London South Bank University
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ENABLE·H2

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Hydrogen safety for ENABLEH2

From the very start of the ENABLEH2 project (and even before) safety has been a cornerstone of our work. We are working hard to maintain safety across the project, and in any technology and designs we produce.

Comparisons with the past

It's been over 80 years since the Hindenburg disaster, (in which 35 of 97 people on board were killed) but that tragic event is still intrinsically linked to the public perception and understanding of hydrogen safety. But are comparisons with present-day technology, modern uses hydrogen and aviation safety fair?

In 1937, the year of the Hindenburg disaster, air travel was in its infancy. As engineers and aviators attempted to push the boundaries of air travel without formal safety standards or studies, crashes were common. There were many airship disasters (for both hydrogen and the non-flammable helium crafts) for a variety of reasons; often related to the poor manoeuvrability and responsiveness of the crafts. One of the worst listed being the USS Akron[1], a helium-filled aircraft carrier, which crashed at sea in 1933 killing 73 of the 76 people on-board. Today safety is a key element of the aviation industry. Although there are always lessons to be learned and improvements to be made, the importance of safety culture in aviation is clear, and largely well developed.

Hydrogen in the modern world

Today Hydrogen is increasingly used safely all around us. So safely that we often don't even know it is there. Although the demise of the Hindenburg was no doubt down to the unwanted ignition of the hydrogen, the combustible gas was contained only in cotton balloons[2] – a far cry from the modern day storage vessels, made of stainless steel or engineered composites, and tested to withstand pressures and impacts. Right now Hydrogen buses and rubbish trucks are operating across Europe [3],[4]. London has had hydrogen buses operating on the RV1[5] route for years and many vehicle makers are now creating vehicles using hydrogen. Hydrogen is increasingly being used in conjunction with fuel cells to power businesses, and a current UK project is testing the use of 20% hydrogen in the natural gas grid.

Several airports around the world (e.g. Heathrow[6], Berlin[7], L.A.[8]) have introduced H_2 fuelling stations for ground support/ transport vehicles. As part of the project, the ENABLEH2 partners, including Heathrow airport, are assessing the possible risks at airports and working out how they might be made safer. Kerosene spillages at airports can result in contaminated surroundings[9], presenting a direct and immediate danger to airport staff, and posing a significant risk to groundwater quality. A major advantage of liquid H_2 in this context is that it vaporises and disperses quickly with no residues.

Hydrogen Safety

While hydrogen is generally more flammable and easier to ignite than many other hydrocarbon fuels a great deal of research work has been carried out on how to use hydrogen safely, and manage these hazards. Projects & organisations like IDEALHY, KnowHy, and HySafe (to name just a few) have produced work to enable the safe use of hydrogen in a variety of industries. The ENABLEH2 project is

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going further, conducting experiments to define the flammability of hydrogen in the low pressure/ low temperature environments found in aircraft, and to define some ignition hazards from some weather events (supporting the Strategic Research and Innovation Agenda (SRIA) Flightpath 2050 goals).

There are even some safety advantages to using hydrogen. Hydrogen evaporates and disperses quicker than many fuels meaning smaller leaks can be diluted to safe levels quickly. Hydrogen also has a shorter burn-time, and emits less heat, than other flammable gases when ignited. In fact, research has shown that, depending on the design (e.g. location & orientation of pressure relief) a hydrogen leak from vehicles and ignition can be safer, and cause less damage, than a comparable petrol or hydrocarbon fuel incident [10],[11]. Hydrogen is no more or less safe than other fuels, but it is different, so the engineering design of the systems will be very important to enable safety.

Hydrogen in aircraft

In aviation, the Tupolev 155[12] successfully trialled cryogenic hydrogen, utilising safety systems such as Nitrogen inerting, but did not continue because of the cost of the fuel. The Cryoplane project also explored hydrogen use as an aircraft fuel. This project (and others) have highlighted knowledge gaps (such as our understanding of large-scale releases - a key area being researched as part of the ENABLEH2 project). But, despite these specific issues, the Cryoplane project found that, while safety precautions (such as leak detection, inerting systems, and contamination) had to be taken seriously, the overall safety level wouldn't be any worse than current jet fuel.

The Strategic Research and Innovation Agenda (SRIA) are targeting less than one accident per ten million commercial flights[13]. Part of the ENABLEH2 project is to produce a safety roadmap to support this objective, and make it a reality.

ENABLEH2 safety work

There are still a great many knowledge gaps to fill, and challenges to meet, before we can hope to integrate hydrogen technology into future civil aviation aircraft. The ENABLEH2 project intends to meet some of these head on, filling in knowledge gaps in the literature, and exploring some of the real-world implications of using this fuel. The work package will also help to produce a safety roadmap, to highlight further work needed beyond the project to make hydrogen aviation technology safe for use around the globe.

We have a designated safety work package with four main novel research areas:

- Hazard assessment of novel fuel and combustion systems
  In conjunction with Chalmers and Cranfield Universities, LSBU staff will examine the specific technical hazards posed by having systems involving liquid hydrogen, through to hot hydrogen gas, on board an aircraft. Analyses will be produced showing the hazards and mitigations. This will also be used to highlight technologies suitable for risk management, and also to identify gaps in our knowledge.

- Fundamental characteristics of hydrogen gas
  LSBU will carry out work to explore the fundamental flammable behaviour of hydrogen in the low temperature (down to -50°C), low pressure (240 mbar) environments in which commercial aircraft operate. This original experimental work will test ignition and flame characteristics of hydrogen gas in these difficult environments, including the minimum ignition energy, laminar burning velocity, and flammability limits. This will better inform further safety assessments on the ignition risk of hydrogen at altitude.

- Large-scale liquid hydrogen release modelling
  This research, also done at LSBU, will comprise of a series of modelling work exploring the behaviour of liquid hydrogen releases, and the risk from possible ignitions. The research will model installations and airport-type scenarios to examine how a leaked hydrogen cloud spread

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and ignition might impact the surrounding infrastructure and area, as well as how to reduce the risk. The work will also examine the risk from pool fires in the case of an extended release.

- Hydrogen at airports.
  Airports are highly complex entities, operating 24 hours a day, seven days a week. Led by Heathrow airport, this section of the work will assess the possibility of liquid hydrogen fuel use at airports. It will examine what the current requirements of an airport are, and how Liquid Hydrogen could meet them. It will also explore what the new risks would be in introducing this fuel into this large and varied environment, and how they could be managed.

A substantial amount of research and engineering work has already been done to understand hydrogen hazards, and the effective and reliable ways to deal with them in ground-based transport and engineering systems. While there are certainly safety challenges to using hydrogen in aviation, and a great deal of work needs to be done to explore how the fuel could be used safely in this industry, the environmental benefits of this carbon-free fuel really makes it worth exploring. We intend to do that while maintaining safety across the project, and helping to maintain it in the future.

Dr Claire Benson
Senior Lecturer | Explosion & Fire Research Group
London South Bank University

[1] https://apps.dtic.mil/dtic/tr/fulltext/u2/a440454.pdf
[2] https://www.chemistryworld.com/news/the-legacy-of-the-hindenburg-disaster/3007067.article
[3] https://www.h2euro.org/page/12/
[4] https://www.governmenteuropa.eu/hydrogen-powered-garbage-trucks/92965/
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