Pipeline Research Council International

PRCI CO_2 Task Force

Project ALT-1-6: Pipeline Transportation of CO_2 – SOTA Review, Gap Analysis and Future Project Roadmap

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DOE CO_2 Workshop: 21-23 February 2023

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CO_2 Task Force (TF) Creation and Vision

- **CO_2 transportation and storage is integral to achieving net zero by 2050**
- **Formed CO_2 TF with Shell, Williams, API and ExxonMobil in April 2022**
- **Vision: a CO_2 TF parallel to the existing PRCI Emerging Fuels Institute**
  - See PRCI as an integral organization in progressing the research and technology necessary to meet the challenge of transitioning to net zero
  - CO_2 Task Force expertise drawn from PRCI members and industry leaders
- **First project funded by CO_2 Task Force is the CO_2 Pipeline Transportation State of the Art Review, Gap Analysis and Future Roadmap (ALT-1-6)**
- **Contracted CSM-Rina for Project ALT-1-6: Three Focus Areas**
  1. Internal Corrosion
  2. Fracture Propagation
  3. CO_2 Safety and Dispersion

ALT-1-6 Time Schedule and Milestones

Project: TBD, Pipeline Transportation of CO2 (SOTA, Gap Analysis, Future Project Roadmap)

Contractor: RINA Consulting - Centro Sviluppo Materiali S.p.A.

Updated by: Gianluca Mannucci

As of: 07/29/2022

MS	Task	MS_Task	Task Name	working weeks 1–32
1	1	1_1	Project kickoff	
1	2	1_2	CO2 pipelines mapping	D1 17 March
2	1	2_1	Literature review	D2 5 May
2	2	2_2	Gap Analysis	D3 2 June
2	3	2_3	Roadmap	D4 30 June
2	4	2_4	Draft Report	DR 7 July
2	4	2_4	Draft Report review by PRCI	
2	5	2_5	Final Report	FR 04 August
2	5	2_5	Final Report approval by PRCI	

Deliverables:

- D1: CO_2 pipelines mapping document (Excel) : 17th March
- D2: Literature review document (PowerPoint) : 5th May
- D3: Gap Analysis document (PowerPoint) : 2nd June
- D4: Roadmap document (PowerPoint) : 30th June
- DR: Draft Report (Word), including an Excel spreadsheet with all the data collected in the project : 7th July
- FR: Final Report (Word), including and Excel spreadsheet with all the data collected in the project : 04th August

CO_2 Symposium:

- 7-8 March : PRCI Research Exchange - Houston
- 5-8 June : PRCI Emerging Fuels - Orlando

ALT-1-6 Tasks

Task 1 - Literature review

- Task 1.1 - Mapping of current CO_2 pipeline projects worldwide
- Task 1.2 - SOTA analysis of existing data
    - Corrosion
    - Fracture
    - Safety / Control Dispersion
    - Re-Purposing

Task 2 - Gap analysis of existing data

Task 3 - Roadmap proposing future R&D projects to address gaps

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Task 1.1 Literature Review:

Mapping of current CO_2 pipeline projects worldwide

- **Data on existing CO_2 pipeline projects worldwide will be collected**
- **Data will be analyzed and classified according to:**
  - Design characteristics
  - Geographical location
  - Purpose: Carbon Capture and Underground Storage, and Enhanced Oil Recovery
- **New CO_2 pipeline projects will also be included, both new construction and re-purposing of existing pipelines**
- **Data will be collected from the public domain and the internal know-how of the project team (respecting confidentiality agreements)**
- **Collected data will be made available to PRCI in electronic format via an Excel spreadsheet**

Task 1.2 SOTA Analysis of Existing Data:
Corrosion

- **CO_2 product specifications coming from different capture sources**
- **The effect of impurities (e.g. SO_X, NO_X) on water solubility, formation of acid species and corrosion of both line pipe and welds**
- **Review available models and published calculations for water solubility considering impurities**
- **Risk of water drop-out for different pipeline scenarios i.e., normal operation, shut-in, and during depressurization**
- **Other Corrosion related risks:**
  - Anodic SCC cracking due to CO_2 and impurity combinations e.g., CO_2-CO
  - Hydrogen embrittlement and cracking due to H_2S impurity in CO_2 pipelines.
  - Corrosion fatigue in CO_2 pipelines also considering impurities
  - Internal flow coating/painting detaching and blistering
- **Corrosion and stress corrosion testing methods and conditions**

Task 1.2 SOTA Analysis of Existing Data:

Fracture Control

- Existing data: full-scale fracture propagation tests, shock tube tests and laboratory-scale experimental data
- Effect of impurities on decompression behavior through the gas and liquid phases and on the saturation pressure
- Limitations of Battelle Two Curve Method (BTCM) and other codified methods for ductile fracture propagation control of new and re-purposed pipelines: including recent attempts to modify BTCM
- The existing numerical models (both coupled and un-coupled) for modelling fracture propagation and arrest (both FEA and Fluid Dynamic models)
- Consideration on low temperature embrittlement, during blow down or leakage, due to Joule Thomson cooling effect
- Consideration on Crack Arrestor design and effectiveness for CO_2 pipeline

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Task 1.2 SOTA Analysis of Existing Data:

HSE and Dispersion Analysis

- **Guidance on appropriate Equations of State (EoS) for specific hydraulic modelling and flow assurance purposes (and associated tools)**
- **Factors influencing public acceptance of CO_2 pipelines**
- **Considerations about emergency response planning**
- **Exposure levels for CO_2 (toxicity level, asphyxiation) including consideration of indoor vs. outdoor receptors (odorant injection will be also considered) and physiological impacts on receptor response**
- **Quantitative Risk Assessment (QRA) and dispersion modelling**
  - Atmospheric dispersion modeling to include impact of geographic terrain
  - CO_2 specific failure modes and release scenarios to include in consequence modelling
  - Potential effects of solids formation on release and dispersion modelling
  - Impact of potential running ductile failure on consequence modelling setup and results
  - Differentiate between gaseous, liquid, and supercritical services
- **Effective mitigation measures consideration: e.g., block valve stations, leak detection, pipeline protection, burial depth, blowdown, etc.**

Task 1.2 SOTA Analysis of Existing Data:
Repurposing

- **Codified methods for re-purposing, and similarities with life extension assessment considering the change in fluid**
- **Analysis of CO_2 pipeline safety performance using US DOT PHMSA and European Gas pipeline Incident data Group (EGIG) data**
- **Identify main failure modes to be addressed in more detail, with specific focus on existing pipeline, such as:**
  - Aged pipeline material
  - Poor original material data
  - Presence of internal corrosion
  - Presence of internal flow coating/painting
  - Low weldment quality
  - Complex routing situation

Task 1.2 SOTA Analysis of Existing Data:

Data/Information Sources

Main information and data sources

- Relevant specifications and recommended practices
- Published individual product specifications for recent or ongoing carbon capture projects
- Published joint industry project results and European financed projects
- National regulation, guidelines and initiatives (USA PHMSA, Canada, EU, Australia)
- Project Team internal know how and experience
- Conference proceedings e.g., NACE, ISOPE, OMAE, IPC et al.
- Academic journal publications
- Thermodynamic modelling software information
- Data and info from the public domain (website and institution reports, publications, etc.)
- Questionnaire sent to PRCI members

Task 2 Gap Analysis

- For each of the 4 technical areas previously identified (Corrosion, Fracture, HSE Dispersion, Repurposing), the range of the existing test data will be quantified, the gaps in the data will be identified as well, and the significance of the gaps will be assessed on a semi-quantitative basis in terms of R&D need, R&D type and associated effort

- DRAFT Example from Fracture Control

Area	Topic	R&D need	R&D type	Effort
Fracture	Running shear fracture control	Develop new predictive model	Modelling	Low-medium
			Lab scale testing	Low-medium
			Full scale testing	High

Task 3: Roadmapping

- **For each of the 4 technical areas previously identified (Corrosion, Fracture, HSE Dispersion, Repurposing), a roadmap including experimental and analytical work to address the identified gaps will be developed**
- **In particular, the following aspects will be addressed within the roadmap:**
  - Definition of main objectives
  - Defining of general requirements for materials to be tested e.g., material grade, welds
  - Providing recommendations for experimental test conditions or methods, including the general characteristics needed so that results relevant to the field situation can be obtained
  - Providing recommendations on any modelling work indicating any software requirements
  - Description of expected outcomes e.g., new knowledge items, specific recommendations and dissemination expectations e.g., standards modification or publications

Deliverables

- **Intermediate results will be provided to PRCI:**
  - D1: CO_2 pipelines mapping, in form of Excel spreadsheet.
  - D2: SOTA analysis of existing data, in form of PowerPoint presentation.
  - D3: Gap analysis of existing data, in form of PowerPoint presentation.
  - D4: Roadmap proposing future R&D projects to address gaps, in form of PowerPoint presentation
- **Monthly status reporting to PRCI in the form of PowerPoint presentation via web exchange**
- **At the end of the project, main deliverable will be a Final Technical Report containing description of all the activities carried out and results obtained for each Task.**
- **"Request for Proposals" will be created for key gaps identified, and will be open for Organizations to submit Project Proposals**

thank you

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