An efficient injection concept for CO_2 geological storage

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INTRODUCTION

CO_2 geological storage is based on the injection of supercritical CO_2 into a deep permeable formation. Supercritical CO_2 is less dense than the resident brine, so it will tend to float and escape from the aquifer. To prevent this, the storage sites require a suitable geological formation of very low permeability and high entry pressure to acts as a seal. One of the problems of the supercritical CO_2 injection is the low storage capacity. Space to be occupied by the CO_2 is obtained basically by: (1) compressing the fluids and expanding the pores of the aquifer, which increases fluid pressure and, thus, the energy cost of the injection and may impact the caprock stability; and (2) displacing the resident water of the aquifer, which in the mid-term could lead to the contamination of freshwater bodies (groundwater and/or surface waters) around the site. In the long-term the CO_2 dissolves into the brine of the aquifer and the above risks vanish, but the time needed for this to occur is uncertain and may be too long. There are still several unresolved problems related to the conventional CO_2 injection: large local pressures, displacement of the resident brine, caprock failure and risks of CO_2 leakage to biosphere.

THE CONCEPT

The concept presented here is intended to reduce the cost of injection. During the injection of carbon dioxide, the fluid within the tubing is likely to be in a dense state and therefore its weight within the wellbore will play an important role in determining the required pressure at the well head for a given CO2 injection rate. The basic idea we propose consists of increasing the density of CO_2 along the entire wellbore by injecting in liquid-phase.

PERSPECTIVES OF IMPLEMENTATION AND ENERGETIC ASSESSMENT

Thermodynamic conditions determine if a phase transition may occur from gaseous to liquid and/or supercritical, and vice versa. Some authors have formulated numerical procedures to evaluate the flow of carbon dioxide and its mixtures in non-isothermal wells (Lu and Connell, 2008; Paterson et al., 2008; Pan et al., 2009; Han et al., 2010). These procedures solve the coupled heat, mass and momentum equations with the various fluid and thermodynamic properties, including the saturation pressure of the gas mixture calculated using a real gas equation of state. Although the processes occurring in the injection well are well known and established, currently there are still some issues that remain not solved or well understood. It is necessary to study, for instance, the different mechanisms that cause the phase transitions experimented by the CO_2 as it flows through the well, and the multiphase flow patterns involved in this phenomenon. In addition, it is crucial to develop accurate calculations of the heating-cooling processes experimented by the fluid, because they will affect the dissolution of CO_2 and/or other species in the mixing zone of the well. Also, a proper description of the compression-expansion work has to be addressed in the energetic balance in order to optimize the well operation.

In order to assess the feasibility and the energetic cost of the proposed injection concept, we run some simulations of non-isothermal flow of CO_2 through an injection well with the phenomena of non-isothermal multiphase flow in the reservoir through the boundary condition at the well bottom. Different operational conditions at the wellhead were considered; we compared CO_2 injection in gas, supercritical and liquid-phase. Also, we made a sensitivity analysis on the thermal properties of the casing and the cement to study the effect of heat exchange between the wellbore and its surroundings. Results show that it is possible to inject CO_2 in dense liquid-phase by controlling the operational variables, which leads to a reduction of the reservoir overpressure and the operational energetic costs. Theoretically, the energetic cost per kg of injected CO_2 is lower than when injecting gas and supercritical CO_2. The system benefits from gravity forces due to higher CO_2 density. Although relatively simple as a concept, the implementation of the operation may require a thoroughly design of compression and refrigeration systems to get the injection conditions. In addition, the system is relatively easy to control. Direct control variables are the injection temperature and pressure. But also the system might be indirectly controlled by a suitable design of the cement to promote the heat transfer between the pipe and the surroundings ensuring the fluid will be in liquid-phase of CO_2 along the entire injection pipe.

The results of this work may contribute to the optimization of the current CO_2 injection operations and the proposal of new injection strategies. Also, the methodology considered here can address an important issue associated with the subsurface CO_2 sequestration plans for several test sites, which practically cannot be examined by other means. This issue is the simulation of what-if scenarios to assist planning and design of injection experiments and future CO_2 injection-storage operations at industrial scale.

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