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To cite this version:

Maximillian Gorensek, Luther Hamm, Gerald Blount, Christophe Kervévan, Kathleen O 'Neil. CO2-DISSOLVED and Aqueous Gas Separation. 13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, Nov 2016, Lausanne, Switzerland. hal-01337657

HAL Id: hal-01337657

https://brgm.hal.science/hal-01337657

Submitted on 27 Jun 2016

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CO_2-DISSOLVED and Aqueous Gas Separation

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Abstract

CO_2-DISSOLVED (Kervévan et al, 2014) is a multi-national project funded by the French National Research Agency (ANR) with Phase II funded as one of the first Geodenergies projects. Geodenergies is a French industry-driven initiative grouping 18 companies and research organizations aiming at: (1) structuring a community of expertise to promote subsurface energy technologies that are key to a global energy transition; (2) cross-fertilizing to develop 3 emerging industrial sectors: geothermal energy production, underground CO_2, and energy storage.

As the name "CO_2-DISSOLVED" implies, the project focuses on the feasibility of the injection of dissolved CO_2 in water, as opposed to supercritical CO_2 injection. In this, and drawing from a process originally developed at a US Department of Energy (DOE) laboratory, Partnering in Innovation, Inc. (Pi-Innovation) offers a novel aqueous gas separation and carbon capture approach. Specific features in the design uniquely integrate multiple energy recovery processes and the potential for contaminant removal (i.e., oxides of sulphur (SOx), nitrogen (NOx), selenium (SeOx), and mercury (HgOx). CO_2-DISSOLVED uses a simplified version of this approach but here we present the process modelling results and testing design for the full gas separation technology.

A plethora of carbon capture technologies have emerged over the past decade. Most rely on chemical solvents, absorbents, or adsorbents. We offer an innovative capture approach that uses a readily available, carbon-neutral, non-hazardous substance (i.e., water) as a physical solvent (Blount et al, 2014). Building from fundamental principles in chemistry, this patented process preferentially dissolves and separates gases across a high pressure gradient. The design specifics support both pressure and heat energy recovery, resulting in a substantial offset of parasitic energy costs.

The Phase II Geodenergies project proposes prototype construction and lab to bench scale demonstration of the technology. The thermodynamic feasibility of the fully integrated system has been modelled in Aspen-Plus™. A customized Thermal-Hydraulic Drift-Flux model was developed to test and optimize the mass transfer, equilibrium, and successive stages of CO_2 concentration. The models, and subsequent independent review, confirm the thermodynamic feasibility, high capture rates (>96%), and highly efficient mass transfer (high product purity). The results indicate that the heat and energy recovery actually result in net excess offset of power and steam (including product compression to pipeline pressures) and net CO_2 reduction of >85%.

In an interesting innovation, the system includes a patented multi-stage cascading absorber suspended in a deep column of water (creating a hydrostatic pressure gradient). There are no moving parts in the submersed absorber system. Water circulation is driven by gas-lift pumping where the effervescing gas is balanced by high pressure emission gas injection, setting up a self-maintaining circulation system.

The use of waste heat from both flue gas and CO_2 product compression represents a significant supplement to the heat from natural gas and also supports sufficient energy for glycol regeneration (product dewatering system). The overall turbo-machinery train (gas compression linked to expander turbines via gearing) is similar to a Compressed Air Energy Storage (CAES) system in concept.

The models, reflecting a consistent base case analysis, were used in a sensitivity analysis and initial design optimization. The process is applicable to post-combustion emission sources and to gas separation in natural gas production and purification operations. Overall, the patented approach is proving to be a fundamentally different, highly efficient, gas separation and capture system potentially capable of reducing the cost, parasitic energy, material, and scaling limitations inherent in current state-of-the-art systems.