



OTC 18866

# Gas Production From Oceanic Class 2 Hydrate Accumulations

George J. Moridis, SPE, and Matthew T. Reagan, Lawrence Berkeley Natl. Laboratory

Copyright 2007, Offshore Technology Conference

This paper was prepared for presentation at the 2007 Offshore Technology Conference held in Houston, Texas, U.S.A., 30 April–3 May 2007.

This paper was selected for presentation by an OTC Program Committee following review of information contained in an abstract submitted by the author(s). Contents of the paper, as presented, have not been reviewed by the Offshore Technology Conference and are subject to correction by the author(s). The material, as presented, does not necessarily reflect any position of the Offshore Technology Conference, its officers, or members. Papers presented at OTC are subject to publication review by Sponsor Society Committees of the Offshore Technology Conference. Electronic reproduction, distribution, or storage of any part of this paper for commercial purposes without the written consent of the Offshore Technology Conference is prohibited. Permission to reproduce in print is restricted to an abstract of not more than 300 words; illustrations may not be copied. The abstract must contain conspicuous acknowledgment of where and by whom the paper was presented. Write Librarian, OTC, P.O. Box 833836, Richardson, TX 75083-3836, U.S.A., fax 01-972-952-9435.

## Abstract

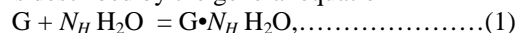
Gas hydrates are solid crystalline compounds in which gas molecules are lodged within the lattices of ice crystals. The vast amounts of hydrocarbon gases that are trapped in hydrate deposits in the permafrost and in deep ocean sediments may constitute a promising energy source.

Class 2 hydrate deposits are characterized by a Hydrate-Bearing Layer (HBL) underlain by a saturated zone of mobile water. In this numerical study we determine that gas can be produced at high rates (several MMSCFD) from hydrate deposits for long times using a single vertical well and conventional technology. The production strategy involves a cyclic approach, with each cycle composed of two stages. The first stage involves depressurization-induced gas production, lasts one to two years, and proceeds until secondary hydrate formation in the vicinity of the wellbore drastically reduces the well pressure. The second stage involves destruction of the secondary hydrate near the wellbore by thermal stimulation or inhibitor injection, and lasts less than a month. The presence of salt in oceanic HBL enhances hydrate dissociation, but the effect is weakened by the release of fresh water. Gas production from Class 2 hydrate accumulations continuously increases over time during each cycle, while the corresponding water production continuously decreases.

The simulation results indicate that gas production is affected by (a) the intrinsic permeability, (b) the initial pressure, temperature and hydrate saturation, (c) the fluid withdrawal rate, (d) the thickness of the water zone, and (f) the permeability of the confining boundaries. The effect of these parameters and conditions on gas production is not uniform over time, and requires the definition of the time frame before conclusions can be stated. Fine discretization in the vicinity of the wellbore is very important for the description of the evolving flow-controlling secondary hydrate accumulations, and of the corresponding dynamic phase changes.

## 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  $CH_4$ , as well as other alkanes), and may also include  $CO_2$ ,  $H_2S$  and  $N_2$  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<sup>1,2,3</sup> (ranging between  $10^{15}$  to  $10^{18}$   $m^3$ ), 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, the ever increasing global energy demand and the dwindling conventional fossil fuel reserves, hydrates are emerging as a potential energy source<sup>4,5</sup> 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 and liquid) fuels. Thus, the production potential of hydrate accumulations as hydrocarbon gas sources clearly demands technical and economic evaluation.

Gas from hydrates can be produced by inducing dissociation, which also releases large amounts of  $H_2O$  (Eq. 1). The three main methods of hydrate dissociation are<sup>6</sup>: (1) depressurization, in which the pressure  $P$  is lowered to a level lower than the hydration pressure  $P_e$  at the prevailing temperature  $T$ , (2) thermal stimulation, in which  $T$  is raised above the hydration temperature  $T_e$  at the prevailing  $P$ , and (3) the use of inhibitors (such as salts and alcohols), which causes a shift in the  $P_e$ - $T_e$  equilibrium through competition with the hydrate for guest and host molecules.

**Classification of hydrate deposits.** Natural hydrate accumulations are divided into three main classes<sup>7,8</sup>. 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 fa-