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Methane Production from Natural Gas Hydrates by Flue Gas Injection under Permafrost Conditions

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Abstract

Natural gas hydrate (NGH) reservoirs are found in cold permafrost and deep ocean sediments under high pressure and low-temperature conditions. Methane recovery from hydrate deposits depends on the characteristics of the porous medium as well as the production method. CO₂ rich gas (such as flue gas) injection into NGH is considered an innovative production technique for methane recovery with simultaneous capture of CO₂. Permafrost gas hydrate deposits are different from marine gas hydrate deposits due to the presence of an ice layer above the hydrate, and the so-called “self-preservation” mechanism of the hydrate. Methane production from permafrost could be preferable to marine hydrate recovery due to the lower technical and economic barrier. In this work, instant depressurization followed by CO₂ rich gas injection is applied to improve diffusion channels and initiate in-situ swapping of trapped methane in hydrate with a mixture of CO₂/N₂. The study aims to investigate the dependence of methane production on the nature of the porous medium in the permafrost region and methane hydrate self-preservation effect.

We quantitatively investigated the methane recovery from this combined method in different artificial methane hydrate-bearing porous media. To shorten the experimental time and to generate similar P-T conditions, a specially designed core flooding setup is used which can run three core flooding experiment in parallel. 15 experimental runs are performed to study the methane production after CO₂ rich gas injection. Key variables studied are the effect of change in porous medium, temperature change and change in CO₂ concentration in the injected flue gas. Porous medium used in this study includes different sand with different average particle size (0.27mm, 0.36mm, 0.44mm) and benthemier sandstone. Temperature is changed between 269.15 -274.15K to represent permafrost conditions and CO₂% concentration varied between 10% to 30% mole in CO₂/N₂ mixture.

The Initial experiments result demonstrated that methane recovery in permafrost region is dependent on temperature and average sand particle sizes. The combined method generates higher methane recovery from 20% to 34% after 120 hours, as the average sand particle size increases. Methane hydrate’s self-preservation mechanism weakens with the increase in average particle size, thus contributing to additional methane recovery. Sandstone showed weaker self-preservation effect compared to unconsolidated sand. Gas chromatography analysis coupled with mass balance indicates that high CO₂% with N₂ allowed additional methane recovery due to an increase in driving force. Overall, results from the study provide an improved understanding of potential recovery of methane gas from permafrost using flue gas injection.

Keywords: Natural Gas Hydrate, Permafrost, Gas injection, Self-preservation, Hydrate swapping