Rules and Regulations for the Safe Integration and Use of Fuel Cells Onboard Ships

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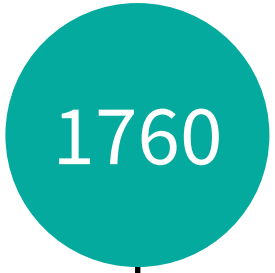
Lloyd’s Register Group Limited

Who we are

We are a global professional services company specialising in engineering and technology for the maritime industry; and marine classification society.

Social business

Part of the LR Foundation, a charity dedicated to research and education in science and engineering.



History

Founded in 1760 as a marine classification society.

What sets us apart

Known for independence, and technical excellence.

Drivers for the Adoption of Fuel Cell Technology in Shipping Industry

IMO Greenhouse Gas Strategy[1]

- Reduce carbon intensity of international shipping by at least
  - 40% by 2030
  - 50% by 2050 (efforts towards 70%)
- Phase out of GHG emissions from international shipping as soon as possible in this century

Zero-emission Sea Zones[2]

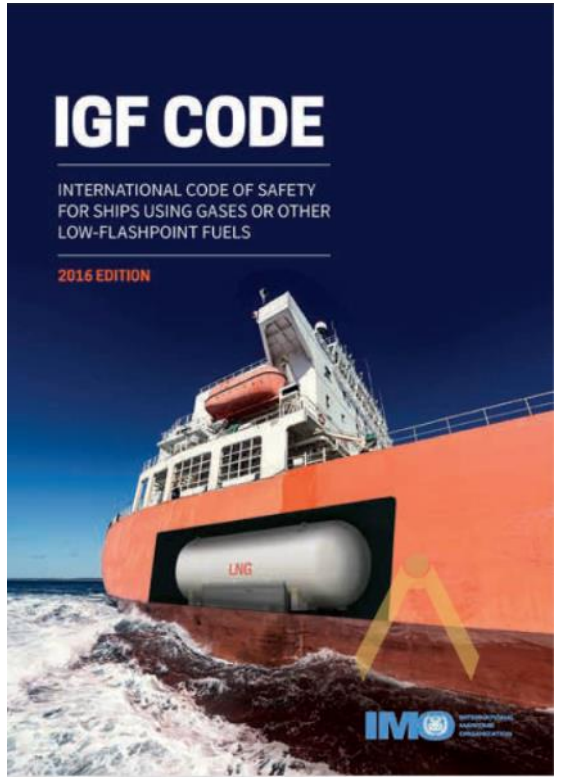
- The Norwegian Parliament has adopted a resolution to halt emissions from cruise ships and ferries in the West Norwegian Fjords – Geirangerfjord and Nærøyfjord World Heritage site by 2026 at the latest.
- This will make the fjords among the world's first zero emission zones at sea.

Sources:
1) https://www.imo.org
2) https://whc.unesco.org

Regulatory Framework

IGF Code – International Code of Safety for Ships using Gases or Other Low-flashpoint Fuels

- Entered into force on 1. January 2017
- Mandatory provisions for the arrangement, installation, control and monitoring of machinery, equipment and systems that use low-flashpoint fuels
- The Alternative Design Approach offers possibility to use other low-flashpoint fuels → risk-based approval process



2.3 Alternative design

2.3.1 This Code contains functional requirements for all appliances and arrangements related to the usage of low-flashpoint fuels.

2.3.2 Fuels, appliances and arrangements of low-flashpoint fuel systems may either:

.1 deviate from those set out in this Code, or

.2 be designed for use of a fuel not specifically addressed in this Code.

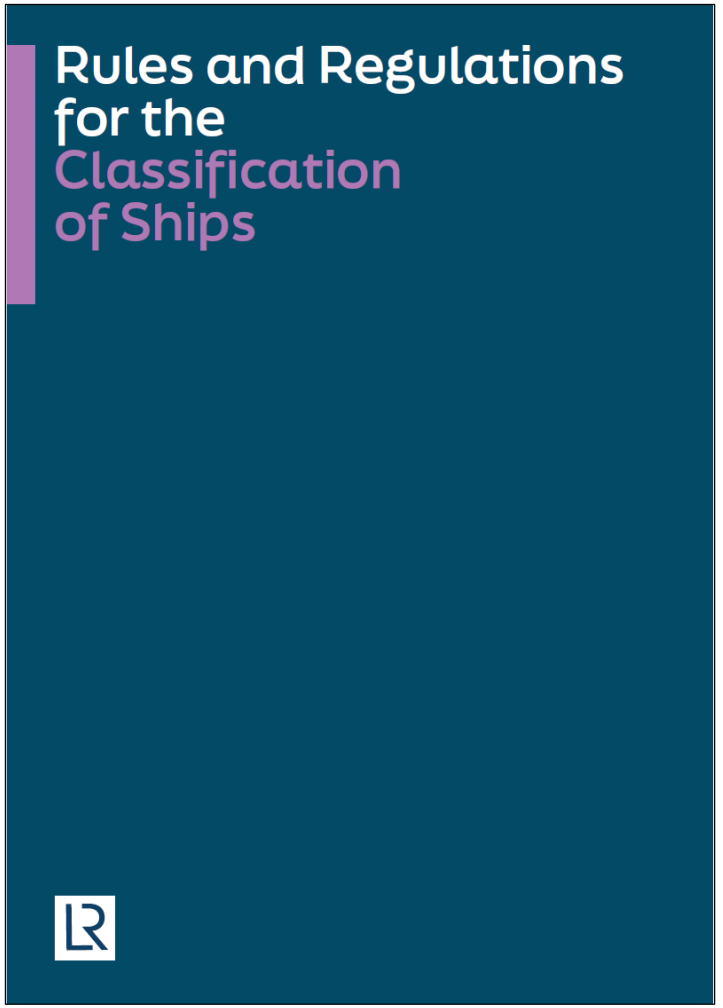
Such fuels, appliances and arrangements can be used provided that these meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety of the relevant chapters.

2.3.3 The equivalence of the alternative design shall be demonstrated as specified in

LR's Fuel Cell Rules

Part 5, Chapter 26 Fuel Cell Power Installations

- Based on IMO's *Draft Interim Guidelines for the Safety of Ships Using Fuel Cell Power Installations*
- Effective date: January 1st, 2022
- Content
  - Section 1 – General
  - Section 2 – Risk-based studies
  - Section 3 – Documentation for review
  - Section 4 – Design principles for fuel cell power installations
  - Section 5 – Materials, equipment and components
  - Section 6 – Fire and explosion safety
  - Section 7 – Testing and trials



Section 1 - General

Description and explanation of rule goals; functional requirements regarding safety, reliability and dependability; and fuel cell terminology

- Goal: Safe and reliable power provision
- Safety, reliability and dependability equivalent to conventional oil-fueled machinery
- Introduction of fuel cell vocabulary to maritime industry

1.1 Goal

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

1.1.2 These Rules do not substitute or supersede statutory conventions but do include fire safety requirements additional to those stated in the statutory conventions specific to the use of fuel cell power systems.

1.1.3 Additional requirements may be imposed by the Administration with which the ship is registered and/or by the Flag Administration within whose territorial jurisdiction the ship is intended to operate.

1.1.4 These Rules specify requirements for fuel cell power installations on board ships that comply with either the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, July 2022* or the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, July 2022*.

1.1.5 All references to the IMO IGF Code throughout these Rules are to be interpreted as references to the *Rules and Regulations for the Classification of Ships using Gases or other Low-flashpoint Fuels, July 2022*, which are fully consistent with the IGF Code.

1.2 Functional requirements

1.2.1 The safety, reliability and dependability of the systems shall 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.

1.2.2 The probability and consequences of fuel-related hazards shall 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.

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

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

1.2.5 Equipment installed in hazardous areas shall be minimised to that required for operational purposes and should be suitably and appropriately certified

Section 2 – Risk based studies

Information regarding risk assessment, alternative design and system dependability assessment

- Risk assessment is required for each installation on board
- Rule deviation is possible, if functional requirements and equivalent level of safety can be proved
- Dependability is to be shown if power for essential services is provided

				Consequence				
Intolerable risk				C1	C2	C3	C4	C5
Tolerable risk - ALARP				Minor Injury	Major injury	One fatality or multiple major injuries	2-10 Fatalities	11+ Fatalities
Broadly acceptable								
Likelihood	L7	Extremely Likely	$\leq 10^{0}$ to 10^{-1}					
	L6	Very Likely	$\leq 10^{-1}$ to 10^{-2}					
	L5	Likely	$\leq 10^{-2}$ to 10^{-3}					
	L4	Unlikely	$\leq 10^{-3}$ to 10^{-4}					
	L3	Very Unlikely	$\leq 10^{-4}$ to 10^{-5}					
	L2	Extremely Unlikely	$\leq 10^{-5}$ to 10^{-6}					
	L1	Remote	$\leq 10^{-6}$					

Section 3 – Documentation for review

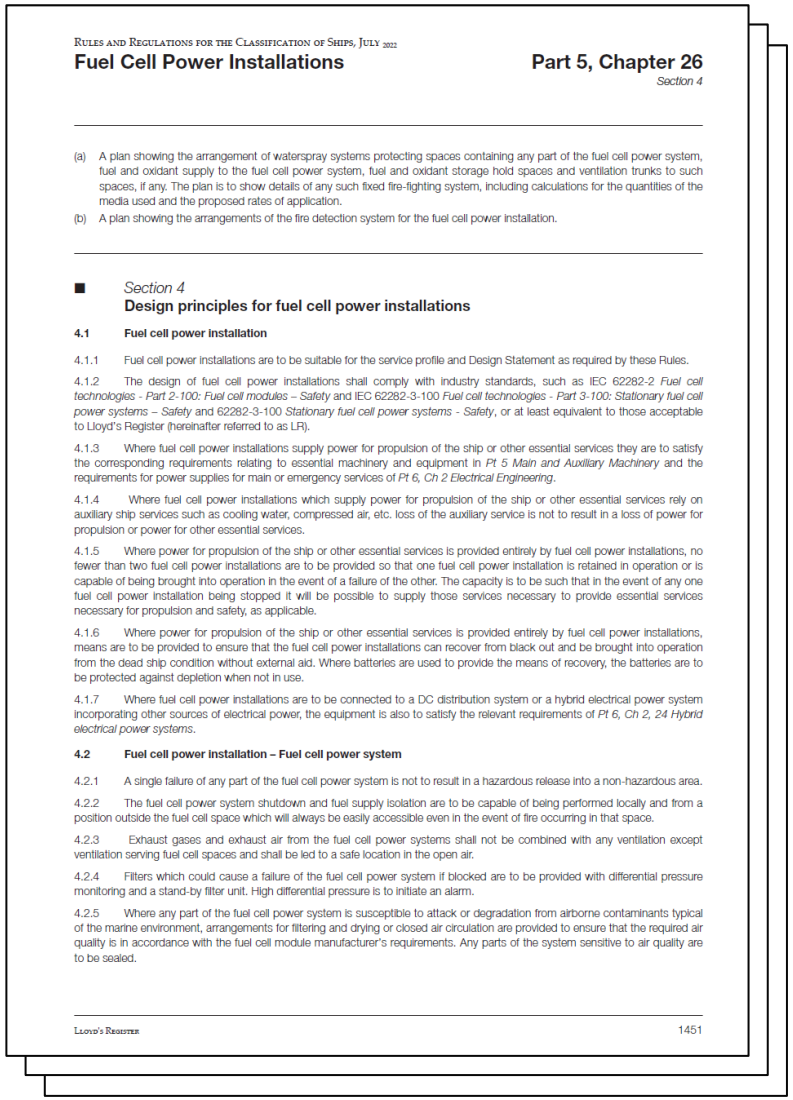
Description of requested documentation for information and appraisal purposes

- Ship profile, principle of operation and risk analysis
- Installation arrangements
- Fuel and oxidant supply
- Fuel cell module
- Thermal management, water and condensate
- Electrical and control equipment
- Fire protection, detection and extinction

Section 4 - Design principles for fuel cell power installations

Contains functional requirements, requirements for ventilation and exhaust, alarm thresholds and safeguards etc. for fuel cell power installations and its sub-systems

- Fuel cell power installations are to be suitable for the service profile
- Redundancy requirements if essential services is entirely provided by fuel cell power
- Gas detection thresholds
  - 20% LEL → alarm
  - 40% LEL at two detectors → alarm & fuel supply isolation and FC power system shutdown



(a) A plan showing the arrangement of waterspray systems protecting spaces containing any part of the fuel cell power system, fuel and oxidant supply to the fuel cell power system, fuel and oxidant storage hold spaces and ventilation trunks to such spaces, if any. The plan is to show details of any such fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.

(b) A plan showing the arrangements of the fire detection system for the fuel cell power installation.

Section 4

Design principles for fuel cell power installations

4.1 Fuel cell power installation

4.1.1 Fuel cell power installations are to be suitable for the service profile and Design Statement as required by these Rules.

4.1.2 The design of fuel cell power installations shall comply with industry standards, such as IEC 62282-2 *Fuel cell technologies - Part 2-100: Fuel cell modules – Safety* and IEC 62282-3-100 *Fuel cell technologies - Part 3-100: Stationary fuel cell power systems – Safety* and 62282-3-100 *Stationary fuel cell power systems - Safety*, or at least equivalent to those acceptable to Lloyd's Register (hereinafter referred to as LR).

4.1.3 Where fuel cell power installations supply power for propulsion of the ship or other essential services they are to satisfy the corresponding requirements relating to essential machinery and equipment in *Pt 5 Main and Auxiliary Machinery* and the requirements for power supplies for main or emergency services of *Pt 6, Ch 2 Electrical Engineering*.

4.1.4 Where fuel cell power installations which supply power for propulsion of the ship or other essential services rely on auxiliary ship services such as cooling water, compressed air, etc. loss of the auxiliary service is not to result in a loss of power for propulsion or power for other essential services.

4.1.5 Where power for propulsion of the ship or other essential services is provided entirely by fuel cell power installations, no fewer than two fuel cell power installations are to be provided so that one fuel cell power installation is retained in operation or is capable of being brought into operation in the event of a failure of the other. The capacity is to be such that in the event of any one fuel cell power installation being stopped it will be possible to supply those services necessary to provide essential services necessary for propulsion and safety, as applicable.

4.1.6 Where power for propulsion of the ship or other essential services is provided entirely by fuel cell power installations, means are to be provided to ensure that the fuel cell power installations can recover from black out and be brought into operation from the dead ship condition without external aid. Where batteries are used to provide the means of recovery, the batteries are to be protected against depletion when not in use.

4.1.7 Where fuel cell power installations are to be connected to a DC distribution system or a hybrid electrical power system incorporating other sources of electrical power, the equipment is also to satisfy the relevant requirements of *Pt 6, Ch 2, 24 Hybrid electrical power systems*.

4.2 Fuel cell power installation – Fuel cell power system

4.2.1 A single failure of any part of the fuel cell power system is not to result in a hazardous release into a non-hazardous area.

4.2.2 The fuel cell power system shutdown and fuel supply isolation are to be capable of being performed locally and from a position outside the fuel cell space which will always be easily accessible even in the event of fire occurring in that space.

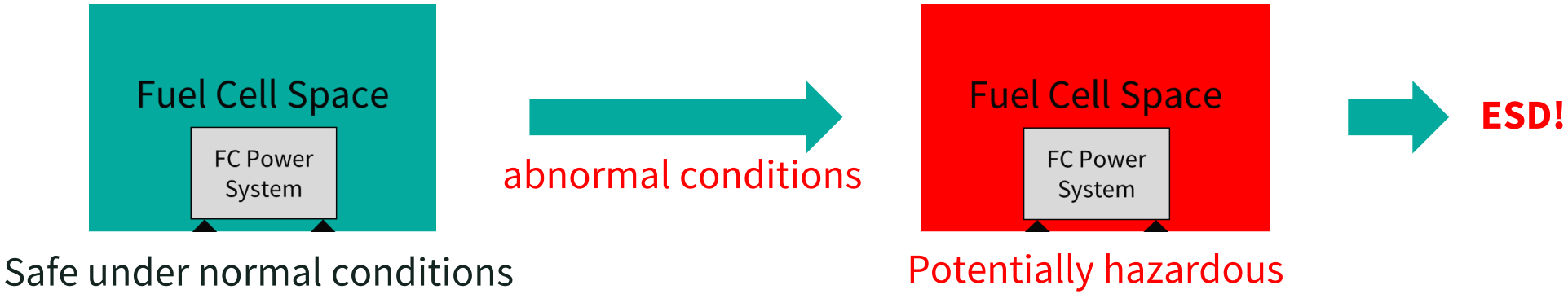
4.2.3 Exhaust gases and exhaust air from the fuel cell power systems shall not be combined with any ventilation except ventilation serving fuel cell spaces and shall be led to a safe location in the open air.

4.2.4 Filters which could cause a failure of the fuel cell power system if blocked are to be provided with differential pressure monitoring and a stand-by filter unit. High differential pressure is to initiate an alarm.

4.2.5 Where any part of the fuel cell power system is susceptible to attack or degradation from airborne contaminants typical of the marine environment, arrangements for filtering and drying or closed air circulation are provided to ensure that the required air quality is in accordance with the fuel cell module manufacturer's requirements. Any parts of the system sensitive to air quality are to be sealed.

Section 4 - Fuel Cell Space

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

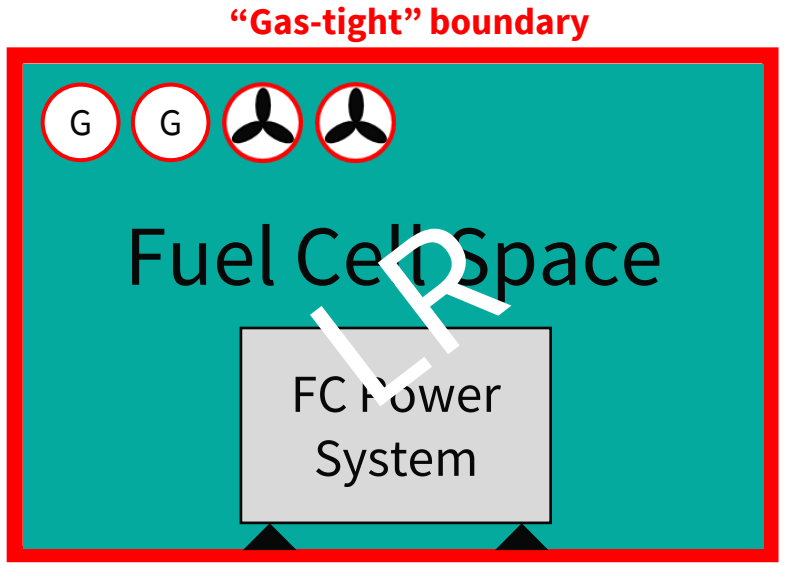


Fuel Cell Space Concept:

- 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; for example: **a single failure may result in a release of gas into the space.**
- Abnormal conditions → emergency shutdown (ESD) of equipment and components that are not suitably certified safe type

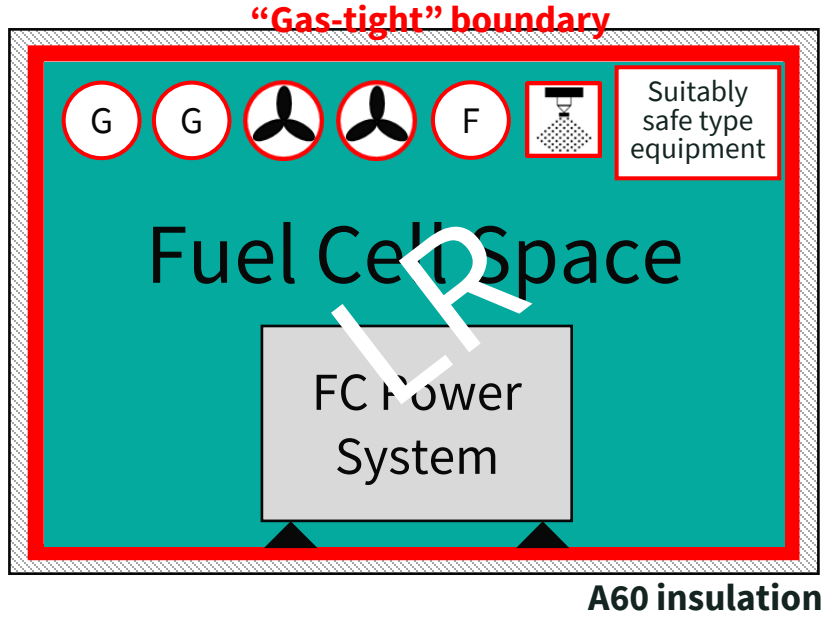
Section 4 - Fuel Cell Space – Requirements (1)

- **Fuel cell spaces are to be designed to**
  - Safely contain fuel leakages; and
  - to be provided with suitable leakage detection systems
- **Fuel Cell Space Ventilation**
  - Effective mechanical ventilation system to maintain underpressure of the complete space
  - Two or more fans → providing 100% redundancy upon loss of one fan
  - 100% ventilation capacity is to be supplied from the emergency source of power
  - The ventilation rate should be sufficient to dilute the average gas concentration below 25% of the LEL (at maximum foreseeable leakage)

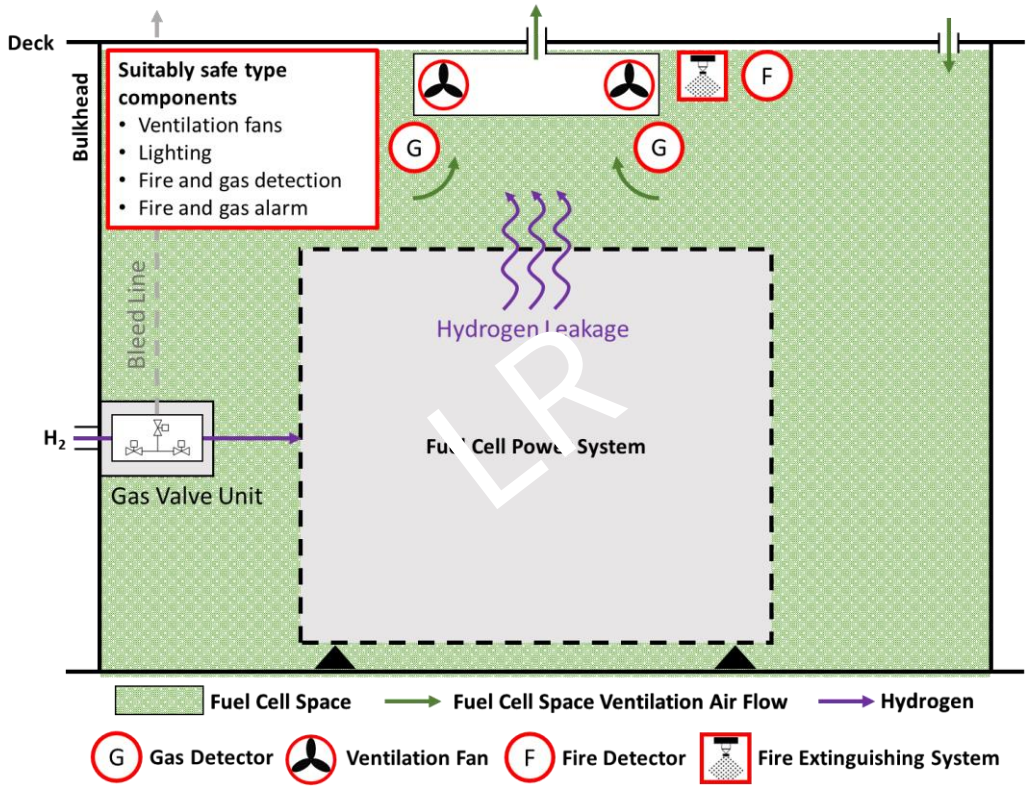


Section 4 - Fuel Cell Space – Requirements (2)

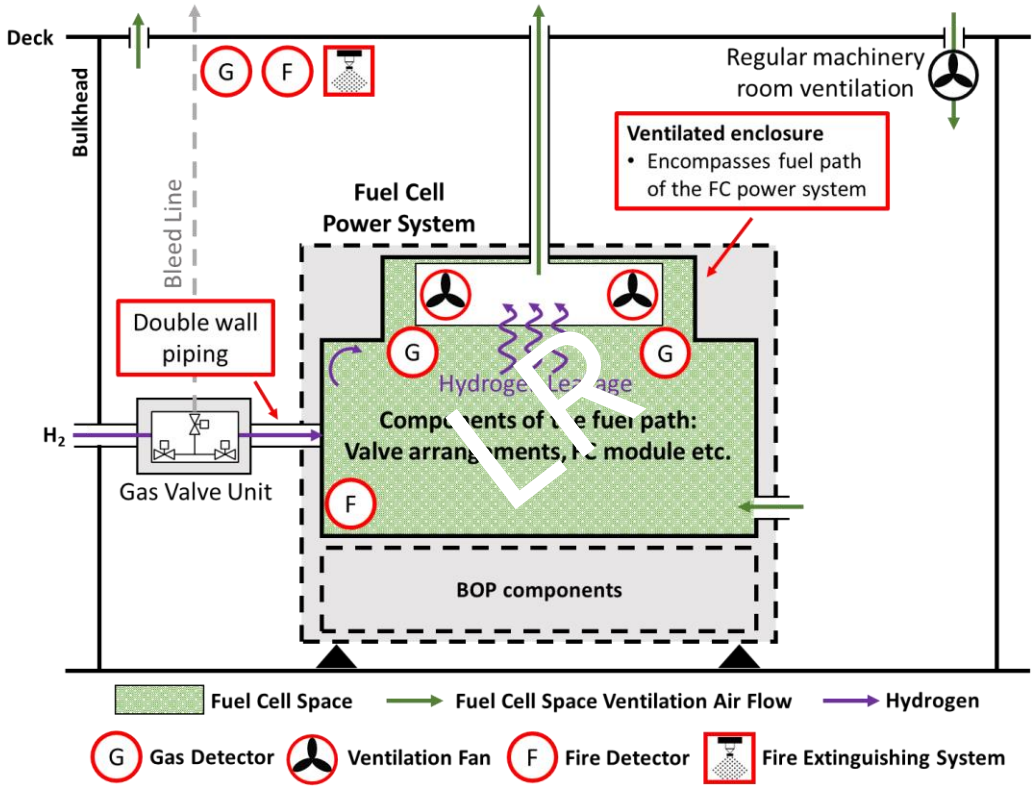
- Boundaries are A60 insulated
- Suitable fire detection and fire extinguishing system
- Equipment protection in fuel cell spaces:
  - Fuel cell spaces → hazardous Zone 1 → electrical equipment in the space shall be certified for Zone 1
  - New area classification according to *IEC 60079-10-1 Explosive atmospheres - Classification of areas* → all electrical equipment shall comply with the resulting area classification
  - Inerting (specific cases)
- Protection of fuel cell spaces by an external boundary that encloses components where fuel is fed shall be achieved by ventilation or inerting



Section 4 - Fuel Cell Space – Examples



- Single failure → gas may leak into the compartment
- Gas detection → ship's gas safety system will initialize ESD
  - Switch off non-suitably safe equipment / De-energize ignition sources
  - Cut-off fuel supply



- Single failure -> gas cannot leak into the compartment
  → **inherently gas safe compartment**
- Gas detection → FC's safety system will initialize
  - Safety shutdown of the FC system
  - Disconnection FC - grid/DCDC
  - Close internal fuel valve

Section 5 – Materials, equipment and components

Requirements for materials, equipment and components of fuel cell power installations

- Supplements other parts of LR rules
- Materials shall be suitable for their intended application
- Piping is to demonstrate electrical continuity
- Fixed hydrogen detector installation at places where hydrogen leakage may occur
- Extent of monitoring and control of the fuel cell power systems shall be analysed

Section 6 – Fire and explosion safety

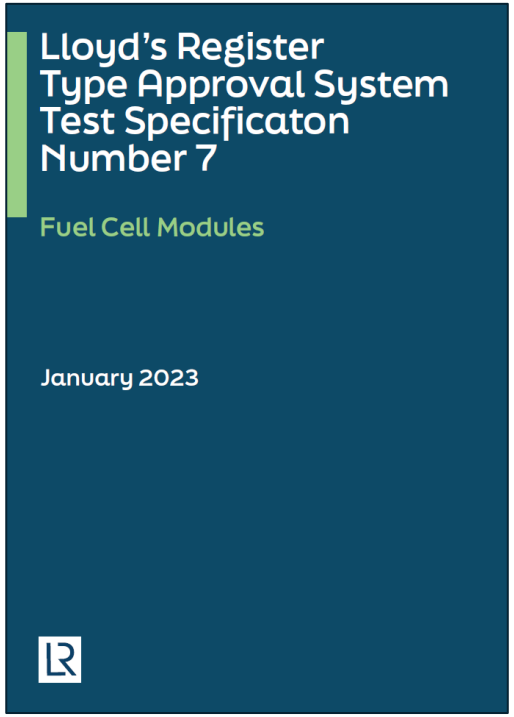
Requirements for fire protection, detection and extinguishing & explosion prevention and protection

- A fuel cell space
  - shall be bounded by A-60 class divisions
  - shall be fitted with suitable fire detectors
  - shall have a fixed installation of fire-extinguishing system, suitable for the used fuel(s)
- Explosion prevention by minimizing probability of gas accumulation
- Sufficient structural strength of installation compartment

Section 7 – Testing and trials

Information and requirements for factory acceptance testing and trials

- Fuel cell power systems are to be factory tested
- Commissioning tests and trials
  - Carried out in accordance with a testing programme agreed by LR
  - Surveyor presence required
- Trials are to include the testing of all alarms and safeguards for all modes of operation as defined in the service profile



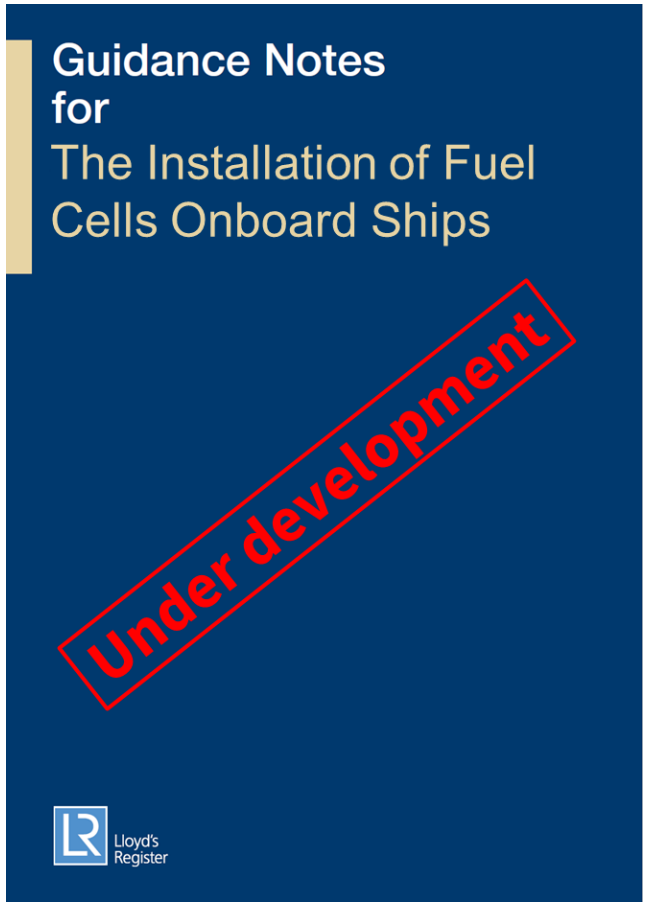
Test standards:

- IEC 62282-2-100 - Fuel cell modules - Safety
- IEC 62282-3-100 - Stationary fuel cell power system – Safety
- IEC 62282-3-200 Stationary fuel cell power system – Performance test methods
- LR Test Specification for Fuel Cell Modules

Guidance Notes for the Installation of Fuel Cells Onboard Ships

Planned content

- Fuel cell introduction
- Considerations and requirements to be addressed in concept and design phase
- Best practices for design and installation of fuel cell power installations onboard ships
- Testing and trials
- System maintenance



Conclusions

- Fuel cell technology has potential to contribute to the decarbonization of maritime industry – however, it also brings new risks and challenges onboard
- Rules and regulations for fuel cell power installations onboard ships are in place and are implemented by the industry
- Experience gained by installation and operation of fuel cells onboard ships will help to further refine the rules for more practicality
- A guidance document is under development to support the maritime industry in the adoption of fuel cell technology by providing technical background and sharing best practices & lessons learned to ease rule understanding and rule implementation

Thank you

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