Requirements for

Hydrogen Fueled Vessels

May 2023

REQUIREMENTS FOR

HYDROGEN FUELED VESSELS

MAY 2023

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

ABS Plaza
1701 City Plaza Drive
Spring, TX 77389 USA

Foreword

With the increased commitment from the International Maritime Organization (IMO) to reduce Greenhouse Gas (GHG) emissions from shipping, the use of Liquefied Natural Gas (LNG), methanol, ethane, Liquefied Petroleum Gas (LPG), hydrogen, ammonia and other gases and low-flashpoint fuels, including e-fuels produced from non-fossil fuel sources, are expected to become more widely adopted by the marine industry to replace conventional residual or distillate marine fuels. In response to the IMO GHG reduction targets, the marine industry has increased its interest in the use of hydrogen as a marine fuel due to its zero-emission fuel properties and the ability to produce hydrogen from renewable and sustainable sources. This document addresses the use of hydrogen as a marine fuel.

The ABS criteria to be applied to gas or other low flashpoint fueled ships is detailed in Part 5C, Chapter 13 of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules*), which incorporates the IMO *International Code of Safety for Ships using Gases or Other Low Flashpoint Fuels* (IGF Code).

Low flashpoint fuels or gases not included in the IGF Code must demonstrate an equivalent level of safety by application of the Alternative Design methodology as specified in SOLAS Chapter II-1 Regulation 55 and guidelines referenced by footnote MSC.1/Circ.1212, or associated guidelines found in MSC.1/Circ.1455.

However, where other prescriptive IMO requirements exist for particular gases or other low flashpoint fuels, either by regulation, or as interim guidelines, these may be applied in lieu of the Alternative Design criteria, subject to agreement by the flag Administration. Requirements for hydrogen as fuel are in development by the IMO MSC Sub-committee on Carriage of Cargoes and Containers (CCC) as CCC 8-WP.3 Draft Interim Guidelines for the Safety of Ships using Hydrogen as Fuel. Although in draft format, this document provides interim guidelines for the safety of ships using hydrogen as a fuel to be adopted by the IMO Maritime Safety Committee, intended to function as an amendment to the IGF Code. It is recognized that when the Draft Interim Guidelines are finalized, the requirements and this document will be updated.

Accordingly, these requirements have been developed to further support the application of hydrogen as fuel to ABS Classed vessels.

Where the requirements are proposed to be used for compliance with the IGF code, such application is subject to approval by the vessel's flag Administration prior to the issuance of relevant statutory certificates on behalf of the same flag Administration by ABS.

The applicable edition of the *Marine Vessel Rules* is to be used in conjunction with this document.

These requirements become 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 document is the most current.

For supplemental information on hydrogen as a marine fuel, refer to the ABS Sustainability Whitepaper *Hydrogen as Marine Fuel*, and the *ABS Requirements for Fuel Cell Power Systems for Marine and Offshore Applications.*

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

REQUIREMENTS FOR

HYDROGEN FUELED VESSELS

CONTENTS

SECTION 1
Introduction

1 General

This document has been developed to provide guidance for the design, construction, and survey of vessels using hydrogen as fuel. This document focuses on systems and arrangements provided for the use of hydrogen for propulsion and auxiliary systems. Refer to the MSC CCC 8-W.3 *Draft Interim Guidelines for the Safety of Ships using Hydrogen as Fuel*, which are yet to be finalized.

Refer to MSC.1/Circ. 1647 for IMO's *Interim Guidelines for the Safety of Ships Using Fuel Cell Power Installations*.

See also the ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications* for ABS' requirements for fuel cell installations.

2 Objective

This document provides Classification requirements, standards and criteria for the arrangements, construction, installation and survey of machinery, equipment and systems for vessels operating with hydrogen as fuel to minimize risks to the vessel, crew and the environment.

3 Classification Notations

3.1 Alternative Low Flashpoint Fueled Ship – Hydrogen

The **LFFS** notation is mandatory and will be assigned to vessels arranged to use or burn hydrogen for propulsion and/or auxiliary purposes and is designed, constructed and tested in accordance with the requirements of this document. The **LFFS** notation will be assigned in association with the specific fuel and the following additional equipment notations (e.g. **(LFFS (DFD – Hydrogen)**, **LFFS (FC-E – Hydrogen)**).

Commentary:

See also 5C-13-1/1.2 of the *Marine Vessel Rules* for more information on ABS notations for IGF Code vessels.

End of Commentary

Vessels seeking the **LFFS** notation for hydrogen as fuel are also to meet the criteria and be assigned the **ACC**, **ACCU** or **ABCU** notations for remote monitoring (see also 5/4.5).

3.2 Dual Fuel Diesel Engine Power Plant

Where a dual fuel diesel engine power plant is installed, the design, construction, and testing are to be in accordance with this document and the applicable parts of 5C-13-10 of the *Marine Vessel Rules*. Where a

dual fuel diesel engine power plant is fitted, the **DFD** notation is required. When the dual fuel diesel power plant is also designed, constructed and tested in association with this document and 5C-13-1/1.2 of the *Marine Vessel Rules* for use with hydrogen, the **DFD** notation will be assigned with a note (e.g., **DFD – Hydrogen**).

3.3 Single Fuel Engine Power Plant

Where a single fuel engine power plant is installed, the unit is to be designed, constructed and tested in accordance with this document and 5C-12-10 of the *Marine Vessel Rules*. In this case, the **SGF** notation is required.

3.4 Fuel Cell Power Plant

Where a fuel cell power plant is installed, the unit is to be designed, constructed and tested in accordance with the ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications.*

3.5 Fuel Ready Notation

Where a ready notation is requested for hydrogen fuel, the notation **Hydrogen Fuel Ready Level 1C, 2D or 3** may be applied according to the ABS *Guide for Gas and Other Low-Flashpoint Fuel Ready Vessels*.

4 Certification

ABS 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* for requirements for the certification of machinery.

Machinery, equipment and systems are to be certified according to the characteristics of hydrogen and any other associated chemicals used, for example nitrogen or helium used for inerting. These gas characteristics include for example, flame properties, gas diffusivity, and phase temperatures and pressures.

Commentary:

Hydrogen fuel systems and auxiliary systems may operate at conditions outside of standard certification parameters, for example the temperature of liquefied hydrogen at -253°C may require additional cryogenic and leak detection provisions for systems, or provisions for handling helium for the purposes of inerting or pre-cooling.

End of Commentary

5 Flag Administration Approval

Where the conditions of these Requirements are proposed to be used to comply with or support the IGF Code Alternative Design process, such application is subject to approval by the vessel's flag Administration prior to issuance of relevant statutory certificates on behalf of the same flag Administration by ABS. Refer to 5C-13-2/3 of the *Marine Vessel Rules* for requirements on the Alternative Design process.

6 Format

This document is based on the technical requirements found in the *International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels* (IGF Code) which is contained in its entirety in 5C-13 of the *Marine Vessel Rules* and is required for classification.

The term "shall be" is to be understood to read as "must be" or "is to be" or "are to be" and unless otherwise specified. The term "Administration" as used in this document is to be read as "Flag Administration.

This document specifies only the unique requirements applicable to vessels using hydrogen fuels and is always to be used in association with the IGF Code, as incorporated in 5C-13 of the *Marine Vessel Rules*, and with other relevant Sections of the Rules.

Where this document includes cross references to Parts A-1, B-1 and C-1 of the IGF Code (5C-13-5 to 5C-13-18 inclusive of the *Marine Vessel Rules*), the terms “natural gas”, “LNG” or “gas”, as related to fuel, are to be understood as referring to hydrogen for application of the requirements of this document.

The text contained in this document that comes directly from the IGF Code is presented in italics.

7 References

ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries*

ABS *Guidance Notes on Strength Assessment of Independent Type C Tanks*

ABS *Guide for Gas and Other Low-Flashpoint Fuel Ready Vessels*

ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications*

ANSI/AIAA G-095A-2017 Guide to Safety of Hydrogen and Hydrogen Systems

ASME B31.12-2019 Hydrogen Piping and Pipelines

ASME Boiler and Pressure Vessel Code

IEC 60079-10-1:2020 Explosive Atmospheres – Part 10-1: Classification of Areas – Explosive Gas Atmospheres

IEC 60079-20-1 Explosive Atmospheres – Part 20-1 Material Characteristics for Gas and Vapour Classification – Test methods and data

IMO CCC 8/WP.3 Annex 2 Draft Interim Guidelines for the Safety of Ships using Hydrogen as Fuel

ISO/TR 15916:2015 Basic Considerations for the safety of hydrogen systems

NASA/TM-2016-218602 Hydrogen Embrittlement

NFPA 2-20 Hydrogen Technologies Code

SECTION 2
General

1 Application

These requirements apply to both new construction and existing vessel conversions, regardless of vessel/unit size, including those of less than 500 gross tonnage, utilizing hydrogen as fuel in internal combustion engines, fuel cells, or other hydrogen combustion equipment (e.g., boilers).

Where this document includes cross references to Parts A-1, B-1 and C-1 of the IGF Code (5C-13-5 to 5C-13-18 inclusive of the *Marine Vessel Rules*) or other recognized standards, requirements for equipment and systems are to be applied as applicable to hydrogen fuel. See Sections 1/1 and 1/4 of this document.

2 Definitions

For the purpose of this document, the terms used possess the meanings defined below. Terms not defined have the same meaning as those found in 5C-13-2/2 of the *Marine Vessel Rules* or 1/5 of the ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications*.

i) "*Engine Room*" is a machinery space containing hydrogen fueled engine(s) or other hydrogen combustion equipment (e.g., boilers).

Commentary:

Requirements for engine room (containing gas combustion equipment) do not include requirements for fuel cell spaces. Definitions and requirements for fuel cell spaces and related systems are to be in accordance with the ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications.*

End of Commentary

ii) "*Fuel preparation room" means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes.*

iii) "*Fuel*" in the context of these requirements means hydrogen, either in its liquefied or gaseous state.

iv) "*Fuel Valve Train*" means Fuel Valve Train and refers to the consumer safety valve unit including the double block and bleed valve block. For gas applications known as Gas Valve Unit (GVU) or Gas Valve Train (GVU) and is typically located in a dedicated space, enclosure or the fuel preparation room.

v) "*Gas dispersion study*" is the analysis of the dispersion behavior of gases using appropriate modeling techniques such as computational fluid dynamics (CFD) analysis. Refer to the ABS *Guidance Notes on Gas Dispersion Studies of Gas Fueled Vessels.*

vi) "*Inerting*" refers to the process of providing a non-combustible environment by adding inert, compatible gases to the environment, which may be carried in pressure vessels or produced on board the ship or supplied from an external source.

3 Alternatives

Equipment, components, and systems for which there are specific requirements in this document, or its associated references, may incorporate alternative arrangements or comply with the requirements of alternative recognized standards in lieu of these requirements. However, this is subject to such alternative arrangements or standards being determined by ABS as being not less effective than the overall safety and strength requirements of this document 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 these requirements 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 to verify compliance with the alternative arrangements or standards. The verification process is to be equivalent to that outlined in this document. See also 4-1-1/1.7 of the *Marine Vessel Rules.*

4 Plans and Data to be Submitted

Plans, data and specifications are to be submitted as follows:

4.1 Ship Arrangements and Systems

Per Section 5, plans and specifications covering the ship arrangements and systems listed below are to be submitted, and are to include, as applicable:

i) Risk assessment plan and associated risk assessment report(s) as referenced by 4/2.2 and 4/2.4, including gas dispersion analysis, where required

ii) General arrangement of vessel

iii) Fuel storage arrangements

iv) Fuel supply system arrangements

v) Fuel bunkering station arrangements

vi) Hazardous area classification plan

vii) Vent mast and venting arrangements

viii) Operations and maintenance manuals (to be submitted for reference purposes only)

ix) Emergency response plan (to be submitted for reference purposes only)

x) Description of the control, monitoring and safety systems, including alarm and shutdown monitoring and cause and effect diagram (see Section 15)

4.2 Fuel Containment System

Per Section 6, plans and specifications covering the fuel containment system listed below are to be submitted, and are to include, as applicable:

i) General arrangement plans of the vessel showing the position of the fuel containment system and details of manholes and other openings in fuel tanks

ii) Plans of the hull structure in way of the fuel tanks, including the installation of attachments, accessories, internal reinforcements, saddles for support and tie-down devices

iii) Plans of the details and installation of the structure of the fuel containment system, including attachments, supports, and accessories

For independent pressure fuel tanks, the standard or code adopted for the construction and design is to be identified. Detailed construction drawings together with design calculations for the pressure boundary, tank support arrangement and analysis for the load distribution. Anti-collision, chocking arrangement and design calculations are to be provided

iv) Details of the distribution of the specific grades and types of steel proposed for the structures of the hull and of the fuel containment system, including supports, attachments, valves, accessories, etc., are to be submitted. Calculation for the temperature distribution and gradients on all affected structures due to conduction of the low temperature of the fuel are also to be included

v) Design loads and structural analyses for the fuel storage tank(s) together with complete stress analysis, as applicable, of the hull and fuel containment system including sloshing analysis

vi) Specifications and plans of the insulation system and calculations of the heat balance

vii) Procedures and calculations of the cooling down and loading operations, including loading limit curve as per 6/7 of this document and 5C-13-6/8.1 of the *Marine Vessel Rules*

viii) Loading and unloading systems, venting systems, and gas-freeing systems, as well as a schematic diagram of the remote-controlled valve system

ix) Plans of the details and installation of the safety valves and relevant calculations of their relieving capacity, including back pressure

x) Plans of the details and installation of the various monitoring and control systems, including the devices for measuring the level of the fuel in the tanks and the temperatures in the containment system

xi) Schematic diagram of the ventilation system indicating the vent pipe sizes and location of the openings

xii) Fuel tank pressure accumulation calculations

xiii) Schematic diagram of the refrigeration system together with the calculations for the refrigerating capacity

xiv) Details of the electrical equipment installed in the fuel containment area and of the electrical bonding of the fuel tanks and piping

xv) Diagram of inert-gas system or hold-space environmental-control system

xvi) Diagram of gas and leak detection systems

xvii) Schematic-wiring diagrams

xviii) Details and arrangements of all fuel and vapor handling equipment

xix) Details and arrangements of fire extinguishing systems

xx) Welding procedures, stress relieving and non-destructive testing plans

xxi) Construction details of submerged fuel pumps including materials specifications

xxii) Operating and maintenance instruction manuals (to be submitted for reference purposes only)

xxiii) Testing procedures during sea/gas trials (submitted for survey verification only)

xxiv) Inspection/survey plan for the liquefied fuel containment system in accordance with 5C-13-6/4.1.8 of the *Marine Vessel Rules.*

4.3 Fuel Bunkering System

Per Section 8, plans and specifications covering the fuel bunkering system listed below are to be submitted, and are to include, as applicable:

i) General arrangement of the fuel bunkering system including location of the gas and leak detectors, electrical equipment and lighting

ii) Details and arrangements of the bunkering station, manifolds, valves, couplings and control stations

iii) Piping systems including details of piping and associated components, design pressures and temperatures

iv) Material specifications for manifolds, valves and associated components

v) Weld procedures, stress relieving and non-destructive testing plans

vi) Ventilation system

vii) Fixed gas and leak detection and alarm systems, and associated shut-off and shutdown systems

viii) Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

ix) Details of all electrical equipment in the bunkering and control stations

x) Equipotential bonding arrangement, including insulating flange, if fitted

xi) Emergency shutdown (ESD) arrangements and ESD flow chart

xii) Operating and maintenance instruction manuals (to be submitted for reference purposes only)

xiii) Testing procedures during sea/gas trials (submitted for survey verification only)

xiv) Inspection/survey plan for the fuel containment system

4.4 Fuel Supply System

Per Section 9, plans and specifications covering the fuel supply system listed below are to be submitted, and are, as applicable, to include:

i) General arrangement of the fuel preparation room including location of the gas and leak detectors, electrical equipment and lighting

ii) Doors and other openings in fuel preparation rooms

iii) Ventilation systems

iv) Material specifications for pumps, piping, valves and associated fuel supply/return/treatment components

v) Fixed gas and leak detection and alarm systems, and associated shut-off and shutdown systems

vi) Fuel piping systems including details of piping and associated components, design pressures, temperatures, insulation and fuel processing or treatment systems, where applicable

vii) Weld procedures, stress relieving and non-destructive testing plans

viii) Compressors

ix) Vaporizers/heaters

x) Pressure vessels

xi) Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

xii) Details of all electrical equipment installations

xiii) Electric bonding (earthing) arrangement

xiv) Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the fuel supply system

xv) Emergency shutdown arrangements

xvi) Operating and maintenance instruction manuals (to be submitted for reference purposes only)

xvii) Testing procedures during sea/gas trials (submitted for survey verification only)

xviii) Inspection/survey plan for the liquefied fuel containment system

4.5 Power Generation Prime Movers and Accessories

Per Section 10, and in addition to the plans and particulars required by 4-2-1/1.5 of the *Marine Vessel Rules*, plans and specifications covering the power generation prime movers and accessories, including propulsion and other energy converters, listed below are to be submitted, and are to include, as applicable:

i) General arrangement of the engine room, including location of the gas and leak detectors, electrical equipment and lighting

ii) Ventilation systems

iii) Fixed gas and leak detection and alarm systems, and associated shut-off and shutdown systems

iv) Fuel specification(s)

v) Fuel piping systems including schematics for main and pilot fuel systems together with details of piping and associated components, design pressures and temperatures

vi) Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions

vii) Details of the electrical equipment

viii) Electric bonding (earthing) arrangement

ix) Arrangement and details for crankcase protection

x) Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the engines for each engine type and fuel

xi) Arrangement of explosion protection for air inlet manifolds and for exhaust manifolds including design basis and size calculations

xii) Safety concept and/or risk analysis documentation

xiii) Emergency shut down arrangements

xiv) Operating and maintenance instruction manuals (to be submitted for reference purposes only)

xv) Testing procedures for shop test and sea trial (submitted for survey verification only)

xvi) Engine specific time referenced by 5C-13-10/3.1.7 of the *Marine Vessel Rules*, after which if the engine has not started the fuel gas supply is to be shut off and exhaust system is to be purged

SECTION 3

Goal and Functional Requirements

1 Goal

The goal of this Section *is to provide for safe and environmentally-friendly design, construction and operation of ships and in particular their installations of systems for propulsion machinery, auxiliary power generation machinery and/or other purpose machinery using* hydrogen as fuel.

2 Functional Requirements

The functional requirements of 5C-13-3/2 of the *Marine Vessel Rules* are applicable and are included below as applicable to the arrangement of the hydrogen fuel system, but are not limited to:

2.1 *The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable* gas and *conventional oil-fueled main and auxiliary machinery.*

2.2 *The probability and consequences of fuel-related hazards shall be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions shall be initiated.*

2.3 *The design philosophy shall ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.*

2.4 *Hazardous areas shall be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.*

2.5 *Equipment installed in hazardous areas shall be minimized to that required for operational purposes and shall be suitably and appropriately certified.*

2.6 *Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented.*

2.7 *System components shall be protected against external damages.*

2.8 *Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions.*

2.9 *It shall be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system shall be designed to prevent venting under all normal operating conditions including idle periods.*

2.10 *Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.*

2.11 *Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.*

2.12 *Fuel containment system and machinery spaces containing source that might release gas into the space shall be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.*

2.13 *Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.*

2.14 *Fixed gas detection suitable for all spaces and areas concerned shall be arranged.*

2.15 *Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.*

2.16 *Commissioning, trials and maintenance of fuel systems and gas utilization machinery shall satisfy the goal in terms of safety, availability and reliability.*

2.17 *The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.*

2.18 *A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.*

SECTION 4
General Provisions

1 Goal

The goal of this Section *is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship.*

2 Risk Assessment

2.1

A risk assessment is to be conducted to address the risks arising from the use of hydrogen as fuel affecting persons on board, the environment, and the structural integrity of the ship. Consideration is to be given to the hazards associated with physical layout, operation and maintenance following any reasonably foreseeable failure. This is to include the arrangement of entrances and other openings in enclosed spaces (refer to 5/8).

2.2

Risks are to be analyzed using acceptable and recognized risk analysis techniques. Loss of function, component damage, fire, explosion, and electric shock should, as a minimum, be considered. The analysis is to seek to minimize or eliminate risks wherever possible. Risks which cannot be eliminated are to be mitigated to an acceptable level of safety. Details of risks, and the means by which they are mitigated, are to be documented by report and submitted for review.

Commentary:

See IACS Recommendation No.146 Risk Assessment as Required by the IGF Code. See also the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries* for further guidance on risk assessment.

Where these requirements and the risk assessment are to support application under the IGF Code Alternative Design criteria and application of SOLAS II-1/55, such application is subject to agreement by the flag Administration, and application of the guidelines referenced by SOLAS II-1/55 footnote to MSC.1/Circ.1212, or associated guidelines MSC.1/Circ.1455.

End of Commentary

The risk assessment is to specifically consider, but is not limited to, the items referenced by these requirements and 5C-13 of the *Marine Vessel Rules*.

i) Mechanical protection of fuel preparation room/space, fuel containment, bunker station and piping – see 5/6.4, Section 6, Section 7 and Section 8.

ii) Capacity of drip trays – see 5/7.

iii) Potential and risk of oxygen deficiency or other negative impacts on crew health due to hydrogen fuel and inert gases, including the required number of compressed air safety equipment sets – see 5/10.

iv) Arrangements of bunker stations – see 8/4 and 13/7.

v) Causes and consequences of fuel supply release, including permeation into and through materials, arrangement of double walled pipes in machinery spaces, and high energy collision with potential to penetrate a liquid hydrogen tank, or the rupture of a compressed hydrogen tank containment system. The possibility of jet fire is to be specifically considered – see 11/8. The consequences of any release of fuel are to be minimized, while providing safe access for operation and inspection – see 9/3.3.

vi) Required gas detection systems and arrangement for ventilation inlets/outlets of accommodation spaces, machinery spaces, service spaces and control stations – see 15/8.

vii) Arrangements of airlocks and performance in the case of the most critical event in the gas dangerous space separated by the airlock – see 5C-13-5/12.3 of the *Marine Vessel Rules.*

viii) Gas detection and closing arrangements of the air intakes and other openings into the accommodation spaces, service spaces and control stations – see 13/3.3 of this document and 5C-13-15/8.1.10 of the *Marine Vessel Rules.*

ix) Arrangements of inert gas system and consequences of loss of inert system – see 6/11.

x) Arrangements and possible issues associated with storage of hydrogen as fuel, including fuel supply arrangements, vicinity to other equipment, corrosion, insulation, extreme low or high temperatures, boil-off gas arrangements, filling limit, and materials for hydrogen service.

xi) Arrangements for the safe handling, marking and carriage of flammable substances, including fire detection arrangements.

xii) Arrangement of Hazardous Areas and causes and consequences of explosion, considering the low ignition energy of flammable hydrogen concentrations, and including all possible areas of fuel leakage – see 3/2.3 through 3/2.5, 4/3 and 12/5.

xiii) Arrangement of any fixed and portable fire extinguishing systems – see 11/3, including quantity of carbon dioxide for the protected spaces as per 11/8.2 or arrangement of other extinguishing agents.

xiv) The need for additional quantitative analysis, such as gas dispersion study or HAZID/HAZOP, to support the design approval and the items identified by Section 13 and Section 15 and 5C-13-6/7.2.8 of the *Marine Vessel Rules.*

xv) Operations, maintenance, and emergency situations related to using or storing hydrogen fuel. See Sections 17 and 18.

xvi) Potential and risk of highly enriched oxygen formation associated with exposed cryogenic temperatures, including insulation – see 9/3.4.

xvii) Potential and risk of fuel contamination and arrangement of fuel system filtering – see 9/3.5.

2.4

The risk assessment plan developed and submitted for review to ABS prior to conducting the risk assessment and is to contain, but is not limited to:

i) Description of proposed function

ii) Quantitative or Qualitative risk assessment method(s) to be used and description if using a non-standard method

iii) Scope and objectives of the assessment

iv) Subject matter experts / participants / risk analysts, including their background and area of expertise

v) Proposed risk acceptance criteria or risk matrix

vi) Risk control and management measures

The risk control and management measures are to be maintained throughout the life of the vessel. Any modifications are to be submitted to ABS for review.

Further guidance on submitting a risk assessment plan can be found in the ABS *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Industries.*

3 Limitation of Explosion Consequences

To limit the consequences of an explosion in any space containing any potential source of release of flammable vapor/liquid and potential ignition sources, the items referenced by these requirements and 5C-13-4/3 of the *Marine Vessel Rules* are applicable.

An explosion in any space containing any potential sources of release and potential ignition sources is not to disrupt the proper functioning of pressure relief systems or ventilation systems.

Note this is applicable to all spaces containing stored hydrogen, fuel preparation equipment, piping systems, consumers and ventilation ducting or ventilation equipment.

Commentary:

Consideration is to be given for any space where hydrogen explosions may occur for explosion-resistant structural protection such as reinforced steel bulkheads and decks, energy absorbing structural arrangements, or the integration of barricade structures.

Double wall fuel pipes are not considered as potential sources of release.

End of Commentary

SECTION 5

Ship Design and Arrangement

1 Goal

The goal of this Section *is to provide for safe location, space arrangements and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment and refueling systems.*

2 Functional Requirements

The functional requirements of 3/2 of this document and 5C-13-5/2 of the *Marine Vessel Rules* are applicable.

3 General Provisions

The fuel containment protection methodology for determining acceptable fuel tank locations of 5C-13-5/3.3 and 5C-13-5/3.5 of the *Marine Vessel Rules* are applicable.

Where the Flag Administration may require the fuel containment location to be further evaluated according to the risk-based approach, the likelihood of penetrating the tank(s) is to be determined using the probabilistic methodology identified in SOLAS Chapter II-1 Regulation 7, the risk assessment method and the risk acceptance criterion need to be agreed with the Flag Administration.

The fuel containment systems are to be located as far as practicable in the open air with sufficient natural ventilation to prevent the accumulation of escaped gas and protected from environmental hazards, damages, and fire risk areas.

3.1

Tanks containing fuel are not to be located within accommodation spaces or machinery spaces of category A.

3.2

Fuel tanks located on open decks are to be protected against mechanical damage.

3.3

Fuel tanks located on deck are not to be located less than 800 mm from the vessel's side.

3.4

Fuel containment systems are to be located as close to centerline as practicable.

3.5

Liquefied hydrogen fuel tanks on open decks are to be surrounded by coamings. Arrangements are to be in place to mitigate the effects of potential cryogenic spills or leaks which could damage materials or structures by exposure to very low temperatures.

3.6

All fuel piping and components in enclosed spaces onboard are to be enclosed in gas and liquid tight enclosures. Single walled pipes in enclosed spaces are not to be used for pipes in hydrogen service.

3.7

Access to the fuel containment system and hull structure for the purpose of inspection, evacuation and maintenance is to be in accordance with 5C-8-3/5.1 through 5C-8-3/5.3, as applicable.

4 Machinery Space (Engine Room) Arrangements

4.1

In order to minimize the probability of a gas explosion in a machinery space with gas-fueled machinery, gas safe machinery space concepts are to be applied in accordance with 5C-13-5/4.1.1 of the *Marine Vessel Rules.*

4.2

A single failure within the fuel system is not to lead to a release of fuel into the machinery space.

4.3

All fuel piping and components within machinery space boundaries is to be enclosed in gas and liquid tight enclosures in accordance with 5C-13-9/6 of the *Marine Vessel Rules* for fuel supply to consumers in gas-safe machinery spaces.

4.4

Fuel cell installations are to be arranged in accordance with the requirements of the ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications.*

4.5

Machinery spaces containing hydrogen as fuel consumers or reformers generating hydrogen are to be arranged for remote monitoring in accordance with the **ACC**, **ACCU** or **ABCU** requirements of 4-9 of the *Marine Vessel Rules.*

4.6

All engine spaces containing hydrogen consumers are to be considered Category A Machinery spaces.

5 Location and Protection of Fuel Piping

5.1

Fuel pipes are to be located and protected in accordance with 5C-13-5/7.1 through 5C-13-5/7.3 of the *Marine Vessel Rules*.

6 Fuel Preparation Room

6.1

Fuel Preparation Rooms are to be located and arranged in accordance with 5C-13-5/8 of the *Marine Vessel Rules*.

Equipment and systems for hydrogen fuel supply, and as applicable, equipment for compression or cooling of hydrogen in the fuel tanks, are to be located in a dedicated fuel preparation room/space.

Drip trays and spray shields, or equivalent means, are to be fitted where leakage may occur from the potential sources of cryogenic hydrogen release. As applicable, arrangements are to consider unacceptable cooling in case of cryogenic leakages, and in consideration of the probable maximum leakage scenario.

6.2

Fuel preparation rooms are to be separated by gastight bulkheads and decks from other spaces.

6.3

Fuel preparation rooms are to be located outside other machinery spaces of category A.

6.4

When located on deck, fuel preparation rooms are to be protected against mechanical damage where vessel operations increase the risk of mechanical impact damage.

6.5

Fuel preparation rooms are to contain only the equipment essential for fuel conditioning, preparation and supply according to Section 9, together with necessary safety equipment such as fire and gas detection, low oxygen level detection system and fire-fighting equipment according to Section 11 and 15/8.

6.6

Fuel preparation rooms are to be designed to withstand the maximum possible pressure build up, or vacuum, during leakages or activation of the safety systems. Alternatively, pressure/vacuum relief venting to a safe location (mast) can be provided.

6.7

Arrangements for entrances and openings to the fuel preparation room are to be in accordance with 5/8.

7 Drip Trays

7.1

Drip tray design and arrangements, as applicable to liquefied hydrogen, are to be in accordance with 5C-13-5/10 of the *Marine Vessel Rules.*

8 Arrangement of Entrances and Other Openings in Enclosed Spaces

8.1

Arrangements of entrances and other opening in enclosed spaces are to be in accordance with 5C-13-5/11.1 to 5C-13-5/11.3 and 5C-13-5/11.5 of the *Marine Vessel Rules.*

9 Airlocks

9.1

Airlocks, where provided, are to be in accordance with 5C-13-5/12 of the *Marine Vessel Rules*.

10 Personnel Safety and PPE

10.1

Systems and arrangements are to be designed so personnel do not enter spaces expected to have hazardous or flammable gas concentrations. When entry is necessary, spaces are to be hydrogen-free prior to personnel entry. See 5C-13-18/5 of the *Marine Vessel Rules.*

10.2

As per 5C-13-18/5.2 of the *Marine Vessel Rules* regarding introduction of potential sources of ignition into spaces unless certified gas-free, special consideration for suitable protective equipment should be given to the low ignition energy of hydrogen and static electricity. Anti-static tools are to be provided for use where necessary suitable for hydrogen service. Personal protective equipment (PPE) for use in potential hydrogen environments includes anti-static protective clothing, including boots and gloves. When handling liquid hydrogen, PPE for potential leaks or splashes should be considered for eye/face protection and other skin protection.

SECTION 6

Fuel Containment System

1 Goal

The goal of this Section *is to provide that gas storage is adequate so as to minimize the risk to personnel, the ship and the environment to a level that is equivalent to a conventional oil fueled ship*.

2 Functional Requirements

The functional requirements detailed in 3/2 of this document and 5C-13-6/2 of the *Marine Vessel Rules* are applicable.

2.1

The materials used for the fuel containment system are to be compatible with the fuel stored. The fuel containment system is to be resistant to hydrogen embrittlement. Refer to Section 7/4 for material requirements of systems for hydrogen service.

3 General

3.1

The general fuel containment requirements of 5C-13-6/3.2 through 5C-13-6/3.12 of the *Marine Vessel Rules*, as applicable to the storage of hydrogen, apply.

4 Fuel Containment

4.1

Storage tanks for compressed hydrogen fuel are to be subject to special consideration. Compressed hydrogen fuel tanks are to be certified and approved by the Flag Administration according to a recognized standard.

4.2

Requirements for compressed fuel containment of 5C-13-6/6.2 through 5C-13-6/6.4 of the *Marine Vessel Rules* as applicable to the storage of hydrogen, apply.

4.3

Storage tanks for liquefied hydrogen fuel are to be in accordance with 5C-13-6/4 of the *Marine Vessel Rules* as applicable to hydrogen fuel.

4.4

Storage tanks for liquefied hydrogen fuel are to be fabricated and tested in accordance with Section 16 as applicable for the intended service.

Commentary:

The fabrication, assembly, erection, inspection, examination and testing of hydrogen containment systems are to be performed in accordance with ABS Rules as they apply to hydrogen (e.g., for Type C independent tanks see 5C-13-6/4.15.3 or 4-4-1 of the *Marine Vessel Rules*) and referenced recognized standards (i.e., ABS *Guidance Notes on Strength Assessment of Independent Type C Tanks*).

End of Commentary

5 Portable Tanks

5.1

Portable fuel tanks are to be arranged in accordance with 5C-13-6/5 of the *Marine Vessel Rules.*

6 Pressure Relief Systems

6.1

Pressure relief valves and systems in accordance with 5C-13-6/7 of the *Marine Vessel Rules* are to be provided.

6.2

Vent masts are to be equipped with fixed hydrogen gas detection and monitored in accordance with Section 15.

7 Filling and Loading Limit for Liquefied Fuel Tanks

7.1

The maximum Loading Limit (LL) to which a liquefied hydrogen fuel tank may be loaded is to be determined in accordance with the formula given in 5C-13-6/8.1 of the *Marine Vessel Rules*. A loading limit curve for the actual fuel loading temperatures is to be prepared.

8 Maintaining Fuel Storage Condition

8.1

Arrangements for maintaining control of pressure and temperature of fuel storage conditions are to be in accordance with 5C-13-6/9 of the *Marine Vessel Rules.*

9 Atmospheric Control Within the Fuel Containment

9.1

Provisions to enable each fuel tank to be gas-freed are to be provided in accordance with 5C-13-6/10 of the *Marine Vessel Rules.*

10 Atmospheric Control Within Fuel Storage Hold Spaces

10.1

Atmospheric control arrangements for interbarrier and fuel storage hold spaces associated with gaseous or liquefied gas fuel containment systems requiring full or partial secondary barriers (fuel containment systems other than Type C), are to be in accordance with 5C-13-6/11 of the *Marine Vessel Rules*.

10.2

Atmospheric control arrangements for dry air in fuel storage hold spaces surrounding Type C independent tanks are to be in accordance with 5C-13-6/12 of the *Marine Vessel Rules*.

11 Inert Gas Arrangements

11.1

Inert gas arrangements are to be in accordance with 5C-13-6/13 of the *Marine Vessel Rules*.

11.2

Appropriate inert gas is to be chosen according to the expected operating temperature ranges of the hydrogen fuel contained in the systems to be inerted. For example, for hydrogen systems operating above the liquefication temperature of nitrogen, -196°C (-320°F), nitrogen gas may be used as an inerting gas. For temperatures below the liquefication point of nitrogen, helium may be considered.

11.3

Where inert gas is produced on board, the production and storage arrangements are to be in accordance with 5C-13-6/14 of the *Marine Vessel Rules*.

SECTION 7

Material and General Pipe Design

1 Goal

The goal of this Section *is to ensure the safe handling of fuel, under all operating conditions, to minimize the risk to the ship, personnel and to the environment, having regard to the nature of the products involved.*

2 Functional Requirements

The functional requirements detailed in 3/2 of this document and 5C-13-7/2 of the *Marine Vessel Rules* are applicable.

3 General Pipe Design

3.1

Fuel pipe design and arrangements are to be in accordance with 5C-13-7/3 of the *Marine Vessel Rules*.

Commentary:

The design, fabrication, assembly, erection, inspection, examination and testing of hydrogen piping systems are to be performed in accordance with an ABS recognized standard (i.e., ASME B31-12, Hydrogen Piping and Pipelines).

End of Commentary

4 Materials

4.1

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

4.2

Materials for fuel containment, fuel piping, process pressure vessels are to be in accordance with recognized standards applicable for hydrogen service at the design temperatures and pressures with special consideration to the requirements of 5C-13-7/4 of the *Marine Vessel Rules*.

4.3

Materials that may be directly exposed to hydrogen or hydrogen rich gases during normal operations are to be suitable for their application considering, but not limited to, hydrogen-specific metallurgical phenomena such as hydrogen permeation, hydrogen-induced cracking, stress corrosion cracking, hydrogen embrittlement and hydrogen attack.

Commentary:

Hydrogen embrittlement is a phenomenon that results in a significant reduction in material tensile strength, ductility, and fracture toughness. The initiation and severity of hydrogen embrittlement depends upon the interaction of materials used, the mechanical loading, and environmental variables.

Such deterioration in properties in turn, leads to accelerated fatigue crack growth and consequently shorter equipment life. Furthermore, if not properly accounted for material degradation due to hydrogen, can result in catastrophic unpredicted failure.

Reference can be made to IMO CCC 8-WP.3 *Draft Interim Guidelines for the Safety of Ships using Hydrogen as Fuel*. Although in draft format, this document contains interim guidelines for the safety of ships using hydrogen as a fuel to be adopted by the IMO Maritime Safety Committee, intended to function as an amendment to the IGF Code.

Information regarding material compatibility with hydrogen environments and effects of material exposure to hydrogen can be found in various industry references, including ANSI/AIAA G-095A-2017 *Guide to Safety of Hydrogen and Hydrogen Systems*, ASTM B31.12 2019 *Hydrogen Piping and Pipelines*, and NASA/TM-2016-218602 *Hydrogen Embrittlement*.

End of Commentary

SECTION 8
Bunkering

1 Goal

The goal of this Section *is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship*.

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-8/2 of the *Marine Vessel Rules* are applicable.

3 General

See the requirements under 5/10 for hydrogen bunkering PPE requirements.

4 Bunkering Station

4.1

Fuel bunkering station arrangements are to be in accordance with 5C-13-8/3 of the *Marine Vessel Rules*.

4.2

If enclosed or semi-enclosed bunkering stations are arranged, the bulkheads of those bunkering stations are to be gas tight.

4.3

Bunkering control arrangements are to allow for remote operations from a safe location. At that location, remote monitoring is to display the tank pressure and tank temperature. High temperature and high pressure alarm, automatic and manual shutdown are also to be indicated at this location.

4.4

Bunkering lines are not to pass directly through accommodation spaces, control stations or service spaces. Bunkering lines passing through enclosed spaces are to be enclosed in a venting duct.

5 Bunkering Manifold

5.1

Fuel bunkering manifold arrangements are to be in accordance with 5C-13-8/4 of the *Marine Vessel Rules*.

5.2

Bunkering couplings are to be appropriate for fuel bunkering operations and are to withstand the design temperature and design pressure.

5.3

The connections at the bunkering station are to be equipped with additional break-away couplings or self-sealing quick release devices. Where the break-away coupling/self-sealing quick release is provided by the bunkering source, signs are to be posted in conspicuous places at the bunkering manifold.

6 Bunkering System

6.1

Fuel bunkering system arrangements are to be in accordance with 5C-13-8/5 of the *Marine Vessel Rules.*

6.2

Fuel tanks are to have maximum temperature of no more than 85 °C (185 °F) during bunkering operations.

7 Gas and Fire Detection

7.1

Enclosed or semi-enclosed bunker stations and ventilated ducts, or double wall piping systems, around fuel bunker pipes are to be fitted with permanently installed gas detectors or leak detection, suitable for flammable hydrogen concentrations, in accordance with 15/8.

7.2

All bunker stations are to be fitted with permanent fire detection suited to detect hydrogen flames. Detection of hydrogen fire at bunkering stations is to automatically shut down the manifold ESD valves.

7.3

The ship is to be provided with at least two sets of portable gas detectors that meet an accepted national or international standard.

7.4

Monitoring and safety system functions are to be provided in accordance with Section 15.

SECTION 9

Fuel Supply to Consumers

1 Goal

The goal of this Section *is to ensure safe and reliable distribution of fuel to the consumers*.

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-9/2 of the *Marine Vessel Rules* are applicable.

3 General

3.1

The requirements specified in this Section are intended to cover the fuel supply arrangements and systems fitted on board to deliver hydrogen from the fuel tank to the prime movers and consumers. Fitted arrangements and systems will vary according to vessel type and prime mover type and thus may for example include compressors, process skids or cryogenic fuel preparation equipment.

3.2

The fuel piping system for hydrogen is to be independent from all other fuel piping systems.

3.3

The piping system for fuel transfer to the consumers is to be designed such that a failure of one barrier is not to result in a leak from the piping system into the surrounding area.

3.4

Insulation or other preventive measures for fuel pipes containing liquid hydrogen and cold hydrogen vapor are to maintain the temperature of exposed surfaces above -183°C (-297°F). Low temperatures and the possibility of condensing oxygen from air forming highly enriched oxygen concentrations are to be considered in the risk assessment in 4/2.

Commentary:

Oxygen and nitrogen may condense from ambient air when exposed to cryogenic temperatures associated with liquified hydrogen. This condition may create flammable regions of highly enriched oxygen concentrations.

End of Commentary

3.5

Appropriate means for the filtration of contaminants from the fuel is to be provided.

The filtration system is to be fitted with means to indicate at all times whether the filter is becoming blocked or experiencing other loss of functionality.

4 Redundancy of Fuel Supply

4.1

Fuel supply redundancy arrangements are to be in accordance with 5C-13-9/3 of the *Marine Vessel Rules* as applicable to hydrogen fuel systems.

4.2

Propulsion and power generation arrangements, together with fuel supply systems, are to be arranged so that a single failure in fuel supply does not lead to an unacceptable loss of power.

5 Safety Functions of the Fuel Supply System

5.1

Fuel supply system safety functions are to be arranged in accordance with 5C-13-9/4.2, 5C-13-9/4.5 through 5C-13-9/4.9, and 5C-13-9/4.11 through 5C-13-9/4.14 and the requirements in this section.

5.2

An additional automatic shutdown valve for a fuel preparation room containing the master fuel valve as required by 5C-13-9/4.2 may be the fuel tank outlet valve required by 5C-13-9/4.1 of the *Marine Vessel Rules.*

Commentary:

The combined master fuel valve and block valve are to be located outside the machinery space, as required by 5C-13-9/4.2 of the *Marine Vessel Rules*. Where such valves are located in a fuel preparation room, that room is to be protected by another automatic shutdown valve outside the room and as required by 9/5.3 of this document.

End of Commentary

5.3

The automatic master fuel valve to the consumers, or set of consumers, is to be operable

i) from safe location on the primary escape route from the engine room

ii) secondary escape route from the engine room

iii) at a location outside the engine room(s)

iv) outside the fuel preparation room

v) at the engine control room and

vi) at the navigation bridge.

The activation device is to be arranged as a physical button, duly marked and protected against inadvertent operation, and operable under emergency power.

5.4

Each hydrogen consumer within an engine room is to be provided with a "double block and bleed" valve arrangement. These valves are to be arranged as outlined in *i)* or *ii)* below, so that when the safety system

required in Section 15 is activated this will cause the shutoff valves that are in series to close automatically and the bleed valve to open automatically. Also:

i) the two shut-off valves are to be in series in the fuel pipe to the consuming equipment. The bleed valve is to be in a pipe that vents to the fuel return system that portion of the fuel piping that is between the two valves in series; or

ii) the function of one of the shutoff valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the consumer will be blocked and the vent line opened.

The parts of the fuel supply system that incorporate the "double block and bleed" valve arrangement, typically known as Fuel Valve Train (FVT), may be located in a dedicated space. In such cases they are to be arranged in accordance with 5C-13-10/3.1.15 of the *Marine Vessel Rules* and are to be considered by the risk assessment required by 4/2.

5.5

Fuel storage tank inlets and outlets shall be provided with valves located as close to the tank as possible. Valves required to be operated during normal operation which are not accessible are to be remotely operated. Tank valves whether accessible or not shall be automatically operated when the safety system required in 5C-13-15/2.2 is activated.

Commentary:

Normal operation in this context is when gas is supplied to consumers and during bunkering operations.

End of Commentary

5.6 (ABS)

Tank valves are to be remotely operated, be of the fail closed type (closed on loss of actuating power), and are to be capable of local manual closure. These valves on liquified hydrogen tanks are to have positive indication of the actual valve positions.

6 Fuel Distribution Outside of Machinery Spaces

6.1

Fuel piping systems outside of machinery spaces are to be arranged in accordance with 5C-13-9/5 of the *Marine Vessel Rules*.

7 Fuel Supply in Gas Safe (Non-Hazardous) Machinery Spaces

7.1

Fuel piping systems in gas safe machinery spaces containing consumers are to be arranged in accordance with 5C-13-9/6 of the *Marine Vessel Rules.*

Enclosures for fuel valve trains (FVT), where provided, are to be arranged in accordance with 5C-13-9/6.1 of the *Marine Vessel Rules*.

8 Design of Fuel Piping Ventilated Duct or Outer Pipe

8.1

The design of the fuel piping ventilated duct or outer pipe is to be in accordance with 5C-13-9/8 of the *Marine Vessel Rules*.

9 Compressors and Pumps

9.1

Compressors and pumps are to be in accordance with 5C-13-9/9 of the *Marine Vessel Rules* as applicable to hydrogen service.

10 Vaporizers, Heat Exchangers and Pressure Vessels

10.1

Vaporizers, heat exchangers and pressure vessels are to be arranged, as applicable, in accordance with 5C-13-9/10 of the *Marine Vessel Rules* as applicable to hydrogen service.

11 Ancillary Systems

11.1

The design of the fuel supply ancillary systems is to be in accordance with 5C-13-9/12 of the *Marine Vessel Rules*.

SECTION 10

Power Generation Including Propulsion and Other Energy Converters

Commentary:

The requirements specified in this section are in addition to all other relevant requirements of the *Marine Vessel Rules.*

End of Commentary

1 Goal

The goal of this Section *is to provide safe and reliable delivery of mechanical, electrical or thermal energy.*

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-10/2 of the *Marine Vessel Rule*s are applicable.

3 General

3.1

Internal combustion engines intended to burn hydrogen as fuel are to be designed, tested and certified in accordance with 4-2-1, 5C-8-16 and 5C-13-10, as applicable, of the *Marine Vessel Rules.*

3.2

The fuel specification required by the engine or fuel cell is to be declared by the manufacturer and detailed in the operation and maintenance manuals.

3.3

Discharges from fuel supply systems are to be led to a safe location in the open air.

3.4

Monitoring of exhaust(s) is to be in accordance with Section 15.

3.5

The design of internal combustion engines of piston type is to be in accordance with 5C-13-10/3.1.1 to 5C-13-10/3.1.7 of the *Marine Vessel Rules.*

3.6

As applicable, where the engine auxiliary systems are likely to contain hydrogen in abnormal conditions as a result of a component failure (refer to FMEA for more information and 10/3.1), they are to be arranged with means to detect leakage. Alarm is to be given when the presence of hydrogen is detected.

3.7

A Failure Modes and Effects Analysis (FMEA) is to be carried out by the consumer manufacturer to determine necessary additional safeguards to address the hazards associated with the use of hydrogen as a fuel, for example protection against explosion and cylinder overpressure, etc. This requirement is in addition to, but may be included by revision of, the FMEA required by 4-2-1/TABLE 1 of the *Marine Vessel Rules*.

The analysis is to identify all plausible scenarios of fuel leakage and the resulting hazards and then identify necessary means to control the identified hazards.

4 Dual Fuel Engines

4.1

Dual fuel internal combustion engines are to be arranged in accordance with 5C-13-10/3.2 of the *Marine Vessel Rules*.

5 Gas-Only Engines

5.1

Gas-only internal combustion engines are to be arranged in accordance with 5C-13-10/3.3 of the *Marine Vessel Rules*.

6 Main and Auxiliary Boilers (ABS)

6.1

Dual fuel main and auxiliary boilers are to be arranged in accordance with this document and 5C-13-10/4 of the *Marine Vessel Rules*.

7 Fuel Cells

7.1

Fuel cells are to be arranged in accordance with this document and the ABS *Requirements for Fuel Cell Power Systems for Marine and Offshore Applications*.

SECTION 11
Fire Safety

1 Goal

The goal of this Section *is to provide for fire protection, detection and fighting for all system components related to the storage, conditioning, transfer and use of* hydrogen as fuel.

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-11/2 of the *Marine Vessel Rules* are applicable.

3 General

3.1

The provisions in this section are additional to those in SOLAS Chapter II-2.

3.2

The fire protection requirements of 5C-13-11/3 of the *Marine Vessel Rules* are applicable.

4 Fire Main

4.1

The fire main is to be arranged in accordance with 5C-13-11/4 of the *Marine Vessel Rules.*

5 Water Spray System

5.1

The water spray system is to be arranged in accordance with 5C-13-11/5 of the *Marine Vessel Rules.*

5.2

In addition to the water spray system providing coverage for the fuel tanks, and the additional locations required by 5C-13-11/5.2 of the *Marine Vessel Rules*, the water spray system is also to be arranged to cover all exposed fuel piping including supply and vent lines located on deck, except where double-walled.

6 Bunker Station Fire-Extinguishing System

6.1

The bunker station fire-extinguishing system is to be arranged with dry chemical powder fire extinguishers in accordance with 5C-13-11/6 of the *Marine Vessel Rules*.

7 Fire Detection and Alarm System

7.1

The fire detection and alarm systems are to be arranged in accordance with Section 15/9 of this document and 5C-13-11/7 of the *Marine Vessel Rules*.

7.2

The fire detection systems are to detect hydrogen flames.

8 Fire Extinguishing

8.1

Category A Machinery spaces, fuel storage hold spaces and fuel preparation rooms where hydrogen fueled consumers or fuel supply systems are located are to be protected by an approved fixed fire-extinguishing system in accordance with SOLAS Chapter II-2 Regulation 10 and the FSS Code. Where hydrogen is used as the primary fuel, the extinguishing media used in the space is to be dry powder or carbon dioxide. In addition, the fire-extinguishing medium used is to be suitable for the extinguishing of hydrogen fires.

8.2

The quantity of dry powder or carbon dioxide for fixed gas fire-extinguishing systems is to be addressed by the risk assessment according to Section 4.

SECTION 12

Explosion Prevention and Area Classification

1 Goal

The goal of this Section *is to provide for the prevention of explosions and for the limitation of effects from explosion.*

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-12/2 of the *Marine Vessel Rules* are applicable and the probability of explosions is to be reduced to a minimum by using certified safe type electrical equipment suitable for the hazardous zone where the use of electrical equipment in hazardous areas is unavoidable.

3 General Provisions

3.1

Hazardous areas on open deck and other spaces not addressed in this chapter are to be determined based on a recognized standard and included in the risk assessment as per Section 4. The electrical equipment fitted within hazardous areas are to be in accordance with the same standard.

Commentary:

Refer to IEC Standard 60079-10-1:2020 Classification of Areas – Explosive gas atmospheres.

End of Commentary

3.2

Electrical equipment and wiring are not to be installed in hazardous areas unless they are certified for use in the hazardous space and essential for operational purposes based on a recognized standard.

3.3

All hazardous areas are to be inaccessible to passengers and unauthorized crew at all times.

4 Area Classification

4.1

Requirements for area classification are to be in accordance with 5C-13-12/4 of the *Marine Vessel Rules.*

4.2

The hazardous area classification requirements of 4-8-4/27 of the *Marine Vessel Rules* are applicable.

5 Hazardous Area Zones

Hazardous area zones are to be evaluated and established according to IEC 60079 Series of Explosive Atmosphere Standards, specifically, 60079-10-1:2020 Classification of Areas – Explosive gas atmospheres and 60079-10-1 Annex H – (Informative) Hydrogen. A HAZID/HAZOP is to be conducted to identify potential sources of release, flow rates and likelihoods of hydrogen release. The resulting data is to be fed into a quantitative gas dispersion study to establish the hazardous zones.

SECTION 13
Ventilation

1 Goal

The goal of this Section *is to provide for the ventilation required for safe operation of gas-fueled machinery and equipment.*

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-13/2 of the *Marine Vessel Rules* are applicable.

3 General

3.1

Ventilation design and arrangements are to be in accordance with 5C-13-13/3 of the *Marine Vessel Rules.*

3.2

The ventilation arrangements are to take account of the density of any potential releases of hydrogen.

Commentary:

Cryogenic hydrogen is denser than hydrogen at ambient temperatures and can be reactive with the surrounding atmosphere. Hydrogen releases in the air may react to form other vapors that are heavier than air.

End of Commentary

3.3

In addition to the requirements of 5C-13-13/3 of the *Marine Vessel Rules*, a HAZID/HAZOP is to be performed regarding the properties of hydrogen to evaluate ventilation systems used to control hazardous areas according to a recognized standard.

4 Tank Connection Space

4.1

The tank connection space arrangements are to be in accordance with 5C-13-13/4 of the *Marine Vessel Rules.*

5 Machinery Spaces

5.1

The ventilation system for machinery spaces containing gas-fueled consumers shall be independent of all other ventilation systems in accordance with 5C-13-13/5.

6 Fuel Preparation Room

6.1 Ventilation of the Fuel Preparation Room

Fuel preparation room ventilation arrangements are to be in accordance with 5C-13-13/6 of the *Marine Vessel Rules* and these requirements.

The fuel preparation room is to be efficiently ventilated, and maintained at underpressure relative to surrounding spaces, by means of mechanical exhaust ventilation designed in accordance with the following requirements:

6.1.1

The ventilation system is to be independent of other shipboard ventilation systems.

6.1.2

The ventilation system is to be designed for continuous operation and alarmed at a continuously manned central control station upon failure.

6.1.3

Air inlet openings are to be positioned as low as practicable in the space being ventilated and exhaust openings are to be at highest point and at opposite sides to the air inlet openings so that no hydrogen accumulates in the space, with ventilation being circulated from the bottom and exhausted at the top.

6.1.4

Design of ventilation fans serving the fuel preparation room are also to be in accordance with 4-8-3/11 of *Marine Vessels Rules* for non-sparking fans designed for hydrogen service.

6.2 Increased Ventilation of the Fuel Preparation Room

Fuel preparation rooms are to be provided with an increased mechanical type gas evacuation system to quickly dissipate a catastrophic leak of hydrogen to reduce the risk of fire and explosion. The increased capacity of the system is to be addressed in the risk assessment per 4/2. The system is to be designed and constructed in accordance with the following requirements:

6.2.1

The gas evacuation system is to be independent of other shipboard ventilation systems; however, it need not be independent of the ventilation system required by 13/6.1.

6.2.2

The gas evacuation system controls are to be positioned outside the space.

7 Bunkering Station

7.1

The bunker station ventilation arrangements are to be in accordance with 5C-13-13/7 of the *Marine Vessel Rules.*

8 Ducts and Double Pipes

8.1

The ventilation arrangements for fuel pipe ducting and double wall pipes are to be in accordance with 5C-13-13/8 of the *Marine Vessel Rules.*

The number and power of the ventilation fans for fuel pipe ducting and double wall piping is to be such that if one fan, or a group of fans with a common circuit from the main switchboard or emergency switchboard, are out of service the capacity of the remaining ventilation fan(s) is not less than 100% of the total required.

SECTION 14

Electrical Installations

1 Goal

The goal of this Section *is to provide for electrical installations that minimize the risk of ignition in the presence of a flammable atmosphere.*

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-14/2 of the *Marine Vessel Rules* are applicable.

3 General

3.1

Electrical installations are to be in accordance with 5C-13-14/3 and 4-8-4/27 of the *Marine Vessel Rules*, as applicable for hydrogen.

3.2

For the purposes of application of IEC standards and selection of electrical equipment, hydrogen has an IEC lower explosive limit (LEL) of 4.0% and an upper explosive limit (UEL) of 75.0%, respectively. Electrical equipment is to meet ISO/IEC 60079-20 group IIC class T1 standards and NEC/CEC Group B standards. Gas detectors are to be in accordance with Subsection 15/8.

SECTION **15**

Control, Monitoring and Safety Systems

1 Goal

The goal of this Section *is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the gas-fueled installation as covered in the other* Sections of this document.

2 Functional Requirements

2.1

The functional requirements detailed in 3/2 of this document and 5C-13-15/2 of the *Marine Vessel Rules* are applicable.

3 General

3.1

Fuel containment and fuel supply instrumentation arrangements are to be in accordance with 5C-13-15/3 of the *Marine Vessel Rules.*

3.2

Machinery spaces containing hydrogen are to be fitted with remote monitoring in accordance with the **ACC**, **ACCU** or **ABCU** requirements 4-9-1 of the *Marine Vessel Rules.*

4 Bunkering and Fuel Tank Monitoring

4.1

Each fuel tank is to be provided with means for indicating fuel level, pressure and temperature.

4.2

For compressed gas tanks, pressure gauges and temperature sensors are to be installed which are to automatically actuate a shutoff valve in a manner which will avoid excessive pressure in the loading line. Overflow control is to be in accordance with 5C-13-15/4.3 to 5C-13-15/4.9 and 5C-13-15/4.11 and 5C-13-15/4.12 of the *Marine Vessel Rules*, as applicable to compressed gas tanks.

4.3

For liquefied gas tanks, the liquid fuel tank level and overflow control monitoring arrangements are to be in accordance with 5C-13-15/4 of the *Marine Vessel Rules.*

4.4

In addition to the indirect and closed level indicator types detailed by 5C-13-15/4.1.3 of the *Marine Vessel Rules*, the fuel tank liquid level gauges may be of the following closed types:

- closed devices which penetrate the fuel tank, but which form part of a closed system and keep the fuel from being released, such as float type systems, electronic probes, magnetic probes and bubble tube indicators. If the closed gauging device is not mounted directly onto the tank, it is to be provided with a shutoff valve located as close as possible to the tank.

5 Bunkering Control

5.1

Bunkering control arrangements are to be in accordance with 5C-13-15/5 of the *Marine Vessel Rules.*

6 Compressor Monitoring

6.1

Compressor monitoring arrangements are to be in accordance with 5C-13-15/6 of the *Marine Vessel Rules*, as applicable to liquefied or gaseous hydrogen.

7 Engine Monitoring

7.1

Engine monitoring arrangements are to be in accordance with 5C-13-15/7 of the *Marine Vessel Rules.*

8 Gas Detection Systems

8.1

Gas detection arrangements are to be in accordance with 5C-13-15/8.1 and 5C-13-15/8.3 through 5C-13-15/8.13 of the *Marine Vessel Rules* suitable for flammable hydrogen concentrations.

8.2

In addition to the (hydrogen) gas detection locations referenced by 5C-13-15/8.1 of the *Marine Vessel Rules*, a hydrogen vapor detection and alarm system is to be provided to warn of the release of hydrogen at the following locations:

i) Fuel storage hold spaces

ii) The vent mast identified under 6/6.2 for monitoring only

8.3

Where the hydrogen gas detector range of operation cannot cover the ppm levels required for flammability detection and the percentage (%) level required for fire and explosion detection, separate gas detectors covering each range of operation are required at each detector location.

9 Fire Detection

9.1

The required safety actions upon fire detection are given under 5C-13-15 of the *Marine Vessel Rules,* as applicable, and 15/12 of this document.

10 Ventilation

10.1

The ventilation requirements are to be in accordance with 5C-13-15/10 of the *Marine Vessel Rules*.

The required safety actions for ventilation are given under 5C-13-15 of the *Marine Vessel Rules,* as applicable, and 15/12 of this document.

11 Safety Functions of Fuel Supply Systems

11.1

The fuel supply safety functions are to be in accordance with 5C-13-15/11 of the *Marine Vessel Rules.*

12 Monitoring and Safety Functions

12.1

Monitoring and safety system functions are to be provided in accordance with Tables 1 to 9 of 5C-13-15 of the *Marine Vessel Rules,* as applicable, and Section 15 Table 1 of this document.

TABLE 1
Monitoring and Safety Functions

Parameter[1)]	*Alarm*	*Automatic shutdown of tank valve (valve(s) referred to in 9/5.3)*	*Automatic shutdown of master fuel valve (valve(s) referred to in 9/5.5)*	*Automatic shutdown of bunkering valve*	*Comments*
Hydrogen detection in air locks	X				Gas detectors are to be permanently installed
Hydrogen detection in fuel storage hold space. Two detectors giving 40% of LEL, [2)]	X	X		X	
High oxygen concentration in inert gas supply at 5% O_2	X [3)]				See *MVR* 5C-13-6/14.1
Low oxygen concentration in nitrogen generator or storage compartment	X				See *MVR* 5C-13-6/14.3
Fire detection at bunker station	X			X	See 8/7.2 Automatic shutdown of the Manifold ESD Valves[4)]

(ABS)
Notes:

1; Any alternative arrangement different than required in the table should be given special considered in a case-by-case basis subject to the risk assessment

2; Two independent gas detectors located close to each other are required for redundancy. If the gas detector is a self-monitoring type, the installation of a single gas detector may be permitted

3; If the oxygen content exceeds 5% by volume, the inert gas should be automatically vented to the atmosphere.

4; ESD signal and automatic activation of the ESD valves on the bunker receiving ship to activate automatic shutdown of the ESD valves and supply pumps at the bunker supplier

SECTION 16

Survey, Manufacture, Workmanship and Testing

1 General

1.1

The manufacture, testing, inspection and documentation is to be in accordance with 5C-13-16 and Part 7 of the *Marine Vessel Rules.*

1.2

When required according to 5C-13-16/5 of the *Marine Vessel Rules*, tightness tests for fuel tanks and piping systems are to use helium or a mixture of 5 percent hydrogen and 95 percent nitrogen as the tightness test medium.

2 Survey During Construction

For survey during construction of various equipment and systems, the survey is to include applicable sections of 5C-13, 4-1-1/Tables 1-6 and 5C-8 of the *Marine Vessel Rules.*

3 Survey After Construction

3.1 Annual Survey

For annual survey, the survey is to include applicable sections of 7-6-2/1.7.1 to 7-6-2/1.7.2, 7-6-2/1.9 and 7-6-2/1.13 of the *Marine Vessel Rules.*

Additionally, annual survey is to include:

1) Functional testing of gas evacuation system for fuel preparation room.

2) Functional testing of alarms for monitoring and safety functions.

3) Testing of portable gas detectors for hydrogen.

4) Testing of fixed gas detection for hydrogen.

5) Testing of gas detection:

- *a)* where the auxiliary heat exchange circuits are likely to contain hydrogen in abnormal conditions as a result of a component failure (refer to FMEA for more information) according to 5C-13-9/4.14 of the *Marine Vessel Rules.*
- *b)* where the engines or engine auxiliary systems are likely to contain hydrogen in abnormal conditions as a result of a component failure (refer to FMEA for more information) according to 10/3.6.

6) Examination of electrical equipment in hazardous areas also complies with ISO/IEC 60079-20 Group IIC Class T1 standards or NEC/CEC Group B standards.

7) Examination of ventilation intakes including gas detection system for hydrogen.

8) Examination of all other personnel safety and PPE specific to hydrogen according to 5/10.

3.2 Intermediate Surveys

For intermediate surveys, the survey is to include applicable sections of 7-3-2/3.1.8 of the *Marine Vessel Rules.*

3.3 Special Periodical Surveys

For special surveys, the survey is to include sections of 7-6-2/3.1, 7-6-2/3.7 and 7-6-2/3.9 of the *Marine Vessel Rules* as applicable to hydrogen systems.

SECTION 17

Training, Drills and Emergency Exercises

1 General

1.1

Drills and emergency exercises are to be conducted on board at regular intervals in accordance with 5C-13-17 of the *Marine Vessel Rules*.

1.2

Training is to be conducted in accordance with 5C-13-19 of the *Marine Vessel Rules*, as applicable to hydrogen fuel systems.

1.3

Training is to cover required arrangements and operational procedures specific to hydrogen in accordance with Section 18.

SECTION 18
Operation

1 General

1.1

Operation and maintenance procedures are to be in accordance with 5C-13-18 of the *Marine Vessel Rules.*

1.2

The operational procedures are to include the limitations for machinery space entry and personnel protective equipment detailed under 5/10 and 12/3.3.