Quarterly Progress Report
(July – September 2007)

Comparative Assessment of Advanced Gas Hydrate Production Methods

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Prepared for:
United States Department of Energy
National Energy Technology Laboratory

October 31, 2007
Executive Summary

This project will compare and contrast, through numerical simulation, conventional and innovative approaches to producing methane from gas hydrate-bearing geologic reservoirs. Initially, the project will investigate the production of gas hydrates from idealized reservoir configurations. If the initial investigation shows promise for the innovative approaches, additional simulation studies will be conducted using actual gas hydrate reservoir data from the Alaska North Slope (ANS) region. Work this quarter focused on establishing a subcontract with the University of Alaska and in conducting additional production simulations in preparation for a Merit Review meeting.

Results of Work During Reporting Period

Phase I

Task 1: Project Management

A subcontract proposal was prepared and sent to the University of Alaska – Fairbanks to conduct their planned experimental work under Task 3. Battelle contracts is awaiting a response from the University before the subcontract can be issued.

A revision to the Research Management Plan will be issued next quarter to reflect changes in spending plan and schedule.

Task 2: Technology Status Assessment

This task was completed in the third quarter of this year with the submission of the summary report.

Task 3: Basic reservoir Simulation

The STOMP-HYD simulator was applied to a series of one- and two-dimensional simulations that investigated the production of CH₄ hydrates in geologic media using CO₂ injection. The petrophysical parameters for the simulations were based on those determined from the MDT flow and recovery tests in the C Unit of the Mount Elbert Well and the subsequent simulations of those experiments using STOMP-HYD. These simulations results were reported at the NETL Merit Review meeting in Golden, Colorado in September, 2007. Effectively there are two approaches to producing CH₄ hydrate in geologic media using CO₂ injection: 1) hydrate dissociation and reformation, and 2) direct molecular exchange. In the hydrate dissociation and reformation approach, the injected CO₂ first dissociates CH₄ hydrate. This stage is followed by reformation of a mixed gas hydrate, which is predominately comprises
CO₂. In the direct molecular exchange approach, the injected CO₂ exchanges with the CH₄ in the hydrate structure, maintaining the hydrate integrity. The dissociation-reformation approach has the advantage of releasing CH₄ in both the small and large cages. In the direct-exchange approach only the CH₄ in the large cages is released. Co-injection of CO₂ and N₂ has been shown to allow molecular exchange of CH₄ in both the small and large cages. Because the STOMP-HYD simulator does not track small- and large-cage occupancies, it is not currently capable of limiting CO₂ exchange with CH₄ to large cages. The principal conclusion from this series of simulations was that both CO₂ exchange approaches yielded faster production times, but lower CH₄ recoveries over pure water injections. Without consideration of the cage occupancies, the direct-exchange yielded faster production times over the dissociation-reformation approach, with nearly equivalent CH₄ recoveries. CO₂ to water ratios in the injectant primarily affected production rates, with higher ratios yielding faster productions.

A contract between Battelle and the Korea Institute for Geoscience and Mineral Resources (KIGAM) was completed. That work principally involves the application and verification of the STOMP-HYD simulator to a CH₄ hydrate production experiment, using the direct-exchange approach. A full verification of the simulator will not be possible as the production experiments conducted at KIGAM involved co-injection of CO₂ and N₂. This work was initiated with a visit to the laboratory by Dr. Won Suk Lee from KIGAM. During this visit, Dr. Lee worked with the STOMP-HYD simulator and provided Battelle with data from the exchange experiments. In working with the simulator on these experiments, a new primary variable switching scheme was developed that uses hydrate saturation as a principal unknown. The KIGAM contract is supporting the investigation of this new scheme for its computational efficiency.

**Task 4: Reservoir Simulation with ANS Field Data**

This task is not scheduled to start until Task 3 scope has been completed.

**Significant Issues and Corrective Action**

None.

**Conference Presentations**

An abstract was submitted for acceptance in an upcoming conference:

### 48984 Gas Hydrates Assessment

#### Planned and Actual Cumulative Spending Curve

(Dollars in Thousands)

July-Sept 2007

| (SK)                  | April | May  | June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | FY07 |
|-----------------------|-------|------|------|------|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Planned Cost          | 7.97  | 14.33| 13.37| 13.70| 14.64| 14.64| 14.60| 14.60| 14.64| 14.64| 14.60| 14.64| 14.60| 14.64| 254.1|
| Actual Cost by Month  | 0.2   | 1.1  | 1.2  | 7.1  | 2.2 | 9.7  | 3.2 | 4.3 | 8.5 | 1.4 | 13.2| 5.1 | 7.1 | 0.7 | 0.7 | 0.2 | 14.3 | 79.0 |
| Variance Cost         | 7.8   | 13.2 | 12.2 | 6.6  | 12.4| 4.9  | 11.4| 10.3| 6.1 | 13.2| 1.4 | 9.5 | 12.9| 13.9| 10.4| 13.9| 14.4 | 0.3  |
| Cumulative Planned    | 8.0   | 22.3 | 35.7 | 49.4 | 64.0| 78.7 | 93.3| 107.9| 122.5|137.1|151.7|166.3|180.9|195.5|210.2|224.8|239.5|254.1 |
| Cumulative Actual     | 0.2   | 1.3  | 2.5  | 9.6  | 11.8| 21.5 | 24.7| 29.0| 37.5| 38.9| 52.1| 57.2| 58.9| 59.6| 63.8| 64.5 | 64.7 | 79.0 |
| Cumulative Variance   | 7.8   | 21.0 | 33.2 | 39.8 | 52.2| 57.2 | 68.6| 78.9| 85.0| 98.2|109.1|122.0|135.9|146.4|160.3|174.7|175.1 |  

#### Milestones

| MILESTONES                        | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | FY07 |
|------------------------------------|-----|-----|------|------|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| Task 1. Prepare a Research Development Plan |     |     |      |      |     |      |     |     |     |     |     |     |     |     |     |     |     |      |
| Task 2. Prepare a Technology Status Assessment |     |     |      |      |     |      |     |     |     |     |     |     |     |     |     |     |     |      |
| Project Kickoff Meeting             |     |     |      |      |     |      |     |     |     |     |     |     |     |     |     |     |     |      |
| Complete Research Management Plan   |     |     |      |      |     |      |     |     |     |     |     |     |     |     |     |     |     |      |
| Quarterly Reports                   |     |     |      |      |     |      |     |     |     |     |     |     |     |     |     |     |     |      |

#### Legend

- SCHEDULED
- DEVIATION
- COMPLETED
- TIME LINE
- ELIMINATED BY REDUCTION
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