

# Experimental Investigation of Methane Hydrate Reformation Under Dissociation Process

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**Methane hydrate reformation was analyzed experimentally under the dissociation process. The authors investigated how the temperature and salinity of injected brine, and a hot-brine injection coupled with depressurization, affect methane hydrate reformation during dissociation. An experimental apparatus was constructed to dissociate the hydrate, which was to inject hot brine into an artificial hydrate-bearing sand column. The hydrate reformation could be recognized by observing a sharp increase of internal pressure. The salinity of hot brine was an effective factor in preventing hydrate reformation, while the temperature of hot brine played a minor role in the range of this study. The hot-brine injection that followed depressurization was more effective in inhibiting the hydrate reformation than the inverse case.**

## INTRODUCTION

Methane hydrate, one of the gas clathrates, is composed of water molecules forming a rigid lattice of cages with most of the cages each containing methane molecules. It has been expected to become one of the alternative energy resources, but is currently considered unconventional.

The environment found in both deep oceanic and permafrost regions can promote the formation of gas hydrates, where the condition of low temperature and high pressure prevails. As of now, the production methods are not commercialized but based on in-situ dissociation of the hydrate into gas and water phases. The conceptual models of dissociation are divided into heat stimulation, depressurization, inhibitor injection, and any combination of these. The effectiveness of hot-brine injection, the association of heat, and salt as an inhibitor have been experimentally investigated (Kamath and Godbole, 1987; Kamath et al., 1991; Tang et al., 2005). The continuous injection of hot brine is essential to be efficient. However, if additional hydrate growth (i.e. the hydrate reformation) occurs due to a recombination of water and dissociated methane during continuous injection, the efficiency would decrease.

Several experimental works have reported a reformation mechanism of methane hydrate (Kawamura et al., 2006; Sakamoto et al., 2007a; Sakamoto et al., 2007b; Kawamura et al., 2008). Sakamoto et al. (2007a, b) analyzed the methane hydrate dissociation by hot-water injection according to the temperature of injected water, reservoir pressure and hydrate saturation, and they explained a mechanism of the hydrate reformation in a laboratory-scale experiment. They showed that the movement speed of the dissociation

front increased with the high-temperature conditions, decreasing reservoir pressure, and decreasing hydrate saturation, and they emphasized the importance of the hydrate reformation for a more favorable matching of experimental data. Kawamura et al. (2006, 2008) investigated the efficiency of an aqueous methanol solution as an inhibitor of the hydrate dissociation, and they suggested that it could effectively prevent the hydrate reformation and contribute to the maintenance of high permeability.

Previous works have concentrated on characterizing the efficiency and the phenomena of dissociation (Kamata et al., 2005; Tang et al., 2005; Sakamoto et al., 2007a), while this paper focuses on the methodology with which to reduce the hydrate reformation. The authors analyzed the influence of temperature and salinity in the hot-brine injection to prevent the hydrate reformation. The methodological sequence that coupled the hot-brine injection with the depressurization was examined as well.

## EXPERIMENTAL PROCEDURE

### Experimental Apparatus

An experimental apparatus to demonstrate the dissociation process of the hydrate was constructed; Sakamoto et al. (2007a) were the motivators of the idea. Fig. 1 illustrated the schematic diagram of the experimental apparatus.

The 590-mm-long pressure vessel was made of stainless steel, with a 70-mm internal diameter. The vessel was divided into 12 blocks in the direction of the axis; 4 thermoelectric modules were set up around each block to control the vessel's temperature. The given temperature was maintained in a whole pressure vessel to form the hydrate in the sand column, while the different temperatures were set at each block to dissociate it. This was to simulate the idealized heat transfer in a 1-dimensional system. Two thermocouples were inserted into each block to measure the sample's inner and outer temperatures.

The other parts of the apparatus were intended to control the fluid injection and the production, and to acquire the data, respec-

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