Oil & Natural Gas Technology

DOE Award No.: DE-FC26-06NT42666

Quarterly Progress Report
(April - June 2007)

Comparative Assessment of Advanced Gas Hydrate Production Methods

Submitted by:
Battelle Pacific Northwest Division
Richland , WA

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

July 31, 2007

Office of Fossil Energy

Award No. DE-FC26-05NT42666
Battelle Pacific Northwest Division

Gas Hydrates Assessment
B. Peter McGrail, Principal Investigator

Quarterly Report – Q3 (FY2007)

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. Task 3 activities began in earnest this quarter.

Results of Work During Reporting Period

Phase I

Task 1: Project Management

New project administrative staff were retained to support this project (in addition to several others). Negotiations continued with KIGAM to resolve IP issues associated with the STOMP-HYD code. We expect those issues to be resolved and a contract signed next quarter. KIGAM will participate as a new cost share partner on this project.

Task 2: Technology Status Assessment

This task has been completed on schedule.

Task 3: Basic reservoir Simulation

During this quarter the STOMP-HYD simulator was tested on a series of CO_2 injection experiments, including those where the CO_2 was injected as a liquid microemulsion and gas microemulsion. In the host geologic media, CO_2 is assumed to exist as a component of the gas phase, dissolved in the aqueous phase, clathrated in hydrate, or as liquid CO_2. Liquid CO_2 is assumed to have intermediate wettability between the gas and aqueous phases. Hydrate and ice phases are assumed to be occluded by the aqueous phase. This pore-scale morphology makes liquid CO_2 behave as a nonaqueous phase liquid. During the initial development of the simulator, four phase conditions were used to model the CO_2-CH_4 geologic media system. The primary variable set for these phase conditions is shown in Table 1. After exercising this system on a suite of CO_2 injection problems, it was discovered that the simulator had difficulties with the low (i.e., 1.e-4 or less) liquid CO_2 saturations that were forming. The simulator was additionally showing convergence problems for no liquid CO_2 unsaturated phase conditions. Both of these algorithmic problems were resolved through the development of a new set of primary variables, shown in Table 2. This new and innovative primary variable set allows the simulator to efficiently handle low liquid CO_2 and mixed unsaturated systems.

Phase Condition	Energy	H_2O Mass	CH_4 Mass	CO_2 Mass	NaCl Mass	P_g, $P_g^{CH_4}$	P_n, $P_g^{CO_2}$
$s_l = 1$ $s_n = 0$	T	P_l	$P_g^{CH_4}$	$P_g^{CO_2}$	ζ_l^s	$P_g = P_l + \frac{\beta_{gl}}{\psi}$	$P_n = P_n^c$
$s_l < 1$ $s_n = 0$	T	P_l	P_g	$P_g^{CO_2}$	ζ_l^s	$P_g^{CH_4} = P_g - P_g^{CO_2} - P_g^{H_2O}$	$P_n = P_n^c$
$s_l = 1$ $s_n > 0$	T	P_l	$P_g^{CH_4}$	P_n	ζ_l^s	$P_g = P_l + \frac{\beta_{gl}}{\psi}$	$P_g^{CO_2} = P_{sat}^{CO_2}$
$s_l < 1$ $s_n > 0$	T	P_l	P_g	P_n	ζ_l^s	$P_g^{CH_4} = P_g - P_g^{CO_2} - P_g^{H_2O}$	$P_g^{CO_2} = P_{sat}^{CO_2}$

Table 1. Conceptual Primary Variable Switching Scheme

Phase Condition	Energy	H_2O Mass	CH_4 Mass	CO_2 Mass	NaCl Mass	P_g, $P_g^{CH_4}$	P_n, $P_g^{CO_2}$
$s_l = 1$ $s_n = 0$	T	P_l	$P_g^{CH_4}$	$P_g^{CO_2}$	ζ_l^s	$P_g = P_l + \frac{\beta_{gl}}{\psi}$	$P_n = P_n^c$
$s_l < 1$ $s_n = 0$	T	P_l	P_g	$P_g^{CO_2}$	ζ_l^s	$P_g^{CH_4} = P_g - P_g^{CO_2} - P_g^{H_2O}$	$P_n = P_n^c$
$s_l < 1$ $s_n = 0$	T	P_l	$P_g^{CH_4}$	P_g	ζ_l^s	$P_g^{CH_4} = P_g - P_g^{CO_2} - P_g^{H_2O}$	$P_n = P_n^c$
$s_l = 1$ $s_n > 0.001$	T	P_l	$P_g^{CH_4}$	P_n	ζ_l^s	$P_g = P_l + \frac{\beta_{gl}}{\psi}$	$P_g^{CO_2} = P_{sat}^{CO_2}$
$s_l < 1$ $s_n > 0.001$	T	P_l	P_g	P_n	ζ_l^s	$P_g^{CH_4} = P_g - P_g^{CO_2} - P_g^{H_2O}$	$P_g^{CO_2} = P_{sat}^{CO_2}$

Table 2. Implemented Primary Variable Switching Scheme

Task 4: Reservoir Simulation with ANS Field Data

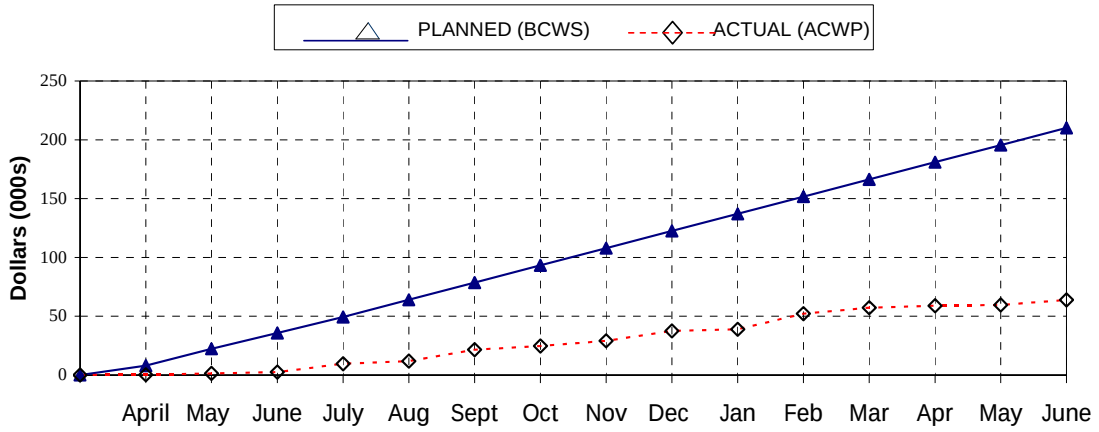
This task is not scheduled to start until Task 3 scope has been completed.

Significant Issues and Corrective Action

Initiation of Task 2 and Task 3 work was delayed due to more extensive modification and revisions to the RMP than expected. Senior staff have also had very limited time available due to other project commitments. This situation will improve in Q4 and beyond. Our spending rate is expected to ramp up significantly in Q4 of FY07. We will rebaseline our spending plan next quarter to better reflect past and projected spending rate on the project.

Contract negotiations between Battelle and the Korea Institute of Geoscience and Mineral Resources (KIGAM) are nearing completion. KIGAM will participate in the Task 3 activities on this project through use of the STOMP-HYD code.

48984 Gas Hydrates Assessment
Planned and Actual Cumulative Spending Curve **June 2007**
(DOLLARS IN THOUSANDS)



($K)	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	FY07
Planned Cost	7.97	14.33	13.37	13.70	14.64	14.64	14.60	14.60	14.64	14.60	14.64	14.60	14.60	14.60	14.64	210.2
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	1.7	0.7	4.2	63.8
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	
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	
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	
Cumulative Variance	7.8	21.0	33.2	39.8	52.2	57.2	68.6	78.9	85.0	98.2	99.6	109.1	122.0	135.9	146.4	

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

LEGEND

SCHEDULED △ DEVIATION ▭ COMPLETED ☆

TIME LINE —— ELIMINATED BY REDUCTION ⊘

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

One West Third Street, Suite 1400
Tulsa, OK 74103-3519

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South
Suite 201
Fairbanks, AK 99709

Visit the NETL website at:
www.netl.doe.gov

Customer Service:
1-800-553-7681