



HySAFER Centre

Ulster University

- One of two universities in Northern Ireland
- 4 campuses (Jordanstown, Belfast, Coleraine, Magee)
- 25,000 registered students

Ulster University is a university with a national and international reputation for excellence, innovation and regional engagement. Core business activities are teaching and learning, widening access to education, research and innovation and technology and knowledge transfer.

<http://ulster.ac.uk>



Hydrogen Safety Engineering and Research Centre (HySAFER)

The centre is carrying out research, consultancy, knowledge and technology transfer in the area of safety of hydrogen and fuel cell technologies, systems and infrastructure.

The centre has been formally established by the University in 2008 as a reflection of changes in research priorities worldwide, in particular the importance of safety in the emerging hydrogen and fuel cell systems including but not limited to hydrogen powered vehicles and refuelling infrastructure, stationary and mobile fuel cell applications, etc.

The aim of the centre is to strengthen the internationally recognised standing of Ulster University in the safety research for the emerging hydrogen economy and beyond.



Expertise

The thrust in HySAFER is on contemporary research methods such as Computational Fluid Dynamics (CFD), in particular Large Eddy Simulation (LES) of unignited releases and dispersion, spontaneous ignition and jet fires, deflagrations and detonations, mitigation techniques, fire resistance, etc. The HySAFER Centre collaborates with leading experimental research centres throughout the globe in closing numerous knowledge gaps in hydrogen safety science and engineering by combining complementarities of analytical, numerical, and experimental studies. The examples of studies below reflects some of the past and ongoing research at the HySAFER Centre.

HySAFER staff (December 2014)

- **Prof Vladimir Molkov**, HySAFER director
- **Dr Dmitriy Makarov**, Reader in Safety of Hydrogen Production and Storage
- **Dr Sile Brennan**, Lecturer in Safety of Hydrogen and Fuel Cell Technologies
- **Dr Svetlana Trestiakova-McNally**, Lecturer in Hydrogen Safety (HyResponse)
- **Dr James Keenan**, Research Associate in Hydrogen Safety (H2FC)
- **Dr Arief Dahoe**, Lecturer in Hydrogen Safety (UU teaching)
- **Dr Wookyung Kim**, Research Associate in Hydrogen Safety (H2FC)
- **Dr Zhiyong Li**, Research Associate in Hydrogen Safety (HyResponse)
- **Dr Boris Chernyavskiy**, Research Associate in Hydrogen Safety (SUSANA)
- **Dr Yangkyun Kim**, Research Associate in Hydrogen Safety (EPSRC)
- **Mr Volodymyr Shentsov**, Research Associate in Hydrogen Safety (HyIndoor)
- **Mr David Yates**, PhD student (EPSRC SUPERGEN HFC Hub, UU funded)
- **Mr Sergii Kashkarov**, PhD student (EPSRC SUPERGEN HFC Hub, UU funded)
- **Mr Mohamed Sakr**, PhD student (VCRS award, UU funded)

Main research themes

- ❖ **Releases and dispersion** outdoors and indoors, including both expanded and under-expanded jets, ventilation, effect of wind
- ❖ **Plane jets** (non-reacting and jet flames) for reduction of separation distances and development of innovative pressure relief devices
- ❖ **Spontaneous ignition** of hydrogen during sudden release into air by “diffusion mechanism”, etc.
- ❖ **Jet fires** (correlation for flame length and separation distances; well-ventilated and under-ventilated fires, including modes of external flame, self-extinction, re-ignition phenomenon, etc.)
- ❖ **Deflagration** multi-phenomena model, incl. Rayleigh-Taylor instability
- ❖ **Deflagration-to-detonation transition (DDT)** modelling
- ❖ **Detonation** propagation model with “grid independency”
- ❖ **Fire resistance** of high-pressure hydrogen storage tanks
- ❖ **Hydrogen safety at nuclear power plants**
- ❖ **Blast waves and fireballs from storage tank rupture in a fire, etc.**

Education and training

University of Ulster (self-funded) activities:

- ❑ World's first postgraduate program in hydrogen safety, i.e. **PgC/PgD/MSc course in Hydrogen Safety Engineering**:
<http://campusone.ulster.ac.uk/potential/postgraduate.php?ppid=24>
- ❑ **International short course and advanced research workshop series "Progress in Hydrogen Safety"**
<http://hysafer.ulster.ac.uk/phs/> (plus IA HySafe bursaries)

Externally (EC and FCH JU) funded activities:

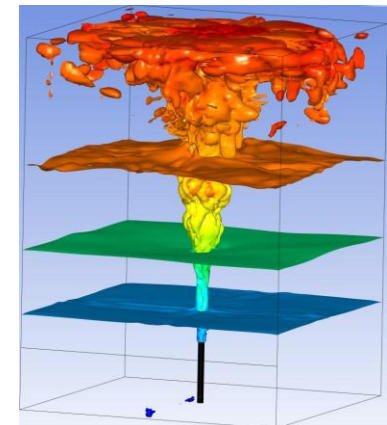
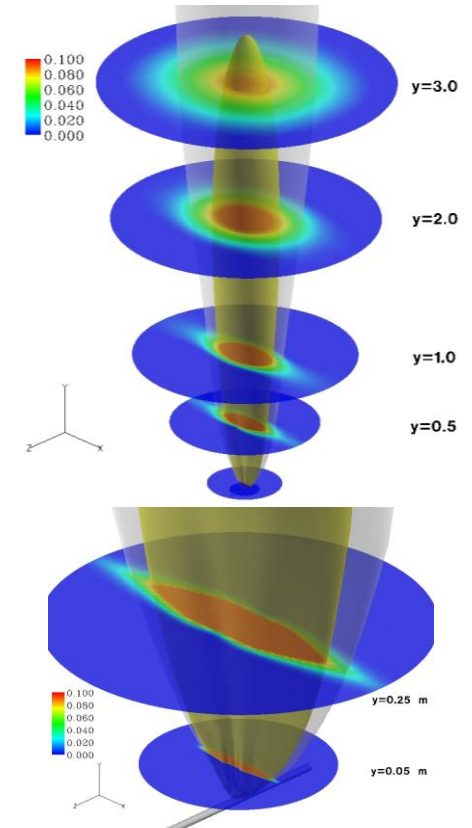
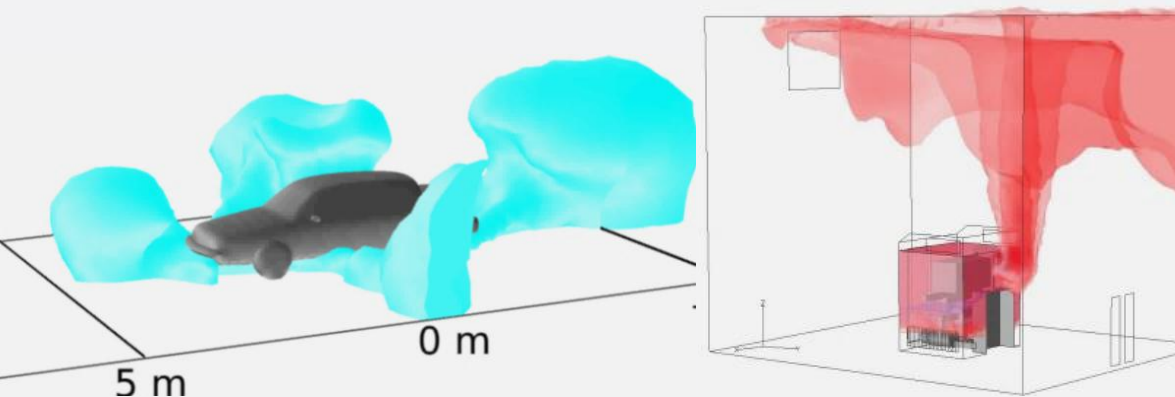
- European NoE [HySafe](#) (EC FP6 NoE): e-Academy of Hydrogen Safety
- HyCourse (EC FP6 MCA): Summer School on Hydrogen Safety
- HySAFEST (EC FP6 MCA): Early stage training (4 PhDs)
- TrainHy-Prof (FCH JU): education/training of young professionals
- [HyFacts](#) (FCH JU): education/training of regulators and safety officials
- [H2FC](#) (EC FP6 Capacity): Technical School on Hydrogen and Fuel Cells
- [HyResponse](#) (FCH JU): education/training of first responders

Ongoing projects (December 2014)

- HyIndoor, <http://www.hyindoor.eu> (02.01.12-01.01.15): FCH JU, No. 278534, Pre-normative research on safe indoor use of fuel cells and hydrogen systems
- H2FC, <http://www.h2fc.eu> (01.11.11-31.10.2015): FP7 (Capacities - Research Infrastructure), Integrating European Infrastructure to support science and development of Hydrogen- and Fuel Cell Technologies
- HyResponse, <http://www.hyresponse.eu> (01.06.13-31.05.16): FCH JU, No. 325348, European hydrogen emergency response training programme for first responders
- EPSRC SUPERGEN HFC Hub, <http://www.h2fcsupergen.com> (2012-2017): SUPERGEN Hydrogen and Fuel Cells Hub
- EPSRC SUPERGEN Challenge: Integrated safety strategies for onboard hydrogen storage systems (2013-2017), EPSRC
- SUSANA, <http://www.support-cfd.eu> (01.09.13-31.08.16): FCH JU, No. 325386, Support to safety analysis of hydrogen and fuel cell technologies
- EPSRC (01.04.14-31.03.19): Centre for Doctoral Training in Fuel Cells and their Fuels - Clean Power for the 21st Century
- GENFUEL (01.02.14-31.01.18): FP7-PEOPLE-2012-IAPP, No. 324337

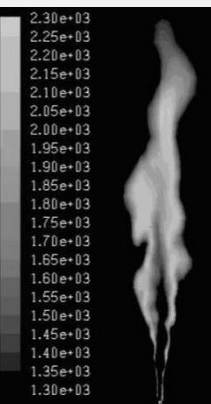
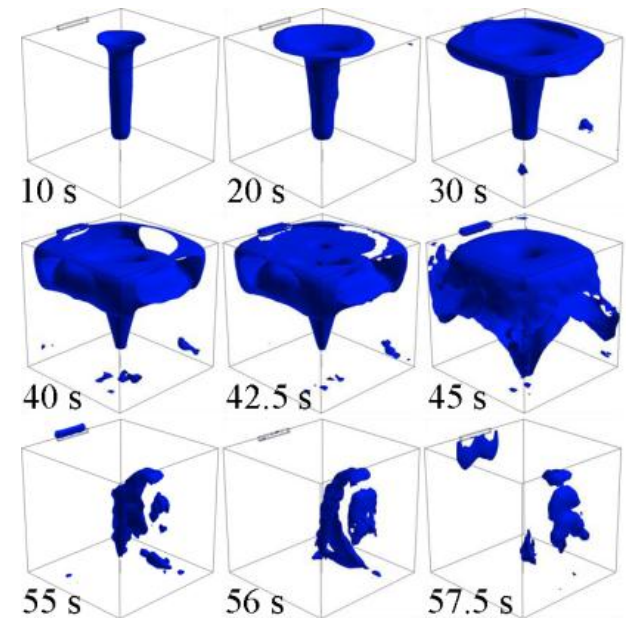
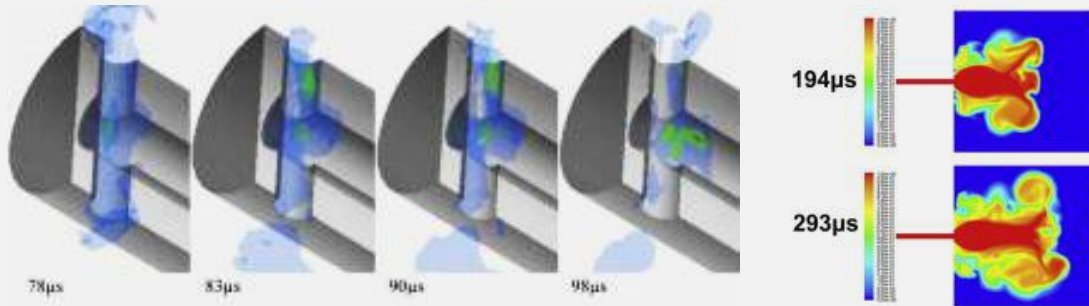
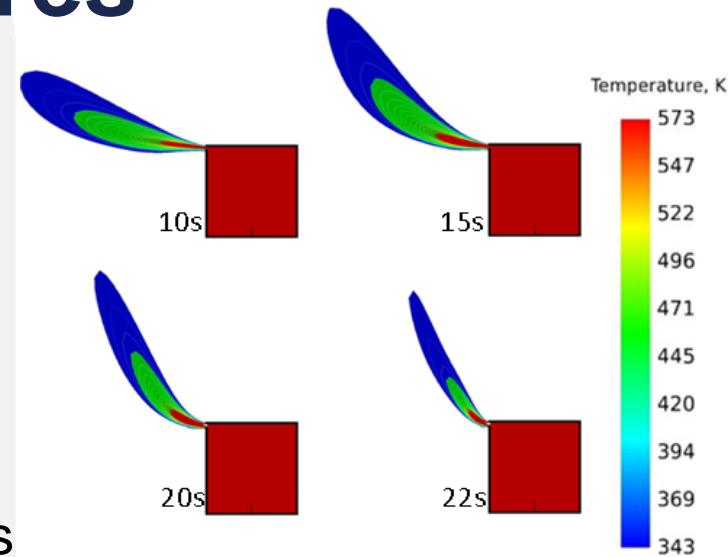
Hydrogen releases and dispersion

- Releases and dispersion outdoors and indoors
- Gaseous and liquefied hydrogen releases
- High pressure storage blow-down dynamics
- Subsonic, sonic and supersonic releases, expanded and under-expanded jets, laminar and turbulent jets, buoyancy-controlled and momentum-dominated jets
- Transition from momentum to buoyant jets
- Simulation of permeated hydrogen dispersion by diffusion and buoyancy
- Pressure peaking phenomenon during hydrogen release in vented enclosure
- Hydrogen concentration decay in expanded and under-expanded momentum-controlled jets
- Natural and passive ventilation
- Reduction of deterministic separation distances



Hydrogen ignition and fires

- Under-expanded jet fires outdoors and indoors
- Under-ventilated enclosure fires regimes, including self-extinction phenomenon
- Lift-off and blow-off phenomena
- Micro-flames
- Novel correlation for hydrogen jet flame length
- Deterministic separation distances from jet fires



Simulation

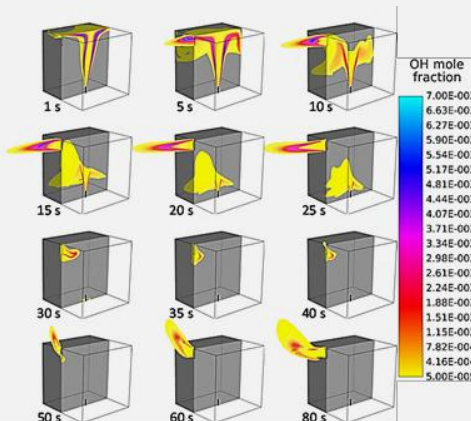
Length = 10.8 m

W:L = 0.2



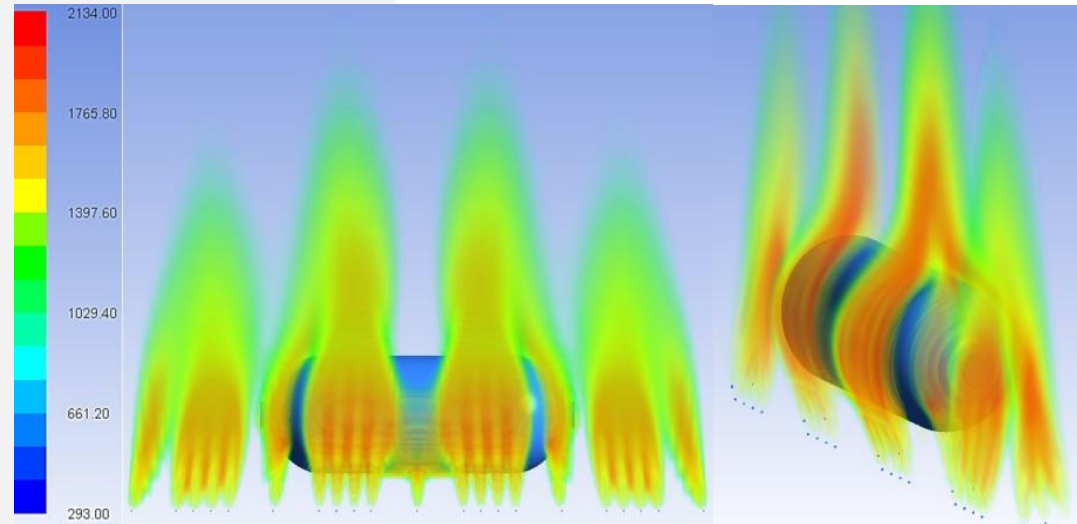
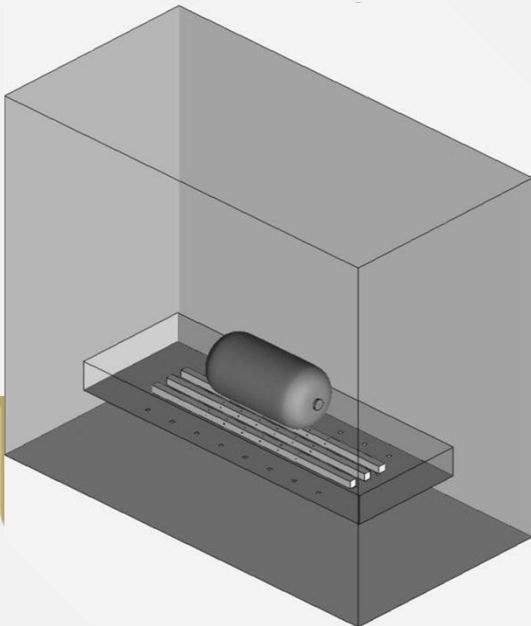
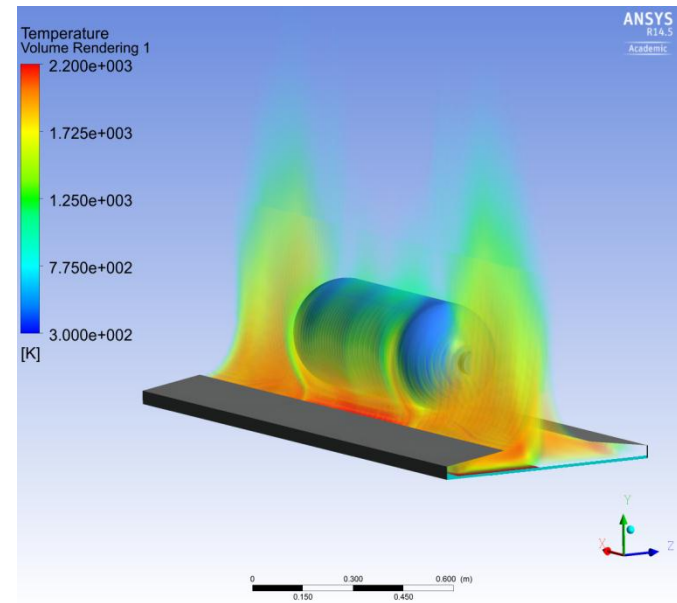
Experiment

Length = 10.6 m



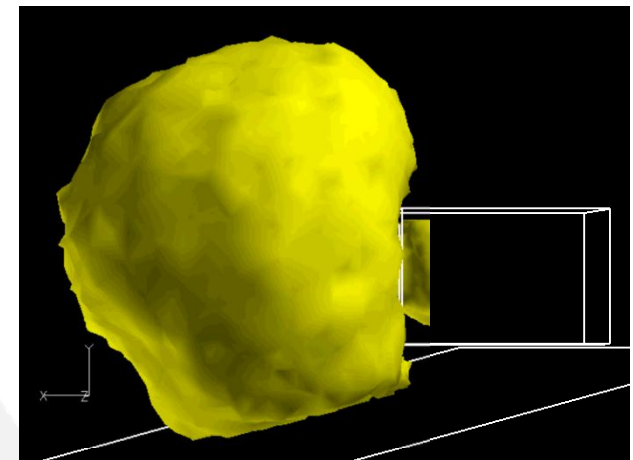
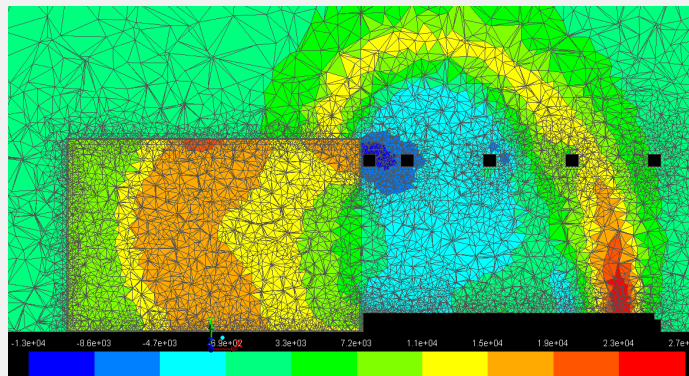
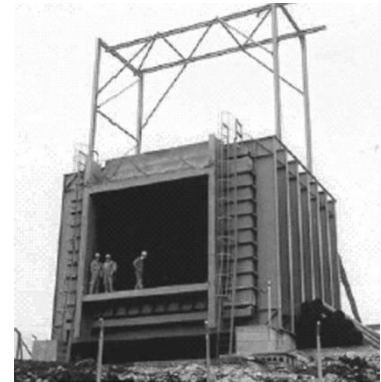
Fire resistance of storage tanks

- Developing of bonfire test design and protocol
- Simulation of bare and thermally protected tank in bonfire test
- Criterion of bare hydrogen tank failure
- Effect of heat release rate and glass transition temperature of resin on fire resistance rating



Deflagrations and detonations

- Multi-phenomena deflagration model, including Rayleigh-Taylor instability and other mechanisms
- Deflagrations in the open atmosphere, large-scale closed vessels, coherent deflagrations in vented enclosures
- Uniform and non-uniform mixture deflagrations in enclosures, including nuclear power plant buildings
- Deflagration-to-detonation transition, including the role of Richtmayer-Meshkov instability
- Hydrogen-air detonations
- Vent sizing engineering technique for deflagration, including localised mixtures



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