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RULES OF SAFETY FOR SHIPS USING HYDROGEN AS A FUEL

Requirements

Ente Nazionale di Ricerca e promozione per la standardizzazione - The National Institution of Italy for Standardization Research and Promotion

ENR

This document (Technical Standard ENR 14002:2021) was drawn up following a contract stipulated between Fincantieri S.p.A. and ENR within the TecBIA project(MISE tender "Major R&D Projects - PON 2014/2020" - Digital Agenda and Sustainable Industry, Ministerial Decree of 1 June 2016, admitted to the concessions with Directorial Decree granting the concessions n. R.0002497 of 2 August 2018). This document contains the drafting of the final project technical regulation for the use of hydrogen as fuel on board ships.

This document (Technical Standard ENR 14002:2021) was drawn up by the Technical Committee for the creation of a voluntary technical standard for the use of hydrogen as fuel on board naval vessels.

This Technical Committee is made up of the following institutions and organizations: The National Institution of Italy for Standardization Research and Promotion (ENR), Fincantieri S.p.A, Isotta Fraschini Motori S.p.A, RINA, CETENA S.p.A.

The drafting by ENR of a technical regulation has allowed the release of the Certificate of Safety and Seaworthiness of the naval prototype IZE (Zero Emissions Boat) with hybrid propulsion.

After an initial verification of the coverage and completeness of the applicable regulatory framework and identification of any regulatory gaps, ENR drafted this regulation on the basis of the experience gained and taking into account the assessments made in the project.

The ENR standards are revised, when necessary, with the publication of new editions or updates. It is therefore important that users of the same make sure they have the latest edition and any updates.

This standard has been drafted trying to take into consideration the points of view of all interested parties to represent the real state of the art of the matter.

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1. PREAMBLE

The purpose of these Rules is to provide a standard for ships using hydrogen as fuel.

The basic philosophy of these Rules is to provide mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems using hydrogen as fuel to minimize the risk to the ship, its crew and the environment, having regard to the nature of the fuel involved.

Throughout the development of these Rules, it was recognized that it is to be based upon sound naval architectural and engineering principles and the best understanding available of current operational experience, field data and research and development.

These Rules address areas that need special consideration for the use of hydrogen as fuel. Goals and functional requirements are specified for each section and form the basis for the ship's design, construction and operation.

The use of hydrogen as fuel in ships requires additional acceptance by the Administration of the State whose flag the ship is entitled to fly on the basis of the alternative design approach as required in paragraph 2.3 of IGF Code.

The references to “fuel”, "gas" and "gas fuel" that are given in the IGF Code, are to be regarded as referring to hydrogen in liquefied or vapour form (except specified otherwise, like "inert gas" or "liquid gas").
All the requirements of these Rules are cross referenced to the applicable Chapters, Sections or paragraphs of the IGF Code, as appropriate.

2. GENERAL

2.1 Application

Unless expressly provided otherwise in the text, these Rules apply to ships using hydrogen as fuel.

2.2 Definitions

Unless otherwise stated below, definitions are as in SOLAS chapter II-2, Rules for Fuel Cells Installation in Ships (FC-SHIPS), Adoption of the International Code of Safety for Ships using gases or other low-flashpoint fuels (IGF Code) and

Amendments to Parts A, C and F of the Rules for the Classification of Ships– Hydrogen fuelled ships.

- *Accident* means an uncontrolled event that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests. (IGF Code 2.2)

- *Breadth* (B) means the greatest moulded breadth of the ship at or below the deepest draught (summer load line draught). (SOLAS II-1/2.8)

- *Bunkering* means the transfer of liquid or gaseous fuel from land based or floating facilities into a ships' permanent tanks or connection of portable tanks to the fuel supply system. (IGF Code 2.2)

- *Certified safe type* means electrical equipment that is certified safe by the relevant recognized authorities for operation in a flammable atmosphere based on a recognized standard. (IGF Code 2.2)

- *CGH2* means compressed gaseous hydrogen. (FC-SHIPS 1.5)

- *Control station* means those spaces defined in SOLAS chapter II-2 and additionally for this Code, the engine control room. (IGF Code 2.2)

- *Design temperature* for selection of materials is the minimum temperature at which liquefied gas fuel may be loaded or transported in the liquefied gas fuel tanks. (IGF Code 2.2)

- *Design vapour pressure "P0"* is the maximum gauge pressure, at the top of the tank, to be used in the design of the tank. (IGF Code 2.2)

- *Double block and bleed valve* means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way valve and a closing valve instead of three separate valves. (IGF Code 2.2)

- *Effluent* means products of combustion plus the excess air being discharged from gas utilization equipment. (FC-SHIPS 1.5)

- *Enclosed space* means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally. (IGF Code 2.2)

- *ESD* means emergency shutdown. (IGF Code 2.2)

- *Essential service*, especially in the case of unconventional arrangements, means main propulsion machinery, auxiliary machinery essential for the power transmission to the 8propulsion, power sufficient to give the ship a navigable speed, ship control, and guarantee the safety of the ship and of the persons on board. (FC-SHIPS 1.5)

- *Explosion* means a deflagration event of uncontrolled combustion. (IGF Code 2.2)

- *Explosion pressure* relief means measures provided to prevent the explosion pressure in a container or an enclosed space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings. (IGF Code 2.2)

- *Fail-safe* is the ability to sustain a failure without causing loss of equipment, injury to personnel or loss of operating time. (FC-SHIPS 1.5)

- *FC* means fuel cell. A fuel cell is a source of electrical power in which the chemical energy of a fuel is converted directly into electrical energy by electrochemical oxidation. A FC installation may consist of one or more FC systems. (FC-SHIPS 1.5)

- *FC system* means the FC, the complete installation of FC fuel containment, FC fuel piping, relevant machinery, electrical and automation systems and the complete system required to transform the energy of the fuel to electric power. (FC-SHIPS 1.5)

- *Filling limit* (FL) means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature (IGF Code 2.2)

- *Fuel cell installation* includes all components required for the production of energy by the FC and the FC ancillary systems, such as the FC system, the FC gas fuel system, the FC water supply system, the FC heat recovery system and the power conversion system. (FC-SHIPS 1.5)

- *Fuel cell module* includes the assembly of one or more FC stacks, electrical connections and systems for command, control and monitoring. (FC-SHIPS 1.5)

- *Fuel cell power system* means a system typically composed by subsystems such as FC module, oxidant processing system, fuel processing system, thermal management system, water treatment system, power conditioning system and relevant control systems. (FC-SHIPS 1.5)

- *Fuel cell space* in this Section is used for machinery spaces containing FC installations. (FC-SHIPS 1.5)

- *Fuel cell stack* consist of an assembly of FC, separators, cooling devices, manifolds and supporting structures that electrochemically converts, typically, hydrogen-rich gas and air reactants to d.c. power, heat, water and other byproducts. (FC-SHIPS 1.5)

- *Fuel containment system* is the arrangement for the storage of fuel including tank connections. It includes where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the fuel storage hold space.

  The spaces around the fuel tank are defined as follows:

1) *Fuel storage hold space* is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space;
2) *Interbarrier space* is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and
3) *Tank connection space* is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces. (IGF Code 2.2)

- *Fuel processing system* means a system that converts and/or conditions the fuel is stored in the on board fuel storage systems into fuel suitable for operation in the FC stack. (FC-SHIPS 1.5)

- *Fuel preparation room* means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes. (IGF Code 2.2)

- *Gas* means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C. (IGF Code 2.2)

- *Gas consumer* means any unit within the ship using gas as a fuel. (IGF Code 2.2)

- *Gas safe spaces* are those spaces considered inherently gas safe under all conditions (normal and abnormal) as a consequence of their arrangement. Specifically, in a gas safe space a single failure cannot lead to release of fuel gas into the space. (FC-SHIPS 1.5)

- *Hazardous area* means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment. (IGF Code 2.2)

- *High pressure* means a maximum working pressure greater than 2.0 MPa. (Rules for the Classification of Ships – Hydrogen fuelled ships 1.3.5)

- *Hydrogen handling system* is the system that processes, conditions, and/or conveys hydrogen - or hydrogen-rich gas - to the FC. (FC-SHIPS 1.5)

- *Independent tanks* are self-supporting, do not form part of the ship's hull and are not essential to the hull strength. (IGF Code 2.2)

- *LEL* means the lower explosive limit. (IGF Code 2.2)

- *Length* (L) is the length as defined in the International Convention on Load Lines in force. (IGF Code 2.2)

- LH2 means liquefied hydrogen gas, but it also means hydrogen vapours. (Rules for the Classification of Ships – Hydrogen fuelled ships 1.3.3)

- *Loading limit* (LL) means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded. (IGF Code 2.2)

- *Low-flashpoint fuel* means gaseous or liquid fuel having a flashpoint lower than otherwise permitted under paragraph 2.1.1 of SOLAS regulation II-2/4. (IGF Code 2.2)

- *MARVS* means the maximum allowable relief valve setting. (IGF Code 2.2)

- M*AWP* means the maximum allowable working pressure of a system component or tank. (IGF Code 2.2)

- *Membrane tanks* are non-self-supporting tanks that consist of a thin liquid and gas tight layer (membrane) supported through insulation by the adjacent hull structure. (IGF Code 2.2)

- *Main tank valve* means a remote operated valve on the FC fuel outlet from a FC fuel storage tank, located as close as possible to the tank outlet point. (FC-SHIPS 1.5)

- *Master fuel valve* means an automatic valve in the FC fuel supply line to each FC located outside the FC space and as close as possible to the fuel storage. (FC-SHIPS 1.5)

- *MH* means metal hydride.

- *Non-hazardous* area means an area in which an explosive gas atmosphere is not expected to be present in quantities such as to require special precautions for the construction, installation and use of equipment. (IGF Code 2.2)

- *Open deck* means a deck having no significant fire risk that at least is open on both ends/sides, or is open on one end and is provided with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side plating or deckhead. (IGF Code 2.2)

- *Oxidant processing system* is a system to treat and process the incoming oxidant (generally air) supply for use within the ranges accepted by the FC module. (FC-SHIPS 1.5)

- *Power conditioning system* consist of the equipment used to adapt the electrical energy produced to the requirements specified by the manufacturer. (FC-SHIPS 1.5)

- *Pressure Relief Valve* is a pressure relief device that opens at a pre-set pressure level and can reclose. (FC-SHIPS 1.5)

- *Risk* is an expression for the combination of the likelihood and the severity of the consequences. (IGF Code 2.2)

- *Reference temperature* means the temperature corresponding to the vapour pressure of the fuel in a fuel tank at the set pressure of the pressure relief valves (PRVs). (IGF Code 2.2)

- *Safe location* means a location (e.g. on open deck) remote from any source of ignition where flammable gases, vapours or liquids can be released to the atmosphere and are expected to be diluted by natural ventilation, without being ventilated in other areas where potential sources of ignitions are present. (FC-SHIPS 1.5)

- *Secondary barrier* is the liquid-resisting outer element of a fuel containment system designed to afford temporary containment of any envisaged leakage of liquid fuel through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level. (IGF Code 2.2)

- *Semi-enclosed space* means a space where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, windbreaks and bulkheads and which are so arranged that dispersion of gas may not occur. (IGF Code 2.2)

- *Source of release* means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere could be formed. (IGF Code 2.2)

- *Thermal management system* are systems to provide cooling and/or heat exchange to maintain thermal equilibrium within the FC power system, as well as the recovery of excess heat and heating the FC during start-up. (FC-SHIPS 1.5)

- *Unacceptable loss of power* means that it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation II-1/26.3. (IGF Code 2.2)

- *Vapour pressure* is the equilibrium pressure of the saturated vapour above the liquid, expressed in MPa absolute at a specified temperature. (IGF Code 2.2.41)

- *Water treatment system* provides the treatment and purification of recovered or added water for use within the FC power systems, as necessary. (FC-SHIPS 1.5)

2.3 Alternative design

(Reference IGF Code Ch. 2, 2.3)

2.3.1 Appliances and arrangements used shall satisfy the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

3. GOAL AND FUNCTIONAL REQUIREMENTS

3.1 Goal

(Reference IGF Code Ch. 3, 3.1)

The goal of these Rules 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.

3.2 Functional requirements

(Reference IGF Code Ch. 3, 3.2)

3.2.1 The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery. A FMEA consistent with the "RINA Guide for FMEA" is to be carried out for the whole hydrogen powered system, including process system, electrical power supplies and control system, to check the potential existence of failure modes that can jeopardize the ship's safety.[1] The results of the FMEA are then to be used to establish a trial program.

3.2.2 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 hydrogen leakage or failure of the risk reducing measures, necessary safety actions shall be initiated.

3.2.3 The design philosophy shall ensure that risk reducing measures and safety actions for the installation of hydrogen as a fuel do not lead to an unacceptable loss of power.

3.2.4 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.

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

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

3.2.7 System components shall be protected against external damages.

1 RINA GUI.3 Guide to perform the failure mode and effect analysis (FMEA) for high speed craft (HSC).

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

3.2.9 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.

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

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

3.2.12 Fuel containment system and machinery spaces containing source that might release hydrogen 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.

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

3.2.14 Fixed hydrogen detection suitable for all spaces and areas concerned shall be arranged.

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

3.2.16 Commissioning, trials and maintenance of fuel systems and machinery for the use of hydrogen shall satisfy the goal in terms of safety, availability and reliability.

3.2.17 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.

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

4. GENERAL REQUIREMENTS

4.1 Goal

(Reference IGF Code Ch. 4, 4.1)

The goal of this chapter 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.

4.2 Risk assessment

(Reference IGF Code Ch. 4, 4.2)

4.2.1 A risk assessment shall be conducted to ensure that risks arising from the use of hydrogen as a fuel and potentially affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration shall be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

4.2.2 For ships to which these Rules applies, the risk assessment required by 4.2.1 need to be conducted:

1. where explicitly required by:
   1) IGF Code paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10, and
   2) paragraphs 4.4 and 6.8 of Annex to IGF Code, and
   3) paragraphs 5.2.1, 5.4.1, 5.10.2, 5.12.2, 6.4.4, 6.5.2, 8.3.2, 8.3.3, 12.5.2, 13.7.1 and 15.7.3 of these Rules, and
2. when other potential hazards connected with the use of hydrogen as fuel are to be addressed.

4.2.3 The risks shall be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock shall as a minimum be considered. The analysis shall ensure that risks are eliminated wherever possible. Risks which cannot be eliminated shall be mitigated as necessary. Details of risks, and the means by which they are mitigated, shall be documented to the satisfaction of the Administration. Guidance on risk analysis techniques can be found in the "RINA Guide on risk analysis".[2]

2 RINA GUI. 15/E Guide for risk analyses.

4.2.4 The assumptions for the risk assessment shall be agreed upon by a team of experts acceptable to the Administration.

4.2.5 The requirements of paragraph 4.2.5 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"The risk assessment can be qualitative or quantitative and is to cover the following aspects:

- *Accidental release and dispersion (scenario for hydrogen leakages due to piping rupture and permeability, hydrogen effects on material e.g. embrittlement or permeation, calculation methods for hydrogen diluition in enclosed space)*
- *Ignition (spontaneous ignition of hydrogen during sudden release, minimum energy for ignition)*
- *Deflagration and detonation (hydrogen explosion hazards due to overpressure)*
- *Fires (jet fire, radiative heat fluxes, fire resistance of hydrogen system)*
- *Impact on people, asset and environment (severity of hydrogen incidents)*
- *Mitigation techniques (detection method, barriers, ventilation level)*
- *Emergency operation (strategy control of incident)*
- *Oxyigen enrichment due to cryogenic hydrogen temperature*

The risk assessment is to include the following hazards:

- *Creation of explosive atmosphere (hydrogen concentration in air)*
- *High flammability*
- *Back firing in pipes*
- *Chemical reaction with oxidant agents*
- *Asphyxiation at high hydrogen concentration and at high inert gas concentration*

- *Hydrogen accumulation on the upper part of spaces*
- *Invisible and very hot flame during H2 burning*
- *Hydrogen embrittlement of metals at high pressure"*

4.3 Limitation of explosion consequences

(Reference IGF Code Ch. 4, 4.3)

4.3.1 The preferred safety policy is to be the elimination of either any source of release or any source of ignition, or both. Only in case this is demonstrated not to be feasible, the following applies.

An explosion in any space containing any potential sources of release and potential ignition sources shall not:

1. cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;
2. damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;
3. damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;
4. disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;
5. damage life-saving equipment or associated launching arrangements;
6. disrupt the proper functioning of firefighting equipment located outside the explosion-damaged space;
7. affect other areas of the ship in such a way that chain reactions involving, inter alia, hydrogen and bunker oil may arise; or
8. prevent persons access to life-saving appliances or impede escape routes.

5. SHIP DESIGN AND ARRANGEMENT

5.1 Goal

(Reference IGF Code Ch. 5, 5.1)

The goal of this chapter is to provide for safe location, space arrangements and mechanical protection of power generation equipment, hydrogen storage systems, hydrogen supply equipment and refuelling systems.

5.2 Functional requirements

(Reference IGF Code Ch. 5, 5.2)

5.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.1 to 3.2.3, 3.2.5, 3.2.6, 3.2.8, 3.2.12 to 3.2.15 and 3.2.17. In particular the following apply:

1. the hydrogen tank(s) shall be located in such a way that the probability for the tank(s) to be damaged following a collision or grounding is reduced to a minimum taking into account the safe operation of the ship and other hazards that may be relevant to the ship. The location of the hydrogen tank(s) shall therefore be chosen upon satisfactory consideration in the context risk analysis;

2. hydrogen containment systems, hydrogen piping and other sources of hydrogen release shall be so located and arranged that released hydrogen is lead to a safe location in the open air;

3. the access or other openings to spaces containing hydrogen sources of release shall be so arranged that hydrogen cannot escape to spaces that are not designed for its presence;

4. hydrogen piping shall be protected against mechanical damage;

5. the propulsion and hydrogen supply system shall be so designed that safety actions after any hydrogen leakage do not lead to an unacceptable loss of power; and

6. the probability of an explosion in a machinery space with hydrogen-fuelled machinery shall be minimized.

5.2.2 The requirements of chapter 5 of the RINA FC-SHIPS Regulation apply. In particular:

"FC spaces where hydrogen may be present are to be arranged with a smooth ceiling sloping up towards the ventilation outlet, without obstructing structures where explosive mixtures could accumulate. Support structures (e.g. girders, stiffeners) are to be facing outwards the spaces. Thin plate ceilings covering the support structures under the deck plating are not to be accepted."

5.2.3 For any new or altered concept / arrangement / configuration a risk analysis are to be carried out as outlined in Section 2 of RINA FC-SHIPS, to identify the hazards, failure modes and consequences associated with design, operation and maintenance of FC installation on board.

5.2.4 The use of hydrogen as FC fuel is to always be specially evaluated by the Administration, following a risk based approach as outlined in Section 2 of RINA FC-SHIPS.

5.3 General rules

(Reference IGF Code Ch. 5, 5.3)

5.3.1 Hydrogen storage tanks shall be protected against mechanical damage.

5.3.2 Equipment on the open deck shall be located to prevent accumulation of escaped hydrogen.

5.3.3 The requirements of paragraphs 5.3.3 to 5.3.5 of chapter 5 of the IGF Code apply.

5.4 Machinery space concepts

(Reference IGF Code Ch. 5, 5.4)

5.4.1 In a machinery space with hydrogen-fuelled machinery, in order to minimize the probability of an explosion, one of these two alternative concepts may be applied:

1. Gas safe machinery spaces: only gas safe machinery concept is allowed, such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

   In a gas safe machinery space a single failure cannot lead to release of fuel gas into the machinery space.

2. Consideration may be given to accept an ESD protected machinery space on ships below 100 GT, provided that the arrangement is considered in the risk assessment.[3]

5.5 Regulations for gas safe machinery space

(Reference IGF Code Ch. 5, 5.5)

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

5.5.2 All fuel piping within machinery space boundaries shall be enclosed in a gas tight enclosure in accordance with paragraph 9.6 of IGF Code.

5.6 Regulations for ESD-protected machinery spaces

(Reference IGF Code Ch. 5, 5.6)

5.6.1 ESD protected Machinery spaces are generally not acceptable and paragraph 5.4.1 applies.

5.7 Regulations for the location and protection of hydrogen piping

(Reference IGF Code Ch. 5, 5.7)

5.7.1 Hydrogen pipes shall not be located less than 800 mm from the ship's side.

5.7.2 Hydrogen piping shall not be led directly through accommodation spaces, service spaces, electrical equipment rooms or control stations as defined in the SOLAS Convention.

5.7.3 Hydrogen pipes led through ro-ro spaces, special category spaces and on open decks shall be protected against mechanical damage.

5.7.4 Hydrogen gas piping in ESD protected machinery spaces shall be located as far as practicable from the electrical installations and tanks containing flammable liquids.

5.7.5 Hydrogen gas piping in ESD protected machinery spaces shall be protected against mechanical damage.

[3] RINA Amendments to Parts A, C and F of the Rules for the Classification of Ships – Hydrogen fuelled ships.

5.8 Regulations for fuel preparation room design

(Reference IGF Code Ch. 5, 5.8)

5.8.1 The requirements of paragraphs 5.8 of chapter 5 of the IGF Code apply.

5.9 Regulations for bilge systems

(Reference IGF Code Ch. 5, 5.9)

5.9.1 The requirements of paragraph 5.9.1 to 5.9.3 of chapter 5 of the IGF Code apply.

5.10 Regulations for drip trays

(Reference IGF Code Ch. 5, 5.10)

5.10.1 The requirements of paragraph 5.10.1 to 5.10.5 of chapter 5 of the IGF Code apply.

5.10.2 The requirements of paragraph 5.10.2 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"The risk assessment is to follow the steps outlined below.

a) *The team of experts is to conduct a Hazard Identification (HAZID) to agree on the scenarios to be subjected to the risk assessment, and on the assumptions regarding the most critical events (typically, connection failures causing an hydrogen release) considering also available internationally recognized standard (e.g. ISO/TR 15916) for the identification of hazards and risks.*

b) *Reasonable assumptions on the extent of connection failures or other selected events and the process parameters of the hydrogen are to be made by the team of experts, preferably on the basis of statistics available in the public domain or provided and documented by stakeholders.*

c) *Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the affected space.*

d) *In order to verify that the hydrogen release will not create flammable concentrations and to demonstrate the drip tray capacity for a hydrogen cryogenic spill, a specific simulation is to be set up, aimed at evaluating the maximum amount of hydrogen spilled and its cloud, the evaporation rate and the possibility to fully accommodate the liquid hydrogen in the drip* *tray. The dispersion of vapors resulting from hydrogen evaporation in the affected space is also to be ascertained in respect of explosive atmosphere.*

e) *The simulation is to be conducted by commercially available and validated tools (typically, by CFD tools). It is to focus on the calculation of the amount of hydrogen spilled before the stop of hydrogen flow. Other calculation methods (e.g. empirical formulas based on literature) will be subject to special consideration.*

f) *As a precaution, in order to maximize the accumulation of hydrogen into the drip tray, hydrogen release is to be assumed as directed downward, impinging on the drip tray, and ambient temperature is to be set to the minimum credible winter temperature. Equipment and space surfaces and drip tray are to be considered adiabatic, to conservatively minimize the heat exchange with the hydrogen droplets, and to increase the amount of liquid accumulated in the drip tray.*

g) *Reasonable assumptions are to be made by the expert team regarding detection time, hydrogen flow stop time and human reaction time, in case operators are credited in the emergency.*

h) *If the simulation demonstrates that the drip tray cannot accommodate the hydrogen spill, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction."*

5.11 Regulations for arrangement of entrances and other openings in enclosed spaces

(Reference IGF Code Ch. 5, 5.11)

5.11.1 The requirements of paragraph 5.11.1 to 5.11.5 of chapter 5 of the IGF Code apply.

5.12 Regulations for airlocks

(Reference IGF Code Ch. 5, 5.12)

5.12.1 The requirements of paragraph 5.12.1 to 5.12.7 of chapter 5 of the IGF Code apply.

5.12.2 The requirements of paragraph 5.12.2 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"In the context of the risk assessment required in IGF Code 5.12.3, the team of experts is to conduct a Hazard Identification (HAZID) to agree on the worst scenario for hydrogen release including the configuration of the airlocks.

In order to assess the structural integrity of the room and the suitability of the designed airlock, the maximum pressure within the spaces identified by the HAZID has to be evaluated, considering the effectiveness of the ventilation system. This calls for a simulation by means of the tools mentioned in [5.10.2]. The following steps, as a minimum, are to be performed.

a) *Representative accidental scenarios of loss of hydrogen from failures in process or containment systems are to be selected by the team of experts in the identified spaces. The simulation is to focus on the calculation of the amount of hydrogen spilled before the stop of the hydrogen flow.*

b) *Reasonable assumptions on the extent of containment failure and the process parameters of the hydrogen are to be made by the team of experts, preferably based on statistics available in the public domain or provided and documented by stakeholders.*

c) *Reasonable assumptions on the operation of ventilation system are to be made according to layout and procedures of the selected spaces.*

d) *As a precaution, in order to maximize the accumulation of hydrogen onto the space floor, hydrogen release is to be directed downward, impinging on the floor, and ambient temperature is to be set to the maximum credible summer temperature in the space. The surfaces are to be considered isothermal at ambient temperature, to conservatively increase the evaporation rate and, consequently, the pressure buildup.*

e) *Reasonable assumptions are to be made by the team of experts regarding detection time, hydrogen flow stop time and human reaction time, in case operators are credited in the emergency.*

If the simulation demonstrates that the analysed airlocks cannot prevent gas release in safe space, mitigating measures are to be provided and subjected to the same simulation process, to appreciate the risk reduction.

6. HYDROGEN CONTAINMENT SYSTEM

6.1 Goal

(Reference IGF Code Ch. 6, 6.1)

The goal of this chapter is to provide that hydrogen 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 or natural gas-fuelled ship.

6.2 Functional requirements

(Reference IGF Code Ch. 6, 6.2)

6.2.1 This chapter relates to functional requirements in IGF Code paragraphs 3.2.1, 3.2.2, 3.2.5 and 3.2.8 to 3.2.17. In particular the following apply:

1. the hydrogen containment system shall be so designed that a leak from the tank or its connections does not endanger the ship, persons on board or the environment. Potential dangers to be avoided include:

   1) exposure of ship materials to temperatures below acceptable limits;
   2) hydrogen that spreads to locations with ignition sources;
   3) toxicity potential and risk of oxygen deficiency due to fuels and inert gases;
   4) restriction of access to shaller stations, escape routes and ife-saving appliances (LSA); and
   5) reduction in availability of LSA.

2. the pressure and temperature in the hydrogen tank shall be kept within the design limits of the containment system and possible carriage requirements of the fuel;

3. the hydrogen containment arrangement shall be so designed that safety actions after any hydrogen leakage do not lead to an unacceptable loss of power;

4. if portable tanks are used for hydrogen storage, the design of the fuel containment system shall be equivalent to permanent installed tanks as described in this chapter.

6.3 General rules

(Reference IGF Code Ch. 6, 6.3)

6.3.1 The requirements of paragraph 6.3.2, 6.3.3 and 6.3.5 to 6.3.12 of chapter 6 of the IGF Code apply.

6.3.2 All tank connections, fittings, flanges and tank valves shall be enclosed in a tank connection spaces which is gastight toward other enclosed spaces, including tank connections. When the fuel storage tank is in an enclosed space, the tank connection space is to be gastight toward other spaces.

6.3.3 The storage of any kind of goods in the MH rooms shall be avoided.

6.4 Regulations for metal hydrides storage tanks

6.4.1 Hydrogen in the context of these Rules is stored in the form of metal hydrides.

The chemical containment system using metal hydrides consists of a group of pressure vessels supported by rack whereby the hydrogen is absorbed in the metal hydrides (metal powder). The following requirements are applicable to systems with design pressure up to 10 MPa.[4]

6.4.2 The requirements of paragraph 6.6.4 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"The rack supporting the pressure vessels and its connection to adjacent structure are to be designed taking into account at least the following loads as defined in IGF code 6.4.9.3.3 and 6.4.9.4:

- *thermally induced loads if any*
- *vibration*
- *hull interaction*
- *weight of containment system*
- *static heel*
- *wind impact, wave impact, green sea effects and ice for installations on open deck*
- *loads due to ship motion*
- *collision load."*

[4] RINA Amendments to Parts A, C and F of the Rules for the Classification of Ships – Hydrogen fuelled ships.

6.4.3 Other hydrogen storage methods will be evaluated on a case by case basis, for justified reasons and upon satisfactory consideration in the context of risk analysis.

6.4.4 The requirements of chapter 6.3.1 of the RINA FC-SHIPS Regulation apply. In particular:

"The risks related to the storage of hydrogen as fuel with respect to collision and potential storage under accommodation spaces are to be specifically evaluated."

6.5 Regulations for pressure relief system

(Reference IGF Code Ch. 6, 6.7)

6.5.1 The requirements of paragraph 6.7.1 and 6.7.3 of chapter 6 of the IGF Code apply.

6.5.2 The sizing of pressure relief systems is to be determined according to international recognized standard where the discharge conditions shall to be defined during the risk assessment taking into account the arrangement and location of containment system.

6.6 Regulations for the maintaining of fuel storage condition

(Reference IGF Code Ch. 6, 6.9)

6.6.1 Venting of fuel vapour for control of the tank pressure is not acceptable except in emergency situations. The activation of the safety system alone is not deemed as an emergency situation.

6.6.2 The requirements of paragraph 6.9.2 and 6.9.4 to 6.9.6 of chapter 6 of the IGF Code apply.

6.7 Regulations on inerting

(Reference IGF Code Ch. 6, 6.13)

6.7.1 The requirements of paragraph 6.13 of chapter 6 of the IGF Code apply.

6.7.2 The spaces where the inert gas double block and bleed valves and closable non-return valve are fitted are to be classified as a Zone 1 hazardous spaces.

6.8 Regulations on inert gas production and storage on board

(Reference IGF Code Ch. 6, 6.14)

6.8.1 The requirements of paragraph 6.14 of chapter 6 of the IGF Code apply.

7. MATERIAL AND GENERAL PIPE DESIGN

7.1 Goal

(Reference IGF Code Ch. 7, 7.1)

The goal of this chapter is to ensure the safe handling of hydrogen, 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.

7.2 Functional requirements

(Reference IGF Code Ch. 7, 7.2)

7.2.1 This chapter relates to functional requirements in IGF Code paragraphs 3.2.1, 3.2.5, 3.2.6, 3.2.8, 3.2.9 and 3.2.10. In particular the following apply:

7.2.1.1 Hydrogen piping shall be capable of absorbing thermal expansion or contraction caused by extreme hydrogen temperatures without developing substantial stresses.

7.2.1.2 Provision shall be made to protect the piping, piping system and components and hydrogen tanks from excessive stresses due to thermal movement and from movements of the hydrogen tanks and hull structure.

7.2.1.3 The requirements of paragraph 7.2.1.3 and 7.2.1.4 of chapter 7 of the IGF Code apply.

7.2.1.4 Oxygen condensation on the surface of low temperature piping is to be prevented.

7.2.1.5 The requirements of chapter 6.1 of the RINA FC-SHIPS Regulation apply. In particular:

"All components in contact with hydrogen are to be made of materials compatible with this element, in particular with respect to embrittlement and hydrogen chemical reactions.

Information on material suitability and compatibility with hydrogen are contained in the International Standards (ISO, IEC or other equivalent).

Austenitic stainless steel – such as 304, 316, 304L and 316L – is to be used for materials in contact with hydrogen. Other materials compatible for storage and transport of hydrogen may be approved after special consideration and/or testing, subject to the submission of the relevant documentation.

When hydrogen is present as compressed gas, its temperature in normal operating conditions is considered to remain in a range between -40°C and +85°C and therefore the normal operating temperature range for materials used in hydrogen components is to be at least the same.

Different temperature ranges may be approved after special consideration and/or testing."

7.3 Regulations for general pipe design

(Reference IGF Code Ch. 7, 7.3)

7.3.1 The requirements of paragraph 7.3.1.1 to 7.3.1.6 of chapter 7 of the IGF Code apply.

7.3.2 The requirements of paragraph 7.3.1 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"Fuel pipes in spaces made gas safe are not to include expansion joints, flexible hoses, bellows or other pipe components with poorer strength, fatigue or leakage properties than the fully welded pipe. The use of metallic flexible components can be only allowed if of double walled type, designed and tested in accordance with international recognized standard and where the sufficient flexibility of piping system cannot be granted with other methods."

7.3.3 The requirements of paragraph 7.3.3 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"Butt welded connections of piping are to be used. Bolted flange connections of piping may be used where welded connections are not feasible.

Threaded connections complying with recognized standards may only be used for accessory lines and instrumentation lines with external diameters of 25 mm or less. The threaded connections are to have an increased pipe thickness and higher nominal pressure (PN). For external diameters diameters exceeding 25 mm and up *to 50 mm the use will be case by case evaluated by the Society considering the arrangement and the rupture risks.*

In any case, threaded connections are to be in accordance with standards approved by the Society, and the use will be specially evaluated by the Society.

Heat treatment post welding is to be required for all butt welds of pipes made of carbon, carbon manganese and low-alloy steels. The Society may waive the recommendation for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system."

7.3.4 The requirements of chapter 6.2 of the RINA FC-SHIPS Regulation apply. In particular:

"In general, hydrogen pipes are to be located in well ventilated spaces, and are to be fully welded, as far as practicable, depending on their diameter (e.g. less than 25mm). For hydrogen pipes, the double wall principle used to make a surrounding space nonhazardous, is only acceptable pending special consideration from the Society."

7.4 Regulations for materials

(Reference IGF Code Ch. 7, 7.4)

7.4.1 The requirements of paragraph 7.4.1.1 to 7.4.1.5 of chapter 7 of the IGF Code apply.

7.4.2 The materials adopted for the entire system shall be suitable for hydrogen applications.

7.4.3 It is to be ensured that deterioration (ageing) of material will not affect its resistance capacity to hydrogen embrittlement.

7.4.4 Materials of construction and ancillary equipment such as insulation are to be resistant to the effects of high oxygen concentrations.

8. BUNKERING

8.1 Goal

(Reference IGF Code Ch. 8, 8.1)

The goal of this chapter 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.

8.2 Functional requirements

(Reference IGF Code Ch. 8, 8.2)

8.2.1 This chapter relates to functional requirements in IGF Code paragraphs 3.2.1 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply: all bunkering operations shall be carried out in such a way that any hydrogen leaks cannot cause dangers to personnel, the environment or the ship.

8.2.2 The requirements of chapter 6.3.4 of the RINA FC-SHIPS Regulation apply. In particular:

"The risk analysis shall take into account the influence of hydrogen properties on the definition of hazardous zones and the minimum safety distances."

8.3 Regulations for bunkering station

(Reference IGF Code Ch. 8, 8.3)

8.3.1 The requirements of paragraph 8.3 of chapter 8 of the IGF Code apply.

8.3.2 A detailed procedure shall be developed with clear instructions for safe bunkering operations in the contest risk analysis (including the case of refilling of a single MH storage rack while the other is operating and feeding the functioning FC system).

8.3.3 A detailed procedure shall be developed with clear instructions for safe bunkering operations in the contest risk analysis (including the case of refilling of a single MH storage rack while the other is operating and feeding the functioning FC system).

8.4 Regulations for manifold

(Reference IGF Code Ch. 8, 8.4)

8.4.1 The requirements of paragraph 8.4 of chapter 8 of the IGF Code apply.

8.5 Regulations for bunkering system

(Reference Rules for the Classification of Ships – Hydrogen fuelled ships Ch. 8, 8.5)

8.5.1 The requirements of paragraph 8.5 of chapter 8 of the Rules for the Classification of Ships – Hydrogen fuelled ships apply.

9. FUEL SUPPLY TO CONSUMERS

9.1 Goal

(Reference IGF Code Ch. 9, 9.1)

The goal of this chapter is to ensure safe and reliable distribution of hydrogen to the consumers.

9.2 Functional requirements

(Reference IGF Code Ch. 9, 9.2)

9.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.1 to 3.2.6, 3.2.8 to 3.2.11 and 3.2.13 to 3.2.17. In particular the following apply:

1. the hydrogen supply system shall be so arranged that the consequences of any release of hydrogen will be minimized, while providing safe access for operation and inspection;

2. the piping system for hydrogen transfer to the consumers shall be designed in a way that a failure of one barrier cannot lead to a leak from the piping system into the surrounding area causing danger to the persons on board, the environment or the ship; and

3. hydrogen lines outside the machinery spaces shall be installed and protected so as to minimize the risk of injury to personnel and damage to the ship in case of leakage.

9.2.2 The requirements of chapter 6.3.2 of the RINA FC-SHIPS Regulation apply. In particular:
"If hydrogen is selected as primary FC fuel, the piping system and the relevant valves, fittings and components are to comply with the requirements of the previous items and the applicable recognize international standards for hydrogen handling."

9.3 Regulations on redundancy of fuel supply

(Reference IGF Code Ch. 9, 9.3)

9.3.1 The requirements of paragraph 9.3 of chapter 9 of the IGF Code apply.

9.4 Regulations on safety functions of gas supply system

(Reference IGF Code Ch. 9, 9.4)

9.4.1 The requirements of paragraph 9.4 of chapter 9 of the IGF Code apply.

9.5 Regulations for fuel distribution outside of machinery space

(Reference IGF Code Ch. 9, 9.5)

9.5.1 Where hydrogen pipes pass through enclosed spaces in the ship, they shall be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system shall be mechanically underpressure ventilated with 30 air changes per hour, and gas detection as required in paraghaph 15.8 of IGF Code shall be provided. In case of low temperatures in the annular space of piping, the ventilation is to be made by dry air. Other solutions providing an equivalent safety level may also be accepted by the Administration (e.g. use of pressurized inert gas in the double wall annular space).

9.5.2 The requirement in 9.5.1 need not be applied for fully welded open ended fuel gas vent pipes led through mechanically ventilated spaces nor for fully welded fuel gas pipes on the open deck.

9.5.3 The requirements of chapter 6.3.2 of the RINA FC-SHIPS Regulation apply. In particular:

"Routing of hydrogen pipes outside of machinery spaces is normally not accepted, however it can be considered only if these spaces are defined as gas hazardous, i.e. all equipment located inside are spark proof and certified safe for hydrogen atmosphere. Such spaces are required to have a ventilation system and ventilation rate as for FC fuel spaces with open hydrogen pipes, and the spaces are to have a simple geometrical shape to prevent any accumulation of explosive gases."

9.6 Regulations for fuel supply to consumers in gas-safe machinery spaces

(Reference IGF Code Ch. 9, 9.6)

9.6.1 The requirements of paragraph 9.6 of chapter 9 of the IGF Code apply.

9.7 Regulations for gas fuel supply to consumers in ESD-protected machinery spaces

9.7.1 ESD protected Machinery spaces are generally not acceptable and paragraph 5.4.1 applies.

9.8 Regulations for the design of ventilation duct, outer pipe against inner pipe gas leakage

(Reference IGF Code Ch. 9, 9.8)

9.8.1 The design pressure of the outer pipe or duct of fuel systems shall not be less than the maximum working pressure of the inner pipe. Alternatively for fuel piping systems with a working pressure greater than 1.0 MPa, the design pressure of the outer pipe or duct shall not be less than the maximum built up pressure arising in the annular space considering the higher of the following:

1. the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;
2. the local instantaneous peak pressure in way of any rupture considering the ventilation arrangements.

9.8.2 The tangential membrane stress of a straight pipe shall not exceed the tensile strength divided by 1.5 (Rm/1.5) when subjected to the above pressures. The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure, the peak pressure found from representative tests can be used. Test reports shall then be submitted.

9.8.3 The requirements of paragraph 9.8.3 to 9.8.4 of chapter 9 of the IGF Code apply.

9.9 Regulations for compressors and pumps

(Reference IGF Code Ch. 9, 9.9)

9.9.1 The requirements of paragraph 9.8 of chapter 9 of the IGF Code apply.

9.9.2 The requirements of paragraph 9.9.2 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"Motors driving hydrogen compressors and pumps are to be of a type certified as suitable for operation in an explosive atmosphere (Hazardous area Zone 1) due to

the presence of hydrogen, even when placed in a motor room separated from the compressors by a gastight bulkhead or deck, unless the motor room is equipped with a ventilation system having a capacity of 30 air changes per hour being continuously operated when the motors are energized. Suitable interlocks and alarms are to be provided to stop and prevent the start of the motors in case of loss of ventilation. Avoidance of unacceptable loss of power as defined in IGF Code 2.2.40 is anyway to be ensured by automatically starting a stand-by motor."

9.10 Regulations for purging

9.10.1 The requirements of chapter 6.3.2 of the RINA FC-SHIPS Regulation apply. In particular:

"FC components containing hydrogen are to be purged with an inert gas before and after operation."

10. POWER GENERATION INCLUDING PROPULSION AND OTHER GAS CONSUMERS

10.1 Goal

(Reference IGF Code Ch. 10, 10.1)

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

10.2 Functional requirements

(Reference IGF Code Ch. 10, 10.2)

10.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.1, 3.2.11, 3.2.13, 3.2.16 and 3.2.17. In particular the following apply:

1. the exhaust systems shall be configured to prevent any accumulation of un-reacted hydrogen;

2. unless designed with the strength to withstand the worst case over pressure due to hydrogen leaks, engine components or systems containing or likely to contain an ignitable hydrogen and air mixture shall be fitted with suitable pressure relief systems. Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

3. the explosion venting shall be led away from where personnel may normally be present; and

4. all gas consumers shall have a separate exhaust system.

10.2.2 The requirements of chapter 7.1 of the RINA FC-SHIPS Regulation apply. In particular:

“Hydrogen will be present through all the process lines between the reforming unit and the FC modules / stacks, although these lines may be very short in case of integrated reformer and FC modules.

Hydrogen safety concerns will always be present in form of possible accumulation of un-burnt gaseous fuel, FC fuel over pressure due to ignited gas leaks and explosion hazards.”

In addition:

“The safety aspects concerning any possible release of hydrogen within the FC system is to be specifically considered, with reference to:
- Installation and use within a FC room of equipment not protected against explosion;
- Effectiveness of minimum ventilation rate and flow dynamics to avoid gas concentrations in the flammable range in all leakage scenarios within the FC compartment and double wall piping.
- Safety requirements for batteries used in the context of hydrogen FC systems.
- Critical scenarios of hydrogen ignition sources, fire and explosion behaviour and risk controlling measures.
- Components and material properties.
- Structural strength / resilience of bulkheads and decks to withstand explosions vs. use of explosion hatches or pressure release panels.”

10.2.3 The requirements of chapter 7.6 of the RINA FC-SHIPS Regulation apply. In particular:

“A detection system of FC hydrogen leaks is to be provided - in accordance with ISO 26142:2010 Hydrogen detection apparatus Stationary applications, or equivalent international standard - to measure and monitor hydrogen concentrations in FC systems.

One or more independent additional detection systems are to be installed for multilevel safety operations, i.e. including nitrogen purging or ventilation and/or system shut-off, depending on the measured hydrogen concentration.

The hydrogen detection system details are to be submitted, including precision of the system, measuring range, response time, stability, selectivity, etc."

10.3 Regulations for internal combustion engines of piston type

(Reference IGF Code Ch. 10, 10.3)

10.3.1 The requirements of paragraph 10.3 of chapter 10 of the IGF Code apply.

10.3.2 The requirements of paragraph 9.9.2 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"For hydrogen fuelled engines where the space below the piston is in direct communication with the crankcase, a crankcase forced ventilation is required, having the inlet from open areas that, in the absence of the considered inlet, would be non-hazardous and going to a dedicated duct having a hydrogen detection system.
The gas extracted from auxiliary systems media is to be vented to a safe location in the atmosphere. In the vent line a gas detection is to be installed for monitoring/ alarm function."

10.4 Regulations for main and auxiliary boilers

(Reference IGF Code Ch. 10, 10.4)

10.4.1 The requirements of paragraph 10.4 of chapter 10 of the IGF Code apply.

10.5 Regulations for gas turbines

(Reference IGF Code Ch. 10, 10.5)

10.5.1 The requirements of paragraph 10.5 of chapter 10 of the IGF Code apply.

10.6 Regulations for Fuel Cell

10.6.1 For the installation of fuel cells, the requirements available in the RINA Regulation for the installation of fuel cells in ships (FC-Ships) apply.

11. FIRE SAFETY

11.1 Goal

(Reference IGF Code Ch. 11, 11.1)

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

11.2 Functional requirements

(Reference IGF Code Ch. 11, 11.2)

11.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.2, 3.2.4, 3.2.5, 3.2.7, 3.2.12, 3.2.14, 3.2.15 and 3.2.17.

11.3 General rules for fire protection

(Reference IGF Code Ch. 11, 11.3)

11.3.1 The requirements of paragraphs 11.3.1 to 11.3.2 and 11.3.5 to 11.3.7 of chapter 11 of the IGF Code apply.

11.3.2 The space containing MH storage tanks shall be separated from the machinery spaces of category A or other rooms with high fire risks. The separation shall be done by a cofferdam of at least 900 mm with insulation of A-60 class. When determining the insulation of the space containing MH storage tanks from other spaces with lower fire risks, MH storage tanks shall be considered as a machinery space of category A, in accordance with SOLAS regulation II-2/9. The boundary between spaces containing MH storage tanks shall be either a cofferdam of at least 900 mm or A-60 class division. For type C tanks, the fuel storage hold space may be considered as a cofferdam.

11.3.3 Metal hydride room shall not be used for machinery or equipment that may have a fire risk.

11.4 Regulations for fire main

(Reference IGF Code Ch. 11, 11.4)

11.4.1 The requirements of paragraphs 11.4 of chapter 11 of the IGF Code apply.

11.4.2 The fire-extinguishing system shall be suitable for use with hydrogen fires (e.g. Novec 1230).

11.4.3 It shall be ensured that the installed fire fighting system does not act as an ignition source e.g. producing static electricity.

11.5 Regulations for water spray system

(Reference IGF Code Ch. 11, 11.5)

11.5.1 The requirements of paragraphs 11.5 of chapter 11 of the IGF Code apply.

11.6 Regulations for dry chemical powder fire-extinguishing system

(Reference IGF Code Ch. 11, 11.6)

11.5.1 The requirements of paragraphs 11.6 of chapter 11 of the IGF Code apply.

11.7 Regulations for fire detection and alarm system

(Reference IGF Code Ch. 11, 11.7)

11.7.1 The requirements of paragraphs 11.7 of chapter 11 of the IGF Code apply.

11.7.2 The requirements of chapter 9.4 of the RINA FC-SHIPS Regulation apply. In particular:

"Hydrogen fire detection is to be specifically addressed - hydrogen fire produces no smoke, little heat radiation and an almost invisible flame in daylight.

12. EXPLOSION PREVENTION

12.1 Goal

(Reference IGF Code Ch. 12, 12.1)

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

12.2 Functional requirements

(Reference IGF Code Ch. 12, 12.2)

12.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.2 to 3.2.5, 3.2.7, 3.2.8, 3.2.12 to 3.2.14 and 3.2.17. In particular the following apply:

The probability of explosions shall be reduced to a minimum by:

1. reducing number of sources of ignition; and

2. reducing the probability of formation of ignitable mixtures.

12.3 General rules

(Reference IGF Code Ch. 12, 12.3)

12.3.1 The requirements of paragraphs 12.3 of chapter 12 of the IGF Code apply.

12.4 Regulations on area classification

(Reference IGF Code Ch. 12, 12.4)

12.4.1 The requirements of paragraphs 12.4 of chapter 12 of the IGF Code apply.

12.5 Hazardous area zones

(Reference IGF Code Ch. 12, 12.5)

12.5.1 The requirements of paragraphs 12.5 of chapter 12 of the IGF Code apply.

12.5.2 The extensions and types (Zone 0, Zone 1, Zone 2) of hazardous areas in way of outlet from the pressure relief valves are to be evaluated in the context of the risk assessment.

12.5.3 The requirements of paragraph 12.5.3 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"a) Fuel storage hold spaces containing Type C tanks with all potential leakage sources in a tank connection space and having no access to any hazardous area, are to be considered as non-hazardous.

b) Where the fuel storage hold spaces include potential leak sources, e.g. tank connections, they are to be considered hazardous area zone 1.

c) Where the fuel storage hold spaces included bolted access to the tank connection space, they are to be considered hazardous are zone 2."

13. VENTILATION

13.1 Goal

(Reference IGF Code Ch. 13, 13.1)

The goal of this chapter is to provide for the ventilation required for safe operation of hydrogen-fuelled machinery and equipment.

13.2 Functional requirements

(Reference IGF Code Ch. 13, 13.2)

13.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.2, 3.2.5, 3.2.8, 3.2.10, 3.2.12 to 3.2.14 and 3.2.17.

13.3 General rules

(Reference IGF Code Ch. 13, 13.3)

13.3.1 The requirements of paragraphs 13.3 of chapter 13 of the IGF Code apply.

13.3.2 Areas where fuel can be present are to be provided with suction points of the mechanical exhaust system fitted in the high part of the space, where hydrogen is likely to accumulate.

13.3.3 The requirements of chapter 6.4 of the RINA FC-SHIPS Regulation apply. In particular:

"Electric fan motors are not to be located in ventilation ducts serving spaces containing hydrogen installations. Ventilation units are to have a safe bonding to the hull."

In addition:

"In spaces containing hydrogen, the ventilation rate is to be sufficient to avoid gas concentration within the flammable range in all leakage scenarios, including pipe rupture.
This is also applicable to spaces containing fully welded hydrogen pipes.
The geometry of ventilation ducts from spaces containing hydrogen piping or other hydrogen release sources, is to be simple, possibly vertical and steadily ascending, to minimize the risk of gas accumulation."

13.4 Regulations for tank connection space

(Reference IGF Code Ch. 13, 13.4)

13.4.1 The requirements of paragraphs 13.4 of chapter 13 of the IGF Code apply

13.5 Regulations for machinery spaces

(Reference IGF Code Ch. 13, 13.5)

13.5.1 The requirements of paragraphs 13.5 of chapter 13 of the IGF Code apply.

13.6 Regulations for fuel preparation room

(Reference IGF Code Ch. 13, 13.6)

13.6.1 The requirements of paragraphs 13.6 of chapter 13 of the IGF Code apply.

13.7 Regulations for bunkering station

(Reference IGF Code Ch. 13, 13.7)

13.7.1 Bunkering station are to be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment.

13.8 Regulations for ducts and double pipes

(Reference IGF Code Ch. 13, 13.8)

13.8.1 The requirements of paragraphs 13.8 of chapter 13 of the IGF Code apply.

13.8.2 The requirements of paragraphs 13.8.2 and 13.8.3 of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply. In particular:

"The ventilation system for double piping and for gas valve unit spaces in gas safe engine rooms is to be independent of all other ventilation systems except other fuel supply ventilation systems.

The ventilation inlet for the double wall piping or duct is always to be located in a non hazardous area in open air away from ignition sources. The inlet opening is to be fitted with a suitable wire mesh guard and protected from ingress of water."

14. ELECTRICAL INSTALLATIONS

14.1 Goal

(Reference IGF Code Ch. 14, 14.1)

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

14.2 Functional requirements

(Reference IGF Code Ch. 14, 14.2)

14.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.1, 3.2.2, 3.2.4, 3.2.7, 3.2.8, 3.2.11, 3.2.13 and 3.2.16 to 3.2.18. In particular the following apply:

Electrical generation and distribution systems, and associated control systems, shall be designed such that a single fault will not result in the loss of ability to maintain the pressures of the MH storage tank and hull structure temperature within normal operating limits.

14.3 General rules

(Reference IGF Code Ch. 14, 14.3)

14.3.1 The requirements of paragraphs 14.3 of chapter 14 of the IGF Code apply.

15. CONTROL, MONITORING AND SAFETY SYSTEM

15.1 Goal

(Reference IGF Code Ch. 15, 15.1)

The goal of this chapter is to provide for the arrangement of control, monitoring and safety systems that support an efficient and safe operation of the hydrogen-fuelled installation as covered in the other chapters of these Rules.

15.2 Functional requirements

(Reference IGF Code Ch. 15, 15.2)

15.2.1 This chapter is related to functional requirements in IGF Code paragraphs 3.2.1, 3.2.2, 3.2.11, 3.2.13 to 3.2.15, 3.2.17 and 3.2.18. In particular the following apply:

1. the control, monitoring and safety systems of the hydrogen-fuelled installation shall be so arranged that the remaining power for propulsion and power generation is in accordance with chapter 9.3.1 of the IGF Code in the event of single failure;

2. a hydrogen safety system shall be arranged to close down the hydrogen supply system automatically, upon failure in systems as described in Table 1 of IGF Code and upon other fault conditions which may develop too fast for manual intervention;

3. for ESD protected machinery configurations the safety system shall shutdown hydrogen supply upon hydrogen leakage and in addition disconnect all non-certified safe type electrical equipment in the machinery space;

4. the safety functions shall be arranged in a dedicated hydrogen safety system that is independent of the hydrogen control system in order to avoid possible common cause failures. This includes power supplies and input and output signal;

5. the safety systems including the field instrumentation shall be arranged to avoid spurious shutdown, e.g. as a result of a faulty hydrogen detector or a wire break in a sensor loop; and

6. where two or more gas supply systems are required to meet the regulations, each system shall be fitted with its own set of independent hydrogen control and hydrogen safety systems.

15.3 General rules

(Reference IGF Code Ch. 15, 15.3)

15.3.1 The requirements of paragraphs 15.3 of chapter 15 of the IGF Code apply.

15.4 Regulations for bunkering control

(Reference IGF Code Ch. 15, 15.5)

15.4.1 The requirements of paragraphs 15.5 of chapter 15 of the IGF Code apply.

15.5 Regulations for gas compressor monitoring

(Reference IGF Code Ch. 15, 15.6)

15.5.1 The requirements of paragraphs 15.6 of chapter 15 of the IGF Code apply.

15.6 Regulations for gas engine monitoring

(Reference IGF Code Ch. 15, 15.7)

15.6.1 The requirements of paragraphs 15.7 of chapter 15 of the IGF Code apply.

15.6.2 The requirements of chapter 11.2.3 of the RINA FC-SHIPS Regulation apply. In particular:

"The ancillaries of the FC unit comprise the equipment for supplying H_2, O_2, and N_2 for reactant humidification, for product water, and waste heat and residual gas removal. If each FC unit is enclosed in a single container, this is to be filled with N_2 inert gas at overpressure to prevent a release of H_2 and/or O_2 in case of leakages."

15.7 Regulations for gas detection

(Reference IGF Code Ch. 15, 15.8)

15.7.1 The requirements of paragraphs 15.8 of chapter 15 of the IGF Code apply.

15.7.2 Gas detection equipment is to be designed, installed and tested in accordance with IEC 60079-29-1 or an equivalent recognized standard acceptable to the Amministration.

15.7.3 Permanently installed gas detectors are also to be fitted:

a) at ventilation inlets to service spaces, ro-ro spaces, special category spaces and other machinery spaces if required based on the risk assessment;
b) in bunker stations.

15.7.4 Audible and visible alarms from the gas detection equipment are to be located on the navigation bridge or in the continuously manned central control station or safety centre.

15.7.5 On hydrogen-fuelled ships, shall be consider to install a gas detection system set according to the following logic:

- activation of alarms upon detection of hydrogen concentration of 20% LEL;
- initiation of safe shut-down routine for the affected fuel cell power system, disconnection of the ignition sources and automatic closing of all

valves required to isolate the leakage upon detection of a hydrogen concentration of 40% LEL.

15.8 Regulations for fire detection

(Reference IGF Code Ch. 15, 15.9)

15.8.1 The requirements of paragraphs 15.9 of chapter 15 of the IGF Code apply.

15.9 Regulations for ventilation

(Reference IGF Code Ch. 15, 15.10)

15.9.1 The requirements of paragraphs 15.10 of chapter 15 of the IGF Code apply.

15.10 Regulations on safety functions of fuel supply system

(Reference IGF Code Ch. 15, 15.11)

15.10.1 The requirements of paragraphs 15.11 of chapter 15 of the IGF Code apply.

16. MANUFACTURE, WORKMANSHIP AND TESTING

16.1 General

(Reference IGF Code Ch. 16, 16.1)

16.1.1 The manufacture, testing, inspection and documentation shall be in accordance with recognized standards and the regulations given in these Rules.

16.1.2 Where post-weld heat treatment is specified or required, the properties of the base material shall be determined in the heat treated condition, in accordance with the applicable Tables of chapter 7 of IGF Code, and the weld properties shall be determined in the heat treated condition in accordance with paragraph 16.3 of the IGF Code. In cases where a post-weld heat treatment is applied, the test regulations may be modified at the discretion of the Administration.

16.1.3 The requirements of chapter 12.1 of the RINA FC-SHIPS Regulation apply. In particular:

"Hydrogen storage and handling procedures are to be based upon recognised international standards, ref. Sec 1, [1.10] (e.g. ISO 16110-1:2007, ISO/TS 15869: 2009, ISO 15399 etc.) for reference."

16.2 General test regulations and specifications

(Reference IGF Code Ch. 16, 16.2)

16.2.1 The requirements of paragraphs 16.2 of chapter 16 of the IGF Code apply.

16.3 Welding of metallic materials and non-destructive testing for the fuel containment system

(Reference IGF Code Ch. 16, 16.3)

16.3.1 The requirements of paragraphs 16.3 of chapter 16 of the IGF Code apply.

16.4 Other regulations for construction in metallic materials

(Reference IGF Code Ch. 16, 16.4)

16.4.1 The requirements of paragraphs 16.4 of chapter 16 of the IGF Code apply.

16.5 Testing

(Reference IGF Code Ch. 16, 16.5)

16.5.1 The requirements of paragraphs 16.5 of chapter 16 of the IGF Code apply.

16.5.2 The requirements of paragraphs 16.5.2 of chapter 16 of the RINA of the RINA Rules for the Classification of Ships – Hydrogen fuelled ships apply.

16.6 Welding, post-weld heat treatment and non-destructive testing

(Reference IGF Code Ch. 16, 16.6)

16.6.1 The requirements of paragraphs 16.6 of chapter 16 of the IGF Code apply.

16.7 Testing regulations

(Reference IGF Code Ch. 16, 16.7)

16.7.1 The requirements of paragraphs 16.7 of chapter 16 of the IGF Code apply.

16.7.2 The requirements of chapter 12.4 of the RINA FC-SHIPS Regulation apply. In particular:

"Valves for use in hydrogen pipes located in ventilated spaces with fully welded hydrogen pipes, are to be tightness tested with hydrogen to demonstrate that there is no leakage of hydrogen from the valve."

17. DRILLS AND EMERGENCY EXERCISES

(Reference IGF Code Ch. 17)

17.1 Drills and emergency exercises on board shall be conducted at regular intervals.

17.2 The response and safety system for hazards and accident control shall be reviewed and tested.

18. OPERATION

(Reference IGF Code Ch. 18)

18.1 Operational procedures for the loading, storage, operation, maintenance, and inspection of hydrogen systems shall minimize the risk to personnel, the ship and the environment and shall be consistent with practices for a conventional ship powered by oil or natural gas taking into account hydrogen as fuel.

19. TRAINING

(Reference IGF Code Ch. 19)

19.1 Seafarers on board hydrogen-fuelled ships to which these Rules apply shall be suitably qualified, trained and experienced.