NETL NATIONAL ENERGY TECHNOLOGY LABORATORY
OIL & GAS

DOE Award No.: ESD12011

Quarterly Research Performance Progress Report)

(Period Ending 3/31/2018)

PROPERTIES OF SEDIMENTS CONTAINING METHANE HYDRATE, WATER, AND GAS SUBJECTED TO CHANGING GAS COMPOSITIONS

Project Period (April 1, 2012 to open)

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Signature

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

Office of Fossil Energy

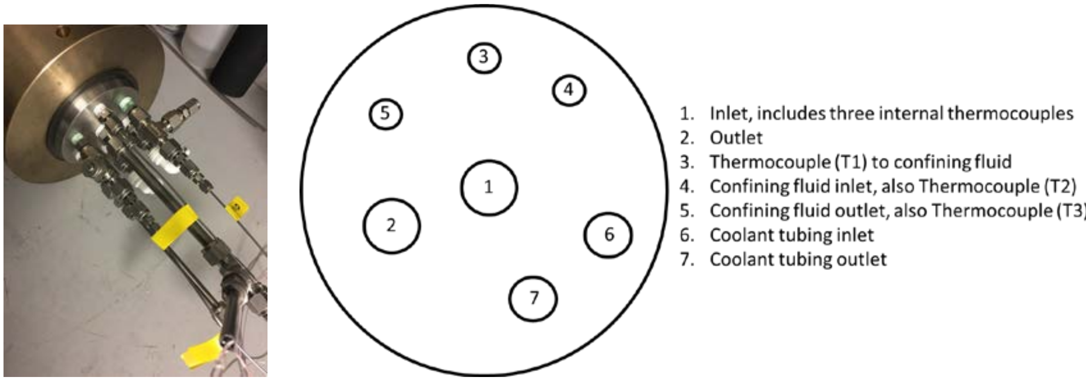
RESEARCH PERFORMANCE PROGRESS REPORT

DISCLAIMER

ACCOMPLISHMENTS:

Task 11. Assessment of thermal gradient modification methods and Investigation of the effect of thermal gradient and gradient oscillation on hydrate behavior –

Accomplishments: In this task, we have built out our assembly and larger vessel. In the latest modification, we installed three thermocouples inside the sample and three in the confining fluid along the length of the sample. We have created a heating/cooling coil to modify the temperature at one side of the sample. We will flow temperature-controlled water through aluminum tubing to heat and/or cool the inlet end of the sample. In this manifestation, the tubing diameter is larger (1/4 inch vs. 1/8 inch) and the aluminum is more amenable to X-ray CT scanning. Our new vessel has seven ports in the endcap to allow for the control of temperature, confining fluid pressure, pore pressure, fluid flow through the sample, and to measure temperature. Other monitoring tools can be used as well. The inlet, outlet, and confining fluid are connected to pressure transducers allowing monitoring of pore pressure and differential pressure. As in our other tests, pressure is controlled by syringe pumps.



Pressure vessel on CT table

Assembly before insertion into pressure vessel

Figure 1. top – photo of pressure vessel endcap assembled for temperature gradient assessment, and schematic of endcap. Bottom left – vessel with cooling jacket, Bottom right – vessel internals including sleeve with endcaps (3 thermocouples are embedded in the packed sand sample), aluminum temperature control tube coil, and thermocouples attached to the outer sleeve at the top, middle, and bottom of the sample.

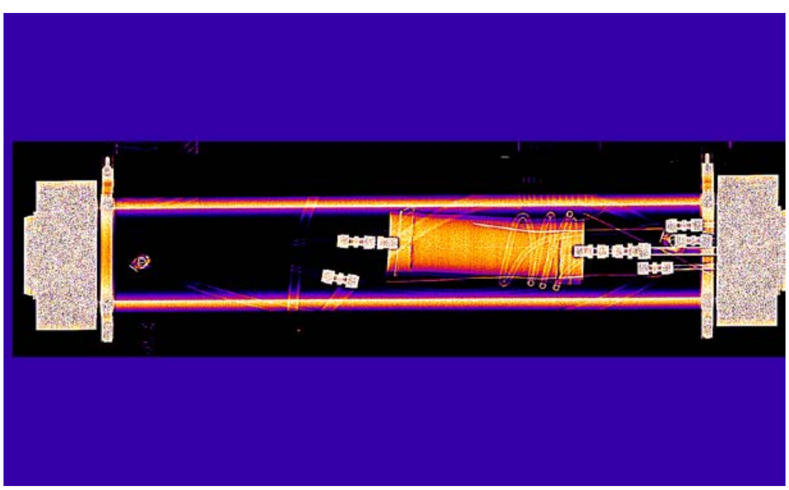


Figure 2. X-ray transparent internal heating coil on right side of sample.

Task 15. Experimental work in response to current challenges

Accomplishments: Participation in overseeing the hydrate geomechanics code comparison study. Led session at Gordon Research Conference on Gas Hydrates

Focus next quarter: Continue focus on layered systems. Future focus on varying brine composition in layered and non-layered systems. Continued participation in managing code comparison study.

Task 16. Continued investigation of layered systems

Accomplishments: We have developed and implemented a technique to create layered systems, and have tested it on both hydrate-bearing and non-hydrate-bearing samples. These tests have been performed largely to look at particle flow in sand/mud samples. To do so, we have overcome a number of complexities. Because we have had difficulties implementing and controlling the temperature gradient, none of our tests to date have been completed with both layered systems and temperature gradients. As the build out of the system has been completed (Task 11) and the layered sample method had been repeated a number of times, these experiments should be completed in the next quarter.

Focus next quarter: Hydrate tests under gradient to begin.

Task 17. Comparison of the effect of vertical and horizontal wells for gas production in a layered hydrate-bearing system

Dissociation of hydrate both by high depressurization rate (representing fast velocities near a vertical well in a horizontal hydrate-bearing layer) and low (representing slow velocities near a horizontal well in a hydrate-bearing layer) depressurization rate in a horizontal sample have been evaluated. The outlet tube (well) was ¼ in ID and contained a mesh that was designed to allow some movement of sand grains while preventing collapse of the sample. The general concept is that for the same gas extraction rate for the well, flow into the horizontal well will be slower than into a vertical well because it will be distributed over a longer distance. In our tests, we scaled the production rate to examine the effect. The rate of sand production was very low, and only small mechanical changes were observed using CT imaging and volume measurements.

CT images from the low dissociation rate test are shown in Figure 3. In this test, the sample was composed from a silt/clay/barite “compacted mud” layer (top layer in Figure 3), and a moist sand layer (bottom layer in Figure 3). Upon hydrate formation, hydrate formed in the sand layer only. This hydrate formation was not significant enough to exert enough cryogenic suction to de-water the mud, thus the mud remained water-satiated. Upon depressurization, dissociation began nearest to the outlet port indicated by the brighter colors in Figure 3. The images in Figure 3 are difference images, showing the difference from the pre-dissociation case and stepwise throughout the process. The key observation is that the overall shape of the sample remained nearly the same and the sample did not fail geomechanically. Additional examinations are being performed of the mud layer CT data to answer more detained questions. Also interesting is that in the third to the right frame there is a bright region that darkens (goes from higher gas saturation to lower as the water in the sand redistributes itself after dissociation. This is also under re-examination.

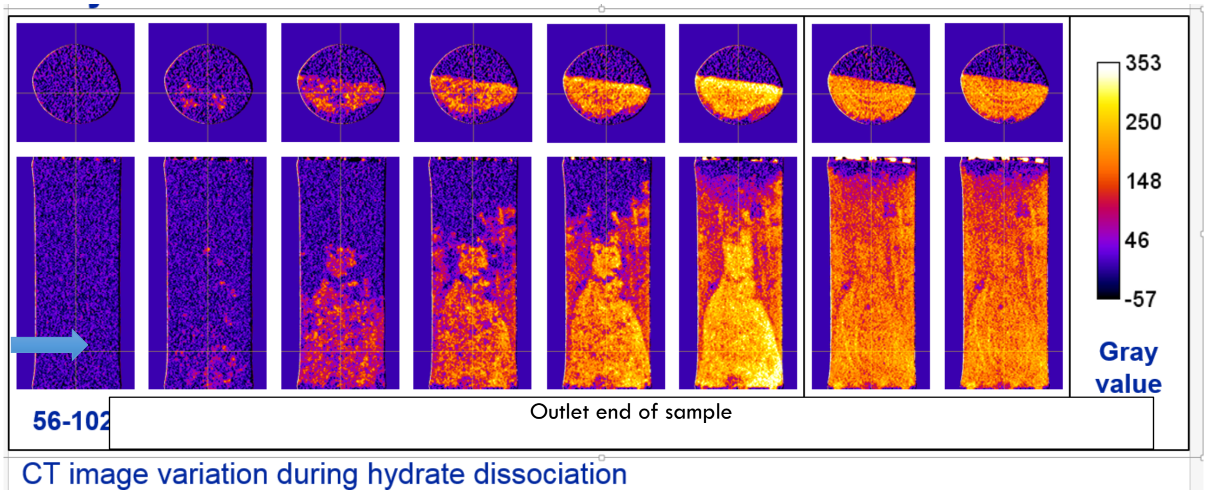


Figure 3. Cross sections along the xy (vertical) and xz (horizontal) planes of the sample during slow hydrate dissociation. Arrow to the left shows approximate location of upper cross section in the 3-D sample. Dissociation begins near the outlet. Brighter colors (yellow) indicate larger density changes. The highest density changes will occur when porespace water and hydrate are replaced by gas. No change is indicated by purple.

Focus next quarter: Reexamine data. Perform confirmatory test if needed.

Milestone Table

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
Report on Layered Hydrate	A report describing the data collected in our first layered hydrate test will be submitted.	January 31, 2015 Delayed – expected by September 30, 2015	Included with quarterly update 5/05/16	Complete
Go/NoGo on vessel	A brief letter report will be submitted following Task 10a to inform the DOE of the go/no go decision on vessel remanufacture. (Tasks 10).	September 30, 2015	Informally contained in update 11/16	Complete
Topical Report	A report documenting the results of laboratory tests examining the effects of thermal gradients and gradient oscillation on hydrate behavior will be submitted. (Task11)	March 31, 2016	Delayed	Will resume in new vessel in Q4
Topical Report	A report documenting the results of laboratory tests investigating the gas hydrate equilibrium point versus the gas production rate will be submitted. (Task 12)	June 30, 2016	June 30, 2016	Laboratory work complete and PowerPoint presentation assembled. Letter report in preparation.
Topical Report	A report documenting the results of laboratory tests on layered systems.	July 31, 2017	Delayed	Work will resume in Q4
Grain-scale Computation of Hydrate-Bearing Sand	A report documenting the results of numerical simulations on multigrain scale flow and mechanical simulations.	May 31, 2017	Delayed, data fields generated and shared with NETL	Simulations will resume in Q4

Properties Based on micro-CT Sample Description				
Topical Report	A report documenting the results of current challenge laboratory tests and their interpretation.	July 31, 2017	Delayed	Experimental work will resume in Q4 with new vessel
Topical Report	A report adding to the observations on layered systems	January 31, 2018	March 31, 2018	Work is under way in a number of projects to support this.
Topical Report	An experiment report documenting the results of gas production from laboratory-simulated vertical and horizontal wells.	July 31, 2018	In progress	
Conference Papers/ Proceedings/ Articles	Documents include conference papers, proceedings, presentations, journal articles, and press releases.	Minimum of 7 business days prior to submission		

PRODUCTS:

None to report this quarter.

CHANGES/PROBLEMS:

Our new student, Bin Wang, is integrating into our laboratory group. In addition, Chun Chang, a post-doctoral researcher with experience in controlled pressure/temperature core flood work is providing assistance to broaden his experience and guiding image analysis.

SPECIAL REPORTING REQUIREMENTS:

NA

BUDGETARY INFORMATION:

BP6 = July 2017 - June 2018	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)
Jul-Sep 2017	$29,402	$29,402	$125,000	$95,598	$457,399	$685,000	$227,601
Oct-Dec 2017	$43,189	$72,591		$52,409	$500,588		$184,412
Jan-Mar 2018	$24,510	$97,101		$27,899	$525,098		$159,902

This chart does NOT include encumbrances.

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