A decorative graphic on the left side of the slide consists of several overlapping, semi-transparent, dark red chevron shapes pointing to the right, creating a layered, arrow-like effect.

# **Carbon Capture, Utilization and Storage (CCUS): Policy Perspectives and Science**

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# Outline

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- Pipeline Safety Regulations (PSR) 1996
- Policy perspectives on CO<sub>2</sub> pipelines
- Previous scientific work on CCUS at HSL
- Future directions?

# Pipeline Safety Regulations (PSR) 1996

- PSR provides a risk-based goal-setting approach to regulating pipelines in Great Britain
- The regulations cover:
  - Definition of a pipeline
  - General requirements for all pipelines (design, construction, operation etc.)
  - Requirement for co-operation amongst pipeline operators
  - Measures to prevent damage to pipelines
  - Amendments to other regulations

# Pipeline Safety Regulations (PSR) 1996

- Major Accident Hazard Pipeline (MAH) is one which conveys a dangerous fluid
- Classification of dangerous fluid given in Schedule 2 of PSR (see next slide)
- PSR sets out requirements for MAH pipelines:
  - Emergency shut-down valves
  - Notifications
  - Major accident prevention document
  - Emergency procedures
  - Emergency plan

## Dangerous Fluid (PSR Schedule 2)

1. Flammable, boiling point  $< 5^{\circ}\text{C}$  at 1 bar(a) and conveyed in the pipeline as a liquid.
2. Flammable, conveyed in the pipeline as a gas at above 8 bar(a)
3. Liquid with vapour pressure  $> 1.5$  bar(a) at temperature of pipeline or  $20^{\circ}\text{C}$
4. Toxic/very toxic fluid which is gas at  $20^{\circ}\text{C}$  and 1 bar(a) and is conveyed as a liquid or a gas
5. Toxic with vapour pressure  $> 0.4$  bar at  $20^{\circ}\text{C}$  and is conveyed in the pipeline as a liquid
6. Acrylonitrile
7. Very toxic with saturated vapour pressure  $> 0.001$  bar(a) at  $20^{\circ}\text{C}$  or is conveyed in the pipeline as a liquid at a pressure  $> 4.5$  bar(a)
8. Oxidising fluid conveyed as a liquid
9. Fluid which reacts violently with water
10. Oxidising liquid and toxic or very toxic fluid, or reacts violently with water if it has been, or is liable to be classified, pursuant to regulation 5 of the Chemicals (Hazard Information and Packaging for Supply) Regulations 1994, as the case may be, oxidising, toxic, very toxic or reacts violently with water.

# CCUS Policy Perspectives

- HSE published guidance on CO<sub>2</sub> pipelines:  
<http://www.hse.gov.uk/pipelines/co2conveying-full.htm>
- CO<sub>2</sub> is not currently classified as a “dangerous fluid” under PSR (1996)
  - Therefore CO<sub>2</sub> pipelines not treated as MAH pipelines
  - Not subject to controls under land-use planning
- However...
  - Previous HSE work has argued that CO<sub>2</sub> pipelines should be treated as MAH pipelines
  - Status remains under review
  - There are other relevant provisions in existing regulations (see next slide)

# CCUS Policy Perspectives

- Health & Safety at Work etc. Act 1974, Sections 2 and 3
  - Employers are required to ensure the health and safety of their employees and others so far as is reasonably practicable
  - CO<sub>2</sub> pipeline operators required to take a proportionate approach to managing the risks from conveying CO<sub>2</sub> at every stage of the pipeline's lifetime
  - Demonstrated through a comprehensive risk assessment which takes account of the range of risks that arise from the design, commissioning, operation (including maintenance and inspection) and decommissioning of the CO<sub>2</sub> pipeline

# CCUS Policy Perspectives

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- ALARP
  - Operators of CO<sub>2</sub> pipelines can demonstrate compliance with PSR and HSWA by making sure that the risks from their pipelines are reduced as low as is reasonably practicable (ALARP)
  - Application of good practice at the design stage is an essential part of this demonstration

# CCUS Policy Perspectives

- Further guidance on HSE website on the topics of:
  - Corrosion
  - Ductile and brittle fracture propagation
  - Saturation pressure
  - CO<sub>2</sub> stream composition and flow assurance
  - Modelling loss of containment
  - Non-metallic components
  - Fluid classification
  - Guidance and Standards

<http://www.hse.gov.uk/pipelines/co2conveying-full.htm>

# Outline

- Pipeline Safety Regulations (PSR) 1996
- Policy perspectives on CO<sub>2</sub> pipelines
- Previous scientific work on CCUS at HSL
- Future directions

# Previous Scientific Work at HSL

Several large EU, UK Government and industry-funded projects:

- CO2PipeHaz
  - <http://co2pipehaz.eu/>
- MATTRAN
  - <https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/G061955/1>
- COOLTRANS
  - Cosham *et al.* (2016) “Analysis of a dense phase carbon dioxide full-scale fracture propagation test in 24 inch diameter pipeline” <http://dx.doi.org/10.1115/IPC2016-64456>
  - Cooper R. and Barnett J. (2014) “Pipelines for transporting CO<sub>2</sub> in the UK” <https://doi.org/10.1016/j.egypro.2014.11.264>
- COSHER
  - Ahmad *et al.* (2015) “COSHER joint industry project: Large scale pipeline rupture tests to study CO<sub>2</sub> release and dispersion” <https://doi.org/10.1016/j.ijggc.2015.04.001>
- CO2PIPETRANS
  - <https://www.dnvgl.com/oilgas/joint-industry-projects/ongoing-jips/co2pipetrans.html>

# Previous Scientific Work at HSL



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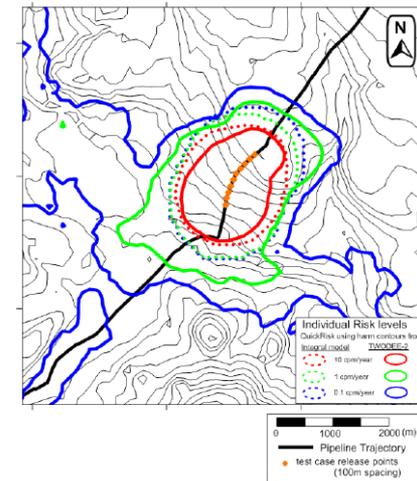
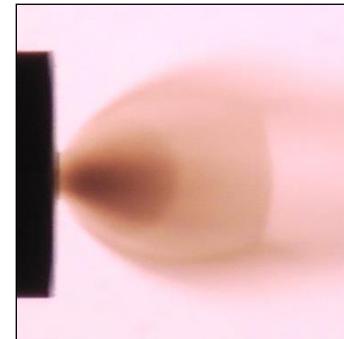
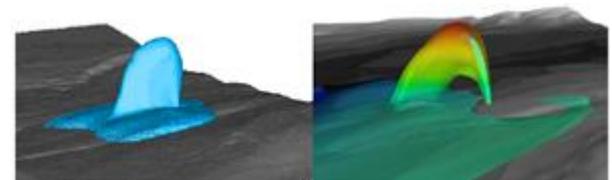
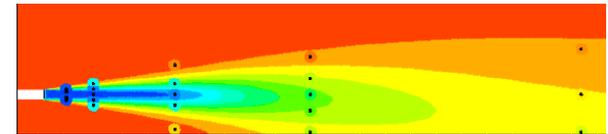
- HSE Buxton Laboratory
- HSE Foresight Centre
- Workplace Health Expert Committee (WHEC)
- Contract opportunities
- Statistics
- Economics of health and safety
- HSE links

## 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.



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

# Previous Scientific Work at HSL

## CONTENTS

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

<b>1</b>	<b>INTRODUCTION .....</b>	<b>1</b>	<b>6</b>	<b>SHERPA CONSULTING REPORT ON CO<sub>2</sub> PIPELINES.....</b>	<b>28</b>
<b>2</b>	<b>HSE RESEARCH PROJECTS.....</b>	<b>2</b>	<b>7</b>	<b>IEA GHG REPORT.....</b>	<b>29</b>
2.1	Assessment of the major hazard potential of CO <sub>2</sub> .....	2	7.1	Background.....	29
2.2	Comparison of risks from CO <sub>2</sub> and natural gas pipelines .....	4	7.2	Objectives .....	29
2.3	Concentration fluctuations and toxic load .....	6	7.3	Methodology .....	29
2.4	Sensitivity analysis of CO <sub>2</sub> jet dispersion models .....	7	7.4	Conclusions .....	29
2.5	Validation of CFD dispersion models with Shell.....	9	<b>8</b>	<b>DECATUR PROJECT .....</b>	<b>31</b>
2.6	Integral modelling of CO <sub>2</sub> pipeline outflow and dispersion.....	10	8.1	Background.....	31
2.7	Flammability of hydrocarbon and CO <sub>2</sub> mixtures.....	11	8.2	Objectives .....	31
2.8	Experimental work at HSL .....	13	<b>9</b>	<b>PROGRESSIVE ENERGY PROJECT.....</b>	<b>32</b>
<b>3</b>	<b>CO<sub>2</sub>PIPEHAZ .....</b>	<b>18</b>	9.1	Background.....	32
3.1	Objectives .....	18	9.2	Objectives .....	32
3.2	Partners .....	18	9.3	Methodology .....	32
3.3	Dispersion modelling .....	19	9.4	Conclusions .....	32
3.4	Decision support.....	20	9.5	Impact .....	32
3.5	Conclusions .....	21	<b>10</b>	<b>RWE-NPOWER PROJECT .....</b>	<b>33</b>
3.6	Impact.....	22	10.1	Background.....	33
<b>4</b>	<b>COOLTRANS .....</b>	<b>23</b>	10.2	Objectives .....	33
4.1	Background.....	23	10.3	Methodology .....	33
4.2	Partners .....	23	10.4	Conclusions .....	33
4.3	Objectives .....	24	<b>11</b>	<b>CONCLUSIONS .....</b>	<b>34</b>
4.4	Model Evaluation Protocol (MEP).....	24	<b>12</b>	<b>REFERENCES .....</b>	<b>35</b>
4.5	Conclusions .....	25			
4.6	Impact.....	25			
<b>5</b>	<b>CO<sub>2</sub>PIPETRANS .....</b>	<b>26</b>			
5.1	Background.....	26			
5.2	Participants .....	26			
5.3	Methodology .....	26			
5.4	JIP progress.....	27			
5.5	HSE and HSL involvement .....	27			
5.6	Impact.....	27			

## Future directions?

- What are the main scientific research questions and knowledge gaps that need to be addressed to enable the safe adoption of CCUS ?
  - e.g. Ship transport – poor understanding of CO<sub>2</sub> releases onto water, no experimental data available?
  - e.g. Running ductile fractures in dense-phase CO<sub>2</sub> pipelines – experimental data shows models are non-conservative/unreliable
  - e.g. What lessons have been learnt from recent operational experience with CCUS, e.g. Boundary Dam, Sleipner
  - e.g. What is the current status of academic research in CCUS safety?



# Thank you

The contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy

# CO<sub>2</sub> Phase Diagram

