TÜRK LOYDU

Chapter 26 – Guidelines For The Use of Fuel Cell Systems On Ships

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This latest edition incorporates all rule changes. The latest revisions are shown with a vertical line. The section title is framed if the section is revised completely. Changes after the publication of the rule are written in red colour.

Unless otherwise specified, these Rules apply to ships for which the date of contract for construction as defined in TL- PR 29 is on or after 1st of January 2024. New rules or amendments entering into force after the date of contract for construction are to be applied if required by those rules. See Rule Change Summary on TL website for details.

"General Conditions" of the respective latest edition will be applicable (see Rules for Classification and Surveys).

If there is a difference between the rules in English and in Turkish, the rule in English is to be considered as valid. This publication is available in print and electronic pdf version. Once downloaded, this document will become UNCONTROLLED. Please check the website below for the valid version.

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GUIDELINES FOR THE USE OF FUEL CELL SYSTEMS ON SHIPS

SECTION 1

GENERAL

A. Application

1. This Guideline is applicable to ships and offshore installations designed or retrofitted with a fuel cell system. Where a fuel cell power system is to be installed, it is to comply with the requirements in this guideline and is to be approved by **TL**.

2. In the case of Fuel Cell (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 **TL** Rules, the additional requirements will be determined within the scope of an individual examination.

3. This Guideline contain functional requirements for all appliances and arrangements related to the usage of fuel cell technology. Appliances and arrangements of fuel cell power systems may deviate from those set out in this Guideline, provided such appliances and arrangements meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant sections. The equivalence of the alternative design should be demonstrated as specified in SOLAS regulation II-1/55 and approved by **TL**. However, **TL** should not allow operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of equipment or type thereof which is prescribed by these Guidelines.

B. Functional Requirements

These Guidelines are related to the goals and functional requirements of the IGF Code. In particular, the following applies:

1. The safety, reliability and dependability of the systems should be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery installations, regardless of the specific fuel cell type and fuel.

2. The probability and consequences of fuel-related hazards should be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions should be initiated.

3. The design philosophy should ensure that risk reducing measures and safety actions for the fuel cell power installation do not lead to an unacceptable loss of power.

4. Hazardous areas should be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board and equipment.

5. Equipment installed in hazardous areas should be minimized to that required for operational purposes and should be suitably and appropriately certified.

6. Fuel cell spaces should be configured to prevent any unintended accumulation of explosive, flammable or toxic gas concentrations.

7. System components should be protected against external damages.

8. Sources of ignition in hazardous areas should be minimized to reduce the probability of explosions.

9. Piping systems and overpressure relief arrangements that are of suitable design, construction and installation for their intended application should be provided.

10. Machinery, systems and components should be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.

11. Fuel cell spaces should be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.

12. Suitable control, alarm, monitoring and shutdown systems should be provided to ensure safe and reliable operation.

13. Fixed leakage detection suitable for all spaces and areas concerned should be arranged.

14. Fire detection, protection and extinction measures appropriate to the hazards concerned should be provided.

15. Commissioning, trials and maintenance of fuel systems and gas utilization machinery should satisfy the goal in terms of safety, availability and reliability.

16. The technical documentation should permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.

17. A single failure in a technical system or component should not lead to an unsafe or unreliable situation.

18. Safe access should be provided for operation, inspection and maintenance.

C. Classification Notations

1. For ships and offshore installations with FC systems conforming to this Guideline 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.

2. 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.

D. Related Rules

1. TL Construction Rules

In addition to these Guidelines, the following **TL** Rules shall apply, if applicable:

Chapter 1 - Hull,

Chapter 4 - Machinery

The following sections of machinery rules apply in particular:
Section 1 - General Rules and Instructions
Section 14 – Pressure Vessels
Section 15 – Oil Burners and Oil Firing Equipment
Section 16 – Pipe Lines, Valves, Fittings and Pumps
Section 18 – Fire Protection and Fire Fighting Equipment
Section 15 - Tankers
Chapter 5 – Electric Installations,
Chapter 19 – Inland Waterway Vessels, Machinery and Electric Rules
Chapter 9 – Construction and Classification of Yachts
Chapter 2 - Material
Chapter 3 - Welding

2. Other Rules

National and international regulations, such as SOLAS, MARPOL, IEC standards etc. shall be observed, if applicable.

E. Definitions

For the purpose of these Guidelines, the terms used have the meanings defined in the following paragraphs. Terms not defined have the same meaning as in SOLAS chapter II-2 and the IGF Code.

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. Certified Safe Type

Certified safe type means electrical equipment that is certified safe by a competent, independent testing laboratory based on a recognized standard.

3. Control Station

Control stations are those spaces in which the vessel’s radio or main navigating equipment or the emergency source of power is located.

4. ESD

ESD is emergency shutdown.

5. Exhaust Gas

Exhaust gas is exhaust from the reformer or anode side of the fuel cell.

6. Exhaust Air

Exhaust air is exhaust from the cathode side of the fuel cell.

7. Fuel Cell

Fuel cell is a source of electrical power in which the chemical energy of a fuel cell fuel is converted directly into electrical and thermal energy by electrochemical oxidation.

8. Fuel Cell Power system

Fuel cell power system is the group of components which may contain fuel or hazardous vapours, fuel cell(s), fuel reformers, if fitted, and associated piping systems.

9. Fuel Cell Power Installation

Fuel cell power installation is the fuel cell power system and other components and systems required to supply electrical power to the ship. It may also include ancillary systems for the fuel cell operation.

10. Fuel Cell Space

Fuel cell space is a space or enclosure containing fuel cell power systems or parts of fuel cell power systems.

11. Fuel Cell Stack

Fuel cell stack means the assembly of cells, separators, cooling plates, manifolds and a supporting structure that electrochemically converts, typically, hydrogen-rich gas and air-reactants to DC power, heat and other reaction products.

12. Fuel Reformer

Fuel reformer is the arrangement of all related fuel-reforming equipment for processing gaseous or liquid primary fuels to reformed fuel for use in the fuel cells.

13. Fuel Containment System

A Fuel Containment System is the arrangement for the storage of fuel including tank connections. It includes, where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure, if necessary, for the support of these elements. If the secondary barrier is part of the hull structure, it may be a boundary of the fuel storage hold space.

The spaces around the fuel tank are defined as follows:

- Fuel storage hold space is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space;

- Interbarrier space is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and

● Tank connection space is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

14. Hazardous Areas

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 6, C.

15. LEL

LEL means lower explosive limit, which, in the context of this Guideline, should be taken as identical to the Lower Flammable Limit (LFL) and which is 4.0% vol. fraction for hydrogen.**(1)**

16. Reformed Fuel

Reformed fuel is hydrogen or hydrogen-rich gas generated in the fuel reformer.

17. Primary Fuel

Primary fuel is fuel supplied to the fuel cell power system.

18. Process Air

Process air is air supplied to the reformer and/or the cathode side of the fuel cell.

19. 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.

20. Protective Systems

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

21. Safe Areas

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

22. Ventilation Air

Ventilation air is air used to ventilate the fuel cell space.

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(1) *For flammability limits for hydrogen refer to ISO /TR 15916:2015 on Basic considerations for the safety of hydrogen systems.*

F. Environmental Conditions

In the selection, design and arrangement of all components of FC systems on seagoing ships, the environmental conditions described in the **TL** Rules, Chapter 4, Machinery, Section 1, C. shall be applied.

For FC systems on inland waterway vessels and pleasure craft, the environmental conditions as per Chapter 19, Inland Waterway Vessels and Chapter 9, Construction and Classification of Yachts shall apply.

G. Documents to be Submitted

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 **TL** approval prior to implementation.

1. General

1.1 General arrangement
1.2 Fuel storage arrangement
1.3 Fuel supply system arrangements
1.4 Fuel bunkering station arrangements
1.5 Fire protection arrangement
1.6 Hazardous area classification plan

2. Risk Assessment of the System

2.1 A risk assessment method in accordance with an appropriate standard is to be identified and agreed upon by **TL**. The fuel cell power system integrator or the supplier are to submit the proposed method. The submitter is to include relevant data from system suppliers.

2.2 The risk assessment is to identify and evaluate the hazards associated with each function of the fuel cell power system throughout its lifecycle.

2.3 Based on the risk assessment results, a revised system category may have to be agreed among **TL** and the system integrator or the supplier.

3. Fuel cell system

3.1 Before production of the FC system commences:

3.1.1 description of the process and function of the FC system

3.1.2 piping and instrumentation diagrams, with block circuit diagrams of the overall system, including parts lists or equipment lists

3.1.3 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)

3.1.4 electrical circuit diagrams, including the circuit diagrams of the alarm system and the protective system

3.1.5 automation concept

3.1.6 fire extinguishing concept

3.1.7 plans of the hazardous areas (Ex zones)

3.1.8 safety and emergency concept, including a safety analysis according to recognized procedures, e.g. fault tree analysis.

3.2 Before the trials according to Section 9:

3.2.1 operation manual

3.2.2 trials programme

H. Onboard Documentation

1. General

At a minimum, the following drawings and data are to be kept on board for reference by the operator for system operation and troubleshooting, maintenance, repair and safety

1.1 Operations and Maintenance Manual for Fuel cell power system (fuel cell module, instrumentation, control and monitoring)

1.2 Fuel cell power system Maintenance Schedule

1.3 Fuel cell power system Functional Testing Schedule

1.4 Safety Training for Fuel

1.5 Possible safety critical scenarios including fire and explosion

1.6 Drill and emergency exercises conduction.

I. Operation and Maintenance Manuals

1. Operation Manual

The operating manual is to denote the safety measures provided and detail proper procedures for the set-up and use of

the fuel cell power system. Particular attention is to be given to the safety measures provided and the anticipated methods of operation.

2. Maintenance Manual

The maintenance manual is to detail proper procedures for the adjustment, servicing, preventive inspection, and repair of the fuel cell. Recommendations on maintenance/servicing records are to be part of the maintenance manual. Where methods for the verification of proper operation are provided (for example, software testing programs), the use of such methods are to be detailed.

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 **TL**. The use of combustible materials within the fuel cell power system should be kept to a minimum.**TL** Material Rules shall be observed.

B. Approved Materials and Material Tests

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

– **TL** Machinery Rules, Chapter 4, Section 14 and Section 16

– **TL** Inland Waterway Vessels, Chapter 19, Section 12

– **TL** Pleasure Craft, Chapter 9, Section 7

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

SECTION 3

DESIGN PRINCIPLES FOR FUEL CELL POWER INSTALLATIONS

A. Fuel Cell Spaces

1. Fuel cell space concept

1.1 In order to minimize the probability of a gas explosion in a fuel cell space, it should meet the requirements of this section, or an equivalent safety concept.

1.2 The fuel cell space concept is such that the space is designed to mitigate hazards to non-hazardous levels under normal conditions, but under certain abnormal conditions may have the potential to become hazardous.

1.3 Equipment protected fuel cell spaces - area classification according to Section 6,B: such fuel cell spaces are considered as hazardous zone 1 and all electrical equipment should be certified for zone 1. The fuel cell stack itself is not considered a source of ignition if the surface temperature of the stack is kept below 300°C **(1)** in all operating conditions and the fuel cell power system should be capable of immediately isolating and de-energizing the fuel cell stack under every load and operating condition.

1.4 In specific cases where the Administration considers the prescriptive area classification to be inappropriate, area classification according to IEC 60079-10-1:2020 should be applied according to Section 6, B.1 taking into account the following guidance: All electrical equipment needs to comply with the resulting area classification.

1.5 In specific cases where the Administration accepts inerting according to D.3, the following guidance should be taken into account: As ignition hazards are mitigated by inerting, there is no need for an immediate (emergency) shutdown of the fuel supply in case of leakage detection. In case of leakage detection, automatic changeover to the other power supply systems should take place and a controlled shutdown of the fuel cell and the affected fuel supply system should be initiated in order thereby to avoid damage to the fuel cell power system.

2. The design of fuel cell power systems should comply with industry standards at least equivalent to those acceptable to the Organization. **(2)**

B. Fuel Cell Power System

1. General Requirements

1.1 Accessible parts of the fuel cell power system are to have no sharp edges, sharp angles or rough surfaces likely to cause injury.

1.2 The easily accessed parts of the fuel cell power system are to be designed and constructed to prevent slipping, tripping or falling hazards.

1.3 The fuel cell power system, components and fittings are to be designed and constructed so that they are stable enough, under the foreseen operating conditions for use without risk of overturning, falling or unexpected movement. Otherwise, appropriate means of anchorage are to be incorporated and indicated in the instructions.

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(1) *The 300°C threshold is taken from ISO/IEC 80079-20-1:2017, where the maximum surface temperature is set to 450°C for Hydrogen and LNG and 300°C for methyl/ethyl alcohol and LPG. To ensure safe operation of fuel cell power systems regardless of the fuel cell and fuel type, these guidelines refer to the lowest threshold for the relevant fuels mentioned in the ISO/IEC 80079-20-1:2017, that is 300°C.*

(2) *Refer to IEC 62282 series: 62282-2-100:2020 and 62282-3-100:2019.*

1.4 The moving parts of the fuel cell power system are to be designed, built and arranged to avoid hazards or, where hazards persist, fixed with guards or protective devices in such a way to prevent all risk of contact.

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

1.6 The fuel cell power system is to be designed, constructed and/or equipped so that risks due to gases, liquids, dust or vapors released during the operation or maintenance of a fuel cell power system are avoided.

1.7 All parts are to be securely mounted or attached and rigidly supported. The use of shock-mounts is permitted when suitable for the application.

1.8 All safety shutdown system components, whose failure may result in a hazardous event are to be recognized, certified or separately tested for their intended usage.

1.9 The manufacturer is to take steps to eliminate any risk of injury caused by contact with, or proximity to, external surfaces of the fuel cell power system enclosure, handle, grips or knobs at high temperatures.

2. Standards

For functional safety, the required installation level, performance level or the class of test and control function are to be determined and designed in accordance with following standards:

- IEC 62282-3-100, applicable to marine power safety systems
- IEC 62282-3-200 for operational and environmental aspects of stationary fuel cell power systems performance

C. Arrangement and Access

1. Fuel cell power installations should be designed for automatic operation and equipped with all the monitoring and control facilities required for safe operation of the system.

2. It should be possible to shut down the fuel cell power system from an easily accessible location outside the fuel cell spaces.

3. Means to safely remove the primary and reformed fuel from the fuel cell power system should be provided.

4. Means should be provided to set a fuel cell power installation into a safe state for maintenance and shutdown.

5. For the auxiliary systems of the fuel cell power system where primary fuel or reformed fuel may leak directly into a system medium (e.g. cooling water), such auxiliary systems should be equipped with appropriate extraction and detection means fitted as close as possible after the media outlet from the system in order to prevent gas dispersion. Gas extracted from the auxiliary system media should be vented to a safe location on the open deck.

6. The reforming equipment, if fitted, may be an integrated part of the fuel cell or arranged as an independent unit with reformed fuel piping connected to the fuel cell(s).

7. Fuel cell space boundaries should be gastight towards other enclosed spaces in the ship.

8. Fuel cell spaces should be arranged outside of accommodation spaces, service spaces, machinery spaces of category A and control stations.

9. Fuel cell spaces should be designed to safely contain fuel leakages and they should be provided with suitable leakage detection systems and should be arranged to avoid the accumulation of hydrogen-rich gas **(3)** by having simple geometrical shape and no obstructing structures in the upper part.

10. Fuel cell spaces containing fuel reformers should also comply with the requirements relevant for the primary fuel.

11. Where an independent and direct access to the fuel cell spaces from the open deck cannot be arranged, access to fuel cell spaces should be through an air lock.

12. An air lock is not required if appropriate technical provisions are made such that access to the space is not required and not made possible before the equipment inside is safely shut down, isolated from the fuel system, and drained of leakages and the inside atmosphere is confirmed gas-free.

13. These provisions include but are not limited to:

13.1 all controls required for safe operation and gas freeing of the equipment and space should be provided for remote operation from outside the space;

13.2 all parameters required for safe operation and gas freeing should be remotely monitored and alarms should be given;

13.3 the space openings should be equipped with an interlock preventing operation with the space open;

13.4 the spaces should be provided with suitable fuel leakage collection and draining arrangements for remote operation from outside the space; and

13.5 provisions should be made that the fuel equipment inside can be isolated from the fuel system, drained of fuel and purged safely for maintenance.

D. Atmospheric Control of Fuel Cell Spaces

1. General

Protection of fuel cell spaces by an external boundary that encloses components where fuel is fed can be achieved by ventilation or inerting. These methods should be equally acceptable to ensure the safety of the space.

2. Ventilation of Fuel Cell Spaces

2.1 Fuel cell spaces should be equipped with an effective mechanical ventilation system to maintain underpressure of the complete space, taking into consideration the density of potentially leaking fuel gases.

(3) *See also IEC 60079-10-1:2020.*

2.2 For fuel cell spaces on open decks, overpressure ventilation may be considered.

2.3 The ventilation rate in fuel cell spaces should be sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios owing to technical failures.

2.4 Any ducting used for the ventilation of fuel cell spaces should not serve any other space.

2.5 Ventilation ducts from spaces containing reformed fuel piping or release sources should be designed and arranged such that any possibility for gas to accumulate is avoided.

2.6 Two or more fans should be installed for the ventilation of the fuel cell space providing 100% redundancy upon loss of one fan. 100% ventilation capacity should also be supplied from the emergency source of power.

2.7 In case of failure of one fan, automatic changeover to another fan should be provided and indicated by an alarm.

2.8 In case of loss of ventilation or loss of underpressure in the fuel cell space the fuel cell power system should carry out an automatic, controlled shutdown of the fuel cell and isolation of the fuel supply.

2.9 Ventilation air inlets for fuel cell spaces should be taken from areas which, in the absence of the considered inlet, would be non-hazardous.

2.10 Ventilation air inlets for non-hazardous enclosed spaces should be taken from non-hazardous areas located at least 1.5 m away from the boundaries of any hazardous area.

2.11 Ventilation air outlets from fuel cell spaces should be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

3. Inerting of Fuel Cell Spaces For Fire Protection Purposes

3.1 Inerting should be accepted for atmospheric control of the fuel cell spaces provided that:

3.1.1 Protection by inerting is only acceptable where a fuel cell space is not possible to enter during inerting or when inerted, and sealing arrangements should ensure that leakages of inert gas to adjacent spaces are prevented;

3.1.2 The inerting system complies with chapter 15 of the Fire Safety Systems Code (FSS Code) and paragraphs 6.13 and 6.14 of the IGF Code;

3.1.3 The pressure of inerting media should always be kept positive and monitored;

3.1.4 Any change in the pressure, indicating a breach of the external outer boundary of fuel cell space, or a breach of the boundary with a space where fuel is flowing (e.g. fuel cell stack, reformer) should activate a controlled shut-off of the fuel supply;

3.1.5 Fuel cell space should be equipped with a mechanical ventilation to evacuate the inerting agent, after an inerting release has been initiated;

3.1.6 Access to the inerted fuel cell space should only be possible when the space is completely ventilated by fresh air and the fuel supply is interrupted and depressurized or purged; and

3.1.7 The inerting system should not be operable under ongoing maintenance or inspection.

E. Piping Arrangement for Fuel Cell Power System

All pipes containing hydrogen or reformed fuel for fuel cell power systems, where fitted, should:

1. not be led through enclosed spaces outside of fuel cell spaces;

2. be fully welded as far as practicable;

3. be arranged to minimize the number of connections; and

4. use fixed hydrogen detectors being capable of detecting a hydrogen leak in places where leakage of hydrogen may occur, such as valves, flanges and seals.

F. Exhaust Gas and Exhaust Air

Exhaust gases and exhaust air from the fuel cell power systems should not be combined with any ventilation except ventilation serving fuel cell spaces and should be led to a safe location in the open air.

SECTION 4

SHIP ARRANGEMENTS AND INSTALLATION REQUIREMENTS

A. General

The requirements specified in this section provide general guidance on ship arrangements and installation of fuel cell power systems.

B. Location and Separation of Spaces

1. Fuel Cell Space

1.1 Fuel cell space as machinery space of category A

The fuel cell space is to be regarded as a Category A machinery space according to SOLAS Chapter II-2, and IGF Code. Additionally, the space is to be bounded by “A-60” class divisions on all sides adjoining control stations, evacuation stations, escape routes, accommodation spaces, stairways, corridors and machinery spaces. The fire-extinguishing system is to be suitable for use with the specific fuel and fuel cell technology proposed.

1.2 Fuel cell space classification

In order to minimize the probability of a gas explosion in a fuel cell space, this is to be designed to mitigate hazards to lower hazardous levels under all operation conditions. Due to the nature of hydrogen leaks within the fuel cell stacks, the fuel cell space is to be classified as a hazardous area Zone 1. Therefore, equipment or components installed in this space are to be of a certified safe type.

2. Arrangement of Fuel Cell Spaces

2.1 Fuel cell space

See Section 3, C.

2.2 Fuel preparation rooms and pumps

2.2.1 Fuel preparation rooms are to be located outside Category A machinery spaces with ventilation of at least 30 air changes per hour. These rooms are to be gas tight and liquid tight to surrounding enclosed spaces and vented to open air.

2.2.2 Hydraulically powered pumps that are submerged in fuel tanks are to be arranged with double barriers preventing the hydraulic system serving the pumps from being directly exposed to fuels. The double barrier is to be arranged for detection and drainage of eventual fuel leakage.

2.2.3 All pumps in the fuel system are to be protected against running dry. All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit.

SECTION 5

FIRE SAFETY

A. General

1. General Provisions on Fire and Explosion Safety

Fuel cell spaces should be designed to provide a geometrical shape that will minimize the accumulation of gases or formation of gas pockets.

1.1 The fuel cell space should be regarded as a machinery space of category A according to SOLAS chapter II-2 for fire protection purposes.

1.2 The fire-extinguishing system should be suitable for use with the specific fuel and fuel cell technology. Administrations may allow any alternative fire safety measures if the equivalence of the measure is demonstrated by a risk assessment considering the characteristics of fuels for use.

1.3 A fixed fire detection and fire alarm system complying with the FSS Code should be provided.

1.4 The type and arrangement of the fire detection system should be selected with due consideration of the fuels and combustible gases which may be present in fuel cell power installations.

1.5 Fuel cell spaces should be fitted with suitable **(1)** fire detectors. Smoke detectors alone are not considered sufficient for rapid detection of a fire when gaseous fuels are used.

1.6 A fuel cell space should be bounded by "A-60" class divisions. Where this is deemed to be impracticable, TL may approve alternative boundary designs that provide for an equivalent level of safety.

2. Fire and explosion protection

2.1 Fuel cell spaces separated by a single bulkhead should have sufficient strength to withstand the effects of a local gas explosion in either space, without affecting the integrity of the adjacent space and equipment within that space.

2.2 Failures leading to dangerous overpressure, e.g. gas pipe ruptures or blow out of gaskets, should be mitigated by suitable explosion pressure relief devices and ESD arrangements.

2.3 The probability of a gas accumulation and explosion in fuel cell spaces should be minimized by a mitigating strategy which may include one or more of the below:

2.3.1 purging the fuel cell power system before initiating the reaction;

2.3.2 purging the system as necessary after shutdown;

2.3.3 providing failure monitoring in the fuel cell fuel containment systems;

2.3.4 monitoring potential contamination of air into fuel cells fuel lines, or fuel cells fuel into air pipes;

2.3.5 monitoring pressures and temperatures;

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(1) *For the selection of suitable fire detectors, ISO/TR 15916:2015 can be taken into account.*

2.3.6 implementing a pre-programmed sequence to contain or manage the propagation of the reaction to other sections of the fuel cell system or to the surrounding space; and

2.3.7 any other strategy to the satisfaction of the Administration.

B. Structural Fire Protection

1. For the purposes of fire protection, fuel preparation rooms are to be regarded as Category A machinery spaces.

2. Any boundary of accommodation including navigation bridge windows, service spaces, control stations, machinery spaces, and escape routes facing fuel tanks on open deck are to have a fire integrity class of A-60. This may be waived, provided that a minimum safe distance between the above spaces and the fuel tank space has been determined, and that appropriate documentation is submitted to **TL** for consideration.

3. The fire integrity of fuel tank cofferdam boundaries facing high fire risk spaces such as machinery spaces and similar are to be separated by a cofferdam of at least 900 mm with insulation of A-60 class.

4. The bunkering station is to be separated by A-60 class divisions between Category A machinery spaces, accommodations, control stations and high fire risk spaces except for spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, and sanitary and similar spaces where the boundary may be reduced to class A-0.

C. Fire Extinguishing System

1. General

1.1 A fixed fire-extinguishing system should be required for fuel cell spaces.

1.2 The fire-extinguishing system should be suitable for use with the specific primary and reformed fuel and fuel cell technology proposed.

1.3 Fixed fire-extinguishing systems should be selected having due regard to the fire growth potential of the protected spaces and are to be readily available..

2. Fire Main

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

3. Machinery spaces

3.1 Machinery spaces and fuel preparation rooms where fuel pumps are arranged are to be protected by an approved fixed fire extinguishing system in accordance with SOLAS Reg.II-2/10 and the FSS Code. In addition, the fire extinguishing medium used is to be suitable for the specific fuel.

3.2 An approved alcohol resistant foam system covering the tank top and bilge area under the floor plates are to be arranged for Category A machinery spaces and fuel preparation rooms containing the specific fuels.

4. Fire Dampers

4.1 Air inlet and outlet openings should be provided with fail-safe automatic closing fire dampers which should be operable from outside the fuel cell space.

4.2 Before actuation of the fire-extinguishing system, the fire dampers should be closed.

SECTION 6

ELECTRICAL SYSTEMS

A. General

1. Electrical equipment should not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

2. Where electrical equipment including components of fuel cell systems is installed in hazardous areas it should be selected, installed and maintained in accordance with standards at least equivalent to those acceptable to the Organization **(1)**.

3. Means should be provided for protection of the fuel cell installation against short circuits and flow of reverse current.

4. Cable penetrations are to satisfy the requirements regulating the dispersion of gas.

5. The lighting system in hazardous areas is to be divided between at least two branch circuits. All switches and protective devices are to interrupt all poles or phases and are to be located in a nonhazardous area.

6. The installation of the electrical equipment units is to provide the safe bonding to the hull of the units themselves.

7. Hoses, transfer arms, piping and fittings provided by the delivering facility used for bunkering are to be electrically continuous, suitably insulated and are to provide a level of safety compliant with recognized standards.

B. Area Classification

1. In order to facilitate the selection of the appropriate electrical equipment and the design of suitable electrical installations, hazardous areas are divided into Zones 0, 1 and 2 according to C.1, C.2 and C.3. In cases where the prescriptive provisions in C.1, C.2 and C.3 are deemed to be inappropriate, area classification according to IEC 60079-10-1:2020 should be applied with special consideration by TL.

2. Means are to be provided for protection of the fuel cell installation against short circuits and flow of reverse current.

C. Hazardous Area Zones

1. Hazardous Area Zone 0

The following areas should be treated as hazardous area zone 0: the interiors of buffer tanks, reformers, pipes and equipment containing low-flashpoint fuel or reformed fuel, any pipework of pressure relief or other venting.

2. Hazardous Area Zone 1

The following areas should be treated as hazardous area zone 1:

2.1 Areas on open deck, or semi-enclosed spaces on deck, within 3 m of any hydrogen or reformed fuel or purge gas outlets or fuel cell space ventilation outlets.

(1) *Refer to standards IEC 60079-10-1:2020 Explosive atmospheres Part 10-1: Classification of areas – Explosive gas atmospheres and guidance and informative examples given in IEC 60092-502:1999, Electrical Installations in Ships – Tankers – Special features for tankers.*

2.2 Areas on open deck, or semi-enclosed spaces on deck, within 3 m of fuel cell exhaust air and exhaust gas outlets.

2.3 Areas on open deck or semi-enclosed spaces on deck within 1.5 m of fuel cell space entrances, fuel cell space ventilation inlets and other openings into zone 1 spaces.

2.4 Areas on open deck or semi-enclosed spaces within 3 m in which other sources of release of hydrogen or reformed fuel are located.

2.5 Fuel cell spaces.

3. Hazardous Area Zone 2

The following areas should be treated as hazardous area zone 2:

3.1 Areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1 as specified above, if not otherwise specified.

3.2 Air locks.

4. Ventilation Ducts

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

D. Risk Analysis

1. For any new or altered concept or configuration of a fuel cell power installation a risk analysis should be conducted in order to ensure that any risks arising from the use of fuel cells affecting the integrity of the ship are addressed. Consideration should be given to the hazards associated with installation, operation and maintenance, following any reasonably foreseeable failure.

2. The risks should be analysed using acceptable and recognized risk analysis techniques and mechanical damage to components, operational and weather-related influences, electrical faults, unwanted chemical reactions, toxicity, auto-ignition of fuels, fire, explosion and short-term power failure (blackout) should as a minimum be considered. The analysis should ensure that risks are eliminated wherever possible. Risks which cannot be eliminated should be mitigated as necessary.

SECTION 7

CONTROL, MONITORING and SAFETY SYSTEMS

A. General Provisions on Control, Monitoring and Safety Systems

1. Safety-related parts of the fuel cell control systems should be designed independent from any other control and monitoring systems or should comply with the process as described in industry standards acceptable to **TL** (refer to ISO 13849-1:2015-06) for the performance level or equivalent.

2. The fuel cell should be monitored according to the manufacturer's recommendations.

B. Gas or Vapour Detection

1. A permanently installed gas/vapour detection system should be provided for:

1.1 fuel cell spaces;

1.2 air locks (if any);

1.3 expansion tanks/degassing vessels in the auxiliary systems of the fuel cell power system where primary fuel or reformed fuel may leak directly into a system medium (e.g. cooling water); and

1.4 other enclosed spaces where primary/reformed fuel may accumulate.

2. The detection systems should continuously monitor for gas/vapour. The number of detectors in the fuel cell space should be considered taking into account the size, layout and ventilation of the space. The detectors should be located where gas/vapour may accumulate and/or in the ventilation outlets. Gas dispersal analysis or a physical smoke test should be used to find the best arrangement.

3. Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of the self-monitoring type, the installation of a single gas detector can be permitted.

C. Ventilation Performance

In order to verify the performance of te ventilation system, a detection system of the ventilation flow and of the fuel cell space pressure should be installed. A running signal from the ventilation fan motor is not sufficient to verify performance.

D. Bilge Wells

Bilge wells in fuel cell spaces should be provided with level sensors.

E. Manual Emergency Shutdown

1. Manual activation of emergency shutdown should be arranged in the following locations as applicable:

1.1 navigation bridge;

1.2 onboard safety centre;

1.3 engine control room

1.4 fire control station; and

1.5 adjacent to the exit of the fuel cell space.

F. Actions of the Alarm System and Safety System

1. Gas or Vapour Detection

1.1 Gas/vapour detection in a fuel cell space above a gas or vapour concentration of 20% LEL should cause an alarm.

1.2 Gas/vapour detection in a fuel cell space above a gas or vapour concentration of 40% LEL should shut down the affected fuel cell power system and disconnect ignition sources and should result in automatic closing of all valves required to isolate the leakage. If not certified for operation in zone 1 hazardous areas, the fuel cell stack should be immediately electrically isolated and de-energized. Valves in the primary fuel system supplying liquid or gaseous fuel to the fuel cell space should close automatically.

1.3 Gas/vapour detection should be provided in the fuel cell's coolant "supply/header" tank, and this should cause an alarm.

2. Liquid Detection

Detection of unintended liquid leakages in the fuel cell space should trigger an alarm. A possible means of detection would be a bilge high-level alarm.

3. Loss of Ventilation

3.1 Loss of ventilation in a fuel cell space should result in an automatic shutdown of the fuel cell by the process control within a limited period of time. The period for the shut down by process control should be considered on a case-by-case basis based on the risk analysis.

3.2 After the period has expired, a safety shutdown should be carried out.

4. Emergency Shutdown Push Buttons

Actuation of the emergency shutdown push button should interrupt the fuel supply to the fuel cell space and de-energize the ignition sources inside the fuel cell space.

5. Loss of Fuel Cell Coolant

Loss of fuel cell coolant should result in an automatic shutdown of the fuel cell by the process control within a limited period of time. To prevent a potential coolant release in the fuel cell space, a secondary containment of the coolant pipe should be provided or the equipment within the fuel cell space should be protected from a coolant release. Consideration should be given to the safe removal of the coolant.

6. Fire Detection

Fire detection within the fuel cell space should initiate automatic shutdown and isolation of the fuel supply.

7. Fue Cell High-temperature Shutdown

For fuel cell spaces rated as hazardous zone 1 where the fuel cell stack is not certified for operation in hazardous zone 1 and the surface temperature of the fuel cell stack exceeds 300°C, the fuel cell power system should immediately shut down and isolate the affected fuel cell space.

G. Alarms

1. The alarm provisions in subsection F, as well as Table 7.1, specify fuel cell power installation alarms.

2. Alarms additional to the ones required by Table 7.1 may be recommended for unconventional or complex fuel cell power installations.

Table 7.1 Alarms

	Alarm conditions
Gas detection at 20% LEL	
Fuel cell spaces	HA
Expansion tanks/degassing vessels in systems fır heating/cooling	HA
Air locks	HA
Other enclosed spaces where primary/refored fuel may accumulate	HA
Liquid detection	
Fuel cell space as per F.1.2	HA
Ventilation	
Reduced ventilation in fuel cell spaces	LA
Other alarm conditions	
Air lock, more than one door moved from closed position	A
Air lock, door open at loss of ventilation	A
A= Alarm activated for logical value LA= Alarm for low value HA= Alarm for high vaue	

H. Safety Actions

1. The safety action provisions in subsection F and Table 7.2 specify fuel cell power installations safety actions to limit the consequences of system failures.

2. Safety actions additional to those required by Table 7.2 may be recommended for unconventional or complex fuel cell power installations.

Table 7.2 Safety actions

	Alarm	Shutdown of fuel cell space valve	Shutdown of ignition source	Signal to other control/safety systems for additional action
Loss of fuel cell coolant as per F.5	X	X		
40% LEL insde fuel cell space (includes detection of hydrogen leaks	X	X	X	If not certified for operation in zone 1 hazardous areas, the fuel cell stack should be immediately electrically isolated and de-energized
Loss of ventilation or loss of negative pressure in a fuel cell space	X	X		The fuel cell should be automatically shut down by process control
Fire detection within the fuel cell space	X	X	X	Shutdown of ventilation, release of fire-extinguishing system
Emergency shutdown button	X	X	X	
Fuel cell stack surface temperature > 300°C	X	X	X	If fuel cell stack is not certified for zone 1

SECTION 8

TESTS and TRIALS

A. General

1. FC systems are subject to the construction supervision and acceptance testing by **TL**. 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.

2. **TL** 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 **TL**.

B. Test Steps

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

1. Evaluation of the technical concept

2. 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.

3. Manufacturing tests, pressure tests and if applicable functional tests of parts and componets.

4. Factory test of control, regulating and protective devices at the manufacturer.

5. Functional test and completeness check of the alarm and protective systems.

6. Functional test and acceptance test of the overall system, including pressure and tightness tests and completeness checks.

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.

C. Pressure and Tightness Test

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.

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

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

D. Trials of the System

1. General

Before the trials commence, a detailed trial programme shall be compiled. The trial programme is subject to approval by **TL**.

2. Trials of the Entire System

The FC system is to be subjected to the following trials after installation on board.

2.1 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.

2.2 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.

2.3 Trials of the fire extinguishing system

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

2.4 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

2.5 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.

SECTION 9

SURVEYS AFTER CONSTRUCTION

A. General

The fuel cell power systems are to be maintained in satisfactory condition. This section pertains to periodical surveys after construction for the equipment described in Section 1 to Section 8 of this Guide.

B. Surveys

1. Annual Survey

The following items are to be carried out at annually:

1.1 Logbooks/Records

The logbooks and operating records are to be examined with regard to correct functioning of the gas detection systems, liquid fuel /gas systems, tracking the fuel cells operation hours, etc. The hours per day of the re-liquefaction plant, gas combustion unit, as applicable, the boil-off rate, and nitrogen consumption (for membrane containment systems) are to be considered together with gas detection records.

1.2 Operating and Maintenance Instruction Manuals

The manufacturer/builder instructions and manuals covering the operations, safety and maintenance requirements and occupational health hazards relevant to fuel storage, fuel bunkering, and fuel supply and associated systems for the use of the fuel, are to be confirmed as being available on board the vessel.

1.3 Control, Monitoring and Safety Systems

1.3.1 Gas detection and other leakage detection equipment in compartments containing fuel storage, fuel bunkering, and fuel supply equipment or components or associated systems is to be confirmed in satisfactory operating condition. Recalibration of the gas detection systems is to be verified in accordance with the manufacturers' recommendations.

1.3.2 Verification of the satisfactory operation of the control, monitoring and automatic shutdown systems of the fuel supply and bunkering systems.

1.3.3 Operational test, as far as practicable, of the shutdown of ESD protected machinery spaces.

1.4 Fuel Handling Piping, Machinery and Equipment

Piping, hoses, emergency shut-down valves, remote operating valves, relief valves, machinery and equipment for fuel storage, fuel bunkering, and fuel supply such as venting, compressing, refrigerating, reliquefaction, heating, cooling or otherwise handling the fuel are to be examined, as far as practicable. Means for inerting is to be examined. Stopping of pumps and compressors upon emergency shutdown of the system is to be verified as far as practicable.

1.5 Ventilation System

Examination of the ventilation system, including portable ventilating equipment where fitted, is to be made for spaces containing fuel storage, fuel bunkering, and fuel supply units or components or associated systems, including air locks,

pump rooms, compressor rooms, fuel preparation rooms, fuel valve rooms, control rooms and spaces containing gas burning equipment. Where alarms, such as differential pressure and loss of pressure alarms, are fitted, these should be operationally tested as far as practicable.

1.6 Drip Trays

Portable and fixed drip trays and insulation for the protection of the ship's structure in the event of leakage are to be examined.

1.7 Hazardous Areas

Electrical equipment and bulkhead/deck penetrations including access openings in hazardous areas are to be examined for continued suitability for their intended service and installation area.

1.8 Fire Protection and Fire Extinguishing Equipment

The required fire protection and fire extinguishing system contained in areas and spaces where fuel storage, fuel bunkering, and fuel supply are fitted are to be examined and operationally tested, in so far as practicable.

1.9 Electrical Bonding

Electrical bonding arrangements in hazardous areas, including bonding straps where fitted, are to be examined.

1.10 Fuel Storage, Bunkering and Supply Systems

The following are to be examined, so far as applicable. Insulation need not be removed, but any deterioration or evidence of dampness is to be investigated:

1.10.1 Fuel Storage

- External examination of the storage tanks including secondary barrier if fitted and accessible.
- General examination of the fuel storage hold place.
- Internal examination of tank connection space.
- External examination of tank and relief valves.
- Verification of satisfactory operation of tank monitoring system.
- Examination and testing of installed bilge alarms and means of drainage of the compartment.
- Testing of the remote and local closing of the installed main tank valve.

1.10.2 Fuel Bunkering System

- Examination of bunkering stations and the fuel bunkering system.
- Verification of satisfactory operation of the fuel bunkering control, monitoring and shutdown systems.

1.10.3 Fuel Supply System

- Examination of the fuel supply system during working condition as far as practicable.
- Verification of satisfactory operation of the fuel supply system control, monitoring and shut-down systems.
- Testing of the remote and local closing of the master fuel valve for each engine compartment.

2. Special Survey

In addition to the above annual survey items, the following items are to be carried out during the special survey:

2.1 Fuel Handling and Piping

All piping for fuel storage, fuel bunkering, and fuel supply such as venting, compressing, refrigerating, liquefying, heating storing, burning or otherwise handling the fuel and liquid nitrogen installations are to be examined. Removal of insulation from the piping and opening for examination may be required. Where deemed suspect, a hydrostatic test to 1.25 times the Maximum Allowable Relief Valve Setting (MARVS) for the pipeline is to be carried out. After reassembly, the complete piping is to be tested for leaks. Where water cannot be tolerated and the piping cannot be dried prior to putting the system into service, the Surveyor may accept alternative testing fluids or alternative means of testing.

2.2 Fuel Valves

All emergency shut-down valves, check valves, block and bleed valves, master gas valves, remote operating valves, isolating valves for pressure relief valves in the fuel storage, fuel bunkering, and fuel supply piping systems are to be examined and proven operable. A random selection of valves is to be opened for examination.

2.3 Pressure Relief Valves

2.3.1 Fuel Storage Tank Pressure Relief Valves

The pressure relief valves for the fuel storage tanks are to be opened for examination, adjusted, and function tested. If the tanks are equipped with relief valves with non-metallic membranes in the main or pilot valves, such non-metallic membranes are to be replaced.

2.3.2 Fuel Supply and Bunkering Piping Pressure Relief Valves

Pressure relief valves for the fuel supply and bunkering piping are to be opened for examination, adjusted, and function tested. Where a proper record of continuous overhaul and retesting of individually identifiable relief valves is maintained, consideration will be given to acceptance on the basis of opening, internal examination, and testing of a representative sampling of valves, including each size and type of liquefied gas or vapor relief valve in use, provided there is logbook evidence that the remaining valves have been overhauled and tested.

2.3.3 Pressure/Vacuum Relief Valves

The pressure/vacuum relief valves, rupture disc and other pressure relief devices for interbarrier spaces and hold spaces are to be opened, examined, tested and readjusted as necessary, depending on their design.

2.4 Electrical Equipment

2.4.1 Examination of electrical equipment to include the physical condition of electrical cables and supports, intrinsically safe, explosion proof, or increased safety features of electrical equipment.

2.4.2 Functional testing of pressurized equipment and associated alarms.

2.4.3 Testing of systems for de-energizing electrical equipment which is not certified for use in hazardous areas.

2.4.4 An electrical insulation resistance test of the circuits terminating in, or passing through, the hazardous zones and spaces is to be carried out.

2.5 Safety Systems

Gas detectors, temperature sensors, pressure sensors, level indicators, and other equipment providing input to the fuel safety system are to be tested to confirm satisfactory operating condition.

2.5.1 Proper response of the fuel safety system upon fault conditions is to be verified.

2.5.2 Pressure, temperature and level indicating equipment are to be calibrated in accordance with the manufacturer's requirements.

2.6 Fuel Storage Tanks

Fuel storage tanks and liquefied gas fuel storage tanks are to be examined.