading system. If there are compressors or odorizes in the discharge system, they would be considered part of the Regasification Plant.

Turret Compartments. Those spaces and trunks that contain equipment and machinery for retrieval and release of the disconnectable turret mooring system, high-pressure hydraulic operating systems, fire protection arrangements and cargo transfer valves.

Upset Condition. Interruptions in the regular running of the work process or other planned activity. Any distraction or break in the normal work routine is considered an Upset Condition.

7 Materials of Construction

Materials in general are to comply with the requirements of the ABS *Rules for Materials and Welding (Part 2)*.

Materials used in gas tanks, gas piping, process pressure vessels, and other components in contact with cryogenic liquids or gases are to be suitable for the intended purpose and in compliance with Section 5C-8-6 of the *Marine Vessel Rules*.

9 Certification

Design review, survey, testing, and the issuance of reports or certificates constitute the certification of machinery, equipment and systems; see also 4-1-1/3 of the *Marine Vessel Rules*.

11 Alternatives

Equipment, components, and systems for which there are specific requirements in this Guide, or its associated references, may incorporate alternative arrangements or comply with the requirements of alternative recognized standards, in lieu of the requirements in this Guide. These alternative arrangements or standards are to be determined by ABS as being not less effective than the overall safety and strength requirements of this Guide or associated references. Where applicable, requirements may be imposed by ABS in addition to those contained in the alternative arrangements or standards so that the intent of this Guide is met. In all cases, the equipment, component or system is subject to design review, survey during construction, tests and trials, as applicable, by ABS for purposes of verification of its compliance with the alternative arrangements or standards. The verification process is to be to the extent as intended by this Guide.

SECTION 2

Vessel Arrangements and System Design

1 Application

The requirements specified in this Section provide general guidance on ship arrangements and regasification plant design.

3 Plans and Data to be Submitted

The following regasification plant plans, calculations and information, as applicable, are to be submitted in addition to those required by 4-1-1/5.3 and 5C-8-1/5 of the *Marine Vessel Rules*, as applicable:

- General arrangement of the regasification plant
- Hazardous area arrangement
- Booklet of installations in classified hazardous areas
- Risk assessment
- Operational manual
- Scantlings and details of foundation drawing in way of regasification and power generation modules
- Strength analysis document in way of regasification and power generation modules.
- Cargo containment and Pump Tower strength analysis (sloshing)
- Escape routes
- Project specification and overall process concept description
- Machinery arrangement of regasification plant and power generation system
- Ventilation system for compartment of cargo machinery space and turret, if applicable
- Cryogenic spill containment
- Failure Modes and Effects Analysis (FMEA) (As required by Subsection 2/19)
- Emergency shutdown (ESD) system
- ESD Cause and effect diagram
- Fire and gas detection and alarm systems
- Fire extinguishing systems
- Piping and Instrumentation Diagram (P&ID)
- Piping material specification
- Process Flow Diagram (PFD)

- Piping arrangement
- Pipe stress analysis (high pressure and cryogenic)
- Details of all cargo and vapor handling equipment including high pressure system
- Details and installation of the safety valves/blow down valves and capacity calculations
- Inert-gas system
- Pressure relief and blowdown calculations
- Mooring details and specification
- Regasification plant testing procedures

5 Risk Assessment

A risk assessment is to be submitted for ABS review per requirements in IGC Code 1.1.10.

5.1 Assessment Criteria

A risk assessment is to be carried out to identify significant hazards and accident scenarios that may affect the installation or any part thereof, and consider the benefit of existing or potential risk control options.

The objective of the risk assessment is to identify areas of the design that may require the implementation of risk control measures to reduce identified risk(s) to an acceptable level.

The risk assessment is to be conducted by using recognized techniques as described by 5C-8-1/1.11 of the *Marine Vessel Rules*. The identified risk control options (prevention and mitigation measures) deemed necessary to be implemented is to be considered part of the design basis of the vessel.

The overall criteria is that systems and equipment be designed to minimize the risk of hazards to personnel, property and environment. Implementation of this criteria to regasification plants and the associated systems is intended to:

i) Prevent an abnormal condition from causing an upset condition

ii) Prevent an upset condition from causing a release of hydrocarbons or cryogenic fluids

iii) Safely collect and dispose of hydrocarbon or cryogenic fluids released

iv) Prevent formation of explosive mixtures

v) Prevent ignition of flammable liquids or gases and vapors released

vi) Limit exposure of personnel to fire and cryogenic hazards

Hazards to be addressed by the risk assessment in addition to 5C-8-1/1.10 of the *Marine Vessel Rules* are to include:

- Pressurized gas discharge to shore
- High pressure gas venting
- Storage and handling of flammable refrigerants (as applicable)
- Ship-to-ship transfer of liquid cargo
- Fire propagation from turret compartments
- Turret compartments structural integrity in case of explosion or uncontrolled high-pressure gas release (overpressure and/or brittle fracture)
- Loss of ability to offload liquefied gas or discharge gas ashore
- Loss of any one critical component in the process system

- Loss of electrical power
- Escape routes

ABS recommends that early in the project a risk assessment plan be developed, documented and submitted to ABS for review prior to conducting the risk assessment. During review of the plan, an agreement will be reached on the extent of ABS participation and/or monitoring of project-related risk studies. ABS's participation in and/or monitoring of key tasks (e.g., Hazard Identification meetings) is necessary in order to establish a minimum level of confidence on the risk assessment results.

Previously conducted risk assessments may have resulted in documentation of a risk model that is pertinent to the design and operation being proposed. If an applicable risk model is available, its use may be considered where proposed in the project risk assessment plan. If an applicable risk model is available, it can also be used in this basic risk assessment step. The rationale is to first apply a simple method and/or existing models to determine if equivalency can be demonstrated with a minor level of effort, without initiating more in-depth and complex studies. The ABS *Guidance Notes on Risk Assessment Application for the Marine and Offshore Industries* contain an overview of the risk assessment process, risk assessment techniques and additional information.

7 Mooring

Plans are to include the site location showing the berthing arrangements, mooring location and mooring configuration. Unless the vessel is to be moored hard up to the berth, the geographic location of the vessel is required to be specified. The mooring system and fender loads are to be assessed and considered while specifying limitations on cargo transfer operation. If a turret or spread mooring arrangement is utilized, the requirements in Section 3-1-4 of the ABS *Rules for Building and Classing Floating Production Installations* are to govern the FSRU mooring system. For jetty mooring, details of the site-specific design of the FSRU mooring system and components are to be submitted for information.

9 Turret Compartment Arrangements

9.1 Structural Fire Protection

Structural fire protection for turret compartments is to be provided in accordance with 5C-8-3/1.4 and 5C-8-3/3.1 of the *Marine Vessel Rules*.

9.3 Fire Propagation

The risk of fire propagation from turret compartments to adjacent spaces is to be evaluated by a risk analysis. Further preventive measures, such as the arrangement of a cofferdam around the turret compartment, are to be provided if needed.

9.5 Explosion or Uncontrolled High-pressure Gas Release

Turret compartments are to be designed to retain their structural integrity in case of explosion or uncontrolled high-pressure gas release (overpressure and/or brittle fracture), the characteristics of which are to be substantiated on the basis of a risk analysis with due consideration of the capabilities of the pressure relieving devices. Blast relief panels may be provided.

11 Sloshing

The vessel's operating profile in a regasification mode will involve a full range of loaded conditions from full to empty. The suitability of the vessels hull structure, containment system, and other in tank components such as pump tower are to be reviewed for the sloshing loads based on the site-specific condition where the vessel will operate as an FSRU. Any special considerations to environmental limitations, operating restrictions, and mitigating measures as associated with sloshing is to be included in the operations manual.

13 Regasification System and Equipment

13.1 General

13.1.1 General

The regasification plant piping system and associated components are to comply with Section 5C-8-5 of the *Marine Vessel Rules*. The following standards may be suitable for the assessment of regasification equipment:

- ASME B31.3 – Process Piping
- API RP 14E – Design and Installation of Offshore Production Platform Piping Systems

13.1.2 Valves

All valves necessary for cargo handling are to be readily accessible to personnel wearing protective clothing.

13.1.3 Pipe Stress Analysis

A pipe stress analysis is to be carried out for high pressure and cryogenic piping associated with the regasification plant, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship for each branch of the piping system.

13.1.4 Spill Containment

Spill containment is to be provided where liquid piping is dismantled regularly, or where liquid leakage may be anticipated to prevent the temperature of the structure from falling below the design temperature of the structure material.

13.3 Pressure Vessels

Pressure vessels are to comply with 5C-8-5/1 of the *Marine Vessel Rules*.

The following standards may be suitable for assessment of regasification equipment:

- ASME Boiler and Pressure Vessel Code Section VIII Div. 1; or Section VIII Div. 2
- Standards of Tubular Exchanger Manufacturers Association
- API Std. 660 – Shell-and-tube Heat Exchangers

Other national standards or codes will be considered, provided that they are no less effective.

13.5 Pumps

Each size and type of pump is to be approved through design assessment and prototype testing in accordance with 5C-8-5/13.1.3 of the *Marine Vessel Rules*.

The following standards may be suitable for assessment of regasification equipment:

- ISO 13709 – Centrifugal pumps for petroleum, petrochemical and natural gas industries
- ISO 24490 – Cryogenic vessels – Pumps for cryogenic service
- API Std 610 – Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries

13.7 Compressors

Compressors are to be suitable for their intended purpose. All equipment and machinery is to be adequately designed for use within a marine environment. Each size and type of compressor is to be design assessed and prototype tested in accordance with 5C-8-5/13.1.4 of the *Marine Vessel Rules*.

The following standards may be suitable for assessment of regasification equipment:

- API Std 617 – Axial and Centrifugal Compressors and Expander-compressors for Petroleum, Chemical and Gas Industry Services
- API Std 618 – Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services
- API Std 619 – Rotary-Type Positive-Displacement Compressors for Petroleum, Petrochemical, and Natural Gas Industries

13.9 Pressure Relief and Venting System

Pressure safety relief valves and venting arrangements and locations are to comply with Section 5C-8-8 of the *Marine Vessel Rules*. Pressure losses upstream and downstream of the PRVs are to be taken into account when determining their size as required by 5C-8-8/4.1 and 5C-8-8/4.2 of the *Marine Vessel Rules*.

The outlet from pressure relief valves in LNG piping or in vapor piping which could see LNG in any failure mode is to be specially considered during the risk assessment so that the passing of LNG will not create a downstream hazard which has not been fully considered in the design and safety features.

The following standards may be suitable for assessment of regasification equipment:

- ASME Section VIII, Division 1 Appendix M.
- API Std 520 – Sizing, Selection, and Installation of Pressure-relieving Devices
- API Std 521 – Pressure-relieving and Depressuring Systems

13.11 Depressurization/Blowdown system

The regasification plant is to be provided with a blow down system (vapor depressuring) to limit the consequences of equipment and piping failure during emergency conditions. Vapor depressuring should follow the design principles in API 521.

i) Manual activation of the blowdown system is to be provided.

ii) Automatic activation of the blowdown system is to be provided if required to safely perform an emergency function as associated with ESD functions as identified the risk assessment, (e.g. emergency buoy release (where fitted), loss of ESD valve actuating medium, fire detection, and emergency push buttons).

iii) The blow down valves are to be fail safe.

iv) Activation of blow down system is to be provided with visual and audible alarm in cargo control room and in cargo area to alert crew.

13.13 Turret Compartment Transfer Systems

For the transfer of vapor cargo through an internal turret arrangement located outside the cargo area, the piping serving this purpose is to comply with 5C-8-5/2.2 of the *Marine Vessel Rules*, as applicable, and the following:

i) Piping is to be located above the weather deck, except for the connection to the turret; Portable arrangements are not permitted.

ii) Arrangements are to be made to allow such piping to be purged and gas-freed after use. The vent pipes connected with the purge are to be located in the cargo area.

iii) Cargo piping and related piping equipment outside the cargo area is to have only welded connections.

iv) The piping is to be full penetration butt-welded, and subjected to full radiographic or ultrasonic inspection, regardless of pipe diameter and design temperature. Flange connections in the piping

are to only be permitted within the cargo area and at connections to cargo hoses and the turret connection.

15 Electrical Systems and Installations

Electrical installations are to be in accordance with the applicable requirements of Part 4, Chapter 8 and Section 5C-8-10 of the *Marine Vessel Rules*.

15.1 Hazardous Areas

Hazardous area are defined by 5C-8-1/2.24 of the *Marine Vessel Rules*. Hazardous area zoning is to be defined in accordance with 5C-8-10/1.1 of the *Marine Vessel Rules* and IEC 60092 -502: 1999.

Consideration is to be given to the risk assessment conducted and possible additional identified electrical hazards and extending extent of hazardous areas

15.1.1 Permanent Notice and Booklet of Certified Safe Equipment

A booklet containing the list of certified safe equipment, as installed, along with the particulars of the equipment (refer to 4-8-1/5.3.2 of the *Marine Vessel Rules*), is to be maintained onboard. Permanent notices are to be posted in the vicinity of hazardous areas in which such electrical equipment is installed to advise the crew of the availability of the booklet so that it can be referenced during repair or maintenance.

17 Fire Safety

Fire Safety is to be provided in accordance with applicable statutory conventions and Section 5C-8-11 of the *Marine Vessel Rules*.

17.1 Water Spray System

Regasification Plant positioned on deck are to be protected by a water spray system in accordance with 5C-8-11/3 of the *Marine Vessel Rules*.

This is to include but not limited to:

- Gas process units
- Suction drum
- Recondenser
- Transfer manifold
- Emergency Shutdown Valves
- Turret compartment internal surfaces

Where a turret is fitted, turret compartments are to be protected by internal water spray, with an application rate of not less than 10 $l/m^2/min$ (0.24 gpm/ft^2) of the largest projected horizontal surface. If the pressure of the gas flow through the turret exceeds 4 MPa, the application rate is to be increased to 20 $l/m^2/min$ (0.48 gpm/ft^2). The system is to be designed to protect all internal surfaces.

17.3 Dry Chemical Powder Fire-extinguishing Systems

Dry chemical powder fire-extinguishing systems are to be provided as required by 5C-8-11/4 of the *Marine Vessel Rules*.

The system is to be capable of delivering powder from at least two hand hose lines or a combination of monitor/hand hose lines, to any part of the exposed cargo liquid and vapor piping, load/unload connection and exposed gas process units.

17.5 Ventilation

Cargo machinery spaces and turret spaces are to be fitted with fixed artificial ventilation systems capable of being controlled from outside such spaces as per Section 5C-8-12 of the *Marine Vessel Rules*. The ventilation is to be run continuously to prevent the accumulation of flammable vapors, with a means of monitoring.

Lighting in cargo machinery spaces and turret compartments, except emergency lighting, is to be interlocked with ventilation such that the ventilation is to be in operation when switching on the lighting. Failure of the ventilation system is not to cause the lighting to go out.

17.7 Fire Detection System

Fire and Gas Detection and Alarm Systems are to be provided for weather decks of the cargo area and/or cargo machinery spaces and/or turret compartments in accordance with 5C-8-18/10.3.2 and 5C-8-18/Table 1 of the *Marine Vessel Rules*.

The fire detectors should be suitable for high pressure jet fires in the areas of the gas process unit, high pressure piping, transfer manifolds, and turret compartments.

17.9 Gas Detection System

Gas detection systems are to be provided in accordance with 5C-8-13/6 of the *Marine Vessel Rules*. Continuous measurement is to be provided for the following areas:

- Regasification units
- Turret Compartment
- High Pressure Gas Export manifold
- Heating system routed through a non-hazardous area
- Other spaces identified by Risk Assessment (as applicable)

19 Instrumentation and Control Systems

i) Instrumentation and Automation Systems are to be provided in accordance with Section 5C-8-13 of the *Marine Vessel Rules*.

ii) The regasification plant control and monitoring system may be connected to an integrated control system or be a stand-alone system.

iii) A Failure Modes Effects Analysis (FMEA) is to be carried out for the regasification plant control system identifying component criticality in accordance with 5C-8-13/9 and Section 4-9-4 of the *Marine Vessel Rules*.

iv) The regasification plant control and monitoring system design is to meet the single failure criteria (i.e., no single control system component failure or single fault condition is to result in an unsafe situation).

For further guidance on implementing FMEA requirements for classification purposes, refer to the ABS *Guidance Notes on Failure Mode and Effects Analysis (FMEA) for Classification*.

The following standards may be suitable for assessment of regasification equipment:

- ISO 10418 – Petroleum and Natural Gas Industries – Offshore Production Installations -- Analysis, Design, Installation and Testing of Basic Surface Process Safety Systems
- API RP 14C – Analysis, Design, Installation and Testing of Basic Surface Safety Systems for Offshore Production Platforms

21 Emergency Shutdown (ESD) System Control

An emergency shutdown system is to be provided in accordance with 5C-8-18/10 and 5C-8-18/Table 1 of the *Marine Vessel Rules*. Other ESD system controls identified by Risk Assessment, as applicable, are to be provided.

A cause and effect diagram is to reflect:

i) Cause inputs that initiate the automatic shutdown effect output

ii) Parameters (set points) that trigger the cause

iii) Action item of the effects (e.g. valve closure, machinery shutdown)

The following standards may be suitable for assessment of regasification equipment:

- API RP 14C - Analysis, Design, Installation and Testing of Basic Surface Safety Systems for Offshore Production Platforms

23 Cargo Operations Manuals

The cargo operation manual as required by Section 5C-8-18 of the *Marine Vessel Rules* is to be provided and include the regasification plant. The vessel is to be provided with copies of suitably detailed cargo system operation manuals.

Detailed instruction manuals are to be provided onboard, covering the operations, safety and maintenance requirements, personal protective equipment and occupational health hazards relevant to the use of the regasification plant. The operational parameters of all systems and components for removing liquefied gas from the storage tanks, pressurizing, heating and vaporizing liquefied gas and in some cases odorizing the liquefied gas vapor and discharge ashore of vaporized gas through an off-loading system are to be addressed in the manual. The content of the manuals is to include, but not be limited to:

- Information regarding the cargo system and associated systems as detailed by 5C-8-18/2.2 of the *Marine Vessel Rules* as applicable to the regasification plants
- System limitations, including minimum temperatures, maximum pressures, transfer rates; details of depressurization and high pressure blow-down philosophy and arrangements; gas piping systems including details of pipes and associated components, design pressures and temperatures
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of all electrical equipment in the regasification plant compartment
- Emergency shutdown arrangements, cause and effects
- Mooring Arrangement and Philosophy
- Environmental limitation and operating restrictions as associated with sloshing

SECTION 3

Modified Tank Entry Program *(1 December 2021)*

1 General

Where a regasification vessel is proposed to undertake long term employment at a single site, a tank entry program with examination dates in excess of 5 years may be considered to satisfy the periodical cargo tank entry surveys required in the ABS *Rules for Survey After Construction (Part 7)* referenced in Subsection 5/3 of this Guide. The Modified Tank Entry Program is to include the structural and cargo containment aspects of the tank along with all electrical, mechanical, piping and machinery and components. The program may be composed of a Risk Based Inspection Plan for fixed equipment and structures in accordance with the ABS *Guide for Risk-Based Inspection for Floating Offshore Installations* or a Modified Tank Entry Program in accordance with Subsection 3/3, and Surveys Based on Preventative Maintenance Techniques for machinery per Appendix 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)* to allow for a maximum time between tank entries of 10 years.

To be considered for the modified tank entry program, vessels should be less than 10 years old at the start of the program, and they are to be enrolled in the continuous survey regime for hull and machinery in accordance with 7-2-1/7 of the ABS *Rules for Survey After Construction (Part 7)*. For vessels greater than 10 years of age that request to enter into such a scheme, a Special Survey of Hull and Machinery is to be completed, and they are to be enrolled in the continuous survey regime for hull and machinery in accordance with 7-2-1/7 of the ABS *Rules for Survey After Construction (Part 7)*. Acceptance of the proposed Modified Tank Entry Programs will be contingent on agreement of the vessel's flag Administration.

Vessels whose Modified Tank Entry Program is accepted will receive a comment in the vessel's records indicating that the vessel has programs that allow for modified tank surveys in addition to any notations applicable to the individual ABS programs (PM, CM, SMART, RBI, etc.) used in development of the overall modified tank entry program inspection plan.

3 Development of Modified Tank Entry Program

Development includes various steps for developing an asset-specific inspection and monitoring plan. During the development activities, Class interface points include participation in risk assessment workshops as well as reviews of interim submittal documents (equipment lists, manufacturer/vendor feedback on equipment suitability, equipment data sheets, piping and instrumentation diagrams, piping data sheets, past inspection reports, past repairs and replacement history, other relevant information).

To understand and apply risk assessment, it is important that ABS, the marine and offshore industries, and the public at large have a common understanding of the terms and concepts involved, and an awareness of how these concepts are to be applied. Refer to the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* (see also Appendix 1 "Sample Risk Assessment Worksheet" of this Guide).

At the completion of the plan development, the Owner will submit the proposed plan to ABS for review and approval. The program is to consider the examination schedules for the tank structure, the containment system, and all items in the tank within the scope of Class.

3.1 Items to be Submitted

3.1.1 Machinery and Equipment

The machinery inside the tanks is required to have an approved preventative maintenance technique that will allow the machinery to operate without examination until the tank is opened up. Available options for surveys of machinery may be selected from Appendix 7-A1-14 of the ABS *Rules for Survey After Construction (Part 7)* or other approved ABS programs for such components. The program of examination is to be developed with input from designers and manufacturers of relevant equipment for items within the cargo tank subject to Survey and submitted for review.

3.1.2 Piping, Valves and Outfitting

The piping, supports, and other items in the cargo tank that are not eligible for PMP and are not part of the hull structure or cargo containment are to be incorporated into a risk-based inspection plan where appropriate and submitted for review.

Identification of damage mechanisms and failure modes is a critical step in the RBI development. The process conditions and the materials of construction should be combined together to identify the potential damage mechanisms. The main damage mechanisms to consider in the plan development should include but not be limited to corrosion, erosion, pitting fatigue cracking, environmentally induced cracking, impacts of cooling down/warm up thermal cycles, mechanical damage, etc.

The inspection/survey strategies of the plan should be developed in conjunction with mitigation measures so that all equipment have an acceptable level of risk.

If a qualitative approach is used to develop the plan, once the risks (i.e., probabilities and consequences) are assessed, the ranking is to be performed using a risk matrix. A sample risk assessment is provided in Appendix 1. The risk matrix is to allow distinguishing different risk levels which are then used for inspection frequency attribution. In cases where significant variation exists in the safety, environment, and economic consequence categories, separate risk matrices can be used. The inspection interval is chosen based on the minimum inspection interval across the separate risk matrices.

If a quantitative approach is used to develop the RBI plan, the detailed quantitative probability of failure and consequence analyses results provide the primary basis for setting the inspection intervals and scope.

Other factors such as sampling inspections and outstanding issues may be used to adjust the inspection intervals and scope.

Note that some components such as safety/pressure relief valves may require alteration to allow surveys to be carried out without needing to open up the tank or take it out of service.

3.1.3 Hull and Cargo Containment:

This is a program that utilizes condition monitoring techniques as an aid to assess item health. The program for tank entry is to be developed with input from relevant parties including containment system designers and manufacturers and is to consider the program of examination for machinery and piping within the cargo tank subject to survey and submitted for review. The program is to include any condition or environmental anomalies that could necessitate earlier entry into tanks

for inspection or maintenance. The following items are to be considered when developing the program:

- Metocean data
- History of damage in cargo tanks
- History of damage to hull structure including (grounding, buckling, vibration, etc.)
- Motion sensor data
- Sloshing analyses
- Heading control
- Data that can be gathered about the tank without entering it
- Time spent with tanks in partial loading conditions while on location
- Loading/unloading sequence

3.3 Continuous Improvement

During the annual class surveys, the program is to include an assessment of collected data in support of the plan with analysis. A program review including physical tank entries is to be conducted which coincides with the Special Survey to verify the continued effectiveness of the program

5 Contents of Modified Tank Entry Program

The following information is to be compiled into a comprehensive document and submitted to ABS for initial review and approval and used during the scheduled surveys. The document is to be treated as a live document, updated as additional information and survey history is developed. The attending Surveyor can accept minor changes and updates subsequent to the initial approval by ABS Engineering, so long as they are satisfied the changes do not affect the condition of the vessel.

- *Operational Description*. Information regarding intended operation at the site including general arrangement of the vessel in operation, mooring principles and operating procedures
- *Site Information*. As applicable to the plan includes metocean wind, wave and current data, extreme events at relevant return periods
- General Arrangement of the cargo area
- Listing of inspectable machinery, components and piping within the tank
- Overview of cargo containment system
- Control and Monitoring description and details including reporting
- Isolation procedures for tank relief valve inspections
- Inspection and Maintenance Philosophies for components including risk-based inspection and preventive maintenance approaches
- Overview of Preventative Maintenance Techniques used for the machinery
- Overview of examination program for piping and outfitting items
- Inspection and Maintenance schedules and plans
- Survey history of tank and all internal inspectable items subject to Survey as applicable
- Tank usage and filling records
- Interbarrier space exam and test records
- Areas of typical damage for the cargo containment system

- History of damage and repairs
- Overview of data analytics software utilized as applicable, i.e. sloshing analysis triggering internal examinations
- Inspection plans for all components identified as being associated with modified tank entry requirements
- Register of program anomalies and action taken
- Sample “Cargo Containment System Annual Health Check Report”

SECTION 4
Surveys

1 Surveys During Installation and Trials

This Section pertains to surveys during installation and trials of a regasification system. The requirements here are in addition to those established in Part 5C, Chapter 8 and Part 5C, Chapter 12 of the *Marine Vessel Rules*.

1.1 Surveys During Installation *(1 December 2021)*

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the regasification plant during installation and testing are to include but not limited to:

i) Piping systems, pressure vessels, and equipment are to be examined and tested, as required by the *Marine Vessel Rules*.

ii) Electrical wiring and connections are to be in accordance with Part 4 of the *Marine Vessel Rules* and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves installed on the unit are to be tested.

v) Control system and shutdowns are to be tested for proper operation.

vi) For units operating at a fixed location, where a plan for modified tank entry is requested in accordance with Section 3 of this Guide and components of the regasification system are impacted by the agreed inspection plan, installation Surveys for those components are to be carried out in accordance with Subsection 3/5 covering the plan.

1.3 Surveys During Trials

During the initial trials, the regasification plant is to be confirmed for its satisfactory operation, including associated controls, alarms and shutdowns. The tests are to be conducted to the satisfaction of the attending ABS Surveyor during trials.

2 Implementation Surveys for Modified Tank Entry Program *(1 December 2021)*

2.1 New Construction Vessels

Implementation surveys will be required for items included in the modified tank entry program. The implementation survey is to confirm that the vessel has the items installed and operating so that the maintenance and monitoring specified by the Modified Tank Entry Program can be recorded. The Maintenance Programs covering the cargo tank machinery will be subject to implementation Surveys in accordance with 7-A1-14/15.1 of the ABS *Rules for Survey After Construction (Part 7)*.

2.3 Existing Vessels

2.3.1 Implementation Surveys

Implementation surveys are to be carried out.

i) All cargo tanks are to be entered to confirm the condition of the cargo containment systems, fatigue prone areas and details, and associated equipment and machinery. Results of examinations will be used to verify initial conditions are in accordance with the assumptions and data in the approved Modified Tank Entry Program. In accordance with Subsection 3/1 above, for vessels greater than 10 years of age, a Special Survey of Hull and Machinery is to be completed.

ii) Verify installation of any additional equipment required as part of the Modified Tank Entry Program. The Maintenance Programs program covering the cargo tank machinery will be subject to implementation Survey in accordance with 7-A1-14/15.1 of the ABS *Rules for Survey After Construction (Part 7)*.

iii) At completion of the implementation survey the vessel is to be enrolled in the continuous survey regime for hull and machinery, as applicable, in accordance with 7-2-1/7 of the ABS *Rules for Survey After Construction (Part 7)*.

iv) When the unit's deployment to the site area of operation is delayed longer than one (1) year, the implementation survey may be required to be repeated prior to entering into service. Each situation is unique and will be evaluated on a case-by-case basis by the Chief Surveyor's Office.

3 Surveys After Construction and Maintenance of Class *(2022)*

See Section 7-9-40 of the ABS *Rules for Survey After Construction (Part 7)*.

APPENDIX **1**

Sample Risk Assessment Worksheet *(1 December 2021)*

The following is a sample Risk Assessment Worksheet that may be used. Additional guidance can be provided when requested. The below is not mandatory, and alternatives may be accepted if the same or greater level of equivalency is achieved.

Example Membrane LNGC tanks Modified Tank Entry - Risk Assessment Worksheet (Cargo Containment System Only)									
Reference: ABS Rules Part 7 Chapter 3 Section 2 / 5.11, 7-6-2/1.5									
					Risk Ranking			Recommendations Remarks	
Inspection Item	ABS Rule requirement description	Maker's reply & Associated files	Hazards Associated with Alternative Inspection Scheme	Safeguards	Severity	Likelihood	Risk		
Liquid Level Indicators	Cargo Tank Venting System and Liquid-level Indicators (2001). Relief valves, liquid level indicators, and venting systems for the primary cargo containment system are to be examined. All relief valves are to be opened, inspected, tested, and readjusted as necessary. If the cargo tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, such non-metallic membranes are to be replaced. Liquid-level indicators and alarms are to be proven satisfactory. Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves including each size of each type of liquefied gas or vapor relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since the crediting of the previous Special Periodical Survey. The testing and setting of relief valves may be carried out in place or after removal.								
Cargo Tanks (Primary Containers).	An internal examination is to be made of all cargo tanks, after being gas free, including internal mountings and equipment								
Secondary Barriers	The secondary barrier is to be checked for its effectiveness by means of a pressure/vacuum test, a visual inspection or other acceptable method. For membrane containment systems, a tightness test of the primary and secondary barrier shall be carried out in accordance with the system designers' procedures and acceptance criteria as approved by ABS. Low differential pressure tests may be used for monitoring the cargo containment system performance, but are not considered an acceptable test for the tightness of the secondary barrier. For membrane containment systems with glued secondary barriers if the designer's threshold values are exceeded, an investigation is to be carried out and additional testing such as thermographic or acoustic emissions testing should be carried out.								
Cargo Pump Towers	All cargo pump tower structures are to be examined including stiffeners, bracings, fasteners and locking devices, spray nozzles, wiring with associated conduits and pipe connections. Where deemed necessary by the Surveyor, dimensional measurements and/or nondestructive testing may be required. See also 7-3-2/5.11.1(j).								

Example Membrane LNGC tanks Modified Tank Entry - Risk Assessment Worksheet (Cargo Containment System Only)									
Reference: ABS Rules Part 7 Chapter 3 Section 2 / 5.11, 7-6-2/1.5									
					Risk Ranking			Recommendations Remarks	
Inspection Item	ABS Rule requirement description	Maker's reply & Associated files	Hazards Associated with Alternative Inspection Scheme	Safeguards	Severity	Likelihood	Risk		
Nondestructive Testing	Nondestructive testing is to supplement cargo tank inspection with special attention to be given to the integrity of the main structural members, tank shell and highly stressed areas, including welded connections as deemed necessary by the Surveyor. However, for type C tanks, this does not mean that non-destructive testing can be dispensed with totally. The following items are, inter alia, considered as highly stressed areas: • Cargo tank supports and anti-rolling/anti pitching devices. • Web frames or stiffening rings. • Y-connections between tank shell and a longitudinal bulkhead of bilobe tanks. • Swash bulkhead boundaries. • Dome and sump connections to the tank shell. • Foundations for pumps, towers, ladders etc. • Pipe connections.								
Drainage Arrangements	Systems for removing water or cargo from interbarrier spaces and holds are to be examined and tested as deemed necessary								
Membrane and Semi-membrane Tank	For membrane and semi-membrane tanks systems, inspection and testing are to be carried out in accordance with programs specially prepared in accordance with an approved method for the actual tank system.								
Gas-tight Bulkhead	All gas-tight bulkheads are to be examined. The effectiveness of gas-tight shaft sealing is to be verified.								
Interbarrier Space Venting System	Venting systems, relief valves or other arrangements provided for emergency removal of gas from the interbarrier spaces and hold spaces are to be opened, inspected, tested and readjusted as necessary.								
Cargo Tank Venting System and Liquid-level Indicators	Relief valves, liquid-level indicators and venting systems for the primary cargo containment system are to be examined. All relief valves are to be opened, inspected, tested and readjusted as necessary. If the cargo tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, such non-metallic membranes are to be replaced. Liquid-level indicators and alarms are to be proven satisfactory. Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination and testing of a representative sampling of valves including each size of each type of liquefied gas or vapor relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested since the crediting of the previous Special Periodical Survey. The testing and setting of relief valves may be carried out in place or after removal								

Example Membrane LNGC tanks Modified Tank Entry - Risk Assessment Worksheet (Cargo Containment System Only)									
Reference: ABS Rules Part 7 Chapter 3 Section 2 / 5.11, 7-6-2/1.5									
					Risk Ranking			Recommendations Remarks	
Inspection Item	ABS Rule requirement description	Maker's reply & Associated files	Hazards Associated with Alternative Inspection Scheme	Safeguards	Severity	Likelihood	Risk		
Cargo Handling and Piping Systems	All piping, machinery and equipment for loading, unloading, venting, compressing, refrigerating, liquefying, heating or otherwise handling the liquefied gas or vapor and liquid nitrogen, and gas burning installations is to be examined including removal of insulation and opening for examination, as deemed necessary. Where deemed suspect, a hydrostatic test to 1.25 times the Maximum Allowable Relief Valve Setting (MARVS) for the pipeline is to be carried out. After reassembly, the complete piping is to be tested for leaks. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, the Surveyor may accept alternative testing fluids or alternative means of testing. All emergency shut-down valves and remote operating valves in the cargo piping systems are to be inspected and proven operable. The pressure relief valves are to be function-tested. A random selection of valves is to be opened for examination and adjusted								
Electrical Bonding	Electrical bonding arrangements, including bonding straps where fitted, of the piping systems located within cargo tanks, ballast tanks, pipe tunnels, cofferdams and void spaces bounding cargo tanks are to be examined								
Miscellaneous	The hoses and spool pieces used for segregation of piping systems for cargo, inert gas and bilge are to be examined.								
BOG Utilization Valves	All emergency shut-down valves, check valves, block and bleed valves, master gas valves, remote operating valves in the BOG utilization piping systems are to be inspected and proven operable. The pressure relief valves are to be function-tested. A random selection of valves is to be opened for examination and adjusted as necessary								
Electrical Equipment	Examination and testing of electrical equipment. This examination is to include the physical condition of electrical cables and supports, intrinsically safe, explosion proof, or increased safety features of electrical equipment, functional testing of pressurized equipment and associated alarms, testing systems for de-energizing electrical equipment which is not certified for use in gas-hazardous areas, and insulation resistance readings of circuits. Where a proper record of testing is maintained, consideration may be given to accepting recent readings.								