PROTECTING PEOPLE AND PLACES FOR 50 YEARS HSE

Overview of Net Zero research at HSE

Simon Gant, Strategic Science Adviser for Net Zero

University of Bologna, Italy, 12 June 2025

Outline

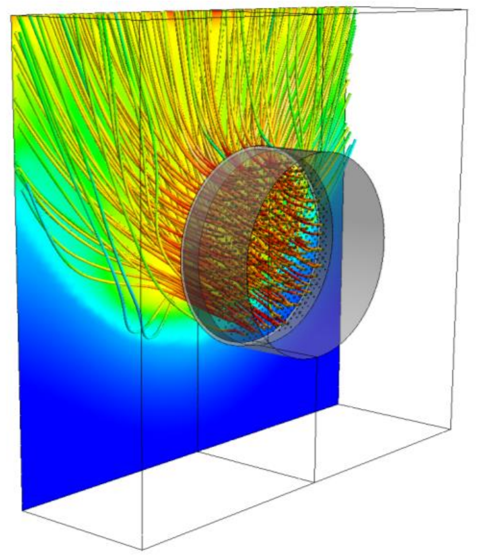
- Introduction to HSE Science and Research Centre
- HSE Strategy and “Areas of Research Interest”
- Previous HSE research
- Recent and ongoing Net Zero research at HSE
  - Hydrogen ← Covered mostly in Janni Vizma’s presentation
  - CCUS
  - Ammonia
  - Batteries
- Possible future research topics

Introduction to the Health and Safety Executive

- HSE is the regulator for workplace health and safety in Great Britain
- Includes onshore/offshore pipelines, chemical/oil/gas infrastructure, offshore platforms etc.
- Activities: evidence gathering, policy development, consultation, regulation, incident investigation, enforcement
- In 2022-23, HSE investigated over 230 fatal and 5,500 non-fatal incidents
- 2,700 total staff (FTE): £262M annual budget, 66% from Government



- HSE Science and Research Centre, Buxton, UK
- 400 staff, 550-acre test site
- Scientific support to HSE and other Government departments
- “Shared research” or joint-industry projects co-funded by HSE
- Bespoke consultancy on a commercial basis

HSE's Strategic Objectives 2022-2032

Protecting people and places

- Reduce work-related ill health, with a specific focus on mental health and stress
- Increase and maintain trust to ensure people feel safe where they live, where they work and, in their environment
- Enable industry to innovate safely to prevent major incidents, supporting the move towards net zero
- Maintain Great Britain's record as one of the safest countries to work in
- Ensure HSE is a great place to work, and we attract and retain exceptional people

https://www.hse.gov.uk/aboutus/the-hse-strategy.htm

HSE’s Areas of Research Interest

Contents

https://ari.org.uk/source_documents/hse-areas-of-research-interest-2024.pdf

https://ari.org.uk/ https://int.octopus.ac/

HSE's Areas of Research Interest

Question 1: How can it be ensured that GB's evolving industrial landscape and the built environment doesn't lead to a higher likelihood of major health and safety incidents?

- What are the significant hazards and risks associated with the deployment and scale-up of new and emerging technologies for Net Zero, such as Carbon Capture Usage and Storage (CCUS) and hydrogen?
- How HSE ensures that dutyholders in new industries such as CCUS, hydrogen, alternative liquid fuels and energy storage, design with safety and health considerations in mind?
- What are the appropriate controls and mitigations that need to be built into new carbon capture infrastructure?
- How do operational fusion power plants compare in risk profile to more traditional industrial installations?
- How can the integrity and safety of industrial assets be ensured across their lifecycle?

Question 2: What evidence is needed to inform how we regulate future technological developments, and the emergence of new industrial sectors to optimise safety in design and operation?

- What evidence is needed to enable the safe and rapid introduction of new and emerging technologies, the use of novel materials and new manufacturing processes in, for example, energy.
- What evidence is needed to ensure that technological advancements serve to maintain or improve existing levels of safety and health and do not present additional risks (either immediate or latent)?
- What other new or emerging innovations might have implications for the safety of building users that merit further consideration, e.g. Artificial Intelligence?

Question 3: To what extent can the experience, knowledge, and lessons learned from traditional industries be applied to new and emerging technologies in the energy transition with a view to improving health and safety outcomes?

- What can be learned from the deployment and scale-up of more mature industries that will help the management of safety outcomes for the emergence of new technologies?
- What are the opportunities and associated benefits of transferring relevant knowledge and skills from hydrocarbon technologies to operators of new and emerging technologies in the energy transition and how might this be best achieved?
- What methods and information are needed to learn from early adopters of new technologies globally, including understanding health and safety failures?
- How can designers, consultants and manufacturers contribute to incorporating improvements in occupational health and safety when considering design of new technologies?

Question 4: What risks are associated with the shift towards a decentralised energy landscape, and how might this impact health and safety outcomes?

- What are the risks associated with the new energy landscape and how could they be best controlled? What new hazards arise from how new energy systems are integrated and controlled? Do co-located technologies pose new hazards and risks?
- What are the human factors and their potential impacts in the safe and effective operation of a new energy system and how can they be effectively understood?
- What are the health and safety challenges associated with growing industries including the retrofitting of domestic and commercial buildings; climate adaptation, installation of low carbon heat solutions and installation of electrical infrastructure for electric vehicles?

Question 5: How is climate change currently affecting the health and safety of workers, building users and communities, and what methods can be employed to best assess its evolving impact on the healthy and safe operation of residential and industrial assets?

- To what extent is climate change affecting health and safety of workers and communities and how is this expected to change over time?
- What is the effect of climate change on the safe operation of industrial assets and what are the best methods to determine the effect?
- What are the main health and safety challenges related to maintenance and repair of ageing low carbon energy infrastructure, such as offshore wind turbines?
- What are the safety implications of widespread adoption (including retrofitting) across the built environment from low carbon heat solutions including the impact of non-fossil fuel heating and storage systems and the impact of heat pumps on noise/acoustic performance standards and legionella control?

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Previous research on Net Zero topics

- HSE has undertaken research on hydrogen, CCUS and other Net Zero topics for more than 20 years
- We work collaboratively to identify potential safety issues and help to prioritise research activities
- Examples include:
  - HSE input to HySafe research priorities workshops
    https://hysafe.info/activities/research-priorities-workshops/
  - HSE raised awareness of CCUS safety research needs in 2007

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HAZARDS FROM HIGH PRESSURE CARBON DIOXIDE RELEASES DURING CARBON DIOXIDE SEQUESTRATION PROCESSES†

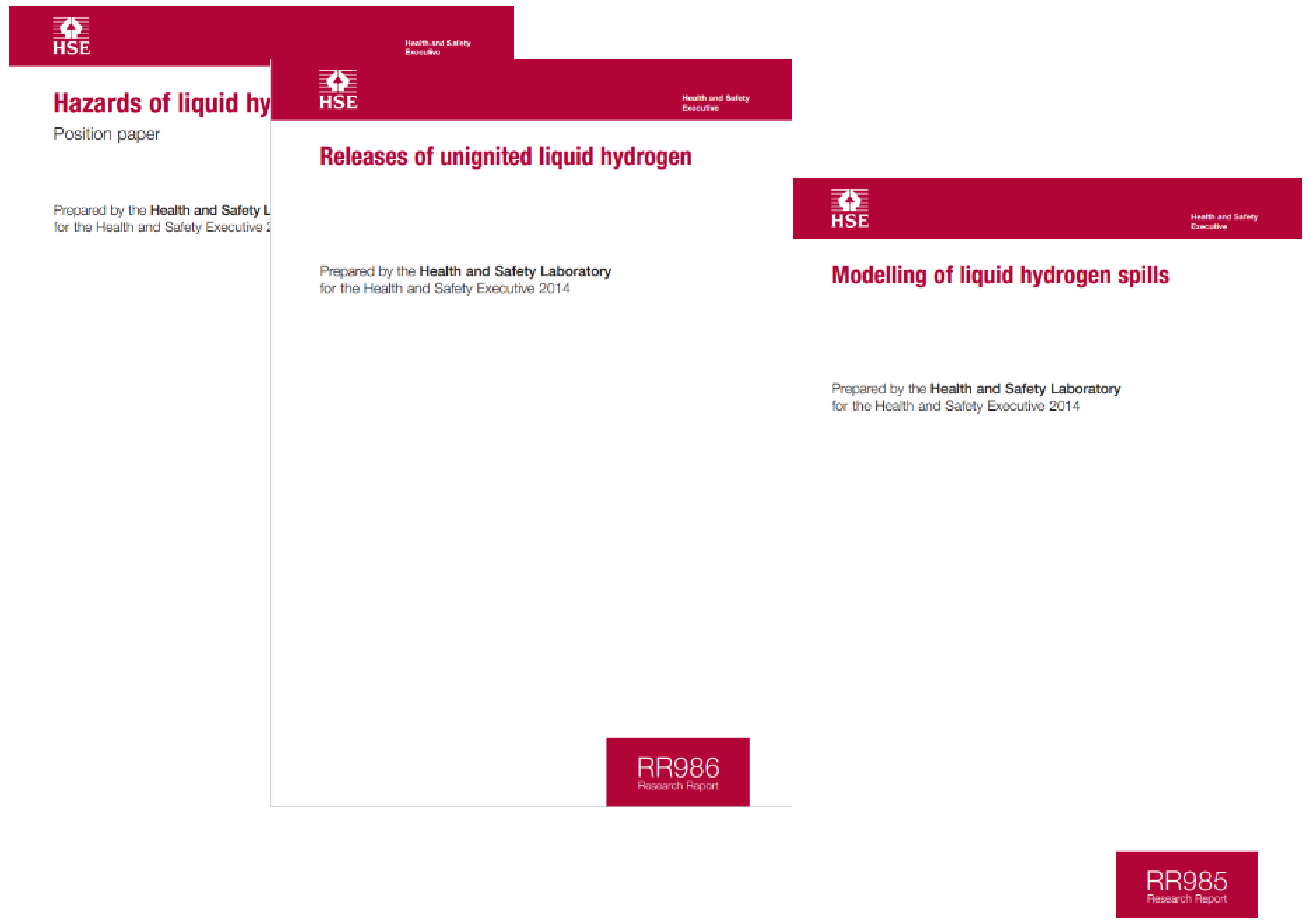
Stephen Connolly[1] and Laurence Cusco[2]

https://www.icheme.org/media/17864/cusco_connolly_2007_hazards_from_co2.pdf

Previous research on hydrogen safety

Examples of HSE publications on hydrogen safety

- RR1133 – Maintaining the integrity of process plant susceptible to high temperature hydrogen attack. Part 1: analysis of non-destructive testing techniques
- RR1134 – Maintaining the integrity of process plant susceptible to high temperature hydrogen attack. Part 2: factors affecting carbon steels
- RR1169 – Hydrogen in the natural gas distribution network: Preliminary analysis of gas release and dispersion behaviour
- RR715 – Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version
- RR1047 – Injecting hydrogen into the gas network – a literature search
- RR769 – Hazards of liquid hydrogen: position paper
- RR985 – Modelling of liquid hydrogen spills
- RR986 – Releases of unignited liquid hydrogen
- RR987 – Ignited releases of liquid hydrogen
- RR1159 – Hydrogen research priorities workshop
- RR615 – Spontaneous ignition of hydrogen: Literature review



https://www.hse.gov.uk/research/rrhtm/index.htm

Previous research on CCUS safety

HSE Health and Safety Executive

Overview of carbon capture and storage (CCS) projects at HSE's Buxton Laboratory

Prepared by the Health and Safety Executive

RR1121
Research Report

CONTENTS

https://www.hse.gov.uk/research/rrhtm/index.htm

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Hydrogen research

- Hydrogen safety training courses
- Liquid hydrogen safety guidebook
- Land, sea and port integration (hydrogen highway)
- Hydrogen burner experiments for food production
- Hydrogen compatibility of components in the gas network
- Hydrogen blends in the gas network
- Zero emissions for sustainable transport
- Aircraft liquid hydrogen container lab tests
- Gaseous hydrogen aircraft fuel sub-system testing
- Cold hydrogen combustion tests for aircraft applications

Externally funded

- Hydrogen heating programme
- MultHyFuel safety of hydrogen at refuelling stations
- ELVHYS liquid hydrogen in transfer operations for mobile applications
- High-pressure hydrogen jets in enclosed spaces
- Hydrogen risk assessment models for land-use planning assessments (both fixed sites and pipelines)
- Facility for materials testing in hydrogen atmospheres
- Review of hydrogen leakage in isolated vessels and pipes

Internally funded by HSE
Shared research (part-funded by HSE)
or UK Government funded

See Janni Vizma's presentation for more information

CCUS research

Ongoing HSE research project activities:

- Task A1 – Oversight and technical coordination
- Task B1 – Develop internal CCUS training course
- Task B2 – Support to regulatory questions
- Task C1 – Collation of JIPs and international projects
- Task C2 – Steering Board engagement
- Task C3 – Review international lessons learned
- Task D1 – Review of industry models
- Task D2 – Update previous modelling
- Task D3 – Modelling offshore scenarios
- Task D4 – Storage thresholds for CO_2
- Task E1 – Understanding industry design
- Task E2 – Flow assurance and process safety
- Task E3 – Suitability of controls
- Task E4 – Understanding the standards landscape
- Task E5 – Definition of hazard and scenarios
- Task E6 – Mitigations and emergency response
- Task F1 – Materials challenges and interactions
- Task F2 – Fracture control
- Task F3 – Corrosion control
- Task F4 – Non-metallic materials and coatings
- Task F5 – Low temperature excursions
- Task G1 – Review of CO_2 toxic levels and dose
- Task G2 – Amines and health effects from the capture process

CCUS research

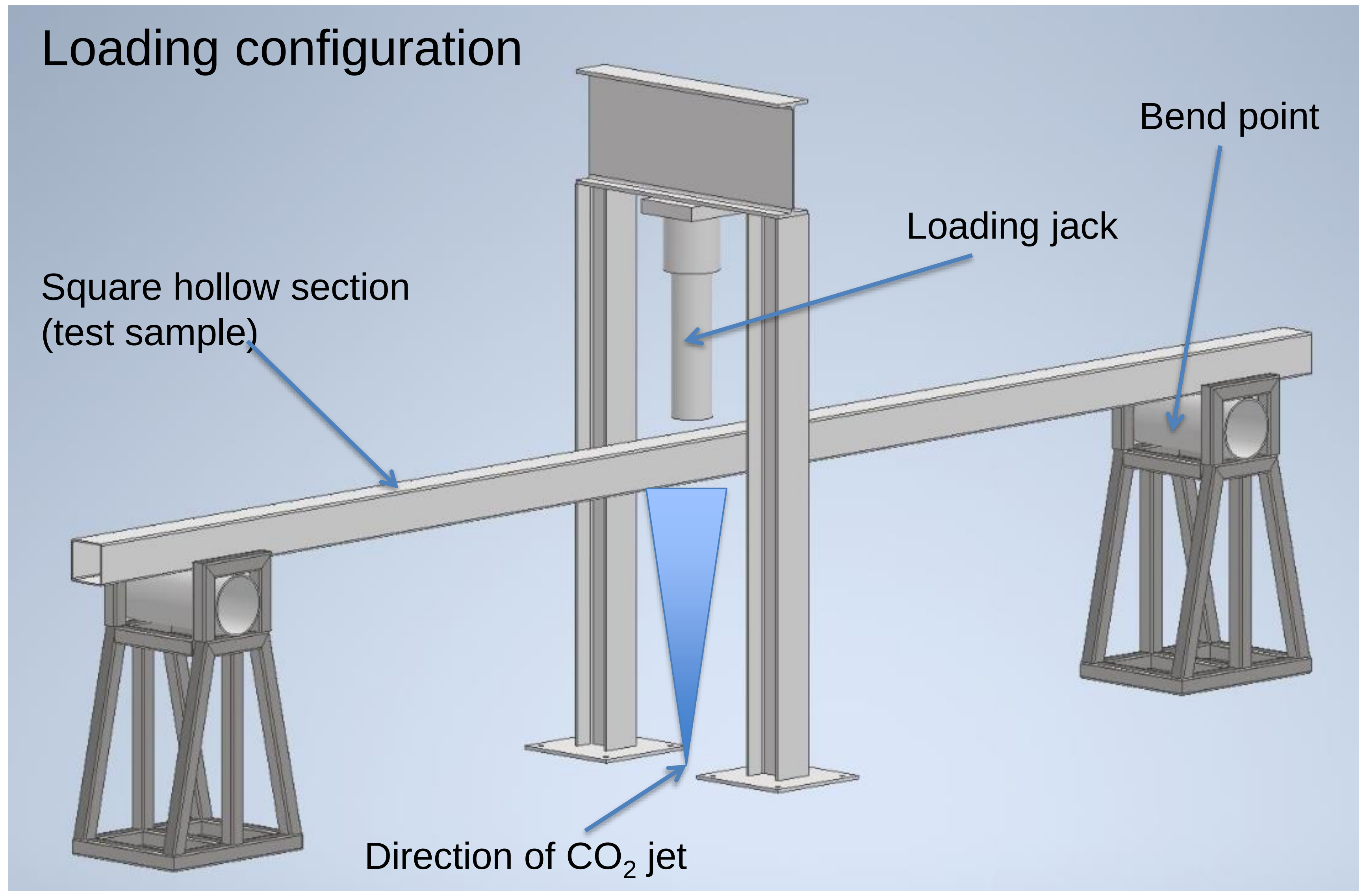
- Task F2 – Fracture control
  - Review control of fracture initiation and propagation in pipelines
  - Identify unique pipeline challenges created by CO_2
  - Review approaches and guidelines for pipeline design for CO_2
  - Undertake some example analyses and investigate mitigation measures

- Task F3 – Corrosion control
  - Review current status of approaches for corrosion control (published research, guidance, standards, etc.)
  - Define the key material and component considerations for CO_2 pipelines and other components

CCUS research

- Task F5 – Low temperature excursions
  - Investigate risk of structural failure from impinging CO_2 jets onto steelwork
  - Potential rapid cooling to -78°C or below, reducing steelwork temperature below design temperature and potentially below the DBTT (Ductile Brittle Transition Temperature)
  - Typically, offshore steels toughness tested at -20°C
  - HSE project activities:
    - Review BS 7910 fitness for service evaluation method
    - Review historical data for offshore steelwork
    - Construct test facility for impinging CO_2 jets onto pre-stressed steelwork to investigate cold embrittlement effects

- Three-point bend test
- Steel hollow section
- With / without artificial defect
- Statically loaded to % SMYS
- CO_2 release at different distances/durations
- Tests scheduled for summer 2025



CCUS research

- Task G1 – Review CO_2 toxic levels and dose
  - Revisit and publish a summary of HSE's assessment of the dangerous toxic load (SLOT and SLOD)
  - Review other published criteria on CO_2 toxicity
  - Review criteria for human impairment and possible impact on disorientation and means of escape

Table 1. Summary of key data supporting the DTL assessment

% CO_2	Exposure duration	Effects	Reference
27.9	25 sec	Onset of unconsciousness, muscle spasms	Committee on Aviation Toxicology, 1953
17	35 sec	Onset of unconsciousness	Committee on Aviation Toxicology, 1953
10, with 21% O_2	15-22 min, following a 40-90 min exposure to 7%	Restlessness, confusion, progressive listlessness	Brackett et al, 1965
7.5	15 min	Shortness of breath, headache, vertigo, sweating, numbness, increased motor activity, loss of control over limbs due to overactivity, visual colour distortions, loss of balance, irritation and disorientation.	Schaefer, 1963
7, with 21% O_2	40-90 min	Heavy breathing, mild headache, burning of eyes (O_2 concentration maintained at 21%)	Brackett et al, 1965
6	5-8 min	Reversible changes in visual intensity discrimination	Gellhorn, 1936
6	16 min	Increased respiration rate, dyspnoea, headache, sweating	White et al, 1952
6	6-8 min	Minor ECG changes	Okajima and Simonson, 1962
3.5-6	6-10 min	Reversible changes in auditory threshold	Gellhorn and Spiesman, 1934, 1936
5.4	15 min	No clinical signs of symptoms. Flicker fusion frequency decreased indicating some CNS depression	Schaefer, 1963
4	14 days	No adverse effects on neurobehavioural test performance	Storm and Gianetta, 1974
3.9	30 min	Headache during heavy exercise	Menn et al. 1970
3.5	60 min	Increased cerebral blood flow, slight dyspnoea	Patterson et al, 1955
2.8	30 min	Intercostal pain, dyspnoea during heavy exercise	Menn et al, 1970
2.5	60 min or 21 days	Mild headaches, awareness of increased respiratory effort during heavy exercise	Sinclair et al, 1971

Summary of HSE's Dangerous Toxic Load assessment for CO_2 (SLOT-SLOD criteria) available on request

CCUS research

- Develop CO_2 pipeline risk assessment model for land-use planning
  - Extension of existing HSE natural gas pipeline risk assessment model (MISHAP)
  - Requires consideration of:
    - Fault trees
    - Failure rates
    - Fracture models
    - Release rate model
    - Dispersion model – including consideration of pipeline crater and terrain effects

Skylark joint industry project

https://www.dnv.com/article/skylark-pioneering-excellence-in-co2-pipeline-safety-250648/

- Kick-off on 13 May 2025, 3-year duration
  1. CO_2 pipeline craters and source terms – DNV
  2. Wind-tunnel experiments – University of Arkansas
  3. Simple terrain dispersion experiments – DNV
  4. Complex terrain dispersion experiments – DNV
  5. Model validation – HSE
  6. Emergency response – NCEC
  7. Venting – DNV

Source of images: Allason D., Armstrong K., Barnett J., Cleaver P. and Halford A. "Behaviour of releases of carbon dioxide from pipelines and vents", Paper IPC2014-33384, Proc. 10th International Pipeline Conference IPC2014, Calgary, Alberta, 29 September – 3 October 2014, © Copyright National Grid / DNV / ASME

http://dx.doi.org/10.1016/j.ijggc.2015.04.001

University of Leeds

Proposed PhD project

Accelerated Fluid Dynamics of CO2 dense gas dispersion in complex terrain

Academic lead: Dr Amirul Khan, School of Civil Engineering, a.khan@leeds.ac.uk
Industrial lead: Dr Simon Gant, Health and Safety Executive (HSE), simon.gant@hse.gov.uk
Co-supervisor(s):
Dr Andrew Ross, School of Earth and Environment, A.N.Ross@leeds.ac.uk, Dr Rory Hetherington, Health and Safety Executive (HSE), rory.hetherington@hse.gov.uk (External)
Project themes:
Clean Energy, Computational & Analytical Tools, Data-driven methods, Multiphysics & Complex Fluids

Carbon Capture and Storage (CCS) is recognised as a crucial element in reaching the target of Net Zero. To support this, an infrastructure of pipelines are required to transport liquid CO2. However, safe operation of pipelines relies on accurately predicting the consequences of a leak or rupture (e.g. 2020 Satartia pipeline release in Mississippi). Key factors in modelling pipeline releases, especially when a risk assessment is undertaken along the full length, include (i) the computational cost of a model and (ii) its capacity to account for complex terrain.

https://fluid-dynamics.leeds.ac.uk/projects/accelerated-fluid-dynamics-of-co2-dense-gas-dispersion-in-complex-terrain/

CCUS Joint Industry Projects

- SAFEN failure rates for CCUS, hydrogen and ammonia
- SINTEF
  - Offshore large-scale subsea CO_2 releases
  - CO_2 EPOC: effect of CO_2 on polymeric materials
  - IntoCloud CO_2 venting
- DNV
  - CO_2SafePipe updating CO_2 pipeline guidance
  - Materials in CO_2 wells
  - CO_2MET quality monitoring (CO_2 composition measurement)
  - CO-CO_2 cracking in pipelines
  - CO_2 CFD simulation software
  - SubCO_2 Phase 3 – subsea CO_2 releases
  - CO_2 offshore injection into subsea reservoirs
- TWI
  - MASCO2T II: Materials assessment for CO_2 transport
  - Permeation of CO_2 through thermosets
- PRCI
  - CO_2 pipeline dispersion modelling

HSE participating in these JIPs

energy institute

PROTECTING PEOPLE AND PLACES FOR 50 YEARS HSE

Energy Institute: CCUS activities

- Recent and ongoing EI projects
  - Hazard analysis for onshore/offshore installations
  - Good plant design and operations
  - Running ductile fracture
  - Repurposing and design guidelines for carbon dioxide pipelines
  - Flow assurance and measurement
  - CO_2 impurities measurement
  - Material degradation, corrosion management and asset integrity
  - Interface between conventional power (thermal) generation and a CCUS plant

Reports now available from: https://www.energyinst.org/technical/publications/sectors/ccus

- Projects under development
  - Hazard identification and risk assessment for new and repurposed offshore structures used for CO_2 streams
  - CO_2 transportation and storage flexibility
  - Non-pipeline transport hubs
  - CO_2 subsurface storage
- Webinar "Good practice guide for CO_2 stream impurity measurement within CCS applications" 12 June 2025
- Joint HSE and Energy Institute workshop on CCUS research priorities planned in coming months

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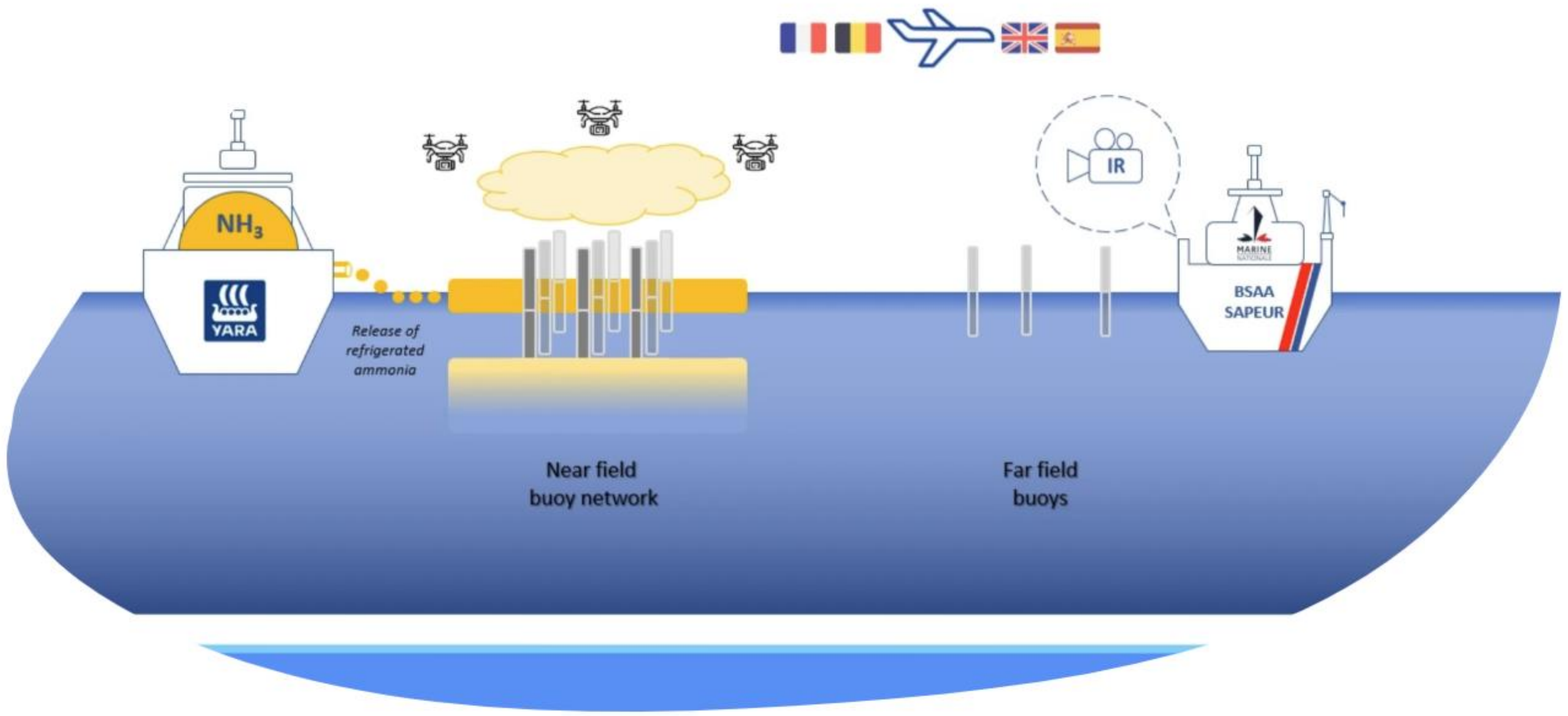
Ammonia research

- HSE is partner in the ARISE Joint Industry Project led by INERIS, CEDRE and Yara Clean Ammonia
- Aims:
  - Conduct multi-tonne spills of ammonia at sea
  - Improve understanding of dispersion in water and air
  - Provide dataset for validation of models
  - Develop methodology for risk assessment for marine applications
- Experiments planned for Sept 2025
- Contacts: Laurent.Ruhlmann@yara.com
  Olivier.Salvi@ineris-developpement.com



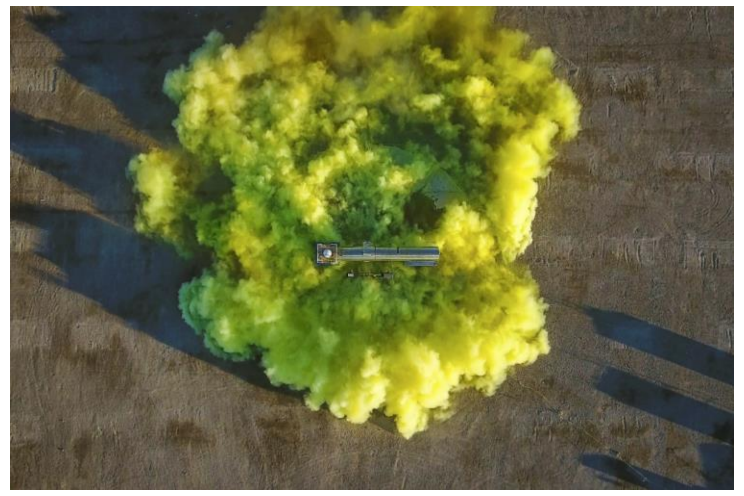
ARISE
Ammonia Response In Sea Emergencies

www.arise-partnership.org

Ammonia research

- Jack Rabbit III ammonia release experiments (2021-ongoing)
  - Led by US Departments of Homeland Security and Defense
  - Aims:
    - Conduct large-scale releases of ammonia, similar to Jack Rabbit II chlorine trials
    - Validate dispersion models
    - Improve preparedness of emergency responders
  - HSE co-chairs the Jack Rabbit III Modelling Working Group and has coordinated international dispersion model inter-comparison exercises
  - Recent indoor ammonia release experiments at Battelle Memorial Institute, Columbus, Ohio
  - Updates to be shared at GMU conference, 24-26 June 2025 http://camp.cos.gmu.edu/announcement.html

Images of previous series of Jack Rabbit II chlorine trials conducted in 2015-2016

Images © DHS S&T CSAC and Utah Valley University https://www.uvu.edu/es/jack-rabbit/

Atmospheric dispersion of pressure-liquefied ammonia: results from the Jack Rabbit III model inter-comparison exercise on Desert Tortoise and FLADIS

Simon Gant[1], Joseph Chang[2], Rory Hetherington[1], Steven Hanna[3], Gemma Tickle[4], Tom Spicer[5], Sun McMasters[6], Shannon Fox[6], Ron Meris[7], Scott Bradley[7], Sean Miner[7], Matthew King[7], Steven Simpson[7], Thomas Mazzola[8], Alison McGillivray[1], Harvey Tucker[1], Oscar Björnham[9], Bertrand Carissimo[10], Luciano Fabbri[11], Maureen Wood[11], Karim Habib[12], Mike Harper[13], Frank Hart[13], Thomas Vik[14], Anders Helgeland[14], Joel Howard[15], Lorenzo Mauri[16], Shona Mackie[16], Andreas Mack[16], Jean-Marc Lacome[17], Stephen Puttick[18], Adeel Ibrahim[18], Derek Miller[19], Seshu Dharmavaram[19], Amy Shen[19], Alyssa Cunningham[20], Desiree Beverly[20], Daniel M. O'Neal[20], Laurent Verdier[21], Stéphane Burkhart[21], Chris Dixon[22], Sandra Nilsen[23], Robert Bradley[24], Hans L. Skarsvåg[25], Eirik H. Fyhn[25] and Ailo Aasen[25]

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[3] Hanna Consultants, Inc., Kennebunkport, Maine, USA
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[5] University of Arkansas, Fayetteville, Arkansas, USA
[6] Chemical Security Analysis Center (CSAC), Science and Technology Directorate (S&T), Department of Homeland Security (DHS), Aberdeen Proving Ground, Maryland, USA
[7] Defense Threat Reduction Agency (DTRA), Fort Belvoir, Virginia and Albuquerque, New Mexico, USA
[8] Systems Planning and Analysis, Inc. (SPA), Alexandria, Virginia, USA
[9] Swedish Defence Research Agency (FOI), Umeå, Sweden
[10] EDF and École des Ponts ParisTech, Paris, France
[11] European Joint Research Centre (JRC), Ispra, Italy
[12] Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany
[13] DNV Digital Solutions, Stockport, UK and Trondheim, Norway
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[15] Defence Science and Technology Laboratory (DSTL), Porton Down, UK
[16] Gexcon, Bergen, Norway and Driebergen-Rijsenburg, Netherlands
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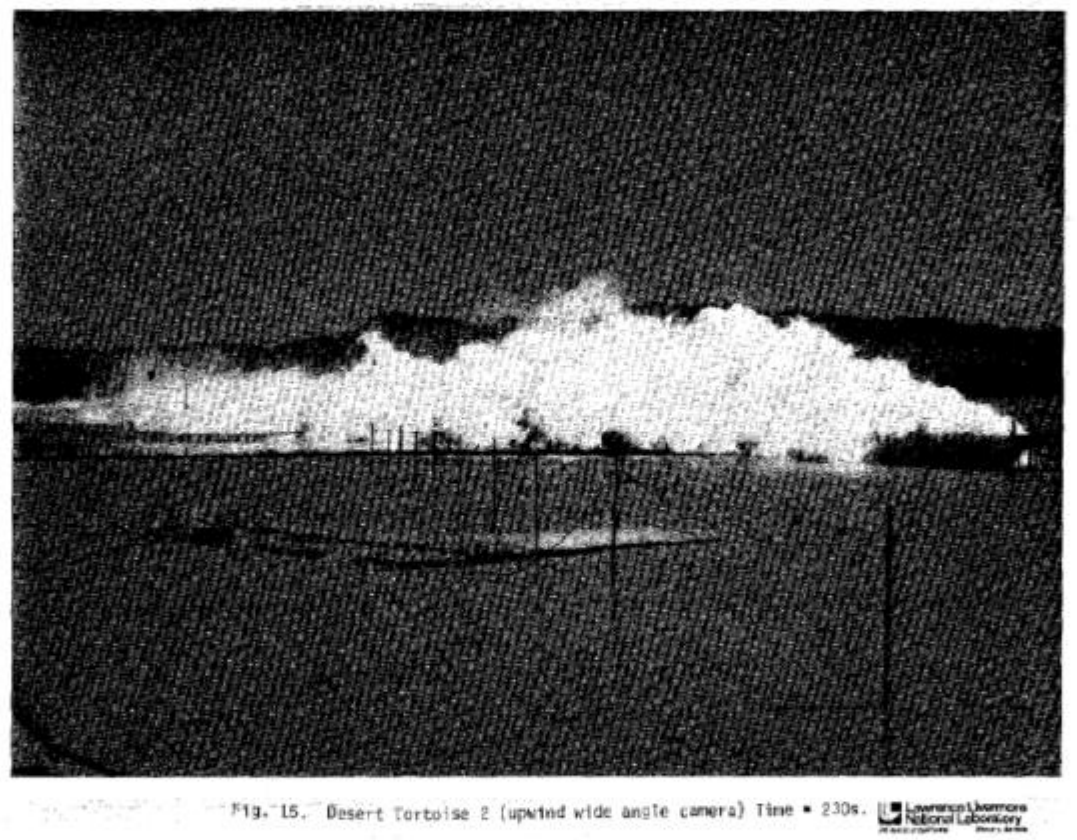
[18] Syngenta, Huddersfield, Yorkshire, UK
[19] Air Products, Allentown, Pennsylvania, USA
[20] Naval Surface Warfare Center Indian Head Division (NSWC IHD), Indian Head, Maryland, USA
[21] Direction Générale de l'Armement (DGA), Paris, France
[22] Shell, London, UK
[23] Equinor, Norway
[24] Emergency Management (EM) Solutions, USA
[25] SINTEF Energy Research, Trondheim, Norway

Initial results presented at Harmo conference in 2022 https://harmo.org/conference.php?id=21
Journal paper currently in late draft stage

Jack Rabbit III ammonia dispersion modelling exercise

#	Organisation	Model	Model Type				Desert Tortoise			FLADIS		
			A	B	C	D	1	2	4	9	16	24
1	Air Products, USA	Ventjet		■			■	■	■	■	■	■
2	BAM, Germany	AUSTAL			■		■	■	■	■	■	■
3		VDI	■				■	■	■	■	■	■
4	CEREA (EDF/Ecole des Ponts), France	Code-Saturne v7.0				■					■	
5		Crunch v3.1		■			■	■	■			
6	DGA, France	PHAST v8.6		■			■	■	■	■	■	■
7		Code-Saturne v6.0				■				■	■	■
8	DNV, UK	PHAST v8.61		■			■	■	■	■	■	■
9	DSTL, UK	HPAC v6.5			■		■	■	■	■	■	■
10	DTRA, ABQ, USA	HPAC v6.7			■		■	■	■	■	■	■
11	EM Solutions, Inc., USA	ALOHA v5.4.7 Gaussian	■				■	■	■	■	■	■
12		ALOHA v5.4.7 Integral		■			■	■	■	■	■	■
13	Equinor, Norway	PHAST v8.6		■			■	■	■			
14	FFI, Norway	ARGOS v9.10			■		■	■	■	■	■	■
15	FOI, Sweden	PUMA			■		■	■	■	■	■	■
16	Gexcon, Netherlands	EFFECTS v11.4		■			■	■	■	■	■	■
17	Gexcon, Norway	FLACS				■	■	■	■	■	■	■
18	GT Science & Software	DRIFT v3.7.19		■			■	■	■	■	■	■
19	Hanna Consultants, USA	Britter & McQuaid WB	■				■	■	■			
20		Gaussian plume model	■							■	■	■
21	HSE, UK	DRIFT v3.7.19		■			■	■	■	■	■	■
22		PHAST v8.4		■			■	■	■	■	■	■
23	INERIS, France	FDS v6.7				■				■	■	■
24	JRC, Italy	ADAM v3.0		■			■	■	■	■	■	■
25	NSWC, USA	RAILCAR-ALOHA	■				■	■	■	■	■	■
26	Shell, UK	FRED 2022		■			■	■	■	■	■	■
27	SINTEF, Norway	OpenFOAM v2206				■	■	■	■	■	■	■
28	Syngenta, UK	PHAST v8.61		■			■	■	■	■	■	■

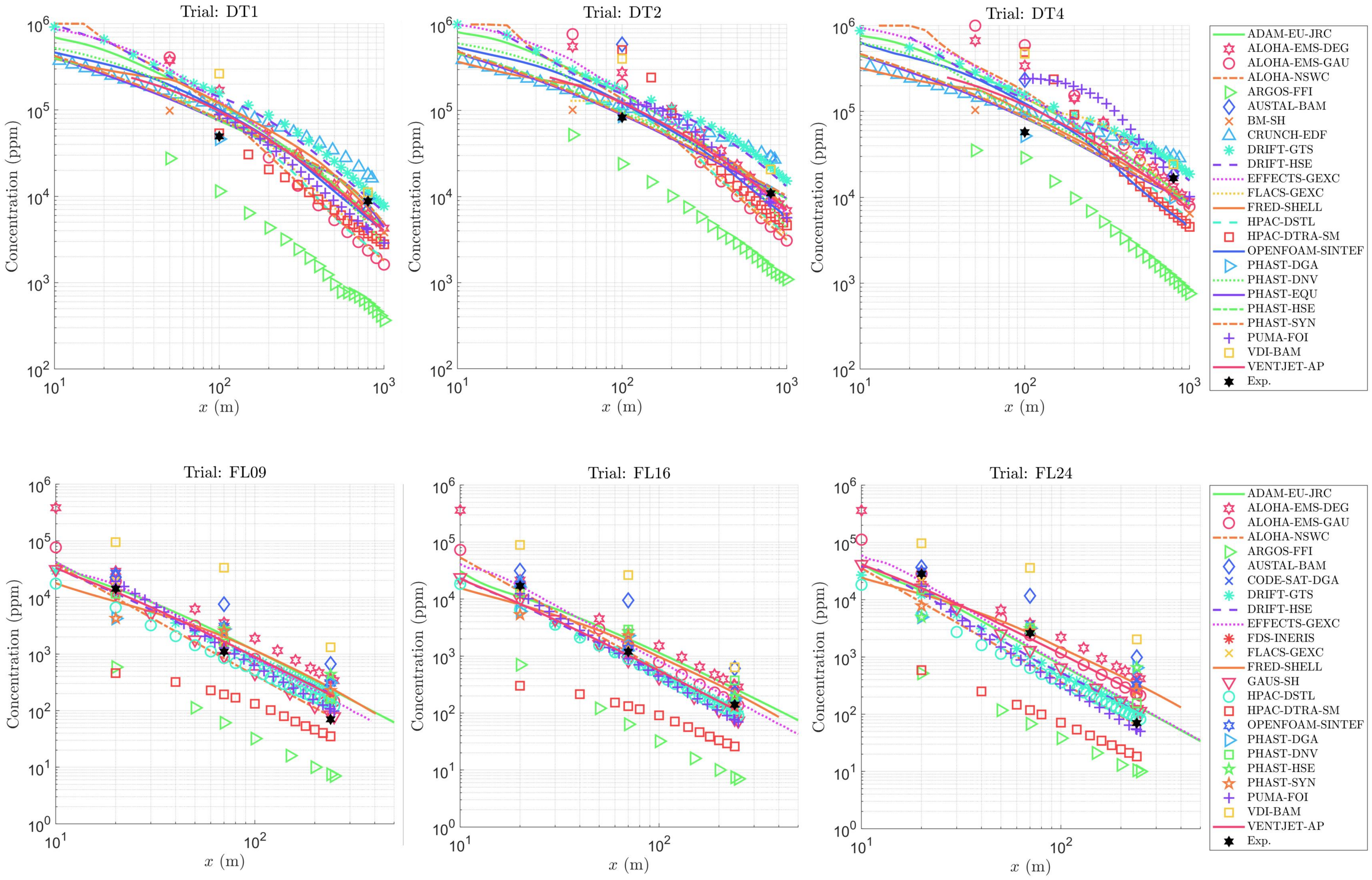
Note: Model Type: A = Empirically-based nomograms/Gaussian plume model; B = Integral model; C = Gaussian puff/Lagrangian model; D = CFD. Shading in the right six columns indicates model was run for that trial. See Glossary for the full names of the organisations and models.



Desert Tortoise ammonia release, Nevada, USA, 1983

FLADIS ammonia release, Sweden, 1993-1994

Jack Rabbit III ammonia dispersion modelling exercise



Ammonia research

- SINTEF
  - SafeAm: ammonia spills onto water

    https://www.sintef.no/en/projects/2023/safeam__increased_safety_of_ammonia_handling_for_maritime_operations/
- Energy Institute
  - Hy2307: use of ammonia and methanol as maritime transport fuels
    - Literature review by ABS on "Health, Safety, Security and Environment (HSSE) Issues Associated with Large Scale Use of Ammonia and Methanol in Marine Transport", 89 pages, Sept 2024
  - New project: "Managing process safety across the entire life cycle of ammonia"

HSE is participating in advisory boards for these projects

Outline

- Introduction to HSE Science and Research Centre
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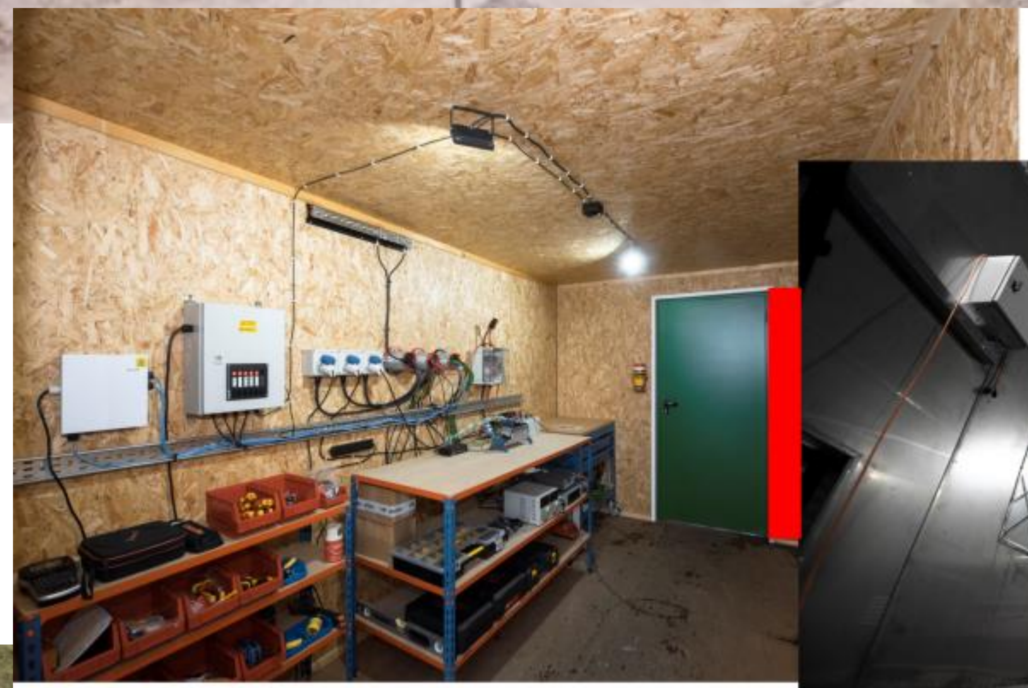
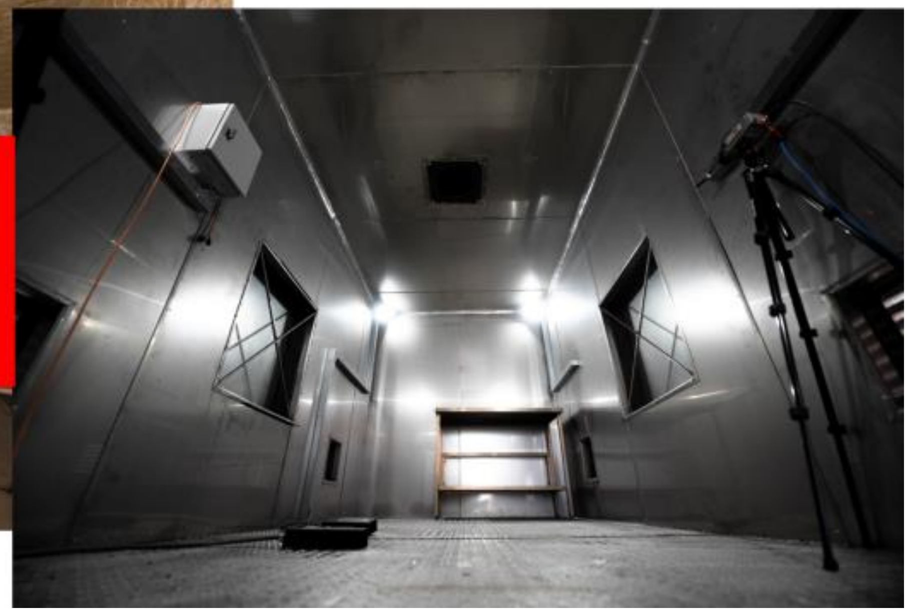
  - CCUS
  - Ammonia
  - Batteries
- Possible future research topics

PROTECTING PEOPLE AND PLACES FOR 50 YEARS HSE

HSE has been performing battery testing for over 10 years

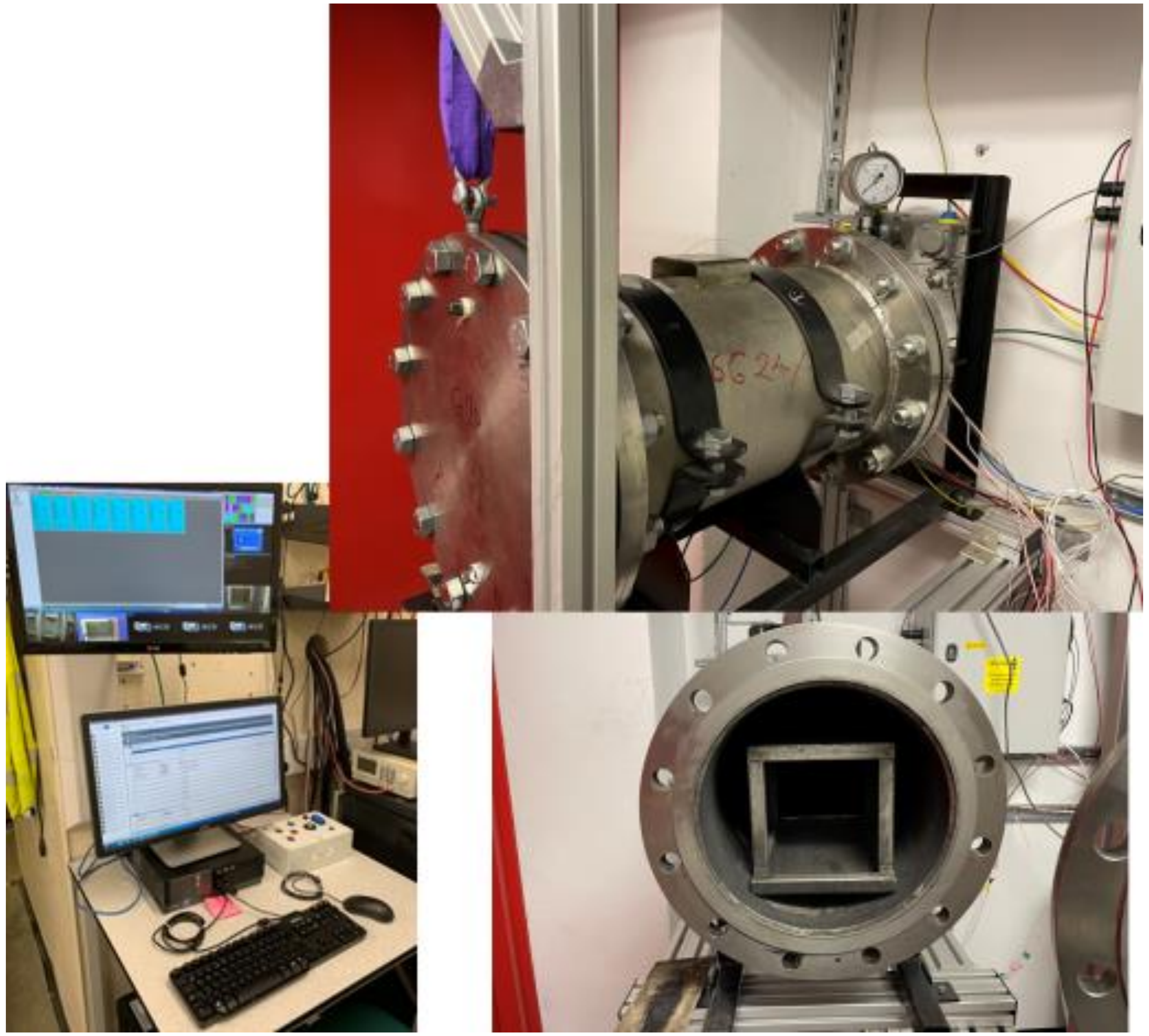
- Significant investment in abuse testing facilities
- 3 Abuse Test chambers (1 module scale, 1 with potential calorimetric addition)
- Use of outdoor test pads/bunkers
- Range of other facilities and equipment





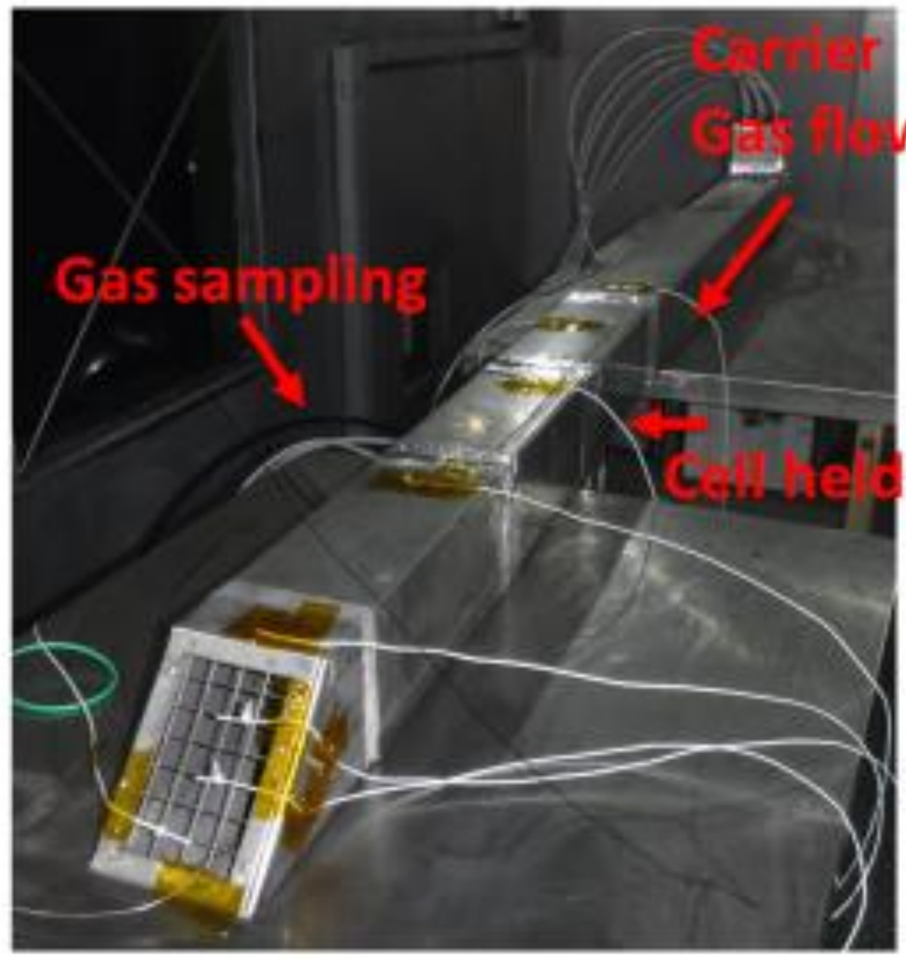
Significant work relating to gas generated by cells in failure

Total Volume and composition



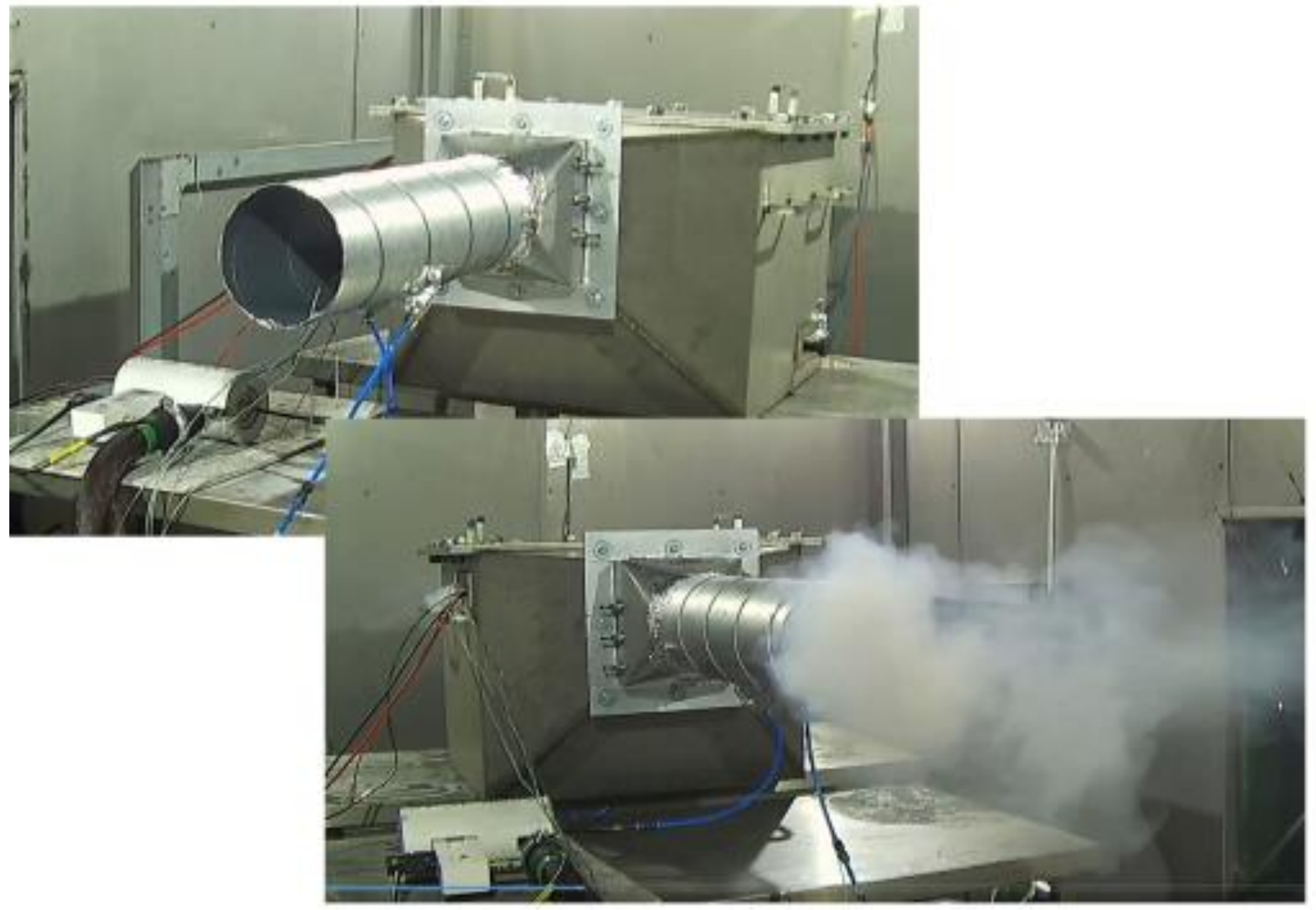
Real Time

Small Cells:



Cells held in enclosed part under main ductwork

Bigger Cells:



~ 210 litre volume

Some recent papers

Energy Advances — ROYAL SOCIETY OF CHEMISTRY

PAPER

Check for updates

Cite this: *Energy Adv.*, 2023, 2, 170

Experimental determination of metals generated during the thermal failure of lithium ion batteries†

Jonathan E. H. Buston,* Jason Gill, Rebecca Lisseman, Jackie Morton, Darren Musgrove and Rhiannon C. E. Williams

https://doi.org/10.1039/D2YA00279E

Journal of Power Sources 539 (2022) 231585

Contents lists available at ScienceDirect

Journal of Power Sources

journal homepage: www.elsevier.com/locate/jpowsour

ELSEVIER

Comprehensive gas analysis of a 21700 $Li(Ni_{0.8}Co_{0.1}Mn_{0.1}O_2)$ cell using mass spectrometry

Katie C. Abbott, Jonathan E.H. Buston, Jason Gill, Steven L. Goddard, Daniel Howard*, Gemma Howard, Elliott Read, Rhiannon C.E. Williams

HSE Science and Research Centre, Harpur Hill, Buxton, Derbyshire, SK17 9JN, United Kingdom

https://doi.org/10.1016/j.jpowsour.2022.231585

Journal of Energy Storage 65 (2023) 107293

Contents lists available at ScienceDirect

Journal of Energy Storage

journal homepage: www.elsevier.com/locate/est

ELSEVIER

Research papers

Experimental study of three commercially available 18650 lithium ion batteries using multiple abuse methods

Katie C. Abbott, Jonathan E.H. Buston*, Jason Gill, Steven L. Goddard, Daniel Howard, Gemma E. Howard, Elliott Read, Rhiannon C.E. Williams

HSE Science and Research Centre, Harpur Hill, Buxton, Derbyshire SK17 9JN, United Kingdom

https://doi.org/10.1016/j.est.2023.107293

batteries — MDPI

Article

Comprehensive Study of the Gas Volume and Composition Generated by 5 Ah Nickel Manganese Cobalt Oxide (NMC) Li-Ion Pouch Cells Through Different Failure Mechanisms at Varying States of Charge

Gemma E. Howard*, Katie C. Abbott, Jonathan E. H. Buston, Jason Gill, Steven L. Goddard and Daniel Howard

https://doi.org/10.3390/batteries11050197

RSC Advances — ROYAL SOCIETY OF CHEMISTRY

PAPER — View Article Online

Check for updates

Cite this: *RSC Adv.*, 2025, 15, 5084

Failure gas analysis of lithium–nickel–cobalt–aluminium oxide cells from different manufacturers

Philip A. P. Reeve,* Jonathan E. H. Buston,* Jason Gill, Steven L. Goddard, Gemma E. Howard and Jack W. Mellor

https://doi.org/10.1039/D4RA07884E

Other papers currently submitted relating to

- Gas produced by LFP cells
- Gas produced by a range of other cells,
- Deflagrations caused by LFP cells
- Battery recycling

SYMPOSIUM SERIES No.168 HAZARDS 31

Smoke, Sparks, Flames or Explosions? An Experimental Study into how Lithium-ion Cell Failure Varies in Open Field

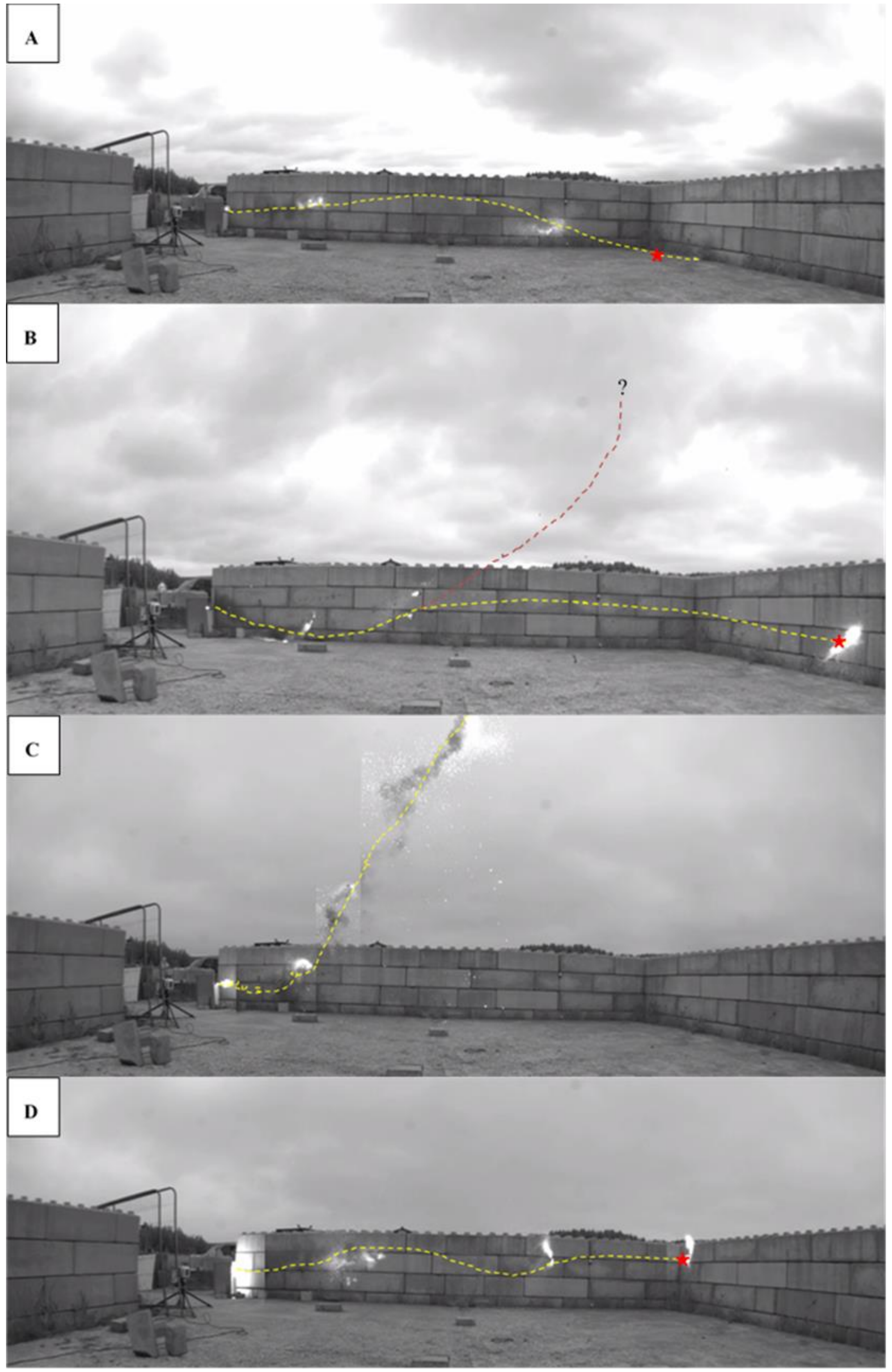
Katie C. Abbott, Jason Gill, Jonathan E.H. Buston, HSE Science and Research Centre, Buxton, Derbyshire, SK17 9JN

Cells of the same format, size and capacity but differing chemistries can display dramatically different failure mechanisms. A combination of closed and open field testing has been conducted including accelerating rate calorimetry (ARC), downward force, and projectile tests to explore cell behaviour during failure. Four types of failure modes have been identified: (i) smoke and fumes with little to no flame produced; (ii) an aggressive jet flame containing molten metallic particles; (iii) a fireball ejecting the contents of the cell; and (iv) complete rupture and/or fragmentation of the cell. These visually identifiable behaviours lead to further questions about pressures and forces each failure mode generates and therefore the damage they can inflict, the projected flame dimensions and duration of the event, as well as the possibility of spreading fire to additional locations. Numerous incidents have been reported involving lithium-ion batteries, therefore better understanding of these vastly different failure mechanisms is crucial to the development of effective means to mitigate, suppress or prevent the events. Currently, it is not possible to rely on models alone to predict the outcomes of these events due to there being too many factors at play. In addition, many of the specific conditions are unknown or not evident, especially when closed cell testing techniques such as ARC are used in isolation. The work presented here offers experimental results and a practical perspective on cell behaviour during failure in open field testing that informs better understanding of this technology. Different failure modes have been demonstrated between three different cells, but also within the same type of cell.

Keywords: Thermal runaway, lithium-ion battery, thermal hazards, accelerating rate calorimetry (ARC), battery fire, battery explosion, projectiles

- Heating cells to failure
- How far can cylindrical cells fly?
- How fast do they travel?
- What stops them?

https://www.icheme.org/media/17627/hazards-31-paper-43-abbott.pdf



Some recent collaborative batteries projects

- RECOVAS (battery recycling)
  (https://recovaspartnership.co.uk/)
- LiBRIS
- PreLiBs
- Cross Government work
- A wide range of work in the commercial sector

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  - Batteries
- Possible future research topics

Possible future research topics: hydrogen

- Hazardous area classification for hydrogen
  - Zone of “negligible extent” criteria
  - Appropriate hole sizes for area classification
  - Selection of hydrogen lower flammable limit value (4% or 8% v/v ?)
  - Buoyancy-induced ventilation in enclosures (produced by hydrogen cloud)
- Mapping of hydrogen regulations, standards and good practice guidelines
  - Led by Energy Institute? Application or sector specific?
- Consequences of LH_2 bulk storage tank failure (immediate/delayed ignition etc.)
- Review of issues relating to sub-COMAH hydrogen installations
- Electrolyser safety issues
- Lessons learnt from operational experience of hydrogen equipment and incidents

This list is not extensive, see also:

- HySafe research priorities
- IEA Task 43 hydrogen safety
- Energy Institute gap analysis

Possible future research topics: CCUS

- Consequences of bulk CO_2 storage vessel failure (cold BLEVE): rainout of dry-ice?
- CO_2 pipeline leaks: potential for enlargement of punctures into ruptures by progressive brittle fracture around the release point. Is brittle fracture mitigated by warm pre-stressing?
- Review of operating procedures and safety measures: purging, venting, inspection, repairs, heaters/vaporisers, CO_2 solid blockages (lessons learnt from operations?)
- CO_2 venting strategies offshore: from the underside of platforms?
- Detection and emergency control systems on platforms handling hydrocarbons and CO_2
- Impact of dense CO_2 clouds on floating support vessels and ingress of CO_2 into lifeboats
- Wells: impact of CO_2 impurities on casing cements, risks associated with varying injection rates, CO_2 phase change in wells, salt precipitation and hydrates

This list is not extensive, further research topics are being pursued in JIPs

EU/OECD Joint Research Centre: hydrogen risks webinars

Hydrogen Fuel Risks Webinar Series

Organised by the EC-Joint Research Centre with the TWG 2 and OECD

Hydrogen is a widely available and highly versatile substance, already playing a crucial role in chemical manufacturing and oil refining. However, its flammable and explosive nature requires stringent controls to prevent serious accidents, especially when used in large quantities. In line with the Seveso Directive and its collaboration with partners in chemical accident risk management within the OECD, the JRC's Major Accident Hazards Bureau (MAHB) began exploring the potential industrial, safety, and health risks posed by the energy transition towards hydrogen. In this context, the JRC and OECD organised a series of three webinars focused on the different aspects of managing the risks associated with hydrogen fuel. Below you may access each webinar programme and available presentations.

Hydrogen Fuel Risks Webinar Part 1

15 September 2023, 09:00 – 13:00 CEST

The first webinar aimed to facilitate knowledge exchange between EU and OECD experts and authorities involved in assessing risks related to hydrogen-based fuel operations. It focused on identifying anticipated technologies and infrastructure across different countries and discussing shared challenges and potential solutions in managing hydrogen risks.

Hydrogen Fuel Risks Webinar Part 2

14 February 2024, 09:00 – 13:15 CEST

The goal of the second webinar was to address key uncertainties including new sites and technologies, alongside challenges in standards, regulations, permitting, and oversight. The presentations and discussion explored new demands on risk assessment, modelling, and accident scenario planning, and possible needs for updated guidance and best practices.

Hydrogen Fuel Risks Webinar Part 3

08 October 2024, 09:00 – 13:30 CEST

The third webinar focused on key topics related to hydrogen safety, including lessons from past accidents, the preparedness of safety and environmental practices for a hydrogen-based economy, and the importance of standardisation. It also explored risk comparisons between different hydrogen forms, regulatory challenges for large-scale deployment, and safety concerns for upcoming hydrogen projects.

Hydrogen Fuel Risks Webinar Part 4

11 March 2025, 09:00– 13:30 CET

The fourth meeting explored the challenges, safety considerations, and regulatory standards associated with using ammonia as an energy carrier for hydrogen. Participants highlighted the importance of collaboration among policy experts, industry stakeholders, and safety professionals to ensure safe and effective implementation.

WEBINAR

EU Technical Working Group for Seveso Inspections (TWG 2) and OECD Working Party on Chemical Accidents

Hydrogen Fuel Risks Webinar Part 4

Organised by the EC-Joint Research Centre with the TWG 2 and OECD
11 March 2025, 09:00– 13:30 CEST

Moderator: Maureen Wood, EC-JRC-MAHB		Co-Moderator: Marie-Ange Baucher, OECD
09:00	**Introductory Session**	
	Welcome to the Webinar	Maureen Wood, EC-JRC and Eeva Leinala, OECD
	Introduction to the Programme	Maureen Wood, EC-JRC
	Session 1	
09:05	Need for closer cooperation between policy, industry and safety experts on ammonia and other hydrogen fuels	Ruta Baltause, EC DG ENER
	Discussion: If you would like to ask a question or comment, please use the Webex chat. Presenters should ideally plan for 20-25 minute presentations leaving time for discussion	
	Session 2	
09:50	Ammonia risks in the hydrogen fuel context	Lorenzo Van Wijk, EC-JRC-MAHB
10:00	Safe Ammonia handling – Challenges & Opportunities	Laurent Ruhlmann, Yara
10:20	Design principles for NH3 Fully Refrigerated Large Quantity Storage	Michel J Ruttens, Advario
10:40	PGS 12 Ammonia, New BAT document on ammonia storage in the Netherlands, Part 1	Jochem Langeveld, DCMR Environmental Service Rijnmond

https://minerva.jrc.ec.europa.eu/EN/content/minerva/a065e0e1-9122-11ef-989f-0050563f0167/euoecd_hydrogen_fuel_risks_webinar_series

HSE Safe Net Zero conference, Edinburgh, 25-26 November 2025

Day 1

Time	Title	Speaker
09:00	Arrival, registration and refreshments	
10:00	Welcome	Chair, Stuart Hawksworth, Health and Safety Executive
	Virtual welcome	Sarah Newton, Chair of the Health and Safety Executive
10:20	Session 1: The international picture	
	Session introduction	Chair, Kate Jeffrey, Health and Safety Executive
	Latest insights into international liquid hydrogen research	Thomas Jordan, Karlsruhe Institute of Technology, Germany
	Large scale storage	Robin Lal Shrestha, Equinor
	Asia Pacific and its hydrogen priorities	Nick Smith, International Association for Hydrogen Safety
	Ensuring safe and efficient ammonia transport from NEOM to international markets	Simon Earnshaw, Air Products
	Panel session	
11:30	Refreshments and networking	
12:00	Keynote address	
	TBC	TBC
12:45	Networking lunch	
13:45	Session 2: Large scale hydrogen production and storage in the UK	
	Session introduction:Scaling up hydrogen production and storage	Chair Nigel Holmes, Hydrogen Scotland
	Safety considerations for electrolytic hydrogen production	Joe Bailey, Progressive Energy
	Hydrogen production	Beau Gray, Centrica
	Panel session	
15:10	Refreshments and networking	
15:30	Session 3: Research and innovation	
	Session introduction	Chair Nigel Holmes, Hydrogen Scotland
	FutureGrid: Results from live trials	Lloyd Mitchell, National Grid
	The role of hydrogen in a decarbonised energy system	Sarah Kimpton, DNV
	Repurposing offshore oil and gas assets	Chris McClane, Centrica
	Speyside hydrogen: Navigating the complexities of scaling green hydrogen	Christina Smitton, Storegga
	Developing the safety case for membrane-free electrolysis	Paul Cassidy, CPH2
	Enabling hydrogen flight to take off - learning by doing, a testing perspective	Mark Eldridge, Element Materials Technology
	Panel session	
17:00	End of day one	

Day 2

Time	Title	Speaker
09:00	Arrival and refreshments	
09:15	Welcome and overview	Lorraine Gavin, Health and Safety Executive
09:30	Session 4: Options and challenges for large scale storage	
	Session introduction	Chair TBC
	Below ground - cylinders	Steven Kirk, Gravitricity
	Safety distances of hydrogen installations: global approaches and UK perspective	Stuart Williams, Air Products
	Storage and transportation - the implications of scaling hydrogen	Will France, ERM
	TBC	TBC
	Panel session	
11:00	Refreshments and networking	
11:30	Session 5: Standards and guidance	
	Session introduction	Ian McCluskey, IGEM
	Addressing net zero health and safety challenges	Mark Scanlon, Energy Institute
	Signposting to guidance and HII's latest report 'Engineering considerations for cryogenic hydrogen applications'	Cameron Blackwell, The Manufacturing Technology Centre
	Panel session - joined by Stew McEwen, SJM 2050	
12:30	Lunch and networking	
13:30	Session 6: Principles for good practice	
	Session introduction	Chair TBC
	Principles for process safety risk management	Kris Ellenthorpe, Process Safety Consulting
	Scaling and tailoring safety assurance on the journey to large scale storage	Ed Macfarlane, Abbot Risk Consulting
	Environmental permitting and guidance for hydrogen production	Jane Durling, Environment Agency
	Navigating design risk management in hydrogen projects: avoiding pitfalls and exploring available best practices	TBC, Cairn Risk
	Panel session	
14:50	Closing remarks	
15:00	Conference close	

TRAINING AND EVENTS FROM HSE

Safe Net Zero 2025: Safety considerations for the production and large scale storage of hydrogen and its derivatives

25-26 November 2025 - Edinburgh

An event from HSE to connect, share knowledge and gain insight into the safe development of hydrogen technologies.

https://solutions.hse.gov.uk/hse-health-and-safety-training-courses/safe-net-zero-2025-safety-considerations-for-the-production-and-large-scale-storage-of-hydrogen-and-its-derivatives

Thank you

Any questions?

simon.gant@hse.gov.uk

- Disclaimer: the contents of this presentation, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy
- To review HSE areas of research interest, search here: https://ari.org.uk/ or https://int.octopus.ac/