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Strategies for Gas Production From Oceanic Class 3 Hydrate Accumulations

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Abstract

Gas hydrates are solid crystalline compounds in which gas molecules are lodged within the lattices of ice crystals. Vast amounts of CH₄ are trapped in hydrates, and a significant effort has recently begun to evaluate hydrate deposits as a potential energy source. Class 3 hydrate deposits are characterized by an isolated Hydrate-Bearing Layer (HBL) that is not in contact with any hydrate-free zone of mobile fluids. The base of the HBL in Class 3 deposits may occur at the edge of, or within, the zone of thermodynamic hydrate stability.

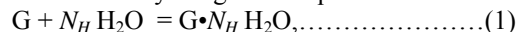
Depressurization may be used in deposits with low hydrate saturation (usually <50%) and higher intrinsic permeability, while thermal stimulation may be a viable option in deposits with high hydrate saturation in formations with low intrinsic permeability. In this numerical study of long-term gas production from typical representatives of unfractured Class 3 deposits, we determine that (a) simple thermal stimulation appears to be an inefficient production method, and (b) depressurization under constant-rate fluid withdrawal is superior to pure thermal stimulation, but suffers from low production rates (< 50 MSCFD). However, an alternative approach involving a staged application of depressurization (constant pressure or constant-rate) and thermal stimulation can lead to very large volumes of hydrate-originating gas that are produced at high rates (> 15 MMSCFD) for long times using conventional technology. Gas production from hydrates is accompanied by a significant production of fresh water. However, the water production rate declines with time, and the disposal of the hydrate-originating water may not pose significant environmental problems because of its superior quality and the oceanic environment.

The simulation results indicate that gas production from oceanic Class 3 deposits is affected by the initial pressure, temperature and hydrate saturation, and by the intrinsic permeability of the HBL. Additionally, gas production by means of thermal stimulation is affected by the rate of heat addition, while depressurization-induced production is affected by the

fluid withdrawal rate and the design of the constant-pressure regime imposed at the well.

Introduction

Background. Gas hydrates are solid crystalline compounds in which gas molecules (referred to as guests) are lodged within the lattices of crystals (called hosts). Under suitable conditions of low temperature T and high pressure P , the hydration reaction of a gas G is described by the general equation



where N_H is the hydration number. Natural hydrates in geological systems involve hydrocarbons (mainly CH₄, as well as other alkanes), and may also include CO₂, H₂S and N₂ as guests. Hydrate deposits occur in two distinctly different geologic settings where the necessary conditions of low T and high P exist for their formation and stability: in the permafrost and in deep ocean sediments.

Although there has been no systematic effort to map and evaluate this resource and current estimates vary widely^{1,2,3} (ranging between 10¹⁵ to 10¹⁸ m³), the consensus is that the worldwide quantity of hydrocarbon gas hydrates is vast. Even the most conservative estimate exceeds by a factor of two the total energy content of the known conventional fossil fuel resources. Given the sheer magnitude of their quantities, ever-increasing global energy demand, and dwindling conventional fossil fuel reserves, hydrates are emerging as a promising energy source^{4,5} even if a limited number of deposits may be suitable for production and/or only a fraction of the trapped gas may be recoverable. The attractiveness of hydrates is further enhanced by the environmental desirability of gas (as opposed to solid or liquid) fuels. Thus, the production potential of hydrate accumulations as hydrocarbon gas sources clearly demands technical and economic evaluation.

Classification of hydrate deposits. Natural hydrate accumulations are divided into three main classes.^{6,7} Class 1 accumulations are composed of two layers: the Hydrate-Bearing Layer (hereafter referred to as HBL) and an underlying two-phase fluid zone with free (mobile) gas. In this class, the bottom of the hydrate stability zone (i.e., the location above which hydrates are stable because of thermodynamically favorable P and T conditions) coincides with the bottom of the hydrate interval. Production from such deposits was discussed in detail by *Moridis et al.*⁷

Class 2 deposits comprise two zones: (1) an HBL, overlying (2) a zone of mobile water (hereafter referred to as WZ). Class 3 accumulations are composed of a single zone, the hydrate interval (HBL), and are characterized by the absence of