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# Quarterly Research Performance Progress Report

(Period Ending 03/31/2019)

## Coupled Hydrologic, Thermodynamic, and Geomechanical Processes of Natural Gas Hydrate Production

Project Period (10/01/2018 to open)

Submitted by:

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Signature

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U.S. DEPARTMENT OF  
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TECHNOLOGY LABORATORY**

Office of Fossil Energy

# RESEARCH PERFORMANCE PROGRESS REPORT

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## ACCOMPLISHMENTS:

### **BP1-Task 1.0 Project Management**

This project is a companion project to one funded by the Korea Institute for Geoscience and Mineral Resources (KIGAM) under the Joint Korea and U.S. Gas Hydrate Research Program. The KIGAM project is currently investigating nitrogen and air injection as a production technology for suboceanic deposits of gas hydrates, such as those found in the Ulleung Basin of the Korean East Sea. During this quarter an annual technical report was submitted to KIGAM, entitled “Numerical Assessment of Natural Gas Hydrate Production via Nitrogen Injection.” This report documented numerical simulation work completed by PNNL, using the STOMP-HYDT-KE simulator, under two objectives: 1) Verification of the GEOMech Module with Hydrate Dissociation and Formation, and 2) Scoping Simulations of Nitrogen Injection for Natural Gas Hydrate Production at the UBGH2-6 Site. The results from the second series of simulations demonstrated the potential for using N<sub>2</sub> injection as a production technology, in particular for scenarios involving initial depressurization, followed with low-pressure N<sub>2</sub> injection, with a potential sequential water flood. Additional simulations will be conducted to understand the merits of this approach.

### **BP1-Task 2.0 IGHCCS**

Work during this quarter was focused on comparing solution submissions, code corrections, and resubmissions. This quarter saw the submission of first solutions against the fifth benchmark problem. Submitted solutions were compared during the study teleconferences. An overview of the status of submissions against the five benchmark problems is shown below. A solution submission closure date of May 2, 2019 has been selected, and we currently anticipate a number of additional solution submissions from Ulsan University and Maria de la Fuente Ruiz, from the National Oceanography Centre, and one solution submission on Benchmark Problem 4 from LBNL.

Benchmark Problem 1 (Problem Champion: Mark White, PNNL)

Case 1: Depressurization (9 solution submissions)

GEOMAR, JLU, LBNL, LLNL, NETL, PNNL, UCB, Ulsan, UTA

Case 2: Thermal Stimulation (9 solution submissions)

GEOMAR, JLU, LBNL, LLNL, NETL, PNNL, UCB, Ulsan, UTA

Benchmark Problem 2 (Problem Champion: Shubhangi Gupta, GEOMAR)

Case 1: No Hydrate Formation (7 solution submissions)

GEOMAR, JLU, LBNL, LLNL, NETL, PNNL, UCB

Case 2: Hydrate Formation (7 solution submissions)

GEOMAR, JLU, LBNL, LLNL, NETL, PNNL, UCB

Case 3: Hydrate Dependent Shear Modulus (7 solution submissions)

GEOMAR, JLU, LBNL, LLNL, NETL, PNNL, UCB

Case 4: Rapid Hydrate Kinetics (6 solution submissions)

GEOMAR, JLU, LBNL, NETL, PNNL, UCB

Benchmark Problem 3 (Problem Champions: Matt Reagan, Alejandro Queiruga, George Moridis, LBNL)

Case 1: Single-phase Depressurization (6 solution submissions)

JLU, LBNL, LLNL, NETL, PNNL, UCB

Case 2: Hydrate Production (6 solution submissions)

JLU, LBNL, LLNL, NETL, PNNL, UCB

Benchmark Problem 4 (Problem Champions: Sayuri Kimoto, Kyoto; Catherine Yonkofski, PNNL)

Case 1: Nankai Trough (5 solution submissions)

Kyoto, LLNL, NETL, UCB, LBNL

Benchmark Problem 5 (Problem Champion: Shun Uchida, RPI)

Case 1: No Hydrate (5 solution submissions)

GEOMAR, LLNL, NETL, PNNL, UCB

Case 2: Hydrate without Dissociation (5 solution submissions)

GEOMAR, LLNL, NETL, PNNL, UCB

Case 3: Hydrate with Dissociation (4 solution submissions)

GEOMAR, NETL, PNNL, UCB

All study participants have found the code comparisons to be beneficial to their development and verification efforts. The number of study members joining the teleconference has held steady, and the number of participants speaking up has increased with each teleconference. All teleconferences were recorded, and those recordings were posted on the NETL EDX system, along with the slide decks from the presentations. Five study teleconferences were held during the quarter:

Teleconference #26: January 17, 2019

Problem Solution Submissions

Benchmark Problem 3

Lawrence Berkeley National Laboratory (LBNL)

Lawrence Livermore National Laboratory (LLNL)

University of California (UCB)

Jilin University (JLU)

National Energy Technology Laboratory (NETL)

Pacific Northwest National Laboratory (PNNL)

Benchmark Problem 4  
University of Kyoto (Kyoto)\*  
Lawrence Livermore National Laboratory (LLNL)  
University of California (UCB)  
National Energy Technology Laboratory (NETL)

Teleconference #27: February 19, 2019  
Problem Solution Submissions  
Benchmark Problem 5  
Pacific Northwest National Laboratory (PNNL)

Teleconference #28: March 7, 2019  
Problem Solution Submissions  
Benchmark Problem 5  
Lawrence Livermore National Laboratory (LLNL)  
National Energy Technology Laboratory (NETL)  
National Energy Technology Laboratory w/ FLAC2D (NETL w/ FLAC2D)  
Pacific Northwest National Laboratory (PNNL)  
University of California Berkeley (UCB)

Teleconference #29: March 28, 2019  
Problem Solution Submissions  
Benchmark Problem 1  
GEOMAR (GEOMAR)  
Benchmark Problem 2  
Lawrence Berkeley National Laboratory (LBNL)  
Pacific Northwest National Laboratory (PNNL)  
Benchmark Problem 5  
National Energy Technology Laboratory (NETL)  
Pacific Northwest National Laboratory (PNNL)  
University of California Berkeley (UCB)

Teleconference #30: April 18, 2019  
Problem Solution Submissions  
Benchmark Problem 1  
GEOMAR (GEOMAR)  
Benchmark Problem 2  
Lawrence Berkeley National Laboratory (LBNL)  
National Energy Technology Laboratory (NETL)  
Status Report on Submissions  
Target Journals  
Draft Outline and Writing Assignments

### **BP1-Task 3.0 STOMP-HYDT-KE Parallelization**

No accomplishments to report for this task during the first quarter of FY19, but in comparing the STOMP-HYDT-KE results against the other submissions for Benchmark Problem 5 a number of bugs were corrected related to the geomechanical solver and coupling with the flow and transport routines. The first bug involved a sign in the application of confining stress on boundary surfaces, and the second bug involved the need to reset the reference state for simulations involving hydrate saturation dependent geomechanical parameters.

**MILESTONES:**

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
Nitrogen Injection (KIGAM-funded, Separate, Coordinated PNNL Project #68908)	Conduct a series of numerical simulations using its STOMP-HYDT-KE simulator to assess the feasibility of the nitrogen injection technology for production natural gas.	6/30/2018	Partially completed	Simulations with STOMP-HYDT-KE against a series of nitrogen injection experiments. Dr. Won Suk Lee visiting PNNL during April to discuss next steps. Progress report submitted on 11/30/2018.
IGHCCS2: Benchmark Problems	Complete the submission and reviews of the five benchmark problems.	12/31/2018	Partially completed	Solution submissions continued to arrive from participants, and reviews are being conducted during the teleconferences. New close date anticipated for end of April 2019.
IGHCCS2: Challenge Problems	Develop and issue two challenge problems.	6/30/2019	Not started	Discussions have occurred about what a challenge problem involves.
IGHCCS2: Journal Paper	Draft a journal paper on the four benchmark problems.	6/30/2019	Not started	Paper will be started with the completion of the benchmark problem submissions and reviews.
Parallelization: OpenMP	Demonstrate the execution of STOMP-HYDT-KE on eight cores with an OpenMP linear system solver.	12/31/2018	Not started	Not started.
Parallelization: GA	Develop a set of Global Array equivalent subroutines in MPI.	06/31/2019	Not started	Not started.

**PRODUCTS:**

A presentation entitled "Modeling of Coupled Thermal, Hydrologic, and Geomechanical Processes in Gas Hydrate Bearing Porous Media: The 2nd International Gas Hydrate Code Comparison Study," was made at the 2018 AGU Fall Meeting, as an invited talk in the session OS23C: Modeling of Gas Hydrate-Related Systems 1.

**IMPACT:**

No significant impacts occurred this quarter.

**CHANGES/PROBLEMS:**

No significant changes or problems, other than the pace of the code comparison study is slower than anticipated. The slower pace is principally due to competing project work for the study participants.

**SPECIAL REPORTING REQUIREMENTS:**

No special reporting requirements occurred during this quarter.

**BUDGETARY INFORMATION:**

Actual Cost (this quarter)	Actual Cost (cumulative for BP)	Funds available (for the BP)	Balance of unspent funds (for the BP)	Actual Cost (cumulative for the full FWP)	Funds available (for the full FWP)	Balance of unspent funds (for the full FWP)
\$39,307	\$61,391	\$151,151	\$89,760	\$61,391	\$151,151	\$89,760

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