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INTERIM GUIDELINES FOR THE SAFETY OF SHIPS USING FUEL CELL POWER INSTALLATIONS

1 The Maritime Safety Committee, at its 105th session (20 to 29 April 2022), having considered a proposal by the Sub-Committee on Carriage of Cargoes and Containers, at its seventh session, recognizing the importance of providing criteria for the arrangement and installation of fuel cell power installations on board ships so as to provide at least the same level of safety and reliability as new and comparable conventional oil-fuelled main and auxiliary machinery installations, approved the *Interim guidelines for the safety of ships using fuel cell power installations*, as set out in the annex.

2 Member States are invited to bring the Interim Guidelines to the attention of shipbuilders, manufacturers, shipowners, ship managers, masters and ship crews, bareboat charterers and all other parties concerned.

3 Member States are invited to recount their experience gained through the use of these Interim Guidelines to the Organization, for the Committee to keep them under review.

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ANNEX

INTERIM GUIDELINES FOR THE SAFETY OF SHIPS USING FUEL CELL POWER INSTALLATIONS

INTRODUCTION

These Interim Guidelines have been developed to provide international standard provisions for ships using fuel cell power installations. The goal of these Interim Guidelines is to provide criteria for the arrangement and installation of fuel cell power installations with at least the same level of safety and reliability as new and comparable conventional oil-fuelled main and auxiliary machinery installations, regardless of the specific fuel cell type and fuel. Depending on the fuel used, other regulations (e.g. IGF Code, part A) and provisions (e.g. *Interim guidelines for the safety of ships using methyl/ethyl alcohol as fuel*) are applicable in addition to these Interim Guidelines. Certain fuel cell power installations use a process of fuel reforming to develop a reformed fuel for use in the fuel cell. These Interim Guidelines are not intended to cover the storage of reformed fuels.

1 GENERAL

1.1 Application

Unless expressly provided otherwise these Interim Guidelines apply to ships to which part G of SOLAS chapter II-1 applies.

1.2 Goal

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

1.3 Functional requirements

These Interim 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.

1.4 Definitions

For the purpose of these Interim 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 ***Exhaust gas*** is exhaust from the reformer or anode side of the fuel cell.

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

.3 ***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.

.4 ***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.

.5 ***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.

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

.7 ***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.

.8 ***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.

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

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

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

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

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

1.5 Alternative design

1.5.1 These Interim Guidelines contain functional requirements for all appliances and arrangements related to the usage of fuel cell technology.

1.5.2 Appliances and arrangements of fuel cell power systems may deviate from those set out in these Interim Guidelines, 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.

1.5.3 The equivalence of the alternative design should be demonstrated as specified in SOLAS regulation II-1/55 and approved by the Administration. However, the Administration 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 Interim Guidelines.

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

2 DESIGN PRINCIPLES FOR FUEL CELL POWER INSTALLATIONS

2.1 Fuel cell spaces

2.1.1 Fuel cell space concept:

.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.

.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 4.2.2: 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[2] 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 (see also table 2).

.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 4.2.1, 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 2.3.3, 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.

2.1.2 The design of fuel cell power systems should comply with industry standards at least equivalent to those acceptable to the Organization.[3]

2.2 Arrangement and access

2.2.1 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.

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

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

[2] 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.

[3] Refer to IEC 62282 series: 62282-2-100:2020 and 62282-3-100:2019.

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

2.2.5 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.

2.2.6 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).

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

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

2.2.9 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[4] by having simple geometrical shape and no obstructing structures in the upper part.

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

2.2.11 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.

2.2.12 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.

2.2.13 These provisions include but are not limited to:

.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;

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

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

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

.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.

[4] See also IEC 60079-10-1:2020.

2.3 Atmospheric control of fuel cell spaces

2.3.1 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.

2.3.2 Ventilation of fuel cell spaces

2.3.2.1 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.

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

2.3.2.3 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.

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

2.3.2.5 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.

2.3.2.6 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.

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

2.3.2.8 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.

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

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

2.3.2.11 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.

2.3.3 Inerting of fuel cell spaces for fire protection purposes

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

.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;

.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 the pressure of inerting media should 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) should activate a controlled shut-off of the fuel supply;

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

.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

.7 the inerting system should not be operable under ongoing maintenance or inspection.

2.4 Materials

2.4.1 The materials within the fuel cell power installation should be suitable for the intended application and should comply with recognized standards.

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

2.5 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.

2.6 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.

3 FIRE SAFETY

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

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

.3 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.

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

.5 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.

.6 Fuel cell spaces should be fitted with suitable[5] fire detectors. Smoke detectors alone are not considered sufficient for rapid detection of a fire when gaseous fuels are used.

3.2 Fire and explosion protection

3.2.1 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.

3.2.2 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.

3.2.3 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:

.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;

[5] For the selection of suitable fire detectors, ISO/TR 15916:2015 can be taken into account.

.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

.7 any other strategy to the satisfaction of the Administration.

3.3 Fire extinguishing

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

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

3.3.3 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.

3.4 Fire dampers

3.4.1 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.

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

4 ELECTRICAL SYSTEMS

4.1 General provisions on electrical systems

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

4.1.2 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.[6]

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

4.2 Area classification

4.2.1 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 4.2.2, 4.2.3 and 4.2.4. In cases where the prescriptive provisions in 4.2.2, 4.2.3 and 4.2.4 are deemed to be inappropriate, area classification according to IEC 60079-10-1:2020 should be applied with special consideration by the Administration.

4.2.2 Hazardous areas 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.

6 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*.

4.2.3 Hazardous areas zone 1

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

.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.

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

.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.

.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.

.5 Fuel cell spaces.

4.2.4 Hazardous areas zone 2

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

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

.2 Air locks.

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

4.3 Risk analysis

4.3.1 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.

4.3.2 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.

5 CONTROL, MONITORING AND SAFETY SYSTEMS

5.1 General provisions on control, monitoring and safety systems

5.1.1 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 the Organization[7] for the performance level or equivalent.

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

5.2 Gas or vapour detection

5.2.1 A permanently installed gas/vapour detection system should 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.

5.2.2 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.

5.2.3 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.

5.3 Ventilation performance

In order to verify the performance of the 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.

5.4 Bilge wells

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

5.5 Manual emergency shutdown

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

.1 navigation bridge;

.2 onboard safety centre;

[7] Refer to ISO 13849-1:2015-06.

.3 engine control room

.4 fire control station; and

.5 adjacent to the exit of the fuel cell space.

5.6 Actions of the alarm system and safety system

5.6.1 **Gas or vapour detection**

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

5.6.1.2 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.

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

5.6.2 **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.

5.6.3 **Loss of ventilation**

5.6.3.1 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.

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

5.6.4 **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.

5.6.5 **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.

5.6.6 **Fire detection**

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

5.6.7 **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°C, the fuel cell power system should immediately shut down and isolate the affected fuel cell space.

5.7 Alarms

5.7.1 The alarm provisions in section 5.6, as well as table 1, specify fuel cell power installation alarms.

5.7.2 Alarms additional to the ones required by table 1 may be recommended for unconventional or complex fuel cell power installations.

Table 1: Alarms

	Alarm conditions
Gas detection at 20% LEL	
Fuel cell spaces	HA
Expansion tanks/degassing vessels in systems for heating/cooling	HA
Air locks	HA
Other enclosed spaces where primary/reformed fuel may accumulate	HA
Liquid detetction	
Fuel cell space as per 5.6.2.1	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 value*	

5.8 Safety actions

5.8.1 The safety action provisions in section 5.6 and table 2 specify fuel cell power installations safety actions to limit the consequences of system failures.

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

Table 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 5.6.6.1	X	X		
40% LEL inside fuel cell space (includes detection of hydrogen leaks as per 2.5.1.4)	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

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