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CO2 – Storage in Salt Caverns

Thermodynamic Analysis and Challenges

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Abstract

In the transition to renewable energies, the focus of the industry lies mainly on hydrogen as a crucial energy carrier in a future energy system. Despite all decarbonization measures, complete avoidance of CO_2 emissions, especially in industries without alternative processes, products and resources, will not be possible. To ensure economically friendly processes in these sectors as well, the introduction of a "CO_2 circular economy" is necessary. This circular economy includes the carbon sequestration, either from industrial processes or from the atmosphere, the CO_2-transport and the further usage of the CO_2, for example in the chemical industry. To guarantee a continuous and reliable supply for CO_2 processing plants, the storage of CO_2 is indispensable. Due to their high safety, high flexibility and extensive experience with other products, storage in salt caverns is of particular interest.

To achieve an economical and safe operation, the analysis of the thermodynamic behavior of CO_2 during cavern operations is essential. For this investigation, the description of the physical and thermodynamic properties of CO_2 under conditions prevailing in salt caverns is necessary, since these differ fundamentally from common storage media like oil or natural gas.

In particular, the phase behavior of CO_2 is to be emphasized here. Under atmospheric conditions, CO_2 is present in a gaseous state. Under higher pressures and temperatures CO_2 can also be present in a multiphase state with liquid and gaseous phase, in a liquid (single-phase) or in a supercritical state. The supercritical state describes a state in which the medium has a density close to liquids and a viscosity similar to gases. CO_2 enters the supercritical state if pressures above 7.38 MPa (1,070 psi) and temperatures above 31.1 °C (88.0 °F) are reached. These pressures are to be expected under in situ conditions in a cavern and a cavern well.

The aim of the present paper is to qualitatively describe the phase behavior and phase transitions of CO_2 in the cavern system, its influences on storage operations, to highlight differences to storage operations with natural gas and to identify further necessary research topics.

For this purpose, a preliminary numerical thermodynamic simulation for a typical cavern in Mid-Europe was carried out for CO_2 and natural gas. The modelling results show that the effects during storage operations differ substantially between CO_2 and natural gas and that a direct comparability between CO_2 and natural gas with regard to cavern operations is difficult. The phase transitions for CO_2 pose challenges in particular for the monitoring of the cavern system.

Key words: Salt Caverns, Storage Cavern, Carbon Dioxide, CO_2 Storage, Thermodynamics, Phase Behavior, Carbon Capture, Supercritical CO_2