RECENT DEVELOPMENTS IN THE USE OF HYDROGEN AS AN ALTERNATIVE FUEL

UKELG: 51ST DISCUSSION MEETING

IMPERIAL COLLEGE 1ST APRIL 2014

NICK HART, ITM POWER PLC

ITM POWER DESIGNS AND MANUFACTURES HYDROGEN ENERGY SYSTEMS FOR ENERGY STORAGE AND CLEAN FUEL PRODUCTION

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RECENT DEVELOPMENTS IN THE USE OF HYDROGEN AS AN ALTERNATIVE FUEL

Overview:

- Introduction / context:
  - Future of hydrogen
  - Relevant legislation / guidance
- Hazards & precautions
- Development of codes of practice / standards

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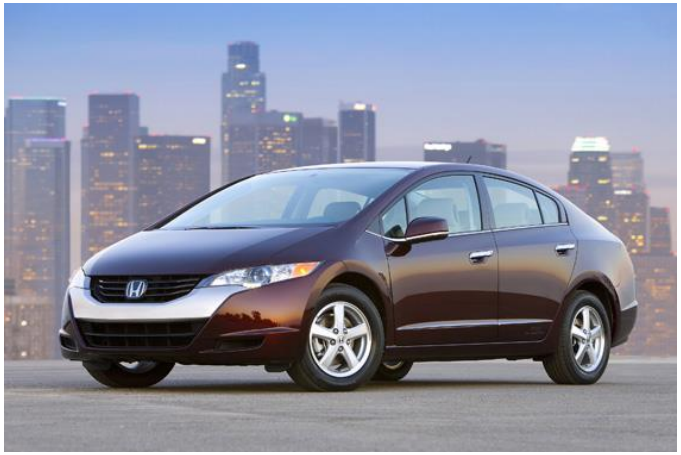
HYDROGEN - WHAT IS NEW?

Developing applications:

- Vehicles
- Energy storage
- Back-up power
- “Power to gas”
- Micro grids

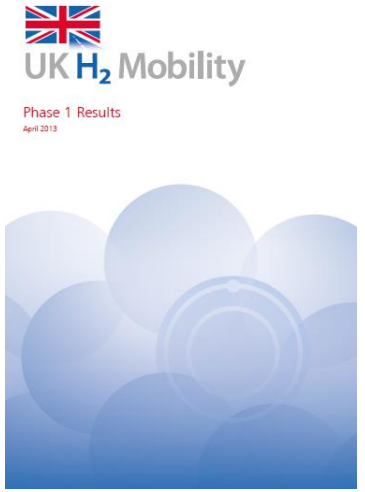


Differences:

- Proximity to public
- Higher pressures
- Higher concentrations

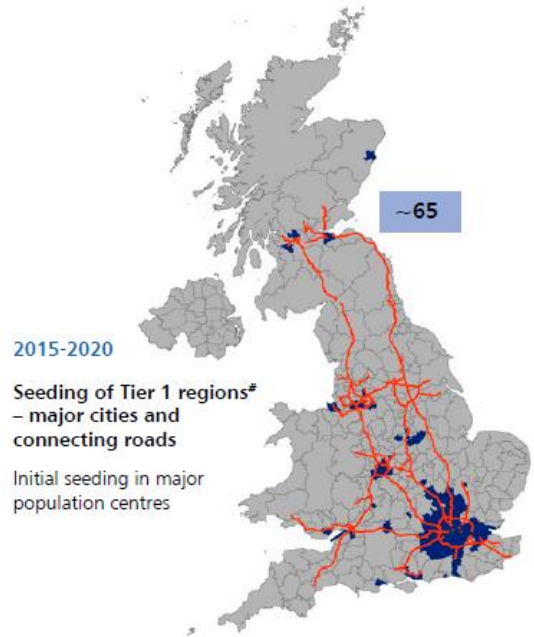
UKH2MOBILITY

http://www.ukh2mobility.co.uk/



Phase 1 report: April 2013

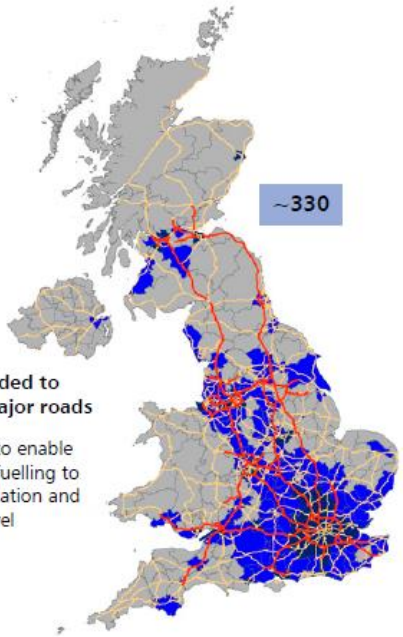
UKH2MOBILITY: ROADMAP



2015-2020

Seeding of Tier 1 regions# – major cities and connecting roads

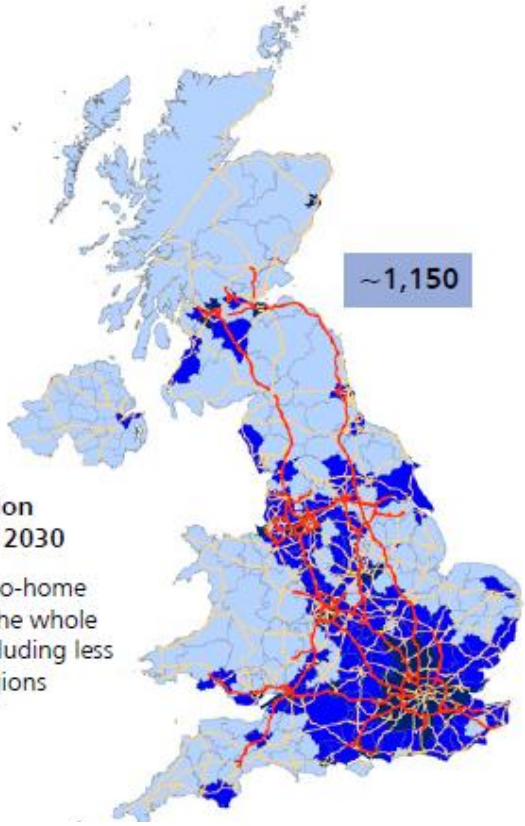
Initial seeding in major population centres



2020-2025

Coverage extended to Tier 2 and all major roads

Extend coverage to enable close-to-home refuelling to 50% of the population and long distance travel



2025-2030

Full population coverage by 2030

Extend close-to-home refuelling to the whole of the UK, including less populated regions

* Tier 1 - LADs with highest spatial density of population and vehicles

* Tier 2 - LADs with intermediate spatial density of population and vehicles

* Tier 3 - LADs with lowest spatial density of population and vehicles

KEY
- Tier 1 roads
- Tier 2 roads

FUTURE OF HYDROGEN

ENERGY STORAGE | CLEAN FUEL

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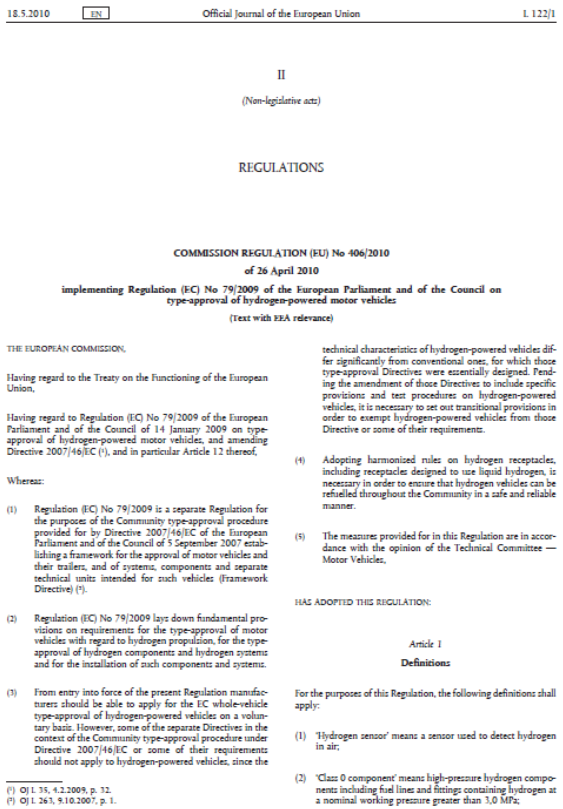
RELEVANT LEGISLATION

Vehicles:

- Regulation (EC) No 79/2009 of the European Parliament and of the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles,
- Commission Regulation (EU) No 406/2010 of 26 April 2010 implementing Regulation (EC) No 79/2009 of the European Parliament and of the Council on type-approval of hydrogen-powered motor vehicles

Energy storage / Back-up power / Micro grids:

- ATEX / DSEAR
- PED / PER
- PSSR
- Machinery Directive / LVD
- Gas Appliances Directive



18.5.2010 EN Official Journal of the European Union L 122/1

II

(Non-legislative acts)

REGULATIONS

COMMISSION REGULATION (EU) No 406/2010

of 26 April 2010

implementing Regulation (EC) No 79/2009 of the European Parliament and of the Council on type-approval of hydrogen-powered motor vehicles

(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EC) No 79/2009 of the European Parliament and of the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC (1), and in particular Article 12 thereof,

Whereas:

(1) Regulation (EC) No 79/2009 is a separate Regulation for the purposes of the Community type-approval procedure provided for by Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (Framework Directive) (2).

(2) Regulation (EC) No 79/2009 lays down fundamental provisions on requirements for the type-approval of motor vehicles with regard to hydrogen propulsion, for the type-approval of hydrogen components and hydrogen systems and for the installation of such components and systems.

(3) From entry into force of the present Regulation manufacturers should be able to apply for the EC whole-vehicle type-approval of hydrogen-powered vehicles on a voluntary basis. However, some of the separate Directives in the context of the Community type-approval procedure under Directive 2007/46/EC or some of their requirements should not apply to hydrogen-powered vehicles, since the technical characteristics of hydrogen-powered vehicles differ significantly from conventional ones, for which those type-approval Directives were essentially designed. Pending the amendment of those Directives to include specific provisions and test procedures on hydrogen-powered vehicles, it is necessary to set out transitional provisions in order to exempt hydrogen-powered vehicles from those Directive or some of their requirements.

(4) Adopting harmonised rules on hydrogen receptacles, including receptacles designed to use liquid hydrogen, is necessary in order to ensure that hydrogen vehicles can be refuelled throughout the Community in a safe and reliable manner.

(5) The measures provided for in this Regulation are in accordance with the opinion of the Technical Committee — Motor Vehicles,

HAS ADOPTED THIS REGULATION:

Article 1

Definitions

For the purposes of this Regulation, the following definitions shall apply:

(1) 'Hydrogen sensor' means a sensor used to detect hydrogen in air;

(2) 'Class 0 component' means high-pressure hydrogen components including fuel lines and fittings containing hydrogen at a nominal working pressure greater than 3,0 MPa;

(1) OJ L 35, 4.2.2009, p. 32.
(2) OJ L 263, 9.10.2007, p. 1.

RELEVANT LEGISLATION

Gaps?

- Domestic / residential hydrogen use (GSIUR 1998)
- “Power to gas” (other than the Gas Safety (Management) Regulations 1996 (GSMR) limit: 0.1% by volume)
- Vehicle refuelling stations


EUROPEAN COMMISSION

Brussels, 24.1.2013
COM(2013) 18 final

2013/0012 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on the deployment of alternative fuels infrastructure

(Text with EEA relevance)

{SWD(2013) 5 final}
{SWD(2013) 6 final}

“Power to gas”:

- Differing limits of hydrogen in natural gas grid across Europe.
- CEN / CENELEC requested reactions and feedback on opportunity / need for standardization of applications of hydrogen / natural gas blends (HCNG) hydrogen technologies.

Hydrogen vehicle refuelling stations (HRS):

- Proposed European Directive for “the deployment of alternative fuels infrastructure” (http://www.europarl.europa.eu/oeil/popups/ficheprocedure.do?reference=2013/0012(COD)&l=en)
- Requirements for electric vehicle charging, hydrogen, CNG and LNG vehicle fuelling
- Both safety and availability
- For hydrogen, current draft includes reference to ISO standards (see Annex III)
- Major reference: ISO TS 20100:2008 – Gaseous hydrogen – Fuelling stations

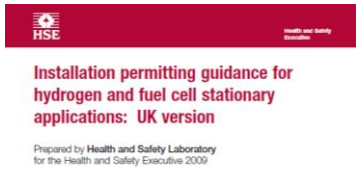
RELEVANT UK GUIDANCE

Low pressure stationary applications:
"RR715 - Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version", 2009
(http://www.hyperproject.eu/)

Refuelling stations:
"HyApproval - Handbook for Approval of Hydrogen Refuelling Stations" (European Commission) (http://www.hyapproval.org/), 2008

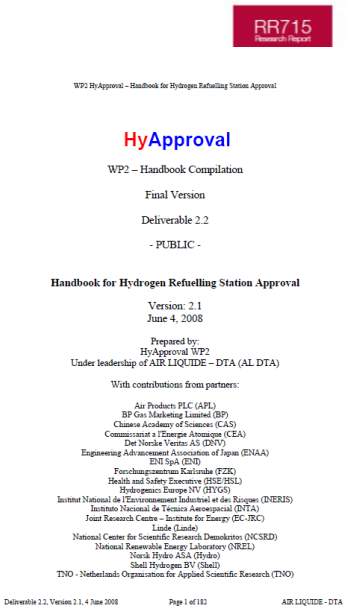
British Compressed Gases Association (BCGA):
Codes of Practice / Industrial guidance

International standards:
IEC TC 105:
Fuel cell applications, such as stationary FC power systems, FC for transportation (e.g. propulsion systems and auxiliary power units), portable FC power systems,
ISO TC 197:
Standardization in the field of systems and devices for the production, storage, transport, measurement and use of hydrogen.


HSE

Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version

Prepared by Health and Safety Laboratory for the Health and Safety Executive 2009


RR715
Research Report

WP2 HyApproval – Handbook for Hydrogen Refuelling Station Approval

HyApproval

WP2 – Handbook Compilation

Final Version

Deliverable 2.2

- PUBLIC -

Handbook for Hydrogen Refuelling Station Approval

Version: 2.1
June 4, 2008

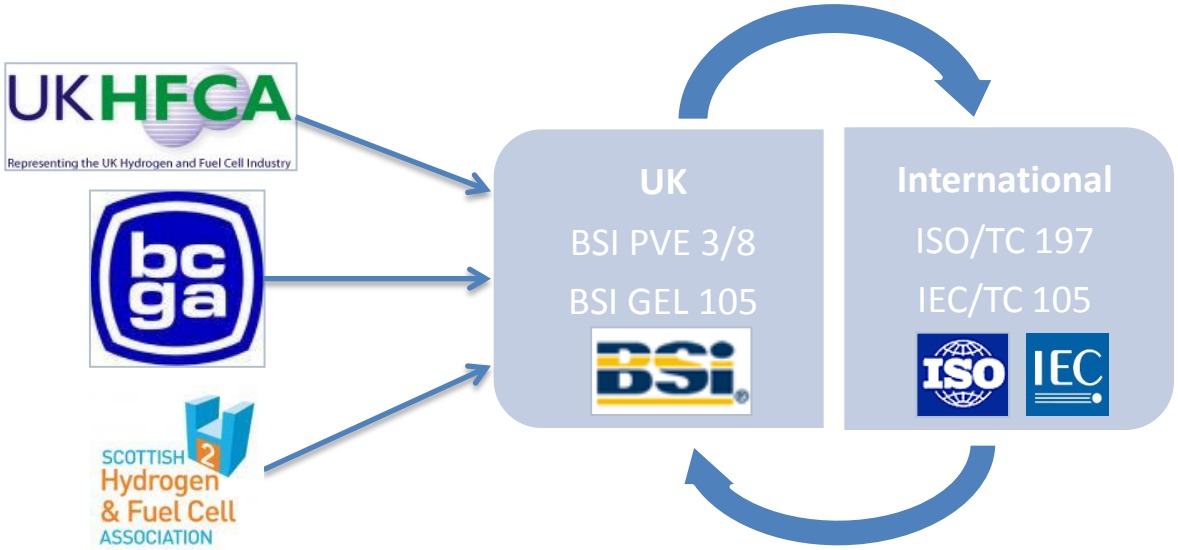
Prepared by:
HyApproval WP2
Under leadership of AIR LIQUIDE – DTA (AL DTA)

With contributions from partners:

Air Products PLC (APL)
BP Gas Marketing Limited (BP)
Chinese Academy of Sciences (CAS)
Commissariat a l'Energie Atomique (CEA)
Det Norske Veritas AS (DNV)
Engineering Advancement Association of Japan (ENAA)
ENI SpA (ENI)
Forschungszentrum Karlsruhe (FZK)
Health and Safety Executive (HSE/HSL)
Hydrogenics Europe NV (HYGS)
Institut National de l'Environnement Industriel et des Risques (INERIS)
Instituto Nacional de Técnica Aeroespacial (INTA)
Joint Research Centre – Institute for Energy (EC-JRC)
Linde (Linde)
National Center for Scientific Research Demokritos (NCSRD)
National Renewable Energy Laboratory (NREL)
Norsk Hydro ASA (Hydro)
Shell Hydrogen BV (Shell)
TNO - Netherlands Organisation for Applied Scientific Research (TNO)

Deliverable 2.2, Version 2.1, 4 June 2008 Page 1 of 182 AIR LIQUIDE - DTA

EXAMPLE UK HYDROGEN WORKING GROUPS



ISO/TC 197 Group	Standard	Title
WG 5:	ISO 17268	Gaseous hydrogen land vehicle refuelling connection devices
WG 8:	ISO 22734-1 / 2	Hydrogen generators using water electrolysis
WG 12:	ISO 14687-2	Hydrogen Fuel - Product Specification - PEM fuel cell for road vehicles
WG 16:	ISO/TR 15916	Basic considerations for the safety of hydrogen systems
WG 24:	ISO 19880-1	Gaseous hydrogen - Fuelling stations

PRODUCT REFERENCE PLANT

Energy Technologies Building: UoN

- First CE marked ITM refueller installation
- On-site hydrogen generation (electrolysis)
- Expandable to 60kg/day
- 350 bar refuelling platform

CE

The University of Nottingham

Upcoming ITM HRS projects:

- EcoIsland (Isle of Wight)
- HyFive (London)
- UKH2Mobility

HAZARDS AND PRECAUTIONS: STORAGE

Examples of hazards that could be reasonably expected to be encountered with hydrogen storage, from small scale to COMAH quantities, at HRS:

- Small leaks from fittings, valves, instruments;
- Over-pressurisation of storage tanks / assemblies;
- Failure of relief valve (e.g. Emeryville Accident);
- Leaks during deliveries;
- Leaks from other equipment: compressors, electrolysers, etc.
- Arson / vandalism / theft

Examples of precautions that could be taken:

- Minimise potential leak points, appropriate material selection;
- Suitable ventilation / open outdoor space with appropriate layout;
- Appropriate use of Ex rated electrics / separation from other sources of ignition;
- Mitigation of effects of fire / explosion (e.g. firewalls, blast panels, separation);
- Prevent jet fire impingement onto storage system;
- Over-pressurisation protection in line with PED / PSSR;
- Separation from sources of heat (fuel store, combustibles, vehicles);
- High level vent exits (zoning);
- Security / signage / maintenance & inspection.

HAZARDS AND PRECAUTIONS: DISPENSING

Examples of hazards that could be reasonably expected to be encountered during vehicle refuelling events:

- Small leaks from hoses, fittings, valves, instruments;
- Leaks from poor connection of nozzle to vehicle receptacle / adapters;
- Hose failure / drive-away events;
- Activation of vehicle storage tank TPRD;
- Overpressurisation of vehicle storage tanks / assemblies;
- Collision with dispenser;
- Arson / vandalism / theft.

Examples of precautions that could be taken:

- Minimise potential leak points at dispenser, appropriate material selection;
- Standardised nozzle / receptacle (no adapters);
- Pressure integrity test at start, and during fill process;
- Excess flow valve / flow meter / pressure alarm / hydrogen sensors
- Suitable ventilation / open space (typically under canopy for weather protection);
- Appropriate use of Ex rated electrics / hydrogen sensors;
- Mitigation of effects of fire / explosion (e.g. separation);
- Pre-cooling of hydrogen / limits on rate of fill;
- Over-pressurisation protection, different nozzles for different pressures (35 / 70 MPa)
- Isolation valve(s) from storage area when not dispensing;
- Separation from other sources of ignition during fill;
- High level venting of nozzle / receptacle volume after fill;

HRS EXPLOSION HAZARDS: PREVIOUSLY EXISTING GUIDANCE / CODES

Generic methodologies exist to establish both DSEAR hazardous area extents and separation distances in an outdoors environment:

- Risk assessment based approach
- Generally based on calculations using system pressure and the anticipated size of the release.
- International Standards harmonised to Directive 94/9/EC include BS EN 60079-10-1 – 2009

Published guidance can be obtained from:

- EI 15 (IP 15) (refinery hydrogen)
- BCGA CP4, CP33 and BCGA GN13 especially pertinent for the hydrogen storage aspects.
- The EIGA IGC Doc 15/06/E suggests similar separation distances to BCGA CP33, other information on determining safety distances available in EIGA IGC Doc 75/07/E .
- Other useful published research includes HSE published guidance RR715 and the HSL document XS/07/07

Alternative guidance that is more specific to hydrogen refuelling stations is available from:

- The US Fire Code published by the National Fire Protection Association (NFPA) NFPA 2,
- The draft International Standard ISO/DIS 20100 (continuation of ISO/TS 20100:2008)
- The German TÜV Merkblatt 514 document.

RECENT BCGA DEVELOPMENTS

Hydrogen (and alternative gaseous fuels)

- Existing codes for use of gas cylinders (CP4), or bulk hydrogen storage (CP33)
- Relevant to hydrogen refuelling stations
- However, further specific guidance required – ISO 20100 preparation stalled
- TSC9 formed for hydrogen and alternative gaseous fuels
- Development of code of practice (CP) for refuelling stations:
  - To outline major considerations required in design, construction, operation and maintenance
  - Appropriate EU and UK legislation to be addressed
  - Sign-post to relevant documents (NFPA, ISO)
- Institution of Gas Engineers and Managers (IGEM) – IGEM/UP/20 (to replace IGE/UP/5)
- Feedback from other UK stakeholders, including:
  - HSE
  - Society of Motor Manufacturers & Traders (SMMT)
  - UKH2Mobility
  - Association for Petroleum and Explosives Administration (APEA)
  - Energy Institute (EI)
  - London Fire Brigade

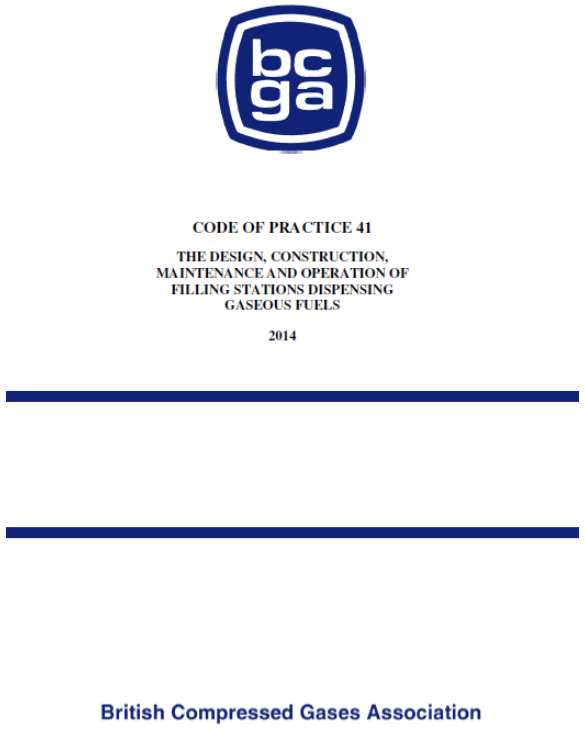
BCGA CODE OF PRACTICE 41

BCGA Code of Practice 41 - The design, construction, maintenance and operation of filling stations dispensing gaseous fuels

Published 17th January 2014

Including

- Layout & Site Selection Criteria
- Design of Filling Station
- Installation & Commissioning
- Operation
- Periodic Examination & Maintenance
- Fuel Quality
- Training
- Personnel Protective Equipment
- Emergency Situations & Procedures



COMPARISON OF SEPARATION DISTANCES DERIVED FROM APPLICABLE STANDARDS

A number of assumptions have had to be made in order to compare the different documents against each other.

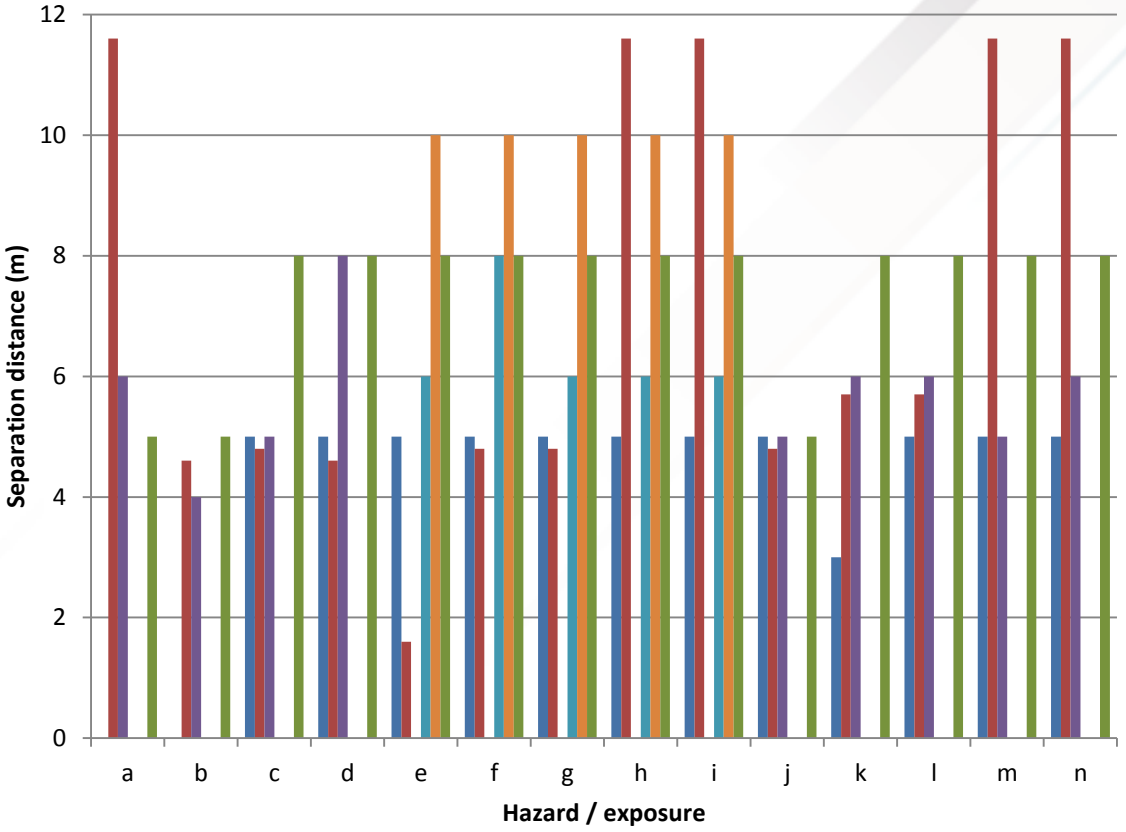
The charts below show the distances as determined from the TUV, NFPA, ISO and BCGA codes of practice listed:

- NFPA 2: Hydrogen Technologies Code, 2011.
- VdTÜV, Merkblatt - MB DRGA 514-englisch: Requirements for hydrogen fueling stations, 2010.
- draft ISO/DIS 20100: Gaseous hydrogen – Fuelling stations, (unpublished draft, dated 18/02/2011).
- BCGA, Code of practice CP33: The bulk storage of gaseous hydrogen at users' premises, 2005.

Where the ISO standard differentiates between occupied and unoccupied buildings for the same hazard, this has been shown with a different entry on the chart for each:

SEPARATION DISTANCES:

700 bar HRS



a	Ignition sources such as open flames and welding
b	Unclassified electrical equipment
c	Non-bulk storage of other flammable gases & liquids, non-flammable hazardous materials or ordinary combustibles, above or below ground
d	Bulk storage of other flammable gases & liquids
e	Buildings of fire-rated construction with a fire resistance rating of not less than 2 hours
f	Buildings and structures of combustible or non-fire rated construction
g	Un-openable openings in buildings of fire-rated or non-fire-rated construction (doors, windows)
h	Openable openings in buildings of fire-rated or non-fire-rated construction (doors, windows)
i	Air intakes (HVAC, compressors, other)
j	Utilities (overhead), inc. electric power, building services, hazardous materials piping or above ground vents
k	Exposed persons other than those involved with the system
l	Parked cars
m	Public roads & railway lines
n	Property boundary

ASSUMPTIONS AND LIMITATIONS OF THIS INTERPRETATION:

NFPA 2:	Assumes pressure in range 520 to 1003 bar, and pipework internal diameter of 8 mm
ISO/DIS 20100:	Assumes inclusion of compressor in system, pressure in range 550 to 1100 bar, and pipework internal diameter of up to 8 mm. NOTE 1: The 15 m distance to bay windows has been omitted from the chart for clarity. (worth noting the 15 m was as low as 3m in the previous ISO/TS 20100)
VdTÜV, Merkblatt 514	No identified restrictions on pressure or pipework diameter limitations. Distances (separation distances) are from storage tanks.
BCGA CP33:	Existing industrial guidance for bulk hydrogen storage, typically at pressure up to 300 bar. Proposed in CP41 for hydrogen vehicle refuelling stations as a start-point, with inclusion of a recommended size restriction on pipework of 8mm internal diameter.

NEXT STEPS:

ISO TC 197:

2014: ISO TR 19880-1

2015: ISO 19880-1

- Outdoor, public stand-alone and integrated fuelling stations;
- Definition & basic principles for defining Safety Distances, inclusion of values if consensus;
- Fuelling protocol reference (SAE J2601);
- Component requirements;
- Station validation;
- Hydrogen quality assurance.

2017: Revised ISO 19880-1

- Inclusion of indoor and residential fuelling stations;
- References to anticipated specific hydrogen component standards.

Involvement through BSI PVE/3/8

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