Oil & Natural Gas Technology

DOE Award No.: DE- FE0013961

Quarterly Research Performance Progress Report
(Period ending 03/31/2016)

Borehole Tool for the Comprehensive Characterization of Hydrate-Bearing Sediments

Project Period (10/1/2013 to 9/30/2016)

Submitted by:
J. Carlos Santamarina

J C Santamarina

Georgia Institute of Technology
DUNS #: 097394084
505 10th street
Atlanta , GA 30332
e-mail: jcs@gatech.edu
Phone number: (404) 894-7605

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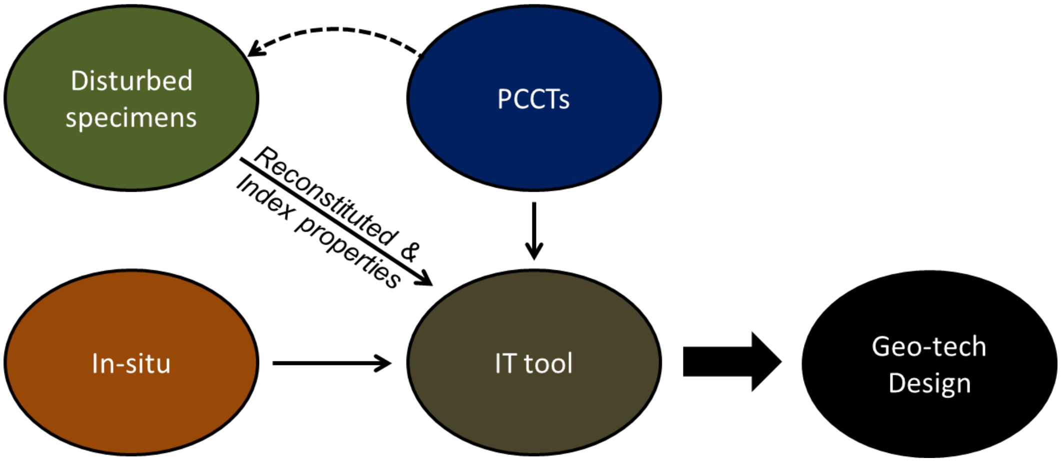
NETL

Office of Fossil Energy

DISCLAIMER:

Context – Goals.

The physical properties of hydrate bearing sediments are critical for gas production strategies, geo-hazard mitigation and its impact on gas recovery engineering. Typically, the determination of physical properties relies on correlations and experimental data recovered from conventional and pressure cores. Inherent sampling disturbance and testing difficulties add significant uncertainty. In this research, we develop a new comprehensive borehole tool for the characterization of hydrate bearing sediments, and an IT tool for the physics-based selection of appropriate parameters.



Accomplishments

The main accomplishments for this period include:

- Borehole tool design: body (sub-task 3.3: design and construction)
    - Camera module design
- Borehole tool (sub-task 3.3: Design of coupling mechanism)
    - Study of off-the-shelf coupling mechanism on drill-strings and future modules
- Borehole tool (sub-task 4.3: Final design and construction)
    - New improved PCB electronics configuration

Plan - Next reporting period

New field tests on KAUST marina: penetration forces, electrical conductivity, water pressure, hydraulic conductivity, video.

Research in Progress

Borehole Tool

The current borehole tool is designed as a modular and highly flexible device. It consists in modules which can couple in series. The whole borehole tool is machined of stainless steel 316 to resist the harsh environment of high salinity seawater.

The proposed modules include: force resistance, temperature, hydraulic conductivity, electrical conductivity, accelerometer, soil and fluids sampling, and video recording.

Tool construction: Video module

Figure 1 shows the new video module and assembly to the tool. This module consists of an expanded body with the ability of holding an off-the-shelf high pressure window (shown in the figure). The camera will be housed behind this window. The system includes LED lights for illumination. This module is currently being machined.

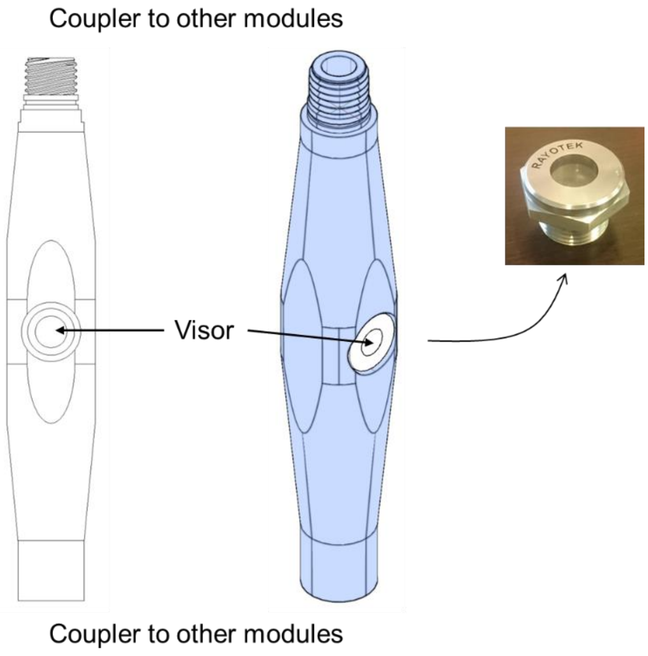


Figure 1: Video module. The visor consists in a high pressure window.

Electronics: new board and circuitry.

The final design for the board (PCB; Figure 2) and circuitry has been finalized. Figure 2 shows the new design; it brings significantly enhanced flexibility for new sensors, as needed in the near future.

This new PCB consists of a Raspberry Pi master controller and an Arduino Mega as a slave. The master commands the Arduino, indicates when to run tests and operating conditions, and is in charge of data storage. At the same time the Raspberry Pi gathers data from the three pressure transducers.

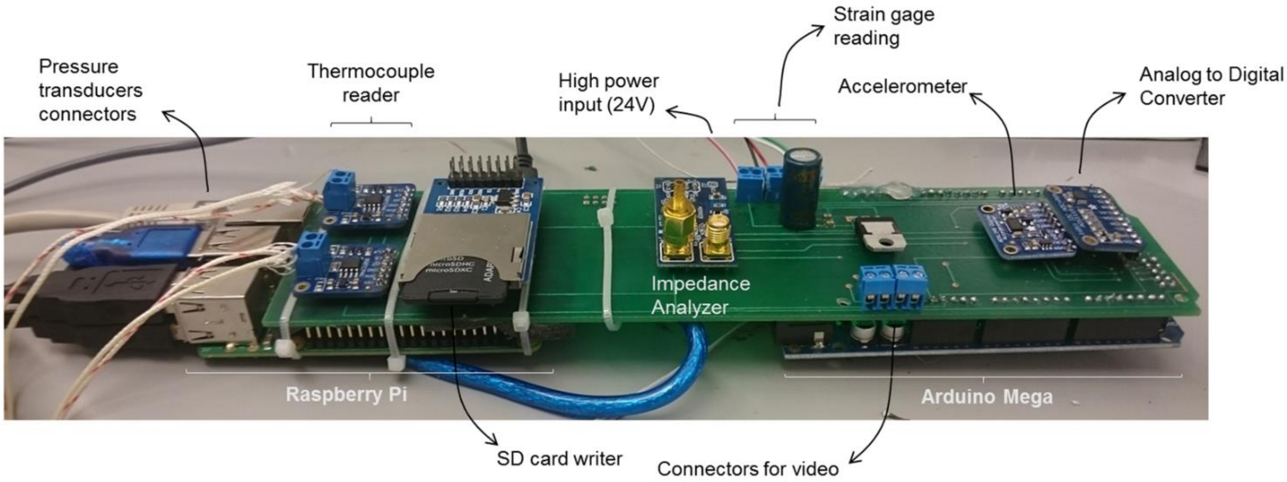


Figure 3: Electronics: new PCB configuration.

Connection components for field deployment

Complimentary studies were conducted to investigate the connection and coupling mechanics of the testing cone with the drill string (i.e., drill bit, Bottom Hole Assembly BHA, and API drill collars and pipes).

A typical downhole test procedure involves drilling to the required depth, lowering the downhole tool into the drill string until it reaches the BHA, advancing the tool below the BHA for testing and sampling; then, upon test completion, the tool is recovered using an overshot and wireline. The Fugro cone penetrometer uses two systems (Fig 4). The testing tool connects with the drill-string through the overshot knob.

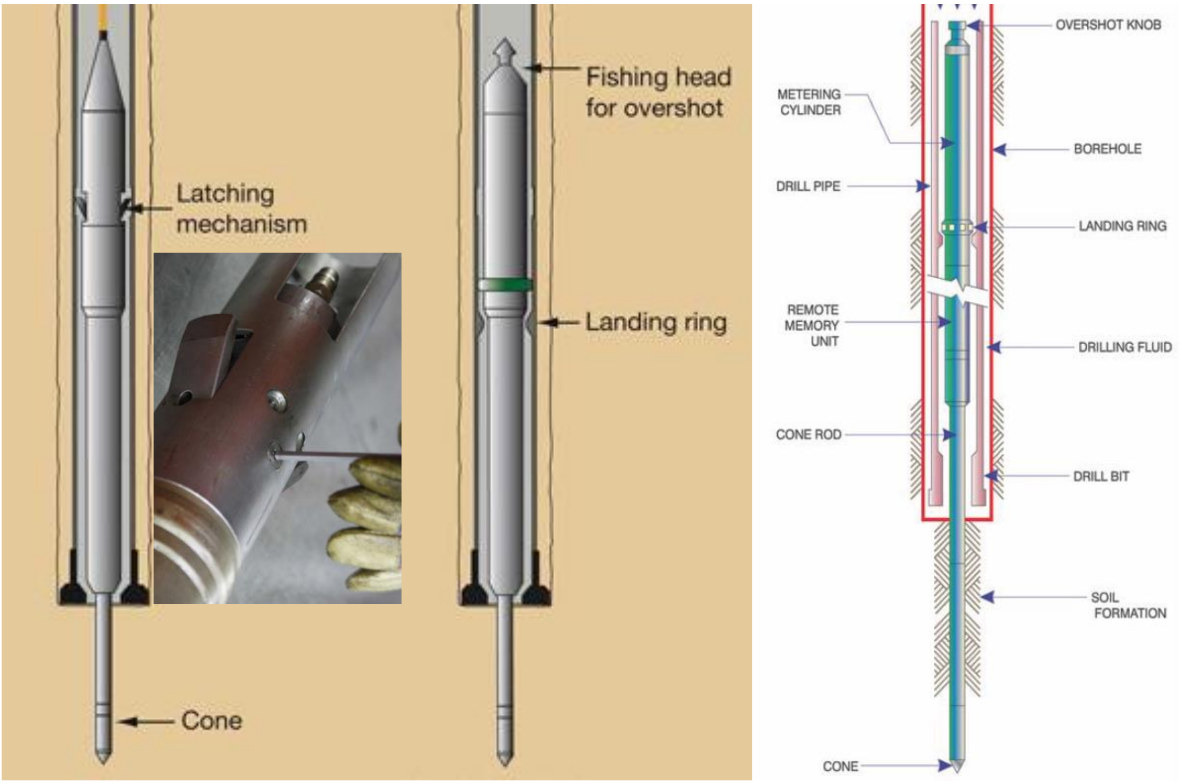


Figure 4. Fugro's downhole cone penetration operation systems. The tool and drill-string is connected through an overshot knob.

Halliburton also provides slickline service tools to furnish the mechanical force necessary for setting, pulling, or servicing subsurface equipment under pressure, including a variety of quick connections (Fig 5a) and pulling tools (Fig 5b). Tool strings are available in various ODs and component lengths designed to be compatible with various tubing sizes.

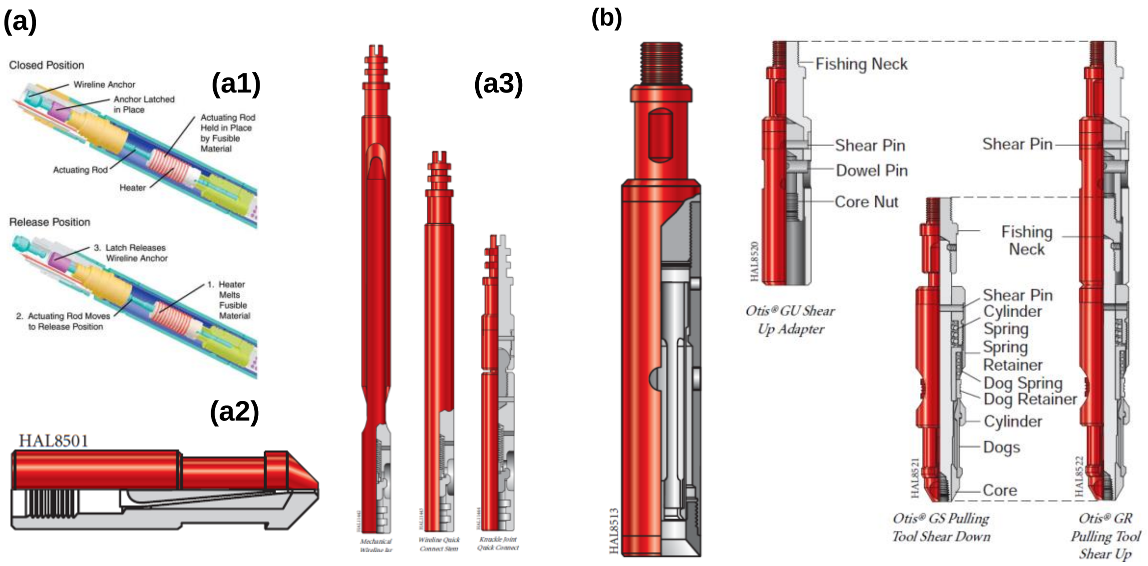


Figure 5. Drill-string service tools from Halliburton. (a) Tool connection mechanisms: (a1) Halliburton RWCH releasable wireline cable head, (a2) Otis Rope Sockets, the wireline is tied around a disc or dart in the socket to achieve a firm connection, (a3) Otis Quick Connect, tested through 50,000 cycles at impact loads of 9,000 to 10,000 lbs in both directions. (b) Halliburton Otis G fishing socket (left) and an array of pulling tools (right)

Additions to Testing Capabilities

<u>Thermal properties</u>: <u>single-sided TPS technique</u>. The thermal properties of granular materials are usually measured using time-consuming static methods or transient methods like thermal needle probe and transient plane source (TPS) technique. However, none of these methods provide surface contact measurement for geomaterials, not even to mention having them equipped on a testing cone for in situ borehole characterization. NETL measured the thermal conductivity of pure hydrate crystals using the singled-side TPS technique (Rosenbaum et al., 2007), which basically glued a TPS sensor on a PVC substrate to measure the thermal properties of the specimen laid on top of the substrate. So this becomes a problem of a plane heat source dissipating into two media, with thermal properties known for the substrate but to be determined for the tested specimen (Figure 6). Reasonably accurate thermal conductivity data of hydrate-bearing sediments can be achieved by using the following assumptions (Dai et al., 2015): (1) simplified heat conduction scenario, such as neglecting heat exchange between the two media, (2) the density of the tested

specimen ρ1 is known, (3) heat capacity c1 can be estimated using volume average, so that the thermal conductivity λ_1 and diffusivity α_1 become essentially one parameter as $\alpha = \lambda/\rho/c$. The next stage of this study plans to use two different substrates (with known thermal properties) in order to obtain two independent equations, so that the thermal conductivity and diffusivity of the tested specimen can both be obtained.

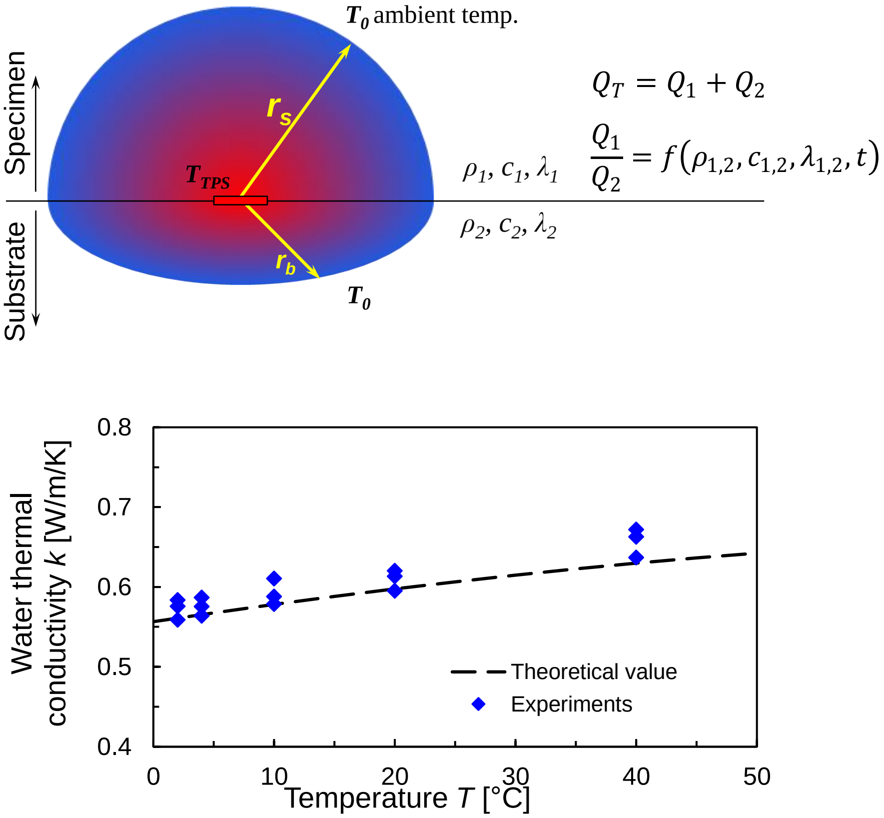


Figure 6. Thermal properties measurement using single-sided TPS technique. Top: illustration of heat dissipation of a plane source into the substrate and the tested specimen. Bottom: measured water thermal conductivity under different temperatures using simplified heat dissipation scenario and data processing method (Dai et al., 2015).

Shear Stiffness. Cone-based shear stiffness measurement (e.g., seismic CPT) usually requires a shear source at the ground surface or seafloor. This limits the penetration depth for CPT to obtained shear wave signatures in the downhole. Accelerometers or geophones are typically used as receivers for CPT tests. Borehole suspension loggers, however, have wave a source and receivers housed within one sonic tool; but it functions based on wave splitting and refraction at drilling fluid and borehole interfaces, which makes it impossible to directly obtain soil shear stiffness particularly for soft sediments.

Combining the state-of-art technologies in seismic cone penetrometer and suspension sonic logger, we will explore the development of a cone-based shear stiffness measuring tool, as one modulated unit compatible with current cone. The stiffness module will contain a (piezoelectric or resonance) source, vibration attenuators/isolators, and multiple receivers (three-way geophones). Preliminary laboratory tests will begin with two isolated geophones to obtain shear stiffness information using the passive wave method.

References:

Rosenbaum, Eilis J., et al. "Thermal conductivity of methane hydrate from experiment and molecular simulation." The Journal of Physical Chemistry B111.46 (2007): 13194-13205.

Dai, Sheng, et al. "Thermal conductivity measurements in unsaturated hydrate-bearing sediments." Geophysical Research Letters 42.15 (2015): 6295-6305.

MILESTONE LOG

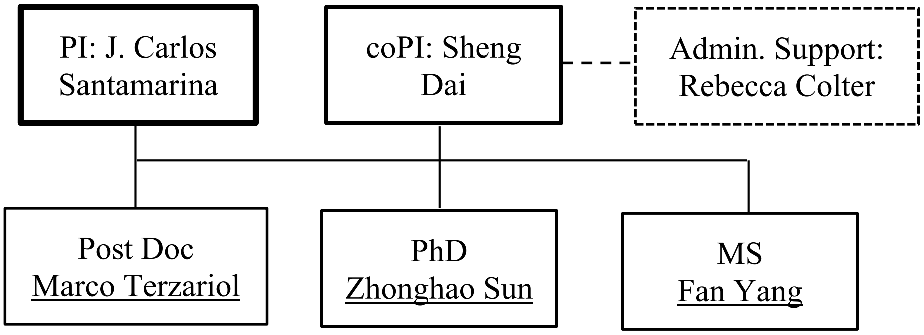
	Milestone	Completion Date	Comments
Title Planned Date Verification method	Completion PMP November 2013 Report	11/2013	
Title Planned Date Verification method	Insertion – Tool design September 2014 Report	9/2014	
Title Planned Date Verification method	Database and IT tool September 2014 Report	9/2014	Paper in preparation
Title Planned Date Verification method	Electronics in operation January 2015 Report	9/2015	
Title Planned Date Verification method	Lab testing of prototype September 2015 Report	9/2015	
Title Planned Date Verification method	Tool deployment Before September 2016 Report	In progress	

PRODUCTS

- **Website:** Publications and key presentations are included in http://egel.kaust.edu.sa (for academic purposes only)
- **Inventions, patent applications, and/or licenses:** None at this point.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Research Team: The current team is shown next. We anticipate including external collaborators as the project advances



IMPACT

None at this point.

CHANGES/PROBLEMS:

None at this point.

SPECIAL REPORTING REQUIREMENTS:

We are progressing towards all goals for this project.

BUDGETARY INFORMATION:

As of the end of this research period, expenditures are summarized in the following table (Note: in our academic cycle, higher expenditures typically take place during the summer quarter):

Baseline Reporting Quarter DE-FE0013961	Budget Period 3							
	Q1		Q2		Q3		Q4	
	10/1/15 - 12/31/15		1/1/16 - 3/31/16		4/1/16 - 6/30/16		7/1/16 - 9/30/16	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total
Baseline Cost Plan								
Federal Share	30,000	345,515	30,000	375,515	30,000	405,515	71,510	477,025
Non-Federal Share	14,693	97,103	14,692	111,795	14,693	126,488	-	126,488
Total Planned	44,693	442,618	44,692	487,310	44,693	532,003	71,510	603,513
Actual Incurred Cost								
Federal Share	6,315	250,608	28,411	279,020		279,020		279,020
Non-Federal Share	15,655	93,760	10,436	104,196		104,196		104,196
Total Incurred Costs	21,969	344,368	38,848	383,216	-	383,216	-	383,216
Variance								
Federal Share	-23,685	-94,907	-1,589	-96,495				
Non-Federal Share	962	-3,343	-4,256	-7,599				
Total Variance	-22,724	-98,250	-5,844	-104,094				

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

13131 Dairy Ashford Road, Suite 225
Sugar Land, TX 77478

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

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