RULES FOR
CLASSIFICATION OF

SHIPS

NEWBUILDINGS

SPECIAL EQUIPMENT AND SYSTEMS
ADDITIONAL CLASS

PART 6 CHAPTER 23

FUEL CELL INSTALLATIONS

JULY 2008

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DET NORSKE VERITAS

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INTRODUCTION

General

The Board approved this new chapter in June 2008.

The rules come into force on 1 January 2009.

This chapter is valid until superseded by a revised chapter. Supplements will not be issued except for an updated list of corrections presented in Pt.0 Ch.1 Sec.3. Pt.0 Ch.1 is normally revised in January and July each year.

Revised chapters will be forwarded to all subscribers to the rules. Buyers of reprints are advised to check the updated list of rule chapters printed in Pt.0 Ch.1 Sec.1 to ensure that the chapter is current.

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SECTION 1
GENERAL REQUIREMENTS

A. Classification

A 100 Application

101 The rules in this chapter apply to fuel cell installations in ships.

102 The rules are applicable for installations with a variety of gaseous and liquid fuels.

Guidance note:

Typical fuels that may be relevant are natural gas, methanol, propane, hydrogen or diesel fuels. Bio- fuels will be subject to special consideration. In this rule chapter only the gaseous fuels as well as liquid fuels with flashpoint below 60 degrees C are regarded as "FC fuel". Liquid fuels with flashpoint above 60 degrees will follow requirements for normal fuel in Pt.4 Ch.6.

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103 Since the fuel cell technology is still under development the requirements of this rule chapter may have to be supported by additional considerations and requirements from case to case. Designs which are not in compliance with this rule chapter may be approved after evaluation by the classification society if they are found to have an equivalent level of safety.

Guidance note:

Parts of IEC 62282-3-1 "Fuel cell technologies Part 3-1 Stationary fuel cell power systems- Safety" may give useful guidance to design of different fuel cell installations

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A 200 Class notation

201 Ships where the fuel cell power is used for essential, important or emergency services shall satisfy the requirements in this rule chapter and will be given class notation **FC-POWER**.

202 Ships where the fuel cell power is not used for essential, important or emergency users shall satisfy the safety and environmental requirements. Installations complying with the requirements in this chapter, except Sec.2 will be given class notation **FC-SAFETY**.

A 300 Survey extent

301 Survey requirements for ships with class notation **FC-POWER** and **FC-SAFETY** can be found in Pt.7 Ch.1 Sec.2 and Pt.7 Ch.1 Sec.3.

B. Definitions

B 100 Terms

101 *Accommodation spaces:* See SOLAS Ch.II-2 Reg.3.

102 *Control stations:* See SOLAS Ch.II-2 Reg.3.

Guidance note:

This does not include special fire control equipment that can be most practically located in the cargo area (if the vessel is a cargo ship).

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103 *Double block and bleed valve* is a set of three automatic valves located at the FC fuel supply to each of the fuel cells. Two of these valves shall be in series in the FC fuel pipe to the consuming equipment. The third valve shall be in a pipe that vents that portion of the FC fuel piping that is between the two valves in series to a safe location in the open air. Alternatively, the function of one of the valves in series and the vent valve can be incorporated into one valve body, so arranged that the flow to the FC fuel utilisation unit will be blocked and the vent opened.

104 *ESD means* emergency shutdown.

105 *Enclosed spaces* are spaces bounded by bulkheads and decks which may have doors, windows or other similar openings.

106 *Emergency service* is defined in Pt.4 Ch.8 Sec.13.

107 *Essential service* is defined in Pt.4 Ch.8 Sec.13.

108 *Fuel cell space* is in this chapter used for machinery spaces containing fuel cell installations.

109 *FC* means fuel cell. A fuel cell is a source of electrical power in which the chemical energy of a fuel is converted directly into electrical energy by electrochemical oxidation.

110 *FC fuel* can be gases or liquids, for instance methane or natural gas, methanol, propane or hydrogen. In this context only the fuels which are gases or have low flash point are covered by the special requirements for FC fuel. Requirements to regular fuel oil and other support system are covered by the requirements in Pt.4 Ch.6.

111 *FC system* is the complete installation of FC fuel containment, FC fuel piping and the fuel cell itself with surrounding machinery, electrical and automation systems.

112 *Gas* is defined as a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

113 *Hazardous area*

Area in which an explosive gas atmosphere or a flammable gas with a 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 and according to the area classification specified in Sec.5 B.

Zone 0

Area in which an explosive gas atmosphere or a flammable gas with a flash point below 60°C is present continuously or is present for long periods

Zone 1

Area in which an explosive gas atmosphere or a flammable gas with a flash point below 60°C is likely to occur in normal operation

Zone 2

Area in which an explosive gas atmosphere 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.

Guidance note:

The definition of hazardous area is only related to the risk of explosion. In this context, health, safety and environmental issues, i.e. toxicity, are not considered.

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114 *Non-hazardous area*

An area not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.

115 *Sources of release* are valves or detachable pipe joints in the FC fuel system. Also compressors and seals of pumps in the FC fuel system are regarded as sources of release.

116 *High pressure piping* is in this context piping with maximum working pressure above 10 bar.

117 *Important service* is defined in Pt.4 Ch.8 Sec.13.

118 *LEL is* lower explosion limit.

119 *Low flashpoint liquids* are liquids with a flashpoint below 60°C.

120 *Main tank valve* is a remote operated valve on the FC fuel outlet from a FC fuel storage tank, located as close to the tank outlet point as possible.

121 *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.

122 *Semi-enclosed spaces* are locations where natural conditions of ventilation are notably different from those on open decks due to the presence of structures such as roofs, wind breakers and bulkheads and which are so arranged that dispersion of gas may not occur.

123 *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.

C. Documentation

C 100 Plans and particulars

101 Special components, equipment or systems not covered in the different parts of the existing rules may be required to be documented. Documentation requirements for such components and equipment will be subject to special consideration.

102 Arrangement plans shall be submitted for approval giving location of:

- machinery and boiler spaces, accommodation, service and control station spaces
- FC fuel tanks and FC fuel containment systems
- FC fuel pump and compressor rooms
- FC fuel piping with shore connections
- tank hatches, ventilation pipes and any other openings to the FC fuel tanks
- ventilating pipes, doors and openings to FC fuel pump rooms, compressor rooms and other hazardous areas
- entrances, air inlets and openings to accommodation, service and control station spaces
- hazardous areas of zone 0, 1 and 2, and their extent.

103 For ships with class notation **FC-POWER** an overall description of the propulsion and power installation and operating philosophy for all relevant operating modes shall be submitted for information. This document must be submitted prior to commencing approval work.

104 A failure mode and effect analysis shall be conducted for the ship, taking all safety aspects in relation to the fuel cell installation into account. This document shall be submitted for approval.

Guidance note:

The safety aspects in this connection are for instance explosion hazards, fire effects from the fuel cell itself or from the fuel cell support systems. If a fuel cell is connected to the grid any potential hazards affecting the ship's total power system should be included.

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105 Plans and particulars for the fuel cell shall be submitted for approval. This is typically to include:

- fuel cell principles
- functional description
- arrangement drawings of the fuel cell including dimensions, materials, operating temperatures, pressures, weights
- strength calculations of pressure containing components, or test reports
- documentation of compliance with environmental conditions as outlined in Pt.4 Ch.1 Sec.3 B200, including calculations or test reports
- voltage and current levels in different parts of the cell
- type of fuels
- maintenance plan (replacement of stack etc.)
- earthing principles
- safety devices with set points
- documentation of life time and availability, e.g. deterioration rate curve or similar.

A failure mode and effect analysis (FMEA) examining all possible faults affecting the processes in the fuel cells shall be submitted for approval, together with a test program for verification of the main conclusions from the FMEA.

The power deterioration rate for the fuel cell shall be documented through analysis or test results, and shall consider different power levels and different modes of operation.

Test programme

Guidance note:

The test programme can be based on the IEC standard 62282-3-1 "Stationary fuel cell power systems- Safety", but will also have to take the environmental and operating conditions in a ship into account.

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106 Plans of the following piping systems shall be submitted for approval:

- drawings and specifications of FC fuel piping including vent lines of safety relief valves or similar piping
- drawings and specifications of offsets, loops, bends and mechanical expansion joints, such as bellows or similar means in the FC fuel piping
- drawings and specifications of flanges, valves and other fittings in the FC fuel piping system
- documentation of type tests for expansion components in FC fuel piping systems
- specification of materials, welding, post-weld heat treatment and non-destructive testing of FC fuel piping
- specification of pressure tests (structural and tightness tests) of FC fuel piping
- program for functional tests of all piping systems including valves, fittings and associated equipment for handling FC fuel (liquid or vapour)
- drawings and specifications of insulation where such insulation is installed
- specification of electrical bonding of piping
- cooling/ heating water system in connection with FC fuel system if fitted
- specification of heat tracing arrangements if fitted.

107 The following plans and particulars for the safety relief valves shall be submitted for approval:

- drawings and specifications for safety relief valves and pressure/vacuum relief valves and associated vent piping.

108 Plans of the following equipment and systems with particulars shall be submitted:

- arrangements and specifications of mechanical ventilation systems in spaces covering FC fuel systems, giving capacity and location of fans and their motors. For fans and ventilators; drawings and material specifications of rotating parts and casings

— arrangement and specifications of piping systems for gas freeing and purging of FC and piping
— for fixed gas detection and alarm systems: specification and location of detectors, alarm devices and call points, and cable routing layout drawing
— bilge and drainage arrangements in FC module, if applicable
— air inlet arrangement including filters
— exhaust arrangement
— specification of FC module outer surface temperature.

109 Plans of the following equipment and systems regarding fire protection shall be submitted for approval:

— arrangement and specification of fire extinguishing systems
— arrangement of fire detection systems
— arrangement of fire insulation, internally between FC system equipment and externally to other ship systems.

110 Plans of electrical installations giving the following particulars shall be submitted for approval, in addition to the documentation requirements in Pt.4 Ch.8 Sec.1:

— area classification drawing(s)
— drawing(s) showing location of all electrical equipment in hazardous areas
— single line diagram for intrinsically safe circuits and data for verification of the compatibility between the barrier and the field component
— list of explosion protected equipment with reference to drawings. See also Pt.4 Ch.8 Sec.11 Table B1
— maintenance manual as specified in Sec.6 D100, for electrical installations in hazardous areas
— single line diagram for main power, auxiliary power and control power distribution
— semi-conductor converters shall be documented as required in Pt.4 Ch.8 Sec.1 Table B6
— electrical power conductors to the FC stacks shall be documented through technical data sheets and design drawings
— short circuit contribution capability
— for ships with notation **FC-POWER** documentation showing that the electrical power system's overall properties are in compliance with Pt.4 Ch.8 shall be submitted. Such documentation may be in the form of system descriptions, system analysis and/or test programs/reports, covering:
  - voltage and frequency variations during steady state and transient modes
  - description of current DC components generated by the FC
  - black out and dead ship recovery required in Sec.2 A103
  - active and reactive load capacities
  - configuration of the system in all operating modes and subsequent power distribution philosophy for different vessel systems or services (essential, important and emergency services)
  - system behaviour in relevant failure modes.

111 Control and monitoring systems shall be documented according to Pt.4 Ch.9 Sec.1 Table C1 and Table C2 as given in the following references:

— system philosophy (Table C1)
— functional description (Table C2) (incl. flow charts if applicable)
— system block diagrams (Table C2)
— power supply arrangements (Table C2)
— list of control and monitoring points (Table C2)
— circuit diagrams (Table C2)
— test program for testing at the manufacturer (Table C2)
— software quality plan (Table C2)
— data sheets with environmental specification (Table C2).

In addition:

— pipe and instrumentation drawings (P&IDs)
— alarm list with cross reference to P&IDs.

112 For ships with notation **FC-POWER** the reliability and availability shall be documented through analysis, complemented with results from development testing, as well as full scale testing.

113 For ships with notation **FC-POWER** a failure mode and effect analysis for the control, monitoring and safety systems for the whole installation including the support and supply systems shall be submitted for approval, together with a test program for verification of the main conclusions from the FMEA.

114 An operation and maintenance manual shall be submitted for approval, to include information as outlined in E100.

115 A test program for onboard testing shall be submitted for approval, refer to Sec.9 C100.

D. Certification

D 100 Fuel cells

101 Fuel cells shall be approved and tested for the application for which they shall be used. Testing shall be performed in accordance with an approved test programme. Scope of the approval and testing of fuel cells for installations with **FC-SAFETY** notation is limited to matters related to safety for the ship and crew.

D 200 Pressure vessels

201 Pressure vessels, which under normal operations will contain gas in the liquid and/or gaseous state, shall be certified as class I pressure vessels in accordance with Pt.4 Ch.7.

D 300 Valves

301 For valves a DNV product certificate is required as given in Pt.4 Ch.6.

Hydrogen valves in spaces made gas safe as outlined in Sec.4 D101 shall be leakage tested with hydrogen.

D 400 Pumps and compressors

401 Pumps and compressors in FC fuel systems shall be delivered with a DNV product certificate for ships with **FC-POWER** notation.

402 For general requirements and in regard to testing of pumps: See Pt.4 Ch.6.

403 For general requirements and with regard to testing of compressors: See Pt.4 Ch.5.

D 500 Electrical components

501 Electrical components shall be certified as outlined in Pt.4 Ch.8 Sec.1 B303.

D 600 Control, monitoring and safety systems

601 Requirements for certification of control, monitoring and safety systems are outlined in Sec.7.

E. Operation and Maintenance Manuals

E 100 Contents

101 An operation manual shall include:

— bunkering procedure

— gas freeing and inerting procedures
— normal operation procedures of the FC system
— emergency operation procedures of the FC system
— FC deterioration rate curves.

102 A plan for systematic maintenance and function testing shall be kept onboard showing in detail how components and systems shall be tested and what shall be observed during the tests. Columns showing test dates and verification of tests carried out shall be included. The plan shall include:

— all instrumentation, automation and control systems affecting the FC system
— test intervals to reflect the consequences of failure involving a particular system. Functional testing of critical alarms should not exceed 3 month intervals. For non-critical alarms, the longest intervals are normally not to surpass 12 months.

The plan should be included in the plan required for class notation **E0**.

SECTION 2
DESIGN PRINCIPLES FOR FC-POWER NOTATION

A. Design Principles

A 100 General

101 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. Active components are defined in Pt.4 Ch.1 Sec.1 B109.

Guidance note:

The fuel cell is defined as an active component.

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102 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.

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

SECTION 3
MATERIALS

A. General

A 100 General

101 Materials are in general to be in accordance with the requirements in Pt.2 of the rules.

B. Special Requirements for Different Fuels

B 100 Material requirements for hydrocarbon gas

101 Materials used in gas tanks, gas piping, process pressure vessels and other components in contact with gas shall be in accordance with Pt.5 Ch.5 Sec.2 D. For piping see Pt.5 Ch.5 Sec.6 C200.

The materials used in gas piping systems shall be furnished with documentation in accordance with Pt.5 Ch.5 Sec.2 Table E1. For the definition of material documentation see Pt.1 Ch.1 Sec.4.

B 200 Material requirements for hydrogen gas

201 Austenitic stainless steel (e.g. 304, 316, 304L and 316L) shall be used for materials in contact with hydrogen. Other materials compatible for storage and transport of hydrogen may be approved after special consideration.

202 The materials used in hydrogen piping systems shall be furnished with documentation in accordance with Pt.5 Ch.5 Sec.2 Table E1. For testing of tank materials relevant parts of Pt.5 Ch.5 Sec.2 shall be used, and where this is not sufficient special considerations will have to be done. For the definition of material documentation see Pt.1 Ch.1 Sec.4.

SECTION 4
ARRANGEMENT AND SYSTEM DESIGN

A. Location and Separation of Spaces

A 100 Fuel cell spaces

101 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.

Guidance note:

Refer to sub-section I for requirements for the ventilation in fuel cell spaces.

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A 200 Tank rooms

201 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 additional insulation to class A-60 standard shall be fitted.

A 300 FC fuel compressor room

301 Compressor rooms, if arranged, shall be located above weather deck level, unless especially approved by the Society.

302 Where compressors are driven by shafting passing through a bulkhead or deck, the bulkhead penetration shall be of gas tight type.

B. Arrangement of Entrances and Other Openings

B 100 General

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

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

103 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

104 Entrances between hazardous and safe spaces in the ship shall be arranged with air locks, see I200.

C. General Pipe Design

C 100 General

101 FC fuel pipes are in general to comply with the applicable parts of rules in Pt.5 Ch.5 Sec.6.

Guidance note:

Applicable parts of Pt.5 Ch.5 Sec.6 are mainly C500 for pipe design. The requirement for electrical bonding in C316 is applicable for gas pipes.

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102 FC fuel pipes in spaces made gas safe as outlined in D101 2) shall not include expansion elements, bellows or other pipe components with poorer strength, fatigue or leakage properties than the fully welded pipe.

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

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

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

106 A system for colour marking of all FC fuel pipes should be used.

107 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.

D. System Configuration

D 100 General

101 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:

1) All FC fuel pipes are enclosed in a gas tight double enclosure (duct or pipe) fulfilling the requirements in E200, except for hydrogen, see E100.
2) 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, see Sec.7.

Guidance note 1:

If hydrogen valves are located in a space kept non hazardous in the above manner (2), 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.

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Guidance note 2:

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 the above manner (2).

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E. FC fuel Supply System In Fuel Cell Spaces

E 100 General

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

fuel used.

102 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.

E 200 FC fuel supply systems for gas safe FC spaces with double FC fuel piping

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

- The space between the FC fuel piping and the wall of the outer pipe or duct shall be pressurised 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
- The air space between the FC fuel piping and the wall of the outer pipe or duct shall be equipped with mechanical underpressure 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.

202 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.

203 For high pressure piping the design pressure of the ducting shall be taken as the higher of the following:

- the maximum built up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space, or
- 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:

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

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 ($R_m/1.5$) 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.

204 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.

F. FC Fuel Storage

F 100 Location of gas tanks

101 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.

102 Hydrogen is not to be stored in enclosed spaces, unless the tank room is arranged with ventilation as given in I500, electrical equipment certified safe for hydrogen atmosphere, and arrangement of the space and ventilation outlets as given in A101.

103 The storage tanks/ tank batteries for gas shall be located at:

- minimum, the lesser of B/5 and 11.5 m from the ship side
- minimum, the lesser of B/15 and 2 m from the bottom plating
- and not less than 760 mm from the shell plating.

104 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.

105 Tanks for liquid gas on open deck with a connection below the highest liquid level, see G102, 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.

106 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. This implies that the material shall be in accordance with Pt.5 Ch.5 Sec.2 D, for secondary barriers, and that the space 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 the Rules called "tank room".

F 200 Low flashpoint fuel storage

201 The storage tank for low flashpoint liquids shall be arranged as outlined in Pt.5 Ch.7 Sec.10 “Offshore Service Vessels for Transportation of Low Flashpoint Liquids”.

G. FC Fuel Tank Design

G 100 Liquefied gas storage tanks

101 The storage tank used for liquefied gas shall be an independent tank type C designed in accordance with Pt.5 Ch.5 Sec.5 and in particular Sec.5 I.

102 Pipe connections to the tank shall be in accordance with Pt.5 Ch.5 Sec.6 C303 to C307. However connections below the lowest liquid level may be accepted after special consideration by the Society, but will not accepted for liquid hydrogen tanks located in enclosed spaces.

103 Pressure relief valves as required in Pt.5 Ch.5 Sec.9 B200 shall be fitted.

104 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 metres. The outlets shall 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.

105 Storage tanks for liquid gas with vapour pressure above the design pressure at 45ºC shall be fitted with efficient insulation.

106 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 Pt.5 Ch.5 Sec.17 A105. A filling limit curve for actual filling temperatures shall be prepared from the formula given in Pt.5 Ch.5 Sec.17 A102. 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%.

G 200 Compressed gas storage tanks

201 The storage tanks to be used for compressed gas shall be in accordance with Pt.4 Ch.3 and shall be certified by DNV.

202 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 C104.

H. Fuel Bunkering System and Distribution System outside Machinery Spaces

H 100 Distribution outside of machinery spaces

101 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.

Guidance note:

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.

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102 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 underpressure ventilated with 30 air changes per hour, and gas detection as required in Sec.7 shall be provided.

103 The duct shall be dimensioned according to E203-204.

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

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

H 200 Fuel bunkering station

201 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.

202 For 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 drained 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.

203 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.

H 300 Bunkering system

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

302 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.

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

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

305 Means shall be provided for draining the liquid from the bunkering pipes at bunkering completion.

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

I. Ventilation System

I 100 General

101 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.

102 For design of ventilation fans serving spaces containing sources of hydrocarbon release see requirements in Pt.5 Ch.5 Sec.10 A200. Fans serving spaces containing sources of hydrogen release will have to be certified as spark proof for hydrocarbon atmosphere.

103 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 503 and A201 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.

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

105 Air inlets for hazardous enclosed spaces shall be taken from areas which, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces shall 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 shall 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.

106 Air outlets from non-hazardous spaces shall be located outside hazardous areas.

107 Air outlets from hazardous enclosed spaces shall 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.

108 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.

I 200 Non-hazardous spaces

201 Spaces with opening to a hazardous area, shall be arranged with an air-lock, and be maintained at overpressure, relative to the external hazardous area.

The overpressure ventilation shall be arranged according to the following requirements:

1) During initial start-up or after loss of overpressure ventilation, it is required before energising any electrical installations not certified safe for the space in the absence of pressurisation, to:
   - proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and
   - pressurise the space.
2) Operation of the overpressure ventilation shall be monitored.
3) In the event of failure of the overpressure ventilation:
   - an audible and visual alarm shall be given at a manned location.
   - if overpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations is required according to IEC 60092-502,Table 5.

I 300 Gas tank room

301 The tank room for gas storage tank located below deck shall be provided with an effective mechanical ventilation system of the underpressure 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 I500.

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

303 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 I500.

I 400 Pump and compressor rooms for hydrocarbon gas

401 Pump and compressor rooms shall be fitted with effective mechanical ventilation system of the underpressure type, providing a ventilation capacity of at least 30 air changes per hour.

402 Ventilation systems for pump and compressor rooms shall 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.

403 When the space is dependent on ventilation for its area classification, the following requirements apply:

1) During initial start-up, and after loss of ventilation, the space shall be purged (at least 5air changes), before connecting electrical installations which are not certified for the area classification in absence of ventilation.
2) Operation of the ventilation shall be monitored.
3) In the event of failure of ventilation, the following requirements apply:
   - an audible and visual alarm shall be given at a manned location
   - immediate action shall be taken to restore ventilation
   - 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 unauthorised reconnection, e.g. by lockable switches.

Guidance note:

Intrinsically safe equipment suitable for Zone 0, is not required to be switched off. Certified flameproof lighting, may have a separate switch-off circuit.

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I 500 Spaces containing hydrogen piping

501 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.

502 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.

Guidance note:

The ventilation fans should be operated in an alternating cycle to test that all fans are operable at all times.

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503 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.

SECTION 5
FIRE SAFETY

A. General

A 100 General

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

102 For the purpose of fire protection gas compressor rooms shall be treated as cargo compressor rooms in accordance with Pt.5 Ch.5 Sec.11.

103 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.

B. Fire Protection

B 100 Construction

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

102 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.

103 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.

104 A FC space shall as a minimum have gas tight steel bulkheads. The categorisation of the FC space as a category (6) or (7) space, refer to SOLAS Ch. II-2/ Table 9.5 and 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.

C. Fire Extinction

C 100 Fire main

101 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.

102 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.

C 200 Water spray systems

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

202 The system shall 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.

203 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.

204 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.

205 A connection to the ships fire main through a stop valve shall be provided.

206 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.

207 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.

C 300 Dry chemical powder fire extinguishing system

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

D. Fire Detection and Alarm Systems

D 100 Detection

101 An approved fixed fire detection system shall be provided for the tank room and the ventilation trunk for tank room below deck, and also for the FC spaces.

Guidance note:

The type of fire detection system must be decided on basis of the actual fuels and combustible gases that may be present in the spaces. Hydrogen must be given special attention as a hydrogen fire is difficult to detect. Is creates no smoke, very little heat radiation and burns with a flame that is almost invisible to the eye in daylight.

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102 Smoke detectors only are not considered sufficient for rapid fire detection when gaseous fuel is used.

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

D 200 Alarms and safety actions

201 Required safety actions at fire detection in the FC space and tank room are given in Sec.7 Table D1. In addition the ventilation shall stop automatically and fire dampers shall close.

SECTION 6
ELECTRICAL SYSTEMS

A. General

A 100 General

101 The requirements in this chapter are additional to those given in Pt.4 Ch.8.

102 Electrical equipment and wiring shall in general not to be installed in hazardous areas unless essential for operational purposes. The type of equipment and installation requirements shall comply with Pt.4 Ch.8 Sec.11 according to the area classification as specified in B.

103 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.

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

105 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.

Guidance note:

For definition of "switch disconnector" refer to IEC60947-3.

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B. Area Classification

B 100 General

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

102 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 200.

103 Areas and spaces other than those classified in 200 shall be subject to special consideration. The principles of the IEC standards shall be applied.

104 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 Sec.4 I400.

105 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 pressurisation are given in Sec.4 I200.

106 Ventilation ducts shall have the same area classification as the ventilated space.

B 200 Definition of zones

201 *Hazardous areas zone 0*

The interiors of gas tanks, pipes and equipment containing gas, any pipework of pressure-relief or other venting systems for gas tanks.

Guidance note:

Instrumentation and electrical apparatus in contact with the gas or liquid 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.

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202 *Hazardous areas zone 1*

1) Tank room, as defined in Sec.4 F106.
2) Gas compressor room arranged with ventilation according to Sec.4 I403.
3) Areas on open deck, or semi- enclosed spaces on deck, within 3 m of any gas tank outlet, gas or vapour outlet (see note), 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.

Guidance note 1:

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

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4) 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.
5) Areas on the open deck within spillage coamings surrounding FC fuel bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck.
6) Enclosed or semi-enclosed spaces in which sources of release are located, e.g. ducts around FC fuel pipes, semi-enclosed bunkering stations.

Guidance note 2:

Open ended ventilation pipes from FC fuel piping systems will not create a hazardous zone in a surrounding well ventilated space.

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203 *Hazardous areas zone 2*

Areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1 as specified in 202, if not otherwise specified in this standard.

Guidance note:

A space containing FC fuel pipes can be regarded as non hazardous if the pipes are fully welded and the ventilation rate is sufficient to avoid gas concentration in the flammable range in all leakage scenarios, including pipe rupture, refer to Sec.4 D.

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C. Inspection and Testing of Electrical Equipment in Hazardous Area

C 100 General

101 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 to Pt.4 Ch.8 Sec.11.

102 For spaces protected by pressurisation 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.

103 For equipment for which safety in hazardous areas depends upon correct operation of protective devices (for example overload protection relays) and / or operation of an alarm (for example loss of pressurisation for an Ex(p) control panel) it shall be verified that the devices have correct settings and/or correct operation of alarms.

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

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

D. Maintenance of Electrical Equipment in Hazardous Area

D 100 General

101 The maintenance manual referred to in Sec.1 C110, shall be in accordance with the recommendations in IEC 60079-17 and 60092-502 and shall contain necessary information on:

— overview of classification of hazardous areas, with information about gas groups and temperature class
— 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.)
— inspection routines with information about level of detail and time intervals between the inspections, acceptance/rejection criteria
— register of inspections, with information about date of inspections and name(s) of person(s) who carried out the inspection and maintenance work.

102 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.

SECTION 7
CONTROL, MONITORING AND SAFETY SYSTEMS

A. General

A 100 General

101 For instrumentation and automation, including computer based control and monitoring, the requirements in this chapter are additional to those given in Pt.4 Ch.9.

The control and monitoring systems shall be certified according to Pt.4 Ch.9 for the following, if installed:

— FC fuel tank level measurement system
— FC fuel tank overflow protection system
— FC fuel supply control and monitoring system
— flammable gas detection system (permanent system only)
— inert gas control and monitoring system
— oxygen indication equipment (permanent system only)
— FC power management systems (for **FC-POWER** notation only)
— FC safety system.

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

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

104 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.

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

— the cargo control room (relevant for cargo ships only)
— navigation bridge
— engine control room
— fire control station.

B. Monitoring

B 100 FC fuel tank monitoring

101 FC fuel tanks shall be monitored and protected against overfilling as required in Pt.5 Ch.5 Sec.13 B100 and B200.

102 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.

B 200 FC fuel compressor monitoring

201 The monitoring system should include items shown in Table B1:

Table B1 - 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:

— control air pressure loss
— high gas concentration in the compressor room (Table D1)
— automatic stop or emergency stop of FC fuel supply to fuel cell.

B 300 Fuel cell monitoring

301 The fuel cell shall be monitored to the extent necessary to avoid that the safety is impaired. For installation with notation **FC-POWER** also monitoring affecting the availability or life time shall be considered. This should be seen in connection with the overall installation redundancy, refer to Sec.2.

302 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:

— cell voltage
— cell voltage deviations
— temperature exhaust gas
— temperature in FC
— current level.

Other typical monitoring that should be considered:

— air flow
— air pressure
— cooling medium flow, pressure, temperature (if used)
— fuel flow
— fuel temperature
— fuel pressure
— gas detection in exhaust gas
— water system level
— water system pressure
— water system purity
— parameters necessary to monitor lifetime/ deterioration.

C. Gas Detection

C 100 Locations

101 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.

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

103 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.

104 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.

Guidance note:

LEL is at 4% in air for hydrogen, at 5.3% in air for methane and at 1.7% in air for propane.

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

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

D. Safety Functions of Gas Supply Systems

D 100 General

101 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 D1.

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.

102 Each FC fuel utilisation 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 D1, 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.

103 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.

104 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 shut off 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.

Guidance note 1:

The shutdown should be time delayed to prevent shutdown due to transient load variations.

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Guidance note 2:

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.

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105 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.

106 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.

107 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 D1 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 20% 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 20% LEL	X	X [1]		
Gas detection in compressor room above 20% LEL	X			
Gas detection on second detector in compressor room above 20% 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 20% 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 some 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
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 separate 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 as outlined in Sec.4 E201, 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.

SECTION 8
COMPRESSORS

A. FC Fuel Compressors

A 100 General

101 The FC fuel compressor shall be fitted with accessories and instrumentation necessary for efficient and reliable function.

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

— the cargo control room (relevant for cargo ships only)
— navigation bridge
— engine control room
— fire control station.

A 200 Vibrations

201 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.

SECTION 9
MANUFACTURE, WORKMANSHIP AND TESTING

A. Liquefied Gas Tank

A 100 Manufacture and testing

101 Tests related to welding and tank testing shall be in accordance with Pt.5 Ch.5 Sec.5 K, L, M, and N.

B. FC Fuel Piping Systems

B 100 FC fuel pipes

101 The FC fuel pipes shall be tested as given in Pt.5 Ch.5 Sec.6 C600 and C700. Butt welded joints of high-pressure gas pipes and hydrogen supply pipes in FC spaces shall be subjected to 100% radiographic testing.

B 200 Ducting

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

B 300 Valves

301 Each type of valve to be used at working temperatures below minus 55ºC shall be prototype tested as given in Pt.5 Ch.5 Sec.6 C801.

302 Valves for use in hydrogen pipes located in non hazardous spaces with fully welded hydrogen pipes, refer to Sec.4 D, shall be tightness tested with hydrogen to show that there is no leakage of hydrogen from the valve.

B 400 Expansion bellows

Expansion bellows intended for use in FC fuel systems shall be prototype tested as given in Pt.5 Ch.5 Sec.6 C802.

C. Onboard Testing of FC Plant

C 100 General

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