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TECHNICAL CODE

FUEL CELL SYSTEM - GENERAL OPERATIONAL AND SAFETY REQUIREMENTS

Developed by

Malaysian Technical Standards Forum Bhd

Registered by

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Development of technical codes

The Communications and Multimedia Act 1998 (‘the Act’) provides for Technical Standards Forum designated under section 184 of the Act or the Malaysian Communications and Multimedia Commission (‘the Commission’) to prepare a technical code. The technical code prepared pursuant to section 185 of the Act shall consist of, at least, the requirement for network interoperability and the promotion of safety of network facilities.

Section 96 of the Act also provides for the Commission to determine a technical code in accordance with section 55 of the Act if the technical code is not developed under an applicable provision of the Act and it is unlikely to be developed by the Technical Standards Forum within a reasonable time.

In exercise of the power conferred by section 184 of the Act, the Commission has designated the Malaysian Technical Standards Forum Bhd (‘MTSFB’) as a Technical Standards Forum, which is obligated, among others, to prepare the technical code under section 185 of the Act.

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Contents

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UCSI University

Universiti Kebangsaan Malaysia

Universiti Teknologi MARA

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Telekom Malaysia Berhad

Foreword

This Technical Code for Fuel Cell System - General Operational And Safety Requirements ('Technical Code') was developed pursuant to section 185 of the Act 588 by the Malaysian Technical Standards Forum Bhd ('MTSFB') via its Green ICT, Environment and Climate Change Working Group.

This Technical Code shall continue to be valid and effective from the date of its registration until it is replaced or revoked.

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FUEL CELL SYSTEM - GENERAL OPERATIONAL AND SAFETY REQUIREMENTS

0. Introduction

In order to protect our environment and to achieve energy security, the Government of Malaysia has already declared its emphasis on renewable and alternative energy resources. The National Plans have encouraged the usage of renewable energy sources with efforts such as the Fifth Fuel Policy (2000 - 2010). One of the potential innovative energies for power generation is fuel cell system. Fuel cells are regarded as one of the cleaner and environmentally friendly renewable energy sources.

Fuel cells may be considered as continuous chemical reactors, which convert fuel and oxidant chemical potential into electrical energy. Fuel cell-based systems are suitable for the vast majority of stationary applications, since they offer a wide variety of technical solutions and can be coupled in order to cover anything from a few watts to several megawatt requirements. The key advantages of fuel cells compared to the conventional electrical power generation technologies are higher efficiency, especially when the waste heat is used for co-generation, quiet operation suitable for residential application, and almost zero levels of pollutant gases produced.

A fuel cell system consists of several sub-systems known as balance of plant and all the sub-systems of the fuel cell module require a proper design, integration, installation and operation at designated locations as standalone off-grid power supply facilities for required application. It is essential to ensure that the system can be smoothly and safely operated without any failure or leakage, either in the gas or liquid phase.

This Technical Code is developed to facilitate the installation of fuel cell modules onsite as a power backup or auxiliary power unit, as well as implementation of decarbonisation exercises for the infrastructure system that utilises hydrogen or hydrogen-rich fuel. The targeted users include manufacturers, engineers, installers, regulators, and maintenance workers.

1. Scope

This Technical Code provides the minimum operational and safety requirements of fuel cell system.

This Technical Code deals with conditions that can yield hazards to persons and cause damage outside the fuel cell system. Protection against damage inside the fuel cell system is not addressed in this Technical Code. This technical code shall be read together with the relevant standards established for particular applications and it is not intended to limit or inhibit technological advancement.

The requirements shall only be applicable for stationary applications of the fuel cell system.

2. Normative references

The following normative references are indispensable for the application of this Technical Code. For dated reference, only the edition cited applies. For undated references, the latest edition of the normative reference (including any amendments) applies.

See Annex A.

3. Abbreviations

For the purposes of this Technical Code, the following abbreviations apply.

AFC	Alkaline Fuel Cell
AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
BS	British Standard
CFD	Computational Fluid Dynamics
DOSH	The Department of Occupational Safety and Health
EIGA	The European Industrial Gases Association
EN	European Standards
EQA	Environmental Quality Act
FMA	Factories and Machinery Act
HSE	Health and Safety Executive
IEC	International Electrotechnical Commission
ISO	International Standards Organisation
LEL	Lower Explosion Limit
LFL	Lower Flammability Limits
LOC	Limiting Oxygen Concentration
LPG	Liquefied Petroleum Gas
MCFC	Molten Carbonate Fuel Cells
MS	Malaysian Standard
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Act
PAFC	Phosphoric Acid Fuel Cells
PEMFC	Polymer Electrolyte Membrane Fuel Cell
SOFC	Solid Oxide Fuel Cell
UFL	Upper Flammability Limits

4. Terms and definitions

For the purposes of this Technical Code, the following terms and definitions apply.

4.1 Authorised person

A person who has been given permission or mandate for approval to undertake any task on behalf of the manufacturer.

4.2 Balance of plant

All supporting facilities or components and supplementary or auxiliary unit in a system to deliver the energy

4.3 Commercial

Relating to the use of fuel cell system or hydrogen generators by laymen in non-manufacturing business facilities such as stores, hotels, office buildings, educational institutes and refilling stations

4.4 Competent person

A person who has been certified by the authority body to be competent to supervise the operation of a fuel cell system.

4.5 Fuel cell system

Generator system that uses fuel cell modules to generate electric power and heat.

4.6 Flammability limits

Lower Flammability Limits (LFL) and Upper Flammability Limits (UFL) concentration thresholds of fuel gas in a flammable mixture at a given temperature and pressure that will sustain propagation of a combustion wave

4.7 Indoor installation

The location where a fuel cell system is sited, whether as a unit or built as an assembly, which is completely surrounded and enclosed by walls, a roof and a floor.

4.8 Industrial

Relating to the use of fuel cell system or hydrogen generators by qualified and experienced personnel in a controlled manufacturing or processing environment, e.g. a chemical plant or a mine

4.9 Local authorities

Rural and town board and local, city, municipal, district and town councils, or other similar local authority established by any written law and includes an authority in charge of a federal territory established by any written law.

4.10 Outdoor installation

The location where a fuel cell and fuels system are sited, whether as a unit or built as an assembly, which is not located inside a building or that has only partial weather protection (maximum coverage of a roof and up to 25 % enclosing walls).

4.11 Purge

Process using an inert gas, i.e. nitrogen to prevent the existence of a hydrogen-air mixture.

4.12 Residential

Relating to the use of fuel cell system or hydrogen generators by laymen in private households

5. Fuel Cell Systems

5.1 Types of fuel cell

A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity, heat and water. Hydrogen may be produced as a by-product of a chemical process, extracted from any hydrocarbon fuels such as natural gas, gasoline, diesel, or methanol via a fuel reformer, or by electrolysis of water. Oxygen is usually obtained from the ambient air around the fuel cell. In some cases where hydrogen is produced by electrolysis, the oxygen co-produced may be used in the fuel cell.

Fuel cells can be loosely grouped into these categories:

a) types of electrolytes (acidic or alkaline); and

b) operating temperatures (low or high).

An example of acidic electrolyte fuel cells is the proton exchange membrane or Polymer Electrolyte Membrane Fuel Cells (PEMFCs). It uses a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst, and the Phosphoric Acid Fuel Cells (PAFCs) that use liquid phosphoric acid as an electrolyte (the acid is contained in a Teflon bonded silicon carbide matrix) and porous carbon electrodes containing a platinum catalyst. PEMFCs are generally designed for lower temperatures, although some may operate at around 80 °C, while PAFCs typically operate at temperatures between 150 °C to 200 °C.

Alkaline Fuel Cells (AFCs) use an aqueous solution of potassium hydroxide as the electrolyte and can use a variety of non-precious metals as a catalyst at the anode and cathode. Most AFCs operate at temperatures of between 100 °C and 250 °C, but new designs operate at lower temperatures of between 20 °C to 70 °C.

High temperature fuel cells include Molten Carbonate Fuel Cells (MCFCs) and Solid Oxide Fuel Cells (SOFCs). MCFCs use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminium oxide, which operate at 650 °C and above. SOFCs use a hard, non-porous ceramic as the electrolyte, which commonly operate at approximately 1,000 °C. Ongoing research is aimed at reducing this operating temperature between 550 °C to 700 °C.

5.2 Components of a fuel cell system

All fuel cells work broadly on the same principle (as shown in Figure 1) with below characteristics:

a) Hydrogen or a hydrogen-rich fuel is fed to the anode, where a catalyst splits the hydrogen molecules into electrons (negative charge) and protons (positive charge).

b) At the cathode, oxygen combines with electrons, and in some cases with species such as protons or water, resulting in water or hydroxide ions respectively.

c) For polymer electrolyte membrane and phosphoric acid fuel cells, protons move through the electrolyte to the cathode to combine with oxygen and electrons to generate water.

d) The electrons from the anode side of the cell cannot pass through the membrane to the positively-charged cathode so they shall travel around it via an electric circuit to reach the other side of the cell. This movement of electrons is an electric current.

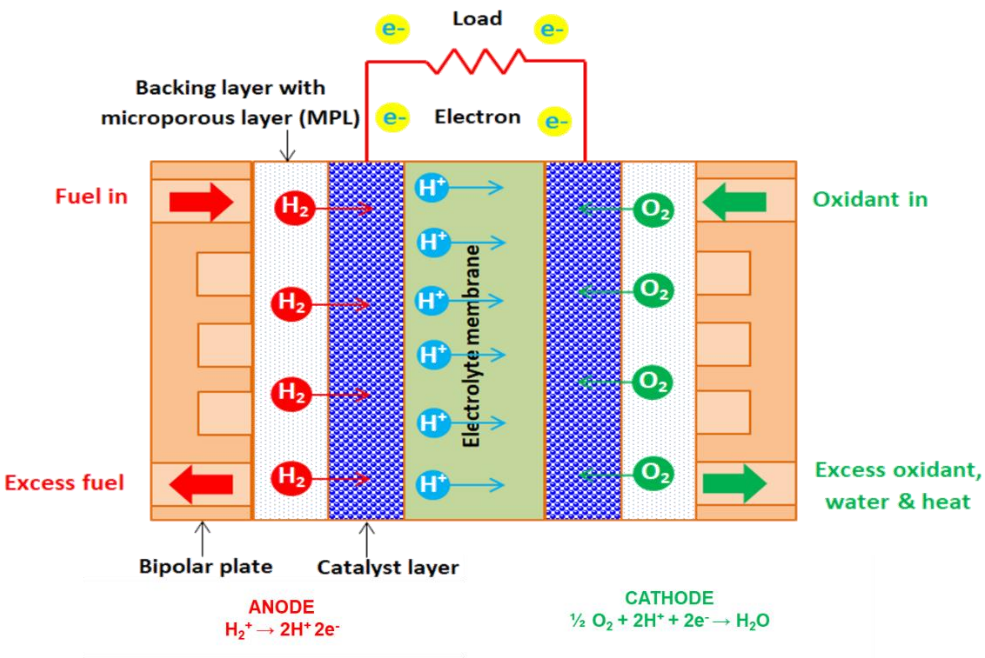

Figure 1. Working principle of PEMFC

The design of fuel cell systems can vary significantly depending on the fuel cell type and application. However, most fuel cell systems consist of four basic components (as shown in Figure 2):

a) A set or stack of individual cells consisting of an electrolyte sandwiched between two thin electrodes.

b) A fuel processor or reformer that converts the hydrogen-rich fuel into a form usable by the fuel cell, an electrolyser or a hydrogen storage system (tank or transportable cylinders). Most fuel cell systems use pure hydrogen or hydrogen-rich fuels, such as methanol, gasoline, methane, diesel or gasified coal, to produce electricity. These fuels are passed through on-board internal reformers within the fuel cell itself, or though external reformers that extract the hydrogen from the fuel.

c) Power-conditioning equipment that converts the direct current produced by the fuel cell into alternating current.

d) A number of subsystems to manage air, water, thermal energy and power.

Careful design consideration and assembly of these components into the whole system is very important.

In addition, a heat recovery system is typically used in high-temperature fuel cell systems that are used for stationary applications where the excess energy in the form of heat can be used to produce steam or hot water or converted to electricity.

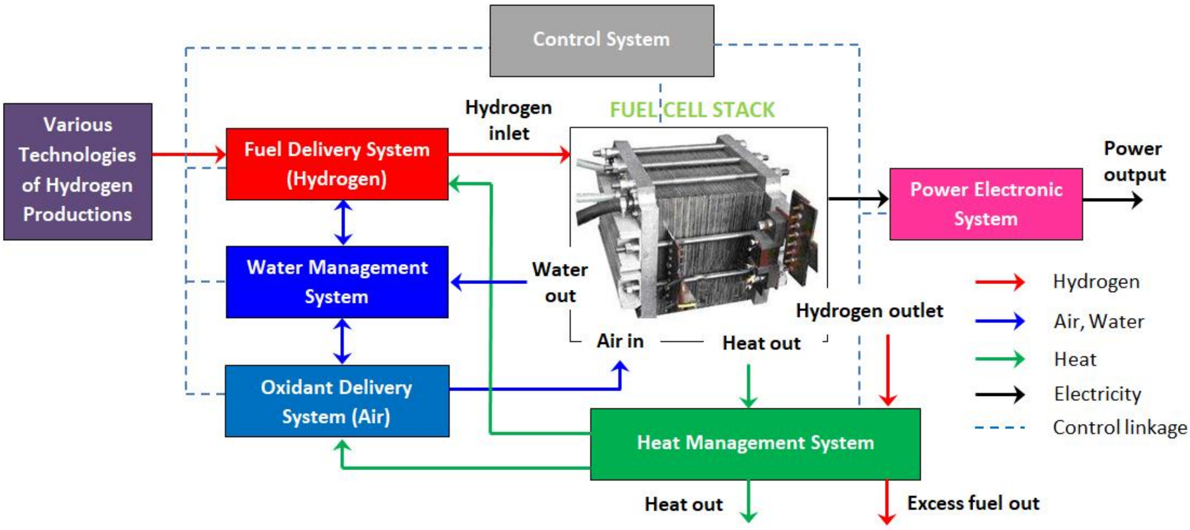

Figure 2. Basic components of PEMFC system

5.3 Approval and Operational Considerations

5.3.1 Regulatory Approval

The installation of fuel cell system may be subjected to the approvals under the following Acts, but not limited to;

a. Act 127, Environmental Quality Act 1974 (EQA 1974);
b. Act 139, Factories and Machinery Act (FMA) 1967;
c. Act 447, Electricity Supply Act 1990.
d. Act 514, Occupational Safety and Health Act 1994 (OSHA 1994) and/ or;
e. Act 549, Standards of Malaysia Act 1996

5.3.2 System Operational Consideration

5.3.2.1 Installation

Equipment shall be properly installed and regularly serviced in accordance with the manufacturer's instructions. These include the location of installation, pressure, ventilation and gas venting system, materials selection for installation, mechanical, thermal, and falling hazards, lightning protection and the manual handling to operate the system. Please refer to 8.1 and 8.2 for the details.

5.3.2.2 Operational

Equipment shall be designed and constructed in such a way as to allow access in safety to all areas where intervention is necessary during operation, adjustment and maintenance of the equipment. Moreover, equipment shall be designed, constructed and equipped so that the need for operator intervention is minimized. If operator intervention cannot be avoided, it shall be possible to carry it out easily and safely.

For an equipment equipped with safety and controlling devices, the functioning of the safety devices shall not be overruled by the controlling devices. All parts of equipment that are set or adjusted at the stage of manufacture should be appropriately protected, where it should not be manipulated by the user or the installer. Levers and other controlling and setting devices shall be clearly marked and provided with appropriate instructions to prevent any error in handling. Their design shall preclude accidental manipulation.

The surface temperature of knobs and levers of equipment's shall not present a danger to the user.

Other areas that need to be addressed in the design of the control system are:

a) safety and reliability of control systems;

b) control devices;

c) starting;

d) stopping;

e) selection of control or operating modes; and

f) failure of the power supply.

5.3.2.3 Maintenance

Equipment shall be designed and constructed in such a way as to allow safe access to all areas where intervention is necessary during operation, adjustment and maintenance of the equipment. Adjustment and maintenance points shall be located outside danger zones. It shall be possible to carry out adjustment, maintenance, repair, cleaning and servicing operations while equipment is at a standstill. If one or more of the above conditions cannot be satisfied for technical reasons, measures shall be taken to ensure that these operations can be carried out safely. In the case of automated equipment and, where necessary, other equipment, a connecting device for mounting diagnostic fault-finding equipment shall be provided. Automated equipment components that need to be changed frequently shall be capable of being easily and safely removed and replaced. Access to the components shall enable these tasks to be carried out with the necessary technical means in accordance with a specified operating method.

5.4 Hazards associated with fuel cell installation and operation

5.4.1 Fire and explosion hazards

The estimation of hazards and hazard levels is essential to the consideration of accidental consequences, e.g. overpressures, thermal radiation, the throw of debris or missiles, and the damage level or the vulnerability of the receiving objects. In chemical fires or explosions that are usually exothermal oxidation reactions, a great proportion of the combustion energy is carried by the developing blast wave, which is uniformly distributed in all directions.

Many flammable gases are widely in use today, such as methane, propane, etc and without appropriate measures being taken, a gas release and subsequent fire and explosion can occur. On the other hand, hydrogen has some significantly different properties from these more commonly used gases, which need to be fully appreciated to achieve comparable levels of safety.

The requirements for hydrogen storage defined in Clause 5 of MCMC MTSFB TC G023 shall apply.

5.4.2 Hazards of fuels other than hydrogen

Many fuel cells use hydrogen produced by the reforming of hydrocarbon fuels, while other high temperature fuel cells are able to utilise suitable hydrocarbons directly. The processing and/or use of these hydrocarbon fuels will produce carbon dioxide. Appropriate measures, such as containment and ventilation, should be taken to ensure that any carbon dioxide effluent stream is effectively discharged and does not produce an asphyxiation risk.

Natural gas (methane) is lighter than air and will tend to diffuse upwards, but at a much slower rate than hydrogen. The explosion limits for natural gas (5 % - 15 % v/v) are also much narrower than hydrogen. The characteristics of both fuels should be considered for any dual fuel systems. The pipe work and equipment used to supply natural gas should also be suitable and designed to an appropriate standard.

Liquefied Petroleum Gas (LPG) is considerably heavier than air. In the event of a leak, LPG vapour will usually percolate downwards and may accumulate on the floor or in low-lying sumps, rapidly producing a flammable atmosphere. Mixtures containing 2 % - 10 % v/v LPG in air will readily ignite and explode. The significant differences in the buoyancy and dispersion characteristics of the two fuels should be carefully considered in systems where LPG and hydrogen may both be present. The pipe work and equipment used to store and supply LPG fuel should also be suitable and be designed to an appropriate standard.

Methanol can be used directly by some types of fuel cell. This fuel has some hazards that demand particular attention. In addition to being a highly flammable liquid, methanol is also toxic by inhalation, ingestion and notably, by skin absorption. Appropriate precautions such as containment and ventilation should be taken to prevent spillages and the accumulation of hazardous methanol-air mixtures whenever it is used.

Overall, compared to the hazards associated with more conventional equivalents to fuel cells e.g. natural gas boilers and batteries, some different hazards have to be considered, including not only the fuel cell but also the means of fuel production, storage and transportation.

6. Safety Requirement for Hydrogen

When installing a hydrogen fuel cell system, many safety factors need to be taken into account. This clause deals with the safety requirement of hydrogen for the operational of fuel cell system.. When seeking to control the risks associated with using hydrogen, it is important to:

a) take all reasonable steps to prevent a loss of containment of hydrogen;

b) ensure if there is a leak that a flammable atmosphere cannot accumulate;

c) control potential ignition sources where flammable atmospheres may accumulate; and

d) use suitable protection against the fire and explosion hazards.

It should be noted that many of the regulations and standards cited in this clause would not be applicable or relevant to residential applications and only apply to the workplace. Nonetheless it is recommended that the general principles be adopted for identifying hazards and implementing prevention and protection measures for residential applications.

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6.1 Hydrogen generation

6.1.1 Generation options

For large central production facilities, hydrogen can be produced on-site from natural gas and delivered to or produced at the point of use. An option for the future is via the existing natural gas transmission system. For small-scale stationary applications, the usual method of delivery from production facilities to site is by single transportable cylinders or manifolded packs of cylinders.

Methods of on-site production include reforming of natural gas that is being supplied by the existing natural gas distribution network and the electrolysis of water. Production units being developed for domestic applications potentially have the capability to generate enough hydrogen to supply a fuel cell (to provide electricity and heating for the home) and re-fuel a hydrogen-powered car. The widespread adoption of on-site production would reduce the need for large-scale hydrogen production, distribution and storage facilities.

6.1.2 Standards and guidance

General guidance on the safety of hydrogen systems can be referred to the International Standard Organisation's (ISO) Technical Report ISO/TR 15916.

ISO 16110-1 covers the safety of stationary hydrogen generators intended for indoor or outdoor commercial, industrial and residential applications using fuel-processing technologies. It applies to packaged, self-contained or factory matched generation systems with a capacity of less than 400 m^3/h that convert the input fuel to a hydrogen-rich stream of composition and condition suitable for the type of device using the hydrogen, e.g. a fuel cell. Input streams include one or a combination of the following fuels:

a) natural gas and other methane-rich gases derived from biomass or fossil fuel sources;

b) fuels derived from oil refining such as petrol, diesel, LPG, alcohols, esters, ethers, aldehydes, ketones and other hydrogen-rich organic compounds; and

c) gaseous mixtures containing hydrogen.

ISO 22734-1 covers the construction, safety and performance requirements of packaged or factory matched generators for both indoor and outdoor using water electrolysis process. Hydrogen generators that can also be used to generate electricity such as reversible fuel cells are excluded from the scope of the standard.

Hydrogen fuel cells such as PEMFC and AFC usually require a hydrogen supply of high purity, as their performance and operational life can be adversely affected by impurities in the hydrogen supply. Meanwhile, the requirements on hydrogen purities for SOFC is less stringent. ISO 14687 deals with product specification for hydrogen fuel. The European Industrial Gases Association (EIGA) document on gaseous hydrogen stations (IGC Doc 15/06/E) contains some guidance on the operation of purification systems. The related codes and standards for hydrogen can be referred to Annex B.

6.2 Hydrogen containment and piping

Measures to prevent the release of dangerous substances should be given the highest priority. The likelihood of a leak occurring can be minimised by using high quality engineering.

Particular attention should be paid to the design, installation, operation and maintenance of hydrogen handling equipment in order to reduce the likelihood and size of any leak. The following points should be taken into account as recommended best practices:

a) to ensure that the storage equipment, pipe work and connections conform to an approved standard for hydrogen equipment;

b) to ensure that maintenance work is effectively controlled and is only carried out by authorised or competent people;

c) to minimise the disturbing frequency for made or repair purpose on the connection or joints

d) for gaseous supply, preference is given to the use of appropriate refillable stationary storage instead of regular replacement of the individually connected gas cylinders;

e) to use the minimum amount of storage that is practical without disproportionately increasing other hazards, such as those associated with moving gas cylinders;

f) to use the minimum length and size of pipe work that is appropriate;

g) to use the minimum length of high-pressure pipe work, from the pressure source to the high-pressure regulator;

h) in order to minimise mass flow of hydrogen and the consequences of any unintended releases, where possible, use as small a diameter and operating pressure. Flow restriction may also be used on high pressure pipe work;

i) to minimise hydrogen inventories where possible;

j) to minimise the number of joints by using continuous lengths of pipe work wherever practicable;

k) where possible, use fusion joints (welded or brazed) to join pipe work. Flange or threaded connectors may be used where necessary;

l) to give due consideration to the risk of fatigue due to vibrations in pipes;

m) to ensure that a leak test on the system is conducted before use in a manner appropriate to hydrogen systems;

n) to use a high-pressure relief valve downstream from the high-pressure regulator that is able to vent into a ‘safe’ place where hydrogen gas cannot accumulate but can freely disperse;

o) to use suitable isolation valves with locking facilities, which enable isolation of sections of pipe work or system for routine maintenance and in emergencies;

p) to ensure all hydrogen handling equipment and piping shall be identified and appropriately labelled;

q) to carry out appropriate inspections of the system at suitable regular intervals and record the results; and

r) to review the operation and maintenance history at suitable intervals.

When high-pressure storage is used, it should be designed and built to an appropriate design code or standard and located in a secure open-air compound. Measures appropriate to the location should be taken to prevent unauthorised access, vandalism and impact from vehicles.

Cryogenic hydrogen storage installations should be constructed to an appropriate code and located in a suitable open-air position and not within an occupied building. Low temperature storage installations should incorporate suitable measures to prevent oxygen-rich liquid air, a powerful oxidising agent, from condensing on uninsulated surfaces exposed to liquid hydrogen temperatures. Potentially flammable materials, including asphalt and tarmac, should not be present beneath pipe work where condensation may occur to avoid the risk from fire.

For the supply of hydrogen, only appropriate pipe work and fittings should be used. Cupronickel and stainless steel are preferred materials for high-pressure pipe work, whereas copper can be used for lower pressures. All pipe work joints should be brazed or welded where possible. Flanged or screwed joints may be used where necessary. Suppliers should be able to provide information on the operating parameters of pipe work and fitting, and the standards used for their manufacture.

Compression joints are generally not recommended for use on hydrogen systems as a leak-free condition is difficult to be achieved and maintained with these joints. Where their use is considered essential, such as on small-bore pipe work, they should be suitable for the duty and used in strict accordance with the manufacturer's instructions.

Particular attention should be given to the design and location joints in the system that may require regular maintenance, or where mechanical joints will be frequently disturbed or made or broken as the likelihood of leaks in these areas is increased. A typical example of this is the connection between the cylinder and the manifold. Therefore, it should be checked with a suitable detection solution or electronic gas detection device whenever the cylinder is changed.

Pipe routing should reflect consideration of factors such as risk from impact damage, formation of flammable mixtures in poorly ventilated areas, heat sources etc. Consequently, there should be no mechanical joints where pipe work passes through enclosed ducts, cavity walls, etc.

Piping should preferably be routed above ground. If underground pipe work is unavoidable, it should be adequately protected against corrosion. The position and route of underground piping should be recorded in the technical documentation to facilitate safe maintenance, inspection or repair. Underground hydrogen pipelines should not be located beneath electrical power lines.

Pipe work should be cleaned before being placed into service using a suitable procedure for the type of containment, which provides a level of cleanliness required by the application.

Systems should be suitably purged using an inert gas (i.e. nitrogen) to prevent little or no mixing between the purge gas and the displaced air. Purging can be implemented by sweep purging, evacuation or repeated pressurisation and venting cycles, using appropriately engineered and sited vent and purge connections. Consideration should also be given to the asphyxiation hazards of using inert gases.

7. Siting

Requirements applicable to the siting of stationary fuel cell installations fuelled by hydrogen and of their attendant storage and hydrogen generation systems (the installation) will vary according to whether the installation is located in domestic dwellings, in commercial premises or buildings, or outside in the open air.

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7.1 General requirements for residential, commercial and industrial installations

During installation, the risk assessment should be made and acceptable until the risk is reduced to as low as reasonably practicable. The following general requirements apply to all systems:

a) the installation should be placed on firm foundations and capable to support the load;

b) the installation area, either enclosure or housing, should be designed with effective high-level and low-level ventilation openings to prevent from trapped hydrogen leakage;

c) the installation components, particularly vent or exhaust outlets, should be sited giving due attention to adjoining doors, windows, outdoor air intakes and other openings into buildings;

d) air intakes shall be located in such a way that the fuel cell is not adversely affected by other exhausts, gases or contaminants;

e) exhaust outlet should not be directed onto walkways or other pedestrian paths;

f) security barriers, fences, landscaping and other enclosures should not affect the required flow into or exhaust out of the installation;

g) any vents (from pressure relief valves or bursting joints, etc.) should be piped to a safe area and any points of possible leakage should be in an area where any gas cannot accumulate or is freely ventilated. Additional attention should be taken so that the vents do not release hydrogen adjacent to walls or along the ground as this may increase the extent of the flammable cloud or flame;

h) safety or separation distances where a release is foreseeable during normal operation should be determined on a case-by-case basis. Separation distances should be measured horizontally from those points in the system, where in the course of operation, an escape of hydrogen may occur. The most recent version of an appropriate standards should be consulted for additional information on the appropriate use of separation distances. In circumstances where it is not practicable to use minimum separation distances, an acceptable situation may be achieved through the use of fire-resistant barriers, fire compartments, fire resistance, room-sealed equipment, appliance compartments, other hydrogen safety engineering or risk reduction techniques;

i) for all indoor locations, the installation should comply with all applicable building regulations as they relate to heating and electrical equipment, fuel storage systems, conservation of fuel and power, protection against pollution and to secure reasonable standards of health and safety for people in or around the buildings;

j) for all indoor fuel cell locations, liquefied and gaseous hydrogen storage should conform to recognised guidance and be located either:

    i) outside in the open air;

    ii) in an appropriate dedicated unoccupied storage building;

    iii) in an appropriately ventilated enclosure; or

    iv) in a purpose designed indoor or underground facility.

7.2 Requirements for commercial and industrial premises

The requirements are as follows:

a) The fuel cell and any associated equipment shall be suitably protected against unauthorised access, interference, vandalism or terrorist attack commensurate with the location and installation environment. Any security arrangements shall not compromise the requirement for effective ventilation.

b) The fuel cell system and associated equipment shall be suitably located to allow access for service, maintenance, fire department and emergency. They also shall be supported, anchored and protected so that they will not be adversely affected by weather conditions (rain, seismic events and lightning) or physical damage. Furthermore, the placing of any components of the fuel cell system should not adversely affect required building exits, under normal operations or in emergencies.

c) If practicable, the installation should be located in an unoccupied room built to appropriate fire-resistance standards and within an appropriate fire-resisting and non-combustible enclosure. Congestion, blockages and obstructions should be kept to an absolute minimum in the room as they may enhance flame acceleration in the event of an accident.

d) The room in which the fuel cell and associated equipment are located shall provide a minimum of 30 minutes fire-resistance and be fitted with a suitable fire detection and alarm system.

e) The installation should not be located in areas that are used or are likely to be used for combustible, flammable or hazardous material storage.

f) Any potential sources of ignition, such as non-flameproof electrical light fittings, should be located well below any equipment from which hydrogen may leak and not immediately below horizontal bulkheads or impervious ceilings under which hydrogen may accumulate.

g) For workplaces, it is a legal requirement under DOSH for the employer to identify fire and explosion hazards, classify areas where explosive atmospheres may exist, evaluate the risks and specify of measures to prevent or, where this is not possible, mitigate the effects of an ignition.

h) All equipment (electrical or mechanical) within the identified hazardous zone shall be certified by Malaysia Standards. Whenever reasonably practicable, the fuel cell and other hydrogen handling equipment shall be located at the highest level within the enclosure and physically isolated from any electrical equipment that is potential sources of ignition.

i) The distance between gas-tight compartments, bulkheads and ventilation should be as far as possible to reduce the likelihood of leaking hydrogen reaching potential ignition sources.

j) The installation should be located away from areas where potentially explosive atmospheres may be present;

k) The emission from the ventilation exhaust or other sources of emission shall be released to a safe place. An appropriate hazardous zone should be identified around any foreseeable release point.

l) The following additional factors should be taken into account in assessing that the risk is acceptable and has been reduced to as low as is reasonably practicable:

    i) smoking permitted areas;

    ii) uncontrolled public areas;

    iii) security barriers; and

    iv) emergency exits.

7.3 Explosion prevention and protection

The measures taken should be appropriate to the nature of the operation being undertaken, in order of priority and in accordance with the following basic principles:

a) the prevention of the formation of explosive atmospheres, or where the nature of the activity does not allow it;

b) the avoidance of ignition sources where an explosive atmosphere could exist; or

c) if ignition sources cannot be eliminated, the employment of measures to mitigate the effects of an ignition.

This approach to explosion safety, using a range of explosion prevention measures and, if the explosion risk cannot be entirely eliminated, explosion protection measures, is referred to as integrated explosion safety. Guidance on the integrated explosion safety approach can be found in BS EN 1127-1, which outlines the basic elements of risk assessment for identifying and assessing hazardous situations. The standards also specify the general design and construction methods to assist designers and manufacturers to integrate explosion safety in the design of equipment, protective systems and components.

7.3.1 Prevention of explosive atmospheres

The first line defence in preventing an explosion is to ensure an explosive atmosphere never exists. Explosive atmospheres can be a result of a leak generating an external explosive atmosphere, air ingress forming an explosive atmosphere inside the equipment, or having a process that operates with gas mixtures in the explosive range.

Hydrogen, due to its low viscosity, is particularly prone to leakage from piping, vessels, etc. Therefore, special attention should be given to ensure gas tight connections in any equipment containing hydrogen. The requirements for hydrogen containment and piping are discussed in 7.2. For processes that operate at sub-atmospheric pressures, leakage of hydrogen will not be an issue but the possibility of air ingress, resulting in the formation of an internal explosive atmosphere, needs to be considered.

Ventilation can be used to prevent small leaks generating an explosive atmosphere by ensuring the escaping gas cannot accumulate to concentrations above the Lower Explosion Limit (LEL). Ventilation is the air movement leading to replacement of a potentially dangerous atmosphere by fresh air. The following principles should be applied to ensure that any foreseeable release of a dangerous substance cannot accumulate to a concentration that affects the safety of people and property.

a) Wherever possible, locate the hydrogen storage or handling equipment in the open air location.

b) Estimate the maximum foreseeable release rate.

c) Provide adequate high and low flow rate ventilation.

d) Beware of low ceilings, canopies, covers and roofs.

e) Ensure the dilution air is drawn from a safe place.

f) Ensure vents and purges discharge to a safe place.

g) Use Computational Fluid Dynamics (CFD) for complex ventilation requirements.

It is always best to locate the hydrogen storage or handling equipment in the open air location, however below precautions still need to be taken to ensure that a flammable atmosphere cannot accumulate for indoor use.

a) Avoid the use of low, impervious roofs, canopies or bulkheads.

b) Avoid locations below eaves or other overhanging structures.

c) Use a suitable, non-combustible security fence rather than a wall.

d) Ensure adequate high- and low-level ventilation apertures where a wall around the storage system in unavoidable.

The size of any foreseeable leak into an enclosed or partially enclosed area should be used as the basis for any calculations of the ventilation requirements. The ventilation regime should be sufficient to ensure that the hydrogen concentration is normally maintained below 10 % of the LEL (0.4 % v/v for hydrogen), with only occasional temporary increases to 25 % of the LEL. Basic equations for calculating degrees of ventilation are described in BS EN 6007910.

Two main types of ventilation are recognised as below:

a) Passive or natural ventilation

The flow of air or gases is caused by the difference in the pressures or gas densities between the outside and inside of a room or enclosed space.

b) Active or forced (mechanical) ventilation

The flow of air or gas is created by artificial means such as a fan, blower or other mechanical means that will push or induce an air flow through the system. The artificial ventilation of an area may be either general or local.

Natural ventilation can be provided by permanent openings. The location of the openings shall be designed to provide air movement across the room or enclosed space to prevent the unwanted quantities of hydrogen-air mixtures. Inlet openings for fresh air intakes should be located near the floor in exterior walls (and only in such a way so that they do not reintroduce air previously evacuated from the process area). Outlet openings should be located at the high point of the room in exterior walls or roof. Inlet and outlet openings shall each have a minimum total set area of the room volume. In the ANSI/AIAA G-095, a minimum total ventilation area of 0.003 m^2/m^3 of room volume was set for the inlet and outlet openings. Discharge from outlet openings shall be directed or conducted to a safe location.

Ventilation openings shall be designed so that they will not become obstructed during normal operation by dust, rain or vegetation in accordance with the expected application. In open air situations, natural ventilation will often be sufficient to ensure dispersal of any explosive gas atmosphere which arises in the area. For outdoor areas, the evaluation of ventilation should normally be based on an assumed minimum wind speed of 0.5 m/s, which will be present virtually continuously.

The effect of wind should be considered when deciding vent orientation. Depending on the position of the vents, wind may impede or enhance the ventilation efficiency.

If it can be verified, natural ventilation should be permitted to provide all required ventilation and makeup air. If mechanical ventilation is required, the ventilation system shall be interlocked to the hydrogen process equipment to prevent process equipment from working in the absence of ventilation and shut it down upon loss of ventilation. It shall also be equipped with an audible and visual alarm in order to give a warning in case of failure. The ventilation unit shall be constructed and installed in such a way as to preclude the presence of mechanical and electrical sparking.

The forced ventilation of an area may be either general or local and differing degrees of air movement and replacement can be appropriate. Although forced ventilation is mainly applied inside a room or enclosed space, it can also be applied to situations in the open air to compensate for restricted or impeded natural ventilation due to obstacles. As in the case of natural ventilation, the diluted air used to artificially ventilate the area should enter at low level and be taken from a safe place. The ventilation outflow should be located at the highest point and discharge to a safe place outdoors. Furthermore, the mechanical means used to ventilate the enclosure should be suitable and in particular, the electrical motors should not be located in the potentially contaminated exhaust air stream.

Suitable arrangements should be in place to detect when the ventilation system is failing to provide adequate ventilation. This may be based on the measurement of flow or pressure. This should raise an alarm and safely isolate the electricity supply outside the enclosure and the hydrogen supply outside the building with a normally closed (fail safe) valve. The fuel cell system should shut down safely upon loss of adequate ventilation.

The cooling or air supply fan or compressor present in many fuel cell modules may sometimes be suitable to provide effective ventilation. Where this approach is used, the air shall be drawn from a safe place and the direction of the forced airflow shall be compatible with the expected movement of any hydrogen release as a result of buoyancy, thermal effects, etc.

Where differential pressure is used to prevent the ingress of hydrogen into adjoining compartments, the pressurisation air should be drawn from or discharged to a safe place. Suitable fail safes should be in place to raise alarms or cause shutdown in the case of any detected loss of ventilation or differential pressure.

The dilution airflow, the number and location of flammable atmosphere detectors should be appropriate in complex systems or congested areas. An appropriate modelling technique should be used in these situations to ensure that pockets of flammable mixture will not accumulate and remain undetected.

In situations where other fuels such as methane, LPG, etc are present in addition to hydrogen, the different densities and diffusivities need to be taken into account to ensure that the ventilation arrangements provided are adequate.

Ventilation is not recommended to be used as a prevention measure for large leaks, for example from the catastrophic failure of pipe as ventilation systems are unlikely to be able to disperse large leaks quickly enough to prevent an explosive atmosphere from accumulating. If ventilation is used as a prevention measure, then the reliability of the system has to be guaranteed and if the ventilation is only activated when a leak occurs then there shall also be a reliable method, e.g. gas detectors, of detecting the leak.

There is a higher risk of an explosive atmosphere being present in equipment during commissioning, when items of equipment will initially contain air before assembly, or during maintenance when equipment is opened up for inspection or repair allowing air ingress. For these operations, inerting can be employed to prevent an explosive atmosphere forming. Inerting is a technique by which the equipment is purged with an inert gas, such as nitrogen or carbon dioxide, until the oxygen concentration falls below the level required for flame propagation to occur. This is called the Limiting Oxygen Concentration (LOC). The LOC depends on the inert gas being used where inerts with higher heat capacities are more efficient and result in higher LOC values for a given flammable gas. For inerting with nitrogen, the LOC for hydrogen is 5 % v/v, while for inerting with carbon dioxide is 6 % v/v. Guidance on the application of the inerting technique can be found in PD CEN/TR 15282:2006.

Even if the formation of an explosive atmosphere cannot be prevented, then at a minimum, measures should be implemented to limit the extent of the explosive atmosphere. Such measures could include ventilation, use of gas tight seals on doors, pipe entry points, etc to prevent gas migration between rooms and compartments, and the use of a soft barrier. An example of a soft barrier is a curtain, made from polythene sheeting, which would allow easy access to the gas source area, but would restrict the flow of gas to the surrounding areas.

7.3.2 Avoidance of ignition sources

If the formation of an explosive atmosphere cannot be prevented or the process operates with a flammable atmosphere, the next level of protection is the avoidance of ignition sources in areas where a flammable atmosphere may occur. The hazardous areas where explosive atmospheres could be formed shall be identified and classified according to the likelihood of an explosive atmosphere being present. For situations where hydrogen and/or other flammable gases or liquids may be present, the following classifications should be used where appropriate:

a) Zone 0 - An area in which an explosive atmosphere is present continuously or for long periods. Only category 1 equipment should be used;

b) Zone 1 - An area where an explosive atmosphere is likely to occur during normal operation. Category 1 or 2 equipment should be used; and

c) Zone 2 - An area where an explosive atmosphere is not likely to occur during normal operation and, if it does occur, is likely to do so infrequently and will only last for a short period. Category 1, 2 or 3 equipment should be used.

Guidance on identifying and classifying the hazardous areas is given in BS EN 60079-10 and BS EN 1127-1.

Electrical and non-electrical equipment that are appropriate for use in the different areas of the workplace should be determined once the hazardous areas have been identified and classified. The EN 60079 series of standards specifies the requirements and testing of electrical equipment for use in the different zones. The MS IEC 60000 series of standards also specifies the electrical installation. Meanwhile, the methodology for the risk assessment of non-electrical equipment for use in potentially explosive atmospheres is provisioned in BS EN 15198.
The hazardous area classification should also be used to ensure that suitable controls are placed on all other foreseeable sources of ignition including hot work, smoking, vehicles, mobile phones and work clothing.

Precautions should also be taken to prevent the build-up of static charges that may lead to an incendive discharge. These may include:

a) ensuring that all pipe work is conductive and has effective electrical continuity, especially over mechanical joints such as flanges;

b) ensuring that all pipe work and equipment is effectively earthed;

c) carrying out and documenting appropriate earthing or continuity checks; and

d) wearing antistatic clothing and footwear in hazardous areas.

Appropriate protection is also required against the risk of lightning strike when designing outdoor fuel cell or hydrogen storage facilities.

7.3.3 Explosion mitigation

If explosive atmospheres may be present and ignition sources cannot be eliminated, then measures to mitigate the effects of the explosion and prevent the explosion from propagating to surrounding areas are required. There are a number of techniques available that can be employed to reduce the explosion pressure generated and/or contain the explosion within a given area.

7.3.3.1 Explosion venting

In this technique, weak areas (explosion vents) that fail early on in the explosion are deliberately incorporated in the item of equipment, venting the combustion products and so reducing the explosion pressure generated inside the equipment. There are a number of methods used to seal the vents, such as thin membranes, bursting discs, lightweight covers held in place by magnetic fasteners and spring-loaded doors. The opening pressure of the covers and the size of the vents are chosen to give explosion pressures below that which would damage the equipment. It may, however, be acceptable to allow some damage to the equipment, e.g. bowing of panels, provided it does not result in damage to the adjacent area or injuries to nearby personnel. It should also be ensured that the explosion is vented to safe areas so it causes no damage or injuries. BS EN 14797, BS EN 14994 and NFPA 68 provide guidance on the design of explosion relief systems and the methods of available for vent sizing.

7.3.3.2 Explosion suppression

Explosion suppression is achieved by injecting a suppressant agent, either water, a liquid or powder suppressant into a developing explosion to quench it before the maximum explosion pressure is attained. Suppressing hydrogen explosions is particularly challenging due to the high flame speeds of hydrogen explosions. Basic requirements for the design and application of explosion suppression systems are provisioned in BS EN 14373.

7.3.3.3 Isolation systems

Explosion isolation is a technique to prevent an explosion from propagating into other parts of the plant via connecting pipes or ducts. There are two types of isolation techniques, which are:

a) complete isolation - explosion pressure wave and a flame; and

b) partial isolation - involving only a flame.

The distinction between the two types is important as in some applications it may only be necessary to achieve flame isolation. The systems can be either be an active type, which requires a means of detecting the explosion and initiating an action to implement the isolation, or passive and requires no additional equipment to function. Examples of an active system are a quick acting valve, a complete isolation system, or an extinguishing barrier. The later system provides partial isolation by injecting a curtain of suppressant into the pipe or duct to quench the explosion. An example of a passive partial isolation system is a flame arrester. This device contains an arresting element, comprising a matrix of small apertures or convoluted gas pathways, with dimensions large enough to allow gas flow with minimal pressure drop, but small enough to quench and prevent the passage of flame through the element.. BS EN 12874 specifies the performance requirements, test methods and limits for use of flame arresters.

7.3.3.4 Containment systems

An alternative mitigation technique to those that aim to reduce the explosion pressure is to use equipment, for example process vessels, strong enough to contain the explosion. Equipment intended to withstand an internal explosion are classed as one of following two types.

a) Explosion-pressure resistant equipment is designed to withstand the expected internal explosion pressure without becoming permanently deformed.

b) Explosion-pressure-shock resistant equipment is designed to withstand the expected internal explosion pressure without rupturing but allowing for some permanent deformation.

EN 14460 specifies the requirements of the two classes of equipment.

7.3.3.5 Blast walls

Equipment and plant vulnerable to blast damage can be protected by blast walls. These are strong walls positioned between the item to be protected and the expected source of blast that will deflect the blast wave and thus reduce the intensity of explosion pressure experienced. They can also provide protection from missiles generated by the explosion. The possible beneficial and detrimental effects of blast walls on the dispersion of leaking gas need to be taken into account in the assessment of the explosion hazards. Depending on the circumstances, for example wind direction and site layout, blast walls may limit the spread of an explosive gas or air cloud. On the other hand, walls may extend the time an explosive cloud is present and thus the likelihood of an ignition, by inhibiting the dispersion of the gas by the wind. These effects are more likely to be important for gases other than hydrogen, as there will be a significant upward dispersal due to buoyancy and its low density.

Annex A
(Normative)

Normative references

The following normative references are indispensable for the application of this Technical Code. For dated reference, only the edition cited applies. For undated references, the latest edition of the normative reference (including any amendments) applies.

Act 127*, Environmental Quality Act 1974 (EQA 1974);*

Act 139, *Factory and Machinery Act 1967*Act 447*, Electricity Supply Act 1990*

Act 514, *Occupational Safety and Health Act 1994* Act 549*, Standards of Malaysia Act 1996*

MCMC MTSFB G023, *Hydrogen Storage and Safety with Fuel Cell as Power Generator for Information, Communications and Technology Infrastructure*

RR715 Research Report, Health and Safety Executive, *Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version*

Telecommunications Industry Association USA Reference Guide, *Regulations, Codes, and Standards for The Deployment of Stationary Fuel Cells*

Annex B
(Informative)

Codes and standards for hydrogen

Table B.1 lists useful codes and standards. Codes and standards are under continuous update and review. For the latest status of the hydrogen and fuel cell codes and standards the user is referred to: http://www.fuelcellstandards.com. This table is reproduced from HSE document with permission of the Health and Safety Executive under the terms of the Open Government Licence.

Table B.1 List of codes and standards.

Application/topic	Applicable codes and standards
Hydrogen system specifications	BS EN 62282-3-1, *Fuel cell technologies – Part 3.1:Stationary Fuel Cell Power Systems – Safety*.
	BS ISO 16110-1, *Hydrogen generators using fuel processing technologies. Safety.*
	Act 139, Factory and Machinery Act 1967.
	Gas Supply Act 1993: Gas Supply Regulations 1997: P.U.(A) 287
	EN 50465, *Gas appliances-Fuel cell gas heating appliance nominal heat input up to 70kW*.
	BS EN 13611, *Safety and control devices for gas burners and gas-burning appliances - general requirements.*
	BS EN 161, *Automatic shut-off valves for gas burners and gas appliances.*
	BS EN 298, *Automatic gas burner control systems for gas burners and gas burning appliances with or without fans.*
	BS EN 437, *Test gases. Test pressures. Appliance categories.*
	BS EN 483, *Gas-fired central heating boilers. Type C boilers of nominal heat input not exceeding 70 kW.*
	BS EN 677, *Gas-fired central heating boilers. Specific requirements for condensing boilers with a nominal heat input not exceeding 70 kW.*
	BS EN ISO 12100-1, *Safety of machinery. Basic concepts, general principles for design. Basic terminology, methodology*.
	BS EN ISO 12100-2, *Safety of machinery. Basic concepts, general principles for design. Technical principles*.
	BS EN 50165, *Electrical equipment of non-electric appliances for household and similar purposes. Safety requirements.*
	BS EN 60079-14, *Explosive atmospheres. Electrical installations design, selection and erection.*
	BS EN 60079-17, *Explosive atmospheres. Electrical installations inspection and maintenance.*
	BS EN 60079-19, *Explosive atmospheres. Equipment repair, overhaul and reclamation.*
	BS EN 60204-1, *Safety of machinery. Electrical equipment of machines. General requirements*

Table B.1 List of codes and standards *(continued)*

Application/topic	Applicable codes and standards
Hydrogen system specifications	BS EN 60335-1, *Specification for safety of household and similar electrical appliances. General requirements.*
	BS EN 60529, *Specification for degrees of protection provided by enclosures (IP code).*
	BS EN 60730 series. *Automatic electrical controls for household and similar use.*
	BS EN 60950-1, *Information technology equipment. Safety. General requirements.*
	BS EN 61000-6-2, *Electromagnetic compatibility (EMC). Generic Standards. Immunity for industrial environments.*
	BS EN 61000-6-4, *Electromagnetic compatibility (EMC). Generic standards. Emission* standard for industrial environments.
	ANSI/AIAA G-095, *Guide to Safety of Hydrogen and Hydrogen System. American National Standards Institute/American Institute of Aeronautics and Astronautics.*
Fire safety	Fire Services Act 1988
	PD 6686. *Guidance on directives, regulations and standards related to prevention of fire and explosion in the process industries.*
Hydrogen systems installation	BS EN 61779 series (Parts 1 to 5)*, Electrical Apparatus for the Detection and Measurement of Flammable Gases.*
	BS EN 60079-29-1, *Explosive atmospheres. Gas detectors. Performance requirements* of detectors for flammable gases.
	BS EN 60079-29-2, *Explosive atmospheres. Gas detectors. Selection, installation, use and maintenance of detectors for flammable gases and oxygen.*
	BS EN 62282-3-3, *Fuel cell technologies – Part Stationary fuel cell power systems – Installation.*
	EN 60079-10, *Electrical apparatus for explosive gas atmosphere. Classification of hazardous areas.*
	HSG243. Fuel cells – Understand the hazards, control the risks. HSE Books.
	An Installation Guide for Hydrogen Fuel Cells and Associated Equipment (Draft). UK Hydrogen Association.
	CGA G-5.4, *Standard for Hydrogen Piping Systems at Consumer Sites. Compressed Gas Association.*
	CGA G-5.5, *Hydrogen Vent Systems. Compressed Gas Association.*
	NFPA 853, *Standard for the Installation of Stationary Fuel Cell Power Plants. National Fire Protection Association.*
	ASME B31, *Hydrogen Piping and Pipeline Project Team. American Society of Mechanical Engineers.*

Table B.1 List of codes and standards *(continued)*

Application/topic	Applicable codes and standards
Hydrogen storage	BS EN ISO 11114-1, *Transportable gas cylinders. Compatibility of cylinder and cylinder valve with gas contents. Metallic materials.*
	BS EN ISO 11114-4, *Transportable gas cylinders. Compatibility of cylinder and cylinder valve with gas contents. Test methods for selecting metallic materials resistant to hydrogen.*
	NFPA 55, *Standard for the Storage, Use and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, cylinders, Equipment and Tanks. National Fire Protection Association.*
	CGA C-10, *Recommended procedures for changes of gas service of compressed gas cylinder. Compressed Gas Association.*
	IGC Doc 100/03/E, *Hydrogen cylinders and transport vessels. European Industrial Gases Association.*
	CGA PS-20 CGA, *Position Statement on the Direct Burial of Gaseous Hydrogen Storage Tanks. Compressed Gas Association.*
	CGA PS-21, *Position Statement on Adjacent Storage of Compressed Hydrogen And Other Flammable Gases. Compressed Gas Association.*
	CGA Doc 02-50, *Hydrogen Storage in Metal Hydrides. Compressed Gas Association.*
General hydrogen safety	Biennial Report on Hydrogen Safety. HYSAFE Network of Excellence.
	Guidance for using hydrogen in confined spaces. InsHYde project (internal project of the HYSAFE Network of Excellence).
	ISO TR 15916, *Basic Considerations for the Safety of Hydrogen Systems.*
	Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002.
	ANSI/AIAA G-095, *Guide to Safety of Hydrogen and Hydrogen System. American National Standards Institute/American Institute of Aeronautics and Astronautics.*
	CGA P-6, *Standard Density Data, Atmospheric Gases and Hydrogen. Compressed Gas Association.*
	NFPA 50A, *Standard for gaseous hydrogen system at consumer sites. National Fire Protection Association.*
	The Fire Protection Research Foundation Technical Report. Siting Requirements for Hydrogen Supplies Serving Fuel cells in Non-combustible Enclosures.
	BS EN 12874, *Flame Arresters - Performance Requirements, test methods and limits for use*
	BS EN 14373, *Explosion suppression systems*
	BS EN 14797, *Explosion venting devices*
	BS EN 14994, *Gas explosion venting protective systems*
	NFPA 68, *Standard on Explosion Protection by Deflagration Venting*

Table B.1 List of codes and standards *(concluded)*

Application/topic	Applicable codes and standards
Safety distances	IGC Doc 15/06/E, *Gaseous Hydrogen Stations. European Industrial Gases Association.*
	IGC Doc 75/01/rev, *Determination of Safety Distances. European Industrial Gases Association.*
	ISO TR 15916, *Basic Considerations for the Safety of Hydrogen Systems.*
	NFPA 50A, 50B, 52 and 55, *National Fire Protection Association.*
Fuel cells - general	BS EN62282-3-1, *Fuel cell technologies – Part 3-1: Stationary fuel cell power systems – Safety.*
	BS EN 62282-3-2, *Fuel cell technologies – Part 3-2: Stationary fuel cell power plants - Performance test methods.*
	BS EN 62282-3-3, *Fuel cell technologies – Part 3-3: Stationary fuel cell power systems – Installation.*
Hydrogen fuel	ISO 14687, *Hydrogen fuel. Product specification.*
	ISO/TS 14687-2, *Hydrogen fuel. Product specification. Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles.*
Hydrogen sensors	BS EN 61779, *Parts 1 to 5. Electrical apparatus for the detection and measurement of flammable gases.*
	BS EN 60079-29-1, *Explosive atmospheres. Gas detectors. Performance requirements of detectors for flammable gases.*
	BS EN 60079-29-2, *Explosive atmospheres. Gas detectors. Selection, installation, use and maintenance of detectors for flammable gases and oxygen.*
	ISO / DIS 26142, *Hydrogen Detection.*
	EN 50073, *Guide for selection, installation, use and maintenance of apparatus for the detection and measurement of combustible gases or oxygen.*
	BS EN 62282-3-3, *Fuel cell technologies – Part 3-3: Stationary fuel cell power systems – Installation.*
	ISO TR 15916:2004. Basic Considerations for the Safety of Hydrogen Systems.
	ANSI/AIAA G-095, *Guide to Safety of Hydrogen and Hydrogen System. American National Standards Institute/American Institute of Aeronautics and Astronautics.*
Explosion venting	EN 14994, *Gas Explosion Venting Protective Systems.*
	NFPA 68, *Standard on explosion protection by deflagration venting (2007 edition). National Fire Protection Association.*

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[14] DOC 06/02/E, *Safety in storage, handling and distribution of liquid hydrogen. EIGA*

[15] EN 14460, *Explosion resistant equipment.*

[16] EN 15098, *Explosion isolation systems.*

[17] EN 15198, *Methodology for the risk assessment of non-electrical equipment and components for intended use in potentially explosive atmospheres.*

[18] IEC 60079, *Explosive atmospheres*

[19] IEC 61000, Electromagnetic compatibility (EMC)

[20] IEC 62040-1, *Uninterruptible power systems (UPS) - Part 1: Safety requirements*

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