NATIONAL ENERGY TECHNOLOGY LABORATORY
OIL & GAS

DOE Award No.: ESD12010

Quarterly Research Performance Progress Report

(Period Ending 6/30/2018)

NUMERICAL STUDIES FOR THE CHARACTERIZATION OF RECOVERABLE RESOURCES FROM METHANE HYDRATE DEPOSITS

Project Period (April 1, 2012 to December 31, 2018)

Submitted by:
Matthew T. Reagan

Matthew T. Reagan

Signature

Lawrence Berkeley National Laboratory
DUNS #:xxxxxxx
1 Cyclotron Road
Berkeley CA 94720
Email: mtreagan@lbl.gov
Phone number: (510) 486-6517

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National Energy Technology Laboratory

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U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Office of Fossil Energy

RESEARCH PERFORMANCE PROGRESS REPORT

DISCLAIMER

ACCOMPLISHMENTS:

Task 1. Project Management Plan

Status: Ongoing

A PMP was submitted for Budget Period #6 in March 2017. A revised FWP and SOPO was submitted on July 31, 2017. A revised for the new, extended BP #6 was submitted in August, 2017.

Task 2. Code Maintenance, Updates, and Support

Subtask 2.6:

Status: Ongoing, task expanded 7/31/2017

Development of the new Millstone geomechanical code has been ongoing, and has now been tested in real-world simulation problems associated with other tasks in the FWP, including new capabilities for static post-processing of pre-existing T+H simulation.

The release of the new coupled T+H/Millstone platform was accompanied by the submission of three papers that document 1) T+H code development, 2) Millstone code development, and 3) testing of the latest coupled simulator. These papers are still in review for *Transport in Porous Media* due to difficulties finding qualified reviewers capable of evaluating the coupled T+H+M simulation process.

Task 3. Support of DOE's Field Activities and Collaborations

Subtask 3.6: Detailed Analysis of the Production Potential of Hydrates Deposits Offshore India

Status: Ongoing

The latest versions of the T+H and Millstone codes, developed in Task 2, were used for ongoing simulations of the India NGHP Site 9 production test. In this quarter, the team completed analysis of all the simulations of production scenarios, with and without coupled geomechanics, using data and geological models developed in consultation with NETL, USGS, and Indian scientists. The final simulations ended in June 2018. Problems caused by purely technical issues were overcome, and recent delays were solely the result of the extremely long execution times required to properly model the system, with multi-million-timestep simulations consuming close to 1 million CPU-hours.

The reason for these very short time steps continued to be the extreme variation in permeability between the hydrate-bearing layers (~1.0 mD or less) and the hydrate-free sand (~10.0D). The 4-order difference in permeability causes a multitude of problems: the very fine radial discretization along the hydrate-free sand lenses result in practically zero pressure differences between adjacent grid elements, making the computation of gradients and derivatives both difficult and inaccurate for the Jacobian needs of the fully implicit model in TOUGH+HYDRATE.

The results from these simulations were submitted to the journal special issue associated with the India NGHP in late April 2018 and the results were presented in a confidential report to the NGHP leadership in April. The paper has undergone one round of review and is currently under revision:

Moridis, G.J., Reagan, M.T., Queiruga, A.F., Collett, T.S., Boswell, R., "Evaluation of the Performance of the Oceanic Hydrate Accumulation at the NGHP-02-9 Site of the Krishna-Godawari Basin During a Production Test and Under Full Production," *submitted to J. Marine and Petroleum Geology.*

Subtask 3.7: Participation in the Code Comparison Study of Coupled Flow, Thermal and Geomechanical Processes

Status: Ongoing

The LBNL team has been participating in the regular meetings and has contributed problem solutions. Matt Reagan and Alejandro Queiruga are designing Problem #3, a variation of a standard axisymmetric coupled flow-mechanical test problem, which will be submitted to the study in August 2018.

As part of this code comparison study, we have also begun an investigation into mesh convergence for our Darcy simulator with and without hydrate in the system. During review of several recent papers, questions were raised about the choice of discretization, particularly near the well. Currently, these values are chosen by experience or by trial and error, and often

decisions are made to limit mesh sizes at the expense of mesh refinement. No formal assessment of this exists. As part of Problem #3, we are performing mesh convergence testing with and without hydrate to assess whether mesh generation is being done correctly, with results expected in Q4.

Task 4. Assessment of Resource Recoverability From Natural Hydrate Deposits

Subtask 4.4:

Status: Completed

Work on Subtask 4.4 concluded in Q3, with the work focusing on simulations of the production behavior of horizontal wells in sloping systems and the geomechanical consequences. Current funding was exhausted at the end of June 2018.

Milestone Table

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
PMP	Maintenance and update of the Project Management Plan	April 30, 2016, March 30, 2017	Included with BP#6 SOPO 3/15/17	Updated 30 days after receipt of added BP #6 funding
Deliverable	Report and presentation(s) regarding the results of the initial Subtask 3.6 simulations	June 30, 2017	Results to date presented at ICGH 9 on June 26-30, 2017.	Subtask 3.6 extended and expanded to cover a wider range of scenarios and parameters through July 2018,
Deliverable	Completed T+H/ROCMECH Code Updates	December 31, 2016	March 27, 2018**	ROCMECH found to be incompatible with cylindrical well simulations (i.e., India NGHP studies). Development suspended in May 2016 with the beginning of Millstone development. **T+H/Millstone v1.0 completed in March 2018.
Deliverable	Submission of a report on the preliminary studies of offshore Indian hydrates	May 31, 2017	May 2017	Report submitted.
Deliverable	Completion of the analysis and submission of a paper evaluating the production performance of slanted wells	July 31, 2016	March 16, 2018	Paper submitted to 2018 Offshore Technologies Conference Asia. Presented May 2, 2018.
Deliverable	Submission of a paper on the expected long-term fate and transport of released gas following the cessation of operations	July 31, 2016	December 12, 2016; June 30, 2017	Results presented as a poster at AGU Fall Meeting. Paper submitted to ICGH 2017 and presented June 30, 2017.
Deliverable	A paper (jointly with T. Kneafsey) on the design and analysis of the planned experiments.	May 31, 2017	Pending	Delays in experiments have resulted in a delay in producing a paper. We are currently evaluating completed tests.
Deliverable	Updated versions serial and parallel versions of the T+M/Millstone code	July 31, 2018	March 27, 2018	Three papers describing T+H/Millstone submitted to Transport in Porous Media.

Deliverable	Completion of analyses and participation in the code comparison study	July 31, 2018	Ongoing	Problem #1 completed in Q2. Problem #2 and #3 to be completed in early Q3. CCS expected to continue into FY19.
Deliverable	Submission of a report on the ongoing studies of offshore Indian hydrates	Jul 31, 2018	April 13, 2018	Report submitted to NGHP; Report condensed into paper submitted to JMPG.
Deliverable	Submission of a report on the evolution of subsidence and strategies to mitigate production problems	Jul 31, 2018	Ongoing	Work ongoing

PRODUCTS:

Publications to date (this BP):

Reagan, M.T., Moridis, G.J., Seim, K.S., "Fast Parametric Relationships for the Large-Scale Reservoir Simulation of Mixed CH4-CO2 Gas Hydrate Systems," *Computers and Geosciences*, **103**, 191-203, 2017.

Moridis, G.J., Reagan, M.T., Queiruga, A.F., "Long-Term System Behavior Following Cessation of Gas Production from Hydrate Deposits," *Proc.* 9th Int. Conference on Gas Hydrates, Denver, CO, 1-3 June 2017.

Moridis, G.J., Queiruga, A.F., Reagan, M.T., "The T+H+M Code for the Analysis of Coupled Flow, Thermal, Chemical and Geomechanical Processes in Hydrate-Bearing Geologic Media," *Proc.* 9th Int. Conference on Gas Hydrates, Denver, CO, 1-3 June 2017.

Moridis, G.J., Reagan, M.T., Queiruga, A.F., "The TOUGH+Millstone Code for the Analysis of Coupled Flow, Thermal, Chemical and Geomechanical Processes in Hydrate-Bearing Geologic Media, Part I: The Hydrate Simulator," submitted to *Transport in Porous Media*.

Queiruga, A.F., Moridis, G.J., Reagan, M.T., "The TOUGH+Millstone Code for the Analysis of Coupled Flow, Thermal, Chemical and Geomechanical Processes in Hydrate-Bearing Geologic Media, Part II: Numerical Algorithms and the Stone Geomechanical Simulator," submitted to *Transport in Porous Media*.

Reagan, M.T., Queiruga, A.F., Moridis, G.J., "The TOUGH+Millstone Code for the Analysis of Coupled Flow, Thermal, Chemical and Geomechanical Processes in Hydrate-Bearing Geologic Media, Part III: Application to Production Simulation," submitted to *Transport in Porous Media*.

Moridis, G.M., Reagan, M.T., Queiruga, A.F., Geomechanical Stability and Overall System Behavior of Sloping Oceanic Accumulations of Hydrates Responding to Dissociation Stimuli, OTC-24896-MS, *Proc.* Offshore Technology Conference-Asia, 20 March 2018.

Moridis, G.J., Reagan, M.T., Queiruga, A.F., Collett, T.S., Boswell, R., Evaluation of the Performance of the Oceanic Hydrate Accumulation at the NGHP-02-9 Site of the Krishna-

Godawari Basin During a Production Test and Under Full Production, submitted to *J. Marine and Petroleum Geology.*

Presentations to date (this BP):

"Long-Term System Behavior Following Cessation of Gas Production from Hydrate Deposits," 9th Int. Conference on Gas Hydrates, Denver, CO, 1-3 June 2017.

"The T+H+M Code for the Analysis of Coupled Flow, Thermal, Chemical and Geomechanical Processes in Hydrate-Bearing Geologic Media," 9th Int. Conference on Gas Hydrates, Denver, CO, 1-3 June 2017.

"Geomechanical Stability and Overall System Behavior of Sloping Oceanic Accumulations of Hydrates Responding to Dissociation Stimuli," OTC-24896 Offshore Technology Conference-Asia, 20 March 2018.

"Modeling at the Reservoir and Field Scales," (invited) Keynote Session, Gordon Research Conference on Natural Gas Hydrates, Galveston, TX, 25 February-2 March 2018.

"Current Advances in Laboratory and Simulation Studies at LBNL," National University of Singapore, 27 March 2018.

SPECIAL REPORTING REQUIREMENTS:

N/A

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)
$58,513	$370,821	$350,000	($20,821)	$1,270,825	$1,250,004	($20,821)

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

1450 Queen Avenue SW
Albany, OR 97321-2198

Arctic Energy Office

420 L Street, Suite 305

Anchorage, AK 99501

Visit the NETL website at:

www.netl.doe.gov

Customer Service Line:

1-800-553-7681