CR

CR Classification Society

FOUNDED 1951

GUIDELINES FOR FUEL CELL INSTALLATIONS
2015

CR CLASSIFICATION SOCIETY

REVISION HISTORY

(This version supersedes all previous ones.)

Edition No.	Editor	Date (yyyy-mm)
001	C.T. Chen	2015-12

GUIDELINES FOR FUEL CELL INSTALLATIONS 2015

CONTENTS

CHAPTER 1 General

1.1 General

1.1.1 These Guidelines apply to fuel cell (FC) installations in ships. A fuel cell is a source of electrical power in which the chemical energy of a fuel is converted directly into electrical energy by electrochemical oxidation and only the gaseous fuels as well as liquid fuels with flashpoint below 60 degrees C are regarded as "FC fuel".

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, IGC Code and IGF Code when applicable. These Guidelines are applicable to new ships. Application to existing ships should be decided by this Society to the extent it deems necessary.

1.2 Definitions

1.2.1 Gas means a fluid having a vapor pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

1.2.2 Hazardous area means an area in which an explosive gas atmosphere or a flammable gas (flashpoint 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 zones 0, 1 and 2 as defined below:

(a) Zone 0 is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is present continuously or is present for long periods.

(b) Zone 1 is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint below 60°C is likely to occur in normal operation.

(c) Zone 2 is an area in which an explosive gas atmosphere or a flammable gas with a flashpoint 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.

1.2.3 Non-hazardous area means an area which is not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.

1.2.4 High-pressure piping means gas fuel piping with maximum working pressure greater than 10 bar.

1.2.5 IEC means the International Electro-technical Commission.

1.2.6 IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, as amended.

1.2.7 LEL means the lower explosion limit.

1.2.8 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.

1.2.9 Master fuel valve is an automatic valve in the FC fuel supply line to each fuel cell located outside the FC space and as close to the fuel storage as possible.

1.2.10 MARVS means the maximum allowable relief valve setting of a gas tank.

1.2.11 Tank room means the gastight space surrounding the bunker tank, containing all tank connections and all tank valves.

1.2.12 ESD means emergency shutdown.

1.2.13 Low flashpoint liquids are liquids with a flashpoint below 60°C.

1.2.14 Service spaces are spaces outside the cargo area used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, store rooms, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

1.2.15 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.

1.3 Class Notations

1.3.1 Ships where the fuel cell energy source is used for essential, important or emergency services shall satisfy the requirements in these Guidelines and will be given class notation **FC Energy**.

1.3.2 Ships where the fuel cell energy source is not used for essential, important or emergency users shall satisfy the safety and environmental requirements. Installations complying with the requirements in these Guidelines, except 2.1 will be given class notation **FC Installation**.

1.4 Plan Approval

1.4.1 Following plans shall be submitted for approval:

(a) general arrangement of the machinery spaces containing the gas utilization equipment and of the gas storage units, with description of the classification of hazardous areas;

(b) testing program and results / type approval reference of the installation components;

(c) drawings and specification of the gas supply system to each gas utilization equipment;

(d) specification of the control, monitoring and safety systems, including Emergency Shut-down Device(ESD) and fire detection and extinguishing systems;

(e) diagram of the gas piping system located in the machinery spaces, including double wall piping or duct system;

(f) material, thickness and joints of the gas piping;

(g) diagram of the inert gas piping system;

(h) diagram of the ventilation system in machinery spaces;

(i) diagram of the oxidant processing, supply and exhaust system;

(j) design data and sizing calculation of the gas storage and piping systems;

(k) other fuel cell power system related information;

(1) operating manual of the fuel cell installation, including:

(i) procedures for starting (in particular from dead ship condition), stop and emergency stop of the gas utilization equipment;

(ii) 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;

(m) procedure for testing the gas monitoring/ detection systems;

(n) procedure for refueling;

(o) programme of installation onboard testing;

(p) drawings and specifications for safety relief valves and pressure/vacuum relief valves and associated vent piping;

(q) a failure mode and effect analysis (FMEA) examining all possible faults affecting the processes in the fuel cells for ships with FC Energy notation;

(r) on board test programme and sea trial programme of fuel cell;

1.4.2 Following data or drawing shall be submitted for review:

(a) description of the different operating configurations of the machinery installation, with indication of the power developed by each component;

(b) diagram of the gas detection system;

(c) instrumentation list;

(d) safety certificates for electrical equipment located in gas-dangerous spaces or zones, where applicable;

(e) fuel characteristics (storage pressure, temperature, lower flammable limit(LEL), toxicity, corrosivity and any other important safety related characteristics);

(f) procedures for maintenance of the gas utilization 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;

(g) procedure for checking the gas tightness of the fuel system.

1.4.3 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.);

(d) electric circuit diagrams;

(e) information (where appropriate) on:

(i) handling, transportation and storage;

(ii) software programming;

(iii) sequence of operations;

(iv) frequency of inspection;

(v) frequency and method of functional testing;

(vi) guidance on the adjustment, maintenance, and repair, particularly of the protective devices and circuits; and

(vii) 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; and

(q) if appropriate, special instructions for extended dormant periods.

1.5 Certificate

1.5.1 Fuel cells shall be approved and certified by this Society. Testing of approval shall be performed in accordance with an approved test program in accordance with these Guidelines and recognized standards.

1.5.2 Other components shall be approved in accordance with the requirements of the Rules for Steel Ships of this Society.

CHAPTER 2 ARRANGEMENT AND SYSTEM DESIGN

2.1 Design principles for FC-Energy notation

2.1.1 The design shall ensure that any single failure in active components of the FC system shall not lead to loss of propulsion or auxiliary power for essential or important users.

2.1.2 The arrangement of the fuel cell spaces must be so that a shut down due to a FC fuel leakage can not lead to loss of propulsion or auxiliary power for essential or important users.

2.1.3 If the power from the fuel cell is needed for restoration of power in a blackout or dead ship situation, the recovery arrangements have to be documented and approved in each case.

2.2 Fuel cell spaces

2.2.1 Fuel cell spaces shall have as simple geometrical shape as possible. Fuel cell spaces where hydrogen may be present shall have no obstructing structures in the upper part and shall be arranged with a smooth ceiling sloping up towards the ventilation outlet. Support structure like girders and stiffeners shall be facing outwards. Thin plate ceiling to cover support structure under the deck plating is not acceptable.

2.3 Tank rooms

2.3.1 Tank room boundaries shall be gas tight. The tank room is not to be located adjacent to machinery spaces of category A. If the separation is by means of a cofferdam then the separation should be at least 900 mm and should be fitted with A-60 insulation.

2.3.2 Tank rooms should be separated from the spaces containing the fuel cell power system components.

2.4 FC fuel compressor rooms

2.4.1 Compressor rooms, if arranged, shall be located above weather deck level, unless especially approved by this Society. Where compressors are driven by shafting passing through a bulkhead or deck, the bulkhead penetration shall be of gas tight type.

2.5 Arrangement of entrances and other openings

2.5.1 If the compressor room is approved located below deck the room shall have a separate access from deck, not shared with any other spaces.

2.5.2 The tank room entrance shall be arranged with a sill height of at least 300 mm.

2.5.3 Access to the tank room is as far as practicable to be through a separate access from the deck, not shared with any other spaces. If the tank room is only partially covering the tank, this requirement shall be applied to the room surrounding the tank, and where the opening to the tank room is located. The access trunk shall be fitted with separate ventilation. If the access to the tank room is from another space in the ship, due consideration shall be made to prevent the possibility of a gas release escaping to non hazardous areas. The tank room shall not be open for entrance during normal operation of the FC fuel system

2.5.4 Entrances between hazardous and safe spaces in the ship shall be arranged with air locks.

2.6 Piping systems

2.6.1 FC fuel pipes are in general to comply with IGC Code, IMO Resolution MSC.391(95) "INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS (IGF CODE)" and Part VI of the Rules for Steel Ships of this Society.

2.6.2 FC fuel pipes in spaces made gas safe shall not include expansion elements, bellows or other pipe components with poorer strength, fatigue or leakage properties than the fully welded pipe.

2.6.3 FC fuel pipes are not to be located less than 760 mm from the ship's side.

2.6.4 An arrangement for purging FC fuel bunkering lines and supply lines with nitrogen shall be provided.

2.6.5 The FC fuel piping system shall be installed with sufficient flexibility. Bellows will not be accepted in enclosed spaces.

2.6.6 A system for color marking of all FC fuel pipes should be used.

2.6.7 If a fuel gas contains heavier components that may condensate in the system, knock out drums or equivalent means for collecting the liquid shall be fitted.

2.7 System configuration

2.7.1 The presence of FC fuel release sources in a fuel cell space will decide if it is regarded as a hazardous or non hazardous space. There are two ways to make a fuel cell space with FC fuel piping inside non hazardous:

(a) All FC fuel pipes are enclosed in a gas tight double enclosure (duct or pipe).

(b) All FC fuel pipes that are not inside a double duct are fully welded and the ventilation rate in the space is sufficient to avoid gas concentration in the flammable range in all leakage scenarios, including pipe rupture. Valves in the FC piping shall be leakage tested for the FC fuel used. In addition the FC space is fitted with gas detection and an automatic shut down system.

2.7.2 If hydrogen valves are located in a space kept non hazardous in 2.7.1(b), the valves should be leakage tested with hydrogen. For other FC fuels normal hydrostatic pressure testing with water as part of the product certification will be sufficient. Compensators or other pipe components with poorer strength, fatigue or leakage properties than the fully welded pipe are not accepted in FC fuel piping in a space kept gas safe in 2.7.1(b).

2.8 FC fuel supply system in fuel cell spaces

2.8.1 In general the temperature of installations in the fuel cell space shall never be above the self ignition temperature for the fuel used.

2.8.2 The double wall principle is not to be used for hydrogen pipes. Hydrogen pipes are in general to be located in well ventilated spaces, and as far as practicable to be fully welded.

2.8.3 If double walls of FC fuel pipes are used to make a surrounding space non hazardous the double pipe or duct shall fulfill one of the following:

(a) The space between the FC fuel piping and the wall of the outer pipe or duct shall be pressurized with inert gas at a pressure greater than the FC fuel pressure. Suitable alarms shall be provided to indicate a loss of inert gas pressure between the pipes; or

(b) The air space between the FC fuel piping and the wall of the outer pipe or duct shall be equipped with mechanical under-pressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity can be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for. The fan motors shall be placed outside the ventilated pipe or duct. The ventilation outlet shall be covered by a protection screen and placed in a position where no flammable gas air mixture may be ignited.

2.8.4 The complete FC fuel piping in the space must be covered by the ducting. The arrangement must facilitate replacement and or overhaul of valves and other components.

2.8.5 For high pressure piping the design pressure of the ducting shall 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 annular space, or

(b) local instantaneous peak pressure in way of the rupture p*. This pressure shall 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 specific volume specific heat
k	=	1.31 for CH_4

The tangential membrane stress of a straight pipe is not to 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 shall 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 must then be submitted.

2.8.6 For low pressure piping the duct shall be dimensioned for a design pressure not less than the maximum working pressure of the FC fuel pipes. The duct is also to be tightness tested.

2.9 FC fuel storage

2.9.1 Locations of gas tanks

(a) Both gases of the compressed and the liquefied type are accepted stored above deck level, while compressed gas will normally not be accepted stored below deck. The maximum acceptable design pressure of a storage tank located below deck level is normally 10 bar.

(b) Hydrogen is not to be stored in enclosed spaces, unless the tank room is arranged with ventilation electrical equipment certified safe for hydrogen atmosphere, and arrangement of the space and ventilation outlets.

(c) The storage tanks/ tank batteries for gas shall be located at:

(i) minimum, the lesser of B/5 and 11.5 m from the ship side

(ii) minimum, the lesser of B/15 and 2 m from the bottom plating

(iii) and not less than 760 mm from the shell plating.

(d) Gas storage tanks/ tank batteries and equipment on open deck shall be located to assure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

(e) Tanks for liquid gas on open deck with a connection below the highest liquid level, shall be fitted with drip trays below the tank of sufficient size to hold the full content of the tank. 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.

(f) Storage tanks for liquid gas and associated valves and piping inside the ship shall be located in a space designed to act as a secondary barrier, in case of liquid gas leakage. Secondary barrier shall be designed to withstand the maximum pressure build up. Alternatively, pressure relief venting to a safe location (mast) can be provided. The space shall be capable of containing leakage, and shall be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling, in case of leakage of the liquid gas. This secondary barrier space is in other parts of this chapter of these Guidelines called "tank room".

2.9.2 The storage tank for low flashpoint liquids shall be arranged and approved by this Society.

2.10 FC fuel tank design

2.10.1 Liquefied gas storage tanks

(a) The storage tank used for liquefied gas shall be an independent tank type C.

(b) Pipe connections to the tank shall be in accordance with Part VI of the Rules for Steel Ships of this Society. However, connections below the lowest liquid level may be accepted after special consideration by this Society, but will not be accepted for liquid hydrogen tanks located in enclosed spaces.

(c) Pressure relief valves shall be fitted.

(d) The outlet from the pressure relief valves are normally to 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 meters. The outlets shall be located at least 10 m from the nearest:

(i) air intake, air outlet or opening to accommodation, service and control spaces, or other gas safe spaces

(ii) exhaust outlet from machinery or from furnace installation.

(e) Storage tanks for liquid gas with vapor pressure above the design pressure at 45ºC shall be fitted with efficient insulation.

(f) Storage tanks for liquid gas shall not be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in 15.1.3 of IGC Code. A filling limit curve for actual filling temperatures shall be prepared from the formula given in 15.5.1 of IGC Code. 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 can be made to allow a higher filling limit than calculated using the reference temperature, but never above 95%.

2.10.2 Compressed gas storage tanks

(a) The storage tanks to be used for compressed gas shall be approved and certified by this Society.

(b) Tanks for compressed gas shall be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in 2.6.3.

2.11 Fuel bunkering system and distribution system outside machinery spaces

2.11.1 Fuel bunkering station

(a) The FC fuel bunkering station shall be so located that sufficient natural ventilation is provided. Closed/semi-enclosed bunkering stations will be subject to special consideration.

(b) Liquid gas drip trays shall be fitted below the bunkering connections and where leakage may occur. The drip trays shall be made of stainless steel, and should drain over the ship's side by a pipe that preferably leads down into the sea. This pipe could be temporarily fitted for bunkering operations. The surrounding hull or deck structures are not to be exposed to unacceptable cooling, in case of leakage of liquid gas.

(c) Control of the bunkering shall be possible from a safe location in regard to bunkering operations. At this location tank pressure and tank level shall be monitored. Overfill alarm and automatic shut down are also to be indicated at this location.

2.11.2 Bunkering system

(a) The bunkering system shall be so arranged that no gas is discharged to air during filling of storage tanks.

(b) A manually operated stop valve and a remote operated shut down valve in series, or a combined manually operated and remote valve shall be fitted in every bunkering line close to the shore connecting point. It shall be possible to release the remote operated valve in the control location for bunkering operations and or another safe location.

(c) If the ventilation in the ducting around the FC fuel bunkering lines stop, an alarm shall sound at the bunkering control location.

(d) If gas is detected in the ducting around the bunkering lines an alarm shall sound at the bunkering control location.

(e) Means shall be provided for draining the liquid from the bunkering pipes at bunkering completion.

(f) Bunkering lines shall be arranged for inerting and gas freeing. During operation of the vessel the bunkering pipes shall be gas free.

2.11.3 Distribution outside of machinery spaces

(a) FC fuel piping is not to be led through accommodation spaces, service spaces or control stations. Hydrogen pipes are not to be led through enclosed spaces in the ship apart from the FC spaces. Hydrogen pipes may be considered accepted led through other spaces if these spaces are defined as gas hazardous, e.g. all equipment inside are spark proof and certified safe for hydrogen atmosphere. Such spaces will have to be arranged with a ventilation system and rate as required for FC fuel spaces with open hydrogen pipes, and the space must have a simple geometrical shape.

(b) Where gas pipes except hydrogen pipes pass through enclosed spaces in the ship, they shall be enclosed in a duct. This duct shall be mechanically under pressure ventilated with 30 air changes per hour, and gas detection system shall be provided.

(c) The duct shall be dimensioned according to 2.8.5.

(d) Gas pipes located in open air shall be so located or protected that they are not likely to be damaged by accidental mechanical impact.

(e) High pressure gas lines outside the FC spaces should be installed and protected so as to minimize the risk of injury to personnel in case of rupture.

2.12 Ventilation system

2.12.1 General

(a) Any ducting used for the ventilation of hazardous spaces caused by the FC installation shall not serve any other spaces and be separate from that used for the ventilation of non-hazardous spaces. Electric fan motors shall not be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served. Electric fan motors shall not be located in ventilation ducts for spaces containing hydrogen installations.

(b) Designs of ventilation fans serving spaces containing sources of hydrocarbon release are to fulfill the followings:

(i) Electric fan motors shall not be installed in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

(ii) Starters for fans for ventilation of non-hazardous spaces are to be located outside the cargo area or on open deck. If electric motors are installed in such rooms, the ventilation capacity shall be great enough to prevent the temperature limits specified in section 1.3, Part VII of the Rules for Steel Ships of this Society, from being exceeded, taking into account the heat generated by the electric motors.

(iii) Fans shall be designed with the least possible risk for spark generation.

(iv) Minimum safety clearances between the casing and rotating parts shall be such as to prevent any friction with each other. In no case is the radial air gap between the impeller and the casing to be less than 0.1 times the diameter of the impeller shaft in way of the bearing but not less than 2 mm. It need not be more than 13 mm.

(v) The parts of the rotating body and of the casing shall be made of materials which are recognized as being spark proof, and they shall have antistatic properties. Furthermore, the installation on board of the ventilation units shall be such as to ensure the safe bonding to the hull of the units themselves. Resistance between any point on the surface of the unit and the hull shall not be greater than 106 ohm. The following combinations of materials and clearances used in way of the impeller and duct are considered to be non-sparking:

(1) impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

(2) impellers and housings of non-ferrous metals;

(3) impellers and housing of austenitic stainless steel;

(4) impellers of aluminum 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

(5) any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

(vi) Any combination of an aluminum 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.

(c) The ventilation system shall ensure a good air circulation in all spaces, and in particular ensure that there is no possibility of formation of gas pockets in the room. For spaces containing hydrogen release sources also refer to 2.12.4(c) and 2.12.1(b)(i) for space and ventilation system design. Ventilation systems in spaces with release sources from piping systems with FC fuel that is heavier than air (propane, butane or similar) have to be designed with special focus on the heavy gases, to avoid any accumulation of released gas. Ventilation suctions in such spaces are normally to be from the lowest points of the space.

(d) Means should be provided to indicate in the engine control station any loss of the required ventilating capacity.

(e) 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.

(f) Air outlets from non-hazardous spaces should be located outside hazardous areas.

(g) 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.

(h) 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 form.

2.12.2 Gas tank rooms

(a) The tank room for gas storage should be provided with an effective mechanical forced ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour. Tank rooms for hydrogen tanks shall have a ventilation rate and arrangement as given in 2.12.4.

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

(c) The number and power of the ventilation fans shall 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. Tank rooms for hydrogen tanks shall follow 2.12.4.

2.12.3 Pump and compressor rooms

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

(b) Ventilation systems for pump and compressor rooms should be in operation when pumps or compressors are working. Signboards to this effect shall be placed in an easily visible position near the control stand.

(c) When the space is dependent on ventilation for its area classification, the following requirements are to apply:

(i) 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.

(ii) Operation of the ventilation should be monitored.

(iii) In the event of failure of ventilation, the following requirements are to apply:

(1) an audible and visual alarm should be given at a manned location;

(2) immediate actions are to be taken to restore ventilation; and

(3) electrical installations shall be disconnected if ventilation cannot be restored for an extended period. The disconnection shall be made outside the hazardous areas, and be protected against unauthorized reconnection, e.g. by lockable switches.

2.12.4 Spaces containing hydrogen piping

(a) For spaces containing hydrogen release sources the ventilation rate shall be sufficient to avoid gas concentration in the flammable range in all leakage scenarios, including pipe rupture. This is also applicable for spaces containing fully welded hydrogen pipes.

(b) The number and power of the ventilation fans shall be such that the capacity is still 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.

(c) Ventilation ducts from spaces containing hydrogen piping or release sources shall be vertical or steadily ascending and without sharp bends to avoid any possibility for gas to accumulate.

2.12.5 Non-hazardous spaces

(a) 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 requirements:

(i) 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:

(1) proceed with purging (at least 5 air changes) or confirm by measurements that the space is nonhazardous; and

(2) pressurize the space.

(ii) Operation of the overpressure ventilation should be monitored.

(iii) In the event of failure of the overpressure ventilation:

(1) an audible and visual alarm should be given at a manned location; and

(2) if overpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations is required according to a recognized standard, such as IEC 60092-502, Table 5.

2.13 Stationary fuel cell power systems

2.13.1 For stationary fuel cell power systems, the test program can be based on the IEC standard 62282-3-100 "Stationary fuel cell power systems - Safety" and 62282-3-200 "Stationary fuel cell power systems - Performance test methods", but will also have to take the environmental and operating conditions in a ship into account.

CHAPTER 3 MATERIAL REQUIREMENTS

3.1 General

3.1.1 Materials are in general to be in accordance with the rquirements in Part XI of the Rules for Steel Ships of this Society.

3.1.2 Material requirements for hydrocarbon gas

(a) 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.

(b) For piping system, some relaxation may, however, be permitted in the quality of the material of open ended vent piping, provided the temperature of the cargo at atmospheric pressure is -55°C or higher, and provided no liquid discharge to the vent piping can occur. Similar relaxation may be permitted under the same temperature conditions to open ended piping inside cargo tanks, excluding discharge piping and all piping inside of membrane and semi-membrane tanks.

(c) Materials having a melting point below 925°C, shall not be used for piping outside the cargo tanks except for short lengths of pipes attached to the cargo tanks, in which case fire-resisting insulation shall be provided.

3.1.3 Material requirements for hydrogen gas

(a) Materials in contact with hydrogen should be austenitic stainless steel (e.g. 304, 316, 304L and 316L) or other materials compatible for storage and transport of hydrogen and approved by this Society.

CHAPTER 4 FIRE SAFETY

4.1 General

4.1.1 The requirements in this chapter are additional to those given in SOLAS Ch.II-2.

4.1.2 A gas compressor room shall be treated as a machinery space of category A for fire protection purposes.

4.1.3 The arrangement of fire fighting systems in fuel cells spaces, and the need for water spray for cooling of fuel cells or other components must be evaluated and approved by the classification society for each installation.

4.2 Fire protection

4.2.1 Construction

(a) Gas tanks / tank batteries located above deck shall be shielded with class A-60 insulation towards accommodation, service stations, cargo spaces and machinery spaces.

(b) The tank room and ventilation trunks to such spaces below the bulkhead deck shall be fire insulated to class A-60 standard. However, where the room is adjacent to tanks, voids, auxiliary machinery spaces of no fire risk, sanitary and similar spaces, the insulation may be reduced to class A-0.

(c) The bunkering station shall be shielded with class A-60 insulation towards other spaces, except for spaces such as tanks, voids, auxiliary machinery spaces of no fire risk, sanitary and similar spaces where the insulation may be reduced to A-0 class.

(d) A FC space shall as a minimum have gas tight steel bulkheads. The categorization of the FC space as a category(6) or (7) space, refer to SOLAS Chapter II-2, Table 9.5 and 9.6, is depending on the amount of combustible material or fuel available in the space. The categories for the FC spaces have to be decided for each installation.

4.3 Fire extinction

4.3.1 Fire main

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

(b) When the storage tank is located above the bulkhead deck, isolating valves shall be fitted in the fire main in order to isolate damage sections of the main.

4.3.2 Water spray systems

(a) A water spray system shall be fitted for cooling and fire prevention and to cover exposed parts of storage tank located above deck.

(b) The system shall be designed to cover all areas as specified above with an application rate of 10 $l/\text{min}/\text{m}^2$ for horizontal projected surfaces and 4 $l/\text{min}/\text{m}^2$ for vertical surfaces.

(c) For the purpose of isolating damage sections, stop valves shall be fitted or the system may be divided into two sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.

(d) The capacity of the water spray pump shall be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above.

(e) A connection to the ships fire main through a stop valve shall be provided.

(f) 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.

(g) The nozzles to be of an approved full bore type and they shall be arranged to ensure an effective distribution of water of the space being protected.

4.3.3 Dry chemical powder fire extinguishing system

(a) One portable dry powder extinguisher of 50 kg shall be located near the bunkering station.

4.4 Fire detection and alarm systems

4.4.1 Detection

(a) An approved fixed fire detection system should be provided for the tank room and the ventilation trunk for tank room below deck.

(b) Smoke detectors alone should not be considered sufficient for rapid fire detection.

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

4.4.2 Alarms and safety actions

(a) Required safety actions at fire detection in the FC space and tank room are given in Table 6-2. In addition, the ventilation should stop automatically and fire dampers are to close.

CHAPTER 5 ELECTRICAL SYSTEMS

5.1 General

5.1.1 The provisions of this chapter should be applied in conjunction with applicable electrical requirements of Part D of SOLAS Chapter II-1.

5.1.2 Hazardous areas on open deck and other spaces not defined in this chapter should be decided based on a recognized standard. The electrical equipment fitted within hazardous areas should be according to the same standard.

5.1.3 Electrical equipment and wiring should in general not be installed in hazardous areas unless essential for operational purposes, and be suitable for the area classification as specified in 5.2.

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

(a) In addition to fire and hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans should be certified safe for hazardous area zone 1.

(b) All electrical equipment in a machinery space containing gas-fuelled engines, and not certified for zone 1 should be automatically disconnected, if gas concentrations above 20% LEL is detected on two detectors in the space containing gas-fuelled engines.

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

5.1.6 Cable penetrations should satisfy the requirements regulating the dispersion of gas.

5.1.7 Protection against excess power shall be provided, either as an integral part of the equipment or as a part of the ships system. It shall be ensured that the fuel cell can be disconnected from the electrical load at any load condition.

5.1.8 The inverter shall be so designed that reverse power, such as breaking power, cannot pass into the fuel cell.

5.1.9 The outgoing circuits on a fuel cell arrangement shall be provided with a switch disconnector for isolating purposes so that isolating for maintenance is possible. Contactors are not accepted as isolating devices.

5.1.10 The electrical equipment fitted within hazardous area should be in compliance with Part VII, Chapter 1 of the Rules for Steel Ships of this Society or recognised standards (e.g. IEC 60079 series). According to the type of explosive gas atmospheres or flammable gases likely to be present in hazardous areas, the types of explosion protection and temperature class of electrical equipment shall be checked.

(a) Gas group and temperature class for hydrogen: IIC and T1.

(b) Gas group and temperature class for natural gas: IIA and T2.

5.2 Area classification

5.2.1 General

(a) 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.

(b) 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 standards IEC 60079-10 and guidance and informative examples given in IEC 60092-502 for tankers. Main features of the guidance are given in 5.2.2.

(c) Areas and spaces other than those classified in 5.2.2 shall be subject to special consideration. The principles of the IEC standards shall be applied.

(d) Area classification of a space may be dependent of ventilation as specified in IEC 60092-502, Table 1. Requirements for such ventilation are given in 2.12.3.

(e) 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. Requirements for such pressurization are given in 2.12.5.

(f) Ventilation ducts should have the same area classification as the ventilated space.

5.2.2 Definition of hazardous area zones

(a) Hazardous area zone 0

This zone includes the interiors of gas tanks, any pipe work of pressure-relief or other venting systems for gas tanks, pipes and equipment containing gas.

(b) Hazardous area zone 1

This zone includes:

(i) tank room;

(ii) gas compressor room arranged with ventilation according to 2.12.3(c);

(iii) areas on open deck, or semi-enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapour outlet, 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;

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

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

(vi) enclosed or semi-enclosed spaces in which pipes containing gas are located, e.g., ducts around gas pipes, semi-enclosed bunkering stations; and

(vii) 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.

(c) Hazardous area zone 2

This zone includes areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1.

5.3 Inspection and testing of electrical equipment in hazardous area

5.3.1 General

(a) Before the electrical installations in hazardous areas are put into service or considered ready for use, they shall be inspected and tested. All equipment, including cables, shall be verified as having been installed in accordance with installation procedures and guidelines issued by the manufacturer of the equipment and cables, and that the installations have been carried out in accordance with Part VII of the Rules for Steel Ships of this Society.

(b) For spaces protected by pressurization it shall be examined and tested that purging can be fully accomplished. Purge time at minimum flow rate shall be documented. Required shutdowns and/or alarms upon ventilation overpressure falling below prescribed values shall be tested. For other spaces where area classification depends on mechanical ventilation it shall be tested that ventilation flow rate is sufficient, and that required ventilation failure alarm operates correctly.

(c) For equipment for which safety in hazardous areas depends upon correct operation of protective devices and/or operation of an alarm it shall be verified that the devices have correct settings and/or correct operation of alarms.

(d) Intrinsically safe circuits shall be verified to ensure that the equipment and wiring are correctly installed.

(e) Verification of the physical installation shall be documented by the yard. Verification documentation shall be available for this Society's surveyor at the site.

5.4 Maintenance of electrical equipment in hazardous area

5.4.1 General

(a) The maintenance manual shall be in accordance with the recommendations in IEC 60079-17 and 60092-502 and shall contain necessary information on:

(i) overview of classification of hazardous areas, with information about gas groups and temperature class;

(ii) records sufficient to enable the certified safe equipment to be maintained in accordance with its type of protection (list and location of equipment, technical information, manufacturer's instructions, spares etc.);

(iii) inspection routines with information about level of detail and time intervals between the inspections, acceptance/rejection criteria; and

(iv) register of inspections, with information about date of inspections and name(s) of person(s) who carried out the inspection and maintenance work.

(b) Updated documentation and maintenance manual shall be kept onboard, with records of date and names of companies and persons who have carried out inspections and maintenance. Inspection and maintenance of installations shall be carried out only by experienced personnel whose training has included instruction on the various types of protection of apparatus and installation practices to be found on the vessel.

CHAPTER 6 CONTROL, MONITORING AND SAFETY SYSTEMS

6.1 General

6.1.1 For instrumentation and automation, including computer based control and monitoring, the requirements in this chapter are additional to those given in Part VIII of the Rules for Steel Ships of this Society. The control and monitoring systems shall be certified, if installed:

(a) FC fuel tank level measurement system

(b) FC fuel tank overflow protection system

(c) FC fuel supply control and monitoring system

(d) Flammable gas detection system (permanent system only)

(e) Inert gas control and monitoring system

(f) Oxygen indication equipment (permanent system only)

(g) FC power management systems (for **FC Energy** notation only)

(h) FC safety system

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

6.1.3 Pressure gauges shall be fitted to FC fuel pump discharge lines and to the bunkering lines.

6.1.4 A bilge well in each tank room surrounding an independent FC fuel tank shall be provided with both a level indicator and a temperature sensor. Alarm shall be given at high level in bilge well. Temperature sensor low temperature indication shall lead to automatic closing of main tank valve.

6.1.5 The fuel cell and the FC fuel supply system shall be arranged for manual remote emergency stop from the following locations:

(a) The cargo control room (relevant for cargo ships only)

(b) Navigation bridge

(c) Engine control room

(d) Fire control station

6.2 Monitoring

6.2.1 FC fuel tank monitoring

(a) FC fuel tanks shall be monitored and protected against overfilling.

(b) Each tank shall be monitored with at least one local indicating instrument for pressure and remote pressure indication at the control position. The manometers and indicators shall 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 shall be provided on the bridge. The alarms shall be activated before the set pressures of the safety valves are reached.

6.2.2 FC fuel compressor monitoring

(a) The monitoring system should include items shown in Table 6-1:

Table 6-1
Monitoring system requirements

	Alarm	Automatic stop
FC fuel heater outlet, temperature high	X	
FC fuel compressor outlet, temperature high	X	X
FC fuel compressor inlet, pressure low	X	
FC fuel compressor outlet, pressure high	X	
FC fuel compressor outlet, pressure low	X	
Control system failure	X	
Sealing FC fuel pressure low	X	
Lubrication oil pressure low	X	X
Lubrication oil temperature high	X	
Master valve close	X	

In addition, high pressure FC fuel compressors shall stop automatically in the event of:

(i) Control air pressure loss

(ii) High gas concentration in the compressor room (Table 6-2)

(iii) Automatic stop or emergency stop of FC fuel supply to fuel cell

6.2.3 Fuel cell monitoring

(a) The fuel cell shall be monitored to the extent necessary to avoid that the safety is impaired. For installation with notation **FC Energy**, a failure mode and effect analysis examining all possible faults affecting the fuel cell operation and safety shall be submitted. Based on the outcome of the analysis the extent of the monitoring and control shall be decided. As a minimum the following items must typically be monitored:

(i) cell voltage

(ii) cell voltage deviations

(iii) temperature exhaust gas

(iv) temperature in FC

(v) current level

Other typical monitoring that should be considered:

(i) air flow

(ii) air pressure

(iii) cooling medium flow, pressure, temperature (if used)

(iv) fuel flow

(v) fuel temperature

(vi) fuel pressure

(vii) gas detection in exhaust gas

(viii) water system level

(ix) water system pressure

(x) water system purity

(xi) parameters necessary to monitor lifetime/ deterioration

6.3 Gas detection

6.3.1 Permanently installed gas detectors shall be fitted in the tank room, in all ducts around gas pipes, in fuel cell spaces, compressor rooms, and other enclosed spaces containing FC fuel piping or other FC fuel equipment, but not including spaces where only completely ducted FC fuel pipes are present. Gas detection systems shall be installed for all types of flammable gases that may occur in the space.

6.3.2 The number of detectors in each space must be considered taking size, layout, fuel density in air and ventilation of the space into account.

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

6.3.4 An audible and visible alarm shall be activated before the vapour concentration reaches 20% of the lower flammable limit (LEL). For ventilated ducts around FC fuel pipes the alarm limit can be set to 30% LEL. LEL is at 4% in air for hydrogen, at 5.3% in air for methane and at 1.7% in air for propane.

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

6.3.6 Continuous detection is required for FC fuel pipe ducts and fuel cell spaces kept gas safe by ventilation and fully welded fuel pipes.

6.4 Safety functions of gas supply systems

6.4.1 The main supply lines for FC fuel shall be equipped with a manually operated stop valve and an automatically operated "master fuel valve" coupled in series or a combined manually and automatically operated stop valve. The valves shall be situated in the part of the piping that is outside the FC space. The master fuel valve is automatically to cut off the FC fuel supply as given in Table 6-2. The automatic master fuel valve shall be operable from a reasonable number of places in the FC space, from a room outside the FC space and from the bridge.

6.4.2 Each FC fuel utilization unit shall be provided with a set of "double block and bleed" valves. These valves shall be arranged so that when automatic shut down is initiated as given in Table 6-2, this will cause the two FC fuel valves which are in series to close automatically and the vent valve to open automatically. The two block valves shall be of fail-to-close type, while the vent valve shall be fail-to-open. The double block and bleed valves are also to be used for normal stop of the fuel cell. In cases where the master fuel valve is automatically shut down also a vent valve that will vent the pipe piece between the master fuel valve and the double block and bleed valve shall open.

6.4.3 There shall be one manually operated shut down valve in the FC fuel supply line to each FC to assure safe isolation during maintenance on the fuel cell installation.

6.4.4 In the main supply FC fuel line to each FC space where fuel piping is not in a double duct an automatic excess flow shut off valve shall be fitted. The valve shall be adjusted to shutoff FC fuel supply in the event of rupture of the FC fuel line. The valve shall be located as close as possible to the point of entry of the FC fuel supply line into the FC space. The shutdown should be time delayed to prevent shutdown due to transient load variations. This requirement may be waived if the FC fuel pipes are located in protected locations, for instance very high in the space or mechanically shielded.

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

6.4.6 If a FC fuel leak leading to a FC fuel supply shut down occurs, the FC fuel supply is not to be operated until the leak has been found and dealt with. Signboards to this effect shall be placed in a prominent position in the machinery space.

6.4.7 A signboard should be fitted in the FC space stating that heavy lifting, maintenance or other activities capable of potentially causing damage to the FC fuel pipes are not to be done when the fuel cell is running.

Table 6-2
Monitoring of FC fuel supply system to fuel cells

Parameter	Alarm	Automatic shut-down of main tank valve	Automatic shut-down of FC fuel supply to FC space	Comment
Gas detection in tank room above 20% LEL	X			
Gas detection on second detector in tank room above 40% LEL	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 FC space above 20% LEL	X			
Gas detection on second detector in duct between tank and FC space above 40% LEL	X	X 1)		
Gas detection in compressor room above 20% LEL	X			
Gas detection on second detector in compressor room above 40% LEL	X	X 1)		
Gas detection in duct inside FC space above 30% LEL	X			If double pipe fitted in FC space
Gas detection on detector in duct inside FC space above 60% LEL	X		X	If double pipe fitted in FC space
Gas detection in FC space above 20% LEL	X			Gas detection not required if all FC pipes are in complete double ducts
Gas detection on second detector in FC space above 40% LEL	X		X	Gas detection not required if all FC pipes are in complete double ducts Is also to lead to disconnection of not certified safe electrical equipment in FC space
Loss of ventilation in duct between tank and FC space 3)	X		X 4)	
Loss of ventilation in duct inside FC space 3)	X		X 4)	If double pipe fitted in FC space
Loss of ventilation in FC space	X			Not for FC spaces with only completely ducted FC fuel pipes
Loss of all ventilation in FC space	X		X	Not for FC spaces with only completely ducted FC fuel pipes
Loss of ventilation in an ESD protected machinery space	X		X	
Fire detection in FC space	X		X	Also to lead to stop of ventilation in FC space
Failure of valve control actuating medium	X		X 2)	Time delayed as found necessary
Automatic shut down of fuel cell (fuel cell failure)	X		X 2)	
Emergency shut-down of fuel cell manually released	X		X	

1) If the tank is supplying FC fuel to more than one fuel cell and the different supply pipes are completely separated and fitted in separated ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into to the duct where gas is detected shall close.
2) Only double block and bleed valves to close.
3) If the duct is protected by inert gas, loss of inert gas overpressure shall lead to the same actions as given here.
4) This parameter is not necessarily to lead to automatic shut down of FC fuel supply, manual options may be considered. Shut down is only needed for the FC fuel leading to the duct that has lost the ventilation.

CHAPTER 7 COMPRESSORS

7.1 FC Fuel compressors

7.1.1 The FC fuel compressor and FC fuel supply shall be arranged for manual remote emergency stop from the following locations:

(a) the cargo control room (relevant for cargo ships only)

(b) navigation bridge

(c) engine control room

(d) fire control station.

7.1.2 The possibility for fatigue problem of the high-pressure FC fuel piping due to vibration caused by the high-pressure FC fuel compressor must be considered. Such vibrations may be caused by unbalanced forces in the compressor itself, by resonant vibrations in the piping system or by resonance in the FC fuel column of the FC fuel discharge lines. Calculations may be required to verify that resonance problems will not occur

CHAPTER 8 MANUFACTURE, WORKMANSHIP AND TESTING

8.1 Liquefied gas tank

8.1.1 Tests related to welding and tank testing shall be in accordance with recognized standards, IGC Code and the Rules for Steel Ships of this Society.

8.2 FC fuel piping systems

8.2.1 FC fuel pipes

(a) The FC fuel pipes shall be tested as given in recognized standards, IGC Code and the Rules for Steel Ships of this Society. Butt welded joints of high-pressure gas pipes and hydrogen supply pipes in FC spaces shall be subjected to 100% radiographic testing.

8.2.2 Ducting

(a) If the FC fuel piping duct contains high pressure pipes the ducting shall be pressure tested to at least 10 bar.

8.2.3 Valves

(a) Each size and type of valve intended to be used at a working temperature below -55˚C shall be approved through design assessment and type testing. Type testing for all valves to the minimum design temperature, or lower and to a pressure not lower than the maximum design pressure foreseen for the valves, shall be witnessed in the presence of this Society's representative. Type testing shall include hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure, and cryogenic testing consisting of valve operation or safety valve set pressure, and leakage verification. In addition, for valves other than safety valves, a seat and stem leakage test at a pressure equal to 1.1 times the design pressure. For valves intended to be used at a working temperature above -55˚C, type testing is not required.

(b) Valves for use in hydrogen pipes located in non hazardous spaces with fully welded hydrogen pipes, shall be tightness tested with hydrogen to show that there is no leakage of hydrogen from the valve.

8.2.4 Expansion bellows

Expansion bellows intended for use in FC fuel systems shall be type tested as follows:

(a) An overpressure test. A type element of the bellows, not pre-compressed, 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.

(b) 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.

(c) 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.

(d) 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 2x106 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.

(e) This Society may waive performance of the tests specified in above, 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.

8.3 Fuel cell power system

8.3.1 Product type approval

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. IEC Standard 62282-3-100 and 62282-3-200). The tests should cover, when relevant and applicable, at least the following items:

(a) Gas leakage test

(b) Liquid leakage test

(c) Strength test of gas and liquid sections

(d) Ambient condition test according to Part VIII Table 2-1 and Table 4-1 of the Rules for Steel Ships of this Society. (At least including visual inspection and tests of power supply variations, dry heat, damp heat , cold, insulation resistance, high voltage, vibration, inclination, performance and external power supply failure.)

(e) Normal operation test

(f) Electrical overload test

(g) Dielectric test simulating abnormal conditions

(h) Shutdown test

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

(j) Automatic control of burners and catalytic oxidation reactors test

(k) Exhaust gas temperature test

(l) Surface and component temperature test

(m) Wind test (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 CR)

(n) Rain test (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)).

(o) CO emission test

8.3.2 Product survey

In case tests listed in 8.3.1 are performed for 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 the following items:

(a) Gas leakage test

(b) Coolant (liquid) leakage test

(c) Normal operation test

(d) Dielectric test simulating abnormal conditions

(e) Burner operating characteristics test

(f) CO emission test

8.4 Onboard testing of FC plant

8.4.1 Testing after installation onboard of the whole system shall be performed in different relevant load conditions (typically: "start up", "normal running", "full load").