2015

# Guidance for Fuel Cell Systems on Board of Ships

KR

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GC-12-E

KR

# APPLICATION OF "GUIDANCE FOR FUEL CELL SYSTEMS ON BOARD OF SHIPS"

1. Unless expressly specified otherwise, the requirements in the Guidance apply to fuel cell systems on board of ships for which contracts for construction are signed on or after 1 July 2015.
2. The amendments to the Guidance for 2014 edition and their effective date are as follows;

**Effective Date 1 July 2015 (base on contract date for construction)**

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**CHAPTER 1 GENERAL**

Section 2 Approval of Plan and Documents
- 202. 4 (8) has been amended.
- 202. 6 (1) has been amended.

**CHAPTER 3 STRUCTURES AND EQUIPMENTS**

Section 1 Arrangements and System Design
- 109. 1. (3) has been amended.

Section 5 Fuel Cells and Associated Components
- 502. 2 has been amended.

Section 6 Manufacture, Workmanship and Testing
- 605. 1 has been amended.
- 606. 1 and 2 has been amended.
- 607. 1, 2 and 3 has been amended.

# CONTENTS

# CHAPTER 1 GENERAL

## Section 1 General

### 101. Application

1. This Guidance is to apply to fuel cell systems on board of ships used as auxiliary or main source of power.
2. In this Guidance, only the gaseous fuels lighter than air in ambient conditions as well as liquid fuels with flash point below 60℃ are regarded as "FC fuel", regardless of **Pt 8 Ch 2 101. 1** (1) of the Rules for the Classification of Steel Ships(hereafter referred to as "the Rules for Steel Ships"). Gas may be stored in gaseous or liquid state. Typical fuels that may be relevant are natural gas, methanol, hydrogen or diesel fuels. Liquid fuels with flash point above 60℃ are to follow the requirements for normal fuel in the Rules for Steel Ships, **Pt 5 Ch 6. Sec.9** and **Pt 8 Ch 2 101.**
3. Items not specified in this Guidance are to be in accordance with each relevant requirement in the Rules for Steel Ships except for the requirements inapplicable to fuel cell systems in ships.
4. Items not included in this Guidance may comply with ISO, IEC, KS or equivalent recognized standards by the appropriate consideration of the Society.
5. Additional requirements to this Guidance may be required.
6. Where installations of fuel cell systems on board of ships are intended, those are to be accepted by the flag state in advance.

### 102. Definitions

The definitions of terms are to follow the Rules for Steel Ships, unless otherwise specified in this Guidance.

1. ″**Accidents**″ means uncontrolled events that may entail the loss of human life, personal injuries, environmental damage or the loss of assets and financial interests.
2. ″**Certified safe type**″ means electrical equipment that is certified safe by the Society based on a recognized standard(refer to IEC 60079 series, explosive atmospheres and IEC 60092-502 Electrical Installations in Ships-Tankers-Special Features). The certification of electrical equipment is to correspond to the category and group for the gas used.
3. ″**Breadth(B)**″ means the breadth defined in **Pt 7 Ch 5. 106. 5** of the Rules for Steel Ships.
4. ″**Control stations**″ means those spaces defined in Part 8 of the Rules for Steel Ships and additionally includes for this Guidance, the engine control room.
5. ″**Double block and bleed valve**″ means a set of three automatic valves located at the FC fuel supply to each of the FC fuel utilization units.
6. ″**Enclosed space**″ means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally(See also definition in IEC 60092-502).
7. ″**ESD**″ means emergency shutdown.
8. ″**Explosion**″ means a deflagration event of uncontrolled combustion.
9. ″**Explosion pressure relief**″ means measures provided to prevent the explosion pressure in a container or an enclosed space exceeding the maximum overpressure the container or space is designed for, by releasing the overpressure through designated openings.
10. ″**Fuel cell(FC)**″ means a source of electrical power in which the chemical energy of a fuel is converted directly into electrical energy by electrochemical oxidation.
11. ″**Fuel cell stack(FC stack)**″ means a assembly consisting of several fuel cells that are electrically connected in series, with internal interconnections for electricity and gas/liquid. An FC stack

in the terms of these Guidance also includes the pipe connection fittings as well as the connections required to supply the electrical energy.

12. "**Fuel cell system (FC system)**" means a complete installation, in general, comprising the fol lowing components:
   (1) fuel cell stacks
   (2) storage, transfer and processing system of fuel
   (3) storage and processing system of the oxidants (air or oxygen)
   (4) processing system of residual gas and exhaust gas
   (5) thermal management system
   (6) water treatment system
   (7) power interconnections between the systems
   (8) control, monitoring and safety system
13. "**Fuel cell installation**" means all the components required for the production of energy by the fuel cell.
14. "**Fuel cell space**" means a space used for machinery spaces containing fuel cell installations.
15. "**FC fuel**" means the fuels which are gases lighter than air in ambient conditions or liquids with low flash point(below 60 °C) and used at fuel cell. The special requirements specified in this Guidance for FC fuel are to be applied to only the FC fuels. FC fuels are, for example, natural gas, methanol, hydrogen or diesel fuels. Liquid fuels with flash point above 60℃ are to follow the requirements for normal fuel in the Rules for Steel Ships, **Pt 5 Ch 6. Sec.9** and **Pt 8 Ch 2 101.**
16. "**Fuel processing system**" means the system that converts, if necessary, or conditions the fuel as stored in the onboard fuel storage into fuel suitable for operation in the fuel cell stack.
17. "**Fuel reformer system**" means a chemical process system necessary for changing supply fuel to suitable composition for fuel cell stack, including relevant heat exchangers and controls.
18. "**Gas**" means a fluid having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8 °C.
19. "**Hazardous area**" means an area in which an explosive gas atmosphere or a flammable gas (flash point below 60 °C) is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus. Hazardous areas are divided into zones 0, 1 and 2 as defined below(refer also to the area classification specified in Sec. 2.5 of IEC 60079-10-1, Part 10-1) :
   (1) Zone 0 is an 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.
   (2) Zone 1 is an 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.
   (3) 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.
20. "**Non-hazardous area**" means an area which is not considered to be hazardous, i.e. gas safe, provided certain conditions are being met.
21. "**High-pressure piping**" means FC fuel piping with maximum working pressure greater than 1.0 MPa.
22. "**IEC**" means the International Electro-technical Commission.
23. "**LEL**" means the lower explosive limit.
24. "**Low flash point liquids**" means liquids with a flash point below 60°C.
25. "**Main tank valve**" means 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.
26. "**MARVS**" means the maximum allowable relief valve setting.
27. "**Master fuel valve**" means an automatic valve in the FC fuel supply line to each fuel cell located outside the FC space and as close to the FC fuel heater (if fitted) as possible.

28. "**Open deck**" means a deck that is open on both ends, or is open on one end and equipped with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side panels or in the deck above.

29. "**Oxidant processing system**" means a system that meters, conditions, processes and pressurizes the incoming oxidant (generally air) supply for use within the fuel cell system, with pressure, temperature, hygrometry, purity and flow rate within the ranges accepted by the fuel cell system.

30. "**Risk**" means the expression of the danger that an undesired event represents to persons, to the environment or to material property. The risk is expressed by the probability and consequences of an accident.

31. "**Recognized standards**" means applicable international or national standards acceptable to the Society or standards laid down and maintained by an organization which complies with the standards adopted by the Organization and which is recognized by the Society.

32. "**Safety management system**" means the international safety management system as described in the ISM Code.

33. "**Second barrier**" means a technical measure which prevents the occurrence of a hazard if the first barrier fails, e.g., second housing of a tank protecting the surroundings from the effect of tank leaks.

34. "**Semi-enclosed space**" means a space limited by decks and/or bulkheads in such manner that the natural conditions of ventilation are notably different from those obtained on open deck (refer also to IEC 60092-502 Electrical Installations in Ships-Tankers-Special Features).

35. "**Source of release**" means any valve, detachable pipe joint, pipe packing, compressor or pump seal in the FC fuel system.

36. "**Tank room**" means the gastight space surrounding the FC fuel tank, containing all tank connections and all tank valves.

37. "**Thermal management system**" means a system that provides cooling and heat rejection to maintain thermal equilibrium within the fuel cell system, and may provide for the recovery of excess heat and assist in heating the power train during start-up.

38. "**Water management system**" means a system that provides the treatment and purification of recovered or added water for use within the fuel cell systems.

## 103. Class notations

1. Ships satisfying the requirements of this Guidance may be given a notation as additional special feature notations as follows:
   (1) Where the fuel cell power is used for propulsion, essential or emergency services, a notation "FC-PWR" may be assigned.
   (2) Where the fuel cell power is not used for propulsion, essential or emergency services, a notation "FC" may be assigned.

## 104. Equivalence

Special equipment, which is not appropriate to apply the requirements of this Guidance or not specified in this Guidance, may be accepted by the Society provided that the Society is satisfied that such equipment is equivalent to or above those complying with the requirements of this Guidance.

## 105. Exclusion from the Guidance

The Society cannot assume responsibility for other technical characteristics for fuel cell systems not covered by this Guidance. However, the Society may advise on such matters upon application.

# Section 2 Approval of Plans and Documents

## 201. Plan and Documents

For a ship in which fuel cell systems are installed, plans and documents(triplicate for approval and 1 copy for reference), specified below para. **202** and **203**, are to be submitted and approved before the work is commenced. And, the Society, where considered necessary, may require further plans and documents other than those specified below.

## 202. Plan and data for approval

1. **Arrangement plans showing location of:**

(1) Machinery spaces, accommodation, service and control station spaces
(2) FC fuel tanks and FC fuel containment systems
(3) FC fuel pump and compressor rooms
(4) FC fuel piping with shore connections
(5) Tank hatches, ventilation pipes and any other openings to the FC fuel tanks
(6) Ventilating pipes, doors and openings to FC fuel pump rooms, compressor rooms and other hazardous areas
(7) Entrances, air inlets and openings to accommodation, service and control station spaces
(8) Hazardous areas of zone 0, 1 and 2

2. **Plans and particulars for fuel cell including :**

(1) Fuel cell principles
(2) Description of the process and function of the FC system
(3) Arrangement drawings of the fuel cell including dimensions, materials, operating temperatures, pressures, weights
(4) Technical documents of the components, including the fuel cell stacks (descriptions, specifications, verification of suitability according to existing standards and rules, approvals and inspection certificates)
(5) Strength calculations of pressure containing components, or test reports
(6) Documentation of compliance with environmental conditions, including calculations or test reports
(7) Voltage and current levels in different parts of the cell
(8) Specification of fuel cell system surface temperature
(9) Type and characteristics of fuels
(10) Maintenance plan (replacement of stack etc.)
(11) Earthing principles
(12) Safety devices with set points
(13) Documentation of life time and availability
(14) A failure mode and effect analysis (FMEA) examining all possible faults affecting the operation of fuel cells, together with a test program for verification of the main conclusions from the FMEA (The power deterioration rate for the fuel cell is to be documented through analysis or test results, and is to consider different power levels and different modes of operation. The test program 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.)

3. **Following plans and data of the gas fuel containment system:**

(1) Drawing of gas tanks including information on non-destructive testing of welds and strength and tightness testing of tanks
(2) Drawings of support and staying of gas tanks
(3) Specification of materials in gas tanks and gas piping systems
(4) Specifications of welding procedures for gas tanks
(5) Specification of stress relieving procedures for independent tanks type C (thermal or mechanical)
(6) Specification of design loads and structural analysis of gas tanks
(7) A complete stress analysis for gas tanks
(8) Specification of cooling-down procedure for gas tanks
(9) Arrangement and specifications of second barriers
(10) Drawings and specifications of gas tank insulation
(11) Drawing of marking plate for gas tanks

**4. Following plans and data of piping systems:**

(1) Drawings and specifications of FC fuel piping including ventilation lines of safety relief valves or similar piping
(2) Drawings and specifications of offsets, loops, bends and mechanical expansion joints, such as bellows, slip joints(only inside tank) or similar means in the FC fuel piping
(3) Drawings and specifications of flanges, valves and other fittings in the FC fuel piping system. For valves intended for piping systems with a design temperature below - 55 °C, documentation for leak test and functional test at design temperature (type test) is required
(4) Complete stress analysis of piping system when design temperature is below - 110 °C
(5) Documentation of type tests for expansion components in FC fuel piping system.
(6) Specification of materials, welding, post-weld heat treatment and non-destructive testing of FC fuel piping
(7) Specification of pressure tests (structural and tightness tests) of FC fuel piping
(8) Test plan and procedures for functional tests of all piping systems including valves, fittings and associated equipment for handling FC fuel(liquid or vapour)
(9) Drawings and specifications of insulation where such insulation is installed
(10) Specification of electrical bonding of piping
(11) Specification of means for removal of liquid contents from bunkering pipes prior to disconnecting the shore connection
(12) Cooling or heating water system in connection with FC fuel system, if fitted.

**5. Following plans and particulars for the safety relief valves**

(1) Drawings and specifications for safety relief valves and pressure/vacuum relief valves and associated ventilation piping
(2) Calculation of required gas tank relief valve capacity, including back pressure
(3) Specification of procedures for changing of set pressures of gas tank safety relief valves if such arrangements are contemplated
(4) Calculations for safety valves ventilation mast : location, height, details

**6. Following plans and data for equipment and systems regarding fire protection and extinction :**

(1) Arrangement and specification of fire extinguishing systems(water spray system, dry chemical powder installation, etc.)
(2) Arrangement of fire detection systems related to FC system
(3) Arrangement of fire insulations related to FC system
(4) Arrangement of ventilation duct required for FC fuel pipes lead through enclosed spaces
(5) Arrangement of ventilation duct for FC fuel storage tank fitted below deck, if applicable

**7. Following plans and data for electrical installations :**

(1) Drawing(s) showing location of all electrical equipment in hazardous areas.
(2) Single line diagram for intrinsically safe circuits
(3) Data for verification of the compatibility between the barrier and the field component for in trinsically safe circuits.
(4) List of explosion protected equipment with reference to drawings together with certificates
(5) Single line diagram for main power, auxiliary power and control power distribution
(6) Short circuit contribution capability
(7) Voltage and frequency variations during steady state and transient modes
(8) Description of current DC components generated by the FC
(9) Description of methods for black out and dead ship recovery (propulsion, essential and emergency services)
(10) Active and reactive load capacities
(11) Configuration of the system in all operating modes and subsequent power distribution concept for different vessel systems or services (propulsion, essential and emergency services)
(12) System behaviour in relevant failure modes (propulsion, essential and emergency services)

**8. Following plans and data for control, monitoring and safety systems :**

(1) Gas detection system
(2) FC fuel tank monitoring system
(3) FC fuel compressors control and monitoring system
(4) FC system control and monitoring system.

(5) FC fuel supply control system
(6) Safety systems including ESD
(7) In case where the power supply to propulsion or essential service is delivered by the fuel cell system, a failure mode and effect analysis for the control, monitoring and safety systems for the whole installation including the support and supply systems, together with a test program for verification of the main conclusions from the FMEA. However, where the requirements of continuity specified in **Pt 6 Ch 1, 201** of the Rules for Steel Ships are satisfied by other means in ships and the fuel cell systems are installed additionally, this FMEA may be waved.
(8) A failure mode and effect analysis according to **Ch.3 403. 3.** (2).

**9. A test program (may be included in programme for sea trials or on-board test)**

**10. Data for a risk analysis according to Ch.3 101.**

### 203. Plans and documents for reference

**1. Plans and data of the following equipment and systems**

(1) Drawings showing location and construction of air locks with alarm equipment, if fitted
(2) Drawings of gastight bulkhead penetrations, if fitted
(3) Arrangements and specifications of mechanical ventilation systems in spaces covering FC fuel system, giving capacity and location of fans and their motors. Drawings and material specifications of rotating parts and casings for fans and portable ventilators
(4) Drawings and specifications of protection of hull steel beneath liquid piping where liquid leakage may be anticipated, such as at shore connections and at pump seals
(5) Arrangement and specifications of piping systems for gas freeing and purging of FC, FC fuel tanks and related piping.
(6) For fixed gas detection and alarm systems: specification and location of detectors, alarm devices and call points, and cable routing layout drawing
(7) Bilge and drainage arrangements in gas pump rooms, compressor rooms, tank rooms
(8) Air inlet arrangement including filters for FC
(9) Arrangements of exhaust system for FC

**2. Calculation sheets of filling limits for FC fuel gas tanks.**

**3. Operation manual for all relevant operating modes (including bunkering, gas freeing, normal operation, emergency operation).** ⚓

# CHAPTER 2 CLASSIFICATION SURVEYS

## Section 1 General

### 101. General

The classification surveys of fuel cell systems on board of ships, except where specially required in this Guidance, are to comply with the requirements specified in **Pt 1** of the Rules for Steel Ships.

## Section 2 Periodical Surveys

### 201. Annal Survey

**1.** For ships with fuel cell systems on board of ships, the survey is to include:

(1) External examination and function testing of remote operated valves in the FC fuel piping system.
(2) External examination of FC fuel pipe ducts
(3) Testing of instrumentation
(4) Testing of safety system, as a minimum by:
(A) Releasing gas detectors and fire detectors
(B) Checking safety functions in connection with the ventilation systems in FC fuel spaces
(5) Verification of the functioning of ventilation systems
(6) Examination of drip trays in bunker station.
(7) Confirming of availability of manual for operation and/or maintenance of fuel cell installations.
(8) List of required signboards or notice plates of fuel cell installations is to be verified.

### 202. Intermediate Survey

**1.** For ships with fuel cell systems onboard of ships, in addition to the requirement of annual survey, the survey is to include testing of all alarm and shutdown functions for:

(1) FC fuel gas compressor
(2) Fuel cell installation.

### 203. Special Survey

**1.** For ships with fuel cell systems on board of ships, in addition to the requirement of intermediate survey, the survey is to include as relevant:

(1) Examination of gastight bulkheads with cable and shaft sealing etc. Shaft sealing is to be checked for lubrication and possible overheating.
(2) Testing of FC fuel tanks high level alarm
(3) Examination and testing of:
(A) FC fuel tanks safety relief valves
(B) Tank room or second barrier space P/V valves and relief hatches, as relevant
(C) FC fuel handling machinery and equipment
(D) Auxiliary systems and equipment for fuel cell installations
(E) Portable gas detectors and oxygen analyser. ⚓

# CHAPTER 3 STRUCTURES AND EQUIPMENTS

## Section 1 Arrangements And System Design

### 101. General

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

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

**3.** An explosion in any space containing open gas sources is not to:

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

**4.** In case where the power supply to propulsion or essential service is delivered by the fuel cell system, this power supply to propulsion or essential service is to be maintained even if one component of the fuel cell installation becomes inoperative.

**5.** 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.

### 102. Materials and welding

#### 1. General

(1) Materials and welding are in general to be in accordance with the requirements in **Pt. 2** of the Rules for Steel Ships and are to be satisfactory without defect. However, in case where the materials or welding not stipulated in this Guidance are intended to be used, documents for them are to be submitted to the Society and to be approved.
(2) The flammable materials is not to be used outside the FC stack.
(3) The flammable materials may be used inside the FC stack by approval of the Society.

#### 2. Material requirements for hydrocarbon gas

(1) Materials and welding used in gas tanks, gas piping, process pressure vessels and other compo nents in contact with gas are to be in accordance with the requirements in **Pt. 7 Ch. 5 Sec. 6** of the Rules for Steel Ships.
(2) Materials for compressed gas tanks, not covered by **Pt. 7 Ch. 5** of the Rules for Steel Ships, may be used by specially consideration of the Society.

#### 3. Material requirements for hydrogen gas

(1) The materials for hydrogen gas are to comply with following.
(A) Austenitic stainless steel (e.g. 304, 316, 304L and 316L) is to be used for materials in contact with hydrogen. In case where other materials than austenitic stainless steel are intended

to be used for storage and transport of hydrogen, documents for them are to be submitted to the Society and to be approved.

(B) For testing of tank materials, relevant parts of **Pt. 7 Ch 5 Sec. 6** of the Rules for Steel Ships are to be applied, and where this is not sufficient, special considerations will have to be done.

## 103. Location and separation of spaces

### 1. The arrangement and location of spaces

(1) All parts of fuel cells and the directly associated components containing fuel during normal operation(evaporator or pre-heaters, compressors, filters, reformers, etc.) are to be arranged in an enclosed space or suitable enclosure.

(2) Fuel cell stacks, fuel cell conditioning system (such as pre-heater, compressor, filter, reformer, etc.) and gas storage system are to be located in spaces separated from each other and from other spaces. For fuel cell systems with aggregate power lower than 375 kW, the installation of the whole fuel cell system in the same compartment may be accepted by the Society provided that suitable arrangements are made in order to prevent gas from reaching the fuel cell stacks in case of a leakage from the storage or conditioning system (e.g. screen or suitable enclosure with exhaust arrangement).

(3) The installation spaces of FC stacks and directly associated components are to be arranged outside of accommodation, service and machinery spaces and control rooms, and are to be separated from such spaces by means of a cofferdam or an A-60 bulkhead. Installation in conventional machinery spaces is not permitted. However, in case where the requirement for a separate space is met by a suitable form of enclosure for the components containing the fuel, the installation in conventional machinery spaces is admissible.

(4) Spaces in which fuel storage tanks are located are to be separated from conventional machinery spaces and the other parts of the FC system.

(5) The arrangement and location of spaces for FC fuel storage, distribution and use are to be such that the number and extent of hazardous areas is kept to a minimum. These spaces are to have as simple geometrical and internal arrangement as possible in order to minimize the possibility of entrapping explosive mixtures.

### 2. Gas compressor room

(1) Compressor rooms, if arranged, are to be located above freeboard deck, unless those rooms are arranged and fitted in accordance with the requirements of these Guidance for tank rooms.

(2) If compressors are driven by shafting passing through a bulkhead or deck, the penetration is to be of gastight type.

### 3. Fuel cell spaces

(1) The arrangement and number of FC spaces, the distribution thereof, and the design of the safety systems are to be such that, in case of fuel or oxidant leakage originating anywhere in the spaces, the automatic safety actions will not result in the loss of essential functions of the ship (propulsion, electrical production).

(2) When more than one FC space is required for fuel cell power system and these spaces are separated by a single bulkhead, the arrangements are to be such that the effects of a gas explosion in either space can be contained or vented without affecting the integrity of the adjacent space and equipment within that space.

(3) Fuel cell spaces are to have as simple geometrical shape as possible.

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

(5) Access to all components of the fuel cell installation are to be possible for survey.

### 4. Tank rooms

(1) Tank room boundaries including access doors are to be gastight.

(2) The tank room is not to be located adjacent to machinery spaces of category A. If the separation is by means of a cofferdam, the separation is to be at least 900 mm and insulation to class A-60 is to be fitted on the machinery space side.

## 104. Arrangement of entrances and other openings

**1.** Entrances, openings and ventilation openings to accommodation, service and machinery spaces and to control stations are to be arranged at a distance of at least 3m from the openings of the installation space of the fuel cells. If it is necessary to deviate from this provision on small craft, etc. the approval of the Society is required.

**2.** Openings for exhaust air and residual gases of the FC stack are to be located on the open deck with a horizontal distance of at least 3m to any sources of ignition and to the openings of accommodation, service and machinery spaces, control station and other spaces containing sources of ignition. If it is necessary to deviate from this provision on small craft, etc. the approval of the Society is required.

**3.** Direct access through doors, gastight or otherwise, is generally not to be permitted from a gas-safe space to a gas-dangerous space. Where such openings are necessary for operational reasons, an air lock which complies with the requirements of the Rules for Steel Ships **Pt. 7 Ch. 5, 306 (para 2 to 7)** is to be provided.

**4.** If the compressor room is approved located below deck, the room is, as far as practicable, to have an independent access direct from the open deck. Where a separate access from deck is not practicable, an air lock which complies with the requirements of the Rules for Steel Ships **Pt. 7 Ch. 5, 306 (para 2 to 7)** is to be provided.

**5.** The tank room entrance is to be arranged with a sill height of at least 300 mm.

**6.** Access to the tank room is as far as practicable to be independent and direct from open deck. If the tank room is only partially covering the tank, this requirement is also to apply to the room surrounding the tank and where the opening to the tank room is located. Where a separate access from the deck is not practicable, an air lock which complies with the requirements of the Rules for Steel Ships **Pt. 7 Ch. 5, 306 (para 2 to 7)** is to be provided. The access trunk is to be fitted with separate ventilation. It is not to be possible to have unauthorized access to the tank room during normal operation of the FC fuel system.

**7.** If the access to an ESD-protected FC space is from another enclosed space in the ship, the entrances is to be arranged with self-closing doors. An audible and visual alarm is to be provided at a permanent manned location. Alarm is to be given if the door is open continuously for more than 1 min. As an alternative, an arrangement with two self-closing doors in series may be acceptable.

## 105. Design for FC fuel piping system

**1.** This requirements apply to FC fuel piping. The Society may accept relaxation from these requirements for the piping inside FC fuel tanks and open-ended piping after special consideration, such as risk assessment.

**2.** FC fuel piping is to be protected against mechanical damage and the piping is to be capable of assimilating thermal expansion without developing substantial tension.

**3.** The piping system is to be joined by welding with a minimum of flange connections. Gaskets are to be protected against blow-out.

**4.** The wall thickness of pipes is not to be less than:

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

where:

$t_0$ = theoretical thickness (mm)

$$t_0 = \frac{PD}{2Ke + P}$$

with:

$P$ = design pressure (MPa) referred to in **Par 5**

$D$ = outside diameter of pipe (mm)

$K$ = allowable stress ($N/mm^2$) referred to in **Par 6**

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

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

$$b = \frac{Dt_0}{2.5r}$$

with :

$r$ = mean radius of the bend (mm)

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

$a$ = negative manufacturing tolerance of thickness (%).

The minimum wall thickness is to be in accordance with recognized standards.

**5.** The greater of the following design conditions is to be used for piping, piping systems and components as appropriate:

(1) for systems or components which may be separated from their relief valves and which contain only vapour at all times: the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Society (See **402. 6** (2) of the Rules for Steel Ships **Pt. 7 Ch. 5**), assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

(2) the MARVS of the FC fuel tanks and FC fuel processing systems; or

(3) the pressure setting of the associated pump or compressor discharge relief valve if of sufficient capacity; or

(4) the maximum total discharge or loading head of the FC fuel piping system; or

(5) the relief valve setting on a pipeline system, if of sufficient capacity; or

(6) The design pressure is not to be less than 1.0 MPa gauge except for open ended lines where it is to be not less than 0.5 MPa gauge.

**6.** For pipes made of steel including stainless steel, the permissible stress to be considered in the formula for $t$ in **Par 4** is the lower of the following values:

$$R_m/A \quad \text{or} \quad R_e/B$$

where:

$R_m$ = specified minimum tensile strength at room temperature ($N/mm^2$)

$R_e$ = specified minimum yield stress or 0.2% proof stress at room temperature ($N/mm^2$)

$A$ = 2.7 and $B$ = 1.8.

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

**7.** Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads from supports, ship deflection or other causes, the wall thickness is to be increased over that required by **Par 4,** or, if this is impracticable or would cause excessive local stresses, these loads are to be reduced, protected against or eliminated by other design methods.

**8.** FC fuel piping systems are to have sufficient constructive strength. For high pressure piping systems, this is to be confirmed by carrying out stress analysis and taking into account:

(1) stresses due to the weight of the piping system;
(2) acceleration loads when significant; and
(3) internal pressure and loads induced by hog and sag of the ship.

**9.** Flanges, valves and other fittings are to comply with recognized standards, taking into account the design pressure defined in **Par 5.**

**10.** All valves and expansion joints used in high pressure gas systems are to be of an approved type.

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

(1) Butt-welded joints with complete penetration at the root may be used in all applications. For design temperatures below -10°C, butt welds are to be either double welded or equivalent to a double welded butt joint. This may be accomplished by use of a backing ring, consumable insert or inert gas back-up on the first pass. For design pressures in excess of 1.0 MPa and design temperatures of -10°C or lower, backing rings are to be removed.
(2) Slip-on welded joints with sleeves and related welding, having dimensions in accordance with recognized standards, are only to be used for open-ended lines with external diameter of 50 mm or less and design temperatures not lower than -55°C.
(3) Screwed couplings are only to be used for accessory lines and instrumentation lines with external diameters of 25 mm or less.

**12.** Flanges in flange connections are to be of the welded neck, slip-on or socket welded type. For all piping except open ended line, the following restrictions apply:

(1) For design temperatures lower than -55°C, only welded neck flanges are to be used.
(2) For design temperatures lower than -10°C, slip-on flanges are not to be used in nominal sizes above 100 mm and socket welded flanges are not to be used in nominal sizes above 50 mm.

**13.** Piping connections, other than those mentioned in **Par 11** and **12,** may be accepted by the Society upon consideration in each case..

**14.** Post-weld heat treatment is to be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels. The Society may waive the requirement for thermal stress relieving of pipes having wall thickness less than 10 mm in relation to the design temperature and pressure of the piping system concerned.

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

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

**17.** FC fuel piping is not to be led through other machinery spaces. Alternatively, double gas piping may be approved, provided the danger of mechanical damage is negligible, the gas piping has no discharge sources and the room is equipped with a gas alarm.

**18.** An arrangement for purging FC fuel bunkering lines and supply lines (only up to the double block and bleed valves if these are located close to the FC fuel utilization unit) with nitrogen is to be provided.

**19.** The FC fuel piping system is to be installed with sufficient flexibility. Bellows will not be accepted in enclosed spaces. Arrangement for provision of the necessary flexibility is to be demonstrated to maintain the integrity of the piping system in all foreseen service situations.

**20.** FC fuel pipes in ESD-protected FC space are not to include expansion elements, bellows or other pipe components with poorer strength, fatigue or leakage properties than the butt-welded pipe with complete penetration.

**21.** FC fuel pipes are to be colour marked based on a recognized standard(Refer to ISO 14726:2008 Ships and marine technology-Identification colours for the content of piping systems).

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

**23.** All pipelines and components which may be isolated containing liquid gas are to be provided with relief valves.

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

## 106. System configuration

**1.** Following two alternative system configurations may be accepted:

(1) Gas safe FC spaces : Arrangements in FC spaces are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

(2) ESD-protected FC spaces : Arrangements in FC 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 is to be automatically executed while equipment or machinery in use or active during these conditions are to be of a certified safe type.

**2.** Gas safe FC spaces are to comply with the following.

(1) All FC fuel supply piping within FC space boundaries are to be enclosed in a gastight enclosure, i.e. double wall piping or ducting(Hydrogen piping is to be arranged in ESD-protected FC spaces, see **107. 1**).

(2) In case of FC spaces for fuel cell power system used to propulsion or essential service, the following are to be complied with.

(A) In case of leakage in a FC fuel supply pipe making shutdown of the FC fuel supply necessary, a secondary independent fuel supply is to be available. Alternatively, in the case of multi fuel cell power systems, independent and separate FC fuel supply systems for each fuel cell power system may be accepted.

(B) The FC fuel storage is to be divided between two or more tanks of approximately equal size. The tanks are to be located in separate compartments.

**3.** ESD-protected FC spaces are to comply with the following.

(1) FC fuel supply piping within ESD-protected FC spaces may be accepted without a gastight external enclosure on the following conditions:

(A) Fuel cell power system used to propulsion or essential service are to be located in two or more FC spaces not having any common boundaries unless it can be documented that the common boundary can withstand an explosion in one of the rooms. Distribution of fuel cell power system between the different FC spaces is to be such that in the case of shutdown of fuel supply to any one FC space, it is possible to maintain at least 40% of the propulsion power plus normal electrical power supply for sea-going services. However, where the requirements of continuity specified in **Pt 6 Ch 1, 201** of the Rules for Steel Ships are satisfied by other means in ships and the fuel cell systems are installed additionally, the fuel cell power system may be located in one FC space.

Incinerators, inert gas generators or other oil fired boilers are not to be located within an ESD-protected FC space.

(B) All FC fuel pipes that are not inside a double wall piping or ducting are to be butt-welded pipe with complete penetration only and the ventilation rate in the space is to be sufficient to avoid gas concentration in the flammable range in all leakage scenarios, including pipe rupture. Pipe components with poorer strength, fatigue or leakage properties than the-butt-welded pipe with complete penetration are not accepted in FC fuel piping. Valves in the FC piping are to be subjected to leakage test for the FC fuel used.

(C) The gas machinery, tank and valve installation spaces are to contain only a minimum of such necessary equipment, components and systems as are required to ensure that any piece of equipment in each individual space maintains its principal function.
(D) Pressure in gas supply lines within FC spaces is to be less than 1.0 MPa, e.g., this concept can only be used for low pressure systems.
(E) A gas detection system arranged to automatically shutdown the FC fuel supply and disconnect all non-explosion protected equipment or installations are to be fitted, as outlined in **404** and **405.**

(2) The FC fuel storage is to be divided between two or more tanks of approximately equal size. The tanks are to be located in separate compartments.

## 107. FC fuel supply system in fuel cell spaces

### 1. General

(1) In general, the temperature of installations in the fuel cell space is never to be above the self ignition temperature for the fuel used.
(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 butt-welded with complete penetration.

**2.** Gas FC fuel supply system for gas safe FC spaces is to comply with the following.

(1) FC fuel supply lines passing through enclosed spaces are to be completely enclosed by a double pipe or duct. This double pipe or duct is to fulfil one of the following:
(A) The FC fuel piping is to be a double wall piping system with the FC fuel contained in the inner pipe. The space between the concentric pipes is to be pressurized with inert gas at a pressure greater than the FC fuel pressure. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure FC fuel, the system is to be so arranged that the pipe between the master gas valve and the the fuel cell power system is automatically purged with inert gas when the master gas valve is closed; or
(B) The FC fuel piping is to be installed within a ventilated pipe or duct. The air space between the FC fuel piping and the wall of the outer pipe or duct is to be equipped with mechanical under pressure ventilation having a capacity of at least 30 air changes per hour. This ventilation capacity may 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 are to be placed outside the ventilated pipe or duct, or are to comply with the required explosion protection in the installation area. The ventilation outlet is to be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited.

(2) The connecting of FC fuel piping and ducting to the fuel cell system fuel inlet is to be so as to provide complete coverage by the ducting. The arrangement is to facilitate replacement and/or overhaul of valves and other components. The double ducting is to be required also for fuel pipes on the fuel cell system itself.
(3) For high-pressure piping, the design pressure of the ducting is to be taken as the higher of the following:
(A) The maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;
(B) Local instantaneous peak pressure ($p$) in way of the rupture: this pressure is to 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

$k$ = Cp/Cv constant pressure specific heat divided by the constant volume specific heat(1.31 for CH4)

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 pressures. The pressure ratings of all other piping components are to 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 are then to be submitted.

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

**3.** Fuel supply system for ESD-protected FC spaces is to comply with the following.

(1) The pressure in the FC fuel supply system is not to exceed 1.0 MPa.

(2) The FC fuel supply lines are to have a design pressure not less than 1.0 MPa.

## 108. FC fuel storage

### 1. Liquefied gas storage tanks

(1) The storage tank used for liquefied gas is to be an independent tank(type C) designed in accordance with the Rules for Steel Ships **Pt. 7 Ch. 5 , Sec. 4**.

(2) Pipe connections to the tank are normally to be mounted above the highest liquid level in the tanks. However, connections below the highest liquid level may be accepted after special consideration by the Society, but will not accepted for liquid hydrogen tanks located in enclosed spaces.

(3) Pressure relief valves as required in the Rules for Steel Ships **Pt. 7 Ch. 5 , Sec. 8.** are to be fitted.

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

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

(B) Exhaust outlet from machinery or from furnace installation.

(5) Storage tanks for liquid gas are not to be filled to more than 98% full at the reference temperature, where the reference temperature is as defined in the Rules for Steel Ships **Pt. 7 Ch. 5**, paragraph **1501. 4.** A filling limit curve for actual filling temperatures is to be prepared from the formula given in the Rules for Steel Ships **Pt. 7 Ch. 5,** paragraph **1501. 2.** However, when the tank insulation and tank location makes the probability very small for the tank contents to be heated up due to external fire, special considerations may be made to allow a higher filling limit than calculated using the reference temperature, but never above 95%.

(6) Means that are not dependent on the FC fuel system are to be provided whereby liquid gas in the storage tanks can be emptied.

(7) It is to be possible to empty, purge gas and vent FC fuel tanks with gas piping systems. Procedures are to be prepared for this. Inerting is to be performed with, for instance, nitrogen, $CO_2$ or argon prior to venting to avoid an explosion hazardous atmosphere in tanks and gas pipes.

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

(9) Storage tanks for liquid gas with vapour pressure above the design pressure at 45ºC are to be fitted with efficient insulation.

### 2. Compressed gas storage tanks

(1) The storage tanks to be used for compressed gas are to be certified and approved by the Society.

(2) Tanks for compressed gas are to be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in **1.(4)**.

### 3. Storage on open deck

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

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

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

(4) Tanks for liquid gas with a connection below the highest liquid level (See **1.**(2) ) are to be fitted with drip trays below the tank which are to be of sufficient capacity to contain the volume which could escape in the event of a pipe connection failure. The material of the drip tray is to be stainless steel, and there are to 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.

### 4. Storage in enclosed space

(1) Gas in a liquid state may be stored in enclosed spaces, with a maximum acceptable working pressure of 1.0 MPa and below. Storage of compressed gas in enclosed spaces and location of gas tanks with a higher pressure than 1.0 MPa in enclosed spaces is normally not acceptable, but may be permitted after special consideration and approval by the Society provided the following is fulfilled in addition to (3).

(A) Adequate means are to be provided to depressurize the tank in case of a fire which can affect the tank; and

(B) All surfaces within the tank room are to be provided with suitable thermal protection against any lost high pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

(C) A fixed fire-extinguishing system is to be installed in the tank room.

(2) Hydrogen is not to be stored in enclosed spaces, unless the tank room is arranged with ventilation as given in **110. 6**, electrical equipment certified safe for hydrogen atmosphere, and arrangement of the space and ventilation outlets as given in **103. 3.** (4).

(3) The gas storage tank(s) are to be placed as close as possible to the center line. But, for ships other than passenger ships and multi-hulls, a tank location closer than B/5 from the ship side may be accepted:

(A) Minimum, the lesser of B/5 and 11.5m from the ship side;

(B) Minimum, the lesser of B/15 and 2m from the bottom plating;

(C) Not less than 760 mm from the shell plating.

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

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

(6) Bilge suctions from the tank room, if provided, are not to be connected to the bilge system for the rest of the ship.

## 109. FC fuel bunkering system and distribution system outside machinery spaces

### 1. FC fuel bunkering station

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

(2) Drip trays are to be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays are to be made of stainless steel, and are to be drained over the ship's side by a pipe that preferably leads down near the sea. This pipe could be temporarily fitted

for bunkering operations. The surrounding hull or deck structures are not to be exposed to unacceptable cooling, in case of leakage of liquid gas. For compressed gas bunkering stations, low temperature steel shielding are to be provided to prevent the possible escape of cold jets impinging on surrounding hull structure.

(3) Control of the bunkering is to be possible from a safe location in regard to bunkering operations. At this location tank pressure and tank level are to be monitored. Over-pressure alarm, overfill alarm and automatic shutdown are also to be indicated at this location.

### 2. FC fuel bunkering system

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

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

(3) If the ventilation in the ducting around the FC fuel bunkering lines stops, an audible and visual alarm is to be provided at bunkering control location.

(4) If gas is detected in the ducting around the bunkering lines, an audible and visual alarm is to be provided at the bunkering control location.

(5) Means are to be provided for draining the liquid from the bunkering pipes at bunkering completion.

(6) Bunkering lines are to be arranged for inerting and gas freeing. During operation of the vessel, the bunkering pipes are to be gas free.

### 3. Distribution outside of machinery spaces

(1) FC fuel piping is not to be led through accommodation spaces, service spaces or control stations.

(2) Hydrogen pipes are not to be led through enclosed spaces other than the FC spaces. However, 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 must have a simple geometrical shape, and are to be arranged with a ventilation system and rate as required for FC fuel spaces with open hydrogen pipes, and the space.

(3) Where gas pipes pass through enclosed spaces in the ship, they are to be enclosed in a duct. This duct is to be mechanically under pressure ventilated with 30 air changes per hour, and gas detection as required in **110. 5.** is to be provided.

(4) The duct is to be dimensioned according to **107. 2.**(3) and (4)**.**

(5) The ventilation inlet for the duct is to always be located in open air, away from ignition sources.

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

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

## 110. Ventilation system

### 1. General

(1) Spaces in which there is a risk that an ignitable gas mixture may be formed by FC fuel are to be equipped with mechanical ventilation systems of the extraction type capable of being controlled from outside such spaces. Provisions are to be made to ventilate such spaces prior to entering the compartment and operating the equipment and a warning notice requiring the use of such ventilation are to be placed outside the compartment.

(2) Any ducting used for the ventilation of hazardous spaces caused by the FC installation is not to serve any other spaces and be separate from that used for the ventilation of non-hazardous spaces.

(3) Electric motors driving fans are to be placed outside ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served. Electric motors driving fans are to be placed outside ventilation ducts for spaces containing hydrogen installations.

(4) Ventilation fans serving spaces containing sources of hydrocarbon release or sources of hydrogen release are not to produce a source of vapour ignition in either the ventilated space or the

ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, for gas-dangerous spaces are to be of non sparking construction defined as:
(A) impellers or housing of nonmetallic construction, due regard being paid to the elimination of static electricity;
(B) impellers and housing of nonferrous materials;
(C) impellers and housing of austenitic stainless steel; and
(D) ferrous impellers and housing with not less than 13 mm design tip clearance.
Any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and is not to be used in these places.
(5) The ventilation system is to 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.
(6) For spaces containing hydrogen release sources, design for arrangements and ventilation is to be in accordance with the requirements in **6.** and **103. 4.**
(7) Means are to be provided to indicate any loss of the required ventilating capacity in the engine control station.
(8) Air inlets for hazardous enclosed spaces are to be taken from areas which, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces are to be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area.
(9) Where the inlet duct passes through a more hazardous space, the duct is to 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.
(10) Air outlets from non-hazardous spaces are to be located outside hazardous areas.
(11) Air outlets from hazardous enclosed spaces are to 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.
(12) The required capacity of the ventilation system is normally based on the total volume of the space. An increase in required ventilation capacity may be necessary for the spaces having a complicated form.
(13) Ventilation systems in spaces with release sources from piping systems with FC fuel that is gases and vapours lighter than air are to be met the following.
(A) The spaces are to be ventilated by means of mechanically driven exhaust air fans.
(B) The supply air inlet is to be connected to the lower part of the spaces.
(C) The spaces are to be designed in such a way that gases collect at the top at central points from which they are extracted.
(D) A suction hood or a suction trunk is to be provided for areas containing flanges, valves etc. The suction hood or suction trunk is to be arranged in such a way that the air flows around the gas-bearing components, and the air/gas mixture can be extracted at the upper part of the suction hood or trunk.

**2. Non-hazardous spaces**

(1) Non-hazardous spaces with opening to a hazardous area are to be arranged with an air-lock and be maintained at overpressure relative to the external hazardous area. The overpressure ventilation is to be arranged according to the following requirements:
(A) During initial start-up or after loss of overpressure ventilation, before energizing any elec trical installations not certified safe for the space in the absence of pressurization, it is to be required to:
(a) proceed with purging (at least 5 air changes) or confirm by measurements that the space is non-hazardous; and
(b) pressurize the space.
(B) Operation of the overpressure ventilation is to be monitored.
(C) In the event of failure of the overpressure ventilation:
(a) an audible and visual alarm is to be given at a manned location; and
(b) if overpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations according to a recognized standard(Refer to IEC 60092-502 Electrical Installations in Ships Tankers-Special Features, table 5.) is to be conducted.

### 3. Gas tank room

(1) The tank room for gas storage is to 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. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations is to be demonstrated by a safety analysis.
(2) In addition to this para., tank rooms for hydrogen tanks are to have a ventilation rate and arrangement as given in **6.**
(3) Approved automatic fail-safe fire dampers are to be fitted in the ventilation trunk for tank room.

### 4. Fuel Cell space

(1) The ventilation system for FC space is to be independent of all other ventilation systems.
(2) ESD-protected FC spaces are to have ventilation with a capacity of at least 30 air changes per hour. The ventilation system is to ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected. As an alternative, arrangements whereby under normal operation the machinery spaces is ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour.
(3) The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50% of the total ventilation capacity, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.
(4) In addition to this para., FC space for hydrogen fuel are to have a ventilation rate and arrangement as given in **6.**

### 5. Gas pump and gas compressor rooms

(1) Pump and compressor rooms are to be fitted with effective mechanical ventilation system of the under pressure type, providing a ventilation capacity of at least 30 air changes per hour.
(2) The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action.
(3) Ventilation systems for pump and compressor rooms are to 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.
(4) When the space is dependent on ventilation for its hazardous area classification, the following is to apply:
  (A) During initial start-up, and after loss of ventilation, the space is to be purged (at least 5 air changes), before connecting electrical installations which are not certified for the hazardous area classification in absence of ventilation. Warning notices to this effect are to be placed in an easily visible position near the control stand.
  (B) Operation of the ventilation is to be monitored.
  (C) In the event of failure of ventilation, the following is to apply:
    (a) an audible and visual alarm is to be given at a manned location;
    (b) immediate action is to be taken to restore ventilation; and
    (c) electrical installations are to be disconnected(Intrinsically safe equipment suitable for zone 0 is not required to be switched off. Certified flameproof lighting may have a separate switch-off circuit.), if ventilation cannot be restored for an extended period. The disconnection is to be made outside the hazardous areas, and be protected against unauthorized re-connection, e.g., by lockable switches.

### 6. Spaces containing hydrogen piping

(1) For spaces containing hydrogen release sources, the ventilation rate is to 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.
(2) The number and power of the ventilation fans are to 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.

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

## Section 2 Fire Protection and Fire Extinction

### 201. General requirements

**1.** The requirements in this Section are to apply in addition to those given in **Pt 8** of the Rules for Steel Ships.
**2.** A gas compressor room is to be regarded as a machinery space of category A for fire protections purposes.
**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 Society for each installation.

### 202. Fire Protection

**1.** Gas tanks or tank batteries located above deck are to be shielded with class A-60 insulation towards accommodation, service stations, cargo spaces and machinery spaces.

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

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

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

**5.** A FC space is to as a minimum have gas tight steel bulkheads.

**6.** The categorization of the FC space as a machinery space of category A or other machinery space 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.

### 203. Fire extinction

**1. Fire main**

(1) The water spray system required below may be part of the fire main system provided that the required fire pump capacity and working pressure is sufficient to operation of both the required numbers of hydrants and hoses and the water spray system simultaneously.
(2) When the storage tank is located on open deck, isolating valves are to be fitted in the fire main in order to isolate damage sections of the main.

**2. Water spray systems**

(1) A water spray system is to be fitted for cooling and fire prevention and to cover exposed parts of gas storage tank located above deck.
(2) The system is to be designed to cover all areas as specified above with an application rate of 10 ℓ/min/m² for horizontal projected surfaces and 4 ℓ/min/m² for vertical surfaces.
(3) For the purpose of isolating damage sections, stop valves are to be fitted at least every 40 m or the system may be divided into two or more sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.
(4) The capacity of the water spray pump is to be sufficient to deliver the required amount of water to the hydraulically most demanding area as specified above in the areas protected.
(5) A connection to the ship's fire main through a stop valve is to be provided.
(6) Remote start of pumps supplying the water spray system and remote operation of any normally

closed valves to the system are to be located in a readily accessible position which is not likely to be cut off in case of fire in the areas protected.

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

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

### 3. Dry chemical powder fire-extinguishing system

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

(2) One portable dry powder extinguisher of at least 5 kg capacity is to be located near the bunkering station.

## 204. Fire detection and alarm system

### 1. Detection

(1) An approved fixed fire detection system is to be provided for the tank room and the ventilation trunk for tank room below deck, and also for the FC spaces.

(2) Smoke detectors alone are not to be considered sufficient for rapid fire detection.

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

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

### 2. Alarms and safety actions

Required safety actions at fire detection in the FC space and tank room are given in **Table 3.1** of **Sec.4.** In addition, the ventilation is to stop automatically and fire dampers are to close.

# Section 3 Electrical Systems

## 301. General requirements

**1.** The requirements in this Section are to apply in addition to those given in **Pt 6 Ch 1** of the Rules for Steel Ships.

**2.** Electrical equipment and wiring is in general not to be installed in hazardous areas specified in **303** unless essential for operational purposes. However, where electrical equipment is installed in such spaces, it is to be of a type approved by the Society for use in the flammable atmosphere concerned in **303.**

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

**4.** The inverter is to be so designed that reverse power, such as breaking power, cannot pass into the fuel cell.

**5.** The outgoing circuits on a fuel cell arrangement is to be provided with a switch disconnector for isolating purposes so that isolating for maintenance is possible. Contactors are not accepted as isolating devices. For definition of “"switch disconnector”" refer to IEC60947-3.

## 302. Hazardous area classification

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

**2.** Hazardous areas for FC system are divided into zones 0, 1 and 2 and the classification is to be in accordance with **303.**

**3.** Areas and spaces other than those classified in **303** are to be subject to special consideration. The principles of the IEC 60079-10 standards are to be applied.

**4.** Area classification of a space may be dependent of ventilation as specified in IEC 60092-502. Requirements for such pressurization are given in **110.**

**5.** 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 **110.**

**6.** Ventilation ducts are to have the same area classification as the ventilated space.

## 303. Hazardous area

### 1. Zone 0

(1) The Zone 0 includes following.
  (A) The interiors of gas tanks
  (B) The interiors of pipes and equipment containing gas
  (C) Any pipe work of pressure-relief or other venting systems for gas tanks
(2) Instrumentation and electrical apparatus in contact with the gas or liquid are to be of a type suitable for zone 0.
(3) Temperature sensors installed in thermo wells, and pressure sensors without additional separating chamber are to be of intrinsically safe type Ex-ia.
(4) Cables are to have armouring or shielding, or to be laid in a metallic tube.

### 2. Zone 1

(1) The Zone 1 includes following.
  (A) Tank room
  (B) Gas compressor room arranged with ventilation in accordance with **110. 5.**
  (C) Areas on open deck, or semi- enclosed spaces on open deck, within 3m of any gas tank outlet, gas or vapour outlet (such areas are, for example, all areas within 3m of gas tank hatches, ullage openings or sounding pipes for gas tanks located on open deck and gas vapour outlets), 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.
  (D) Areas on open deck or semi-enclosed spaces on open 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.
  (E) Areas on the open deck within spillage coamings surrounding FC fuel bunker manifold valves and 3m beyond these, up to a height of 2.4 m above the deck.
  (F) Enclosed or semi-enclosed spaces in which sources of release are located, e.g. ducts around FC fuel pipes, semi-enclosed bunkering stations. However, open ended ventilation pipes from FC fuel piping systems will not create a hazardous zone in a surrounding well ventilated space.
(2) Cables are to have armouring or shielding, or to be laid in a metallic tube.

### 3. Zone 2

(1) The Zone 2 includes following.
  (A) Areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1 as specified in **para 2**, if not otherwise specified in this Guidance.

## Section 4 Controls, Monitoring and Safety Systems

### 401. General requirements

**1.** For instrumentation and automation, including computer based control and monitoring, the requirements in this Section are to apply in addition to those given in **Pt 6 Ch 2** of the Rules for Steel Ships.

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

**3.** Pressure gauges are to be fitted to FC fuel pump discharge lines and to the bunkering lines.

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

**5.** The fuel cell and the FC fuel supply system are to be arranged for manual remote emergency stop from the following locations:

(1) the cargo control room (if any)
(2) navigation bridge
(3) engine control room
(4) fire control station (if any).

### 402. Control systems

**1.** If at least two control devices suited for the operation of FC systems are stipulated by the **Pt 6, Ch 2, 201** of the Rules for Steel Ships, then they are to function independently of each other and are not to affect each other in the event of a failure.

**2.** The effects of the control actions must be indicated at the control panel. If control actions can be taken at several control units (control panels), the following requirements are to be observed:

(1) conflicting operator actions are to be prevented by means of suitable inter-locks
(2) the control panel which is currently active must be indicated appropriately

**3.** Control devices are to be designed in a way that no serious damage or loss of essential functions can occur in the case of faulty operating actions.

**4.** It is to be ensured that the fuel cells can be disconnected from the electrical load at any load condition.

**5. Automatic control devices**

(1) For the FC systems, regulating devices are to be provided to keep the process variables within the specified limits under normal operating conditions.
(2) The regulating behaviour is to cover the entire range of operation. Parameter changes which can be anticipated must be considered during the design phase.
(3) Faults in a regulating circuit are not to affect the proper functioning of other regulating circuits. The power supply to the regulating circuits is to be monitored and an alarm must be generated on failure of the power supply.
(4) Regulating devices containing computers are to be designed in accordance with the require ments in **Pt 6, Ch 2, 201. 7** of the Rules for Steel Ships.
(5) Regulating devices for fuel cell systems are to be subjected to type approval.

### 403. Monitoring Systems

**1. FC fuel tank monitoring**

(1) FC fuel tanks are to be monitored and protected against overfilling as required in **Pt 7 Ch 5 1302** and **1303** of the Rules for Steel Ships.
(2) Each tank is to be monitored with at least one local indicating instrument for pressure and remote pressure indication at the control position. The manometers and indicators are to be clearly marked with the highest and lowest pressure permitted in the tank. In addition to high pressure alarm, and if vacuum protection is required, low pressure alarm is to be provided on the bridge.

The alarms are to be activated before the set pressures of the safety valves are reached.

**2. FC compressor monitoring**

(1) FC fuel compressors are to be fitted with audible and visual alarms both on the bridge and in the engine room. As a minimum, the alarms are to be in relation to low gas input pressure, low gas output pressure, high gas output pressure, outlet temper(2) In addition, high pressure FC fuel compressors are to be stopped automatically in the event of:
(A) control air pressure loss
(B) high gas concentration in the compressor room
(C) automatic stop or emergency stop of FC fuel supply to fuel cell.

**3. Fuel Cell monitoring**

(1) The fuel cell is to be monitored to the extent necessary to avoid that the safety is impaired.
(2) A failure mode and effect analysis examining all possible faults affecting the fuel cell operation and safety is to be submitted. Based on the outcome of the analysis the extent of the monitoring and control is to be decided.
(A) As a minimum, the following items must typically be monitored:
(a) cell voltage
(b) cell voltage deviations
(c) exhaust gas temperature
(d) temperature in FC
(e) current level.
(B) Other typical monitoring that are to be considered:
(a) air flow
(b) air pressure
(c) cooling medium flow, pressure, temperature (if used)
(d) fuel flow
(e) fuel temperature
(f) fuel pressure
(g) gas detection in exhaust gas
(h) water system level
(i) water system pressure
(j) water system purity
(k) parameters necessary to monitor lifetime/deterioration.

## 404. Gas Detection

**1.** Permanently installed gas detectors are to 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 are to be installed for all types of flammable gases that may occur in the space.

**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.

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

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

**5.** Audible and visible alarms from the gas detection equipment are to be located on the bridge and in the engine control room.

**6.** Continuous detection is required for FC fuel pipe ducts and fuel cell spaces kept gas safe by ventilation and fully welded fuel pipes(ESD-protected FC spaces).

## 405. Safety Functions of FC fuel Supply Systems

**1.** Each FC fuel storage tank is to be provided with a tank valve capable of being remote operated and is to be located as close to the tank outlet as possible.

**2. Master fuel valve**

(1) The main supply lines for FC fuel is to 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 are to be situated in the part of the piping that is outside the FC space.

(2) The master fuel valve is automatically to cut off the FC fuel supply as given in **Table 3.1.**

(3) The automatic master fuel valve is to be operable from a reasonable number of places in the FC space, from a suitable location outside the FC space and from the bridge.

**3. Double block and bleed valve**

Each FC fuel utilization unit is to be provided with a set of "double block and bleed" valves. These valves are to be arranged so that when automatic shut down is initiated as given in **Table 3.1**, this will cause the two FC fuel valves which are in series to close automatically and the vent valve to open automatically, and :

(1) Two of these valves are to be in series in the FC fuel pipe to the FC fuel consuming equipment. The third valve is to be in a pipe that vents to a safe location in the open air that portion of the FC fuel piping that is between the two valves in series. The function of one of the valves in series and the ventilation valve can be incorporated into one valve body, so arranged that the flow to the FC fuel utilization unit will be blocked and the ventilation opened. The vent valve is to be connected to the piping to vent a gas to a safe location in the open air.

(2) The two block valves are to be of fail-to-close type, while the vent valve is to be fail-to-open.

(3) The double block and bleed valves are also to be used for normal stop of the fuel cell.

**4.** 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 is to be opened.

**5.** There are to be one manually operated shut down valve in the FC fuel supply line to each FC fuel utilization unit upstream of the double block and bleed valves to assure safe isolation dur ing maintenance on the gas utilization equipment.

**6.** 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 is to be fitted. The valve is to be adjusted to shut off FC fuel supply in the event of rupture of the FC fuel line. The valve is to be located as close as possible to the point of entry of the FC fuel supply line into the FC space. The shutdown is to be time delayed to prevent shutdown due to transient load variations. The requirement of this Para. may be waived if the FC fuel pipes are located in protected locations, for instance very high in the space or mechanically shielded.

**7.** 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 is to be placed at the operating station for the shut-off valves in the FC fuel supply lines.

**8.** 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 are to be placed in a prominent position in the machinery space.

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

### Table 3.1 Monitoring of FC fuel supply system to fuel cells (1/2)

| Parameter | Alarm | Automatic shut-down of main tank valve | Automatic shutdown of FC fuel supply to FC space | Remarks |
|---|---|---|---|---|
| Gas detection in tank room above 20% LEL | X | | | |
| Gas detection on two detectors [1] 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 two detectors [1] in duct between tank and FC space above 40% LEL | X | X[2] | | |
| Gas detection in compressor room above 20% LEL | X | | | |
| Gas detection on two detectors [1] in compressor room above 40% LEL | X | X[2] | | |
| Gas detection in duct inside FC space above 30% LEL | X | | | If double pipe fitted in FC space |
| Gas detection on two detectors [1] in duct inside FC space above 40% LEL | X | | X[3] | 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 two detectors [1] 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 [6] | X | | X[2] | |
| Loss of ventilation in duct inside FC space [6] | X | | X[3] | If double pipe fitted in FC space. |
| Loss of 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. |
| Abnormal gas pressure in gas supply pipe | X | | X | |
| Failure of valve control actuating medium | X | | X[5] | Time delayed as found necessary |
| Automatic shut down of fuel cell (fuel cell failure) | X | | X[5] | |
| Emergency shut-down of fuel cell manually released | X | | X | |

Note :
[1] Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self monitoring type, the installation of a single gas detector can be permitted.
[2] 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 each duct, only the master valve on the supply pipe leading into to the duct where gas or loss of ventilation is detected is to be closed.
[3] If the FC fuel is supplied 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 each duct and outside of the FC space, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to be closed.
[4] Only double block and bleed valves to close.
[5] If the duct is protected by inert gas (See **107. 2**) then loss of inert gas overpressure is to lead to the same ac tions as given in this table.

## Section 5 Fuel Cells and Associated Components

### 501. General

**1.** The For the fuel cell module, the requirements in KS C IEC 62282-2 "Fuel cell technology-Sec.2:fuel cell module" or equivalent standards may be complied with, but will also have to take the environmental and operating conditions in a ship into account.

### 502. Fuel Cell Stacks

**1.** For FC stacks which have a total electrical output greater than 1 MW and which contain flammable materials, additional fire protection measures may be required by the Society.

**2.** If fuel cells are used for supplying essential consumers, then every fuel cell stack is to be subjected to a performance test at the manufacturer''s works. The electrical output, airtightness and the thermal output of the fuel cells are to be verified by means of a suitable performance test.

**3.** If fuel cell stacks are used for supplying essential consumers, then redundancy is to be ensured.

### 503. FC Fuel Compressors

**1.** The FC fuel compressor is to be fitted with accessories and instrumentation necessary for efficient and reliable function.

**2.** The FC fuel compressor and FC fuel supply are to be arranged for manual remote emergency stop from the following locations:

(1) The cargo control room (if any);
(2) Navigation bridge;
(3) Engine control room; and
(4) Fire control station.

**3.** 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.

### 504. Evaporators

**1.** Heating media for liquefied-gas evaporators or gas preheaters that are routed back into spaces located outside the area of the gas treatment plant is to be passed through degassing containers which are located within the hazardous area.

**2.** A gas detection and alarm system is to be provided within the degassing container.

**3.** The outlet opening of the vent pipe of the degassing container is to be located in a safe area and provided with an approved flame arrester.

## 505. Fuel Reformer Systems

### 1. General

(1) Fuel reformer systems are to be designed for automatic operation and equipped with all the in dicating and control facilities required for assessment and control of the process.
(2) The chemical processes taking place within the unit are to be monitored.
(3) If limit values determined for the control process are exceeded, the unit must be switched off and inter-locked by an independent protective device.
(4) It is to be possible to switch off the reformer unit from a permanently accessible point outside the installation space.
(5) If high surface temperatures may occur, the corresponding insulation or contact protection is to be provided.

### 2. Firing equipment

Firing equipment in fuel reformer systems is to be designed for automatic operation. Manual oper ation (even for emergencies) is not permissible.

### 3. Gas purification

The gas purity required for the operation of the fuel cell is to be monitored by suitable methods. If the determined limit values are exceeded, an alarm is to be generated or the system is to be switched off. If this requirement is not met for installations, verification shall be provided that no additional hazard can occur through inadmissible impurities.

### 4. Exhaust gases

The exhaust gases arising during the reforming process is to be discharged safely to the open air at an adequate distance from openings to accommodation, machinery and service spaces.

### 5. Residual gases

The recirculation of fuel (residual gas) from the FC to the reformer is permissible. The recirculation is to be protected by an automatic shut-off valve.

# Section 6 Manufacture, Workmanship and Testing

## 601. General

**1**. The manufacture, testing, inspection and documentation are to be in accordance with the specific requirements and recognized standards given in the Guidance.

**2.** For FC fuel related equipment, the manufacture, testing and inspection not specified in this section are to be in accordance with relevant requirements in **Pt.7, Ch.5** of the Rules for Steel Ships.

**3.** The fuel cell systems are to be subjected to type approval, and the type tests are to be in accordance with 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.

**4.** Each fuel cell system subjected to the type approval is to be performed following tests before installation onboard. (Refer to IEC 62282-3-1, para.6)

(1) Gas leakage tests
(2) Coolant (liquid) leakage tests
(3) Normal operation test
(4) Dielectric tests simulating abnormal conditions
(5) Burner operating characteristics tests
(6) CO emission tests

**5.** For equipment storing, carrying or utilizing hydrogen, relevant specific tests according to recognised standards are to be performed in addition to the tests specified in the Section.

## 602. Gas tanks

Tests related to welding and tank testing are to be in accordance with **Pt.7**, **Ch. 5**, **410**. and **411**. of the Rules for Steel Ships.

## 603. FC fuel piping systems

**1**. The requirements for testing are to apply to FC fuel piping inside and outside the gas tanks. However, relaxation from these requirements may be accepted for piping inside gas tanks and open-ended piping.

**2.** Welding procedure tests are to be required for fuel piping and are to be similar to those required for gas tanks in the **Pt.7, Ch.5, 603. 3** of the Rules for Steel Ships. Unless otherwise especially agreed with the Society, the test requirements are to be in accordance with para. **3** below.

**3. Test requirements**

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

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

(3) Charpy V-notch impact tests : Charpy tests are to be conducted at the temperature prescribed for the base material being joined. The results of the weld impact tests, minimum average energy (E), is to be no less than 27 J. The weld metal requirements for sub-size specimens and singe energy values are to be in accordance with **Pt.7 Ch.5, 601. 4** of the Rules for Steel Ships. The results of fusion line and heat affected zone impact tests are to show a minimum average energy (E) in accordance with the transverse or longitudinal requirements of the base material, whichever applicable, and for sub-size specimens, the minimum average energy (E) is to be in accordance with **Pt.7 Ch.5, 601. 4** of the Rules for Steel Ships. If the material thickness does not permit machining either full-sized or standard sub-size specimens, the testing procedure and acceptance standards are to in accordance with recognized standards. Impact testing is not required for piping with thickness less than 6 mm.

**4.** In addition to normal controls before and during the welding and to the visual inspection of the finished welds, the following tests are to be required :

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

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

(3) For other butt welded joints of pipes, spot radiographic tests or other non-destructive tests are to be carried out at the discretion of the Society depending upon service, position and materials. In general, at least 10% of butt welded joints of pipes is to be radio- graphed.

(4) Butt welded joints of high-pressure gas pipes, hydrogen supply pipes and gas supply pipes in ESD-protected FC spaces are to be subjected to 100% radio-graphic testing.

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

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

**6.** After assembly on board, each fuel piping system is to be subjected to a leak test using air, halides or other suitable medium.

**7.** All fuel piping systems including valves, fittings and associated equipment for handling fuel are to be tested under normal operating condition before set into normal operation.

### 604. Ducting

If the FC fuel piping duct contains high-pressure pipes, the ducting is to be pressure tested to at least 1.0 MPa after manufacturing.

### 605. Valves

**1. Type tests**

Each size and type of valve intended to be used at a working temperature below -55°C is to be type approved in accordance with the **Ch 3, Sec 15, Table 3.15.1** of the **Guidance for Approval of Manufacturing Process and Type Approval, Etc.** For valves intended to be used at a working temperature above -55°C, type approval is not required.

**2. Production tests**

All valves are to be tested at the plant of manufacturer in the presence of the Surveyor including the following.

(1) Hydrostatic test of the valve body at a pressure equal to 1.5 times the design pressure for all valves.
(2) Seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves. In addition, cryogenic testing at design temperature consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C.
(3) The set pressure of safety valves is to be tested at ambient temperature.

**3.** As an alternative to the above **2**, the manufacturer may request the Society to certify a valve subject to the following:

(1) The valve has been type approved as required by **1** for valves intended to be used at a working temperature below -55°C, and
(2) The manufacturer has a recognized quality system that has been assessed and certified by the Society subject to periodic audits, and
(3) The quality control plan contains a provision to subject the following, and
   (A) Each valve to a hydrostatic test of the valve body at a pressure equal to 1.5 times the de sign pressure for all valves.
   (B) Seat and stem leakage test at a pressure equal to 1.1 times the design pressure for valves other than safety valves.
   (C) The set pressure of safety valves is to be tested at ambient temperature.
(4) Cryogenic testing at design temperature consisting of valve operation and leakage verification at the design temperature for a minimum of 10 % of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55 °C in the presence of the Society' representative.

**4.** When leakage test of Para. 1, 2, 3, valves for use in hydrogen pipes located in ESD protected FC spaces, are to be tightness tested with hydrogen to show that there is no leakage of hydrogen from the valve.

### 606. Expansion bellows

**1.** Each type of expansion bellows intended for use in FC fuel piping, primarily on those used outside the gas tank are to be type approved in accordance with **Ch 3, Sec 15, Table 3.15.1** of the **Guidance for Approval of Manufacturing Process and Type Approval, Etc.**

### 607. FC fuel pumps

**1. Type tests**

Each size and type of pumps are to be type approved in accordance with **Ch 3, Sec 15, Table 3.15.1** of the **Guidance for Approval of Manufacturing Process and Type Approval, Etc.**

**2. Production tests**

All pumps which have been type approved are subject to the tests of following (1) and (2) at the plant of manufacturer in the presence of the Surveyor.

(1) hydrostatic test of the pump body equal to 1.5 times the design pressure
(2) the following capacity tests;
(A) For submerged pumps, the capacity test is to be carried out with the design medium or with a medium below the design temperature.
(B) For deep well pumps, the capacity test may be carried out with water.

**3.** The manufacturer may request the Society to waive the test of above **par. 2.** subject to the following:

(1) The pump has been type approved as required by **par. 1** and
(2) The manufacturer has a recognised quality system that has been assessed and certified by the Society subject to periodic audits, and
(3) The quality control plan contains a provision to subject each pump to a hydrostatic test of the pump body equal to 1.5 times the design pressure and a capacity test. The manufacturer is to maintain records of such tests.

## 608. Onboard tests of FC system

**1.** Before the tests commence, a detailed test programme is to be submitted and approved.

**2.** The FC entire system is to be subjected to the following tests after installation on board: However, the items to be tested during sea trial may be included in sea trial program.

(1) Functional trials of components :
Safety shut-off valves, automatic shut-off valves, level indicators, temperature measurement devices, pressure gauges, gas detection systems and alarm devices shall be subjected to a functional trial.

(2) Trials of the protective devices and system :
During the trial, it is to be verified that, in the event of the following faults, the FC system is automatically transferred into a safe condition:
(A) Alarm of the fire detection devices
(B) Alarm of the gas detection system
(C) Failure of the power supply
(D) Failure of the programmable logic controllers(PLCs)
(E) Faults in the protective devices or system
It is to be verified that the requirements of the risk analysis performed as per **101. 1**, are met.

(3) Functional trials of the FC system
The following operating conditions of the FC system is to be tested (as far as applicable):
(A) Automatic start-up of the FC system
(B) Operational switch-off of the FC system
(C) Load change, load steps
(D) Load shedding
(E) Switch-off during system malfunctions that do not endanger the safety of persons and equipment

(4) Functional trials of the ship
Within the scope of the functional trials, the interaction of the FC system with the ship systems is to be tested as follows (as far as applicable):
(A) Power generation by the FC system alone
(B) FC system together with conventional shipboard generation of electrical power
(C) FC system together with batteries
(D) Change-over to the emergency source of electrical power
(E) Switching the FC system online or offline
If the FC system constitutes the main propulsion system of the ship, it is to be verified that the ship has adequate propulsion power in all maneuvering situations. ⚓

# GUIDANCE FOR FUEL CELL SYSTEM ON BOARD OF SHIPS

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