

Design and implementation of mobile and static hydrogen refuelling sites – Code of practice

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Department
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Foreword

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The content in this version is part of an iterative process. It is likely to change from time to time with subsequent iterations.

Supersession

This version of BSI Flex 2073 v2.0:2025 supersedes BSI Flex 2073 v1.0:2024-10, which is withdrawn.

Relationship with other publications

This BSI Flex is part of the zero emission HGV and infrastructure demonstrator programme, alongside:

- BSI Flex 2071, *Design and implementation of publicly accessible charging sites for battery electric HGVs – Code of practice*
- BSI Flex 2072, *Battery electric and hydrogen-fuelled heavy-duty vehicles – Workshops and protocols for maintenance and inspection – Specification*

Information about this document

This is Version 2.0 of BSI Flex 2073, which is the last planned version of the document. All comments received will be reviewed to inform the future direction of this document. Interested parties are encouraged to check the BSI website for updates regarding any future plans.

This is a partial update of the document, and introduces the following principal changes:

- amendments and refinements to some clauses have been made to reflect in-practice operations;
- additional references to existing standards, legislation, regulations, and guidance literature have been added;
- terminology and definitions for earthing, pressure, pipeline and pipework have been updated;
- Table 1 has been expanded and a sub-clause added on utilities;
- references to performance level and safety integrity level have been clarified;
- risk assessments regarding unauthorized, malicious or incorrect use, and separated measures around physical or remote access have been added;
- updated text for hazardous area classification and relationship to equipment protection levels (EPLs) has been explained;
- sub-clauses have been added to cover the effects of vermin, dispenser sampling and emergency response planning;
- description of risk assessments have been added categorized in Annex A;
- signage requirements have been updated;
- clarity on the types of technical files have been added to Annex C; and
- the need to demonstrate competency has been added throughout.

This publication can be withdrawn, revised, partially superseded or superseded. Information regarding the status of this publication can be found in the Standards Catalogue on the BSI website at knowledge.bsigroup.com, or by contacting the Customer Services team.

Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Use of this document

As a code of practice, this BSI Flex takes the form of recommendations and guidance. It is not to be quoted as if it were a specification. Users are expected to ensure that claims of compliance are not misleading.

Users may substitute any of the recommendations in this BSI Flex with practices of equivalent or better outcome. Any user claiming compliance with this BSI Flex is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this BSI Flex that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this document are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. "organization" rather than "organisation").

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Compliance with a BSI Flex cannot confer immunity from legal obligations.

In particular, attention is drawn to the following specific regulations:

- Pressure Equipment (Safety) Regulations 2016 [1];
- Pressure Systems Safety Regulations 2000 (PSSR) [2];
- Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) [3];
- Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016 (EPSR) [4];
- Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (as amended) [5];
- Electricity at Work Regulations 1989 [6]; and
- Supply of Machinery (Safety) Regulations 2008 [7].

0 Introduction

0.1 Background

This BSI Flex is intended to drive innovation in the design of both mobile and static hydrogen dispensers, to enable operational safety, reliability, efficiency, and suitability for various hydrogen service levels and fuel grades.

Operating mobile hydrogen refuelling systems introduces specific challenges. This document references existing guidance for static systems and how they relate to mobile contexts, identifying where current guidelines are applicable and outlining additional recommendations necessary for mobile deployments.

0.2 Ad-hoc refuelling

It is important for users of this BSI Flex to understand the paramount importance of safety when deploying and operating a hydrogen refuelling system.

Hydrogen refuelling can only be undertaken in controlled conditions. Deployment sites that receive a mobile hydrogen system with the intention of conducting refuelling activities are to be fully risk assessed, with control measures in place prior to receiving the mobile hydrogen system. Ad-hoc fuelling, undertaken outside of these conditions, is not permissible.

Restrictive measures prevent deployments that are not subject to the stringent safety protocol and control measures necessary to perform the safe and controlled refuelling of hydrogen.

There is a shared responsibility between both the system operator and site operator to jointly deploy and operate a hydrogen refuelling system such that it meets the recommendations of this code of practice.

0.3 Basic properties of hydrogen

Hydrogen is the lightest and most abundant chemical element in the universe, primarily existing as a diatomic molecule (H_2). It is colourless, odourless, non-toxic, and extremely flammable, requiring careful handling particularly under pressure or when there is potential for it to mix with air/oxygen.

Hydrogen has a low ignition energy and a wide range of flammable concentrations in air. Its properties allow for high efficiency in fuel cells and as a combustion fuel in internal combustion engines, making it a versatile alternative energy source. Subsequently low carbon hydrogen offers great potential to help reach future emissions targets.

Hydrogen is difficult to contain, leak detection and containment is critical to achieve safety in refuelling applications.

NOTE 1 PD ISO/TR 15916:2015 provides a detailed explanation of hydrogen's characteristics.

NOTE 2 BS EN ISO 80079-20-1 provides a table of the properties of hydrogen.

0.4 Safety evaluation and management of gaseous hydrogen

Due to its extremely flammable nature, stringent safety measures are required throughout the design and application lifecycles. Designers, manufacturers, installers and operators of the hydrogen system need to demonstrate competency and prove that they have evaluated and managed risks effectively in all hydrogen systems that they are involved with.

The primary hazards of hydrogen include:

- a) flammability: extremely high flammability and wide explosive range with air;
- b) thermal effects: risks associated with handling pre-cooled gas at -40 °C, which can cause cold burns or affect material integrity;
- c) pressure effects: risks from high-pressure systems used in storage and dispensing;
- d) easy ignitability: low energy requirement for ignition;
- e) small molecule size, leading to high permeability;
- f) low viscosity and high diffusion rate, enhancing its ability to spread quickly;
- g) high buoyancy, causing rapid dispersion upwards in air;
- h) material Interactions: embrittlement of certain metals, impacting structural integrity;
- i) asphyxiation hazard: displacement of oxygen in enclosed areas;
- j) storage hazards: elevated pressures for gas storage; and
- k) reverse Joule-Thomson effect: temperature changes during gas expansion or compression.

NOTE PD ISO/TR 15916:2015, Clause 6, provides expanded detailed safety guidelines.

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1 Scope

This BSI Flex gives design recommendations for mobile and static gaseous hydrogen refuelling systems intended for roadworthy heavy-duty vehicles. It covers the design, manufacture, installation, operation, and maintenance of both mobile and stationary compressed hydrogen refuelling sites within the UK, with fuelling pressures up to 70 MPa (700 bar).

This BSI Flex is applicable to the implementation of mobile and static elements of gaseous hydrogen refuelling systems.

This BSI Flex is of use to designers, manufacturers, installers, operators, inspectors and maintenance personnel of non-retail, commercial hydrogen refuelling systems for heavy-duty vehicles.

This BSI Flex might be of interest to designers, manufacturers, installers, operators, inspectors and maintenance personnel of commercial hydrogen refuelling systems for light commercial vehicles and for non-road mobile machinery (NRMM) application.

This BSI Flex does not cover marine, aviation, aerospace, rail applications or retail filling stations.

This BSI Flex does not provide details for installation or operation of on-site hydrogen production technologies. It does not cover liquid hydrogen storage and/or dispensing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions, or limits the application, of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 1127-1:2019, *Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology*

BS 7430, *Code of practice for protective earthing of electrical installations*

BS 7671:2018/A3:2024, *Requirements for Electrical Installations – IET Wiring Regulations*

BS EN 16942, *Fuels – Identification of vehicle compatibility – Graphical expression for consumer information*

BS EN 62023, *Structuring of technical information and documentation*

BS EN 62305 (all parts), *Protection against lightning*

BS EN IEC 60079-0:2018+A11:2024, *Explosive atmospheres – Equipment – Part 0: General requirements*

BS EN 60079-14, *Explosive atmospheres – Part 14: Electrical installation design, selection and installation of equipment, including initial erection*

BS EN IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

BS EN IEC 60079-19, *Explosive atmospheres – Part 19: Equipment repair, overhaul and reclamation*

BS EN 60204-1:2018, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

BS EN IEC 60947-4-1, *Low-voltage switchgear and control gear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

BS EN IEC/IEEE 82079-1, *Preparation of information for use (instructions for use) of products – Part 1: Principles and general requirements*

BS EN ISO 7010:2020+A6, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

BS EN ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

BS EN ISO 14120, *Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards*

BS EN ISO 17268-1, *Gaseous hydrogen land vehicle refuelling connection devices – Part 1: Flow capacities up to and including 120 g/s*

BS EN ISO 80079-36, *Explosive atmospheres – Part 36: Non-electrical equipment for explosive atmospheres – Basic method and requirements*

BSI Flex 2072 v1.0:2024, *Battery electric and hydrogen-fuelled heavy-duty vehicles – Workshops and protocols for maintenance and inspection – Specification*

BS ISO 14687, *Hydrogen fuel quality – Product specification*

BS ISO 16110-1, *Hydrogen generators using fuel processing technologies – Part 1: Safety*

BS ISO 19880-1:2020, *Gaseous hydrogen – Fuelling stations – Part 1: General requirements*

BS ISO 19880-3:2018, *Gaseous hydrogen – Fuelling stations – Part 3: Valves*

BS ISO 19880-5, *Gaseous hydrogen – Fuelling stations – Part 5: Dispenser hoses and hose assemblies*

BS ISO 19880-9, *Gaseous hydrogen – Fuelling stations – Part 9: Sampling for fuel quality analysis*

BS ISO 22734, *Hydrogen generators using water electrolysis – Industrial, commercial, and residential applications*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

PD CLC/TR 60079-32-1, *Explosive atmospheres – Part 32-1: Electrostatic hazards, guidance*

PD ISO/TR 15916:2015, *Basic considerations for the safety of hydrogen systems*

Other publications

[N1] SAE J2601-1, *Fueling protocols for light duty gaseous hydrogen surface vehicles*¹⁾

[N2] SAE J2601-2, *Fueling protocol for gaseous hydrogen powered heavy duty vehicles*²⁾

[N3] SAE J2601-5, *High-flow prescriptive fueling protocols for gaseous hydrogen powered medium and heavy-duty vehicles*³⁾

[N4] SAE J2799, *Hydrogen surface vehicle to station communications hardware and software*⁴⁾

¹⁾ Available at https://www.sae.org/standards/content/j2601_202005/.

²⁾ Available at https://www.sae.org/standards/content/j2601/2_201409/.

³⁾ Available at <https://www.sae.org/standards/content/j2601/5/>.

⁴⁾ Available at https://www.sae.org/standards/content/j2799_201912/.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

3.1.1 ad-hoc refuelling

improvised activity of undertaking refuelling in a location or under conditions that have not been approved and authorized for that purpose

3.1.2 battery vehicles

vehicle equipped with multiple gas containing cylinder elements each connected by a manifold and mounted on a permanently attached frame

NOTE A detailed description for a battery-vehicle can be found in the International Carriage of Dangerous Goods by Road (2023) (ADR) [8].

3.1.3 buffer storage

pressure vessels that are designed for the purpose of storing compressed hydrogen, located either between a hydrogen generator and a compressor for an even flow of gas to the compressor or between the compressor and dispensing system for accumulation of pressurized gas supply for vehicle fuelling

NOTE Buffer storage vessels can either be static or mobile systems.

3.1.4 control system

system which responds to input signals from the process and/or from an operator and generates output signals causing the process to operate in the desired manner

3.1.5 earthing

method of connecting the exposed metallic parts of an electrical appliance or installation to the earth itself by providing a protective conductor for a fault current to flow to earth

NOTE In other standards, the term "grounding" might be used.

3.1.6 equipment protection levels (EPLs)

classification system that defines the level of protection required by equipment used in environments with potentially explosive atmospheres

3.1.7 explosive atmosphere

mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour, or dust which, after ignition, permits self-sustaining propagation

NOTE This term is also known as flammable atmosphere.

[SOURCE: BS EN IEC 60079-10-1:2021, 3.1, modified – note added]

3.1.8 hazardous area

area in which an explosive gas atmosphere is present, or can be expected to be present, in quantities such that special precautions for the construction, installation and use of equipment are required due to increased risk of fire or explosion

[SOURCE: BS EN IEC 60079-10-1:2021, 3.3.1, modified – "due to increased risk of fire or explosion" added]

3.1.9 heavy-duty vehicle (HDV)

classification for a vehicle with a total weight over 3.5 t, which includes heavy goods vehicles, buses, and coaches

NOTE In the use case of zero-emission vehicles, with a total weight over 4.25 t.

3.1.10 heavy goods vehicle (HGV)

classification for a vehicle with a total weight over 3.5 t, intended for the transportation of heavy loads

NOTE In the use case of zero-emission vehicles, with a total weight over 4.25 t.

3.1.11 hydrogen systems

3.1.11.1 mobile

hydrogen refuelling systems that are designed for transportation and deployment across multiple locations, which operate either independently or as part of a larger network

NOTE 1 Mobile systems can operate in conjunction with static systems.

NOTE 2 These systems are typically mounted on vehicles, trailers, skids/frames or placed within transport containers, and where they do not form a permanent part of a vehicle, can be disconnected, unplugged and/or unhitched enabling them to be moved between deployment sites.

NOTE 3 Mobile systems include but are not limited to mobile hydrogen dispensers, mobile hydrogen storage and mobile hydrogen compressors.

3.1.11.2 static

fixed hydrogen refuelling system elements deployed at a specific location that are not intended to be moved once installed except when being decommissioned

NOTE 1 Static systems can operate in conjunction with mobile systems, for example, a fixed dispenser supplied by a mobile storage system.

NOTE 2 The emphasis on the term static is that it defines a part of a system which is fixed to the site and not easily mobilized.

3.1.12 lower flammable limit (LFL)

concentration of flammable gas or vapour in air, below which an explosive gas atmosphere does not form

NOTE 1 The term "lower flammability limit" might also be known as "lower explosive limit" (LEL).

NOTE 2 The term "upper flammability limit" (UFL) might also be known as "upper explosive limit" (UEL).

[SOURCE: BS EN IEC 60079-10-1:2021, 3.6.12, modified – note 2 added]

3.1.13 maximum allowable working pressure (MAWP)

maximum pressure permissible in a system at the temperature specified for the pressure

NOTE 1 The maximum allowable working pressure can also be defined as the design pressure, the maximum allowable operating pressure, the maximum permissible working pressure, or the maximum allowable pressure for the rating of pressure vessels and equipment manufactured in accordance with national pressure vessel codes.

NOTE 2 Maximum allowable pressure is used within the Pressure Equipment (Safety) Regulations 2016 [1] and the Pressure System Safety Regulations 2000 [2].

[SOURCE: BS ISO 19880-1:2020, 3.45, modified – note 2 added]

3.1.14 maximum operating pressure (MOP)

highest pressure that is expected for a component or system during normal operation including anticipated transients

NOTE In the case of the dispensing system, the MOP is equivalent to the maximum fuelling pressure of the vehicle.

[SOURCE: BS ISO 19880-1:2020, 3.47]

3.1.15 mobile storage unit

any hydrogen storage system that is mobile, this can include MEGCs and MCPs, with or without a dispensing system

3.1.16 mobile units

any element of the system which is mobile

NOTE Examples can include portable dispensers with or without storage, compression platforms, metering skids, filtration and sampling systems.

3.1.17 multiple element gas containers (MEGCs)

unit that consists of multiple gas containing cylinder or tube elements interconnected by a manifold and mounted on a common frame designed for the transport of gases with a volumetric capacity exceeding 450 l

NOTE They are particularly useful for bulk transport of hydrogen gas under high pressure, making them a strategic choice for fuelling stations without onsite production capabilities.

3.1.18 pipeline

pipe or interconnected system of pipes that transport relevant fluids across premises boundaries, including any equipment and associated components used to facilitate the flow of the fluid within the pipe or system

NOTE Attention is drawn to the Pressure Systems Safety Regulation 2000 [2].

3.1.19 pipework

pipe or system of pipes accompanied by related equipment such as valves, pumps, compressors, and other components designed to contain pressure but does not include a pipeline or protective device

NOTE The term piping is used prolifically through ISO standards, however pipework is the term used within the Pressure Equipment (Safety) Regulation 2016 [1].

3.1.20 terms of permanence

3.1.20.1 permanent

any hydrogen refuelling system or systems that are intended to be continually present at a given location and have a continuous presence of hydrogen containing elements deployed at the site

NOTE 1 This includes instances where the systems are exchanged or operate in rotation.

NOTE 2 Local authorities determine if the proposed deployment site requires any specific planning or permitting irrespective of whether it is considered temporary or permanent.

3.1.20.2 temporary

hydrogen refuelling system deployments that are set up for a limited period and can include either mobile or static hydrogen elements

NOTE 1 They are designed for easy setup and removal, providing flexibility in locations where permanent infrastructure is not viable or requires additional support.

NOTE 2 These systems are often mobile and are deployed to meet short-term needs, such as events, pilot projects, trials, or temporary increases in demand.

NOTE 3 Local authorities determine if the proposed deployment site requires any specific planning or permitting irrespective of whether it is considered temporary or permanent.

3.1.21 thermal pressure relief valve (TPRV)

pressure relief valve activated by temperature

3.1.22 transport unit

motor vehicle with or without an attached trailer

3.1.23 zone

hazardous area classification based on frequency of the occurrence and duration of the explosive atmosphere

[SOURCE: BS EN IEC 60079-10-1:2021, 3.3.3]

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

CHSS	compressed hydrogen storage system
EIA	environmental impact assessment
EHSR	essential health and safety requirements
EMI	electromagnetic interference
EPL	equipment protection levels
ESS	emergency shutdown system
HDV	heavy-duty vehicle
HGV	heavy goods vehicle
HSL	hydrogen service level
IrDA	infrared data association
LFL	lower flammable limit
MAWP	maximum allowable working pressure
MCP	manifolded cylinder pallet
MEGC	multiple element gas container
MOP	maximum operating pressure
NRMM	non-road mobile machinery
PFAS	perfluoroalkyl and polyfluoroalkyl substances
TPRV	thermal pressure relief valve
XDF	explosive decompression failure

4 Conceptual design

COMMENTARY ON CLAUSE 4

This clause outlines the basic principles that guide conceptual design of a hydrogen refuelling system, focusing on achieving efficiency, safety and compliance to standards.

4.1 General

Any design for hydrogen refuelling, whether for mobile or static systems, should define the intended use case and evaluate key characteristics that impact its design from the outset (see Table 1 for description of characteristics).

Designers and manufacturers should be able to demonstrate competency and safe working knowledge of the hydrogen system and should have completed a comprehensive training programme before initiating design of the hydrogen system (see 0.4, 5.1 and 7.3).

Designers should plan, manage and monitor health and safety requirements during the pre-construction phase and co-ordinate measures to eliminate, reduce and control foreseeable risk with all duty-holders involved with the construction of the hydrogen system, including any receiving infrastructure for mobile systems. Whichever type of hydrogen system being designed, safety standards should be of equal import.

NOTE 1 Attention is drawn to the Construction (Design and Management) Regulations 2015 [9] which are UK regulations concerning health, safety, and welfare in construction projects.

NOTE 2 There are some distinct differences in design characteristics between static and mobile hydrogen systems, examples of these are summarized in Table 1.

Table 1 – Characteristics of static stations and mobile units

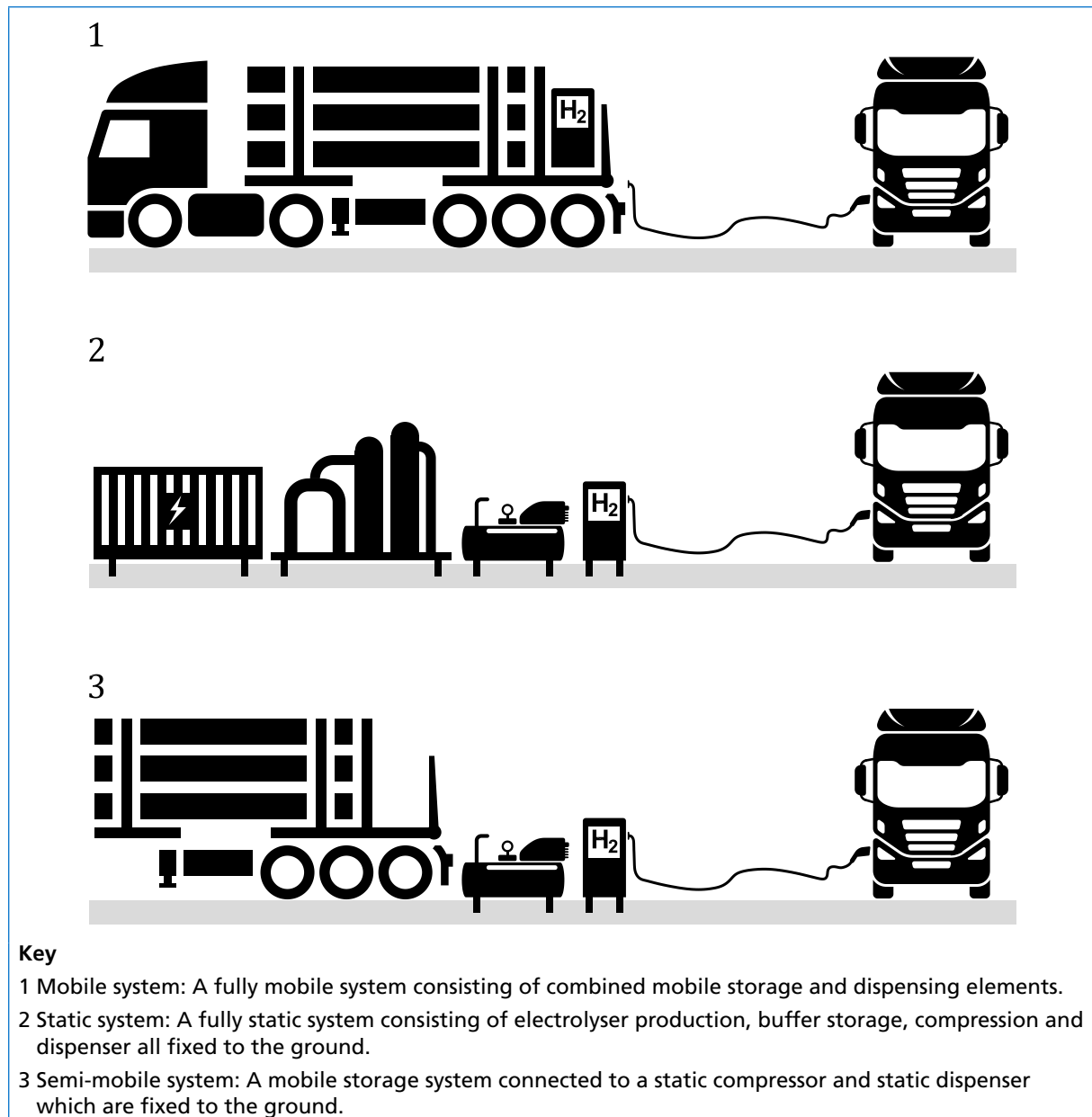
Characteristic	Static stations	Mobile units
Storage and infrastructure	Typically serve higher volumes which require (or benefit from) additional infrastructure, including compressors, pre-cooling, and space for multiple element gas container (MEGC) exchange replacement or onsite production.	The need to frequently transport mobile units to different locations introduces risks related to the handling and moving of high-pressure hydrogen tanks and systems. Compression and/or pre-cooling might not be possible or practicable. Vibration or accidents during transport might lead to leaks or explosions.
Operational safety	The methodology for applying hazardous zoning requirements to static stations is more consistent and predictable. The focus is on comprehensive initial design and construction to meet permanent zoning requirements.	For mobile stations, the methodology is inherently dynamic. Operators should continuously assess and adapt to the safety requirements of each new location, employing agile management practices and more frequent liaisons with local authorities.

Table 1 – Characteristics of static stations and mobile units (*continued*)

Characteristic	Static stations	Mobile units
Security	Being fixed locations, static stations should be continually monitored and protected from unauthorized access to prevent vandalism or terrorist attacks.	Unlike static stations, which can be equipped with permanent and robust security measures, mobile stations are often temporarily set up in diverse locations where site security should be in place.
Emergency response	Planning emergency response for a static hydrogen refuelling installation tends to be less complex than for a mobile site due to the permanent nature of the infrastructure and the predictable operational environment.	Mobile stations should be equipped to handle emergencies in a variety of settings, potentially without the immediate support that is otherwise available in permanent locations.
Supporting utilities	Typical utilities include instrument air for pneumatic instruments, nitrogen for purging, cooling medium for compressions, and electrical supply. Provision for utilities within static installations is achievable due to consistency in functional parameters and operational conditions.	Mobile stations are subject to a possibility of variance in utility requirements, availability might be limited at some locations. Mobile systems might require integral utilities necessary for correct function and safe operation, this could include battery operated or generator power supply, bottled instrument air or nitrogen supply, lighting, earthing and cooling systems.

Mobile and static hydrogen systems are illustrated in Figure 1.

NOTE 3 *Mobile, static and semi-mobile systems can be considered either permanent or temporary. The term of permanence (see 3.1.20) is not determined on the basis of whether the system is mobile (see 3.1.11.1) or static (see 3.1.11.2).*

Figure 1 – Mobile and static hydrogen systems

4.2 Inherent safety function

COMMENTARY ON 4.2

Inherent safety focuses on designing processes and systems to eliminate or significantly reduce hazards at their source. This approach emphasizes fundamental changes to the design and operation of systems to avoid the creation of hazards, rather than managing them with additional safety measures.

Hydrogen systems and facilities should be designed:

- a) with simplified procedures to minimize the likelihood of errors;
- b) for fail-safe operation, such that the system defaults to a safe state in case of failure;
- c) using materials and processes that have been assessed to meet safety targets; and
- d) using recognized and proven risk assessment methodology (in accordance with Annex A).

NOTE 1 BS EN IEC 31010 provides details of recognized risk assessment methodology.

Inherent safety features and characteristics should be integral to the overall system design and include the following.

- 1) Fail-safe measures. Fail-safe design enable redundancy with backup components and default safe positions for valves during power failures. Fail-safe measures are integral safety design functions which enable a system to automatically revert to a safe state in the event of a malfunction or failure. These measures prioritize safety by incorporating redundancy, allowing critical components to have backups that operate should the primary components fail.
- 2) Redundancy. Redundancy involves adding extra components or systems that can take over or support the primary function in case of a failure. This design principle is fundamental within the design of fail-safe measures, such that if one component or part of the system fails, another can maintain the system's safety and functionality.
- 3) Automatic safety mechanisms. Active controls that require energy input to function. They are designed to respond to changes in system conditions automatically, without human intervention. Examples include sensors that detect high pressure or hydrogen leaks and automatically initiate countermeasures such as shutting down operations, activating ventilation systems, or closing valves to prevent accidents.
- 4) Passive safety mechanisms. Passive controls that do not require any external power source or action to function. Their effectiveness is derived from their design and material properties. Examples include pressure relief valves, thermal actuators and using materials that are inherently non-flammable. In the event of a system failure, these passive mechanisms inherently minimize the risk of an accident.
- 5) Alert devices. Alert devices in a system are components designed to notify operators or users of abnormal conditions or potential hazards. These devices include visual signals and auditory alarms. Their primary function is to provide immediate notification to help prevent accidents by enabling prompt human intervention or to initiate automated safety measures. In industrial settings like hydrogen refuelling stations, these devices are critical for enabling operational safety and maintaining system integrity.
- 6) Functional safety assessment. Under recognized methodology, these assessments enable the system to operate to a high level of reliability. Recognized methodology should include Performance Level (PL) or Safety Integrity Level (SIL) evaluation. During design, the methodology used, whether PL or SIL, should be applied consistently and documented uniformly across all project materials. Where external assets are expected to be in use, which might have been designed using an alternative methodology, then a compatibility check should be carried out to verify suitability.

NOTE 2 See BS EN ISO 13849-1 for PL evaluation or the IEC 61508 series for SIL evaluation.

- 7) Operational control. Equipment should remain operational in the presence of an explosive atmosphere but should be designed to prevent the dispensing of hydrogen when conditions are unsafe as determined by the risk assessments described in Annex A.

4.3 Safety fault tolerance

NOTE 1 Fault tolerance is a crucial feature in engineering that enables a system to continue to operate safely in the event of a failure within one or more of its components.

The degree of fault tolerance required for each element of the system design should be determined by the risk assessment(s) carried out in accordance with Annex A (see also 5.6 and 6.1).

The hydrogen system should include an independent safety system, that is separate from the primary control system, that mitigates the risk of catastrophic failure.

NOTE 2 PD ISO/TR 15916:2015, Clause 7, gives detailed safety guidelines.

4.4 Defined permissible operational parameters

The system design should define the permissible operational parameters in which the system should be stored and operated safely. Control measures should be applied to prevent operation outside of approved parameters.

Permissible operational parameters should be defined, including equipment function, performance characteristics and environmental conditions.

NOTE Examples include, but are not limited to:

- a) equipment function; operational voltages, frequency of use, vehicle tank capacity;
- b) performance characteristics; above or below specific inlet pressure, fuel temperature; and
- c) environmental conditions; not during an electrical storm, not on uneven ground.

Safe operational parameters should be defined for each element of the system, for example, storage, compressor, buffer tank, dispenser, filter, cooling system, fuelling assembly.

Permissible operational parameters should be specified within the technical file in accordance with Annex C, and in accompanying equipment (training, operation and maintenance) documentation.

4.5 Prevention of unauthorized, malicious or incorrect use

4.5.1 General

The system should not be capable of producing unsafe conditions from either deliberate or incorrect use.

The design should be risk assessed to include security measures which safeguard against unauthorized access, malicious and incorrect use of the dispensing system.

Access to the system should be restricted to authorized persons.

4.5.2 Physical measures

Physical security measures such as access controls and barriers should be in place to restrict access.

The site-specific risk assessment should evaluate the use of cameras, motion detection systems and security personnel to enhance security and deter unauthorized or malicious actions.

Control systems should be protected.

4.5.3 Remote measures

The design should integrate robust digital and network cybersecurity protocols to safeguard against malicious digital actions and maintain the integrity of operational data.

NOTE 1 These can include:

- a) employing multi-factor authentication;
- b) using intrusion detection systems;
- c) continuous monitoring of network traffic; and
- d) keeping software and firmware up to date.

Where possible, the system should be able to quickly identify and respond to potential cyber threats. Localized and remote shutdown protocols should be included that enable the system to default to a safe dormant state in the event of an identified attack.

NOTE 2 BS EN IEC 62443-3-2:2020 provides guidance on security risk assessment for industrial automation and control systems.

4.6 Hazardous area classification and reduction

Hazardous area classification should be completed and documented for both mobile and static systems. Installations and systems handling or storing hydrogen should be designed, constructed, operated, and maintained to minimize the release of hydrogen. This should include reducing the frequency, duration, and volume of any releases to limit the extent of potentially explosive atmospheres forming as far as is reasonably practicable and as dictated by the risk assessment.

The internal enclosures and chambers of the system in addition to the external surrounding areas should be assessed to determine the extent of any explosive atmosphere formation that might occur during the following conditions:

- normal operation;
- maintenance service and inspection operations;
- foreseeable misuse; and
- under fault conditions.

NOTE Attention is drawn to the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002 [3].

Hazardous area classification assessments are applicable to the entire installation and should include the surrounding environment and any adjacent hazards, for example, flammable materials storage, refuelling or charging infrastructure (risk assessment recommendations are given in Annex A).

The hazardous area classification should detail the frequency of the occurrence and duration of explosive atmospheres and classify them into zones in accordance with BS EN IEC 60079-10-1.

The classification should also account for the ignition characteristics of the explosive atmospheres that form the hazardous areas.

The assessment and subsequent classification of these hazardous areas should be documented within the technical file in accordance with Annex C.

4.7 System architecture and equipment selection

Both mechanical and electrical equipment should be rated to function correctly within its expected environment and operational conditions.

The hazardous area classification (see 4.6) should be used to determine the required component and equipment ratings for equipment that operates in a potentially explosive atmosphere.

NOTE 1 Equipment ratings can be categorized as either Equipment Categories or Equipment Protection Levels (EPLs). Table 2 illustrates the relationship between Equipment Categories and EPLs.

Table 2 – Relationship between equipment categories and EPLs for explosive (gas) atmospheres

BS EN IEC 60079-0		Directive 2014/34/EU [10]		BS EN IEC 60079-10-1
EPL	Group	Equipment group	Equipment category	Zones
Ga	II	II	1G	0
Gb			2G	1
Gc			3G	2

Where equipment is located within a hazardous area, the equipment should have a means of protection such that sources of ignition do not become active during either normal operation, or under fault or multiple fault conditions as specified by the design risk assessment.

NOTE 1 *BS EN 1127-1 includes various safety aspects for explosive atmospheres.*

NOTE 2 *Attention is drawn to the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016 [4].*

To maintain safety, equipment should be able to operate reliably even in the presence of an explosive atmosphere (see 6.2).

Any roofs, canopies and other areas of the workspace at the installation location should not allow hydrogen gas to accumulate.

NOTE 3 *BS ISO 19880-1:2020, 5.3.4, provides details on the mitigation for the formation of a flammable mixture under a canopy.*

4.8 Accessibility

The design of a hydrogen refuelling site should account for users and other persons on site with accessibility requirements and accommodate users with diverse needs, including those with visual impairments, for example, colour blindness, by integrating accessibility features that enhance usability for all.

NOTE 1 *This might include, but is not limited to, the following.*

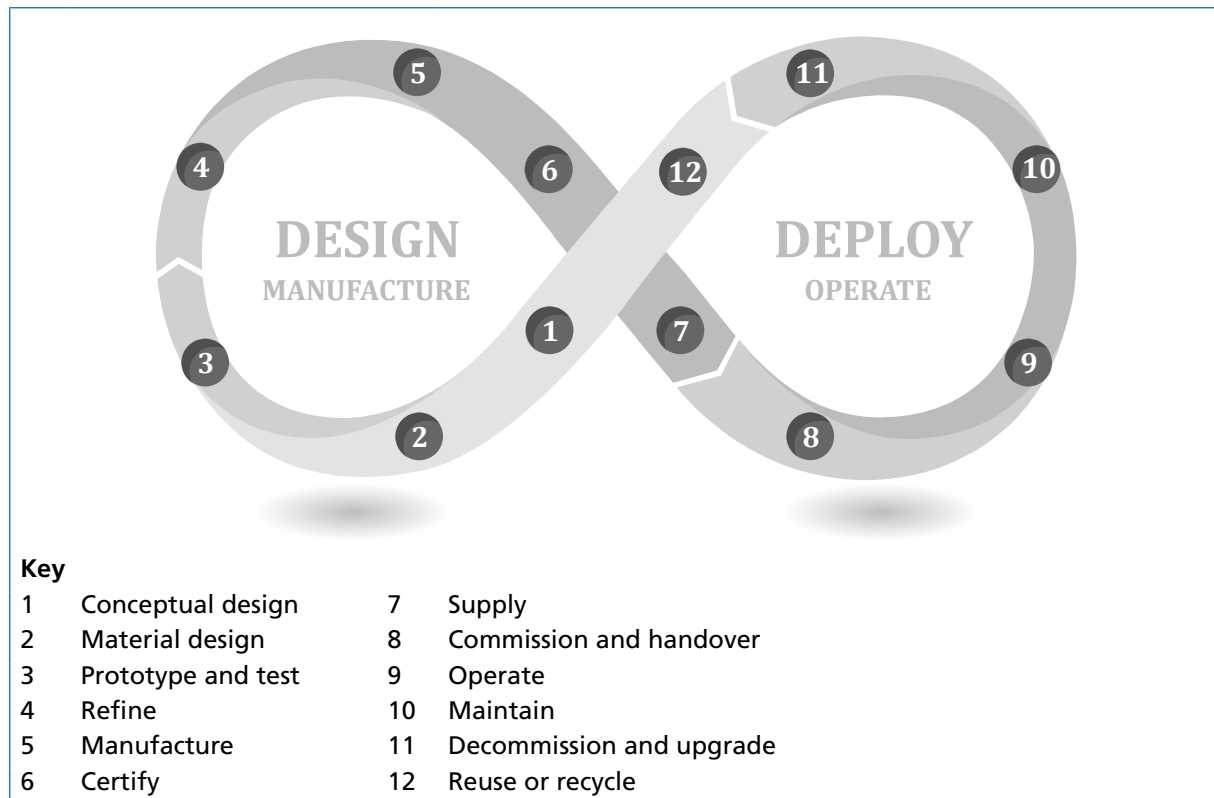
- a) *Colour and contrast: use of high-contrast colour schemes and, where possible, textures that are easily distinguishable to aid those with colour blindness or low vision.*
- b) *Tactile feedback: incorporate tactile indicators on key components such as buttons and emergency shut-off mechanisms to allow operation by touch.*
- c) *Auditory cues: implement auditory feedback systems that provide clear, distinct sounds for different actions or alerts, aiding those with visual impairments.*
- d) *Clear labelling: provide labelling with sufficient contrast and large fonts. For example, braille labels should be included alongside conventional text.*
- e) *Ergonomic design: easily reachable and operable design interfaces and controls for use by individuals with varying physical capabilities, including those who use mobility aids.*
- f) *Assistance button: incorporate an assistance button in systems that alerts site operators notifies them immediately that assistance is required.*
- g) *Contact details: place clear and accessible contact details at the dispenser for emergency or assistance purposes.*
- h) *Accessible pathways: include pathways, made of materials suitable for ease of mobility and safety, which are free of obstacles and clearly marked, in the system layout and wide enough for mobility aids.*
- i) *Training for staff: provide protocol and training to those who might be required to provide user assistance (see 7.3).*
- j) *Language selection: display important information on the system in the languages used at the destination site.*

NOTE 2 *BS EN IEC 60073 includes guidelines for the design of interfaces to be accessible for users with disabilities.*

4.9 Design lifecycle management

The design should integrate lifecycle assessment into the development, manufacturing and operational processes of the system and its associated equipment, including the end-of-life decommissioning, disposal and reuse or recycling of materials, enabling long-term safety, efficiency and sustainability (see Figure 2 for typical stages of design lifecycle management).

Figure 2 – Design lifecycle management



Recommended actions for the keys shown in Figure 2 are:

1. Conceptual design: the basic framework and requirements should be established, to determine intended use and safety compliance.
2. Material design: materials should be selected that meet the requirements for durability, compatibility, environmental and safety standards necessary to extend product life and enable long-term operation.
3. Prototype and test: prototypes should be developed and should undergo rigorous testing to validate design assumptions and compliance with safety standards.
4. Refine: test results should be analysed and fed back to the design processes to refine and optimize the design for better performance and reliability.
5. Manufacture: designs should be implemented using best manufacturing practices to achieve quality and adherence to specifications.
6. Certify: certifications which verify that the equipment meets all industry and safety standards should be kept on record.
7. Supply: equipment should be delivered to sites, such that all systems are delivered safely and ready for installation.
8. Commission and handover: equipment should be set-up at the user's location, final checks performed, and handed over to the operations team with complete documentation.
9. Operate: equipment should be utilized in its intended environment, enabling it to perform as expected.
10. Inspect and maintain: equipment should be inspected and maintained in accordance with manufacturer's instructions, recognized standards and current regulations to preserve its functionality, extend its lifespan and to maintain safety compliance.
11. Decommission or upgrade: equipment should be responsibly removed or upgraded when it reaches the end of its useful life or when more efficient options become available (see Clause 10).
12. Recycle and reuse where possible: at the end of the lifecycle, components should be reused or dismantled and recycled to minimize negative environmental impact (see 5.3.1.6).