

Health and Safety Executive

- Aim of HSE involvement in UKCCSRC meetings, 31 Jan – 3 Feb 2022
 - To re-engage with the CCUS research community
 - To understand what research has been ongoing on CCUS in the last 5 years
 - To see whether previously identified safety-related knowledge gaps have been filled
 - To identify any other safety-related issues across the full chain (capture, transport, utilization/storage) with which HSE should engage
- Presentation by Trevor Sexty (HSE) at CCSA on 16 Sept 2021 on “Regulation of transport and underground storage of carbon dioxide” – available on request
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Overview of Previous CCUS Research and Remaining Knowledge Gaps

Simon Gant and Catherine Spriggs

UKCCSRC Industry and policy led ‘what are our research needs’ workshop on Environmental impacts (including Health and Safety), 1 February 2022

Research - HSE funded to provide evidence which underpins its policy and regulatory activities

Guidance - freely available to help people comply with health and safety law

Initial safety concerns

IChemE SYMPOSIUM SERIES NO. 153

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

Stephen Connolly¹ and Laurence Cusco²

12th International Symposium on Loss Prevention and Safety Promotion in the Process Industries, Loss Prevention 2007, Edinburgh, UK, 22 - 24 May, 2007

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

Uncertainties:

- Dispersion modelling of (liquid/solid + gas) CO₂ jet releases: how does it behave? Can we predict extent of hazardous zones?
- Implications of severe Joule-Thomson cooling (embrittlement?)
- Solid CO₂ implications for blowdown (blocking valves?)
- Solid CO₂ particles scouring and erosion (jet cleaning and cutting)
- Solid CO₂ deposition as dry-ice bank (prolonged sublimation)
- Running ductile crack propagation along CO₂ pipelines
- Equation of state for CO₂ + impurities for flow assurance modelling
- Corrosion issues

Carbon dioxide incidents

- Onshore well-head blowout in Hungary, 1998
- 207 bar release of CO₂ and H₂S
- 5,000 people evacuated, no significant injuries or fatalities
- Solid CO₂ snow bank 1.5 – 2 metres thick, -30 °C near release point



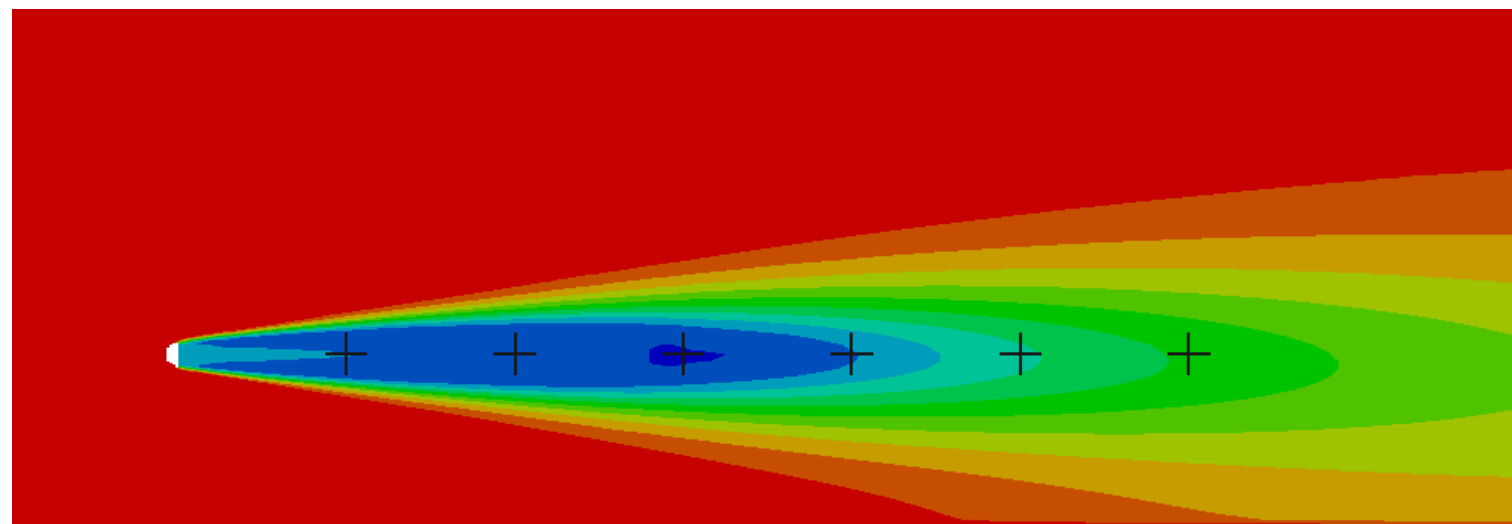
https://publishing.energyinst.org/_data/assets/file/0006/71394/Guidance-on-HA-for-onshore-CCS-installations-WEB-VERSION.pdf

CCS research over the period from 2007 - 2017

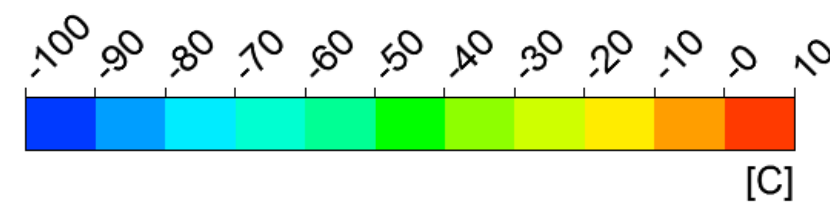
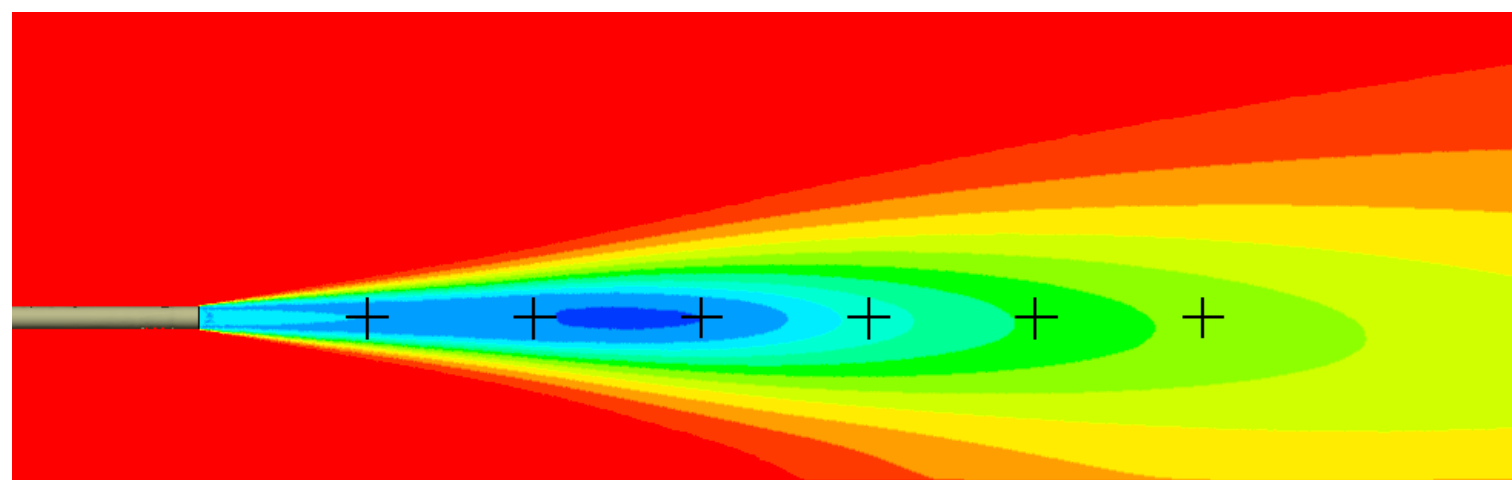
Experiments
(DNV)



OpenFOAM
(Shell)

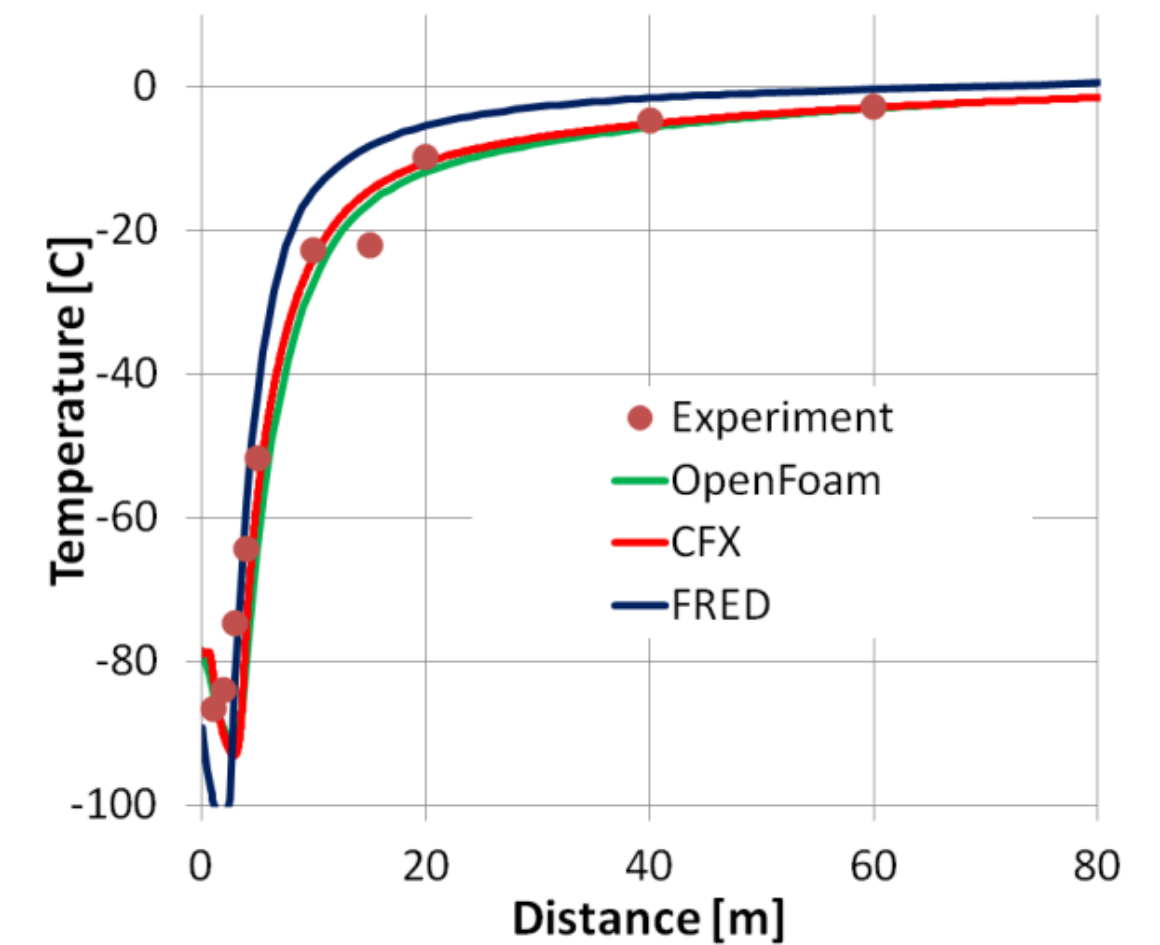
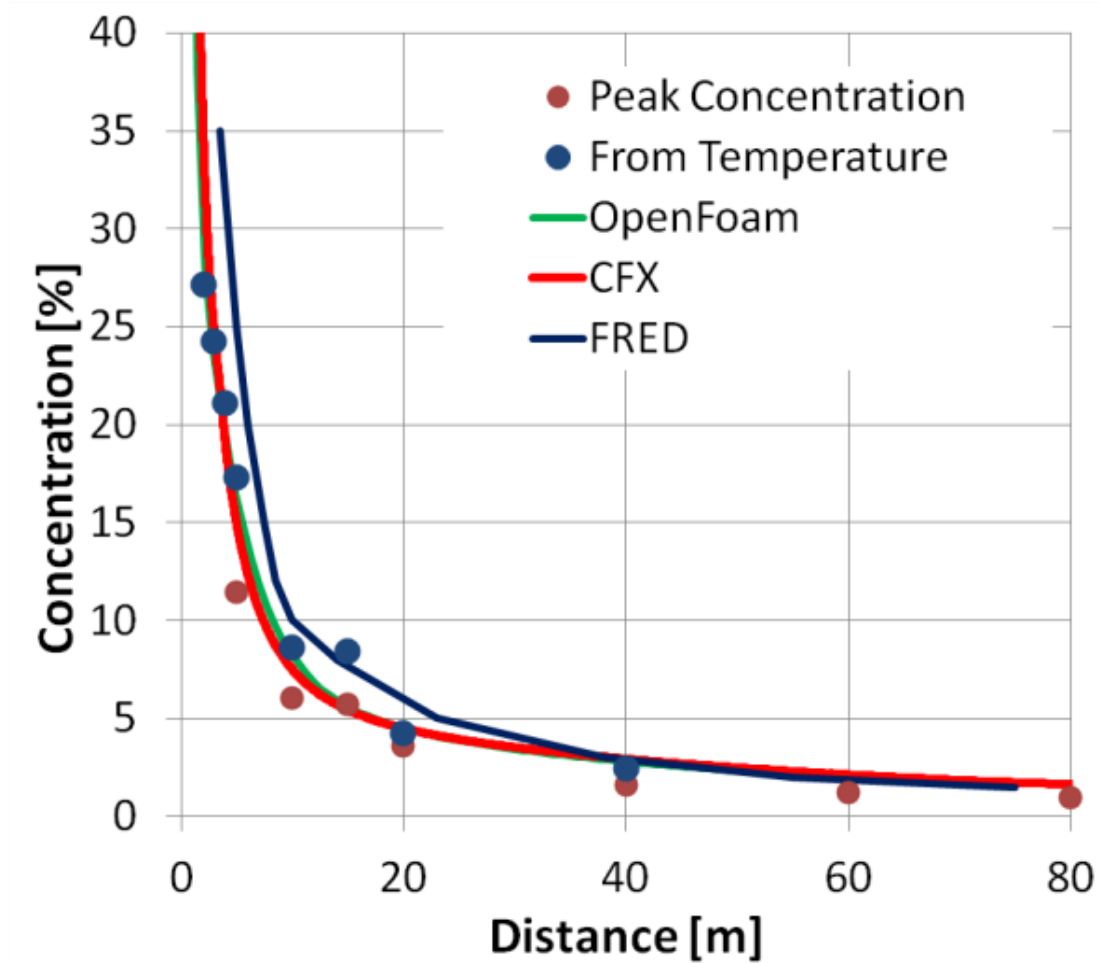


CFX
(HSL)



Images copyright Shell / DNV

Dense-phase CO₂ jet experiments at DNV Spadeadam funded by Shell



Dixon C.M., Gant S.E., Obiorah C. and Bilio M. "Validation of dispersion models for high pressure carbon dioxide releases" IChemE Hazards XXIII Conference, Southport, UK, 12-15 November 2012

CCS research over the period from 2007 - 2017

COOLTRANS Research Programme

Proceedings of the 2014 10th International Pipeline Conference
 IPC2014
 September 29 - October 3, 2014, Calgary, Alberta, Canada

IPC2014-33370

THE COOLTRANS RESEARCH PROGRAMME – LEARNING FOR THE DESIGN OF CO₂ PIPELINES

Julian Barnett
 National Grid Carbon
 Solihull, UK

Russell Cooper
 National Grid Carbon
 Solihull, UK

Proceedings of the 2016 11th International Pipeline Conference
 IPC2016
 September 26-30, 2016, Calgary, Alberta, Canada

IPC2016-64456

ANALYSIS OF A DENSE PHASE CARBON DIOXIDE FULL-SCALE FRACTURE PROPAGATION TEST IN 24 INCH DIAMETER PIPE

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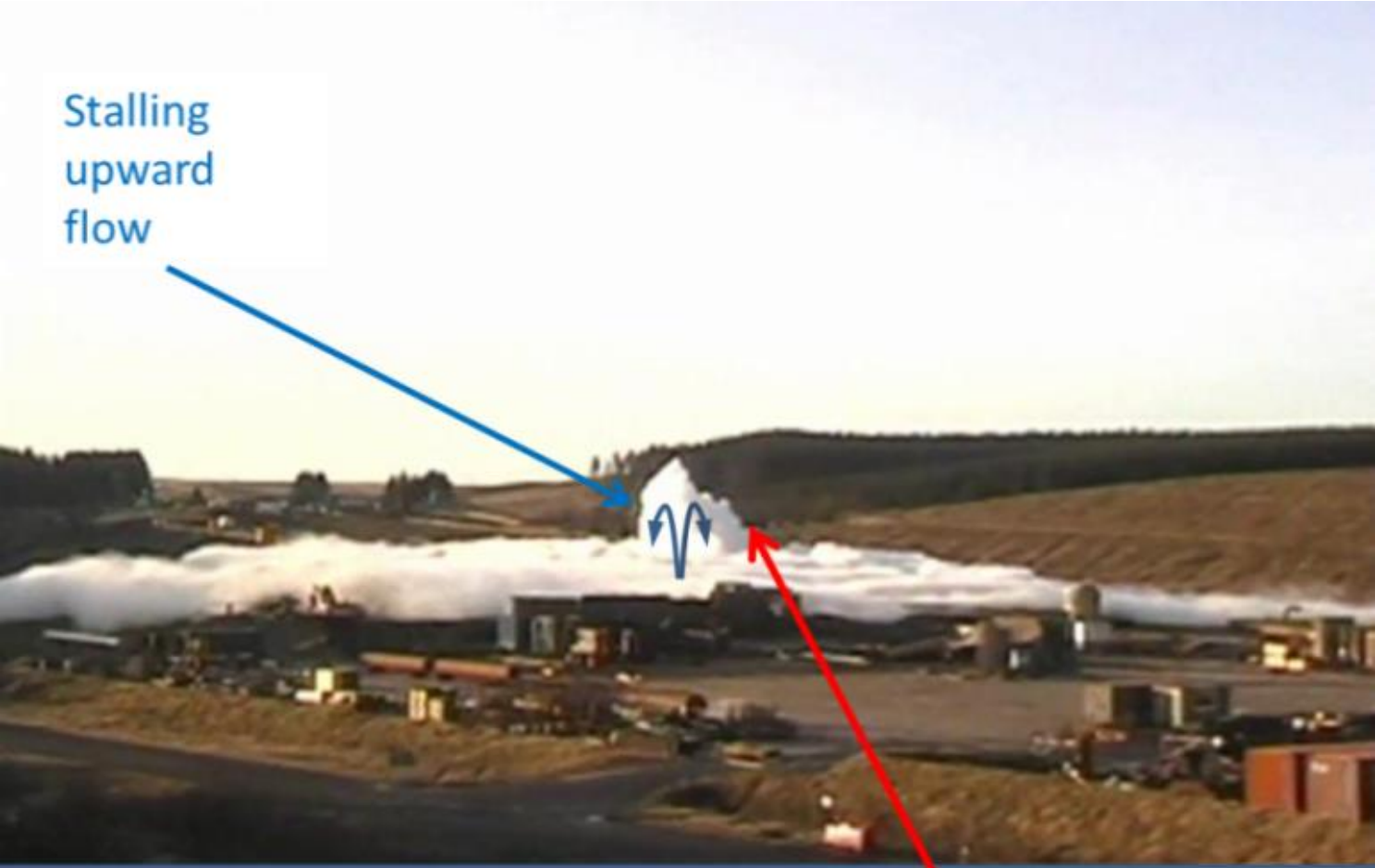
Julian Barnett
 National Grid
 Solihull, UK

Crater size and its influence on releases of CO₂ from buried pipelines

by Philip Cleaver¹, Ann Halford¹, Karen Warhurst¹, and Julian Barnett²
 1 GL Noble Denton, Loughborough, UK
 2 National Grid Carbon, Warwick, UK

4th International Forum on the Transportation of CO₂ by Pipeline

Hilton Gateshead-Newcastle Hotel, Gateshead, UK
 19-20 June, 2013



Crater is covered by vapour blanket – mixture released previously is drawn into flow



Fresh air entrainment possible around plume base

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CCS research over the period from 2007 - 2017



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RR1121 - Overview of carbon capture and storage (CCS) projects at HSE's Buxton Laboratory

Over the last decade, the UK Government has supported innovation and growth in Carbon Capture and Storage (CCS) technology with the aim of commercial deployment. CCS research across the UK has reduced potential risks by helping to develop a thorough understanding of the operational hazards and by contributing to the design of safe plant and processes.

This report provides an overview of applied scientific work on CCS undertaken at HSE's Buxton Laboratory. The work includes laboratory-scale and field-scale experiments, evaluation of complex dispersion models for dense-phase carbon dioxide releases, development of decision support tools for pipeline risk assessment and publication of best practice guidelines. In particular, work has focussed on assessing the hazards posed by the accidental release of dense-phase carbon dioxide transported by pipeline. The research has been primarily funded by HSE and industry, with support from the European Union.

HSE's scientific work will help reduce both the risks and costs of any future development of industrial-scale CCS by contributing to the assessment and control of risks early in the design and deployment of the technology. The research has contributed to the scientific evidence base that, if CCS is deployed in with UK, will inform HSE policy decisions to ensure that the regulatory framework for pipelines is effective and proportionate to the potential risks associated with CCS.

Related content

- HSE Buxton Laboratory
- HSE Foresight Centre
- Workplace Health Expert Committee (WHEC)
- Contract opportunities
- Statistics
- Economics of health and safety
- HSE jobs

<http://www.hse.gov.uk/research/rrhtm/rr1121.htm>

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Remaining Knowledge Gaps?

- Capture plant
 - Do we understand the risks from toxic amines, nitrosamines etc.?
- Pipeline design
 - Is there a validated model for predicting running ductile crack propagation along CO₂ pipelines that can be used to specify material toughness and/or crack arrester requirements?
 - Do we understand corrosion regimes (e.g. non-dry CO₂ streams from different sources, process-upset conditions)? – lessons from Gorgon project

Proceedings of the 2020 13th International Pipeline Conference

IPC2020

September 28-30, 2020, Virtual, Online

AN EMPIRICAL FRACTURE CONTROL MODEL FOR DENSE-PHASE CO₂ CARRYING PIPELINES

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IPC2020-9421

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Remaining Knowledge Gaps?

- Pipeline risk assessment
 - Pipeline failure rates: need for modifications to fracture mechanics model in pipeline risk assessment models?
 - Need to develop a fast method for CO₂ dispersion modelling incorporating terrain effects on along pipeline route (as a screening tool)?
 - Need to develop a toxic risk methodology that takes into account sublimating solids (only for dense-phase pipelines, but just being used offshore)?

- Ship transport and subsea CO₂ pipelines
 - For transport of UK CO₂ to Norwegian “Northern Lights” project?
 - Do we understand impact of CO₂ releases onto water – no freely available data (recent DNV SUB CO₂ JIP experiments)
 - Potential for RPTs following release from ship or failure of loading arms?

Remaining Knowledge Gaps?

- What lessons have been learnt from recent experience?
 - CCS and carbon dioxide pipeline incidents
 - “While workers did a controlled blow-down to remove any remaining CO₂ from the section, a valve froze in the open position due to internal ice formation and gas poured out”
https://www.huffingtonpost.co.uk/entry/gassing-satartia-mississippi-co2-pipeline_n_60ddea9fe4b0ddef8b0ddc8f
 - Operational experience, e.g., Boundary Dam, Gorgon, Sleipner, Snøhvit, USA EOR pipelines – can we share good practice, info on near misses etc.?

- Current status of industrial/academic research on CCUS safety
 - HSE has not been engaged with CCUS community since 2017, but some research has been ongoing. What have been the recent findings on safety-related issues?

Acknowledgements



Thank you – any comments or questions?

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- 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.
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