Oil & Natural Gas Technology

DOE Award No.: DE- FE0013961

Quarterly Research Performance Progress Report
(Period ending 3/31/2014)

Borehole Tool for the Comprehensive Characterization of Hydrate-Bearing Sediments

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

Submitted by:
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National Energy Technology Laboratory

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Office of Fossil Energy

DISCLAIMER:

ACCOMPLISHMENTS

Context – Goals. *The determination of physical properties for hydrate bearing sediments relies on correlations with geophysical measurements, and experimental data gathered on conventional and pressure cores; however, there are intrinsic uncertainty in correlations and inherent sampling disturbance and testing difficulties when hydrate bearing sediments are involved. This research focuses on the development of a robust borehole tool for the comprehensive characterization of hydrate bearing sediments in-situ, complemented with an IT tool for the selection of appropriate material parameters.*

Accomplished

The main accomplishments for this period include:

- IT tool (sub-task 2.1: Update database of hydrate-bearing sediment properties)
    - Compilation database of hydrate-bearing sediments
- IT tool (sub-task 2.2: Robust correlations)
    - Math-Cad based tool
- Borehole tool (sub-task 3.1: Evaluation and design of alternatives)
    - Sensor modules development
- Micro-electronics (sub-task 4.1: Development of penetrometer)
        - Stand-alone Arduino system
        - Video-system development

Plan - Next reporting period

Optimize the mechanical design of the hydraulic, fluid sampler and production system. Build the first prototype. Improve the interface and efficiency of the IT tool and its suitability with in-situ data.

Research in Progress

Borehole Tool Design: Sensor module

The designed tool is a multi-stage sensor system with a simple, versatile and robust architecture. The body is stainless steel and the hooking system can be adapted in order to connect to most operators' tools. This in-situ tool allows connecting multiple modules in series to measure various parameters needed for the comprehensive characterization of the formation in situ.

Figure 1 shows the tool inserted ahead of the borehole base and details of the tip module for penetration resistance. This module is designed to extract fluid at high pressure without causing dissociation and to run a small-scale pressure-controlled production test. Gas and water are stored in small stainless steel vessels within the tool body. The numerical verification of stresses and deflections is shown in Figure 2.

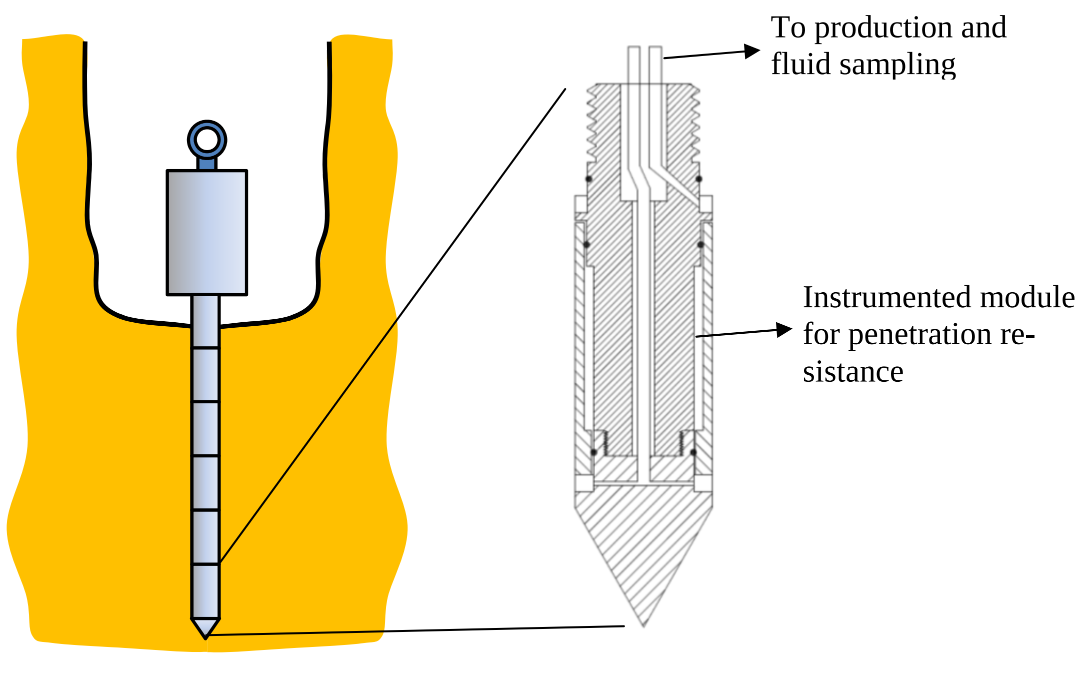
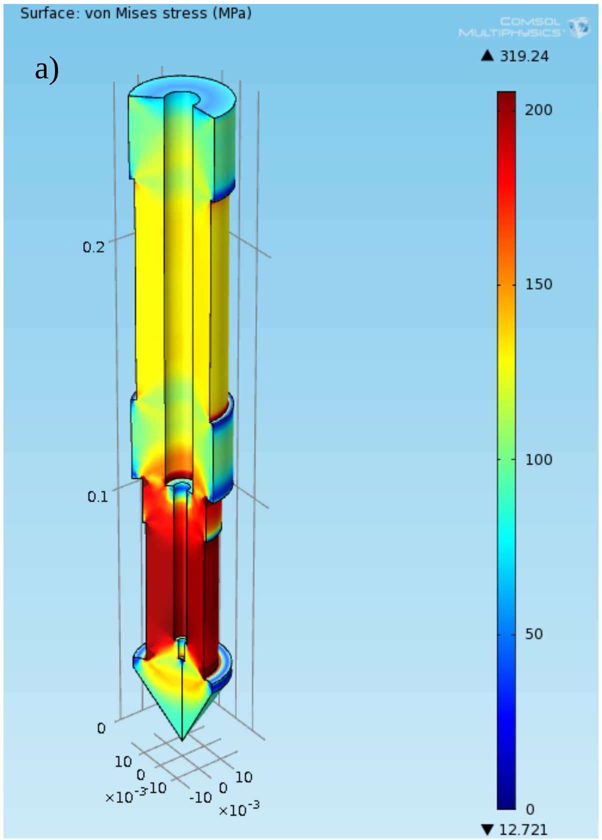


Figure 1. Borehole tool. a) Inserted tool; b) Penetration module.



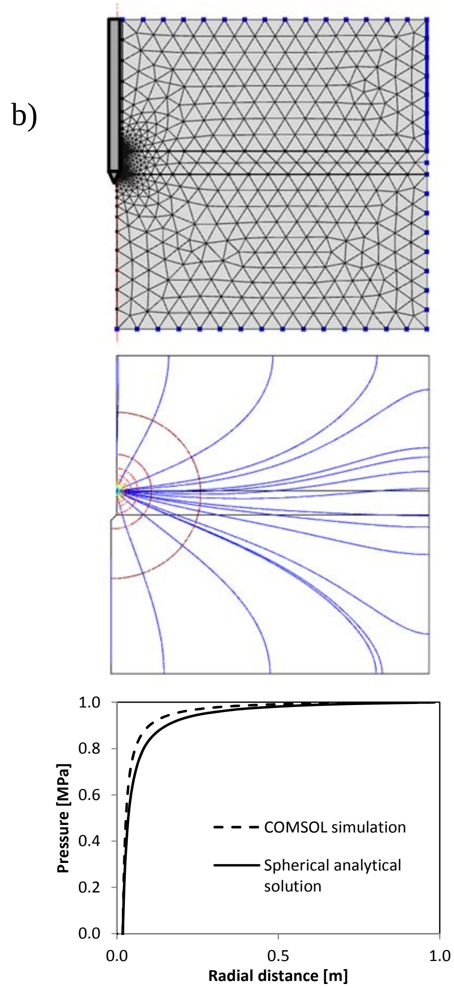


Figure 2. Numerical simulation: a) Stresses at maximum capacity; b) hydraulic conductivity: mesh, flow lines and pressure field.

Micro-electronics

An Arduino UNO runs together with a SD data storage shield to conduct several tests in stand-alone mode. Sensor data were reported previously. A new miniature, high-resolution video capability to be installed in one of the modules is documented herein.

Video. Figure 3-a shows a picture of the camera attached to the microprocessor and power supply. Data is stored in a standard SD card. The size of the camera is 30mm x 30mm and the lens can be manipulated in order to change the focal distance, with a maximum focal length of 30mm. Table 1 presents calibration results. The video system allows to detection of 0.5mm features, such as grains, lenses, or layers.

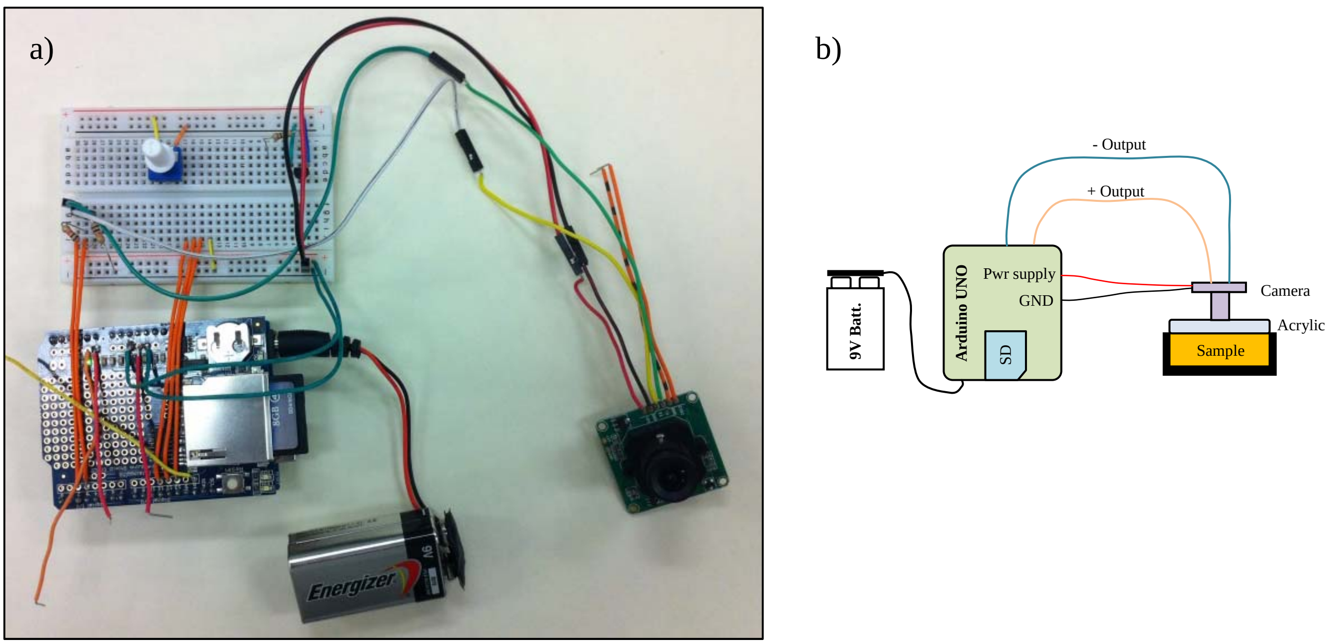
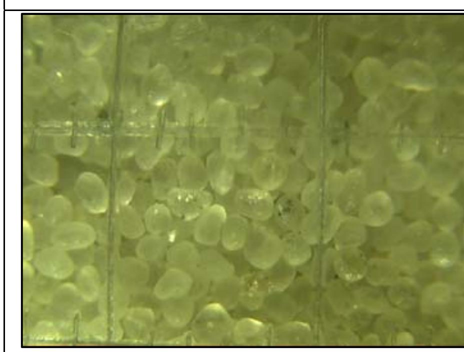
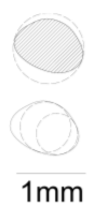
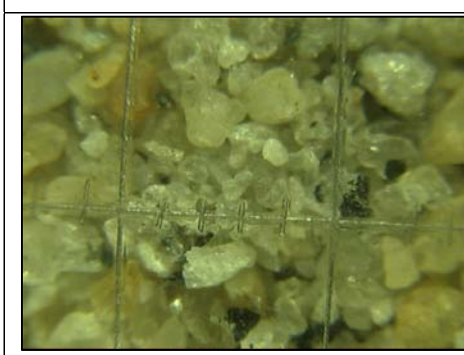
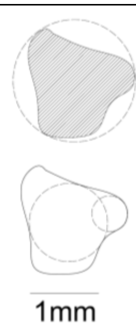


Figure 3. Video-system a) Arduino UNO, power supply, SD shield and camera; b) schematics of the calibration test.

Table 1: Calibration test results

<table>
<tr><th>Images</th><th>Typical grain</th><th>Properties</th></tr>
<tr><td></td><td>
</td><td><u>Blasting sand</u>
<table>
<tr><th></th><th>From image</th><th>From sieve</th></tr>
<tr><td>D_{50}</td><td>1.1mm</td><td>0.90mm</td></tr>
</table>
Sphericity = 0.51
Roundness = 0.55</td></tr>
<tr><td></td><td>
</td><td><u>Silica Sand</u>
<table>
<tr><th></th><th>From image</th><th>From sieve</th></tr>
<tr><td>D_{50}</td><td>0.35mm</td><td>0.30mm</td></tr>
</table>
Sphericity = 0.56
Roundness = 0.38</td></tr>
<tr><td></td><td>
</td><td><u>Ottawa sand 20-30</u>
<table>
<tr><th></th><th>From image</th><th>From sieve</th></tr>
<tr><td>D_{50}</td><td>0.80mm</td><td>0.74mm</td></tr>
</table>
Sphericity = 0.70
Roundness = 0.81</td></tr>
<tr><td></td><td>
</td><td><u>Mixed grains</u>
<table>
<tr><th></th><th>From image</th><th>From sieve</th></tr>
<tr><td>D_{50}</td><td>0.90mm</td><td>0.70mm</td></tr>
</table>
Sphericity = 0.65
Roundness = 0.45</td></tr>
</table>

Sphericity = area of particle projection / area of the circle with diameter equal to the longest length of the projection.
Roundness= average radius of curvature of surface features / radius of maximum sphere that can be inscribed.

IT tool

The IT tool is designed to help select reliable properties for hydrate-bearing sediments (Table 2). For most properties, the tool offers various alternative equations obtained from experimental data. A user-friendly interface facilitates its use. Figures 4, 5 and 6 show examples of comparison between predictive trends and compiled experimental data.

Table 2. Lists of properties built in the current version of the IT tool.

Phase properties	Hydrate phase properties
	Gas phase properties
	Liquid phase properties
Mechanical	Strength
	Stiffness
	Wave velocities
Hydraulic	Soil water characteristic curve
	Hydraulic conductivity
	Permeability
	Relative permeability
Thermal	Thermal conductivity
	Heat capacity

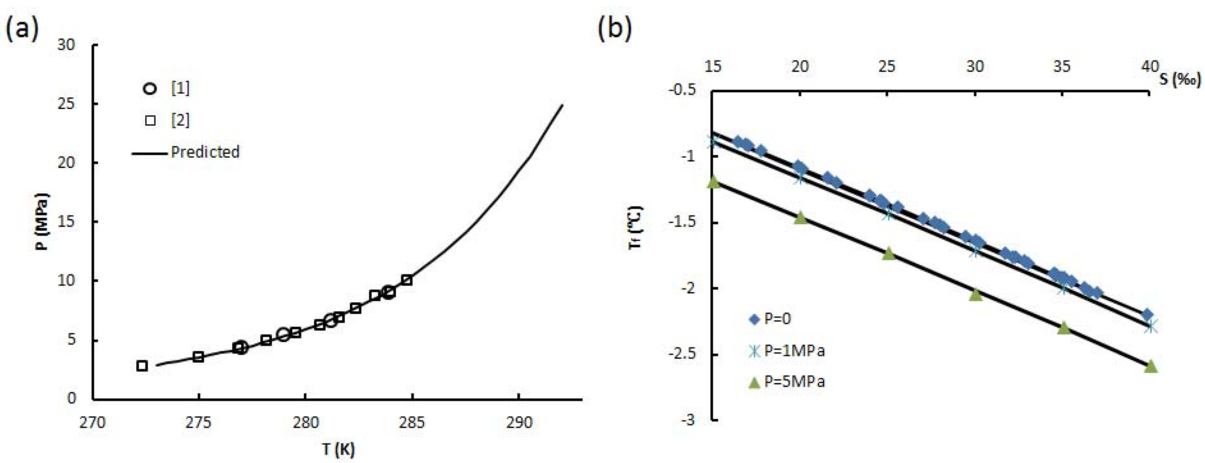


Figure 4. Phase boundaries: (a) hydrate phase equilibrium in seawater; (b) freezing point of seawater

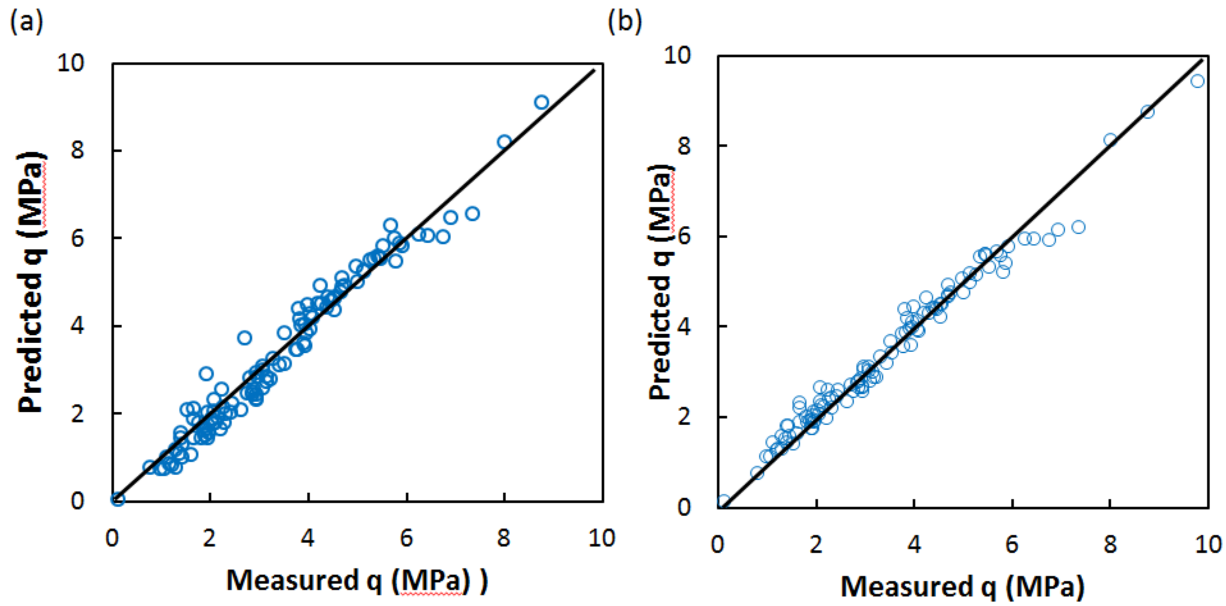


Figure 5. Mechanical properties: Strength (a) Santamarina and Ruppel, (2008); (b) Miyazaki et al. (2012).

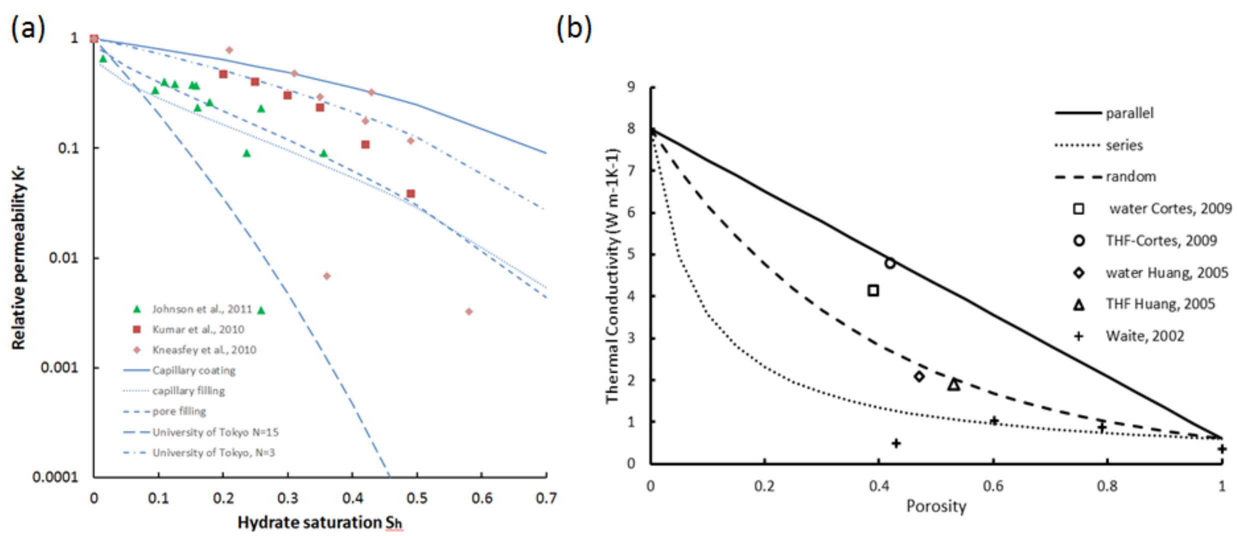


Figure 6. Hydraulic and thermal properties. (a) Relative permeability. (b) Thermal conductivity of hydrate-bearing sediments.

The IT tool consists of two parts. The first part classifies functions according to properties. The second part predictions properties in terms of available input parameters (Figure 7).

Figure 7. Interface of IT tool: (a) Input, (b) parameters, and (c) output.

MILESTONE LOG

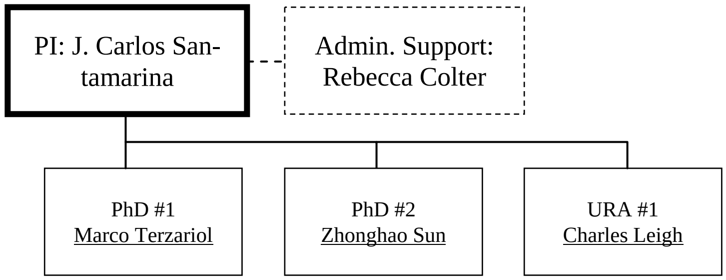
	Milestone	Completion Date	Comments
Title Planned Date Verification method	Completion PMP November 2013 Report	11/2013	
Title Planned Date Verification method	Insertion – Tool design September 2014 Report	In progress	
Title Planned Date Verification method	Database and IT tool September 2014 Report	In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

PRODUCTS

- **Publications – Presentations:** None at this point
- **Website:** Publications and key presentations are included in http://pmrl.ce.gatech.edu/. (for academic purposes only)
- **Technologies or techniques:** None at this point.
- **Inventions, patent applications, and/or licenses:** None at this point.
- **Other products:** 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	Budget Period 1							
	Q1		Q2		Q3		Q4	
	10/1/13 - 12/31/13		1/1/14 - 3/31/14		4/1/14 - 6/30/14		7/1/14 - 9/30/14	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total
Baseline Cost Plan								
Federal Share	18,000	18,000	18,000	36,000	18,000	54,000	84,945	138,945
Non-Federal Share	13,326	13,326	13,327	26,653	13,327	39,980	-	39,980
Total Planned	31,326	31,326	31,327	62,653	31,327	93,980	84,945	178,925
Actual Incurred Cost								
Federal Share	18,242	18,242	19,731	37,973				
Non-Federal Share	13,326	13,326	13,327	26,653				
Total Incurred Costs	31,568	31,568	33,058	64,626				
Variance								
Federal Share	242	242	1,731	1,973				
Non-Federal Share	0	0	0	0				
Total Variance	242	242	1,731	1,973				

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