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COOLTRANS Research Programme

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Aim of presentation

- Provide an overview of the COOLTRANS dense phase Carbon Dioxide (CO_2) research programme
- Detail some key findings and the application of results to pipeline projects
- Outline the full scale experimental work being conducted

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COOLTRANS research programme

- National Grid has developed a detailed R&D programme for dense phase CO_2 transportation - called "***COOLTRANS***"
  - 3 year research programme - commenced January 2011 and completes in December 2013
  - Over 60% complete - learning to date is being applied to pipeline design
- The COOLTRANS R&D programme aims to address knowledge gaps relating to the safe design and operation of onshore, buried, pipelines for transporting anthropogenic, high pressure, dense phase CO_2
- The COOLTRANS strategy involves:
  - reviewing the work carried out in the 1970s and 1980s on natural gas and rich gas pipelines to extract learning points and relevant data
  - extending the learning and data for dense phase anthropogenic CO_2 using advanced analysis and validation tests
  - the application of research results

R&D work streams

- There are six main work streams in the research programme:

1. Thermodynamic characteristics of CO_2
2. Fracture control
3. Quantified Risk Assessment (QRA)
4. Pipeline design and integrity
5. Environmental and public perception studies
6. Application (of research findings)

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Management and organisation

Work stream	Involvement
Overall management	National Grid
Thermodynamic characteristics of dense phase CO_2	Nottingham University University College London (UCL) Leeds University Kingston University HSL GLND
Quantified Risk Analysis	Newcastle University GLND
Fracture Control	Newcastle University Atkins, PIE, Penspen
Design Studies	Newcastle University UCL GLND MACAW Engineering Limited PIE
Environmental and social studies	Nottingham University Manchester University, Tyndall Centre
Experimental Studies	GLND, Spadeadam

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Key findings and application

Key Finding	Application
CO_2 quality requirements specification	Needs to take due cognisance of hydraulic, safety and integrity requirements. Published specifications must be used with care as many do not consider all the above aspects
Fracture control	Pipe toughness levels for fracture arrest are (i) more onerous for lower operating pressures, higher operating temperatures, and (ii) need to be based on the CO_2 mixture saturation pressure. Wall thickness determines maximum saturation pressure for a pipeline and is greater than that required for 0.72 design factor
Design	Need for use of special materials and increased pipe wall thickness increases costs and requires techno-economic assessment
QRA	Toxic risk transects show low risk levels which extend for significant distances. QRA and pipeline routeing require societal risk assessment
Effect of CO_2 on plants and crops	No major environmental impact
The above requires changes to the standard design process and the criteria used to assess whether a design is acceptable	

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Full scale experimental test work

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Full scale experimental test work

- A comprehensive programme of full scale experimental tests is being conducted, in order to provide validation and demonstration data
- Scope was defined based on the knowledge generated during the original natural gas research programme and National Grid's pipeline operating experience
- Test programme includes investigations into below ground releases, simulated pipeline punctures at full scale, full scale fracture propagation tests

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Test programme

Test	Principal purpose	Number	Status
Shock tube tests	Obtain decompression data for pure CO_2 and mixtures as well as dispersion data.	33	Complete
Vent trials	Provide dispersion data for a range of vent arrangements	14	Complete
Puncture tests	Provide visual evidence of the behaviour of realistic releases from a buried pipeline by simulating external interference and corrosion	8	Complete
Cold gas release tests	Measure local pipe wall cooling around leaks of different geometries	4	Complete
Instrumented burst tests	Investigate the potential to generate a long running shear fracture in the full scale crack propagation test	3	Complete
Full scale crack propagation test	Demonstrate crack arrest in 914 mm diameter commercially available linepipe and validate the methodology for estimating crack arrest toughness	2	Complete
Underpressure welding trials	Carry out temperature decay tests during underpressure welding operations on pipe containing circulating dense phase CO_2	29	Complete
Rupture tests	Provide visual evidence of the behaviour of realistic releases (ruptures) from buried pipelines	4	Scheduled
Demonstration test	Demonstrate whether rupture by continuous brittle initiation can occur from a leak due to localised cooling	4	Scheduled

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Conclusions

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Conclusions

- The £8 million investment in the COOLTRANS research programme is providing the knowledge required for viable, safe and cost effective dense phase CO_2 pipelines
- The results are demonstrating complex interactions between key design parameters which require new design rules
- National Grid has developed a pipeline design process which uses and applies the key learning obtained from the COOLTRANS research programme
- The design process relies upon a CO_2 quality requirements specification which allows the assessment of corrosion and fracture control to be accounted for and uses a QRA methodology developed for dense phase CO_2 which is aligned with current pipeline design codes
- At the heart of the COOLTRANS research programme is an extensive and robust experimental programme (100+ tests)

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Any questions?