2024

Guidance for Fuel Cell Systems on Board Ships

KR

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GC-12-E

KR

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

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2024.
2. The amendments to the Guidance for 2023 edition and their effective date are as follows;

Effective Date 1 July 2024 (Date of contract for construction)

CHAPTER 1 GENERAL

Section 1 General
- 103. 1 has been amended.

CHAPTER 2 CONSTRUCTION AND INSTALLATION

Section 1 General
- 101. has been amended.

Section 4 Electrical Systems
- 401. 4 has been newly added.

Section 5 Control, Monitoring and Safety Systems
- 506. 6 has been amended.

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CHAPTER 1 GENERAL

Section 1 General

101. Application *(2020)*

1. This Guidance is to apply to with fuel cell power installations on board ships used as auxiliary or main source of power.

2. The scope of this Guidance mainly covers the requirements for the arrangement and design of fuel cell power installations in **102. 3** (6) and the spaces containing such installations. Regulations such as storage, preparation, distribution, etc. of fuel other than this guidance are to be covered by the relevant regulations of **Rules for Ships using Low-flashpoint Fuels** depending on the fuel used. *(2022)*

3. Items not specified in this Guidance relating to fuel cell power installation are to be in accordance with each relevant requirement in **Rules for the Classification of Steel Ships** except for the requirements inapplicable to fuel cell power installations in ships.

4. Items not included in this Guidance may comply with ISO, IEC, KS or equivalent standards as deemed appropriate by the Society.

5. Additional requirements to this Guidance may be required.

102. General *(2020)*

1. Goal

The goal of this Guidance is to provide safe and reliable delivery of electrical and/or thermal energy through the use of fuel cell technology.

2. Functional requirements

This Guidance is related to the goals and functional requirements of **Rules for Ships using Low-flashpoint Fuels**. In particular, the following apply.

(1) The safety, reliability and dependability of the systems are to be equivalent to those 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 are to 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 are to be initiated.
(3) The design philosophy is to 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 are to 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 is to be minimized to that required for operational purposes and is to be suitably and appropriately certified.
(6) Fuel cell spaces are to be configured to prevent any unintended accumulation of explosive, flammable or toxic gas concentrations.
(7) System components are to be protected against external damages.
(8) Sources of ignition in hazardous areas are to 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 is to be provided.
(10) Machinery, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.
(11) Fuel cell spaces are to 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 are to be provided to ensure safe and reliable operation.

(13) Fixed leakage detection suitable for all spaces and areas concerned is to be arranged.
(14) Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided.
(15) Commissioning, trials and maintenance of fuel systems and gas utilization machinery are to satisfy the goal in terms of safety, availability and reliability.
(16) The technical documentation is to 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 is not to lead to an unsafe or unreliable situation.
(18) Safe access is to be provided for operation, inspection and maintenance.

3. Definitions

For the purpose of these Guidances, 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 **Rules for Ships using Low-flashpoint Fuels**.

(1) **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.
(2) **Fuel cell stack** is an 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. *(2022)*
(3) **Fuel cell module** is an assembly incorporating one or more fuel cell stacks and, if applicable, additional components, which is intended to be integrated into a power system or a vehicle. A fuel cell module comprises the following main components: one or more fuel cell stack(s), a piping system for conveying fuels, oxidants and exhausts, electric connections for the power delivered by the stack(s) and means for monitoring, control or both. Additionally, a fuel cell module can comprise: means for conveying additional fluids (e.g. cooling media, inert gas), means for detecting normal and abnormal operating conditions, enclosures or pressure vessels and module ventilation systems, and the required electronic components for module operation and power conditioning. *(2022)*
(4) **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.
(5) **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.
(6) **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. (refer to **Fig 1.1**)

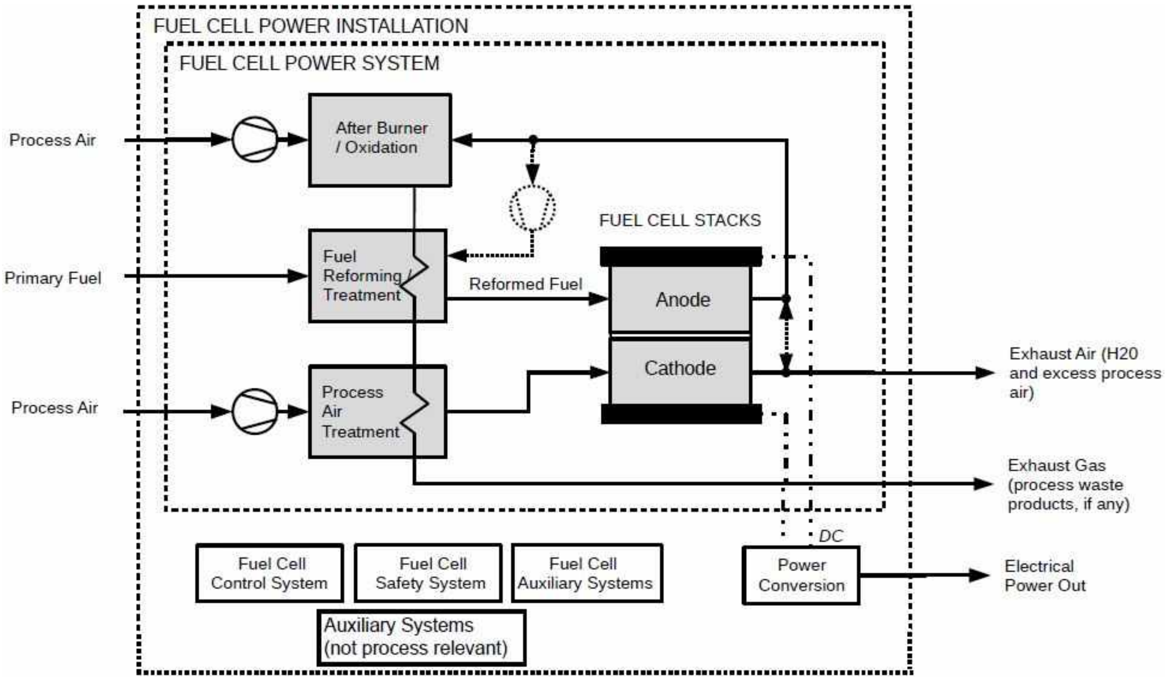
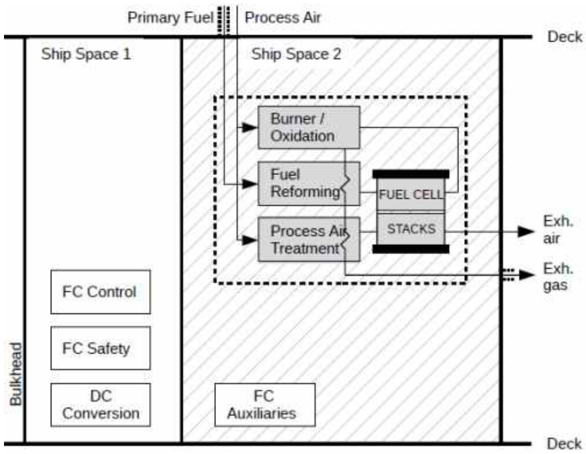
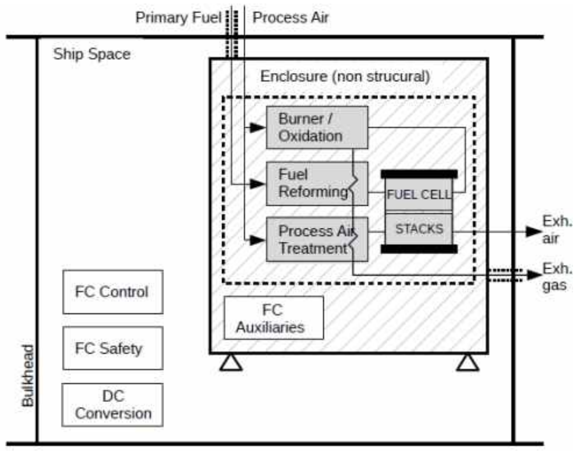


Fig 1.1 Components of Typical Fuel Cell Power Installation

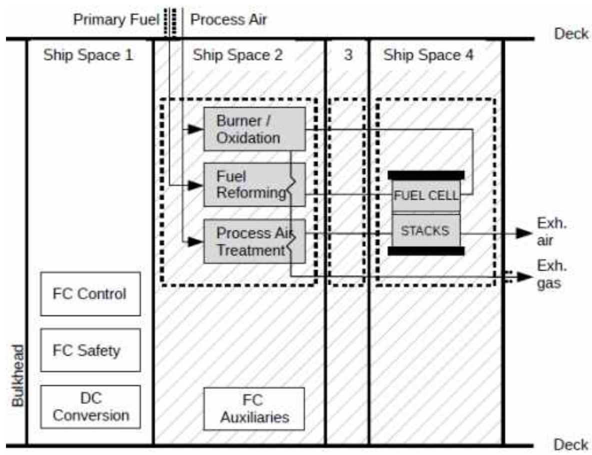
(7) **Fuel cell space** is a space containing fuel cell power systems or parts of fuel cell power systems. (refer to **Fig 1.2**)
(8) **Reformed fuel** is hydrogen rich gas generated in the fuel reformer.
(9) **Primary fuel** is fuel supplied to the fuel cell power system.
(10) **Exhaust gas** is exhaust from the reformer or anode side of the fuel cell.
(11) **Exhaust air** is exhaust from the cathode side of the fuel cell.
(12) **Process air** is air supply to the reformer and/or the cathode side of the fuel cell.
(13) **Ventilation air** is air used to ventilate the fuel cell space.
(14) **LEL** means lower explosive limit, which, in the context of these Interim Guidelines, is to be taken as identical to the Lower Flammable Limit (LFL) and which is 4.0% vol. fraction for hydrogen. *(2023)*



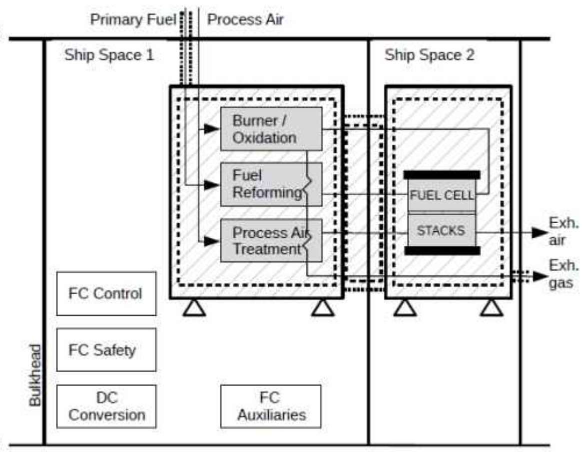
Ex.1) Fuel cell space as a structural ship space



Ex.2) Fuel cell space as a non-structural enlosure within a ship space



Ex.3) Multiple fuel cell space as a structural ship



Ex.4) Multiple fuel cell space as a non-structural space enclosures within a ship space

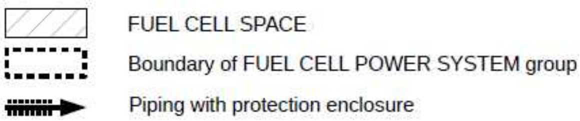


Fig 1.2 Examples for Fuel Cell Spaces

103. Class notations *(2024)*

1. As additional special feature notations, a notation is to be assigned as follows:
   (1) Ships installing fuel cell power installations are to comply with the requirements of this Guidance and a notation “FC” is to be assigned.
   (2) In addition to above, where the fuel cell power is used for propulsion or essential services and the redundancy requirements of **Ch 2, 101.** are satisfied, a notation "FC-PWR" is to be assigned.

104. Alternative design *(2020)*

1. These Guidances contain functional requirements for all appliances and arrangements related to the usage of fuel cell technology.

2. Appliances and arrangements of fuel cell power systems may deviate from those set out in these Guidances, 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.

3. The equivalence of the alternative design is to be demonstrated as specified in **SOLAS Reg. II-1/55** and approved by the Society. However, the Society is not to allow operational methods or proce-dures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of

equipment or type thereof which is prescribed by these Guidances.

105. Exclusion from the Guidance

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

CHAPTER 2 CONSTRUCTION AND INSTALLATION *(2020)*

Section 1 General

101. Redundancy of fuel cell power system *(2024)*

A notation “FC-PWR” is to be assigned where the following requirements are satisfied.

1. The fuel cell power system is to consist of at least two independent systems located in two independent fuel cell spaces. In case of applying a hybrid system, one of the two independent systems can be used as generator or battery or other types of energy sources.

2. Under normal sea-going conditions, when one system is out of service, the capacity of the remaining systems is to be sufficient to carry all of the loads for vessel services (essential services and services for habitability). Also when fuel cell power system is used for electric propulsion, in addition to above capacity, it is to be sufficient to carry the propulsion loads to provide for a speed of not less than 7 knots or one half of the design speed, whichever is the lesser.

3. The fuel cell power system is to be so arranged that the electrical supply to equipment necessary for propulsion and steering and to ensure safety of the ship will be maintained or immediately restored in the case of loss of any one of the systems in service. Preference tripping or other equivalent arrangements are to be provided to protect the fuel cell power systems against sustained overload.

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

102. Risk assessment *(2023)*

1. For any new or altered concept or configuration of a fuel cell power installation a risk analysis is to 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 is to be given to the hazards associated with installation, operation and maintenance, following any reasonably foreseeable failure.

2. The risks are to be analysed using acceptable and recognized risk analysis techniques and details are in accordance with **Ch 3, Sec 2** of **Rules for Ships using Low-flashpoint Fuels.** In the analysis 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) as a minimum are to be considered. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary.

Section 2 Design Principles for Fuel Cell Power Installations

201. Fuel cell spaces

1. Fuel cell space concept *(2023)*

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

(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.

(3) Equipment protected fuel cell spaces - area classification according to **402. 2**: such fuel cell spaces are considered as hazardous zone 1 and all electrical equipment is to 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 ℃ in all operating conditions and the fuel cell power system is to be capable of immediately isolating and de-energizing the fuel cell stack under every load and operating condition (see also **Table 2.2**).

(4) In specific cases where the Administration considers the prescriptive area classification to be in-

appropriate, area classification according to IEC 60079-10-1 is to be applied according to **402. 1**, taking into account the following guidance: All electrical equipment needs to comply with the resulting area classification.

(5) In specific cases where the Administration accepts inerting according to **203. 3**, the following guidance is to 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 is to take place and a controlled shutdown of the fuel cell and the affected fuel supply system is to be initiated in order thereby to avoid damage to the fuel cell power system.

2. The design of fuel cell power systems other than specified in this guidance is to properly comply with industry standards deemed appropriate by the Society (eg. IEC 62282-2-100 and IEC 62282-3-100 or equivalent) in consideration of various technologies and types of fuel cells and operating conditions in the ship environment. *(2023)*

202. Arrangement and access

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

2. It is to 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 are to be provided.

4. Means are to 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 are to 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 is to 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 cells.

7. Fuel cell spaces boundaries are to be gastight towards other enclosed spaces in the ship.

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

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

10. Fuel cell spaces containing fuel reformers are to 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 is to be through an airlock.

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 fuel cell space is safely shut down, isolated from the fuel system, and drained of leakages and the inside atmosphere is confirmed gas-free. These provisions include but are not limited to: *(2023)*

(1) all controls required for safe operation and gas freeing of the equipment and space is to be provided for remote operation from outside the space;

(2) all parameters required for safe operation and gas freeing are to be remotely monitored and alarms are to be given;

(3) the space openings are to be equipped with an interlock preventing operation with the space open;

(4) the spaces are to be provided with suitable fuel leakage collection and draining arrangements for remote operation from outside the space; and

(5) provisions are to be made that the fuel equipment inside can be isolated from the fuel system,

drained of fuel and purged safely for maintenance.

203. 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 are to be equally acceptable to ensure the safety of the space.

2. Ventilation of fuel cell spaces

(1) Fuel cell spaces are to 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.
(2) For fuel cell spaces on open decks, overpressure ventilation may be considered.
(3) The ventilation rate in fuel cell spaces is to be sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios owing to technical failures. *(2023)*
(4) Any ducting used for the ventilation of fuel cell spaces is not to serve any other space.
(5) Ventilation ducts from spaces containing reformed fuel piping or release sources are to be designed and arranged such that any possibility for gas to accumulate is avoided. *(2023)*
(6) Two or more fans are to be installed for the ventilation of the fuel cell space providing 100% redundancy upon loss of one fan. 100% ventilation capacity is to also be supplied from the emergency source of power. *(2023)*
(7) In case of failure of one fan, automatic changeover to another fan is to be provided and indicated by an alarm. *(2023)*
(8) In case of loss of ventilation or loss of underpressure in the fuel cell space the fuel cell power system is to carry out an automatic, controlled shutdown of the fuel cell and isolation of the fuel supply.
(9) Ventilation air inlets for fuel cell spaces are to be taken from areas which, in the absence of the considered inlet, would be non-hazardous.
(10) Ventilation air inlets for non-hazardous enclosed spaces are to be taken from non-hazardous areas located at least 1.5 m away from the boundaries of any hazardous area.
(11) Ventilation air outlets from fuel cell spaces are to be located in an open area which, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

3. Inerting of fuel cell spaces

Inerting is to be accepted for atmospheric control of the fuel cell spaces provided all of the followings.

(1) Protection by inerting is only acceptable where a fuel cell space is too small to be entered and sealing arrangements are to ensure that leakages of inert gas to adjacent spaces are prevented.
(2) The inerting system complies with **Ch 15** of the **Fire Safety Systems Code** (**FSS Code**) and **Ch 6 Sec 13**, **Ch 6 Sec 14** of **Rules for Ships using Low-flashpoint Fuels**. *(2023)*
(3) The pressure of inerting media is to always be kept positive and monitored.
(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, etc.) is to activate a controlled shut-off of the fuel supply.
(5) Fuel cell space shall be equipped with a mechanical ventilation to evacuate inerting agent, after an inerting release have been initiated.
(6) Access to the inerted fuel cell space is to only be possible when the space is completely ventilated by fresh air and the fuel supply is interrupted and depressurized or purged. *(2023)*
(7) Inerting system shall not be operable under ongoing maintenance or inspection.

204. Materials

1. The materials within the fuel cell power installation are to be suitable for the intended application and are to comply with recognized standards. Suitable materials are to be used to prevent any deterioration owing to hydrogen embrittlement, as necessary, at places where contact with hydrogen is anticipated. *(2023)*

2. The use of combustible materials within the fuel cell power system is to be kept to a minimum.

205. Piping arrangement for fuel cell power system

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

1. not be led through enclosed spaces outside of fuel cell spaces, when passing through enclosed spaces is necessary, they are to be protected by a secondary enclosure in accordance with **Ch 9, 501.** of **Rules for Ships using Low-flashpoint Fuels**; *(2023)*
2. be fully welded as far as practicable; and
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. *(2023)*

206. Exhaust gas and exhaust air

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

Section 3 Fire Safety

301. General provisions on fire and explosion safety

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

1. The fuel cell space is to be regarded as a machinery space of category A according to **SOLAS II-2** for fire protection purposes.
2. A fuel cell space is to be bounded by A-60 class divisions. Where this is deemed to be impracticable, the Society may approve alternative boundary designs that provide for an equivalent level of safety.
3. The fire-extinguishing system is to be suitable for use with the specific fuel and fuel cell technology. The Society 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.
4. A fixed fire detection and fire alarm system complying with the FSS Code is to be provided. *(2023)*
5. The type and arrangement of the fire detection system is to be selected with due consideration of the fuels and combustible gases which may be present in fuel cell power installations. *(2023)*
6. Fuel cell spaces are to be fitted with suitable fire detectors. Smoke detectors alone are not considered sufficient for rapid detection of a fire when gaseous fuels are used. *(2023)*

302. Fire and explosion protection

1. Fuel cell spaces separated by a single bulkhead are to 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. Failures leading to dangerous overpressure, e.g. gas pipe ruptures or blow out of gaskets, are to be mitigated by suitable explosion pressure relief devices and ESD arrangements. As explosion pressure relief devices, deflagration vents can be installed on parts of the walls of fuel cell spaces so that the explosion pressure is concentrated through the weak wall surfaces when an explosion occurs. In this case, deflagration vents are not to contact with areas related to the safety of life and operation of ships, such as passenger spaces, accommodation spaces, control stations, and machinery spaces. *(2023)*
3. The probability of a gas accumulation and explosion in fuel cell spaces is to be minimized by a mitigating strategy which may include one or more of the below. Based on the results of the risk as-

sessment, the mitigation strategy is to be finalized. *(2023)*
(1) purging the fuel cell power system before initiating the reaction
(2) purging the system as necessary after shutdown
(3) providing failure monitoring in the fuel cell fuel containment systems
(4) monitoring potential contamination of air into fuel cells fuel lines, or fuel cells fuel into air pipes
(5) monitoring pressures and temperatures
(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
(7) any other strategy to the satisfaction of the Administration

303. Fire extinguishing *(2023)*

1. A fixed fire-extinguishing system complying with the requirements of the FSS Code is to be installed for fuel cell spaces. If a fire extinguishing system not specified in the FSS Code is applied, the fire performance of the fire-extinguishing system is to be proven through fire test data or technical data, etc.

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

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

304. Fire dampers *(2023)*

1. Air inlet and outlet openings of the fuel cell spaces are to be installed with automatic fire dampers (automatically closed when exposed to fire) which can be operable from outside the fuel cell space. The actuating devices of the fire damper are to be of a fail-safe type that will close the damper in a fire even upon loss of electrical power or hydraulic or pneumatic pressure loss.

2. Before actuation of the fire-extinguishing system, the fire dampers are to be closed automatically.

Section 4 Electrical Systems

401. General provisions on electrical systems

1. Electrical equipment is not to 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 is to be selected, installed and maintained in accordance with IEC 60079 and IEC 60092-502 or standards at least equivalent to those.

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

4. The outgoing circuits on the fuel cell power system is to be provided with a switch disconnector for maintenance purposes. *(2024)*

402. Area classification

1. In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2, according to **2**. In cases where the prescriptive provisions in **2** are deemed to be inappropriate, area classification according to IEC 60079-10-1 is to be applied with special consideration by the Society.

2. Definition of zones

(1) The following areas are to 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) The following areas are to be treated as hazardous areas zone 1
(A) Areas on open deck, or semi-enclosed spaces on deck, within 3 m of any hydrogen or re-

formed fuel or purge gas outlets or fuel cell space ventilation outlets;
(B) Areas on open deck, or semi-enclosed spaces on deck, within 3 m of fuel cell exhaust air and exhaust gas outlets;
(C) 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;
(D) Areas on open deck or semi-enclosed spaces within 3 m in which other sources of release of hydrogen or reformed fuel are located; and
(E) Fuel cell spaces.

(3) The following areas are to be treated as hazardous areas zone 2
(A) Areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1 as specified above, if not otherwise specified; and
(B) Air locks.

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

Section 5 Control, Monitoring and Safety Systems

501. General provisions on control, monitoring and safety systems *(2023)*

1. Safety-related parts of the fuel cell control systems are to be designed independent from any other control and monitoring systems or comply with the process as described in industry standards acceptable to the Society for the performance level or equivalent.

2. The fuel cell is to be monitored according to the manufacturer's recommendations. A failure mode and effect analysis examining all possible faults affecting the fuel cell operation and safety is to be submitted. Based on the outcome of the analysis the extent of the monitoring and control is to be finally decided.

(1) Monitoring items to be typically considered:
(A) cell voltage
(B) cell voltage deviations
(C) exhaust gas temperature
(D) temperature in FC
(E) current level.

(2) Other monitoring items to be considered:
(A) process air flow
(B) process air pressure
(C) flow, pressure, temperature of cooling medium
(D) fuel flow
(E) fuel temperature
(F) fuel pressure
(G) gas detection in exhaust gas
(H) level, pressure, purity of process water system
(I) parameters necessary to monitor lifetime/deterioration.

502. Gas or vapour detection *(2023)*

1. A permanently installed gas/vapour detection system is to be provided for:
(1) Fuel cell spaces;
(2) Air locks (if any);
(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
(4) Other enclosed spaces where primary/reformed fuel may accumulate.

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

3. For detectors in the place required in the above **1**, 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.

503. Ventilation performance *(2023)*

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

504. Bilge wells *(2023)*

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

505. Manual emergency shutdown *(2023)*

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

(1) Navigation bridge;
(2) Onboard safety centre;
(3) Engine control room
(4) Fire control station; and
(5) Adjacent to the exit of the fuel cell space.

506. Actions of the alarm system and safety system *(2023)*

1. Gas or vapour detection

(1) Gas/vapour detection in a fuel cell space above a gas or vapour concentration of 20% LEL is to cause an alarm.
(2) Gas/vapour detection in a fuel cell space above a gas or vapour concentration of 40% LEL is to shut down the affected fuel cell power system and disconnect ignition sources and is to 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 is to be immediately electrically isolated and de-energized. Valves in the primary fuel system supplying liquid or gaseous fuel to the fuel cell space is to close automatically.
(3) Gas/vapour detection is to be provided in the fuel cell's coolant "supply/header" tank, and this is to cause an alarm.

2. Liquid detection

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

3. Loss of ventilation

(1) Loss of ventilation in a fuel cell space is to 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 is to be considered on a case-by-case basis based on the risk analysis.
(2) After the period has expired, a safety shutdown is to be carried out.

4. Emergency shutdown push buttons

Actuation of the emergency shutdown push button is to 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 is to 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 is to be provided or the equipment within the fuel cell space is to be protected from a coolant release. Consideration is to be given to the safe removal of the coolant.

6. Fire detection

Fire detection within the fuel cell space is to initiate automatic shutdown of fuel cell and ventilation fans for fuel cell space, and isolation of the fuel supply. *(2024)*

7. Fuel 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 ℃, the fuel cell power system is to immediately shut down and isolate the affected fuel cell space.

507. Alarms *(2023)*

1. The alarm provisions in **506.**, as well as **Table 2.1**, specify fuel cell power installation alarms.

2. Alarms additional to the ones required by **Table 2.1** may be recommended for unconventional or complex fuel cell power installations.

Table 2.1 Alarms *(2023)*

Monitored parameter [H=High L=Low O=Abnormal status]		Alarm
Gas detection at 20 % LEL	Fuel cell spaces	H
	Expansion tanks/degassing vessels in systems for heating/cooling	H
	Air locks	H
	Other enclosed spaces where primary/reformed fuel may accumulate	H
Liquid detetction	Fuel cell space as per **506. 2**	H
Ventilation	Reduced ventilation in fuel cell spaces	L
Other alarm conditions	Air lock, more than one door moved from closed position	O
	Air lock, door open at loss of ventilation	O

508. Safety actions *(2023)*

1. The safety action provisions in **506.** and **Table 2.2** specify fuel cell power installations safety actions to limit the consequences of system failures.

2. Safety actions additional to those required by **Table 2.2** may be recommended for unconventional or complex fuel cell power installations.

Table 2.2 Safety actions *(2023)*

Safety actions [●=apply]	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 **506. 5**	●	●		
40% LEL inside fuel cell space (includes detection of hydrogen leaks as per **205. 4**)	●	●	●	If not certified for operation in zone 1 hazardous areas, the fuel cell stack is to be immediately electrically isolated and de-energized
Loss of ventilation or loss of negative pressure in a fuel cell space	●	●		The fuel cell is to be automatically shut down by process control
Fire detection within the fuel cell space	●	●	●	Shutdown of ventilation, close of fire damper, release of fire-extinguishing system
Emergency shutdown button	●	●	●	
Fuel cell stack surface temperature 〉 300 °C	●	●	●	If fuel cell stack is not certified for zone 1

Section 6 Fuel Cells Associated Auxiliaries

601. Fuel Reformer Systems

1. General

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

2. Firing equipment

(1) Firing equipment in fuel reformer systems is to be designed for automatic operation. Manual op-eration (even for emergencies) is not permissible.
(2) The combustion chamber and the exhaust gas system is to be purged with air or an inerting medium after the firing equipment is switched off.
(3) The firing equipment is to be equipped with a type approved burner control box and flame mon-itoring devices. Reliable operation of the flame monitoring devices is to be verified for the corre-sponding type of fuel and mode of combustion.
(4) The Society may require additional requirements for the firing equipment depending on the type of fuel and the burner.

3. Gas purification

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

4. Residual gases

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

Section 7 Manufacture, Workmanship and Testing

701. General

1. Fuel cell module is to be type approved in accordance with IEC 62282-2-100 “Fuel cell technologies - Fuel cell modules - Safety” or standards recognized by the Society. The type test requirements may be reduced or added in consideration of various technologies and types of fuel cells and oper-ating conditions in the ship environment. *(2022)*

2. Fuel cell power installation is be type approved in accordance with IEC 62282-3-100 "Fuel cell technologies - Stationary fuel cell power systems - Safety" or standards recognized by the Society. The type test requirements may be reduced or added in consideration of various technologies and types of fuel cells and operating conditions in the ship environment. *(2022)*

3. Valves containing reformed fuel are to be tightness tested with hydrogen or an appropriate test gas to show that there is no leakage. After assembly, piping systems containing reformed fuel are to be tightness tested with hydrogen or an appropriate test gas to show that there is no leakage.

4. Expansion bellows for fuel cell fuel system are subject to type approval.

702. Shop tests of fuel cell power installation

1. Each fuel cell power system subjected to the type approval is to be performed following tests be-

fore installation onboard. (Refer to IEC 62282-3-100, para. 6)
(1) Gas leakage tests
(2) Normal operation test
(3) Dielectric strength tests
(4) Burner operating tests

703. Onboard tests of fuel cell power installation

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

2. The fuel cell power installation is to be subjected to the following tests after installation on board: However, the items to be tested during sea trial may be included in sea trial program.

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

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

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

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

704. Composite material pressure vessels for fuel containment of compressed hydrogen gas *(2022)*

1. Composite material pressure vessels for fuel containment of compressed hydrogen gas with an internal volume of 450L or less that supply hydrogen fuel to fuel cells (hereinafter referred to as “vessels”) are to obtain type approval from the Society.

2. Tests and inspections

(1) The composition, quality, etc. of the vessel materials are verified through test reports signed by the material manufacturer.
(2) The vessel manufacturers verify that the construction of all finished vessels is consistent with the design. In addition, it is to be verified and recorded that the main dimensions and weight of vessels satisfy the design tolerances set by the manufacturers.
(3) The vessel manufacturers are to measure and record the dimensions of the threads of the at-

tachment ports of all vessels valves with a plug gauge, etc..

(4) The vessel manufacturers are to conduct and record the following non-destructive tests for all manufactured vessels.

(A) That the maximum defect size of the metal liner does not exceed the allowable defects are to be confirmed by ultrasonic tests or non-destructive tests equivalent in accordance with (KS B) ISO 9809-1 Annex B or (KS B) ISO 9809-3 Annex B. The non-destructive testing method used for verification is to be capable of detecting the maximum allowable defect size.

(B) Whether the defects present in the non-metallic liner exceed the limit value of the allowable defects suggested by the vessel manufacturers is to be checked through visual inspection or non-destructive tests.

(5) The vessel manufacturers are to measure and record the hardness according to ISO 6506-1 after heat treatment for all manufactured Type 3 metal liners, check whether the value determined in the design conditions is obtained. The hardness for the liner is measured at the center of the vessel and at the end of the hemisphere.

(6) All vessels of Type 4 are to be subjected to a tightness test in accordance with the following.

(A) Vessels are to be dried so that it is free of moisture.

(B) Nitrogen is to be filled with containing a detectable gas such as hydrogen or helium and hold the pressure for at least 3 minutes to working pressure.

(C) No gas leakage through cracks or defects is to be identified.

(7) All vessels are subjected to pressure test according to the following.

(A) The pressure test is to be carried out at pressure of 1.5 times or more of working pressure. However, in any case, the autofrettage pressure is not to be exceeded. In the case of Type 3 vessels, before autofrettage and pressure test, the internal pressure is not to exceed 90% of the pressure test pressure in any case.

(B) The pressure is to be maintained for at least 30 seconds to allow the vessel to expand enough. If the test pressure cannot be maintained due to a problem with the test equipment, the test is to be retested at an increased pressure of 0.7 MPa. The retest is not to be repeated more than two times.

(C) The leakage through cracks or defects is not to be occur, and for Type 3 vessels, the permanent expansion rate is not to exceed 5%, and for Type 4 vessels, the elastic expansion rate is not to exceed 10% of the batch average value of the elastic expansion rate. ⚓

GUIDANCE FOR FUEL CELL SYSTEM ON BOARD SHIPS

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