Oil & Natural Gas Technology

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Quarterly Progress Report
(January – March 2008)

Comparative Assessment of Advanced Gas Hydrate Production Methods

Submitted by:
Battelle Pacific Northwest Division
Richland , WA

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National Energy Technology Laboratory

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Gas Hydrates Assessment
B. Peter McGrail, Principal Investigator

Quarterly Report – Q2 (FY2008)

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. A revised Research Management Plan was issued this quarter to reflect changes in project scope and schedule that have occurred since the initial award. A suite of demonstration production problems for a five-spot well configuration also were completed.

Results of Work During Reporting Period

Phase I

Task 1: Project Management

A revised Research Management Plan was issued this quarter to reflect changes in project scope and schedule that have occurred since the initial award. The task structure was also adjusted to reflect changes in modeling work scope anticipated in Task 3.

A second contract proposal between Battelle and the Korea Institute for Geoscience and Mineral Resources (KIGAM) was submitted for continued numerical simulation work. The proposed work supports the long term objectives of the KIGAM hydrate project and complements the numerical simulation work being conducted under this project. In particular, the recent scientific expedition in the Korean East Sea discovered and recovered gas hydrate cores from suboceanic hydrate-bearing sediments. Korea is currently investigating suboceanic accumulations of methane hydrate to determine if this potential resource can meet its natural gas consumption needs. Conventional production methods for these deposits of methane hydrate are being considered as part of the overall objects of the hydrate research at KIGAM, with particular consideration to the geomechanical stability of the hydrate-bearing sediments with production. In addition to these investigations, being conducted collaboratively with KIGAM and Lawrence Berkeley National Laboratory, Korea is supporting investigations into more innovative production technologies. This project is specifically concerned with the production of natural gas hydrates using the guest exchange technology; where, the methane guest molecule in the clathrate structure is replaced with another molecule (e.g., N_2, CO_2). The activities of the proposed project are directed at expanding the capabilities of the suite of STOMP-HYD numerical simulators and at validating the developed simulation capabilities against laboratory experiments conducted at KIGAM. The specific objectives of the proposed research are:

a. Develop numerical simulation capabilities for modeling the ternary CH_4-CO_2-N_2 hydrate system by expanding on the existing capabilities of the STOMP-HYD simulator for modeling the binary CH_4-CO_2 hydrate system.

b. Validate the developed numerical simulation capabilities against laboratory experiments conducted by KIGAM

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

A suite of demonstration production problems for a five-spot well configuration were completed. The computational domain involved a 1-m thick horizon of natural gas hydrate bearing sandstone with no-flow upper and lower boundaries and homogeneous properties. To inhibit hydrate dissociation via thermal stimulation from heat transfer into the domain, the upper and lower boundaries were considered to be adiabatic. A five-spot well configuration for natural gas hydrate production was considered with a 100-m spacing between the production wells. Symmetry in the system allowed for a ¼ computational domain that comprised ¼ of the injection well and 1 production well. Pure CO_2 was injected in the center well and CH_4 was produced at the perimeter wells. Initially the domain was at 6 MPa and 3°C with a uniform hydrate saturation of 0.7. The initial condition state is liquid saturated with a low effective aqueous permeability (i.e., 0.12 mD). To increase the formation permeability and lower the formation pressure, the initial stage of production involved depressurization of the formation to 3 MPa, which keeps the formation above the freezing point of water. This depressurization stage causes hydrate dissociation, which produced gas at all five of the wells. Following depressurization, pure CO_2 is injected at 15°C at 1) 4 MPa, 2) 5 MPa, and 3) 6 MPa. At 4 MPa, the CO_2 is a gas (i.e., 5.3°C saturation temperature); at 5 MPa the CO_2 is a gas near the saturation line (i.e., 14.3°C saturation temperature); and at 6 MPa the CO_2 is a liquid (22.0°C saturation temperature). Important limitations in the present simulations were ignoring the kinetics of the CO_2-CH_4 exchange and sI cage occupancies of the guest molecules. Methane production was halted when the CO_2 gas mass fraction of the effluent exceeded 0.01. Simulation results for the five-spot well demonstration are being described in detail in a manuscript being submitted to the Offshore Technology Conference this spring. The main conclusions from the simulations were:

- preliminary depressurization to a point above the freezing point of the aqueous phase opens pore space for injection of mobile fluids
- kinetics of the direct exchange of hydrate formers (i.e., CO_2 with CH_4) are an important consideration that will be evaluated in the future by tracking mobile and hydrate components separately
- cage occupancies of the sI structure are expected to have significant impacts on the efficiency of direct gas phase CO_2-CH_4 exchange. These effects will be considered in the future by tracking small and large cage occupancies of hydrate components
- controlling secondary hydrate formation is critical to prevent pore plugging
- heat transfer into the production zone is not required under properly controlled production conditions.

The next task of the reservoir simulator development and application involves converting STOMP-HYD to scalable form. This work was recently initiated and involves two parallel subtasks. The first subtask involves combining the four STOMP-HYD simulators (i.e., STOMP-HYD, STOMP-HYD2, STOMP-HYD3, and STOMP-HYD-KNC) into a single simulator with the full suite of capabilities. The second subtask involves converting the code to scalable form. Prior conversions of STOMP to scalable form have used imbedded directives and a preprocessor to convert serial code to scalable form with MPI as the base parallel language. Since developing this paradigm, the Global Arrays (GA) toolkit, developed at PNNL for Northwest Chem has matured as an approach for converting code to scalable form. In addition to the maturity of the toolkit, PNNL will be investing new money through its LDRD program to further develop the GA toolkit for peta-scale and

beyond to exa-scale computing. Because of these two factors (i.e., toolkit maturity and future advancement) the STOMP-HYD simulator will be converted to scalable form using the GA toolkit.

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.

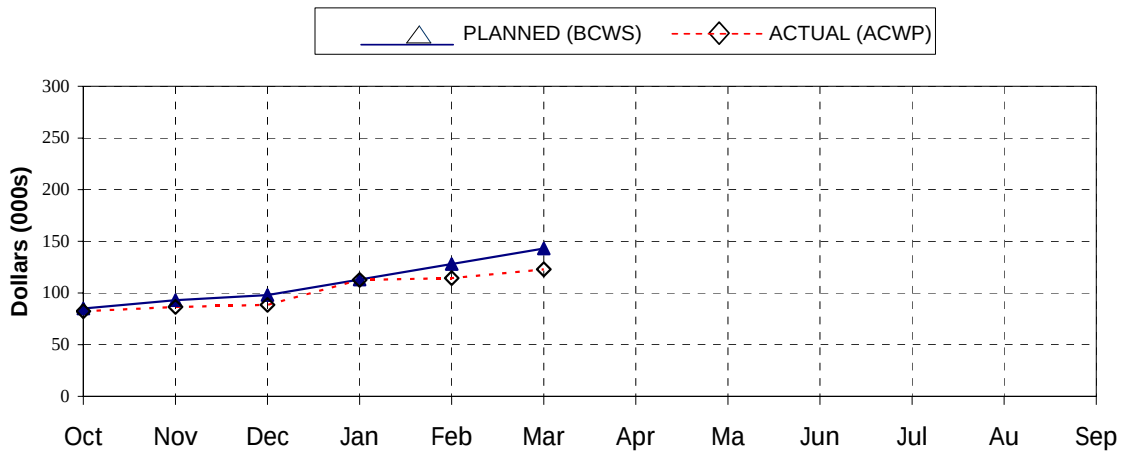
Publications and Presentations

One manuscript was submitted for presentation in an upcoming conference:

White, M.D., and B.P. McGrail, "Numerical Simulation of Methane Hydrate Production from Geologic Formations via Carbon Dioxide Injection," Special Session on Gas Production From Hydrates, 2008 Offshore Technology Conference, May 5-8, 2008, Houston, Texas.

References

48984 Gas Hydrates Assessment
Planned and Actual Cumulative Spending Curve **Jan-March 2008**
(DOLLARS IN THOUSANDS)



($K)	FY07 TD	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	FY08
Planned Cost	80.00	5.00	8.00	5.00	15.00	15.00	15.00	20.00	25.00	25.00	25.00	25.00	30.00	293.0
Actual Cost by Month	79.1	3.3	4.0	2.0	24.2	1.8	8.5	0.0	0.0	0.0	0.0	0.0	0.0	122.9
Variance Cost	0.9	1.7	4.0	3.0	-9.2	13.2	6.5	0.0	0.0	0.0	0.0	0.0	0.0	
Cumulative Planned	80.0	85.0	93.0	98.0	113.0	128.0	143.0	163.0	188.0	213.0	238.0	263.0	293.0	
Cumulative Actual	79.1	82.4	86.4	88.4	112.6	114.4	122.9	0.0	0.0	0.0	0.0	0.0	0.0	
Cumulative Variance	0.9	2.6	6.6	9.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

MILESTONES		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	FY08
Complete Task 3 Simulations														
Quarterly Reports														

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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

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