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Thematic Report

Transport Session May 2013

A report from the European CCS Demonstration Project Network

Public version

Proceedings from the Doncaster knowledge sharing event 20 and 21 May 2013

Introduction

This report presents the discussions, conclusions and actions agreed at the first thematic workshop on CO_2 transportation by the European CCS Demonstration Project Network, which was held at Doncaster, and hosted by the Don Valley Power Project (UK) on 20-21 May 2012. The workshop was one of three parallel tracks in the Network knowledge sharing event. The other thematic groups were Storage and Regulatory development.

All relevant member projects were represented, including: Don Valley (UK – 2CO and National Grid), ROAD (NL), Compostilla (ES – Ciuden and Endessa), and Porto Tolle (IT).

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CO_2 Specification

An overview of National Grid's approach to the Humber (Don Valley)

The session was introduced by National Grid regarding the Don Valley project. The primary message conveyed was that certain impurities had a large impact on the transportation of CO_2, and should be carefully considered.

The specifications for the CO_2 composition that National Grid has provisionally set are based on the consideration of a number of elements, including:

1. Safety,
2. Hydraulic efficiency,
3. Integrity / fracture control of the pipeline.

There is a view that there is insufficient operational data at the moment (despite experiences in North America, which primarily carries natural CO_2) and that there are no suitable databases regarding CO_2 pipeline failure rates. The limits that have been set (see table 1 below) are therefore felt to be appropriate at this stage, and will be revised as operational experiences are gained.

Dynamis has been used by National Grid to define the primary specifications for the CO_2 composition, but required some amendments. As SINTEF's CO_2 quality recommendations are based on pure CO_2, it was felt that further work will be required to consider the impact of impurities. In particular, it was considered that there were two primary impurities that needed to be tightly limited:

- water content to limit corrosion rates,
- hydrogen due to its impact on fracture control.

These elements have been extensively discussed with the CO_2 producer, including design decisions such as cooling the CO_2 at the power plant, as higher temperatures may limit non-condensables (sometimes dramatically).

Peng-Robinson has been found to be the most practical equation of state (EoS) to use. Results from the University of Nottingham showed that European Gas Research Group (GERG)'s EoS was not applicable to CCS. Others, such as Span-Wagner, have been considered, but which are time consuming to use.

Pigging rates will be determined by the corrosion rates, possibly every 5-10 years, and after an event.

Published specifications must be used with care as many do not consider all of the impacts of impurities within the CO_2 stream. Quality requirements should seek to 'engineer out' potential problems, while allowing for favourable storage conditions and a variety of capture technologies.

An overview of Enel's approach *(Porto Tolle)*

The Porto Tolle project is in the process of concluding its basic engineering study for the transport elements of the project, which will be finalised in June of this year.

Based on the proposed amine post-combustion stripping process that will be employed at the project, and is currently being demonstrated at Brindisi, a very pure stream of CO_2 is expected (99.6%). It is anticipated that a dryer will be required to reach the required water concentration of 100 ppm, which was deemed to be sufficient to stop free water. There will not be investigations regarding the oxygen content, which is expected to be around 0.4%.

Like National Grid, the Peng-Robinson EoS has been used.

Summary of the CO_2 specifications and discussions

The Dynamis recommendations were initially used by National Grid and Endesa to define the specifications for the CO_2 composition, however, with some amendments.

Critical components were identified:

- H_2O : risk of corrosion and hydrate formation,
- H_2S : avoid qualification as sour services,
- H_2 : risk of fracture and impact on cricondenbar,
- O_2 : risk of corrosion (and oxidation in EOR).

A wide variation of minimum CO2 concentrations was set (Table 1). National Grid set a specific maximum level on the H2 concentration (< 2%).

The statement was made that with respect to the water concentration, the requirement was to be set as high as reasonably practical. However, the dehydration step used in almost all projects meant that strict requirements could be set. One opinion is that much higher concentrations could possibly be allowed (and might even be preferential based on experience at Statoil/Snøhvit). In experiments made by Endesa corrosion was measured at concentrations of 500 ppmv H_2O (although those experiments could not yet be presented, so no exact conditions are known). Furthermore, National Grid made the observation that at Weyburn the allowed concentration of H2O is 20 ppmv. The specified water content for each of the demonstration projects is listed in Table 2.

Almost all parties would like to see improvements in the equation of state (EoS) modeling in case of impurities. The water saturation concentration in CO_2 in case of impurities was considered to remain a big unknown.

Table 1: Minimum CO_2 concentration.

Project	CO_2 concentration [% mole]	Plant characteristics
Don Valley	91% (gas phase) 96% (dense phase)	IGCC
ROAD		Post combustion
Compostilla	> 96 %	Oxy combustion
Porto Tolle	> 99.6 %	Post combustion

Table 2: Maximum water concentration

Project	Water concentration
Don Valley	50 ppmv
ROAD	50 ppmv
Compostilla	10 ppmv
Porto Tolle	100 ppmv

Specific issues discussed:

- *Particulates*. ROAD uses a 1μm sieve onshore to remove particulates. The pressure drop over the sieve is approximately 1 bar. A discussion was started if internal coatings could give particulates. ROAD is not using coating within the pipe. Endesa representative gave reference to US expertise saying that coating does not work well with liquid CO_2.
- *Equation of State*. National Grid reported to have reasonable experiences with Peng-Robinson equation of state (PR) and some less with that of the European Gas Research Group (GERG).
- *Flow metering*. This is introduced as a discussion item for the next Knowledge Sharing Event.

Combined session with the storage group: Flow assurance and designing a long-term injection operation

The following session was held in conjunction with the Storage group. For more information, please see the public report (the following is a summary version).

Designing a high pressure injection system *(Don Valley)*

In this session the main metrics of the Don Valley project's transport and storage system were presented: the export pressure may reach 250 bar and 15°C. Over the 335-360 km long pipeline the tail-end pressure drops to 100 bar (lowest pressure in the system) and the temperature will be typically 4-7°C (approaching the sea-bed temperature). The flow rate is 245-490 kg/s.

For EOR the concentration of water after the wellhead may be higher than in the pipeline because of recirculation of CO_2 split from the produced oil. Hence, chemicals are used to avoid corrosion rather than using advanced alloys.

The bottom-hole pressure is 485 bar and the temperature is within the range 125-140°C at 3200m depth. 6-12 injectors are used, and there are 9-25 producers and 42 slots.

Hydrates are prone to occur in the presence of CO_2, methane and free water, depending however on concentrations as well as pressure and temperature.

Technically, the CO_2 injection system is designed for 99.5% availability, ensured by selecting 4 pumps, each with 50% capacity (alternatively by having 3 pumps with 50% capacity, or 2 pumps with 100% capacity). This availability does not take into consideration the availability of the power plant, which will always be shut down in the summer season.

It is assumed that 5 Mtpa of CO_2 is feasible within the EOR concept.

The produced oil may contain an allowable amount of 0.5% of dissolved CO_2.

With IGCC, there is a risk of hydrogen cracking that must be considered carefully. For this reason, the level of hydrogen will be rather low – in the order of a few ppm.

Designing a low pressure injection system *(ROAD)*

A flow assurance study of the ROAD project was presented. The offshore storage is designed to inject the CO_2 at subcritical pressure at the outset (i.e. 20-300 bar at 3500 meter in a closed depleted gas reservoir). Efforts have been made to avoid heating on the platform. A 16 inch 25 km long insulated pipeline is used. The maximum pressure is 129 bar, and the normal operation range is 80-100 bar depending on the back-pressure which will gradually increase as CO_2 is injected into the reservoir.

Injection strategies; liquid vs. super-critical CO_2 injection *(Compostilla)*

A study was presented on injecting either liquid or dense CO_2. The main conclusion is that owing to the lower temperature of the liquid CO2, the reservoir may be less vulnerable to the injected CO_2. This may possibly have an impact on reservoirs with thin cap rocks.

Compostilla Phase I

With an injection rate of 1.4 Mtpa over 30 years, the required capacity is 42 Mt of CO_2.

Due to the planned operation of the power station, the time-wise availability will be only 64%. This intermittent operation is bad for the reservoir.

Although Compostilla is an oxy-combustion plant, H_2S is taken into consideration because alternative CO_2 sources may be connected to the CO_2 transport and storage system at a later stage.

The saline formation is an open reservoir that can take large amounts of CO_2 without pressure build-up. Hence, it is not required to release water from the formation.

Thematic Discussion: Dispersion from leakage

In this session the discussion went wider than only the dispersion of CO_2. Also other aspects of the qualitative risk assessment (QRA) were covered.

ROAD

- Probit methodology has been used by the project.
- Ship lane crossing (5m depth).
- No isolation valves.
- No leakage detection.
- Chance of rupture (anchor) is considered very low.
- Total failure frequency : 1.47e-4 $km^{-1}yr^{-1}$ (onshore), 5.1e-5 $km^{-1}yr^{-1}$ (off shore).

Compostilla

- Probit methodology has been used by the project.
- Valve stations separated from each other (10 – 30 km).
- Worse case scenario is for a horizontal outflow at low air velocities.

Public data of previous CO_2 release experiments is available to the modelling community and can be found on DNV site:
http://www.dnv.com/industry/energy/segments/carbon_capture_storage/recommended_practice_guidelines/co2pipetrans/index.asp

Don Valley

There was a presentation regarding the outcome of a number of CO_2 venting trials.

Analytical approach/modelling was carried out in collaboration with a number of partners. University College London (UCL) was involved in work regarding outflow from release; University of Leeds undertook work regarding near field dispersion; and Kingston University worked on far-field dispersion. A number of results from this work was shared with the group, and some general conclusions made:

- No large solid formation raining out in plume. Some solid formation, but these evaporate fast.
- In case of venting, also the main piping is subjected to low temperatures. This must be evaluated in the procedures.
- In experiments no liquid CO_2 was observed in crater formed due to jet.
- National grid puts a minimum of 15m between two pipelines.
- The white cloud at a leak/rupture is very visible. This is a good warning (although nowadays people are more attracted to disasters to make photographs and video recordings with their mobile phones, rather than running away).
- Worst case scenario: not too low air velocities.
- CO_2 from the vertical blast was recognizable up to 200 meters above the ground.

General observations

Specific issues that were discussed by the group, included:

- Dry ice. National Grid indicated that at full scale tests, minimal dry ice was formed.
- Noise. National Grid indicated that at rupture, similar noise levels were measured for natural gas as for CO_2.
- CO_2 absorption in sea water. Only negligible amounts of the CO_2 will be dissolved.
- Distance to wind turbines. National grid used a minimum distance to a wind turbine of 1.5 times the mast height.

- Uncertainty in evaluating influence neighbouring pipelines in trench. National Grid indicated that in a crater no liquid CO_2 would remain.

The European CCS Demonstration Project Network was established in 2009 by the European Commission to accelerate the deployment of safe, large-scale and commercially viable CCS projects. The Network that has been formed is a community of leading demonstration projects which is committed to sharing knowledge and experiences, and is united towards the goal of achieving safe and CCS. The learnings that are gained will be disseminated to other projects, stakeholders and public to help gain acceptance of the technology –and support CCS to achieve its full potential as a vital technique in our fight against climate change.

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