**Rescue and Fire Fighting Services (RFFS) – Responding to Incidents involving hydrogen**

**1. Introduction**

1.1 With the growth in environmental awareness and the move to zero emissions, the use of hydrogen in vehicles, hybrid vehicles, aircraft, and Ground Service Equipment (GSE) at aerodromes is increasing. Hydrogen production and storage facilities sited at aerodromes may also be found.

1.2 Manufacturers’ designs differ substantially, and the related technology is evolving continually. Aerodrome Operators should consider having information in the form of an Emergency Response Guide, specific to the infrastructure supporting the storage and production of hydrogen, as well as the make and type of vehicles, hybrid vehicles, aircraft, and GSE fuelled by hydrogen at their aerodrome.

1.5 It is imperative that RFFS crews are aware of the risks and hazards posed by hydrogen when responding to incidents involving such infrastructure, vehicles, GSE and aircraft.

**2.Hydrogen Properties**

* 1. General characteristics include:
* Hydrogen has a flammable range of 4 -75%.
* Hydrogen has an explosive range of 11 – 59%.
* A hydrogen flame is difficult to detect in day light (Hydrogen fires have a different wavelength to Class A and Class B fires.)
* Hydrogen fires emit little radiated heat.
* The energy density of hydrogen is approximately 3 times greater than that of diesel and petrol.
* Hydrogen tends to detonate (the combustion of a substance which is initiated suddenly and propagates extremely rapidly, giving rise to a shock wave).
* Hydrogen is susceptible to Diffusion Ignition (the spontaneous ignition of high-pressure hydrogen during its sudden release).
* Hydrogen may be found stored at pressures between 350 – 1000 bar.
* Liquid hydrogen is usually stored at -253 degrees C.
* Studies have shown that 80% of liquid hydrogen spills on to water ignite.
* Hydrogen fires can produce long, directional flames. Studies have shown that hydrogen stored at 350 bar, will produce a 5 metre long flame when released from a 3mm nozzle (V. Molkov et al)

**3. Common Terminology**

3.1 Common hydrogen classifications may include but are not limited to:

* Green/clean using renewable energy sources to split water into O2 and H2 using electrolysers
* Grey burning fossil fuel to turn methane into hydrogen and carbon dioxide,

* Blue burning fossil fuel but capturing the CO2 in underground reservoirs (low carbon hydrogen)
* Turquoise mixture of blue and green hydrogen
* Pink or red using nuclear energy to split water into O2 and H2.

3.2 Current thinking suggests that for the time being, the most common hydrogen classifications found at aerodromes will be grey and blue.

**4. Safety Regulations**

4.1 Safety regulations include but are not limited to:

* **COMAH Regulations** describe the duties for lower tier operators one of which is to prepare a major accident prevention policy (MAPP).

“The MAPP will usually be a short, simple document setting out what is to be achieved. But it should also include a summary and further references to the safety management system that will be used to put the policy into action. The detail will be contained in other documentation relating to the establishment, for example plant operating procedures, training records, job descriptions and audit reports, which the MAPP can refer to.” (Regulation 7).

The MAPP also must address issues relating to the operator's safety management system. Details can be found in Schedule 2, but the key areas are:

* organisation and personnel
* identification and evaluation of major hazards
* operational control
* management of change
* planning for emergencies
* monitoring, audit and review
* The HSE require a Hazardous Substance consent where 2T and above of hydrogen are stored. ([FAQ - Hazardous Substance Consent Application](https://hazardousconsent.hse.gov.uk/faq/))
* **DSEAR** assessment. DSEAR requires employers to assess the risks of fires and explosions that may be caused by dangerous substances in workplace. <http://www.legislation.gov.uk/uksi/2002/2776/contents>
* A review of **BS EN IEC 60079-10-1: 2021** will help with Hazard Area Classification and cordons.

**5. Operational Considerations**

Operational considerations may include but are not limited to:

5.1 In daylight, hydrogen burns with a nearly invisible flame. This can make it difficult to visually detect fires. RFFS crews should be aware of this and consider the use thermal imaging cameras or other flame-detection technologies to identify and assess the extent of a hydrogen fire.

5.2 Although hydrogen fires emit little radiated heat, flame temperatures may exceed 2000 degrees C.

5.3 Hydrogen's wide flammability range (4% to 75% by volume in air) increases the risk of fires and explosions. RFFS crews should be aware that even small leaks can create a flammable mixture in a confined space.

5.4 Hydrogen has a very low ignition energy, meaning it can ignite easily with a small spark, static discharge, or even a hot surface. RFFS crews should therefore, approach hydrogen releases with caution. Consideration should be given to the provision of firefighting PPE that complies with both BS EN 469 and BS EN 1149-5.

5.5 Fires involving gaseous hydrogen should be extinguished by closing supply valves where safe to do so. Consider protecting peripheral risks and evacuating the surrounding area.

5.6 If closing valves is not possible, consider allowing the hydrogen supply to burn until it has been exhausted.

5.7 Steel tanks have rupture disks so that the hydrogen is released before the pressure of the tank reaches burst level.

5.8 Composite cylinders may have a thermally activated pressure relieve device (TPRD) which will melt, open, and release the entire contents of the cylinder.

5.9 Due to its low density, hydrogen rises at approximately 40 miles per hour and disperses rapidly in air but may collect in high level enclosed spaces. This can cause hydrogen fires to spread vertically, making them difficult to extinguish. RFFS crews should be aware of the importance of proper ventilation in controlling and extinguishing hydrogen fires. The use of PPV fans should be considered.

5.10 RFFS crews should be aware that hydrogen flames can pass through very small gaps.

5.11 Consideration should be given to the provision of catalytic and optical gas detection equipment. Infrared detection equipment may not effective.

5.12 Care should be taken to ensure that water is not applied to pressure relief devices or valves. There is potential for water to freeze and block such devices and valves.

5.13 Where aerodromes have on-site infrastructure supporting the storage and/or production of hydrogen, liaison with the relevant operators is essential.

**6. Training**

6.1 RFFS training programmes should include but are not limited to:

· Awareness of the range of hydrogen fuelled vehicles and/or aircraft operating and where installed, the types of hydrogen infrastructure at their aerodrome.

· How to recognise the types of hydrogen fuelled vehicles and/or aircraft operating at their aerodrome.

· Use and interpretation of manufacturers’ Emergency Responder Guides (ERGs).

· Tactics and techniques required when responding to incidents involving hydrogen.

· The use of suitable equipment to deal with incidents involving hydrogen.

· Use of appropriate detection equipment.

· Use of Thermal Imaging Cameras, and their limits.

· Use of appropriate PPE & RPE.

· The use of Hot zone cordons and the importance of Hazard Classification Zones.

. Understanding the importance of reducing the potential to generate static electricity.

· Knowledge and understanding of the risks and hazards posed by hydrogen.

· Liaison/handover with Local Authority Fire & Rescue Service colleagues and use of specialist officers (Hazmat/NILOs etc).

· Liaison/handover with vehicle/aircraft recovery operators

· Awareness of the potential for rapid fire spread, due to intense, localised directional flames and radiated heat where other vehicles, aircraft, buildings, or combustible materials are nearby.

**7. Bibliography**

* FRS National Operational Guidance –<https://www.ukfrs.com/> Alternative Fuelled Vehicles & Environmental Agencies Response to Incidents.
* HSE – COMAH [Control Of Major Accident Hazards Regulations 2015 (COMAH)](https://www.hse.gov.uk/comah/background/comah15.htm)
* HSE - [DSEAR in detail - HSE](https://www.hse.gov.uk/fireandexplosion/dsear-background.htm)
* HSE - [Hazardous Area Classification and Control of Ignition Sources](https://www.hse.gov.uk/comah/sragtech/techmeasareaclas.htm)
* HSE - [Hydrogen Safety](https://solutions.hse.gov.uk/safe-net-zero/hydrogen-safety)
* ICAO Doc 9137-AN 898 Airport Services Manual Part 1-Recue and Firefighting 4th Edition 2015 (As amended January 2023). <https://www.icao.int>
* NFCC - Emergency responders guide for alternatively fuelled vehicles) Emergency responders guide for alternatively fuelled vehicles [National Fire Chiefs Council - NFCC](https://nfcc.org.uk/)
* NFPA - NFPA - Emergency Response Guides for Alternative Fuel Vehicles
* NFPA 2 Hydrogen Technologies Code [NFPA LiNK | Access Codes & Standards Digitally](https://www.nfpa.org/for-professionals/codes-and-standards/nfpa-link)