



**BUREAU
VERITAS**

Guidelines for Fuel Cell Systems Onboard Commercial Ships

April 2009

**Guidance Note
NI 547 DR R00 E**

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MARINE DIVISION

GENERAL CONDITIONS

ARTICLE 1

1.1. - BUREAU VERITAS is a Society the purpose of whose Marine Division (the "Society") is the classification ("Classification") of any ship or vessel or structure of any type or part of it or system therein collectively hereinafter referred to as a "Unit" whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

The Society:

- prepares and publishes Rules for classification, Guidance Notes and other documents ("Rules");
- issues Certificates, Attestations and Reports following its interventions ("Certificates");
- publishes Registers.

1.2. - The Society also participates in the application of National and International Regulations or Standards, in particular by delegation from different Governments. Those activities are hereafter collectively referred to as "Certification".

1.3. - The Society can also provide services related to Classification and Certification such as ship and company safety management certification; ship and port security certification, training activities; all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

1.4. - The interventions mentioned in 1.1., 1.2. and 1.3. are referred to as "Services". The party and/or its representative requesting the services is hereinafter referred to as the "Client". **The Services are prepared and carried out on the assumption that the Clients are aware of the International Maritime and/or Offshore Industry (the "Industry") practices.**

1.5. - The Society is neither and may not be considered as an Underwriter, Broker in ship's sale or chartering, Expert in Unit's valuation, Consulting Engineer, Controller, Naval Architect, Manufacturer, Ship-builder, Repair yard, Charterer or Shipowner who are not relieved of any of their expressed or implied obligations by the interventions of the Society.

ARTICLE 2

2.1. - Classification is the appraisal given by the Society for its Client, at a certain date, following surveys by its Surveyors along the lines specified in Articles 3 and 4 hereafter on the level of compliance of a Unit to its Rules or part of them. This appraisal is represented by a class entered on the Certificates and periodically transcribed in the Society's Register.

2.2. - Certification is carried out by the Society along the same lines as set out in Articles 3 and 4 hereafter and with reference to the applicable National and International Regulations or Standards.

2.3. - It is incumbent upon the Client to maintain the condition of the Unit after surveys, to present the Unit for surveys and to inform the Society without delay of circumstances which may affect the given appraisal or cause to modify its scope.

2.4. - The Client is to give to the Society all access and information necessary for the safe and efficient performance of the requested Services. The Client is the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out.

ARTICLE 3

3.1. - The Rules, procedures and instructions of the Society take into account at the date of their preparation the state of currently available and proven technical knowledge of the Industry. They are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.

Committees consisting of personalities from the Industry contribute to the development of those documents.

3.2. - The Society only is qualified to apply its Rules and to interpret them. Any reference to them has no effect unless it involves the Society's intervention.

3.3. - The Services of the Society are carried out by professional Surveyors according to the applicable Rules and to the Code of Ethics of the Society. Surveyors have authority to decide locally on matters related to classification and certification of the Units, unless the Rules provide otherwise.

3.4. - The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not in any circumstances involve monitoring or exhaustive verification.

ARTICLE 4

4.1. - The Society, acting by reference to its Rules:

- reviews the construction arrangements of the Units as shown on the documents presented by the Client;
- conducts surveys at the place of their construction;
- classes Units and enters their class in its Register;
- surveys periodically the Units in service to note that the requirements for the maintenance of class are met.

The Client is to inform the Society without delay of circumstances which may cause the date or the extent of the surveys to be changed.

ARTICLE 5

5.1. - The Society acts as a provider of services. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty.

5.2. - The certificates issued by the Society pursuant to 5.1. here above are a statement on the level of compliance of the Unit to its Rules or to the documents of reference for the Services provided for.

In particular, the Society does not engage in any work relating to the design, building, production or repair checks, neither in the operation of the Units or in their trade, neither in any advisory services, and cannot be held liable on those accounts. Its certificates cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

5.3. - The Society does not declare the acceptance or commissioning of a Unit, nor of its construction in conformity with its design, that being the exclusive responsibility of its owner or builder, respectively.

5.4. - The Services of the Society cannot create any obligation bearing on the Society or constitute any warranty of proper operation, beyond any representation set forth in the Rules, of any Unit, equipment or machinery, computer software of any sort or other comparable concepts that has been subject to any survey by the Society.

ARTICLE 6

6.1. - The Society accepts no responsibility for the use of information related to its Services which was not provided for the purpose by the Society or with its assistance.

6.2. - If the Services of the Society cause to the Client a damage which is proved to be the direct and reasonably foreseeable consequence of an error or omission of the Society, its liability towards the Client is limited to ten times the amount of fee paid for the Service having caused the damage, provided however that this limit shall be subject to a minimum of eight thousand (8,000) Euro, and to a maximum which is the greater of eight hundred thousand (800,000) Euro and one and a half times the above mentioned fee.

The Society bears no liability for indirect or consequential loss such as e.g. loss of revenue, loss of profit, loss of production, loss relative to other contracts and indemnities for termination of other agreements.

6.3. - All claims are to be presented to the Society in writing within three months of the date when the Services were supplied or (if later) the date when the events which are relied on were first known to the Client, and any claim which is not so presented shall be deemed waived and absolutely barred. Time is to be interrupted thereafter with the same periodicity.

ARTICLE 7

7.1. - Requests for Services are to be in writing.

7.2. - Either the Client or the Society can terminate as of right the requested Services after giving the other party thirty days' written notice, for convenience, and without prejudice to the provisions in Article 8 hereunder.

7.3. - The class granted to the concerned Units and the previously issued certificates remain valid until the date of effect of the notice issued according to 7.2. here above subject to compliance with 2.3. here above and Article 8 hereunder.

7.4. - The contract for classification and/or certification of a Unit cannot be transferred neither assigned.

ARTICLE 8

8.1. - The Services of the Society, whether completed or not, involve, for the part carried out, the payment of fee upon receipt of the invoice and the reimbursement of the expenses incurred.

8.2. Overdue amounts are increased as of right by interest in accordance with the applicable legislation.

8.3. - The class of a Unit may be suspended in the event of non-payment of fee after a first unfruitful notification to pay.

ARTICLE 9

9.1. - The documents and data provided to or prepared by the Society for its Services, and the information available to the Society, are treated as confidential. However:

- clients have access to the data they have provided to the Society and, during the period of classification of the Unit for them, to the **classification file** consisting of survey reports and certificates which have been prepared at any time by the Society for the classification of the Unit;
- copy of the documents made available for the classification of the Unit and of available survey reports can be handed over to another Classification Society, where appropriate, in case of the Unit's transfer of class;
- the data relative to the evolution of the Register, to the class suspension and to the survey status of the Units, as well as general technical information related to hull and equipment damages, are passed on to IACS (International Association of Classification Societies) according to the association working rules;
- the certificates, documents and information relative to the Units classed with the Society may be reviewed during certifying bodies audits and are disclosed upon order of the concerned governmental or inter-governmental authorities or of a Court having jurisdiction.

The documents and data are subject to a file management plan.

ARTICLE 10

10.1. - Any delay or shortcoming in the performance of its Services by the Society arising from an event not reasonably foreseeable by or beyond the control of the Society shall be deemed not to be a breach of contract.

ARTICLE 11

11.1. - In case of diverging opinions during surveys between the Client and the Society's surveyor, the Society may designate another of its surveyors at the request of the Client.

11.2. - Disagreements of a technical nature between the Client and the Society can be submitted by the Society to the advice of its Marine Advisory Committee.

ARTICLE 12

12.1. - Disputes over the Services carried out by delegation of Governments are assessed within the framework of the applicable agreements with the States, international Conventions and national rules.

12.2. - Disputes arising out of the payment of the Society's invoices by the Client are submitted to the Court of Nanterre, France.

12.3. - Other disputes over the present General Conditions or over the Services of the Society are exclusively submitted to arbitration, by three arbitrators, in London according to the Arbitration Act 1996 or any statutory modification or re-enactment thereof. The contract between the Society and the Client shall be governed by English law.

ARTICLE 13

13.1. - These General Conditions constitute the sole contractual obligations binding together the Society and the Client, to the exclusion of all other representation, statements, terms, conditions whether express or implied. They may be varied in writing by mutual agreement.

13.2. - The invalidity of one or more stipulations of the present General Conditions does not affect the validity of the remaining provisions.

13.3. - The definitions herein take precedence over any definitions serving the same purpose which may appear in other documents issued by the Society.

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Chapter 1 - General

1.1 Application

- 1.1.1** These Guidelines apply to fuel cell systems installations in ships using a gas (see 1.3.17) as fuel and oxygen from ambient air as oxidant. The gas may be stored in gaseous compressed state or liquid state. Other types of processes, e.g. use of metal hydride hydrogen storage and use of pure oxygen as oxidant, should be subject to special examination by the Society. Additionally, the use onboard of both gas and hydrocarbon based fuels should also be subject to special examination by the Society.
- 1.1.2** These Guidelines should be applied in addition to the relevant provisions of the International Convention for the Safety of Life at Sea (SOLAS) 1974 and its Protocol of 1988, as amended, when applicable.
- 1.1.3** Specific recommendations should be considered when the power supply of equipment that is essential for propulsion, control or safety of the ship is delivered by the fuel cell installation and when this powering should be maintained if one component of the fuel cell installation becomes inoperative. These recommendations are printed in *italics*.
- 1.1.4** These Guidelines are applicable to new ships. Application to existing ships should be decided by the Society to the extent it deems necessary.

1.2 Hazards

These Guidelines address the hazards related to the arrangements for the storage, distribution and use of a gas fuel with a fuel cell system.

1.3 Definitions

Note: Unless otherwise stated below, definitions are as defined in SOLAS chapter II-2.

- 1.3.1** *Accidents* mean uncontrolled events that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.
- 1.3.2** *Certified safe type* means electrical equipment that is certified safe by a recognised body based on a recognised standard (e.g. IEC 60079 series, Explosive atmospheres and IEC 60092-502, Electrical Installations in Ships – Tankers – Special Features). The certification of electrical equipment is to correspond to the category and group for the gas used.
- 1.3.3** *CGH2* means compressed gaseous hydrogen.
- 1.3.4** *Control stations* mean those spaces defined in SOLAS chapter II-2 and additionally for these Guidelines, the engine control room.

- 1.3.5** *Double block and bleed valve* means a set of three automatic valves located at the fuel supply to each of the gas utilisation equipment.
- 1.3.6** *Effluent*: Products of combustion plus the excess air being discharged from gas utilisation equipment.
- 1.3.7** *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 (see also definition in IEC 60092-502).
- 1.3.8** *ESD* means emergency shutdown.
- 1.3.9** *Explosion* means a deflagration event of uncontrolled combustion.
- 1.3.10** *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.
- 1.3.11** *Fail-safe*: ability to sustain a failure without causing loss of equipment, injury to personnel, or loss of operating time.
- 1.3.12** *Fuel cell installation*: all the components required for the production of energy by the fuel cell; it includes the fuel cell system and the gas fuel system.
- 1.3.13** *Fuel cell module*: assembly of one or more fuel cell stacks, electrical connections for the power delivered by the stacks, and means for monitoring and/or control.
- 1.3.14** *Fuel cell power system*: system typically containing the following subsystems: fuel cell module, oxidant processing system, fuel processing system, thermal management system, water treatment system, power conditioning system and their control systems.
- 1.3.15** *Fuel cell stack*: assembly of cells, separators, cooling plates, manifolds and a supporting structure that electrochemically converts, typically, hydrogen rich gas and air reactants to d.c. power, heat, water and other by-products.
- 1.3.16** *Fuel processing system*: system that converts, if necessary, and/or conditions the fuel as stored in the onboard fuel storage into fuel suitable for operation in the fuel cell stack.
- 1.3.17** *Gas* means a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C. The present guidelines mainly address gases lighter than air in ambient conditions, and in particular Hydrogen.

- 1.3.18** *Gas component*: Gas container and all other parts of the installation that are in direct contact with gas or which form part of a system installed because of the use of gas.
- 1.3.19** *Gas fuel system*: the gas fuel system consists of the gas storage system and the gas handling system.
- 1.3.20** *Gas storage system*: it consists of the pressurized containment vessel(s), Pressure Relief Devices, shut off device(s), and all components, fittings and fuel lines between the containment vessel(s) and these shut off device(s) that isolate the stored gas from the remainder of the fuel system and the environment.
- 1.3.21** *Gas utilisation equipment* means any equipment of the fuel cell power system which makes use of gas (e.g. fuel cell module, oxidation reactors if they use gas as defined in 1.3.17).
- 1.3.22** *Hazardous area* means an area in which an explosive gas atmosphere or a flammable gas (flash point below 60°C) is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.
- Hazardous areas are divided into zone 0, 1 and 2 as defined below (refer also to the area classification specified in sec. 2.5 of IEC 60079-10-1, Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres):
1. *Zone 0* is an area in which an explosive gas atmosphere (reaching 25% LFL) or a flammable gas with a flash point below 60°C is present continuously or is present for long periods.
 2. *Zone 1* is an area in which an explosive gas atmosphere (reaching 25% LFL) or a flammable gas with a flash point below 60°C is likely to occur in normal operation.
 3. *Zone 2* is an area in which an explosive gas atmosphere (reaching 25% LFL) or a flammable gas with a flash point below 60°C is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.
- 1.3.23** *Non-hazardous area* means an area which is not considered to be hazardous, i.e., gas safe, provided certain conditions are being met.
- 1.3.24** *High-pressure piping* means gas fuel piping with maximum working pressure greater than 10 bar.
- 1.3.25** *Hydrogen handling system*: the system that processes, conditions, and/or conveys hydrogen (or hydrogen-rich gas) to the fuel cell.
- 1.3.26** *IEC* means the International Electrotechnical Commission.
- 1.3.27** *IGC Code* means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.
- 1.3.28** *LFL* means the Lower Flammable Limit

- 1.3.29** *Machinery space of category A*: those spaces and trunks to such spaces which contain: internal combustion machinery used for main propulsion, or internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW, or any oil fired boiler or fuel oil unit, or gas generators, incinerators, waste disposal units, etc., which use oil fired equipment. Spaces containing a fuel-fired boiler or heating device belonging to the fuel cell installation should be considered as machinery spaces of category A.
- 1.3.30** *Machinery spaces*: Machinery spaces are all machinery spaces of Category A and all other spaces containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces. Spaces containing any component of the fuel cell power system should be considered as machinery spaces.
- 1.3.31** *Main tank valve* means a remote operated valve on the gas outlet from a gas storage tank, located as close to the tank outlet point as possible.
- 1.3.32** *MARVS* means the maximum allowable relief valve setting of a gas tank.
- 1.3.33** *Master gas fuel valve* means an automatic valve in the gas supply line to each fuel cell power system located outside the machinery space(s) for fuel cell power systems and as close to the gas heater (if fitted) as possible.
- 1.3.34** *Open deck* means a deck that is open on both ends, or is open on one end and equipped with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side panels or in the deck above.
- 1.3.35** *Organization* means the International Maritime Organization (IMO).
- 1.3.36** *Oxidant processing system*: meters, conditions, processes and may pressurize the incoming oxidant (generally air) supply for use within the fuel cell power system, with pressure, temperature, hygrometry, purity and flow rate within the ranges accepted by the fuel cell module.
- 1.3.37** *Power conditioning system*: equipment which is used to adapt the electrical energy produced to the requirements as specified by the manufacturer.
- 1.3.38** *Pressure Relief Valve*: a pressure relief device that opens at a preset pressure level and can re-close.
- 1.3.39** *Risk* means the expression of the danger that an undesired event represents to persons, to the environment or to material property. The risk is expressed by the probability and consequences of an accident.

- 1.3.40** *Recognised standards* means applicable international or national standards acceptable to the Society or standards laid down and maintained by an organization which complies with the standards adopted by the Organization and which is recognised by the Society.
- 1.3.41** *Safety management system* means the international safety management system as described in the ISM Code.
- 1.3.42** *Second Barrier* means a technical measure which prevents the occurrence of a hazard if the first barrier fails. E.g. second housing of a tank protecting the surroundings from the effect of tank leaks.
- 1.3.43** *Semi-enclosed space* means a space limited by decks and or bulkheads in such manner that the natural conditions of ventilation are notably different from those obtained on open deck (refer also to IEC 60092-502, Electrical installations in ships – Tankers - Special Features).
- 1.3.44** *Society* means Bureau Veritas
- 1.3.45** *SOLAS Convention* means the International Convention for the Safety of Life at Sea, 1974, as amended.
- 1.3.46** *Source of release* means any valve, detachable pipe joint, pipe packing, compressor or pump seal in the gas fuel system.
- 1.3.47** *Tank room* means the gas-tight space surrounding the bunker tank, containing all tank connections and all tank valves.
- 1.3.48** *Thermal management system:* provides cooling and heat rejection to maintain thermal equilibrium within the fuel cell power system, and may provide for the recovery of excess heat and assist in heating the power train during start-up.
- 1.3.49** *Water treatment system:* provides the treatment and purification of recovered or added water for use within the fuel cell power systems.

1.4 Documentation to be submitted

1.4.1 Drawings and related information

- .1 The drawings and related information that should be submitted are listed in Tab 1.
- .2 information that should be provided for the fuel cell power system should cover at least the following items:
 - a. a clear, comprehensive description of the equipment, installation and mounting, and the connection to electrical supply(ies);
 - b. electrical supply(ies) requirements;
 - c. physical environment and operating conditions (fuel and water supply characteristics, etc.) according to 6.1.5;
 - d. electric circuit diagrams;
 - e. information (where appropriate) on:
 - handling, transportation and storage;
 - software programming;
 - sequence of operations;
 - frequency of inspection;
 - frequency and method of functional testing;
 - guidance on the adjustment, maintenance, and repair, particularly of the protective devices and circuits;
 - parts list and recommended spare parts list;
 - f. a description (including interconnection diagrams) of the safeguards, interlocking functions, and interlocking of guards for potentially hazardous situations;
 - g. a description of the safeguarding and of the means provided where it is necessary to suspend the safeguarding (for example, for manual programming, programme verification).
 - h. an interconnection diagram or table providing full information about all external connections (for example, electrical supply, fuel supply, water supply, control signals, exhaust venting, ventilation connections, etc.).
 - i. Manufacturer's recommendations on location and design of the fuel cell power system foundation; ventilation requirements; protection from weather hazards;
 - j. recommended height in relation to the base flood elevation; security enclosure; acceptable distances from combustible materials and from walkways.
 - k. the manufacturer's or distributor's name and location, and the model number of the fuel cell power system;
 - l. the minimum and maximum fuel supply pressures and the method of determining these pressures;
 - m. adequate clearances around air supply, ventilation and exhaust openings;
 - n. adequate clearances for maintenance, servicing and proper operation;
 - o. adequate clearances to combustible materials;

- p. if sediment trap or filter must be provided upstream of the fuel controls, when applicable;
- q. if appropriate, special instructions for extended dormant periods.

1.4.2 Operating manuals and procedures

The operating manuals and procedures that should be submitted are listed in Tab 2.

1.5 Installation trials

1.5.1 Prior to servicing, a complete set of trials should be performed.

1.5.2 The programme of trials should be documented and presented for approval to the Society (Table 2, item 6). It should at least cover tests of the following items:

- .1 Tests to be performed onboard as specified in Chapter 7 -
- .2 All control, monitoring and safety systems as described in Chapter 5 -
- .3 All procedures as described in Table 2.
- .4 Protective measures which have been installed for items representing significant risks, according to the risk analysis performed as per 2.1.2, 6.1.2 and Appendix 1

1.5.3 Relevant provisions of [16], Sec 15 related to regulatory machinery tests onboard should also be considered for defining the test plan.

1.6 References

These Guidelines are primarily based on the Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships prepared by the Sub-Committee on Bulk Liquids and Gases (BLG) of the Organization which should be later replaced by the International Code of safety for Gas-fuelled Ships (IGF Code) to be developed by the Organization. The IGF Code should address not only natural gas fuel, but also other gas fuel types, such as hydrogen.

The Bureau Veritas Rule Note “Safety Rules for Gas-Fuelled Engine Installations in Ships”, NR529 DTM R00 E February 2007, based on an earlier version of the BLG Interim Guidelines have been used, and updated accounting for the most recent revision of the Interim Guidelines.

All the above documents, and the present guidelines as well, make reference to various parts of the IGC Code.

Hydrogen and fuel cell specificities have been added in the present Guidelines, by including parts of, or making references to, the following references, which are recommended to read:

- [1] ISO 23273-1:2006: Fuel cell road vehicles – safety specifications; Part1: Vehicle functional safety
- [2] ISO 23273-2:2006: Fuel cell road vehicles – safety specifications; Part2: Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
- [3] ISO/TR 15916:2004: Basic considerations for the safety of hydrogen systems
- [4] ISO 11114-4:2005: Transportable gas cylinders – Compatibility of cylinders and valve materials with gas contents – Part 4: Test methods for hydrogen compatibility with metals
- [5] ISO/TS 15869: 2009: Gaseous hydrogen and hydrogen blends – Land vehicle fuel tanks

- [6] EN ISO 14726:2008: Ships and marine technology. Identification colours for the content of piping systems
- [7] IEC 60092-502:1999: Electrical Installations in Ships – Tankers – Special Features
- [8] IEC 60079-10-1:2008: Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres
- [9] IEC 60079-17:2007: Explosive atmospheres - Part 17: Electrical installations inspection and maintenance
- [10] IEC 62282-3-1:2007: Fuel cell technologies – Part 3.1: Stationary fuel cell power systems – Safety
- [11] IEC 62282-3-2:2006: Fuel cell technologies – Part 3.2: Stationary fuel cell power systems – Performance test methods
- [12] SAE J2578 (January 2009): Recommended practice for general fuel cell vehicle safety
- [13] SAE J2579 (January 2009): Technical Information Report for fuel systems in fuel cell and other hydrogen vehicles
- [14] Proposal for a regulation of the European Parliament and of the Council on type approval of hydrogen powered motor vehicles and amending Directive 2007/46/EC, COM(2007)593 2007/0214(COD)
- [15] Draft ECE Compressed Gaseous Hydrogen Regulation, revision 12b, 12/10/2003 (EIHP2)

References are also made to various parts of the Bureau Veritas Rules for the Classification of Steel Ships (called Rules in the remainder of the present document), and in particular to the following parts of these Rules:

- [16] PtC, Ch1: Machinery and PtD (and/or Ch21, Sec3 – Ships not covered by SOLAS – Machinery)
- [17] PtC, Ch2: Electrical Installations (and/or PtD, Ch21, Sec4 – Ships not covered by SOLAS – Electrical Installations)
- [18] PtC, Ch3: Automation
- [19] PtC, Ch4: Fire protection, detection and extinction (and/or PtD, Ch21, Sec5 – Ships not covered by SOLAS – Fire Protection)
- [20] PtE, Ch6: Comfort on board (COMF)

Table 1: Documents to be submitted

Item N°	I/A (1)	Documents (2)
1	A	General arrangement of the machinery spaces containing the gas utilisation equipment and of the gas storage units, with description of the classification of hazardous areas
2	I	Description of the different operating configurations of the machinery installation, with indication of the power developed by each component.
3	A	Risk analysis (see Appendix 1)
4	A	Testing program and results / type approval reference (see Chapter 7 -) of the installation components
5	A	Drawings and specification of the gas supply system to each gas utilisation equipment
6	A	Specification of the control, monitoring and safety systems, including ESD and fire detection and extinguishing systems
7	A	Diagram of the gas piping system located in the machinery spaces, including double wall piping or duct system
8	A	Material, thickness and joints of the gas piping
9	A	Diagram of the inert gas piping system
10	A	Diagram of the ventilation system in machinery spaces
11	A	Diagram of the oxidant processing, supply and exhaust system
12	I	Diagram of the gas detection system
13	I	Instrumentation list
14	I	Safety certificates for electrical equipment located in gas-dangerous spaces or zones, where applicable
15	A	Design data and sizing calculation of the gas storage and piping systems
16	I	Fuel characteristics (storage pressure, temperature, LFL, toxicity, corrosivity and any other important safety related characteristics)
17	A	Other fuel cell power system related information as per 1.4.1.2
⁽¹⁾ A= to be submitted for approval I= to be submitted for information ⁽²⁾ Diagrams should also include, where applicable, the local and remote control systems and automation systems		

Table 2: Procedures to be submitted

Item N°	I/A (1)	Documents
1	A	Operating manual of the fuel cell installation, including: - Procedures for starting (in particular from dead ship condition), stop and emergency stop of the gas utilisation equipment. - Steps to be taken in case of gas detection in the machinery spaces, in the double wall pipes or ducts or in the ventilation hoods or casings.
2	I	Procedures for maintenance of the gas utilisation equipment, other gas related equipment (including detectors verification and calibration), and other fuel cell power system components including the steps to be taken prior to servicing the units.
3	A	Procedure for testing the gas monitoring / detection systems.
4	I	Procedure for checking the gas tightness of the fuel system
5	A	Procedure for refuelling
6	A	Programme of installation onboard testing
⁽¹⁾ A= to be submitted for approval I= to be submitted for information		

1.7 Main safety principles

1.7.1 The goal of these Guidelines is to provide criteria for the arrangement and installation of machinery for propulsion and auxiliary purposes, using fuel cell installations, which will have an equivalent level of integrity in terms of safety, reliability and dependability as that which can be achieved with a new and comparable conventional oil fuelled main and auxiliary machinery.

1.7.2 To achieve this goal, the functional requirements described below are embodied in the relevant parts of these Guidelines:

- .1 Apply fail-safe design principles.
- .2 Minimize hazardous areas as far as is practicable to minimize potential risks that might affect the safety of the ship, personnel and equipment.
- .3 Minimize equipment installed in hazardous areas to that required for operational purposes. Equipment installed in hazardous areas should be suitable and appropriately certified.
- .4 Arrange hazardous areas to ensure pockets of gas cannot accumulate under normal and foreseeable failure conditions.
- .5 *Arrange propulsion and electrical power generating installation to be capable of sustained or restored operation in the event that a gas fuelled essential service becomes inoperative.*
- .6 Provide ventilation to protect personnel from an oxygen deficient atmosphere in the event of a gas leakage.
- .7 Minimize the number of ignition sources in hazardous spaces by design, arrangements and selection of suitable equipment.
- .8 Arrange safe and suitable gas fuel storage and bunkering arrangements capable of taking on board and containing the gas fuel in the required state without leakage and overpressure.
- .9 Provide gas piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application.
- .10 Design, construct, install, operate and protect gas fuelled machinery, gas system and components to achieve safe and reliable operation consistent with that of oil fuelled machinery.
- .11 *Arrange and locate gas storage tank rooms and machinery spaces such that a fire or explosion in either will not render the machinery/equipment in other compartments inoperable.*
- .12 Provide safe and reliable gas-fuel control engineering arrangements consistent with those of oil fuelled machinery.
- .13 Provide appropriate selection of certified equipment and materials that are suitable for use within gas systems.
- .14 Provide gas detection suitable for the space concerned together with monitoring, alarm and shutdown arrangements.

- .15 Provide protection against the potential effects of a gas-fuel explosion.
- .16 Prevent explosion and hazardous consequences.
- .17 Provide fire detection, protection and extinction measures appropriate to the hazards concerned.
- .18 Provide a level of confidence in a gas fuelled unit that is equivalent to that for an oil fuelled unit.
- .19 Ensure that commissioning, trials and maintenance of gas utilisation machinery satisfy the goal in terms of reliability, availability and safety.
- .20 Provide provision for procedures detailing the guidelines for safe routine and unscheduled inspection and maintenance.
- .21 Provide operational safety through appropriate training and certification of crew.
- .22 Provide for submission of technical documentation in order to permit an assessment of the compliance of the system and its components with the applicable rules and guidelines.

Chapter 2 - Ship Arrangements and System Design

2.1 General

2.1.1 For any new or altered concept or configuration a risk analysis should be conducted in order to ensure that any risks arising from the use of the fuel cell installation affecting the structural strength and the integrity of the ship are addressed. Consideration should be given to the hazards associated with installation, operation, and maintenance, following any reasonably foreseeable failure.

2.1.2 Hazards must be identified using acceptable and recognised hazard identification techniques. The effects of the following should be considered:

- the ship's operational profile
- the ship's operational status
- modes of operation
- environmental conditions (see [17], Sec 2 and Sec 3 §4)
- dependencies - power, fuel, air, cooling, heating, data, human input
- environmental impact and failures - human error, supply failure, system, machinery,
- equipment and component failure, random, systematic, common cause.

2.1.3 The risks should be analysed using acceptable and recognised risk analysis techniques and loss of function, component damage, fire, explosion and electric shock should as a minimum be considered. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary. Details of risks, and the means by which they are mitigated, should be included in the operating manual.

2.1.4 The scope of the risk analysis should comply with the provisions of Appendix 1.

2.1.5 Guidance on selecting and performing the various risk assessment techniques is widely available, with certain techniques being more suited for particular applications than others. Relevant international standards should be followed, such as IEC61882 Hazard and operability studies (HAZOP studies) – application guide, IEC60812 Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA) and IEC61025 Fault tree analysis.

2.1.6 The risk analysis should identify the spaces in which explosive mixtures may be encountered, their volumes, their probability of explosion and the associated consequences. An explosion in such space containing an explosive mixture should not:

- .1 cause damage to any space other than that in which the incident occurs;
- .2 disrupt the proper functioning of other zones;

- .3 damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;
- .4 damage work areas or accommodation in such a way that people who stay in such areas under normal operating conditions are injured;
- .5 disrupt the proper functioning of control stations and switchboard rooms for necessary power distribution;
- .6 damage life-saving equipment or associated launching arrangements;
- .7 disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space; or
- .8 affect other areas in the vessel in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise.

2.1.7 *The arrangement and number of spaces containing fuel cell installation components, the distribution thereof, and the design of the safety systems should be such that, in case of gas leakage originating anywhere in the spaces, the automatic safety actions will not result in the loss of essential functions of the ship (propulsion, electrical production).*

2.1.8 Access to all components of the fuel cell installation should be possible for survey.

2.2 Material requirements

2.2.1 All equipment and components should be made of materials that are suitable for the ship service life with the range of process fluids and conditions expected during both normal operation and fault management. Specific consideration for hydrogen compatibility is given in 2.2.6.

2.2.2 Materials used in gas tanks, gas piping, process pressure vessels and other components in contact with gas should be in accordance with IGC Code Chapter 6. For compressed gas tanks, the use of materials not covered by the IGC Code may be specially considered by the Society.

2.2.3 Materials for piping system for liquefied gases should comply with the requirements of IGC Code Chapter 6.2. Some relaxation may, however, be permitted in the quality of the material of open ended vent piping, provided the temperature of the gas at atmospheric pressure is -55°C or higher and provided no liquid discharge to the vent piping can occur. Materials should be in general in accordance with recognised standards.

2.2.4 Materials having a melting point below 925°C, should not be used for piping outside the gas tanks except for short lengths of pipes attached to the gas tanks, in which case the low melting point materials should be wrapped in class A-60 insulation.

2.2.5 The materials used for the gas piping systems should be certified as class 1 pipes, in accordance with the requirements of [16], Sec 10.

- 2.2.6** All components in contact with hydrogen should be made of material compatible with this element, in particular with respect to embrittlement and hydrogen attack phenomena. Information on material compatibility with hydrogen can be found in [3], [5] and [13]. Tests for checking the compatibility of metals with hydrogen are specified in [4]. The demonstration of the suitability of materials should be performed by tests according to specifications given in [5], [15] Annexes 7 and 8, [13], [14] or to any other equivalent recognised standard.
- 2.2.7** In the case of compressed gaseous hydrogen, the normal operating temperature range for materials used in hydrogen components should be -40°C to $+85^{\circ}\text{C}$. The gas temperature should be between -40°C to $+85^{\circ}\text{C}$ in normal operating conditions including filling or discharging.
- 2.2.8** Materials for piping of the fuel cell installation containing other fluids than the hydrogen or natural gas should be in accordance with [16], Sec 10.

2.3 Location and separation of spaces

- 2.3.1** The arrangement and location of spaces for gas fuel storage, distribution, processing and use should be such that the number and extent of hazardous areas is kept to a minimum. These spaces should have as simple geometrical and internal arrangement as possible in order to minimize the possibility of entrapping explosive mixtures.
- 2.3.2** The fuel cell installation components should be located in spaces separated from other machinery spaces. Tank rooms should be separated from the spaces containing the fuel cell power system components. Fuel-fired boilers or heating devices should also be located in spaces separated from the spaces containing the other fuel cell power system components.

2.3.3 Gas compressor rooms

- .1 Compressor rooms, if arranged, should be located above freeboard deck unless those rooms are arranged and fitted in accordance with the recommendations of these guidelines for tank rooms (2.3.6).
- .2 If compressors are driven by shafting passing through a bulkhead or deck, the bulkhead penetration should be of gastight type.

- 2.3.4** The spaces containing fuel cell power systems components should be considered as machinery spaces. Spaces containing a fuel-fired boiler or heating device belonging to the fuel cell installation should be considered as machinery spaces of category A (see 1.3.29 & 1.3.30).

2.3.5 Machinery spaces containing fuel cell power system components

- .1 *When more than one machinery space is required for fuel cell power system components and these spaces are separated by a single bulkhead, the arrangements should be such that the effects of a gas explosion in either space, in conditions to be determined as described in 2.1.6, can be contained or vented without affecting the integrity of the adjacent space and equipment within the space.*

2.3.6 Tank rooms

- .1 Tank room boundaries including access doors should be gas tight.
- .2 The tank room should not be located adjacent to machinery spaces of category A. If the separation is by means of a cofferdam the separation should be at least 900 mm and insulation to class A-60 should be fitted on the machinery space side.

2.4 Arrangement of entrances and other openings

- 2.4.1 Direct access through doors, gastight or otherwise, should generally not be permitted from a gas-safe space to a gas-dangerous space. Where such openings are necessary for operational reasons, an air lock which complies with the requirements of Chapter 3.6 (2 to 7) of the IGC Code should be provided. Special precautions are also described in [7].
- 2.4.2 If the compressor room is approved located below deck, the room should, as far as practicable, have an independent access direct from the open deck. Where a separate access from deck is not practicable, an air lock which complies with the requirements of Chapter 3.6 (2 to 7) of the IGC Code should be provided. Special precautions are also described in [7].
- 2.4.3 In case of liquid gas fuel storage, the tank room entrance should be arranged with a sill height of at least 300 mm.
- 2.4.4 Access to the tank room should as far as practicable be independent and direct from open deck. If the tank room is only partially covering the tank, this recommendation should also apply to the room surrounding the tank and where the opening to the tank room is located. Where a separate access from deck is not practicable, an air lock which complies with the requirements of Chapter 3.6 (2 to 7) of the IGC Code should be provided. Special precautions are also described in [7]. The access trunk should be fitted with separate ventilation. It should not be possible to have authorised access to the tank room during normal operation of the gas system.
- 2.4.5 If the access to an ESD protected machinery space is possible from another enclosed space in the ship, the entrances should be arranged with self-closing doors. An audible and visual alarm should be provided at a permanent manned location. Alarm should be given if the door is open continuously for more than 1 min. As an alternative, an arrangement with two self-closing doors in series may be acceptable.

2.5 General pipe design and arrangement

- 2.5.1** The recommendations of this section apply to gas piping. The Society may accept relaxation from these recommendations for gas piping inside gas tanks and open ended piping after special consideration, such as risk assessment. Piping of the fuel cell installation containing other fluids than the hydrogen or natural gas should be designed in accordance with [16], Sec 10.
- 2.5.2** Gas piping should be protected against mechanical damage (e.g. due to handling of equipment in the vicinity of the piping) and the piping should be capable of assimilating thermal expansion without developing substantial tension.
- 2.5.3** The piping system should be joined by welding with a minimum of flange connections. Gaskets should be protected against blow-out.
- 2.5.4** The wall thickness of pipes should not be less than:

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}} \quad (\text{mm})$$

where:

t_0 = theoretical thickness

$t_0 = pD/(20Ke + p)$

with:

p = design pressure (bar), refer to 2.5.5

D = outside diameter (mm)

K = allowable stress (N/mm²), refer to 2.5.6

e = efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with recognised standards. In other cases an efficiency factor value depending on the manufacturing process may be determined by the Society.

b = allowance for bending (mm). The value of b should be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b should be:

$$b = \frac{Dt_0}{2.5r} \quad (\text{mm})$$

with:

r = mean radius of the bend (mm)

c = corrosion allowance (mm). If corrosion allowance or erosion is expected, the wall thickness of the piping should be increased over that required by other design requirements. This allowance should be consistent with the expected life of the piping.

a = negative manufacturing tolerance for thickness (%)

The minimum wall thickness should be in accordance with Recognised Standards.

2.5.5 The greater of the following design conditions should be used for piping, piping system and components as appropriate (see also [16], Sec 10):

- .1 For systems or components which may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Society (ref. IGC Code paragraph 4.2.6.2), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or
- .2 The MARVS of the gas tanks and gas processing systems; or
- .3 The pressure setting of the associated pump or compressor discharge relief valve if the latter is of sufficient discharge capacity to ensure that the pressure in the piping will drop; or
- .4 The maximum total discharge or loading head of the gas piping system; or
- .5 The pressure relief valve setting on a pipeline system if of sufficient capacity; or
- .6 A pressure of 10 bar except for open ended lines where it should not be less than 5 bar.

2.5.6 For pipes made of steel including stainless steel, the permissible stress to be considered in the formula of the strength thickness in 2.5.4 is the lower of the following values:

$$\frac{R_m}{2.7} \text{ or } \frac{R_e}{1.8}$$

with:

R_m: specified minimum tensile strength at room temperature, in N/mm²

R_e: specified lower minimum yield stress or 0.2% proof stress at room temperature, in N/mm²

For pipes made of materials other than steel, the allowable stress should be considered by the Society.

2.5.7 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipe due to superimposed loads from supports, ship deflection or other causes, the wall thickness should be increased over that required by 2.5.4 or, if this is impractical or would cause excessive local stresses, these loads should be reduced, protected against or eliminated by other design methods.

2.5.8 Gas piping systems should have sufficient constructive strength. This should be confirmed by carrying out stress analysis and taking into account:

- .1 stresses due to the weight of the piping system;
- .2 acceleration loads when significant, accounting for both normal and accidental navigation conditions; and
- .3 internal pressure and loads induced by hog and sag of the ship.

2.5.9 Flanges, valves, fittings, etc. should be in accordance with Recognised Standards taking into account the design pressure defined in 2.5.5 (e.g. see [13], [14], [15] and [16], Sec 10).

2.5.10 All valves and expansion joints used in high pressure gas systems should be of an approved type (e.g. see [13], [14], [15] and [16], Sec 10).

2.5.11 The following types of connections may be considered for direct connection of pipe lengths (without flanges):

- .1 Butt welded joints with complete penetration at the root may be used in all applications. For design temperature below -10°C , butt welds should be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 10 bar and design temperatures above -10°C , backing rings should be removed.
- .2 Slip-on welded joints with sleeves and related welding, having dimensions satisfactory to the Society, should only be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C .
- .3 The use of screwed couplings should be subject to special examination by the Society.

2.5.12 Flanges should be of the welding neck, slip-on or socket welding type. For all piping (except open ended lines), the following restrictions apply:

- .1 For design temperatures $< -55^{\circ}\text{C}$ only welding neck flanges should be used.
- .2 For design temperatures $< -10^{\circ}\text{C}$ slip-on flanges should not be used in nominal sizes above 100 mm and socket welding flanges should not be used in nominal sizes above 50 mm.

2.5.13 Piping connections other than those mentioned above may be accepted upon consideration in each case.

2.5.14 Postweld heat treatment should be required for all butt welds of pipes made with 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 concerned.