

Rules for Classification and Construction

VI Additional Rules and Guidelines

3 Machinery Installations



11 Guidelines for the Use of Fuel Cell Systems on Board of Ships and Boats

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Germanischer Lloyd Aktiengesellschaft

Head Office

Vorsetzen 35, 20459 Hamburg, Germany

Phone: +49 40 36149-0

Fax: +49 40 36149-200

headoffice@gl-group.com

www.gl-group.com

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Section 1

General

A. Scope of Application

1. These Guidelines apply to the use of fuel-cell systems (FC systems) permanently installed on ships and boats. They describe the technical requirements for the safe operation of FC systems.

2. In the case of FC systems which are used as the sole means of propulsion, for the emergency electrical supply or for the supply of essential consumers in accordance with the GL Construction Rules, the additional requirements will be determined within the scope of an individual examination.

3. Designs which deviate from these Guidelines or from the applicable Rules may be approved if they are examined by GL for suitability and then approved as being equivalent.

4. Deviating designs are necessary to some extent for submersibles. These can be approved by GL, especially with regard to the ventilation systems and pressure relief devices.

5. For water craft with FC systems conforming to these Guidelines and having a rated output greater than or equal to 10 % of the rated output of the machinery installation the class notation **FC-xxx** will be assigned. The wild-card symbol "**xxx**" designates the percentage share of the FC system in relation to the rated output of the machinery installation.

For FC systems having a rated output lower than 10 % of the rated output of the machinery installation the class notation **with FC** will be assigned.

B. Applicable Rules

1. Rules for Classification and Construction

In addition to these Guidelines, the following Rules for Classification and Construction shall apply, if applicable:

- Main Group I – Ship Technology
 - Part 1 – Seagoing Ships
 - Chapter 1 – Hull Structures
- Main Group I – Ship Technology
 - Part 1 – Seagoing Ships
 - Chapter 2 – Machinery Installations

Here the following apply in particular:

Section 1 General Rules and Instructions

Section 8 Pressure Vessels

Section 9 Oil Firing Equipment

Section 10 Storage of Liquid Fuels, Lubricating, Hydraulic and Thermal Oils as well as Oil Residues

Section 11 Piping Systems, Valves and Pumps

Section 12 Fire Protection and Fire Extinguishing Equipment

Section 15 Special Rules for Tankers

- Main Group I – Ship Technology
 - Part 1 – Seagoing Ships
 - Chapter 3 – Electrical Installations
 - Chapter 4 – Automation
- Main Group I – Ship Technology
 - Part 2 – Inland Waterway Vessels
 - Chapter 2 – Machinery Installations
 - Chapter 3 – Electrical Installations
- Main Group I – Ship Technology
 - Part 3 – Special Craft
- Main Group II – Materials and Welding
 - Part 1 – Metallic Materials
 - Part 2 – Non metallic Materials
 - Part 3 – Welding

2. Other rules

National and international regulations, such as **SOLAS-74**, **MARPOL 73/74**, IEC standards etc. shall be observed, if applicable.

C. Definitions

1. Alarm system

System for generating an alarm when the upper or lower limiting values are transgressed. There is no automatic intervention in the system.

2. Fuel cell

A fuel cell is a source of electrical power in which the chemical energy of a fuel is converted directly into electrical energy by electrochemical oxidation (also known as "cold combustion").

3. Fuel cell stack

A fuel cell stack (FC stack) is a unit 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 Guidelines also includes the pipe connection fittings as well as the connections required to supply the electrical energy.

4. Fuel cell system (FC system)

An FC system in terms of these Guidelines can comprise the following components:

- fuel cell stacks
- arrangements for the transfer and storage of fuel, including the necessary auxiliary equipment (e.g. heating/cooling)
- arrangements for fuel distribution
- arrangements for fuel conditioning, including any reformer systems, gas humidifiers etc.
- installation spaces, including the ventilation systems
- conditioning and storage of the oxidants (air or oxygen)
- electrolyte systems
- arrangements for the conditioning of residual gas and exhaust gas
- cooling systems
- interconnections between the systems
- safety, regulating and monitoring equipment
- electrical inverter systems
- other auxiliary systems
- other energy converters integrated into the system, e.g. gas turbines in systems with high-temperature fuel cells

5. Hazardous areas (Ex zones)

These are areas in which the accumulation of flammable gases or vapours in a hazardous concentration or

quantity may be expected. Depending on the probability of an explosive atmosphere, hazardous areas are classed as explosion zone 0, 1 or 2 according to [Section 7, B](#).

6. Protective devices

Protective devices detect critical deviations from limit values and prevent an immediate risk to persons, ship or machinery. In the event of a failure, protective devices transfer the system into a safe state and prevent uncontrolled restarting.

7. Protective systems

A protective system consists of the grouping of several protective devices to form a functional unit.

8. Safe areas

Safe areas are the zones outside of the hazardous areas of a ship.

D. Environmental Conditions

In the selection, design and arrangement of all components of FC systems on seagoing ships, the environmental conditions described in the GL Construction Rules, Main Group I – [Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations, Section 1, C](#). shall be applied.

For FC systems on inland waterway vessels and pleasure craft, the environmental conditions as per Main Group I, [Part 2, Chapter 2, Section 1, C.3.](#) and [C.4.](#) or Main Group I, [Part 3, Chapter 3, Section 1, C.2.](#) shall apply.

E. Fuels

1. Fuels in terms of these Guidelines are the fuels kept in the storage tanks of the FC system as well as the fuels available after conditioning or distribution.

2. With the corresponding conditioning through the reforming process, FC systems can be supplied both with conventional marine fuels (flashpoint above 60 °C) and with fuels which have a flashpoint below 60 °C. The latter fuel types include, for example, methanol, liquefied gases such as LPG, the cryogenic liquefied gases LNG and LH2, as well as pressurized gases such as CNG, compressed hydrogen or propane.

3. For the use of fuels with a flashpoint of 60 °C or lower, the technical requirements specified in these Guidelines shall apply. Additional requirements may be stipulated by GL. Furthermore, the consent of the competent approval authority (e.g. Flag State Administration) is required.

4. For the use of fuels with a flashpoint above 60 °C, the requirements specified in the GL Construction Rules, Main Group I, Part 1, Chapter 2, Section 10 and 11, shall apply.

F. Documents to be Submitted

1. General

The technical documents shall permit an assessment of the compliance of the system and its components with the applicable requirements of these Guidelines and of other rules that must be met. Insofar as needed for the assessment, the documents shall cover the design, production and functional principles, and shall permit a check that actual construction is in compliance with the documentation.

Once the documents submitted have been approved, they shall be binding. Any subsequent modifications require GL approval prior to implementation.

2. Safety concept

It shall be demonstrated that

- the FC systems function safely when used for their intended purpose including the maintenance activities
- malfunctions can be prevented with the aid of the monitoring, alarm and protective devices
- dangerous operational situations which according to general experience can arise, even though the time of occurrence cannot be predicted (e.g. critical deviations from limit values), and/or which occur as a result of possible negligence (e.g. foreseeable misuse) are brought under control
- the effects of damage are limited by appropriate precautionary measures

3. Safety functions

The documents submitted must show what technical safety measures or solutions are effective for the operational situations stated under 2. In addition, it shall be verified that the safety measures were selected according to the following sequence of the criteria:

- directly acting safety functions
- indirectly acting safety functions
- organizational safety precautions

4. Documents

The following documents shall be submitted in triplicate.

Before production of the FC system commences:

- description of the process and function of the FC system
- piping and instrumentation diagrams, with block circuit diagrams of the overall system, including parts lists or equipment lists
- technical documents of the components, including the fuel cell stacks themselves (descriptions, specifications, verification of suitability according to existing standards and rules, approvals and inspection certificates)
- electrical circuit diagrams, including the circuit diagrams of the alarm system and the protective system
- automation concept
- fire extinguishing concept
- plans of the hazardous areas (Ex zones)
- safety and emergency concept, including a safety analysis according to recognized procedures, e.g. fault tree analysis, see F.2. and F.3.

Before the trials according to Section 10:

- operation manual
- trials programme

G. Testing and Trials

1. General

1.1 FC systems are subject to the construction supervision and acceptance testing by GL. Compliance with the approved documents, the workmanship, the suitability of the material and the documentation of the material characteristics as well as conformance with the specification are checked.

1.2 GL reserves the right to extend the scope of the tests, and also to subject to testing those parts which are not explicitly to be tested according to the Rules. For parts produced in series, the prescribed tests may be replaced by other tests agreed with GL.

2. Test steps

The testing of an FC system by GL comprises the following steps:

- evaluation of the technical concept

- examination of the system documentation, the technical documents for the components subject to mandatory testing, and the technical documents of the alarm and protective systems
- manufacturing tests, pressure tests and – if applicable – functional tests of parts and components
- factory test of control, regulating and protective devices, and of protective systems, at the manufacturer
- functional test and completeness check of the alarm and protective systems
- functional test and acceptance test of the overall system, including pressure and tightness tests and completeness checks, see [Section 10](#)
- determination of the periodical tests, insofar as these are not stipulated by the GL Classification Rules

On successful execution of the above-mentioned test steps, the proper construction and workmanship of the system in accordance with the provisions of these Guidelines is certified, and the Class Notation **FC** is assigned.

3. Pressure and tightness test

3.1 The piping systems and components shall be subjected to a hydrostatic pressure test with a test pressure equal to 1,5 times the maximum working pressure as well as a tightness test with a test pressure equal to 0,9 times the maximum allowable working overpressure.

3.2 The shut-off valves must be tested additionally for tightness with 1,1 times the maximum allowable working overpressure.

3.3 A deviating procedure is only permissible if this is necessary for technical reasons and if it has been examined and approved by GL.

H. Power supply of Essential Consumers

If the FC system is used to supply essential consumers as per Main Group I, [Part 1, Chapter 3, Section 1, B.2., B.3. and B.4.](#), then verification of adequate reliability and fail-safety of the FC system shall be provided. The scope and type of the required verification is specified in each individual case by GL.

I. Installation

1. FC systems shall be located in separate spaces. Installation in conventional machinery spaces is not permitted.

The requirement for a separate space can also be met by a suitable form of enclosure for the components transferring the fuel. In such a case, installation in conventional machinery spaces is admissible.

2. Spaces in which fuel storage tanks are located shall be separated from conventional machinery spaces and the other parts of the FC system.

3. Spaces in which components of the FC system are installed shall be equipped with a mechanical ventilation system or other suitable ventilation devices of the extraction type as per [Section 5](#). The spaces shall be monitored by gas detection systems as per [Section 8, C](#). Special attention shall be paid to areas with a low rate of air circulation.

Alternative constructions approved by GL as being equivalent are permissible for submersibles and pleasure craft.

Section 2

Materials

A. General Requirements

The materials shall be suitable for the intended application and shall comply with recognized standards. Their suitability shall be proven to GL. The use of flammable materials is not allowed outside the FC stack. The Rules for Materials issued by GL shall be observed. The use of flammable materials inside the FC stack requires the approval of GL. [Section 4, B.1.](#) shall be observed.

- seagoing ships:
[Main Group I, Part 1, Chapter 2, Section 8 and Section 11](#)
- Inland waterway vessels:
[Main Group I, Part 2, Chapter 2, Section 7 and Section 10](#)
- pleasure craft:
[Main Group I, Part 3, Chapter 3, Section 5](#)

B. Approved Materials and Material Tests

For pressure vessels, piping, valves and pumps, the following requirements shall apply:

Pipes for flammable liquids or gases shall be constructed of suitable metallic materials. The use of other materials requires the consent of GL.

Section 3

Fuel Systems

A. Fuel Transfer System

1. The fuel transfer systems include all components needed for filling the fuel tanks/containers. The connections to exchangeable tanks/containers shall be regarded as part of the fuel storage system.

Fuel transfer systems shall be permanently installed, completely separated from other pipeline systems, and clearly marked.

2. The bunkering station shall be located on the open deck.

3. The bunkering station and fuel transfer pipes shall be provided with shut-off valves located directly at the transfer point and directly before the distribution manifold to the fuel tanks. The shut-off valves shall be designed in a way that they can be closed manually and by remote control. The position of the shut-off valve shall be indicated locally and in the control room.

Remote-controlled valves and the position indicator in the control room are not required in the following cases:

- fuel transfer systems with pipes up to 10 m in length, if the nominal diameter is less than or equal to 12 mm
- systems where a suitable non-return valve is integrated into the pipe at the fuel transfer point

4. A suitable fire extinguishing device shall be provided in the vicinity of the bunkering station.

5. If the fuel transfer system is installed in a safe area according to [Section 1, C.8.](#), then measures shall be taken to ensure that the fuel transfer pipe can be gas-freed after use. Openings of blow-off pipes for gas-freeing shall be arranged at points where no sources of ignition exist.

6. During fuel transfer the requirements of zone 1 as per [Section 7](#) shall apply for the immediate vicinity of the bunkering station. The immediate vicinity is defined as the space within a spherical radius of 3 m around the transfer connection. A reduction of this distance is only permissible with the approval of GL.

7. Entrances, ventilation openings and openings leading to accommodation and service spaces, machinery spaces, and control rooms shall be located outside hazardous areas. They shall not face the bunkering station.

8. Openings to spaces which are located up to 10 m away from the transfer connection shall be kept closed during fuel transfer. Appropriate warning notices shall be displayed.

B. Fuel Storage

1. Fuel shall be stored in suitable tanks or containers. Tanks/containers shall be secured against the ship movements occurring during operation at sea. Proof of the suitability of the tanks/containers and their securing arrangements shall be submitted to GL.

2. The installation spaces for tanks/containers shall be located outside of accommodation, service and machinery spaces and of control rooms, and shall be separated from such spaces by gastight bulkheads. If the installation space is adjacent to a space with potential fire load, separation by means of an A-60 bulkhead is required. Tanks, which are part of the ship structure, shall be separated from other spaces by means of cofferdams.

If it is necessary to deviate from this provision on board small craft, the approval of GL is required.

3. Entrances, openings and ventilation openings to accommodation, service and machinery spaces and to control rooms shall be arranged at a distance of at least 3 m from the openings of the installation space.

If it is necessary to deviate from this provision on small craft, the approval of GL is required.

4. The ventilation and blow-off pipes of the tanks shall be routed to the open air and so arranged that the exhaust vapours and gases can be discharged without any danger. Up to a spherical radius of 3 m around the outlet opening, there shall be no sources of ignition or openings which lead to spaces containing sources of ignition.

Technically equivalent solutions are permissible, if it is not possible to vent vapours and gases to the open air.

5. Fuel tanks intended for liquefied and pressurized gases and subjected to overpressure shall be protected against inadmissible temperature increases resulting from a fire in the vicinity. Fire loads are not permissible within the installation space. The installation space shall be protected against inadmissible heating in the event of fire, by means of a water sprinkler system or, alternatively, through A-60 fire insulation.

If it is necessary to deviate from this provision on small craft, the approval of GL is required.

C. Fuel Conditioning

1. General

1.1 All components for conditioning the fuel – such as preheaters, compressors, filters, reformers etc. – shall be located in a closed space or a suitable enclosure. This space or enclosure shall be ventilated according to [Section 5](#) and shall be equipped with a gas detection system according to [Section 8, C.](#) and [Section 9](#).

1.2 The installation spaces of the fuel conditioning system shall be separated from the spaces used for storage of the fuel. Doors between the spaces used for fuel storage and those used for fuel conditioning are not permitted.

1.3 In the pipes to the fuel conditioning system, remote-controlled shut-offs, which can be closed from outside the spaces, shall be arranged at the bulkheads.

1.4 The installation space shall be situated outside of accommodation, service and machinery spaces and control rooms, and shall be separated from such spaces by means of a cofferdam or an A-60 bulkhead. Installation in a conventional machinery space is admissible, on condition that a suitable enclosure is provided.

1.5 Entrances, openings and ventilation openings to accommodation, service and machinery spaces and to control rooms shall be arranged at a distance of at least 3 m from the openings of the installation space used for fuel conditioning, and shall not face them.

If it is necessary to deviate from this provision on small craft, the approval of GL is required

2. Requirements for fuel conditioning

2.1 Compressors and pressure reduction devices

2.1.1 It shall be possible to switch off the compressors from a permanently accessible point outside the installation space. In addition, the compressor shall be stopped automatically if the suction pressure is too low. The compressor shall not be restarted automatically before a manual reset has been carried out.

2.1.2 Positive displacement compressors shall be fitted with relief valves routed into the suction line of the compressors. The relief valves shall be so dimensioned that, with the discharge of the compressor in the closed position, the maximum allowable working pressure is not exceeded by more than 10 %.

2.1.3 Pressure reduction devices shall be so designed that failure of a pressure reduction valve cannot endanger the downstream components. In particular, the pipes downstream of the pressure reducer shall be protected by safety valves or shall be designed to a pressure rating corresponding to the maximum allowable working pressure that is permissible before the pressure reducer.

2.2 Evaporators

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

2.2.2 A gas detection and alarm system shall be provided within the degassing container.

2.2.3 The outlet opening of the vent pipe of the degassing container shall be located in a safe area and provided with an approved flame arrester.

2.3 Reformer Systems

2.3.1 General

2.3.1.1 Reformer systems shall be designed for automatic operation and equipped with all the indicating and control facilities required for assessment and control of the process.

2.3.1.2 The chemical processes taking place within the unit shall be monitored, see [Section 8, C.3](#).

2.3.1.3 If limit values determined for the control process are exceeded, the unit must be switched off and interlocked by an independent protective device.

2.3.1.4 It shall be possible to switch off the reformer unit from a permanently accessible point outside the installation space.

2.3.1.5 If high surface temperatures may occur, the corresponding insulation or contact protection shall be provided.

2.3.2 Firing equipment

2.3.2.1 For fuels in terms of these Guidelines, the GL Construction Rules, Main Group I, Part 1, Chapter 2, Section 9 – Oil Firing Equipment shall be applied as appropriate.

2.3.2.2 Firing equipment in reformer systems shall be designed for automatic operation. Manual operation (even for emergencies) is not permissible.

2.3.2.3 The firing equipment shall be equipped with a type-tested burner control box and flame monitoring devices. Reliable operation of the flame monitoring devices shall be verified for the corresponding type of fuel and mode of combustion.

2.3.2.4 After the firing equipment has been switched off, the combustion chamber and the exhaust gas system shall be purged with air or an inerting medium.

2.3.2.5 Depending on the type of fuel and the burner, GL may define additional requirements for the firing equipment.

2.3.2.6 The use of gaskets and insulating materials which contain asbestos is not permissible.

2.3.3 Catalytic converters

Catalytic converters in reformer units shall comply with the GL Construction Rules in regard of the environmental conditions to be considered, especially the requirements related to vibration loading. For seagoing ships, the Rules as per Main Group I, Part 1, Chapter 1, Section 1 – General Rules and Instructions shall apply.

2.3.4 Gas purification

For installations as per Section 1, A.2., the gas purity required for the operation of the fuel cell shall be monitored by suitable methods. If the determined limit values are exceeded, an alarm shall be generated or the system shall be switched off.

If this requirement is not met for installations as per Section 1, A.1., verification shall be provided that no additional hazard can occur through inadmissible impurities.

2.3.5 Exhaust gases

The exhaust gases arising during the reforming process shall be discharged safely to the open air at an

adequate distance from openings to accommodation, machinery and service spaces.

2.3.6 Residual gases

The recirculation of fuel (residual gas) from the FC to the reformer is permissible. The recirculation shall be protected by an automatic shut-off valve as per Section 9, D.

D. Fuel Distribution

1. General

1.1 Fuel pipes shall be independent of other piping systems. Use for other media than fuel has to be prevented. Through their arrangement, it shall be ensured that they are protected against damage.

1.2 The fuel pipes between the supply tanks, the fuel conditioning system and the machinery space must be as short as possible. Fuel pipes shall be arranged with the greatest possible horizontal distance to the outer shell of the hull.

1.3 Fuel pipes shall not be routed through safe areas, such as accommodation and service spaces or control rooms. If, in exceptional cases, fuel pipes have to be routed through a safe area, they shall be constructed either as a double-wall piping system or as a pipe within the ventilation duct, see Section 5.

1.4 Fuel pipes in hazardous areas can be arranged without a double pipe or outside of a ventilation duct, if they are located in a space/area ventilated according to Section 5 or in an enclosed housing which is adequately ventilated and monitored, and if the requirements for explosion protection as per Section 7 are met.

2. Pipes for gaseous fuels

2.1 Direct connections of pipes

2.1.1 Pipes shall be connected by butt welding with full penetration.

2.1.2 Screw fittings according to standards which are approved by GL for this application can be used for pipes with external diameters of 25 mm or less.

2.1.3 Flanged joints shall only be used at locations where this is unavoidable. Only flange types approved by GL for that particular application shall be used.

2.2 Flanged joints

2.2.1 If flanged joints cannot be avoided in installation spaces, they are only permissible within ventilated spaces and in areas in which ventilation of the extraction type is provided, see [Section 5](#).

2.2.2 Flanged joints are permissible at the bunkering station.

2.2.3 With regard to type, make and quality assurance, flanges shall comply with recognized standards.

2.3 Inerting

It shall be possible to inert and gas-free the fuel pipes.

Section 4

Fuel Cells and Associated Components

A. Installation

1. All parts of fuel cells and the directly associated components containing fuel during normal operation shall be arranged in an enclosed space or suitable enclosure. This space/enclosure shall be ventilated according to [Section 5](#) and equipped with a gas detection system according to [Section 8, C.2](#).

Alternative constructions approved by GL as being equivalent are permissible for submersibles and pleasure craft.

2. The installation spaces of fuel cells and their directly associated components shall be separated from the spaces used for fuel storage. Doors between the spaces used for fuel storage and the installation spaces of the fuel cells are not permissible.

3. The installation spaces of FC stacks and directly associated components shall be arranged outside of accommodation, service and machinery spaces and control rooms, and shall be separated from such spaces by means of a cofferdam or an A-60 bulkhead. Installation in a conventional machinery space is admissible, on condition that a suitable enclosure is provided.

4. Entrances, openings and ventilation openings to accommodation, service and machinery spaces and to control rooms shall be arranged at a distance of at least 3 m from the openings of the installation space of the fuel cells. The openings of the installation space shall not face the entrances, openings and ventilation openings to accommodation, service and machinery spaces and to control rooms.

If it is necessary to deviate from this provision on small craft, the approval of GL is required.

5. Openings for exhaust air and residual gases of the FC stack shall be located on the open deck with a horizontal distance of at least 3 m to any sources of ignition and to the openings of accommodation, ser-

vice and machinery spaces, and to control rooms and other spaces containing sources of ignition.

Alternative constructions approved by GL as being equivalent are permissible for submersibles and pleasure craft.

B. 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 GL.

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

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

C. Inverters Following Fuel Cells

If propulsion units or other essential consumers are supplied with electricity from FC systems, then the inverters shall be so designed that reverse power, such as braking power, cannot pass into the fuel cells.

In general, the requirements set out in the GL Construction Rules, Main Group I, [Part 1, Chapter 3](#) apply.

Section 5

Ventilation Systems

A. General

1. Spaces in which there is a risk that an ignitable gas mixture may be formed have to be equipped with mechanical ventilation systems of the extraction type. Depending on the expected type of fuel release, either the entire space or the hazardous areas must be fitted with suction ventilators.

For small installations, a natural ventilation arrangement can be approved by GL.

2. It must be possible to control the ventilation systems from a point outside the ventilated spaces. The spaces must be ventilated before access and before taking the equipment into operation. Notices must be provided outside the spaces, with the warning that the ventilation system must be switched on before entering the spaces.

3. Ventilation systems must be permanently installed. The ventilation systems are not allowed to be connected to those of other ship spaces.

4. The extracted air must be monitored for fuel constituents. The requirements set out in [Section 8, C.2.](#) apply.

B. Spaces with Mechanical Ventilation

1. The inlet and outlet openings of the mechanical ventilation system must be arranged in such locations that an adequate flow of air prevents the accumulation of flammable vapours and ensures a safe working atmosphere throughout the entire room.

2. The ventilation system shall be designed for at least 30 air changes per hour with regard to the total geometric volume of the empty space. If the ventilation system fails, an alarm must be generated. Alternative constructions approved by GL as being equivalent are permissible for submersibles and pleasure craft.

3. Suitable design of the spaces shall ensure that no gas can accumulate in recesses or pockets.

4. Air inlet and outlet openings shall be provided with fire dampers, which must be operable from outside the spaces. Protective screens with a mesh spacing of not more than 13 mm shall be mounted at the outer openings of ventilation ducts.

5. Fans shall not form a source of ignition neither within the ventilated space nor within the ventilation system connected to the space. Fans must be of a non-sparking type and must comply with the GL Construction Rules, Main Group I, Part 1, Chapter 2, Section 15, B.5.3.

6. Fuel pipes that are routed into the ventilated space must be shut-off automatically by means of a safety shut-off valve as per [Section 9, C.](#), if the required air flow is not achieved or cannot be sustained, or if a fuel leak is detected.

C. Gases and Vapours Heavier than Air

1. The spaces shall be ventilated by means of mechanically driven exhaust air fans. The supply air shall be introduced into the upper part of the spaces.

2. The exhaust air duct shall be routed as closely as possible to the floor of the space. The space shall be so designed that gases collect at central points from which they are extracted.

D. Gases Lighter than Air

1. The spaces shall be ventilated by means of mechanically driven exhaust air fans. The supply air shall be introduced into the lower part of the spaces.

2. The spaces shall be designed in such a way that gases collect at the top at central points from which they are extracted.

3. A suction hood or a suction trunk shall be provided for areas containing flanges, valves etc.

4. The suction hood or suction trunk shall 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.

E. Ventilation Ducts for Fuel Pipes

1. As an alternative to routing the fuel pipe within a double-wall pipe as per F. the fuel pipe can be laid in a tube or tunnel fitted with mechanical ventilation of the extraction type.

2. Electrical cables are not permitted to pass through this tube or tunnel.

3. The ventilated tunnel intended for the fuel pipe shall be routed until a space is reached which is equipped with a ventilation system.

4. The ventilation must be constantly in operation whenever fuel is present in the line. A gas detection unit shall be located in the extracted air stream and be in permanent operation, in order to indicate any leaks and to shut off the fuel supply automatically as per Section 9, C. The safety shut-off valve must close automatically whenever the required air flow is not achieved or cannot be sustained.

5. The ventilation system must be capable of maintaining a pressure below atmospheric pressure. The fan motors shall be arranged outside the ventilated tube or tunnel. For the design of the fans, see B.5.

F. Double-Wall Piping System

1. As an alternative to routing the fuel pipe through a ventilation duct as per E. a double-wall pipe can be used. In the case of double-wall pipes, the fuel

must be in the inner pipe. The space between the concentric pipes shall be pressurized with inert gas at a pressure between the atmospheric pressure and the fuel pressure. The outer pipe shall be designed for at least the design pressure of the inner pipe.

As an alternative to this design for the outer pipe, a pressure relief arrangement for the outer pipe can be approved by GL, on condition that proof of equivalent safety is provided. The pressure in the jacket pipe and the triggering of the pressure relief device shall be monitored.

2. In the event of an inadmissible pressure change in the space between the two pipes, an alarm must be triggered.

G. Arrangement of the Supply Air and Exhaust Air Openings on Deck

1. To prevent dangerous gases or vapours from being drawn in again, the supply air and exhaust air openings of the ventilation systems (to the outside atmosphere) on the open deck shall be arranged as far away from each other as possible. They shall be located with a horizontal distance of at least 3 m to any sources of ignition and to the openings of accommodation, service and machinery spaces, control rooms and other spaces containing sources of ignition.

Alternative constructions approved by GL as being equivalent are permissible for submersibles and pleasure craft.

2. Exhaust air openings should be situated as far away as possible from areas in which persons are regularly to be found. These include, for example, embarkation areas, muster stations for life-saving appliances, deck work zones and passenger areas.

3. Exhaust air ducts must vent upwards.

Section 6

Fire Extinguishing Systems

A. General

cell system, GL may request that a fire extinguishing system be installed.

1. The area around the manifold for fuel transfer and the installation spaces for systems in which fuels in terms of these Guidelines are used shall be equipped with fire extinguishing systems of a suitable type. For all other spaces containing parts of the fuel

2. The supply facilities of the fire extinguishing system shall always be arranged outside the spaces or areas which are to be protected. It must be possible to set off the fire extinguishing system at a permanently accessible point.

Section 7

Explosion Protection

A. Explosion-Protected Systems

1. Electrical equipment is regarded as being explosion-protected if it has been manufactured according to a recognized standard, e.g. the IEC 60079 publications or EN 50014 – 50020, and if it has been inspected and approved by a recognized institution body. Any instructions and restrictions noted in the approval certificates shall be observed.

2. With regard to the explosion protection, the requirements set out in IEC 60079-14 shall be observed. The required explosion group and temperature class of the electrical equipment in the Ex zones depend on the type of fuel, and shall be defined for each individual case.

B. Classification into Zones

1. General

Hazardous areas (Ex zones) shall be classified into zones according to the probability of potentially explosive mixtures, in compliance with IEC 60079-10.

Depending on the influence of the ventilation and its availability, an Ex area can be reclassified from its original theoretical zone into an effective zone with a lower hazard level.

2. Hazardous area, zone 0

2.1 Hazardous areas of zone 0 are areas in which an ignitable gas mixture must be expected to be present permanently. These areas include e.g. the inside of tanks or pipes containing flammable liquids with a flash point ≤ 60 °C or with flammable gases.

2.2 Explosion zone 0 also includes the inside of tanks, containers, heaters, pipes etc. for liquids or fuels with a flashpoint above 60 °C, if these liquids are heated to more than 10° C below their flashpoint.

2.3 For electrical installations in these areas, only the following may be used:

- intrinsically safe electrical circuits with the degree of protection Ex ia
- equipment specially approved for use in this zone

2.4 Cables shall have armouring or shielding, or shall be laid in a metallic tube.

3. Hazardous area, zone 1

3.1 Hazardous areas of zone 1 are areas in which an ignitable gas mixture can be expected to be present occasionally. These areas can include e.g. spaces with FC stacks, spaces with fuel tanks and pipes, spaces with fuel conditioning systems, ventilation ducts of pipes, and the monitoring space of double-wall pipes.

3.2 The extent of zone 1 shall be defined in compliance with IEC 60079-10.

3.3 For the electrical equipment in this area, only explosion-protected units of a type suitable for ship-board applications shall be used.

3.4 Cables shall have armouring or shielding, or shall be laid in a metallic tube.

4. Extended hazardous area, zone 2

Extended hazardous areas of zone 2 are areas in which an ignitable gas mixture can be expected to be present only very occasionally, and then only for a short period. Areas directly adjacent to zone 1 that are not separated in a gastight manner from zone 1 are assigned to zone 2. The extent of zone 2 shall be defined in compliance with IEC 60079-10.

For electrical equipment in the areas belonging to zone 2, protective measures should be taken depending on the type and application of the equipment. These can comprise the following, for example:

- explosion-protected equipment
- equipment with the degree of protection Ex n
- equipment which generates no sparks in normal operation, and where the surfaces exposed to the outside air cannot reach inadmissible temperatures
- equipment which is contained in a pressurized enclosure in a simplified manner or enclosed in a fume-tight enclosure (minimum protection IP 55), where their surfaces cannot reach inadmissible temperatures. The permissible temperatures depend on the type of fuel, and shall be defined for each individual case.

Section 8

Control, Regulating, Monitoring and Alarm Devices

A. Control and Operating Devices

1. If at least two control devices suited for the operation of FC systems are stipulated by the GL Construction Rules, Main Group I, Part 1, Chapter 3, Section 9, B.3., then they shall function independently of each other and shall not 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 shall be observed:

- conflicting operator actions shall be prevented by means of suitable interlocks
- the control panel which is currently active must be indicated appropriately

3. Control devices should 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 shall be ensured that the fuel cells can be disconnected from the electrical load at any load condition.

B. Automatic Control Devices

1. For the FC systems, regulating devices shall be provided to keep the process variables within the specified limits under normal operating conditions. The regulating behaviour shall cover the entire range of operation. Parameter changes which can be anticipated must be considered during the design phase. Faults in a regulating circuit shall not affect the proper functioning of other regulating circuits. The power supply to the regulating circuits shall be monitored and an alarm must be generated on failure of the power supply.

2. Regulating devices containing computers shall be designed according to the GL Construction Rules, Main Group I, Part 1, Chapter 3, Section 10.

3. Regulating devices for fuel cell systems are subject to mandatory type testing.

C. Monitoring and Alarm Devices

1. General

1.1 Alarm systems shall be provided which indicate unacceptable deviations from normal operating figures by visible and audible alarms.

1.2 Alarm delays shall be kept within time limits which prevent any risk to the monitored system in the event that a limit value is exceeded.

1.3 Visible signals shall be individually indicated.

1.4 In addition, the GL Construction Rules, Main Group I, Part 1, Chapter 3, Section 9, C. shall be observed.

2. Gas detection system

2.1 Spaces in which gas leaks cannot be ruled out shall be monitored by gas detection systems. When a concentration equal to 5 % of the lower explosion limit is reached, a visible and audible alarm must be generated at the control station. When a concentration equal to 10 % of the lower explosion limit is reached, a safety switch-off of the affected system must take place, see also Section 9, A.

2.2 Gas sensors must be arranged at all locations where an accumulation of gases can be expected.

2.3 Gas detection systems are subject to approval by GL.

3. Monitoring of chemical reactions

Chemical reactions, such as those taking place during fuel conditioning and within the fuel cell, shall be monitored, e.g. by means of temperature, pressure or voltage monitoring.

4. Monitoring the performance of the fuel cells

4.1 If an FC system is used to supply consumers as per Section 1, A.2., then the electrical power provided by the FC system shall be monitored.

4.2 In the case of load shedding, it shall be ensured that the FC system is automatically transferred into a safe condition from which it can be brought to the normal operating state again.

Section 9

Protective Devices and Protective Systems

A. Protective Devices

1. Protective devices shall be as simple as possible, and must be reliable and direct in operation. Where external energy is required for the function of protective devices, the energy supply shall be monitored for possible failure. The suitability and proper function of protective devices must be demonstrated for the given application.

2. Protective devices shall be designed in a way that potential faults such as, for example, loss of voltage or a broken wire, cannot create a hazard to human life, ship or machinery. The occurrence of these faults and also the tripping of protective devices shall be indicated by an alarm.

3. Protective devices shall be designed to be fail-safe.

4. The adjustment facilities for protective devices shall be designed in a way that the last setting can be verified.

5. Protective devices, including sensors and actuators, must be independent of control, regulating and monitoring systems. Faults in one protective device shall not affect any other protective device. Protective devices shall be assigned to the systems which are to be protected.

6. The monitored open-circuit principle shall be used for protective devices. Alternatively, the closed-circuit principle shall be applied where national regulations demand it. Equivalent monitoring principles are permitted.

7. Faults occurring in protective devices must be indicated by an alarm.

8. In case of the following events, the affected FC system must be switched off with due consideration to safety, and then locked out:

- emergency shutdown (protective device)
- gas detection: when a concentration equal to 10 % of the lower explosion limit is reached
- fire detection in hazardous areas
- safety switch-off of the system owing to deviations from permissible operating parameters, including chemical reactions

9. It shall be ensured that the electric power output can be switched off at any load condition, see [Section 8, A.4.](#)

10. Protective devices are subject to mandatory type testing.

11. The control and regulating devices on the one hand and the protective devices on the other shall be located in separate spaces, so that, in the event of fire or water ingress, both systems are not adversely affected at the same time.

B. Protective Systems

1. General

1.1 A process-related interlinking of protective devices by the protective system shall not result in an impairment of the safety objectives.

1.2 When a protective system demands a requirement class of 4 or higher according to the GL Construction Rules, Main Group I, Part 1, Chapter 3, Section 10, the following criteria shall be observed:

- The protective system should be of a fault-tolerant design (multi-module).
- The modules should consist of different hardware.
- If the modules contain software, this should be programmed according to different design criteria and by different persons (redundancy through diversity).

1.3 Computers in protective systems shall be designed according to the GL Construction Rules, Main Group I, Part 1, Chapter 3, Section 10.

1.4 Protective systems for FC systems are subject to mandatory type testing.

1.5 The control and regulating devices on the one hand and the protective system on the other shall be located in separate spaces, so that, in the event of fire or water ingress, both systems are not adversely affected at the same time.

C. Safety Shut-Off Valves

1. Safety shut-off valves

Safety shut-off valves shall be provided at the following points of the fuel system:

- at the outlets from the fuel storage tanks
- at the outlet from the fuel conditioning unit
- at the inlet of fuel pipes in monitored spaces
- Depending on the structure of the system, additional safety shut-off valves may be required.

2. It must be possible to close the safety shut-off valves by means of the protective devices and also from a constantly manned position. They must be so constructed that they can only be reset manually.

3. In the event of a leak, the fuel supply shall only be taken into operation again when the cause of the leak has been detected and remedied. Instructions on this requirement shall be displayed in a conspicuous position in the installation space.

4. Safety shut-off valves have to be GL type-approved.

D. Automatic Shut-Off Valve of Consumers

1. Each gas consumer (fuel cells, burners of reformers etc.) must be fitted with a group of valves consisting of three automatically actuated shut-off valves. Two of these shut-off valves must be located

in series in the gas pipe leading to the consumer. By means of the third shut-off valve, it shall be possible to relieve the pressure in the section of gas pipe lying between the two shut-off valves. The vent pipe shall lead to the open air. For the outlet of the vent pipe, the requirements set out in [Section 3, B.4.](#) apply.

Alternative constructions approved by GL as being equivalent are permissible for submersibles and pleasure craft.

2. The shut-off valves must be arranged in a way that actuation or failure of the control circuit of the shut-off valves will cause the two series-connected shut-off valves to close automatically and the vent valve to open automatically. Alternatively, the function of one of the series-connected valves and the vent valve can be incorporated into one valve body so arranged that on actuation the flow to the gas consumer will be blocked and the vent line opened. The three shut-off valves shall be constructed in a way that they can only be reset by hand.

3. The shut-off valves must close automatically under the following operating conditions:

- emergency shutdown
- safety shutdown of the system

4. It must be possible to actuate the shut-off valves locally and also from any control panel.

Section 10

Trials of the System

A. General

Before the trials commence, a detailed trial programme shall be compiled. The trial programme is subject to approval by GL, see [Section 1, F](#).

B. Trials of the Entire System

The FC system shall be subjected to the following trials after installation on board:

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 protective system

During the trial, it shall be verified that, in the event of the following faults, the FC system is automatically transferred into a safe condition:

- alarm of the fire detection devices
- alarm of the gas detection system
- failure of the power supply
- failure of the programmable logic controllers (PLCs)
- triggering of the protective devices
- faults in the protective devices
- faults in the protective system

It shall be verified that the requirements of the safety analysis are met, see [Section 1, F](#).

3. Trials of the fire extinguishing system

The functional readiness of the fire extinguishing system shall be verified.

4. Functional trials of the FC system

The following operating conditions of the FC system shall be tested (as far as applicable):

- automatic start-up of the FC system
- operational switch-off of the FC system
- load change, load steps
- load shedding
- switch-off during system malfunctions that do not endanger the safety of persons and equipment

5. Functional trials of the ship

Within the scope of the functional trials, the interaction of the FC system with the ship systems shall be tested as follows (as far as applicable):

- power generation by the FC system alone
- FC system together with conventional shipboard generation of electrical power
- FC system together with batteries
- change-over to the emergency source of electrical power
- switching the FC system online or offline

If the FC system constitutes the main propulsion system of the ship, it shall be verified that the ship has adequate propulsion power in all manoeuvring situations

