Small Scale Hydrogen Use

An introductory primer for users

Disclaimer – This document is for information purposes only and does not constitute advice. Even where not explicitly specified, it is imperative that users refer to up-to-date and relevant standards and legislation, and conform to all relevant regulations.

Executive Summary

This report is published by the Hydrogen Innovation Initiative (HII), with contributions from the Offshore Renewable Energy Catapult (ORE Catapult) and the Connected Places Catapult (CPC). The authorship of the report was outsourced to Abbott Risk Consulting Ltd (ARC).

This document is intended to provide a high-level introduction to the safe and legally compliant use of small scale compressed gaseous hydrogen systems in the United Kingdom. It is not a document to provide guidance/instruction in its own right but serves to signpost users to existing documents.

The following are used as examples of small-scale hydrogen systems:

- Fuel cells on narrowboats for domestic power use onboard;
- Off-grid power unit;
- Hydrogen-electric powered mobile cherry picker, or other mobile plant, for construction.

This information provides high-level summaries of the following:

- The limits of what can be considered ‘small scale’ hydrogen applications;
- Background information on gaseous compressed hydrogen properties and generation;
- The principal hazards associated with compressed gaseous hydrogen and associated broad safety principles;
- Overview of relevant legislation, standards and guidance and the arising requirements;
- High-level information on application of the arising requirements to the storage, transport and end-use of compressed gaseous hydrogen.

This document should be used in conjunction with the identified supporting documentation and guidance and is not intended to be the sole source of information for users of small-scale hydrogen systems.

This document has been written at a specific point in time, and users should assure themselves that they are accessing the most up to date supporting documentation and guidance.

Abbreviations

Abbreviation	Definition
ACoP	Approved Code of Practice
ADR	European Agreement on the Carriage of Dangerous Goods by Road
ALARP	As Low As Reasonably Practicable
ARC	Abbott Risk Consulting Ltd
BCGA	British Compressed Gas Association
CCS	Carbon Capture and Storage
CDG	Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009
COMAH	Control of Major Accidents and Hazards
COSHH	Control of Substances Hazardous to Health Regulations
CP	Code of Practice
CPC	Connected Places Catapult
DfT	Department of Transport
DGSA	Dangerous Goods Safety Adviser
DSEAR	The Dangerous Substances and Explosive Atmospheres Regulations
EIGA	European Industrial Gases Association
HPC	Hazardous Planning Consent
HSE	Health and Safety Executive
ORE Catapult	Offshore Renewable Energy Catapult
MCP	Manifolded Cylinder Pallet
NDA	International Carriage of Dangerous Goods by Inland Waterways
NG	Natural Gas
NRMM	Non-Road Mobile Machinery
PED	Personal Electronic Devices

Abbreviation	Definition
PPE	Personal Protective Equipment
PSSR	Pressure Systems Safety Regulations
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
SMR	Steam Methane Reformation
SSS	Solid State Storage
ToR	Terms of Reference
UK	United Kingdom

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1.0 Introduction

This document has been produced for the Offshore Renewable Energy Catapult (ORE Catapult) and Connected Places Catapult (CPC) as part of the Hydrogen Innovation Initiative, to provide a high-level introduction to the safe and legally compliant transport, storage and use of small-scale hydrogen systems in the United Kingdom (UK), as well as the design of storage vessels / systems to support this.

2.0 Limitations of this Document

The use of hydrogen across the UK is undergoing rapid change and development, with the associated regulation and practice developing in parallel to deployments of hydrogen systems across multiple sectors. Any published document will lag emerging best practice and the subsequent formalisation into standards and legislation.

The use of hydrogen is a still developing and emerging field. The scope of this document may not explicitly identify every potential application. Users of this document will therefore need to review this document and determine if it bounds their intended application.

Therefore, users of this document should ensure that they have reviewed the identified Terms of Reference (ToR) to ensure that they have not been superseded by updates after the publishing of this document in October 2024.

3.0 Scope

The scope of this document is intended to cover small-scale users and distributors of hydrogen systems, for both personal use and small scale commercial use. Typical use cases include, but are not limited to:

- Remote power provision for work-sites;
- Motive power for Non-Road Mobile Machinery (NRMM);
- Remote power provision for domestic use, including but not limited to:
    - Provision of electricity and heat at remote dwellings;
    - Provision of electricity and heat on inland waterway vessels;
    - Provision of electricity and heat for marine vessels.

Therefore, the scope of this document is intended to cover:

- Use in the UK including Northern Ireland;
- Commercially available hydrogen storage in the following vessel types and quantities:

- G20 cylinder (a 20 litre capacity cylinder [49]) or similar single person portable cylinders, either individually or several up to 333 litres of capacity; the threshold for small volumes of Compressed Hydrogen according to the British Compressed Gas Association (BCGA) Code of Practice (CP) 50 [9]. This will include the commercial supply of hydrogen up to this limit in any single transfer;
- Single Manifolded Cylinder Pallet (MCP) up to a capacity of ~50 litre @ 200 bar;
- Single Tube Trailer up to a capacity of ~250 kg @ 200 bar;
- Other storage technologies that store equivalent capacities of hydrogen at or below 200 bar e.g. solid state storage.

- Use of the MCP or Tube Trailer in an outdoor environment segregated from enclosed spaces or overhead structures;
- Use of the G20 equivalent in outdoor, or outdoor equivalent, environment. An outdoor equivalent environment would be a large volume warehouse or similar, where the available air volume and passive ventilation provides similar potential for dilution of any hydrogen leaks as an outdoor environment.

3.1 Scope Exclusions

This document is not intended to provide information to support the following:

- Use of cryogenic or liquid hydrogen;
- Use of hydrogen in confined internal environment e.g. hydrogen gas ring in a canal barge or Tube Trailer in a warehouse;
- Commercial supply of hydrogen above the small-scale. This is assumed to be covered by the large-scale commercial hydrogen supplier;
- Bespoke hydrogen storage solutions;
- Hydrogen systems that will contain, in storage vessels and pipework, hydrogen inventories in excess of the following:
  - Hazardous Planning Consent (HPC) threshold of 2 tonnes of hydrogen;
  - Control of Major Accidents and Hazards (COMAH) Lower Tier threshold of 5 tonnes of hydrogen;
  - COMAH Upper Tier threshold of 50 tonnes of hydrogen.

4.0 Use of This Document

The following section is intended to help readers of this document identify what specific information they need to use and focus on what additional reference documentation they will need to access for more detailed information.

NB this document is not the only information that should be referred to by small scale hydrogen system users, and is intended to help signpost users to the most relevant information. Users will still need to discharge their health and safety responsibilities appropriately.

This document has been structured in a logical way, as presented in Table 1, to support readers in familiarising themselves with hydrogen system use and determining which sections they should review, and how to assess the information presented in each section for relevance to their specific use.

The intent is for users to understand the end-to-end process of hydrogen use, so that they can identify both their specific place within that process and their dependence on other steps in that process.

To help with navigating this document the following broad categories have been used:

- Private users of very small inventories of hydrogen – private individuals using hydrogen for personal applications well below the small load categories defined in legislation and guidance. Private users are exempt from the Agreement on the Carriage of Dangerous Goods by Road (ADR) [50] and therefore, the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG) regulations [4], but there remains the expectation that the gas is transported safely. BCGA Leaflet 17 [46] provides instruction as to what is considered safe practice;

- Commercial users of very small inventories of hydrogen – commercial entities (individuals or organizations) using hydrogen for commercial applications, but well below the small load categories defined in legislation and guidance. Inventories considered to be small loads have some exemptions from the full CDG regulations when transported by road or inland waterway;

- Commercial users of small inventories of hydrogen – commercial entities (individuals or organizations) using hydrogen for commercial applications, above the small load categories defined in legislation and guidance but well below the thresholds for Hazardous Planning Consent or COMAH legislation. For these users the CDG regulations must be met in full.

NB these categories are not legal definitions, and users should ensure that they have assured themselves they have identified and are complying with all their legal requirements for their specific application and inventory of hydrogen being used.

Table 1 – Document Structure and User Relevance Guidance

Section No.	Page No.	Description	Relevance to Users
5.1	11	Hydrogen Chemical and Physical Properties	Relevant to all categories of user
5.2	12	Hydrogen Generation	Relevant to all categories of user
5.3	12	Principal Hazards of Compressed Gaseous Hydrogen	Relevant to all categories of user
5.4	15	High-level Safety Principles for Gaseous Hydrogen	Relevant to all categories of user
5.5	19	Terms of Reference (ToR)	Primarily intended for commercial users, but of relevance to private individuals to understand the legislative and legal context for their application, as well as further useful sources of guidance. The intention of this section is to make the reader aware of the legislation covering their activities and then to link that to relevant industry standards and guidelines. The ToR are the latest versions at the time of writing. The reader should be aware that future updates to legislation and practice could impact their responsibilities.
5.6	20	Baseline requirements for transportation of compressed hydrogen gas	Primarily intended for commercial users, but of relevance to private individuals to understand the underlying transport of compressed gaseous hydrogen requirements that may become directly applicable at greater inventory sizes. This section is primarily focused on Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG) [4]
4.7	23	Storage of Hydrogen	Relevant to all categories of user, the requirements of which are appropriate to all volumes.
5.8	25	Transport by public road	Primarily intended for commercial users, but of relevance to private individuals to understand the underlying transport of compressed gaseous hydrogen requirements that may become directly applicable at greater inventory sizes.
5.8	25	Transport by inland waterways	Primarily intended for commercial users, but of relevance to private individuals to understand the underlying transport of compressed gaseous hydrogen requirements that may become directly applicable at greater inventory sizes.

Section No.	Page No.	Description	Relevance to Users
5.9	30	Specific application guidance	Primarily intended for commercial users, but of relevance to private individuals to understand the underlying transport of compressed gaseous hydrogen requirements that may become directly applicable at greater inventory sizes.

5.0 Introduction to Small Scale Hydrogen Use

5.1 Summary of Compressed Gaseous Hydrogen Properties

The following are some of the principal properties of hydrogen when used as a compressed gas:

- Hydrogen is the first element in the periodic table with a low density. It is therefore buoyant relative to air at room temperature and pressure. In addition, for practical storage systems, gaseous hydrogen requires significant compression to high pressures;
- It is both colourless and odourless to the observer, can displace oxygen in enclosed environments and, therefore, poses a potential asphyxiation hazard;
- Hydrogen gas is considered extremely flammable with a flammability range between 4% and 77%, a very low minimum ignition energy of 0.017mJ, but an autoignition temperature of around 560˚C. This means hydrogen, within its flammability limits, can be ignited by sparks from static or electrical systems e.g. light switches. In addition, hydrogen has a very fast flame speed compared with other flammable gases;
- Hydrogen flames burn at high temperature but radiate less heat outside of the flame contour than a comparable natural gas flame, primarily emitting in the Ultra-Violet (UV) range. As a result, hydrogen flames are difficult to spot by eye in daylight, or detect through radiant heat unless the flame is directly impinging on a surface. As a result, it is very easy to ignite flammable/explosive gases in the vicinity, so it is important that safe separation distances are maintained;
- Hydrogen has a high diffusivity so will quickly migrate from location of releases to other locations and also disperse rapidly in open areas;
- Hydrogen can embrittle materials that are used to store and transfer it (i.e. cylinders and pipework) so materials selected should be appropriate for hydrogen service;
- Hydrogen has a small molecular size and low friction so is capable of escaping from smaller hole sizes with appreciable flow rates in comparison to natural gas. Hydrogen systems should therefore aim to minimise credible points for leaks (e.g. minimise joints with all welded pipework where practicable);
- Due to storage at high pressures, the following properties are also relevant:
    - Cylinders of compressed hydrogen gas may explode if exposed to local heat sources, or subject to significant external mechanical impacts;

- Hydrogen leaks can generate high pressure gas jets. The gas jet momentum can overcome the inherent buoyancy of hydrogen until momentum is lost;

- Reaction forces from gas jets can cause movement of systems elements (e.g. flexible hoses), and the leak may cause significant noise / whistling.

The complete list of chemical and physical properties of Compressed Hydrogen gas, plus the required handling of it, can be found in any appropriate Material Safety Data Sheet [35].

For more information see chapter one of "Hydrogen Safety for Energy Applications" [36] or "Basic considerations for the safety of hydrogen systems" [34].

5.2 Hydrogen Generation

Currently commercially available hydrogen will have been generated through two principal processes, although there are other methods that can be used. It is important for hydrogen systems users to be aware of the production method as it can be important for the specific application of the hydrogen. The two principal methods of production, and their implications are:

- Steam Methane Reformation (SMR) from Natural gas (NG) – this is far and away how the majority of hydrogen is currently produced in the world. The hydrogen produced from this method will be of high quality, however depending on the post generation treatments it may contain appreciable impurities. This will not normally be of concern for hydrogen applications that combust the hydrogen. However, applications that consume through electrochemical processes, such as Fuel Cells or Catalytic Combustors, may have more stringent purity requirements on the hydrogen fuel. In addition, unless the SMR is using Carbon Capture and Storage (CCS), the carbon dioxide produced as part of this process will still be released to atmosphere;

- Electrolysis of water – this process can use a range of different electrolysis technologies, alongside various post generation treatments, that produce hydrogen that is normally of higher purity than from SMR production. This hydrogen should be suitable for both combustion and electrochemical applications. There are also no direct carbon dioxide emissions associated with the hydrogen production, however there may be carbon dioxide emissions associated with the electricity source and any necessary pre-treatment of the water consumed in the process.

5.3 Principal Hazards of Compressed Gaseous Hydrogen

The following principal hazards associated with use of compressed gaseous hydrogen presented below are based in part on Section 5 of the BCGA CP52 [24]. The hazards associated with hydrogen arise from the following properties of compressed gaseous hydrogen:

- High pressure gas – hydrogen is stored under high pressure, significantly higher than for NG systems, which results in the following hazards that should be considered:
    - Asphyxiation – released hydrogen in enclosed spaces can displace oxygen. This can also occur in spaces where buoyant hydrogen can accumulate over time;
    - Equalisation overpressure – spontaneous / catastrophic release of hydrogen from its storage vessel can result in significant pressure peaks as the pressure equalises with the ambient pressure, even in the absence of subsequent ignition of the released hydrogen;
    - Missile / Debris / Shrapnel - spontaneous / catastrophic rupture, or full-bore rupture of pipelines / cylinder heads, can result in the formation of debris / shrapnel or missiles (e.g. cylinder body or cap);
    - Pipe-whip / vessel topple – larger leaks of high-pressure hydrogen can result in significant movement of equipment including unsecured / flexible pipeline (pipe-whip), as well as bulk movement of vessel assemblies, due to the reaction force of the escaping gas jet;
    - Gas injection / gas jet impingement – smaller releases from joints / valves or pin-hole leaks through cylinder body thickness can result in direct gas injection to users who are impinged by the gas jet. Larger releases can generate significant loads on equipment / material impacted by the resulting gas jet;
    - Acoustic – high pressure hydrogen escaping can generate significant noise that can cause hearing impairment;
    - Expansion joint heating – for the pressures and temperatures of the applications in scope of this document, hydrogen expansion through an orifice results in heating at the orifice rather than cooling due to the Joules Thompson effect. This is counter to most experience with expanding gases.
- Flammable gas – as stated previously hydrogen is highly flammable, with very fast flame speed once ignited:
    - Jet Fire – if hydrogen is released continuously and immediately ignited it will result in a jet-fire originating from point of release. Jet-fires can cause damage or injury due to either radiated heat or direct impingement of the flame. Hydrogen jet-fires however are slightly different from NG jet fires in the following two ways:
        - Hydrogen jet-fires burn at a much high temperature and therefore emit less infrared radiation (and more ultra-violet radiation) than NG

jet-fires so have smaller comparable thermal 'footprints'. However, direct impingement by the hydrogen jet-fire will be more damaging than a comparable NG jet-fire;

- Hydrogen jet-fires are not as visible in daylight as NG gas fires, due to the lower amount of carbon particles in the flame that emit in the visible spectrum. They may have some orange colour, due to entrained carbon dioxide from ambient air, but this is most visible for large hydrogen jet-fires or at night.

- Fireball – if a significant volume of hydrogen is released spontaneously / catastrophically and immediately ignited, it can result in a fireball. A fire ball is a large mass of gas that rises as the inventory is burnt, rather than the entire mass being consumed immediately. Impacts are primarily due to the thermal impacts from either radiated heat, or within the fireball itself; there is no significant over-pressure associated with a fireball;

- Flash fire – if a significant volume of hydrogen is released continuously, so that an appreciable flammable cloud is generated in an unconfined and uncongested location with a delayed ignition, this is called a flash fire. The flammable mass will be consumed immediately, but there will be no appreciable over-pressure. Impacts are due to the thermal impacts within the flash fire volume, defined by the gas cloud volume with the hydrogen lower and upper flammable limits itself. There are no significant impacts from radiated heat, as the flash fire is too transient for significant energy transfer outside of the flash fire volume;

- Explosion – if a significant volume of hydrogen is released continuously and accumulates, or is released spontaneously / catastrophically, in a sufficiently congested and confined location with subsequent delayed ignition, this can result in an explosion. Hydrogen explosions can be of two types:

  - Deflagration – comparable to NG explosions, deflagration is characterised by a turbulent front that mixes flammable gas with ambient air, which is subsequently ignited at the flame front with subsequent pressure increase behind the flame front. Deflagrations are characterised by an appreciable ramp up and down either side of the peak over-pressure point. Damage and injury is caused by direct overpressure effects, debris formation, physical displacement of people and objects as well as subsequent structure collapse;

  - Detonation – detonation occurs when the turbulent mixing, flame front and pressure rise become coincident, and the pressure rise directly heats the flammable gas mix above its autoignition temperature. Detonations are characterised by rapid pressure ramp

up and ramp down either side of the peak pressure. This rapid ramp up and down means that impacted structures do not have enough time to deform plastically and can suffer brittle fracture. Damage and injury is caused by direct overpressure effects, debris formation, physical displacement of people and objects as well as subsequent structure collapse.

- Additional considerations for Solid State Storage (SSS). One alternative to simple gas compression storage of gaseous hydrogen is the use of solid materials that can absorb hydrogen. Current commercially available technologies are based on the use of metal hydrides. These technologies typically operate below the pressures of simple compressed gaseous storage (~5 - 10 bar), but have other specific hazards associated with them. These include:
    - Toxic, carcinogenic or caustic effects - depending on the specific metal used in the hydride, the materials may cause burns to skin, eyes or mucous membranes and may have toxic / carcinogenic effects if inhaled, ingested or absorbed through the skin;
    - Reaction with water - metal hydrides react with water to produce hydrogen and other potential oxidation products. The strength of the reaction, and the products evolved, will depend on the specific hydride being used;
    - Environmental contamination - the metal component of metal hydrides may also act as a heavy metal environmental contaminant;
    - Dust / powder - metal hydrides are typically powdered to maximise surface area and storage of hydrogen. If released, especially under pressure, they may be spread with associated risks of dusts / powders. However, due to their high density they do not normally stay suspended in air;
    - Weight - metal hydrides are normally quite dense and larger vessels may be of significant weight for lifting or supporting within structures / restraints.

As it is highly flammable, Hydrogen gas, regardless of volume, will require a Dangerous Substances and Explosive Atmospheres Regulation (DSEAR) [13] risk assessment. Specific guidance is available at BCGA GN13 [12].

5.4 High-Level Safety Principles for Compressed Gaseous Hydrogen

The following broad safety principles presented in Table 2 are intended to provide users with a baseline of understanding to then interpret and apply the detailed and specific guidance referred to in this document.

NB these safety principles are neither exhaustive or specific and should be viewed alongside the identified guidance in referenced documents.

Table 2 – Broad Safety Principles

Safety principle	Introductory details
Minimise inventory	Users should aim to minimise as far as practicable the inventory of compressed gaseous hydrogen they are using at any one time. Minimisation of inventory could include: - Reduction to the largest single inventory e.g. using multiple smaller cylinders as opposed to a single large cylinder; - Only opening some of the cylinders to the system at one time, rather than all available cylinders manifolded and open together; - Minimisation of the total inventory at one time e.g. only having the minimum number of cylinders for one day of activity rather than an entire week worth of cylinders; - Reduction of pressure as early and as low as possible e.g. dropping pressure at the cylinder before running fuel line across a site; - Maintain safe separation distance for the storage of Hydrogen not in use.
Appropriate design	Whilst the user may not be able to directly influence this, they should assure themselves as far practicable that the equipment has been appropriately designed for high pressure gaseous hydrogen use. This should account for both the high-pressure gas considerations and the material compatibilities with hydrogen. This assurance can either be provided from the equipment designer / supplier alongside the equipment (e.g. user manuals, equipment specifications) or confirmed through appropriate marking of equipment for high pressure gaseous hydrogen use.
Appropriate support / restraint / protection	The hydrogen system should be provided with the appropriate structures, protections and restraints to account for: - Movement of the hydrogen equipment that could result in potential leaks; - Dropped objects or other mechanical impacts (e.g. vehicle impact) that could lead to damage to the hydrogen equipment that could lead to further escalation / injury; - Movement of the hydrogen equipment on the release of high-pressure gas, so that there will be no significant movement that could lead to further escalation / injury; The intent of the above measures is to a) prevent potential initiation of leaks and b) if leaks do occur to ensure that equipment is properly restrained to prevent e.g. pipe-whip.

Safety principle	Introductory details
Minimise leak sources	The user can achieve this through the following actions: - Minimising the number of joints, valves or other connections in the system. These are the most credible leak points; - Confirm pressure integrity of the system when initially pressurised or re-pressurised. This will normally be through incremental pressurisation and holds with leak check (combination of aural, use of leak check fluids / sprays or potential handheld hydrogen detectors / 'sniffers'), until the full working pressure is reached; - Ensure that personnel operating the system are properly trained / aware to prevent accidental leaks due to e.g. inappropriate opening of valves; - When lines are being removed or the system dismantled, that the system is properly isolated, depressurised and potentially inerted before any connections are broken; - Protect the system from potential mechanical impacts such as dropped loads or vehicles such as forklift trucks; this could be through either separation of movement areas, or physical barriers.
Maximise ventilation	For the scope of applications covered by this document maximum ventilation is primarily achieved by undertaking activities outdoors, or in spaces that are equivalent to outdoor, or transporting externally to the vehicles providing the transport. The following specific considerations should also be made: - If weather protection is provided over the system this should be shaped so there are no volumes where released hydrogen could accumulate. A mono-pitch awning would provide an adequate solution; - The area around the system should be as open as practicable, with e.g. walls or buildings far enough away to allow free air movement around the system.
Minimise ignition sources	This will primarily be achieved through having exclusion zones (with associated signage) both around and above the hydrogen system. Of specific concern, considering hydrogen's low ignition energy, are static sparks. Listed below are prevention measures to common sources of ignition: - Use of Personal Electronic Devices (PEDs) such as mobile phones with the appropriate ATEX rating; - Anti-static clothing; - Adequate earthing; - Lightning protection (where in an open area); - Active fire detection and alarm system.
Minimise confinement and congestion	For hydrogen systems deployed outdoors this should be easily achievable, however the following should also be considered: - Overhead confinement (e.g. adjacent roof structures) or congestion (e.g. trees) as a buoyant hydrogen cloud may rise for an appreciable distance above the hydrogen system before dispersing below the lower flammability limit. This is of concern as they can exacerbate the severity of any hydrogen explosions that occur.

Safety principle	Introductory details
Maximise separation distances	The hydrogen systems should be separated as far as practicable from surrounding infrastructure, to minimise the potential for escalation from any incidents. Where adequate separation distances cannot be achieved consideration should be made of appropriate fire barriers / walls, whilst maintaining adequate ventilation and minimising congestion and confinement.
Appropriate emergency procedure	Appropriate emergency response actions should be in place. This should include: - Awareness that hydrogen flames are difficult to see in daylight, so escape paths should consider potential jet-fire impingement; - Ability to access isolation points / valves under incident / accident scenarios; - Ability to protect other equipment impinged by hydrogen fires, so that escalation is prevented once hydrogen is isolated and allowed to burn itself out; - Appropriate information to be available for 1st responders, such as hydrogen inventories and location of pressure gauges and isolation point. The HyResponder website provides a wealth of information for 1st Responders: HyResponder – European Hydrogen Train the Trainer Programme for Responders.
Personal Protective Equipment (PPE)	Appropriate PPE for both the high-pressure gas and flammable gas considerations should be used. Of specific concern is anti-static PPE to minimise the potential for static sparks.
Metal hydride clean-up / containment	Where metal hydrides may be accidentally released from their containment vessels, appropriate process and equipment should be in place to: - Limit any secondary hazards e.g. contact with hazardous oxidation products; - Prevent release to the wider environment e.g. spill kits; - Allow safe clean-up of powdered material e.g. appropriate damp / wetted towels or vacuum equipment; - Appropriate PPE in addition to that for compressed gaseous hydrogen e.g. face masks to prevent inhalation of powders.

5.5 Relevant legislation, standards and guidance

Table 3 lists the regulations, and related standards and guidelines, appropriate to the handling of Compressed Hydrogen Gas for the operations outlined throughout this section. As mentioned earlier, it is imperative that users ensure they are accessing the most up-to-date versions of the referenced documents and/or any additional documents that have superseded them.

Table 3 - Appropriate legislation, standards and guidance

Regulation	Industry Standards and Guidelines
Manual Handling Operations Regulations 1992 [1].	BCGA GN3: Gas Cylinder – Manual Handling Operations [5]. Health and Safety Executive (HSE) L23: Manual Handling [44].
The Management of Health and Safety at Work Regulations 1999 [2].	HSE INDG163: Five steps to risk assessment [6]. BCGA TIS49: Risk assessment considerations for activities involving compressed gas cylinders within the workplace [7]. HSE HSG136: A guide to workplace transport safety [14]. BCGA TIS38: Moving Gas Cylinders And Bundles Within The Workplace [33]. BCGA CP52: The management of risks from gases in the workplace [24]. HSE HSG65: Managing for health and safety [25].
Lifting Operations and Lifting Equipment Regulations 1998 [3].	HSE L113: Safe use of lifting equipment [8].
The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) [13].	BCGA GN13: DSEAR risk assessment guidance for compressed gases [12]. BCGA GN41: Separation distances in the gases industry [39]
The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 [15].	
Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDG) [4].	BCGA CP50: The Carriage Of Gas Cylinders On Vehicles [9]. BCGA GN45: Dangerous Goods Safety Adviser [10]. BCGA Leaflet 1: The Carriage Of Small Quantities Of Gas Cylinders [20].

	European Industrial Gases Association (EIGA) 173: ADR Transport Security Guidelines [21]. BCGA GN23: Gas safety. Information, instruction and training [30]. BCGA CP43: The Safe Filling Of Gas Cylinders [41].
The Pressure Systems Safety Regulations 2000 (PSSR) [17].	BCGA CP47: The Safe Use Of Individual Portable Or Mobile Cylinder Gas Supply Equipment [16]. BCGA CP39: In-Service Requirements Of Pressure Equipment (Gas Storage And Gas Distribution Systems) [18]. BCGA GN44: Portable Or Mobile Cylinder Gas Equipment - Thorough Inspection [19].
Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 [22].	HSE INDG453: Reporting accidents and incidents at work [23].
Control Of Major Accident Hazards Regulations 2015 [26].	HSE L111: The Control of Major Accident Hazards Regulations 2015 [27].
Planning (Hazardous Substances) Regulations 2015 [28].	BCGA CP44: The storage of gas cylinders [29].
Personal Protective Equipment Regulations 2018 [32].	HSE L25: Personal Protective Equipment at Work [31].
The Regulatory Reform (Fire Safety) Order 2005 [38].	BCGA CP44: The storage of gas cylinders [29].
Control of Substances Hazardous to Health (COSHH) Regulations 2002 [47].	HSE INDG136: Working with substances hazardous to health [48].

5.6 General Legislative Requirements

According to the CDG regulations [4] there are a number of general legislative requirements demanded of all parties involved in the distribution of compressed Hydrogen gas cylinders over the UK roadways and inland waterways:

- Management of health and safety;
- Site Planning Requirements;
- Actions in the event of an incident and Emergency Response;
- Reporting of serious incidents;
- Competence and training;

- Security.

5.6.1 Management of health and safety

All organisations involved in the loading, filling, transport or unloading of compressed Hydrogen gas cylinders are required to put in place arrangements to control health and safety risks. Part 1 of the HSE HSG65 document [25], lists those processes and procedures that should be in place to meet the legal requirements.

5.6.1.1 Personal Protective Equipment

Any activity requiring personnel in the handling of compressed Hydrogen gas cylinders shall have a work activity risk assessment, to ensure practical control measures are in place. Where these control measures are not considered to reduce the risk to As Low As Reasonably Practical (ALARP) PPE may be considered as a control measure. Where PPE is required, a PPE assessment shall be carried out in accordance with the Personal Protective Equipment Regulations[32]. Guidance is provided by the HSE Approved Code of Practice (ACoP) L25 [31].

5.6.2 Site Planning Requirements

Consent for storage of compressed Hydrogen gas will have to be obtained under two sets of regulations:

- Planning (Hazardous Substances) Regulations 2015 [28];
- Control Of Major Accident Hazards Regulations 2015 [26].

For small quantities of compressed Hydrogen gas storage, specifically below 2 tonnes, and in the absence of other dangerous substances on site, no consent is required. If the total quantity of compressed Hydrogen gas falls below 40 kg, and in the absence of other dangerous substances on site, then the site development is considered too trivial or minor to merit consideration by law (‘de minimis’).

For further information see BCGA CP44 [29].

5.6.2.1 Planning (Hazardous Substances)

All organisations that intend to hold at least 2 tonnes of compressed Hydrogen gas at their site are required to obtain consent from the local authority. Further planning guidance can be found at: https://www.gov.uk/guidance/hazardous-substances [37].

5.6.2.2 Control of Major Accident Hazards

All organisations that hold at least 5 tonnes of compressed Hydrogen gas at their site are required to notify the local COMAH authority and to demonstrate they have effective controls to prevent or mitigate major accidents, in accordance with the Control of Major

Accident Hazards Regulations [26]. These duties become more stringent on the site operator over the threshold of 50 tonnes of compressed Hydrogen gas.

These duties are detailed in the HSE ACoP document L111 [27].

5.6.3 Actions in the event of an incident and Emergency Response

There are a number of foreseeable incidents which can be prepared for, these include:

- a gas leak;
- an incident involving the vehicle;
- a fire on the vehicle where cylinders are involved.

Section 11 of BCGA CP50 [9] provide a series of immediate actions in the event of either of these incidents.

Wherever compressed Hydrogen gas is to be handled an emergency plan shall be established and implemented, to prepare for and understand how to deal with emergency situations. Section 11 of BCGA CP52 [24] details what is to be included within the emergency plan and the risk assessments to support it.

5.6.4 Reporting of Serious Incidents

In the event a serious incident takes place during loading, filling, transport or unloading of compressed Hydrogen gas cylinders, the incident shall be reported to the Competent Authority, in the UK the Department for Transport (DfT), within one month of the date of the incident taking place, by the Consignor, filler, carrier, unloader or Consignee, respectively, in accordance with the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) [22]. Instruction on how to fully comply with RIDDOR is provided by the HSE guidance document INDG453 [23].

5.6.5 Competence and training

Everyone involved in the handling of compressed Hydrogen gas shall have the necessary competence to enable them to carry out their responsibilities and duties and have received appropriate training in the hazards, properties and dangers of compressed Hydrogen gas. “They shall receive appropriate information, instruction, training and supervision. This should include induction and refresher sessions, as required. It is the duty of the Employer to ensure their persons are competent. It is recommended that a training programme with a competency assessment is carried out under a formalised system. Records shall be kept of the information, instruction, training and supervision provided and of the competence level achieved.” [9].

For further information see BCGA GN23 [30].

5.6.6 Security

According to Section 12 of BCGA CP50 [9]:

"All persons engaged in the carriage of dangerous goods shall take the measures necessary to minimise the theft or misuse of dangerous goods that may endanger persons, property or the environment.

The carriage of high consequence dangerous goods requires additional security measures. A security plan shall be adopted, implemented and complied with. For guidance refer to EIGA 173" [21].

5.7 Storage of Hydrogen

The storage of compressed Hydrogen gas cylinders is, here, broken down into the following activities:

1. The identification of suitable cylinders for storage;
2. The filling of cylinders;
3. The identification and build of a suitable storage location.

5.7.1 The identification of suitable cylinders for storage

5.7.1.1 Introduction

The legislation for this activity covers the following operations:

- The use of appropriate cylinders for the filling and storage of Compressed Hydrogen Gas.

5.7.1.2 Responsible stakeholders

It is the site operator of the storage facility who has sole responsibility for this activity according to BCGA CP43 [41]. The rightful owner of the gas cylinder must be identified and authorise its use.

5.7.1.3 Summary of Duties on Responsible Stakeholders

Specific requirements on the identification of suitable cylinders are detailed in Section 4.6 of BCGA CP43 [41].

5.7.2 The filling of cylinders

5.7.2.1 Introduction

The legislation for this activity covers the following operations:

- Compression and transfer of Hydrogen Gas between vessels.

5.7.2.2 Responsible stakeholders

It is the operator of the refill facility who has sole responsibility for this activity according to BCGA CP43 [41].

5.7.2.3 Summary of Duties on Responsible Stakeholders

The CDG Regulations [4] require that Compressed Hydrogen Gas Cylinders are checked prior to Filling. The filling of these cylinders shall only then be carried out by specially equipped centres, with qualified staff using appropriate procedures. These requirements are addressed in detail in Section 4 of BCGA CP43 [41].

5.7.3 The Identification and build of a suitable storage location

5.7.3.1 Introduction

The legislation for this activity covers the following operations:

- Siting of a storage facility;
- Design and construction of the facility.

5.7.3.2 Responsible stakeholders

It is the site operator of the storage facility who has sole responsibility for this activity according to BCGA CP44 [29].

5.7.3.3 Summary of Duties on Responsible Stakeholders

Any storage facility should, according to BCGA CP44 [29] follow four basic principles:

- be well ventilated;
- be outdoors;
- have adequate security;
- meet the required separation distances.

Any prospective location should have a safety risk assessment carried out. As it is highly flammable, Hydrogen gas, regardless of volume, will require a DSEAR [13] risk assessment. Specific guidance is available at BCGA GN13 [12].

For the legal and planning requirements refer to Section 5.6.2 above.

The site operator is responsible for the safe design and safe use of the site's traffic routes, to limit the risk of personal injury where there is movement of both vehicle and personnel. Guidelines for these traffic routes are given in HSG136 [14].

As stated above, the ideal storage facility should be well ventilated and located outdoors. Storage is considered outdoors if 30% of the perimeter is open with no roof, or if 50% of the perimeter is open with a roof. If the facility does not meet the criteria then a risk assessment must be carried out to determine the necessary controls. See BCGA CP52 [24] for guidance.

Further guidance to the requirements for the construction of a storage facility can be found in Section 5 of BCGA 44 [29]. This includes guidance on ventilation, construction of the floor and roof, layout, access, electrical power, lighting and signage.

The proposed storage facility will be subject to a safety fire risk assessment in accordance with the Regulatory Reform (Fire Safety) Order [38]. Refer to BCGA CP44 Section 5.12 [29] and BCGA GN41 [39] for further guidance.

Where storage is provided by a dedicated cage, its security requirements are included in BCGA TIS48 [40].

5.8 Transport of Hydrogen on UK Roadways and Internal Waterways

The transport of compressed Hydrogen gas cylinders is, here, broken down into the following activities:

1. Transport Hydrogen gas cylinders internally at site to loading bay;
2. Inspection of Hydrogen gas cylinders prior to loading;
3. Loading Hydrogen gas cylinders on to vehicle;
4. Transport Between Sites on Public Roads and Internal Waterways;
5. Inspection on receipt;
6. Unloading Hydrogen gas cylinders from vehicle;
7. Transport internally at site to storage location.

5.8.1 Transport Hydrogen gas cylinders internally at site to loading bay / to storage location

5.8.1.1 Introduction

The legislation for this activity covers the following operations:

- Transfer of Hydrogen gas cylinders between their place of storage and the nominated loading area.

5.8.1.2 Responsible stakeholders

Any internal movement of Hydrogen gas cylinders is the responsibility of the site operator.

5.8.1.3 Summary of Duties on Responsible Stakeholders

Guidance on the physical movement of gas cylinders is provided in BCGA TIS38 [33].

The site operator is responsible for the safe design and safe use of the site's traffic routes, to limit the risk of personal injury where there is movement of both vehicle and personnel. Guidelines for these traffic routes are given in HSG136 [14].

5.8.2 Inspection of Hydrogen gas cylinders prior to loading and on receipt

5.8.2.1 Introduction

The legislation for this activity covers the following operations:

- The regular maintenance and inspection of the Hydrogen Gas cylinders in storage;
- The inspections of the Hydrogen gas cylinders before loading on to the transport vehicle and on arrival.

5.8.2.2 Responsible stakeholders

For gas cylinders, the owner has responsibility for inspection and maintenance. In the case of gas cylinders fitted with a valve with an integral pressure regulator, the responsibility for its serviceability is also with the owner of the cylinder [16].

5.8.2.3 Summary of Duties on Responsible Stakeholders

Before loading the gas cylinders on to the transport vehicle, the owner is required to undertake a series of inspections as specified in Section 4 of BCGA CP50 [9]. Both the BCGA CP39 [18] and BCGA GN44 [19] detail a thorough inspection regime as part of the Written Scheme of Examination demanded within the PSSR [17].

Gas cylinders may be transported providing they are in-date for their periodic inspection and test.

Each gas cylinder shall have a product identification label which identifies its contents.

5.8.3 Loading Hydrogen Gas Cylinders on to the vehicle / Unloading Hydrogen Gas Cylinders from the Vehicle

5.8.3.1 Introduction

The legislation for this activity covers the following operations:

- Locating a suitable site for the loading and unloading of Hydrogen gas cylinders;

- Lifting of the Hydrogen gas cylinders, both manual and mechanical;
- Safely securing the Hydrogen gas cylinders to the transport vehicle.

5.8.3.2 Responsible stakeholders

It is the Consignor who has the legal responsibility for placing the load on the vehicle under the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations [4].

5.8.3.3 Summary of Duties on Responsible Stakeholders

Guidance for the safe loading and unloading practices and the requirements for nominated loading and unloading sites are detailed within HSG136 [14] for workplace transport safety.

5.8.3.4 Location for loading and unloading operations

Compressed Hydrogen gas Is classified as a dangerous substance and is in scope of the DSEAR [13]. At the nominated site for loading or unloading a risk assessment is required to implement the necessary controls and emergency plans. Instruction for a DSEAR risk assessment can be found in BCGA GN13 [12].

Loading and unloading operations should not be carried out in an enclosed space [9]. Where this is not possible then the building used must have good high-level and low-level natural ventilation to the open air. For further guidance on selecting a suitable loading/unloading site, see HSG136 [14].

The nominated area shall be devoid of all potential ignition sources. For example, all parties should enforce appropriate policies and operating discipline such as no smoking, no naked lights, no electronic cigarettes (or similar devices).

The vehicle engine shall be shut-off during loading and un-loading, unless it is necessary for the actual process [9].

5.8.3.5 Lifting of Gas Cylinders

Any lifting operation must be thoroughly planned, assessed, controlled and executed by a competent person. As part of this task, the potential risks during lifting are to be identified and their impact assessed. Controls are to be put into place to eliminate or reduce as far as reasonably practicable the risk impact. Guidance on risk assessment in general, can be found in Risk assessment: A brief guide to controlling risks in the workplace INDG163 [6].

Ideally mechanical lifting equipment should be used to prevent injuries associated with manual lifting. The operator must adhere to the HSE's ACoP L113 [8] to comply with the Lifting Operations and Lifting Equipment Regulations [3].

Where loading and unloading of the gas cylinders includes manual lifting, then refer to BCGA GN 3 [5] and HSE L23 for manual handling [44], two guidelines which define the principles of safe practice for handling gas cylinders at work in line with the Manual Handling Operations Regulations [1].

5.8.3.6 Safely Securing the Gas Cylinders to the Vehicle

The gas cylinders must be restrained so that they cannot be moved during transport. They shall not project beyond the sides or ends of the vehicle. Ensure that the load quantity and weight is appropriate for the vehicle and is evenly balanced across the load space. Further detail for securing gas cylinders is provided in BCGA CP50 section 4 [9].

5.8.4 Transport Between Sites on Public Roads

5.8.4.1 Introduction

The legislation for this activity covers the following operations:

- Transport of Compressed Hydrogen Gas Cylinders on public roads;
- Transport of small loads on public roads.

5.8.4.2 Responsible stakeholders

Whilst transporting the Hydrogen cylinders, it is the driver who has the responsibility from a road safety and a general safety perspective. Drivers shall have completed an approved training course, passed an approved examination and been issued an ADR Training Certificate [9].

It is the vehicle operator who has the responsibility that the vehicle is fit for the purpose of transporting Hydrogen gas cylinders and has been subject to regular inspection and maintenance.

5.8.4.3 Summary of Duties on Responsible Stakeholders

According to BCGA CP50 [9], for loads above the small load threshold of 333 litres water capacity, there are several specific requirements for full compliance with ADR without exception. These include:

- having the appropriate documentation;
- vehicle placarding and marking;
- additional equipment for specific types of dangerous goods;
- training commensurate with a person's responsibilities and duties;
- the appointment of a Dangerous Goods Safety Advisor (DGSA); reference BCGA GN45 [10];

- unauthorised passengers are prohibited on vehicles transporting dangerous goods;
- smoking is prohibited inside the vehicle and in the vicinity during loading and unloading;
- the vehicle engine shall be shut-off during loading and un-loading, unless it is necessary for the actual process;
- the vehicle crew shall not open any cylinder valves during the transport journey.

5.8.4.4 Transport of small loads

According to BCGA CP50 [9] the threshold for Compressed Hydrogen is 333 litres water capacity; however all parties involved in the transport must agree that the load is small.

Small loads do not have to meet the full requirements of the CDG regulations summarised in Section 5.8.4.3. There are specific requirements for small loads which are detailed in Section 5 of BCGA CP50 [9]. These can be summarised as follows:

- Drivers are not required to carry the appropriate documentation but it may help emergency services in the event of an accident;
- A single fire extinguisher with a minimum capacity of 2 kg dry powder (or equivalent) shall be carried;
- vehicle hazard labelling is not required but may help the emergency services in the event of an accident;
- Where gas cylinders are carried inside a vehicle, in the same space as people, then a suitable and sufficient risk assessment and appropriate controls shall be implemented.

BCGA Leaflet 1 [20], "The carriage of small quantities of gas cylinders" [20], sets out the legal and basic safety requirements for transporting small quantities of gas cylinders on a vehicle whilst at work and provides sound advice if transporting gas cylinders for personal use.

Where the Hydrogen is intended for private or domestic use there is still the requirement to transport the Hydrogen safely. What is meant by this is detailed in BCGA Leaflet 17 [46].

5.8.5 Transport Between Sites on Internal Waterways

5.8.5.1 Introduction

The legislation for this activity covers the following operations:

- Transport of Compressed Hydrogen Gas Cylinders on internal waterways;

- Transport of small loads on internal waterways.

5.8.5.2 Responsible stakeholders

The UK is not a signatory to the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN). Authorisation [45] is given by the DfT until February 2025 to transport Dangerous Goods by Ship under CDG regulations [4]. So, compliance is required with these CDG regulations [4], the same as for transport by road.

The responsible stakeholder is as section 5.8.4.2 for transport on public roads.

5.8.5.3 Summary of Duties on Responsible Stakeholders

The general requirements listed in section 5.6 and the transport requirements listed in this section 5.8 still apply for inland waterways, at least until February 2025. So, for example, where the requirement is to the driver, then read the skipper and where the requirement is to the vehicle, then read the vessel.

5.9 Use of Hydrogen in Systems

Until now this document has provided information in general terms and not considered specific uses of Compressed Hydrogen Gas.

In this section three specific uses are considered:

1. Fuel cells on narrowboats for domestic power use on board;
2. Off-grid power unit;
3. Hydrogen-electric powered mobile cherry picker for construction.

This section only concentrates on the end use and does not include the supply chain to the point of use.

In Table 4 those activities appropriate to each of the uses have been cross referenced.

Table 4 - Cross Reference of Hydrogen Use to Legislative Guide

Activity	User Guide Ref.(specific uses)		
	1	2	3
Management of health and safety (Section 5.6.1)		✓	
Site Planning Requirements (Section 5.6.2)		✓	
Actions in the event of an incident (Section 5.6.3)	✓	✓	✓
Reporting of Serious Incidents (Section 5.6.4)		✓	
Competence and training (Section 5.6.5)	✓	✓	✓
Security (Section 5.6.6)	✓	✓	✓
The identification of suitable cylinders for storage (Section 5.7.1)		✓	
The filling of cylinders (Section 5.7.2)		✓	
The identification and build of a suitable storage location (Section 5.7.3)	✓	✓	✓
Transport Hydrogen gas cylinders internally at site to loading bay / to storage location (Section 5.8.1)		✓	
Inspection of Hydrogen gas cylinders prior to loading and on receipt (Section 5.8.2)		✓	
Loading Hydrogen Gas Cylinders on to the vehicle / Unloading Hydrogen Gas Cylinders from the Vehicle (Section 5.8.3)	✓	✓	✓
Transport Between Sites on Public Roads (Section 5.8.4)		✓	✓
Transport Between Sites on Inland Waterways (Section 5.8.5)	✓		

5.9.1 Narrowboat Domestic Power

The narrowboat domestic power has room for just the single G20 cylinder. This is well below the 333 litre threshold as specified in Section 5.8.4.4 and each is considered a small load. All that is required of the user of the narrowboat is contained in BCGA Leaflet 1 [20].

It is assumed that the Narrowboat will have no facility to store G20 compressed gas cylinders above the threshold for small loads or that refill operations will be conducted on board. The weight of a G20 bottle is 22.5kg full, just below the 25kg low risk level for manual lifting stated in HSE L23 for Manual Operations [44] for a man but well above that of 16kg for a woman.

The Narrowboat falls under the definition as a pleasure vessel as defined in the Merchant Shipping (Survey and Certification) Regulations [43], “a vessel wholly owned by an individual or individuals, used only for the sport or pleasure of the owner or the immediate family or friends of the owner”. For this reason, the MCA do not require certification of the vessel.

Should the narrowboat be part of a commercial fleet of narrowboats, leased to the public, then all activities in Table 4 apply.

5.9.2 Off-grid Power Unit

An off-grid power unit, however, is different. The number of Compressed Hydrogen Gas MCPs at any one time can far exceed this small load threshold, as shown in Figure 1. In such a case the full scope of this user guide is of relevance.

Figure 1 - Typical Use of an off-grid power unit

5.9.3 Hydrogen-electric Mobile Cherry Picker

The hydrogen-electric cherry picker has room for just the single G20 cylinder. This is well below the 333 litre threshold as specified in Section 5.8.4.4 and each is considered a small load. All that is required of the user of the cherry picker is contained in BCGA Leaflet 1 [20]. Should the user store volumes of compressed hydrogen gas over the 333 litre threshold or fill the G20 cylinder on site then the full scope of this user guide is of relevance.

6.0 References

[1] SI 1992 No. 2793, "Manual Handling Operations Regulations 1992".

[2] SI 1999 No 3242, "The Management of Health and Safety at Work Regulations 1999".

[3] SI 1998 No. 2307, "Lifting Operations and Lifting Equipment Regulations 1998".

[4] SI 2009 No. 1348, "Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009".

[5] BCGA Guidance Note GN3, "Gas Cylinder – Manual Handling Operations", Revision 4, 2022.

[6] HSE Industry Guidance INDG163, "Five steps to risk assessment", revision 2, 2006.

[7] BCGA Technical Information Sheet TIS49, "Risk assessment considerations for activities involving compressed gas cylinders within the workplace", 2023.

[8] HSE Health and Safety Approved Code of Practice L113, "Safe use of lifting equipment".

[9] BCGA Code of Practice CP50, "The Carriage Of Gas Cylinders On Vehicles", 2023.

[10] BCGA Guidance Note GN45, "Dangerous Goods Safety Adviser", 2022.

[11] BCGA Code of Practice CP33, "The bulk Storage of Gaseous Hydrogen at Users' Premises", Revision 1, 2012.

[12] BCGA Guidance Note GN13, "DSEAR risk assessment guidance for compressed gases", Revision 1, 2021.

[13] SI 2002 No. 2776, "The Dangerous Substances and Explosive Atmospheres Regulations".

[14] HSE Health and Safety Guide HSG136, "A guide to workplace transport safety", 3rd Edition, 2014.

[15] SI 2016 No. 1107, "The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016".

[16] BCGA Code of Practice CP47, "The Safe Use Of Individual Portable Or Mobile Cylinder Gas Supply Equipment". Revision 1, 2018.

[17] SI 2000 No. 128, "The Pressure Systems Safety Regulations".

[18] BCGA Code of Practice CP39, "In-Service Requirements Of Pressure Equipment (Gas Storage And Gas Distribution Systems)", Revision 2, 2017.

[19] BCGA Guidance Note GN44, "Portable Or Mobile Cylinder Gas Equipment - Thorough Inspection", 2021.
[20] BCGA Leaflet 1, "The Carriage Of Small Quantities Of Gas Cylinders", Revision 6, 2021.
[21] EIGA 173/20, "ADR Transport Security Guidelines".
[22] SI 2013 No. 1471, "Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013".
[23] HSE Health and Safety Industry Guidance INDG453, "Reporting accidents and incidents at work", Revision 1, 2013.
[24] BCGA Code of Practice CP52, "The management of risks from gases in the workplace", 2023.
[25] HSE Health and Safety Guide HSG65, "Managing for health and safety", 3rd Edition, 2013.
[26] SI 2015 No.483, "Control Of Major Accident Hazards Regulations 2015".
[27] HSE Health and Safety Approved Code of Practice L111, "The Control of Major Accident Hazards Regulations 2015", 3rd Edition, 2015.
[28] SI 2015 No.627, "Planning (Hazardous Substances) Regulations 2015".
[29] BCGA Code of Practice CP44, "The storage of gas cylinders", Revision 1, 2022.
[30] BCGA Guidance Note GN23, "Gas safety. Information, instruction and training", Revision 2, 2023.
[31] HSE Health and Safety Approved Code of Practice L25, "Personal Protective Equipment at Work", 4th Edition, 2022.
[32] SI 2018 No.390, "Personal Protective Equipment (Enforcement) Regulations 2018".
[33] BCGA Technical Information Sheet TIS38, "Moving Gas Cylinders And Bundles Within The Workplace", Revision 1, 2022.
[34] ISO/TR 15916:2015, "Basic Considerations for the Safety of Hydrogen Systems", Edition 2, 2015.
[35] BOC, MSDS No. 000010021694, "Hydrogen Compressed", 18th August 2023.
[36] Alexei Kotchourko and Thomas Jordan, "Hydrogen Safety for Energy Applications", Butterworth-Heinemann, 2022.
[37] "Guidance Hazardous substances", GOV.UK, https://www.gov.uk/guidance/hazardous-substances.
[38] SI 2005 No.1541, "The Regulatory Reform (Fire Safety) Order 2005".
[39] BCGA Guidance Note GN41, "Separation distances in the gases industry", 2020.
[40] BCGA Technical Information Sheet TIS48, "Gas equipment. Security cages.", 2021.
[41] BCGA Code of Practice CP43, "The Safe Filling Of Gas Cylinders", Revision 2, 2024.
[42] UNECE, Country Information (Competent Authorities, notifications according to 1.9.4).

[43] SI 2015 No.508, "The Merchant Shipping (Survey and Certification) Regulations 2015".

[44] HSE Health and Safety Guidance on Regulations L23, "Manual Handling Operations Regulations 1992", Fourth Edition, 2016.

[45] DfT Authorisation No. 443, "The Carriage of Dangerous Goods and use Transportable Pressure Equipment Regulations 2009", 19th February 2015.

[46] BCGA Leaflet 17, "Information For Customers Collecting Gas Cylinders", 2022.

[47] SI 2002 No. 2677, "Control of Substances Hazardous to Health Regulations 2002".

[48] HSE Health and Safety Industry Guidance INDG136, "Working with substances hazardous to health", Revision 5, 2012.

[49] Linde Hydrogen GENIE Gas Cylinder.

[50] ECE/TRANS/275, "European Agreement Concerning the International Carriage of Dangerous Goods by Road", January 2019.