Guidelines for Fuel Cell Systems Onboard Commercial Ships

April 2009

Guidance Note
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MARINE DIVISON
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, Shipbuilder, 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 appraisement 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 appraisement 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 appraisement 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 of 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 certificating 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, were 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°C .The gas temperature should be between -40°C to +85°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:

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

where:

t0 = theoretical thickness

t0 = 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:

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

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:

$$\frac{Rm}{2.7} \text{ or } \frac{Re}{1.8}$$

with:

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

Re: 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°C only welding neck flanges should be used.

.2 For design temperatures < -10°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.

2.5.15 When the design temperature is -110°C or lower, a complete stress analysis for each branch of the piping system should be submitted. This analysis should take into account all stresses due to weight of pipes with gas fuel (including acceleration if significant), internal pressure, thermal contraction and loads induced by movements of the ship. For temperatures above -110°C, a stress analysis may be required by the Society. In any case, consideration should be given to thermal stresses, even if calculations need not be submitted. The analysis should be carried out according to a recognised code of practice.

2.5.16 Gas pipes should not be located less than 760 mm from the ship's side.

2.5.17 Gas fuel piping should not pass through accommodation spaces, services spaces, or control stations. Gas fuel piping may pass through or extend into other spaces provided that:

.1 they fulfil the provisions of 2.7.1

.2 the danger of mechanical damage is negligible (to be assessed in the risk analysis, Appendix 1, 2.2)

.3 the gas piping has no sources of release and

.4 the space is equipped with a gas alarm.

2.5.18 An arrangement for purging gas bunkering lines and supply lines (only up to the double block and bleed valves if these are located close to the gas utilisation equipment) with a suitable inert gas (see 2.12) should be provided.

2.5.19 The gas piping system should be installed with sufficient flexibility to account for hull deflection. Arrangement for provision of the necessary flexibility should be demonstrated to maintain the integrity of the piping system in all foreseen service situations.

2.5.20 Gas pipes should be colour marked based on a recognised standard (e.g. [6]).

2.5.21 If the fuel gas contains heavier components that may condense in the system, knock out drums or equivalent means for safely removing the liquid should be fitted.

2.5.22 All pipelines and components which may be isolated when containing liquid gas should be provided with pressure relief valves.

2.5.23 Where tanks or piping are separated from the ship's structure by thermal isolation, provision should be made for electrically bonding to the ship's structure both the piping and the tanks. All gasketed pipe joints and hose connections should be electrically bonded.

2.5.24 Non-metallic piping carrying hydrogen gas may accumulate electrostatic charge along its exterior surface. Discharges from the external surface of this pipe may be sufficient to ignite a flammable mixture of gas or vapour in the surrounding environment. When used in Zone 1 or Zone 2 (according to [8]) locations, measures to eliminate electrostatic discharges should be taken. This may be achieved by specifying a pipe material with sufficient conductivity, or by limiting gas flow velocity to values below which electrostatic charge does not accumulate. Piping that relies on a protective system to eliminate electrostatic discharge (i.e., a grounding wire or braid) should not be used in a Zone 0 location.

NOTE: Metal braid coverings, or conductive wires within the non-metallic piping wall may increase the chance of electrostatic discharge if those conductors become disconnected from their bonding conductor. In Zone 1 and 2 areas, such conductors should be mechanically secured with positive means.

2.6 System configuration

2.6.1 Two alternative system configurations may be accepted:

.1 *Gas safe machinery spaces:* arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions i.e. inherently gas safe.

.2 *ESD protected machinery spaces:* arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery should be automatically executed while equipment or machinery in use or active during these conditions should be of a certified safe type.

2.6.2 Gas safe machinery spaces

.1 All gas supply piping within machinery space boundaries should be enclosed in a gas tight enclosure, i.e. double wall piping or ducting.

.2 In case of leakage in a gas supply pipe making shutdown of the gas supply necessary, a secondary independent fuel supply should be available. Alternatively, in the case of multi fuel cell power systems, independent and separate gas supply systems for each fuel cell power system may be accepted.

.3 The fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

2.6.3 ESD protected machinery spaces.

.1 Gas supply piping within machinery spaces may be accepted without a gas tight external enclosure on the following conditions:

a. Fuel cell power systems should be located in two or more machinery spaces not having any common boundaries unless it can be documented that the common boundary can withstand an explosion in one of the rooms. Distribution of fuel cell power systems components between the different machinery spaces should be such that in the case of shutdown of fuel supply to any one machinery space it is possible to maintain at least 40% of the propulsion power plus normal electrical power supply for sea going services. Incinerators, inert gas generators or other oil fired boilers should not be located within an ESD protected machinery space.

b. An enclosure should be provided for the area occupied by flanges, valves and other components of the gas supply system. This enclosure should be equipped with an individual exhaust ventilation system and a gas detection system in compliance with 2.7.1.1.1b. Gas supply pipe lengths outside the enclosure should have butt-welded connections only, in compliance with 2.5.11.1.

c. The gas machinery, tank and valve installation spaces should contain only a minimum of such necessary equipment, components and systems as are required to ensure that any piece of equipment in each individual space maintains its principal function.

d. Pressure in gas supply lines within machinery spaces should be less than 10 bar, i.e. this concept can only be used for low pressure systems.

e. A gas detection system arranged to automatically shutdown the gas supply and disconnect all non-explosion protected equipment or installations should be fitted, as outlined in 5.5 and 5.6.

.2 The fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments.

.3 For multi fuel cell power systems, each machinery space (ESD protected or gas safe) should be supplied by a separate gas fuel line directly from the tanks, each one having its own master gas fuel valve.

.4 Ventilation should be provided according to 2.10.3

.5 The machinery spaces containing gas utilisation equipments should comply with ESD requirements. This may be revised after special examination by the Society if gas utilisation equipments are enclosed in gastight cabinets (see 6.11).

2.7 Gas supply system in gas machinery spaces

2.7.1 Gas supply system for gas safe machinery spaces

.1 Gas supply lines passing through gas safe machinery spaces should be completely enclosed by a double pipe or duct. This double pipe or duct should fulfil one of the following:

a. The gas piping should be a double wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes should be pressurised with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms should be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure gas the system should be so arranged that the pipe between the master gas valve and the fuel cell power system is automatically purged with inert gas when the master gas valve is closed; or

b. The gas fuel piping should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and the wall of the outer pipe or duct should be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. Such a minimum ventilation rate should be provided everywhere in this air space to ensure that no explosive mixture can be entrapped in any location of this space. This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with suitable inert gas (see 2.12) upon detection of gas is arranged for. The fan motors should be placed outside the ventilation pipe or duct or should be of safe type suitable for operation in hazardous areas zone 1 (see 4.3.2). The ventilation outlet should be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited. The ventilation should always be in operation when there is gas in the piping. Continuous gas detection should be provided for each gas supply line to indicate leaks and to shut down the gas supply to the machinery space in accordance with Table 3. The master gas fuel valve should close automatically if the air flow is not established and maintained by the exhaust ventilation system. A differential pressure monitoring device or flow monitoring device should be provided for that purpose.

   The fan should be of non-sparking construction as defined in 2.10.1.3.

   The air intakes to the ventilation pipe or duct should be from a safe location in open air, remote from any source of ignition. Alternatively, for low pressure piping, the air intakes can be from within the machinery space provided that they are fitted with non-return devices effective for gas leak or with a gas detector complying with 5.5.

.2 The connecting of gas piping and ducting to the fuel cell system gas inlet should be so as to provide complete coverage by the ducting. The arrangement should facilitate the fuel cell system maintenance. The double ducting should be required also for gas pipes on the fuel cell system itself.

.3 For high-pressure piping the design pressure of the ducting should be taken as the higher of the following:

a. the maximum built up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

b. local instantaneous peak pressure in way of the rupture: this pressure should be taken as the critical pressure and is given by the following expression:

$$p^* = p_0 \left(\frac{2}{k+1} \right)^{\frac{k}{k+1}}$$

where:

p_0 = maximum working pressure of the inner pipe

k = C_p/C_v constant pressure specific heat divided by the constant volume specific heat (1.31 for CH_4, 1.41 for H_2)

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

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

.4 For low pressure piping the duct should be dimensioned for a design pressure not less than the maximum working pressure of the gas pipes. The duct should also be pressure tested to show that it can withstand the expected maximum pressure at gas pipe rupture.

2.7.2 Gas supply system for ESD protected machinery spaces

.1 The pressure in the gas supply system should not exceed 10 bar.

.2 The gas supply lines should have a design pressure not less than 10 bar.

2.8 Gas fuel storage

2.8.1 Liquefied gas storage tanks

.1 The storage tank used for liquefied gas should be an independent tank type C designed in accordance with the IGC Code Chapter 4.

.2 Pipe connections to the tank should normally be mounted above the highest liquid level in the tanks. However, connections below the highest liquid level may be accepted after special consideration by the Society.

.3 Pressure relief valves as required in IGC Code Chapter 8 should be fitted.

.4 The design of pipes connected to the pressure relief valves should comply with 2.10.1.2.

.5 The outlet from the pressure relief valves should normally be located at least B/3 or 6 m, whichever is greater, above the weather deck and 6 m above the working area and gangways, where B is the greatest moulded breadth of the ship in metres. The outlets should be located at least 10 m from the nearest:

- air intake, air outlet or opening to accommodation, service and control spaces, or other gas safe spaces.
- exhaust outlet from machinery or from furnace installation.

NOTE: relaxation on the pressure relief valves oulet location may be permitted for small ships.

.6 Storage tanks for liquid gas should not be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in IGC Code paragraph 15.1.4. A filling limit curve for actual filling temperatures should be prepared from the formula given in IGC Code paragraph 15.1.2. However, when the tank insulation and tank location makes the probability very small for the tank contents to be heated up due to external fire, special considerations may be made to allow a higher filling limit than calculated using the reference temperature, but never above 95%.

.7 Means that are not dependent on the gas machinery system should be provided whereby liquid gas in the storage tanks can be emptied.

.8 It should be possible to empty, purge gas and vent bunker tanks with gas piping systems. Procedures should be prepared for this. Inerting should be performed, with an inert gas that cannot freeze and form a plug when exposed to cold hydrogen, prior to venting to avoid an explosion hazardous atmosphere in tanks and gas pipes.

.9 In case of liquid hydrogen storage, the inner pressure vessel must be designed to operate at a temperature of -253°C. Fill piping and piping before a vaporizer must also be designed to these temperatures. The rest of the system must be designed to accept temperatures likely to be encountered after installation in the ship.

.10 The formation of flammable mixtures due to potential entry of air into the fuel system should be addressed. Air could be drawn into a cold, empty cryogenic container if valves were left open. Additionally, materials and design must minimize risk due to liquefaction and pooling of oxygen-rich air in the system. Materials that are normally inert could ignite more easily in the presence of higher concentrations of oxygen.

.11 The system must be designed to withstand at least twice the anticipated filling cycles during the ship lifetime.

2.8.2 Compressed gas storage tanks

.1 The storage tanks to be used for compressed gas should be certified and approved by the Society. The design and construction of compressed gas storage tanks should comply with relevant Recognised Codes and Standards (e.g. [16], Sec 3 and, for hydrogen storage, [5], [13], [14] and [15]). The applicability of Codes and Standards to sea going containment system should be demonstrated. Subject to special consideration by the Society, these Codes and Standards may be amended to take into account specificities of the proposed design.

.2 Tanks for compressed gas should be fitted with pressure relief valves with a set point below the design pressure of the tank (see [16], Sec 3 §3.5.1 for guidance), connected to a pipe complying with 2.10.1.2 and with outlet located as required in 2.8.1.5.

.3 The system must be designed to withstand the anticipated filling cycles during the lifetime of the ship.

2.8.3 Storage on open deck

.1 Both gases of the compressed and the liquefied type will be accepted stored on open deck.

.2 The storage tanks or tank batteries should be located at least B/5 from the ship's side. For ships other than passenger ships a tank location closer than B/5 from the ship side but not less than 760 mm from the ship’s side may be accepted.

.3 The gas storage tanks or tank batteries and equipment should be located to assure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

.4 Tanks for liquid gas with a connection below the highest liquid level, (see 2.8.1.2) should be fitted with drip trays below the tank which should be of sufficient capacity to contain the volume which could escape in the event of a pipe connection failure. The material of the drip tray should be stainless steel, and there should be efficient separation or isolation so that the hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid gas.

2.8.4 Storage in enclosed spaces

.1 Gas in a liquid state can be stored in enclosed spaces, with a maximum acceptable working pressure of 10 bar. Storage of compressed gas in enclosed spaces and location of gas tanks with a higher pressure than 10 bar below deck should normally not be acceptable, but may also be permitted after special consideration provided that the following is fulfilled in addition to 2.8.4.3:

a. adequate means are provided to depressurise the tank in case of a fire which can affect the tank; and

b. all surfaces within the tank room are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

c. a permanent gas detection system is fitted in the tank room with audible and visual alarms in a permanently manned space as well as the bridge and engine room; and

d. the tank room is fitted with a ventilation and passive pressure relief system that is vented away to protect the structure from overpressure in the event of failure of the gas storage tank(s) and systems; and

e. a fixed fire extinguishing system is installed in the tank room arranged to discharge when the gas detection system reaches 20 % LFL.

.2 The gas storage tanks should be placed as close as possible to the centreline.

a. minimum, the lesser of B/5 and 11.5 m from the ship side

b. minimum, the lesser of B/15 and 2 m from the bottom plating

c. not less than 760 mm from the shell plating.

For ships other than passenger ships and multihulls, a tank location closer than B/5 from the ship side may be accepted.

.3 The storage tank and associated valves and piping should be located in a space designed to act as a second barrier, in case of liquid or compressed gas leakage. The material of the bulkheads of this space should have the same design temperature as the gas tank, and the space should be designed to withstand the maximum pressure build up. Alternatively, pressure relief venting to a safe location (mast) can be provided. The space should be capable of containing leakage, and should be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling, in case of leakage of the liquid or compressed gas. This second barrier space is in other parts of these guidelines called “tank room”. When the tank is double walled and the outer tank shell is made of cold resistant material, a tank room could be arranged as a box fully welded to the outer shell of the tank, covering all tank connections and valves, but not necessarily all of the outer tank shell.

.4 The tank room may be accepted as the outer shell of a stainless steel vacuum insulated tank in combination with a stainless steel box welded to the outer shell, containing all tank pipe connections, valves, piping etc. In this case the requirements for ventilation and gas detection should be made applicable to the box, but not to the double barrier of the tank.

.5 Bilge suctions from the tank room, if provided, should not be connected to the bilge system for the rest of the ship.

2.8.5 Storage tanks supports and fixation

.1 The support and fixation of independent storage tanks, either for compressed or liquefied gas storage, should be designed in order to prevent movement of the tank under static and dynamic loads associated to the ship motions and inclinations, while allowing contraction and expansion due to the tank temperature and internal pressure variations and to the hull deflections, without undue stressing of the tank and of the hull. Inclination values as specified in [17] should be considered. Ship motions should be evaluated by seakeeping analysis, accounting for the six degrees of freedom ship motion, to determine the most probable largest loads the ship will encounter during its operating life (normally taken to correspond to a probability of 10^8 wave encounters).

.2 The supports of independent storage tanks, if these tanks are located in a floodable space, should withstand the buoyancy forces that would be applied on the tanks, if fully submerged, without deformation likely to endanger the tank structure and the piping connection to the tanks.

.3 The supports of independent storage tanks should withstand a collision force acting on the tank corresponding to one half the weight of the tank and cargo in the forward direction, one quarter the weight of the tank and cargo in the aft direction and the weight of the tank and cargo in the horizontal transverse direction without deformation likely to endanger the tank structure and the piping connection to the tanks.

.4 A fatigue analysis of ship supports should be performed when deemed necessary.

2.9 Gas fuel bunkering system and distribution system outside machinery spaces

2.9.1 Fuel bunkering station

.1 The bunkering station should be so located that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations will be subject to special consideration. The bunkering station should be physically separated and structurally shielded from accommodation, cargo/working deck and control stations. Connections and piping should be so positioned and arranged that any damage to the gas piping does not cause damage to the vessel's gas storage tank arrangement leading to uncontrolled gas discharge.

.2 Drip trays should be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays should be made of stainless steel, and should be drained over the ship's side by a pipe that preferably leads down near the sea. This pipe could be temporarily fitted for bunkering operations. The surrounding hull or deck structures should not be exposed to unacceptable cooling, in case of leakage of liquid gas. For compressed gas bunkering stations, low temperature steel shielding should be provided to prevent the possible escape of cold jets impinging on surrounding hull structure.

.3 Control of the bunkering should be possible from a safe location in regard to bunkering operations. At this location tank pressure and tank level should be monitored. Overfill alarm and automatic shutdown should also be indicated at this location.

.4 During the refilling process the gas fuel system should have the means to provide electrical continuity with the refilling facilities before gas transfer is permitted.

2.9.2 Bunkering system

.1 The bunkering system should be so arranged that no gas is discharged to air during filling of storage tanks.

.2 A manually operated stop valve and a remote operated shutdown valve in series or a combined manually operated and remote valve should be fitted in every bunkering line close to the shore connecting point. It should be possible to release the remote operated valve from the control location for bunkering operations and from another safe location.

.3 If the ventilation in the ducting around the gas bunkering lines stops, a visual and audible alarm should be provided at bunkering control location.

.4 If gas is detected in the ducting around the bunkering lines a visual and audible alarm should be provided at the bunkering control location.

.5 Means should be provided for draining the liquid from the bunkering pipes at bunkering completion.

.6 Bunkering lines should be arranged for inerting and gas freeing. During operation of the vessel the bunkering pipes should be gas free.

2.9.3 Distribution outside of machinery spaces

.1 Gas fuel piping may pass outside of machinery spaces in the conditions stated in 2.5.17.

.2 Where gas pipes pass through enclosed spaces in the ship, they should be enclosed in a duct. This duct should be mechanically under pressure ventilated with at least 30 air changes per hour, and gas detection as required in 5.5 should be provided.

.3 The duct should be dimensioned according to 2.7.1.

.4 The ventilation inlet for the duct should always be located in open air, away from ignition sources.

.5 Gas pipes located in open air should be so located or protected that they are not likely to be damaged by accidental mechanical impact.

.6 High-pressure gas lines outside the machinery spaces containing gas utilisation equipment should be installed and protected so as to minimise the risk of injury to personnel in case of rupture.

2.10 Ventilation system

2.10.1 General

.1 Any ducting used for the ventilation of hazardous spaces should be separate from that used for the ventilation of non-hazardous spaces. Additionally, any ducting used for the ventilation of one hazardous space should be separated from that used for the ventilation of any another hazardous space. The ventilation should function at all temperature conditions the ship will be operating in (see environmental conditions in [17]). Electric fan motors should not be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

.2 Ducts used for ventilation of hazardous spaces should be designed to prohibit the build up of explosive gas mixture pockets. In this purpose, they should run continuously upward from the ventilated space up to the ventilation outlet, without small radii of curvatures.

.3 Design of ventilation fans serving spaces containing gas sources should fulfil the following:

a. Electric motors driving fans should comply with the required explosion protection in the installation area. Ventilation fans should not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, should be of non sparking construction defined as:

- impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;
- impellers and housings of non-ferrous metals;
- impellers and housing of austenitic stainless steel;

- impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or
- any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

b. In no case should the radial air gap between the impeller and the casing be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

c. Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and should not be used in these places.

d. The installation on board of the ventilation units should be such as to ensure the safe bonding to the hull of the units themselves.

.4 Any loss of the required ventilating capacity should give an audible and visual alarm at a permanently manned location.

.5 Required ventilation systems to avoid any gas accumulation should consist of independent fans, each of sufficient capacity, unless otherwise specified in these Guidelines.

.6 Air inlets for hazardous enclosed spaces should be taken from areas which, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas at least 1,5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct should have over-pressure relative to this space, unless mechanical integrity and gas-tightness of the duct will ensure that gases will not leak into it.

.7 Air outlets from non-hazardous spaces should be located outside hazardous areas.

.8 Air outlets from hazardous enclosed spaces should be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

.9 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated shape and/or arrangement.

.10 Non-hazardous spaces with opening to a hazardous area should be arranged with an air lock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation should be arranged according to the following specifications:

a. During initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it should be required to:

- proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and
- pressurize the space

b. Operation of the overpressure ventilation should be monitored.

c. In the event of failure of the overpressure ventilation:

- an audible and visual alarm should be given at a manned location; and

– if overpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations according to recognised standards (e.g. [7], Table 5) should be required.

2.10.2 Tank room

.1 The tank room for gas storage should be provided with an effective mechanical forced ventilation system of under pressure type, providing a ventilation capacity of at least 30 air changes per hour. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations should be demonstrated by a safety analysis.

.2 Approved automatic fail-safe fire dampers should be fitted in the ventilation trunk for tank room.

.3 The number and power of the ventilation fans should be such that the capacity is maintained at 100%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.

2.10.3 Machinery spaces containing gas utilisation equipment

.1 The ventilation system for machinery spaces containing gas utilisation equipment should be independent of all other ventilation systems.

.2 ESD protected machinery spaces should have ventilation with a capacity of at least 30 air changes per hour. The ventilation system should ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected.

As an alternative, arrangements whereby under normal operation the machinery space is ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to at least 30 an hour.

.3 The number and power of the ventilation fans should be such that the capacity is not reduced by more than 50% of the total ventilation capacity, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.

2.10.4 Pump and compressor rooms

.1 Pump and compressor rooms should be fitted with effective mechanical ventilation system of under pressure type, providing a ventilation capacity of at least 30 air changes per hour.

.2 The number and power of the ventilation fans should be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.

.3 Ventilation systems for pump and compressor rooms should be in operation when pumps or compressors are working.

.4 When the space is dependent on ventilation for its area classification, the following should apply:

a. During initial start-up, and after loss of ventilation, the space should be purged (at least 5 air changes), before connecting electrical installations which are not certified for the area classification in absence of ventilation. Warning notices to this effect should be placed in an easily visible position near the control stand.

b. Operation of the ventilation should be monitored.

c. In the event of failure of ventilation, the following should apply:

- an audible and visual alarm should be given at a manned location;
- immediate action should be taken to restore ventilation; and
- electrical installations, except intrinsically safe equipment suitable for zone 0, should be disconnected if ventilation cannot be restored for an extended period. The disconnection should be made from outside the hazardous areas. Re-connection should be performed manually by authorised personnel only. Certified flameproof lighting may have a separate switch off circuit.

2.11 Fuel filters

2.11.1 If filters are used for reducing hazards associated with contamination, especially from solid particles, and, in liquid hydrogen systems, from solid particles that could include oxygen, the following recommendations should be accounted for:

.1 Filters should be accessible and capable of being isolated for cleaning.

.2 Filters should not be cleaned by back-flushing through the system.

.3 Filters should be cleaned or replaced periodically or whenever the pressure drop across the filter reaches a specified value.

.4 The quantity and location of filters should be determined as required to minimize impurities in a system (refill or re-supply lines are primary locations for filters).

The use of non-metallic filter to trap particles can increase build-up of electric charge and can produce from 10 to 200 more charge than a system with no filter. The large surface area of filters allows static charge to accumulate more readily. Grounding should be designed accordingly.

2.12 Purging

2.12.1 A gas containing component should be purged with an inert gas to remove air before admitting gas fuel into the component, and the component should be purged of gas fuel before opening it to air. Purging should particularly be considered in relations to the following paragraphs: 2.5.18, 2.7.1.1.1a, 2.8.1.7, 6.4.5 and 6.6.5.4

2.12.2 An inert gas subsystem is needed for various purging operations. Hydrogen equipment should be purged with an inert gas before and after using hydrogen in the equipment.

2.12.3 The inert gas should be compatible with the characteristics of the gas to be purged. In particular, when used with cryogenic gas, it should have a lower melting point than the one of the gas it is exposed to in order to avoid freezing and formation of a plug.

2.12.4 The selection of the proper purging technique requires an evaluation of the equipment to be purged. Important purge parameters include flowrate, duration, mixing and dilution.

2.12.5 The inert-gas subsystem should be protected by a suitable means against contamination with hydrogen.

2.12.6 The purged gas should be vented to an open outdoor area, away from user areas, ignition sources, air intakes, building openings and overhangs. (see also 2.10.1.2 and 2.8.1.5)

Chapter 3 - Fire Safety

3.1 General

3.1.1 The recommendations in this chapter are additional to the requirements given in SOLAS Ch.II-2 and in [19].

3.1.2 A compressor room should be regarded as a machinery space of category A for fire protection purposes.

3.2 Fire protection

3.2.1 Tanks or tank batteries located above deck should be shielded with class A-60 insulation towards accommodation, service stations, cargo spaces and machinery spaces.

3.2.2 The tank room boundaries and ventilation trunks to such spaces below the bulkhead deck should be constructed to class A-60. However, where the room is adjacent to tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces, the insulation standard may be reduced to A-0.

3.2.3 The fire and mechanical protection of gas pipes lead through ro-ro spaces on open deck should be subject to special consideration by the Society depending on the use and expected pressure in the pipes. Gas pipes lead through ro-ro spaces on open deck should be provided with guards or bollards to prevent vehicle collision damage.

3.2.4 The bunkering station should be separated by A-60 class division towards other spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces where the standard may be reduced to class A-0.

3.2.5 *When more than one machinery space is required and these spaces are separated by a single bulkhead, the bulkhead should be class A-60 .*

3.3 Fire extinction

3.3.1 Fire main

.1 The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure is sufficient to operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.

.2 When the storage tank is located on open deck, isolating valves should be fitted in the fire main in order to isolate damage sections of the main. Isolation of a section of fire main shall not deprive the fire line ahead of the isolated section of water.

3.3.2 Water spray systems

.1 A water spray system should be fitted for cooling and fire prevention and to cover exposed parts of storage tank located above deck.

.2 The system should be designed to cover all areas as specified above with an application rate of 10 l/min/m^2 for horizontal projected surfaces and 4 l/min/m^2 for vertical surfaces.

.3 For the purpose of isolating damage sections, stop valves should be fitted at least every 40 m or the system may be divided into two or more sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.

.4 The capacity of the water spray pump should be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the protected areas.

.5 A connection to the ship's fire main through a stop valve should be provided.

.6 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system should be located in a readily accessible position which is not likely to be cut off in case of fire in the areas protected.

.7 The nozzles should be of an approved full bore type and they should be arranged to ensure an effective distribution of water throughout the space being protected.

.8 An equivalent system to the water spray system may be fitted provided it has been tested for its on-deck cooling capability to the satisfaction of the Society.

3.3.3 Dry chemical powder fire extinguishing system

.1 In the bunkering station area a permanently installed dry chemical powder extinguishing system should cover all possible leak points. The capacity should be at least 3.5 kg/s for a minimum of 45 s discharges. The system should be arranged for easy manual release from a safe location outside the protected area.

.2 One portable dry powder extinguisher of at least 5 kg capacity should be located near the bunkering station.

3.4 Fire detection and alarm system

3.4.1 Detection

.1 In addition to the provisions of [19], an approved fixed fire detection system should be provided for the tank room and the ventilation trunk for tank room below deck.

.2 Smoke detectors alone should not be considered sufficient for rapid fire detection.

.3 Where the fire detection system does not include means of remotely identifying each detector individually, the detectors should be arranged on separate loops.

.4 The detectors should be adapted to the flame produced by the gas used.

3.4.2 Alarms and safety actions

.1 Required safety actions at fire detection in the machinery space containing gas utilisation equipment and tank room are given in Chapter 5 - Table 3. In addition the ventilation should stop automatically and fire dampers should close.

Chapter 4 - Electrical Systems

4.1 General

4.1.1 The provisions of this chapter should be applied in conjunction with applicable electrical requirements of [17].

4.1.2 Hazardous areas on open deck and other spaces not defined in this chapter should be decided based on a recognised standard (e.g. [7], part 4.4 "Tankers carrying flammable liquefied gases" as applicable). The electrical equipment fitted within hazardous areas should be according to the same standard.

4.1.3 Electrical equipment and wiring should in general not be installed in hazardous areas unless essential for operational purposes. The type of equipment and installation requirements should comply with [7] and [8] according to the area classification.

4.1.4 Electrical equipment fitted in an ESD protected machinery space should fulfil the following:

.1 Fire and gas detectors and fire and gas alarms, lighting and ventilation fans should not be disconnected and therefore should be certified safe for hazardous area zone 1.

.2 All electrical equipment in a machinery space containing gas utilisation equipment, and not certified for zone 1 should be automatically disconnected if gas concentrations above 20% LFL is detected on two detectors in the space containing gas utilisation equipment.

4.1.5 There should be an equalization connection between the bunker supplier and the bunkering station on the ship when a flammable gas/liquid is transferred.

4.1.6 Cable penetrations should be sealed against the passage of gas or vapour.

4.1.7 Power supply connections should not permit the ingress of gaseous mixtures where gas fuel leaks are possible.

4.2 Area classification

4.2.1 General

.1 Area classification is a method of analyzing and classifying the areas where explosive gas atmospheres may occur. The object of the classification is to allow the selection of electrical apparatus able to be operated safely in these areas.

.2 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2 according to the principles of the standard [8] and guidance and informative examples given in [7]. Main features of the guidance are given in 4.3. The definition of each zone is given in 1.3.22.

.3 Area classification of a space may be dependent on ventilation as specified in [7], Table 1.

.4 A space with opening to an adjacent hazardous area on open deck, may be made into a less hazardous or non-hazardous space, by means of overpressure. Specifications for such pressurization are given in 2.10.

.5 Ventilation ducts should have the same area classification as the ventilated space.

4.3 Definition of hazardous area zones

4.3.1 Hazardous area zone 0

This zone includes:

.1 The interiors of gas tanks, any pipe work of pressure-relief or other venting systems for gas tanks, pipes and equipment containing gas[1].

4.3.2 Hazardous area zone 1

This zone includes:

.1 tank room;

.2 compressor room arranged with ventilation according to .3;

.3 areas on open deck, or semi- enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapour outlet[2], bunker manifold valve, other gas valve, gas pipe flange, gas pump-room ventilation outlets and gas tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

.4 areas on open deck or semi-enclosed spaces on deck, within 1.5 m of gas compressor entrances, gas pump and compressor room ventilation inlets and other openings into zone 1 spaces;

.5 areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

.6 compartments for gas bunkering hoses;

.7 enclosed or semi-enclosed spaces in which pipes containing gas are located, e.g. ducts around gas pipes, gas valve unit enclosures, semi-enclosed bunkering stations; and

.8 the ESD protected machinery space is considered as non-hazardous area during normal operation, but changes to zone 1 in the event of gas leakage.

4.3.3 Hazardous area zone 2

This zone includes:

.1 areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1 as specified in [7] or [8], as applicable, if not otherwise specified in this standard.

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[1] Instrumentation and electrical apparatus in contact with the gas or liquid gas should be of a type suitable for zone 0. Temperature sensors installed in thermo wells, and pressure sensors without additional separating chamber should be of intrinsically safe type Ex-ia

[2] Such areas are, for example, all areas within 3 m of gas tank hatches, ullage openings or sounding pipes for gas tanks located on open deck and gas vapour outlets

Chapter 5 - Control, Monitoring and Safety Systems

5.1 General

5.1.1 A local reading pressure gauge should be fitted between the stop valve and the connection to shore at each bunker pipe.

5.1.2 Pressure gauges should be fitted to gas pump discharge lines and to the bunkering lines.

5.1.3 A bilge well in each tank room surrounding an independent liquid gas storage tank should be provided with both a level indicator and a temperature sensor. Alarm should be given at high level in bilge well. Low temperature indication should lead to automatic closing of main tank valve.

5.1.4 Sensors and detectors used in control, monitoring and safety systems should be adapted to their use and working environment. They should have adequate ranges, sensitivity and response times. It should be possible to regularly verify their proper functioning, either by built-in auto-test function or by an appropriate procedure. They should be calibrated and maintained according to the manufacturer's specifications

5.1.5 The recommendations given in the following paragraphs may be adapted on the basis of the risk analysis to be performed according to 2.1.5 and Appendix 1. In particular, Monitoring and control options should be defined for systems not covered in the following paragraphs but for which the risk analysis would show significant risks.

5.2 Gas tank monitoring

5.2.1 Gas tanks should be monitored and protected against overfilling as required in IGC Code sections 13.2 and 13.3.

5.2.2 Each tank should be monitored with at least one local indicating instrument for pressure and remote pressure indication at the control position. The pressure indicators should be clearly marked with the highest and lowest pressure permitted in the tank. In addition, high-pressure alarm, and if vacuum protection is required, low pressure alarm should be provided on the bridge. The alarms should be activated before the set pressures of the safety valves are reached.

5.3 Gas compressor monitoring

5.3.1 Gas compressors should be fitted with audible and visual alarms both on the bridge and in the engine room. As a minimum the alarms should be in relation to low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

5.4 Fuel cell power system monitoring

5.4.1 Additional to the instrumentation provided in accordance with [16], Sec 3 §5.2 and with [18], indicators should be fitted on the navigation bridge, the engine control room and the manoeuvring platform, for operation of the fuel cell power system.

5.4.2 Auxiliary systems where gas may leak directly into the system medium (lubricating oil, cooling water) should be equipped with appropriate gas extraction measures fitted directly after the medium outlet from the system in order to prevent gas dispersion. The gas extracted from auxiliary systems media should be vented to a safe location in the open air (see also 2.10.1.2 and 2.8.1.5).

5.4.3 The fuel processing unit(s) should be fitted with audible and visual alarms both on the bridge and in the engine room. The parameters to be monitored and the levels for raising alarms should be defined according to the risk analysis performed on this system (see 6.1.2).

5.4.4 Monitoring of fuel-fired boiler and/or oxidation reactors proper ignition and operation should be provided when applicable.

5.4.5 Recommendations for protection against fire and explosion hazards, as given in 6.4 should be accounted for.

5.4.6 The following are faults associated with the fuel cell module components that may require monitoring to address potentially hazardous conditions:

.1 Cell Stack or Process fault: out-of-limit thermal, pressure, flow or composition conditions within cell stacks or other reactors in the fuel cell system which could lead to internal or external component failures and subsequently expose personnel to hazards.

.2 Ground Fault: electrical isolation below the limit defined for high voltage isolation in operation represents a hazard to service personnel.

.3 Low Voltage Fault: the fuel cell stack or individual cells may experience low voltage that could lead to internal or external component failures and subsequently expose personnel to hazards.

.4 Overcurrent Fault: currents greater than the rated values could lead to internal or external component failures and subsequently expose personnel to hazards.

Items which can encounter such exceedance of limits for safe operations should be designed according to the fail-safe principle. If such exceedance occur, immediate actions should be taken by means of fail-safe procedures.

5.4.7 Recommendations for protection against fire and explosion hazards, as given in 6.4 should be accounted for.

5.5 Gas detection

5.5.1 Permanently installed gas detectors should be fitted in the tank room, in all ducts around gas pipes, in the oxidant processing system exhaust pipe, in machinery spaces of the ESD-protected type and other enclosed spaces containing gas piping or other gas equipment without ducting. In each ESD-protected machinery space, two independent gas detector systems should be required. The gas detector should comply with recognised standards.

5.5.2 The number of detectors in each space should be considered taking size, layout and ventilation of the space into account.

5.5.3 The detection equipment should be located where gas may accumulate and in the ventilation outlets. Gas dispersal analysis or a physical smoke test should be used to find the best arrangement.

5.5.4 An audible and visible alarm should be activated before the vapour concentration reaches 20% LFL. For ventilated ducts around gas pipes in the machinery spaces containing gas utilisation equipment, the alarm limit can be set to 30% LFL. The protective system should be activated at a LFL of 40 %.

5.5.5 Audible and visible alarms from the gas detection equipment should be located on the bridge and in the engine control room.

5.5.6 Gas detection for gas pipe ducts and machinery spaces containing gas utilisation equipment should be continuous without delay.

5.6 Safety functions of gas supply systems

5.6.1 Each gas storage tank should be provided with a main tank valve capable of being remote operated and should be located as close to the tank outlet as possible.

5.6.2 Master gas fuel valve:

.1 The main supply lines for gas to each fuel cell power system should be equipped with a manually operated stop valve and an automatically operated "master gas fuel valve" coupled in series or a combined manually and automatically operated valve. The valves should be situated in the part of the piping that is outside machinery space containing gas utilisation equipment, and, in case of liquid gas, placed as near as possible to the installation for heating the gas if fitted. The master gas fuel valve should automatically cut off the gas supply as given in Table 3.

.2 The automatic master gas fuel valve should also be operable from a reasonable number of places in the machinery space containing gas utilisation equipment, from a suitable location outside the space and from the bridge.

5.6.3 Double block and bleed valves

Each gas utilisation equipment should be provided with a set of "double block and bleed" valves. These valves should be arranged so that when automatic shutdown is initiated as given in Table 3, this will cause the two gas fuel valves that are in series to close automatically and the ventilation valve to open automatically and:

a. Two of these valves should be in series in the gas fuel pipe to the gas consuming equipment. The third valve should be in a pipe that vents to a safe location in the open air that portion of the gas fuel piping that is between the two valves in series (see also 2.10.1.2 and 2.8.1.5); or

b. the function of one of the valves in series and the ventilation valve can be incorporated into one valve body, so arranged that the flow to the gas utilisation unit will be blocked and the ventilation opened.

.2 The two block valves should be of the fail-to-close type, while the vent valve should be fail-to-open.

.3 The double block and bleed valves should also be used for normal stop of the gas utilisation equipment.

5.6.4 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve should be ventilated, if reverse flow from the fuel cell power system to the pipe must be assumed.

5.6.5 There should be one manually operated shutdown valve in the gas supply line to each gas utilisation equipment upstream of the double block and bleed valves to assure safe isolation during maintenance on the gas utilisation equipment.

5.6.6 For one-fuel cell power system installations and multi-fuel cell power systems installations, where a separate master valve is provided for each fuel cell power system, the master gas fuel valve and the double block and bleed valve functions can be combined.

5.6.7 *In case of a redundant fuel cell power installation in more than one machinery space, the total loss of ventilation in one of these machinery spaces should, additionally to what is given in Table 3, lead to the start of the second fuel cell power system, with automatic shutdown of the first one.*

If only one machinery space for the fuel cell power system is fitted and ventilation in one of the enclosed ducts around the gas pipes is lost, the master gas fuel and double block and bleed valves in that supply line should close automatically provided the other gas supply unit is ready to deliver.

5.6.8 If the gas supply is shut off due to activation of an automatic valve, the gas supply should not be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect should be placed at the operating station for the shut-off valves in the gas supply lines.

5.6.9 If a gas leak leading to a gas supply shutdown occurs, the gas fuel supply should not be operated until the leak has been found and dealt with. Instructions to this effect should be placed in a prominent position in the machinery space.

5.6.10 A signboard should be permanently fitted in the machinery space containing gas utilisation equipment stating that heavy lifting, implying danger of damage to the gas pipes, should not be done when the gas utilisation equipment are running.

5.6.11 The last gas valve prior to gas utilisation equipment should be controlled by the fuel cell power system control or by the equipment gas demand.

5.6.12 The use of an Excess Flow System that closes in the event of line rupture or abnormal flow condition should be subject to special examination by the Society.

5.7 Safety functions of the fuel cell power system

5.7.1 In case of exceeding limits for safe operations of items which are monitored as recommended in 5.4, immediate actions should be taken by means of fail-safe procedures.

5.7.2 These procedures should include recommendations on protection against fire and explosion hazards, on shutdowns and on protective components as given in 6.4, 6.6.6 and 6.6.11 respectively.

5.7.3 These procedures should be verified and completed when necessary according to the risk analysis performed on the fuel cell power system (see 6.1.2)

Table 3: Monitoring of the fuel cell installation				
Parameter	**Alarm**	**Automatic shutdown of main tank valve**	**Automatic shutdown of gas supply to machinery space containing gas utilisation equipment**	**Comment**
Gas detection in tank room above 20% LFL	X			
Gas detection on two detectors [1] in tank room above 40% LFL	X	X		
Fire detection in tank room	X	X		
Bilge well high level tank room	X			
Bilge well low temperature in tank room	X	X		
Gas detection in duct between tank and machinery space containing gas utilisation equipment above 20% LFL	X			
Gas detection on two detectors [1] in duct between tank and machinery space containing gas above 40% LFL	X	X [2]		
Gas detection in oxidant exhaust system above 20% LFL	X			
Gas detection on two detectors [1] in oxidant exhaust system above 40% LFL	X	X [2]		
Gas detection in compressor room above 20% LFL	X			
Gas detection on two detectors [1] in compressor room above 40% LFL	X	X [2]		
Gas detection in duct inside machinery space containing gas utilisation equipment above 30% LFL	X			If double pipe fitted in machinery space containing gas utilisation equipment
Gas detection on two detectors [1] in duct inside machinery space containing gas utilisation equipment above 40% LFL	X		X [3]	If double pipe fitted in machinery space containing gas utilisation equipment
Gas detection in machinery space containing gas utilisation equipment above 20% LFL	X			Gas detection only required for ESD protected machinery space.
Gas detection on two detectors [1] in machinery space containing gas utilisation equipment above 40% LFL	X		X	Gas detection only required for ESD protected machinery space containing gas utilisation equipment. It should also disconnect non certified safe electrical equipment in machinery space containing gas utilisation equipment.

Table 3: Monitoring of the fuel cell installation

Parameter	Alarm	Automatic shutdown of main tank valve	Automatic shutdown of gas supply to machinery space containing gas utilisation equipment	Comment
Loss of ventilation in duct between tank and machinery space containing gas utilisation equipment [5]	X		X [2]	
Loss of ventilation in duct inside machinery space containing gas utilisation equipment [5]	X		X [3]	If double pipe fitted in machinery space containing gas utilisation equipment
Loss of ventilation in machinery space containing gas utilisation equipment	X		X	ESD protected machinery space containing gas utilisation equipment only
Fire detection in machinery space containing gas utilisation equipment	X		X	
Abnormal gas pressure in gas supply pipe	X		X	
Failure of valve control actuating medium	X		X [4]	Time delayed as found necessary
Automatic shutdown of fuel cell power system (system failure)	X		X [4]	
Emergency shutdown of fuel cell power system manually actuated	X		X	

[1] Two independent gas detectors located close to each other should be provided for redundancy reasons. If the gas detector is of self monitoring type the installation of a single gas detector could be sufficient.

[2] If the tank is supplying gas to more than one fuel cell power system and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected should close.

[3] If the gas is supplied to more than one fuel cell power system and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas utilisation equipment, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected should close.

[4] Only double block and bleed valves should close.

[5] If the duct is protected by inert gas (see 2.7.1) then loss of inert gas overpressure should lead to the same actions as given in this table.

Chapter 6 - Fuel cell power system

6.1 General

6.1.1 The fuel cell power system should comply with recognised standards such as [10] and [11].

6.1.2 A safety and reliability analysis of the fuel cell power system should be performed, e.g. according to [10], §4, in order to identify all foreseeable hazards, hazardous situations and events associated with the fuel cell power systems throughout their anticipated lifetime. The risk of each of these hazards should be estimated from the combination of probability of occurrence of the hazard and of its foreseeable severity. A list of hazards on which special care needs to be addressed can be found in [10], Annex A. It should be demonstrated that the necessary protection measures in relation to risks that are not eliminated have been taken. Foreseeable abnormal operating conditions should be considered in the analysis.

6.1.3 In so far as their purpose allows, accessible parts of the fuel cell power system should have no sharp edges, no sharp angles, and no rough surfaces likely to cause injury.

6.1.4 The fuel cell power system or parts of it where persons are liable to move about or stand should be designed and constructed to prevent persons slipping, tripping or falling on or off these parts.

6.1.5 The fuel cell power system components and fittings should be designed and installed in order to ensure a safe operation with the physical environment (environmental conditions, quality of power supply and electromagnetic susceptibility) it will encounter onboard, as specified in [17], Sec 2 and Sec 3 §4. The possible influence of the dynamic feature of ship motions on the fuel cell system operation should be analysed.

6.1.6 The fuel cell power system components and fittings supports and fixation should be designed and constructing accounting for loads related to ship motions, hull deformation, vibration in normal operation as well as acceleration due to collision. The same type of analysis as requested for storage tanks supports and fixation (see 2.8.5) should be performed.

6.1.7 The moving parts of the fuel cell power system should be designed, built and laid out to avoid hazards or, where hazards persist, fixed with guards or protective devices in such a way as to prevent all risk of contact which could lead to accidents.

6.1.8 The various parts of the fuel cell power system and their linkages should be so constructed that, when used normally, no instability, distortion, breakage or wear likely to impair their safety can occur.

6.1.9 The fuel cell power system should be so designed, constructed and/or equipped that risks due to gases, liquids, dust, or vapours released during the operation or maintenance of a fuel cell power system, or used in its construction can be avoided.

6.1.10 All safety shutdown system components whose failure may result in a hazardous event, as identified by the reliability/safety analysis noted in 6.1.2, should be recognised, certified or separately tested for their intended usage.

6.1.11 Risk of injury caused by contact with, or proximity to, external surfaces of the appliance enclosure, handles, grips, or knobs at high temperatures should be properly addressed, e.g. according to [10], §4.4.9 and should comply with [16], Sec 1 §3.7.

6.1.12 The fuel cell power system should be so designed and constructed that the emission of airborne noise is reduced to a level suited for the intended use or location in compliance with applicable regional or national airborne noise codes and standards or in compliance with relevant class notation (e.g. BV COMF notation, [20]) if applicable.

6.1.13 The fuel cell power system exhaust to atmosphere, under normal steady-state operating conditions, should not contain concentrations of carbon monoxide in excess of 300 ppm in an air-free sample of the effluents, which is a sample that has its effluent CO concentration mathematically corrected as though there was zero per cent excess air.

6.1.14 Where explosive, flammable, or toxic fluids are contained in the piping, appropriate precautions should be taken in the design and marking of sampling and take-off points.

6.1.15 The maximum temperatures of components and materials, as installed in the fuel cell power system, should not exceed their temperature ratings.

6.1.16 The manufacturer should give consideration to the suitability of the fuel cell power system to operate where contaminants (for example, dust, salt, smoke, and corrosive gases) are present in the physical environment.

6.1.17 The fuel cell power system enclosure should be designed to safely contain any anticipated hazardous liquid leaks. The containment means should have a capacity of 110 % of the maximum volume of fluid anticipated to leak.

6.1.18 All components containing gas should be protected against mechanical damage.

6.2 Pressure equipment and piping

6.2.1 Fuel cell power system containing high pressure fluid should comply with recognised standards such as [10] and [11], with relevant recommendations of 2.5 and 2.8 and with relevant BV rules ([16], Sec 3).

6.3 Effluents venting system

6.3.1 The fuel cell power system should be provided with a vent system to convey products of combustion from fuel utilisation equipment to the outside atmosphere. The vent pipe parts should be so designed and constructed, in particular relative to mechanical strength, corrosion, temperature limitation, strength and resistance to the action of condensate, that they do not become damaged to the extent that they permit unsafe fuel cell power system operation. Requirements of [16], Sec 2 §3.4 and Sec 10 should be accounted for.

6.3.2 The outlets of the effluent gas venting system should be located outdoors in a safe location, away from user areas, ignition sources, air intakes, building openings and overhangs (see also 2.8.1.5). They should be considered as hazardous zones representing possible sources of ignition for explosive gaseous mixtures for defining their location with respect to other ventilation inlet/outlet and vents outlet.

6.3.3 The exhaust pipes of gas utilisation equipment should not be connected to the exhaust pipes of other gas utilisation equipment or systems.

6.3.4 The vent pipe should be properly supported and should be provided with a protective screen that would not limit or obstruct the gas flow from venting vertically upward (see also 2.10.1.2).

6.3.5 Pressure switches used to prove exhaust gas flow, if used, should be factory set, or at the manufacturer's discretion, be set by authorized personnel at the construction site. The adjustment means should then be locked. A pressure switch should bear a marking indicating clearly the appliance manufacturer's or distributor's part number or appropriate documentation which correlates to the locked pressure setting.

6.3.6 Parts of a pressure switch in contact with exhaust gas condensate should be corrosion resistant to exhaust gas condensate at the normal operating temperatures.

6.3.7 The presence of external air flow (e.g. resulting from ship relative wind speed) at the gas effluent venting system outlets should not lead to a fuel cell power system shutdown or unsafe operation.

6.3.8 When the fuel cell power system is provided with a venting system, the average temperature of the exhaust gases conveyed by that venting system should not exceed temperatures acceptable for the materials used to construct the venting system.

6.3.9 In case of effluent venting systems which may contain gas (e.g. exhaust of the air supply to the fuel cell system which may contain hydrogen in case of internal fuel cell stack leakage or membrane leakage), a gas detector should be installed at the venting outlet and actions taken in case of gas detection as indicated in Table 3.

6.3.10 Oxidant processing system

.1 In normal conditions, the oxidant processing system may release oxygen depleted gaseous mixture. Care should be taken that the further processing of this exhaust mixture (release to atmosphere, reuse onboard) will not represent anoxia hazards for people onboard.

.2 In abnormal conditions, e.g. gas tightness failure in the fuel cell stack, the oxidant processing system exhaust may contain a flammable or explosive gaseous mixture. Similar recommendations as given in 6.3.9 should be followed for the oxidant processing system exhaust part.

6.3.11 Oxidant processing system

.1 Specific fuel processing systems, such as reforming units, should be given special attention, and discussed with the Society.

6.4 Protection against fire or explosion hazards

6.4.1 All gas fuel cell power system components, systems and subsystems should be designed to:

.1 exclude any explosion at all possible situations; or

.2 to allow explosions without detrimental effect and to discharge to a safe location. The explosion event should not interrupt the safe operation of the fuel cell power system unless other safety measures allow the shutdown of the affected components.

6.4.2 For fuel cell power systems enclosed within a cabinet, means of prevention against fire and explosion hazard should be provided according to recognised standards (e.g. [10], §4.6.1).

6.4.3 Means of prevention against fire and explosion hazards in any fuel-fired boiler or heating device of fuel cell power systems should be provided according to recognised standards (e.g. [10], §4.6.2).

6.4.4 Means of prevention against fire and explosion hazards in catalytic fuel oxidation systems of fuel cell power systems should be provided according to recognised standards (e.g. [10], §4.6.3).

6.4.5 The following general recommendations for fuel processing systems, as provided in [13], should be followed:

.1 Within a fuel system or process that utilizes controlled oxidation reaction(s), e.g. catalytic burners, reactors or thermal burners, the potential formation of flammables should be managed. The following items should be addressed:

a. Purging when appropriate before the initiation of reaction

b. Air-to-fuel regulation as necessary during operation

c. Reactant shutoff, purging or passivation as necessary after shutdown.

.2 Fault monitoring should be provided to ensure that the reaction remains within prescribe process limits throughout all operating modes.

.3 Possible formation of flammable mixtures due to failures in fuel containing systems, including thermal and catalytic burners, if present, should be addressed. In particular, the design should consider potential air ingestion, cross-flow or back-flow of air into fuel lines or fuel into air lines. If necessary, countermeasures should be implemented to prevent hazardous situations such as the pressure and temperature build up due to the reaction of a flammable mixture. The design of the fuel system should be able to contain or release these pressure and temperature build-ups and manage the propagation of the reaction to other sections of the fuel system or to the external environment.

.4 The potential formation of flammables outside the fuel system should be managed too.

6.5 Electrical safety

6.5.1 Applicable requirements of [17] should be considered.

6.5.2 In addition to 6.5.1, relevant specifications for electrical safety of recognised standards for fuel cell power systems (e.g. [10], §4.7) should be used. The following aspects should be particularly addressed:

.1 Protection against electric shock and energy hazards.

a. Attention should be paid to the need and means of limiting Operator access to energized parts.

b. The fuel cell generator should be provided with an integral single emergency switching device, or terminals, for connection of a remote emergency switching device, which prevents further supply to the load in any mode of operation. Plug-connected fuel cell generators should not require an emergency switching device if the plug can perform the same function.

.2 Electrical components

.3 Input current

.4 Insulation

.5 Limited current circuits and limited power circuits

.6 Protective earthing

.7 AC and DC power isolation

.8 Over-current and earth fault protection

6.5.3 The fuel cell module should be protected from unintended back-feed of power from energy.

6.6 Control systems and protective components

6.6.1 The protection parameters of the safety circuit should be set on the basis of the safety and reliability analysis as specified in 6.1.2.

6.6.2 The fuel cell power system should be designed in such a way that the single failure of a component does not cascade into a hazardous condition. Means to prevent cascade failures can be found in [10], §4.9.1.2.

6.6.3 Automatic electrical and electronic controls of fuel cell power systems should be designed and constructed so that they are safe and reliable. Standards for automatic electrical heating devices (burners) control systems and for automatic electrical control systems for catalytic oxidation reactors are given in [10], §4.9.2.

6.6.4 Manual controls should be clearly marked and designed to prevent inadvertent adjustment and activation.

6.6.5 Start

.1 The start of an operation should be possible only when all the safeguards are in place and are functional.

.2 Suitable interlocks should be provided to secure correct sequential starting.

.3 It should be possible for automated plant functioning in automatic mode to be restarted after a stoppage once the safety conditions have been fulfilled. It should also be possible to restart the fuel cell power system by intentional actuation of a control provided for the purpose, provided such restarting is verifiably non-hazardous. This recommendation should not apply to the restarting of the fuel cell power system resulting from the normal sequence of an automatic cycle.

.4 If the start of a gas utilisation equipment has not been detected by the fuel cell power system monitoring system within an equipment specific time after opening of the gas supply valve, the gas supply valve should be automatically shut off and the starting sequence terminated. It should be ensured by any means that any unburned gas mixture is flushed away from the exhaust system.

6.6.6 Shutdowns

.1 As determined by the reliability assessment indicated in 6.1.2 and the functional requirements of the fuel cell power system, the latter should be provided with safety shutdowns and controlled shutdowns.

.2 A safety shutdown is the de-energization of the main fuel flow means and/or the de-energization of both the process air flow and the main fuel flow means, as the result of the action of a limiter, a cut-out or the detection of an internal fault of the system.

a. Safety shutdowns should be incorporated as part of the fuel cell power system in order to avert actual or impending danger that cannot be corrected by controls. These functions should:

- stop the dangerous condition without creating additional hazards;
- trigger or permit the triggering of certain safeguard actions where necessary;
- override all other functions and operations in all modes;
- prevent reset from initiating a restart;

– be fitted with restart lock-outs in such a way that a new start command may take effect on normal operation only after the restart lock-outs have been intentionally reset.

b. Emergency stops (i.e. manual safety shutdown), if required by the safety and reliability analysis in 6.1.2, should have clearly identifiable, clearly visible and quickly accessible controls such as buttons, in accordance with recognised standards (e.g. ISO 13850). Emergency stops should stop the fuel and air processing flow, and should electrically isolate both poles of the fuel cell module, and other high voltage sources (if fitted) from external circuitry or components.

c. In case of fault in the control system logic or failure of, or damage to, the control system hardware:

– the fuel cell power system should not be prevented from stopping once the stop command has been given;

– automatic or manual stopping of the moving parts should be unimpeded;

– the protection devices should remain fully effective;

– the fuel cell power system should not restart unexpectedly.

When a protective device or interlock causes a safety shutdown of the fuel cell power system, that condition should be signalled to the logic of the control system. The reset of the shutdown function should not initiate any hazardous condition. Control/monitoring systems that can operate safely in the hazardous situation may be left energized to provide system information.

.3 A controlled shutdown is the de-energization of the main fuel flow means and/or the de-energization of both the process air flow and the main fuel flow means, as the result of the opening of a control loop by a control device such as a thermostat. The system returns to the start position. Upset conditions that can be safely controlled or that do not pose immediate danger may be corrected with a controlled shutdown. A controlled shutdown may remove all power to the equipment, or may leave power available to the fuel cell power system actuators.

6.6.7 Permissives should be implemented consistent with requirements established from the safety and reliability analysis described in 6.1.2. A "permissive" is defined as a condition within a logic sequence that must be satisfied before the sequence is allowed to proceed to the next phase.

6.6.8 When the fuel cell power system is designed to work together with other equipment, the fuel cell power system stop controls, including the emergency stop, should be provided with means, such as signal interfaces, to enable the coordinated shutdown with equipment upstream and/or downstream, as applicable, of the fuel cell power system if continued operation can be dangerous.

6.6.9 Manual controls locations

.1 It should be possible to activate manual controls locally (close to the fuel cell power system component to control), from the navigation bridge and from the engine control room. The priority should be given to local activations.

.2 It should be possible to activate emergency stops locally, from the navigation bridge, from the engine control room and from the fire control room.

.3 When a protective device or interlock causes a safety shutdown of the fuel cell power system, that condition should be signalled in the navigation bridge and in the engine control room.

6.6.10 Operating modes

.1 The operating modes of the fuel cell power system, the corresponding status of the fuel cell installation components, and the transitions between modes should be documented and presented to the Society.

.2 The gas supply operation should be adapted to the current fuel cell power system operation mode. This should be provided either by automatic systems or with control systems (e.g. interlocks) which should prevent any unsafe operation of gas supply and fuel cell power system. Transitions between operating modes should also be considered.

.3 Machinery spaces containing fuel cell power system components should have a local, labelled switch or other means to disconnect the fuel cell power components from remote control signals that may be used while a local operator performs inspection or maintenance. Means should be provided so that a local disconnection does not lead to unsafe condition of the fuel cell installation.

6.6.11 Protective devices should be provided as required by the safety and reliability analysis in 6.1.2. The following aspects should be considered:

.1 Protective devices can consist of adequate monitoring devices such as indicators and/or alarms which enable adequate action to be taken either automatically or manually to keep the fuel cell power system within the allowable limits;

.2 Protective devices should be so designed and constructed as to be reliable and suitable for their intended duty and take into account the maintenance and testing requirements of the devices, where applicable;

.3 Protective devices should have their protective functions independent of other possible functions;

.4 Dangerous overloading of equipment should be prevented at the design stage by means of integrated measurement, regulation and control devices, such as over-current cut-off switches, temperature limiters, differential pressure switches, flow-meters, time-lag relays, over-speed monitors and/or similar types of monitoring devices;

.5 Protective devices with a measuring function should be designed and constructed so that they can cope with foreseeable operating requirements and special conditions of use. Where necessary, it should be possible to check the reading accuracy and serviceability of devices. These devices should incorporate a safety factor that ensures that the alarm threshold lies far enough outside the limits to be registered, taking into account, in particular, the operating conditions of the installation and possible aberrations in the measuring system.

.6 Sensors used as protective devices should have adequate ranges and response times. They should be calibrated and maintained according to the manufacturer's specifications.

.7 All parts of fuel cell power systems which are set or adjusted at the stage of manufacture, and which should not be manipulated by the user or the installer, should be appropriately protected.

.8 Levers and other controlling and setting devices should be clearly marked and given appropriate instructions so as to prevent any error in handling. Their design should be such as to preclude accidental manipulation.

6.7 Pneumatic and hydraulic powered equipment

6.7.1 Pneumatic and hydraulic equipment of fuel cell power systems should be designed according to [16], Sec 10 §17 and §14.

6.8 Valves

6.8.1 Shut-off valves

.1 Shut-off valves should be provided for all equipment and systems where containment or blockage of the process fluid flow is necessary during shutdown, testing, maintenance, upset, or emergency conditions.

.2 Shut-off valves should be rated for the service pressure, temperature, and fluid characteristics.

.3 Actuators mounted on shut-off valves should be temperature-rated to withstand heat conducted from the valve body.

.4 Electrically, hydraulically or pneumatically operated shut-off valves should be of a type that will move to a failsafe position upon loss of actuation energy.

6.8.2 All fuel supplied to the fuel cell power supply system should pass through at least a double block and bleed valve, as per 5.6.3.

6.9 Rotating equipment

6.9.1 Rotating equipment of the fuel cell power system should comply with relevant requirements of [17], Sec 4.

6.10 Pumps and compressors

6.10.1 Recommendations on pumps and compressors given in various other sections of these guidelines apply to the pumps and compressors of the fuel cell power.

6.11 Cabinets

6.11.1 Fuel cell power system cabinets should have sufficient strength, rigidity, durability, resistance to corrosion and other physical properties to support and protect all fuel cell power system components and piping; and to meet the requirements of storage, transport, installation, and final location conditions.

6.11.2 Fuel cell power system cabinets should comply with the requirements of [17], Sec 3 §4 on the degrees of protection of enclosures.

6.11.3 Ventilation openings should be so designed that they will not become obstructed during normal operation either by dust, snow or vegetation in accordance with the expected application.

6.11.4 All materials used to construct cabinets, including joints, vents, and gaskets of doors should be capable of withstanding the physical, chemical and thermal conditions that are reasonably foreseeable throughout the fuel cell power system life both inside the cabinet and outside (see environmental conditions given in [17], Sec 2.

6.11.5 Access panels, covers or insulation that need to be removed for normal servicing and accessibility should be designed such that repeated removal and replacement will not cause damage or impair insulating value.

6.11.6 Access panels, covers or insulation that need to be removed for normal servicing and accessibility should not be interchangeable if that interchange may lead to an unsafe condition.

6.11.7 Any access panel, cover or door that is intended to protect equipment from entry by users or untrained personnel should have means for retaining it in place and should require the use of a tool, key or similar mechanical means to open. For residential units, this should include all access panels, covers, or doors.

6.11.8 All parts of fuel cell power systems that are set or adjusted at the stage of manufacture and that should not be manipulated by the user or the installer should be adequately protected.

6.11.9 Means should be provided to drain collected liquids and to pipe them to the exterior for disposal or redirect them to processes associated with the fuel cell power system.

6.11.10 Where personnel can fully enter the cabinet, the cabinet should be considered a confined space and adequate guidelines should be provided in the product's technical documentation.

6.11.11 The definition of the type of hazardous zone of a space containing a fuel cell power system enclosed in a cabinet should be proposed by the supplier and approved by the Society.

6.12 Thermal insulating materials

6.12.1 Insulation systems employed in the fuel cell power system should be designed to provide chemical compatibility with the material being insulated and ambient conditions, protection of insulation systems from expected thermal and mechanical abuse (including damage by atmospheric conditions), fire safety (by limiting surface temperature of heat-producing objects to prevent ignition of materials in the vicinity of them) and future accessibility of piping, fittings, etc. for maintenance purposes

6.12.2 If necessary to avoid hazards to health and safety, the manufacturer should specify in the maintenance manual the thermal insulation system inspection and safety requirements.

6.13 Utilities

6.13.1 The fuel cell power system should be designed and constructed such that in the case of the loss of the utility supply, i.e., the interruption of electrical supply, feed water, cooling water, instrument air, etc., the system shuts down safely without

.1 the creation of any health or safety hazards;

.2 permanent distortion or damage to the system

6.13.2 Where the fuel cell power system requires water to operate, it should be provided through a self-contained water source; or shown to produce water in sufficient quantities during operation.

6.13.3 If applicable, means should be provided to prevent backflow of steam into the water treatment system of the fuel cell power system. A suitable check valve or equivalent device meets the intent of this provision

Chapter 7 - Manufacture, Workmanship and Testing

7.1 General

7.1.1 The manufacture, testing, inspection and documentation should be in accordance with relevant BV Rules and recognised standards and the specific recommendations given in this document.

7.1.2 For equipment storing, carrying or utilizing hydrogen, relevant specific tests should be performed in addition to the tests specified in the next paragraphs. These specific tests should be defined and performed according to recognised standards. For guidance, tests specified in [5], [14] and [15] for hydrogen containers and for other components carrying hydrogen could be used as a basis.

7.1.3 The list and description of tests that will be performed, or with which the installation component comply (type approval) should be submitted and approved as early as possible.

7.2 Gas tanks

Tests related to welding and tank testing should be in accordance with the IGC Code paragraphs 4.10 and 4.11.

7.3 Gas piping systems

7.3.1 The specifications for testing should apply to gas piping inside and outside the gas tanks. However, relaxation from these specifications may be accepted for piping inside gas tanks and open ended piping.

7.3.2 Welding procedure tests should be required for gas piping and should be similar to those required for gas tanks in IGC Code paragraph 6.3.3. Unless otherwise especially agreed with the Society, the test specifications should be in accordance with 7.3.3 below.

7.3.3 Test specifications

.1 **Tensile tests:** Generally, tensile strength should not be less than the specified minimum tensile strength for the appropriate parent materials. The Society may also require that the transverse weld tensile strength should not be less than the specified tensile strength for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture should be reported for information.

.2 **Bend tests:** No fracture is acceptable after a 180° bend over a former of a diameter four times the thickness of the test piece, unless otherwise specially required or agreed with the Society.

.3 **Charpy V-notch impact tests:** Charpy tests should be conducted at the temperature prescribed for the base material being joined. The results of the weld impact tests, minimum average energy (E), should be no less than 27 J. The weld metal requirements for sub size specimens and single energy values should be in accordance with IGC Code paragraph 6.1.4. The results of fusion line and heat affected zone impact tests should show a minimum average energy (E) in accordance with the transverse or longitudinal requirements of the base material, whichever applicable, and for sub size specimens, the minimum average energy (E) should be in accordance with IGC Code paragraph 6.1.4. If the material thickness does not permit machining either full-sized or standard sub size specimens, the testing procedure and acceptance standards should be in accordance with recognised standards.

Impact testing is not required for piping with wall thickness less than 6 mm.

7.3.4 In addition to normal controls before and during the welding and to the visual inspection of the finished welds, the following tests should be required:

.1 For butt welded joints for piping systems with design temperatures lower than -10°C and with inside diameters of more than 75 mm or wall thicknesses greater than 10 mm, 100% radiographic testing should be required.

.2 When such butt welded joints of piping sections are made by automatic welding processes in the pipe fabrication shop, upon special approval, the extent of radiographic inspection may be progressively reduced but in no case to less than 10% of the joints. If defects are revealed the extent of examination should be increased to 100% and should include inspection of previously accepted welds. This special approval should only be granted if well-documented quality assurance procedures and records are available to enable the Society to assess the ability of the manufacturer to produce satisfactory welds consistently.

.3 For other butt welded joints of pipes, spot radiographic tests or other non-destructive tests should be carried out at the discretion of the Society depending upon service, position and materials. In general, at least 10% of butt welded joints of pipes should be radiographed.

Butt welded joints of high-pressure gas pipes and gas supply pipes in ESD protected machinery spaces should be subjected to 100% radiographic testing.

The radiographs should be assessed according to a recognised standard (e.g. ISO 5817:2003 "Arc-welded joints in steel-Guidance on quality levels for imperfections", and should at least meet the requirements for quality level B).

7.3.5 After assembly, all gas piping should be subjected to a hydrostatic test to at least 1.5 times the design pressure. However, when piping systems or parts of systems are completely manufactured and equipped with all fittings, the hydrostatic test may be conducted prior to installation aboard ship. Joints welded onboard should be hydrostatically tested to at least 1.5 times the design pressure. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, proposals for alternative testing fluids or testing methods should be submitted for approval.

7.3.6 After assembly onboard, each gas piping system should be subjected to a leak test using air, halides or other suitable medium.

7.3.7 All gas piping systems including valves, fittings and associated equipment for handling gas should be tested under normal operating condition before set into normal operation.

7.4 Ducting

If the gas piping duct contains high-pressure pipes the ducting should be pressure tested to at least 10 bar.

7.5 Valves

Each size and each type of valve intended to be used at a working temperature below -55°C should be prototype tested as follows. It should be subjected to a tightness test at the minimum design temperature or lower and to a pressure not lower than the design pressure for the valves. During the test the good operation of the valve should be ascertained.

7.6 Expansion bellows

7.6.1 The following prototype tests should be performed on each type of expansion bellows intended for use in gas piping, primarily on those used outside the gas tank:

.1 An overpressure test. A type element of the bellows, not precompressed, should be pressure tested to a pressure not less than 5 times the design pressure without bursting. The duration of the test should not be less than 5 minutes.

.2 A pressure test on a type expansion joint complete with all the accessories (flanges, stays, articulations, etc.) at twice the design pressure at the extreme displacement conditions recommended by the manufacturer. No permanent deformations should be allowed. Depending on materials it may be required to perform the test at the minimum design temperature.

.3 A cyclic test (thermal movements). The test should be performed on a complete expansion joint, which is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. Testing at room temperature, when conservative, may be permitted.

.4 A cyclic fatigue test (ship deformation). The test should be performed on a complete expansion joint, without internal pressure, by simulating the bellow movement corresponding to a compensated pipe length for at least $2x10^6$ cycles at a frequency not higher than 5 Hz. This test should only be required when, due to the piping arrangement, ship deformation loads are actually experienced.

7.6.2 The Society may waive performance of the tests specified in 7.6.1, provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions. When the maximum internal pressure exceeds 1 bar, this documentation should include sufficient tests data to justify the design method used, with particular reference to correlation between calculation and test results.

7.7 Fuel cell power system

7.7.1 The fuel cell system to be installed on the ship, or a representative production sample of this system should be subject to a series of type tests according to recognised standards (e.g. [10], §5 and guidance for measurement and analysis in [11]). The tests should cover, when relevant and applicable, at least the following items:

.1 Gas leakage tests

.2 Liquid leakage tests

.3 Strength tests of gas and liquid sections

.4 Ambient condition tests (according to conditions as defined in [17], Sec 2)

.5 Normal operation test

.6 Electrical overload test

.7 Dielectric tests simulating abnormal conditions

.8 Shutdown tests

.9 Burner operating characteristics tests (applicable to fuel cell power systems equipped with any fuel-fired boiler or heating device, for example, the start burner of the reformer section)

.10 Automatic control of burners and catalytic oxidation reactors tests

.11 Exhaust gas temperature tests

.12 Surface and component temperature tests

.13 Wind tests (applicable for fuel cell systems intended for installation on open deck or for units in enclosed spaces having horizontal air inlets and exhaust to the outdoors; wind conditions to be defined with the Society)

.14 Rain tests (applicable for fuel cell systems intended for installation on open deck; test conditions should correspond to the IP rating declared by the manufacturer and tests should be performed according to a recognised standard (e.g. IEC 60529, Degrees of protection provided by enclosures (IP Code))

.15 CO emission tests

7.7.2 In case tests listed in 7.7.1 are performed a representative production sample of the fuel cell system, routine tests should be performed on the unit that will be installed onboard. These tests should cover at least (e.g. see [10], §6 and [11] for guidance) the following items:

.1 Gas leakage tests

.2 Coolant (liquid) leakage tests

.3 Normal operation test

.4 Dielectric tests simulating abnormal conditions

.5 Burner operating characteristics tests

.6 CO emission tests

7.8 Marking and labelling

7.8.1 Gas pipes should be colour marked in accordance with [6].

7.8.2 Other requirements related to the marking piping systems [16], Sec 10 §2.6.5 and Appendix 2 should be accounted for.

7.8.3 The marking of pressure equipment should comply with [16], Sec 3 §3.

7.8.4 High voltage equipment should be marked according to [17], Sec 13.

7.8.5 The fuel cell power system should bear a data plate clearly stating any restrictions on use, in particular the restriction whereby the fuel cell power system should be installed only in areas where there is sufficient ventilation. If the fuel cell power system is rated under hazardous area classification according to [8], it should be marked accordingly. The data plate should also include information related to its electrical input/output ranges, fuel type used and supply pressure, range of ambient temperature, reference to the standard it complies with, and any other relevant information suitable for a safe installation and use of the system (e.g. see [10], §7 for guidance).

7.8.6 All user serviceable parts of the fuel cell installation should be identified to match the installation drawings in the user's manual.

7.8.7 Warning signs should be appropriately placed to identify electrical hazards, hot component hazards and any other relevant hazards related to the fuel cell installation. Standard symbols should be used.

7.8.8 Control devices, visual indicators, and displays (particularly those related to safety) used in the man-machine interface should be clearly marked with regard to their functions either on or adjacent to the item. Preference should be given to the use of standard symbols

Chapter 8 - Operational and training recommendations

8.1 Operational recommendations

8.1.1 The whole operational crew of a ship making use of gas utilisation equipment should have necessary training in gas-related safety, operation and maintenance prior to the commencement of work on board.

8.1.2 Additionally, crew members with a direct responsibility for the operation of gas-related equipment on board should receive special training. The company should document that the personnel have acquired the necessary knowledge and that this knowledge is maintained at all times.

8.1.3 Training should be delivered by the fuel cell system manufacturer, by the gas provider and/or by any organisation having an in-depth knowledge of the safe operation and maintenance of the fuel cell system installed onboard.

8.1.4 Gas-related emergency exercises should be conducted at regular intervals. Safety and response systems for the handling of defined hazards and accidents should be reviewed and tested.

8.1.5 A training manual should be developed and a training programme and exercises should be specially designed for each individual vessel and its gas installations.

8.1.6 Operating manual

.1 The system supplier should provide the operator with an operating manual.

.2 This manual should present illustrations should be used to identify fuel cell components, dimensions and clearances, assembled components, and connection points as needed to make the instructions clear. Illustrations should also be used to identify the location of serviceable components and illustrate correct methods for performing service procedures.

.3 It should also contain relevant safety information such as, as applicable:

a. Most important safety instructions to be presented on the front cover

b. A safety section presenting the list of potential hazards and safety-related instructions for the particular fuel cell installation, with references to the corresponding sections of the manual. These instructions should address in particular issues such as necessary verifications prior to starting up the installation and frequency of other necessary inspections. It should also make reference to the maintenance manual.

c. In-text safety information presenting:

- more detailed information on the hazards related to the use of the fuel cell installation;
- detailed proper procedures for the set-up and use of the fuel cell power system. Particular attention should be given to the safety measures provided and to the improper methods of operation that are anticipated;

- where the operation of equipment can be programmed, detailed information on methods of programming, equipment required, programme verification and additional safety procedures (where required) should be provided.
- The instructions should give information concerning airborne noise emissions by the fuel cell power system, either the actual value or a value established on the basis of measurements made on identical fuel cell power system.

8.2 Gas-related training

8.2.1 Training in general

The training on gas-fuelled ships should be divided into the following categories:

.1 category A: basic training for the basic safety crew;

.2 category B: supplementary training for deck officers; and

.3 category C: supplementary training for engineer officers.

8.2.2 Category A training

The goal of the category A training should provide the basic safety crew with a basic understanding of the gas in question as a fuel, the technical properties of liquid and compressed gas, explosion limits, ignition sources, risk reducing and consequence reducing measures, and the rules and procedures that must be followed during normal operation and in emergency situations.

The general basic training required for the basic safety crew is based on the assumption that the crew does not have any prior knowledge of gas and gas utilisation equipment. The instructors should include one or more of the suppliers of the technical gas equipment or gas systems, alternatively other specialists with in-depth knowledge of the gas in question and the technical gas systems that are installed on board.

The training should consist of both theoretical and practical exercises that involve gas and the relevant systems, as well as personal protection while handling liquid and compressed gas. Practical extinguishing of gas fires should form part of the training, and should take place at an approved safety centre.

8.2.3 Categories B and C training

Deck and engineer officers should have gas training beyond the general basic training. Category B and category C training should be divided technically between deck and engineer officers. The Company's training manager and the Master should determine what comes under deck operations and what comes under engineering.

Those ordinary crew members who are to participate in the actual bunkering work, as well as gas purging, or are to perform work on gas utilisation equipment or gas installations, etc., should participate in all or parts of the training for category B/C. The Company and the Master should be responsible for arranging such training based on an evaluation of the concerned crew member's job instructions/area of responsibility on board.

The instructors used for such supplementary training should be the same as outlined for category A.

All gas-related systems on board should be reviewed. The ship's maintenance manual, gas supply system manual and manual for electrical equipment in explosion hazardous spaces and zones should be used as a basis for this part of the training.

This regulation should be regularly reviewed by the Company and onboard Senior Management team as part of the SMS system. Risk analysis should be emphasized, and any risk analysis and sub analyses performed should be available to course participants during training.

If the ship's own crew will be performing technical maintenance of gas equipment, the training for this type of work should be documented.

The Master and the Chief engineer officer should give the basic safety crew on board their final clearance prior to the entry into service of the ship. The clearance document should only apply to gas-related training, and it should be signed by both the Master/Chief engineer officer and the course participant. The clearance document for gas-related training may be integrated in the ship's general training programme, but it should be clearly evident what is regarded as gas-related training and what is regarded as other training.

The training requirements related to the gas system should be evaluated in the same manner as other training requirements on board at least once a year. The training plan should be evaluated at regular intervals.

8.3 Maintenance

8.3.1 A special maintenance manual should be prepared for the gas supply system, the fuel cell power system and for the control/monitoring/safety systems on board.

8.3.2 The maintenance manual should detail proper procedures for adjustment, servicing, and preventive inspection, and repair. It should comply with the recommendations of the suppliers of the equipment Recommendations on maintenance/servicing records should be part of the maintenance manual. Where methods for the verification of proper operation are provided (for example, software testing programmes), the use of such methods should be detailed.

8.3.3 This manual should contain clearly defined, legible and complete instructions for at least the following.

.1 Personnel qualified to carry out maintenance.

.2 Instructions for starting and shutting down the fuel cell installation. These instructions should pictorially illustrate and locate all relevant components.

.3 The intervals for and the extent of the replacement/approval of gas valves should be established

.4 Specifications for the frequency of filter change or cleaning and the dimensional size and type of filter for replacements. These instructions should contain directions for removal and replacement of filters and pictorially illustrate and locate all components supplied by the manufacturer referred to in the instructions for removal and replacement of filters.

.5 Instructions to caution users to any electrical components that may retain residual voltage/energy after shutdown, and how to properly dissipate the voltage/energy to a safe level.

.6 Recommended methods for periodic cleaning of necessary parts.

.7 Instructions for lubrication of moving parts, including type, grade and amount of lubricant.

.8 Instructions for examining the fuel cell power system installation to determine that

- any intake or exhaust openings are clear and free of obstructions;
- there are no obvious signs of physical deterioration of the fuel cell power system or its support (i.e. base, frame, cabinet, etc.).

.9 Periodic examination of the venting system, gas detection, and related functional parts.

.10 A replacement parts list, including information necessary for ordering spare or replacement parts.

.11 Directions that the area surrounding the fuel cell power system must be kept clean and free of combustible materials, gasoline and other flammable vapors and liquids.

.12 The following statement: Do not use this fuel cell power system if any part has been under water. Immediately call qualified service personnel to inspect the fuel cell power system and to replace any function part which has been under water.

.13 Instructions and a schedule for neutralizing condensate, if appropriate.

.14 The maintenance manual should also provide an enumeration of all regular and routine maintenance activities to be performed on the fuel cell installation components and indicate the necessity and minimum frequency for these examinations. The maintenance manual should specify the periodic inspection of the fuel cell installation that should be performed by qualified service personnel.

8.3.4 The manual should include maintenance procedures for all components of the control, monitoring and safety systems, and should comply with the recommendations of the suppliers of the equipment. The intervals for and the extent of the verification/calibration/replacement/approval of detectors should be established. The maintenance procedures should specify who is qualified to carry out maintenance.

8.3.5 A special maintenance manual should be prepared for electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces should be performed in accordance with a recognised standard (e.g. [9]).

8.3.6 Any personnel that should carry out inspections and maintenance of electrical installations in explosion hazardous spaces, should be qualified pursuant to a recognised standard (e.g. [9], item 4.2).

8.3.7 Design and operational recommendations for maintenance

.1 Adjustment, lubrication and maintenance points should be located outside zones in which a person is exposed to risk of injury or damage to health; or maintenance instructions should be provided in the maintenance manual as necessary to avoid risks to health or safety.

.2 It should be possible to carry out adjustment, maintenance, repair, cleaning and servicing operations while the fuel cell power system is at a standstill. When adjustment, maintenance, repair, cleaning and servicing should be conducted while the fuel cell power system is operating, the fuel cell power system should be designed so that those functions can be performed without the risk of injury.

.3 Automated fuel cell installation components that have to be changed frequently should be capable of being removed and replaced in without the risk of injury. Access to the components should enable these tasks to be carried out with the necessary technical means (tools, measuring instruments, etc.) in accordance with the product's technical documentation.

.4 Where for protection of health, safety instructions or diagrams are to be adhered to the fuel cell installation, they should be displayed using a permanent method, resistant to, or protected from, the environmental conditions of use.

Appendix 1 – Scope of the Risk Analysis

1 Introduction

1.1 Purpose of this appendix

1.1.1 The purpose of this appendix is to define the scope of the risk analysis which is required for the fuel cell installation systems to assess the consequences of:

- a failure affecting the concerned systems
- a gas leakage.

1.2 Form of the risk analysis

1.2.1 The required analysis can be a FTA, FMEA, HAZOP analysis or another type of analysis providing equivalent information.

1.3 Single failure concept

1.3.1 The required analysis should be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non detectable failures should be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, should also be considered.

1.4 Scope of the risk analysis

1.4.1 The scope of the risk analysis is to:

.1 Identify all the possible failures in the concerned systems which could lead to a loss of the assigned functions. For guidance, a list of hazardous situations and events on which special care needs to be addressed can be found in [10], Annex A.

Note 1: The systems and their functions are defined in 2 below.

.2 Evaluate the consequences.

.3 Identify the failure detection method.

.4 Identify the corrective measures:

a. in the system design, such as:
   - redundancies
   - safety devices, monitoring or alarm provisions which permit restricted operation of the system

b. in the system operation, such as:
   - initiation of the redundancy
   - activation of an alternative mode of operation.

1.4.2 The results of the risk analysis should be documented and confirmed by a practical test.

2 Systems to be analysed

2.1 General

2.1.1 The risk analysis should be performed at least for the systems and functions defined hereafter.

2.2 Fuel gas piping system

2.2.1 Definition

The fuel gas piping system includes all the equipment used to supply gas to the fuel cell system, but excludes tanks and fuel cell stack. It includes in particular all pumps, heat exchangers, valves, pipes and fittings.

The gas supply system also includes the control and monitoring equipment.

2.2.2 Functions

The functions of the fuel gas piping system are to:

- maintain the gas pressure, temperature and flow rate at the fuel cell stack inlet within the required range to allow satisfactory gas supply to the fuel cell system in all ship loading and ship speed conditions.

2.3 Fuel gas containment/ventilation systems

2.3.1 Definition

The fuel gas containment / ventilation systems include:

- the gas piping system enclosures (double wall pipes or ducts, hoods and casings, ESD machinery spaces);
- the associated ventilation systems.

2.3.2 Functions

The functions of the gas fuel containment/ventilation systems are to:

- contain within the enclosure any possible leakage arising on the gas piping and maintain in the enclosure a pressure less than that in the adjacent space;
- ensure an efficient removal of the leaking gas from the enclosure, avoiding the presence of dead spaces;
- allow an efficient detection of any gas leakage.

2.4 Gas detection systems

2.4.1 Definition

Gas detection systems include:

- the gas detection sensors;
- the centralized monitoring unit and its power supply;
- the wiring between the sensors and the centralized monitoring unit.

2.4.2 Function

The function of the gas detection systems is to detect any gas leakage by measuring gas concentration in air, taking into account the actual air parameters at the measuring point (in particular air velocity).

2.5 Control, monitoring and safety systems

2.5.1 Definition

Control, monitoring and safety systems include the relevant equipment serving:

- the gas system supplying the fuel cell system;
- the ventilation systems serving the gas piping system;
- the gas detection system.

2.5.2 Function

Function of the control, monitoring and safety systems is considered as self-explanatory.

2.6 Fuel cell power system

2.6.1 Definition

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.

2.6.2 Function

This system converts the fuel as stored onboard into electrical power.

2.6.3 Specific aspects to be accounted for in the risk analysis

- A safety and reliability analysis of the fuel cell power system should be performed, e.g. according to [10], §4, in order to identify all foreseeable hazards, hazardous situations and events associated with the fuel cell power systems throughout their anticipated lifetime. The risk of each of these hazards should be estimated from the combination of probability of occurrence of the hazard and of its foreseeable severity.

- The analysis should cover at least the following aspects:
  - failure of the gas-related component and of stack components
  - failure of the fuel cell system control system
  - failure of the fuel processing system
  - failure of the thermal management system
  - failure of oxidant processing system
  - failure of the water treatment system
  - failure of the water discharge system
  - change in air and gas fuel quality
  - deviation of any process parameter (HAZOP analysis)
- It should be demonstrated that the necessary protection measures in relation to risks that are not eliminated have been taken. Foreseeable abnormal operating conditions should be considered in the analysis.

2.7 Other ship systems

2.7.1 The risk analysis referred to in 1.1.1 should also cover the other systems which have no direct relation to the gas utilisation but which could be influenced by the fuel cell installation failure of dysfunction, such as the power management system, etc.

2.8 Gas leakage

2.8.1 The possibilities and consequences of a gas leakage should be analysed.

2.9 Black-out

2.9.1 The risk analysis referred to in 1.1.1 should also cover the consequences of a black-out.

2.10 Human factor

2.10.1 The risks related to human error (e.g. in procedures requiring human action, such as refuelling, etc.) should be analysed.

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