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Deepwater Reverse Circulation Primary Cementing

10121-4502-01
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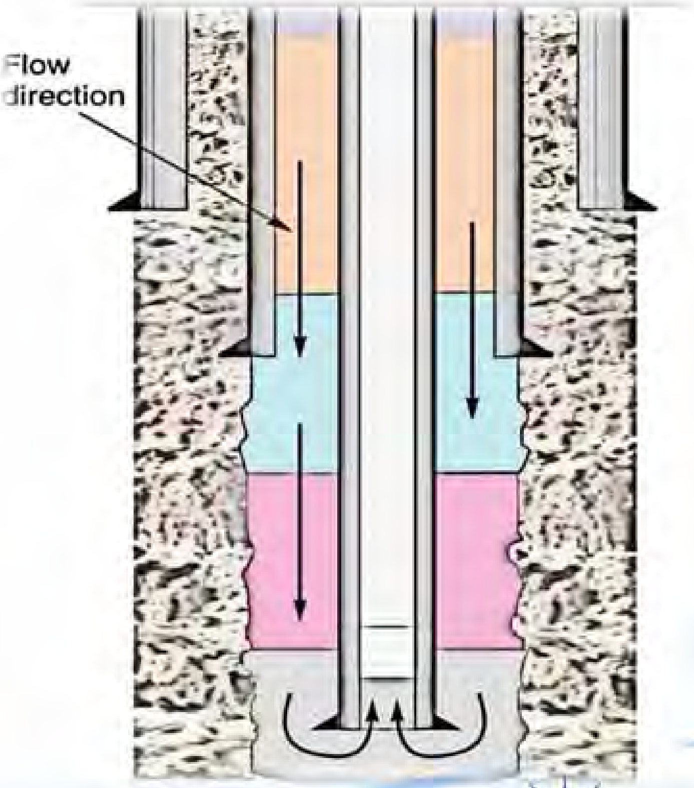
CSI Technologies, LLC

Ultra-Deepwater Drilling, Completions and Interventions TAC meeting
January 29, 2014
Greater Fort Bend Economic Development Council Boardroom, Sugar Land, TX

Project Background

Reverse-Circulation Primary Cementing (RCPC)

- Used on land wells since 1960's
- Few cases of RCPC offshore
  - None in US deepwater
- Potential Benefits
  - Reduced ECDs
  - Reduced risk of lost circulation
- Expected Challenges
  - Placement simulators and modeling
  - Mechanical placement controls
  - Fluid design and mud removal



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Project Objectives

- Provide step-by-step development path for deepwater RCPC

- Phase I Objectives:
  - Assess viability of performing RCPC on deepwater wells
  - Determine required technology to apply RCPC in deepwater wells

- Phase II Objectives
  - Present development strategy for required technologies
  - Develop operational procedures to perform deepwater RCPC
    - Including contingencies

- "Prototype Tested" Technology Readiness Level

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Project Milestones and Deliverables

Milestone	Target Date	Delivered Date
Deliverable 1 – Project Management Plan Draft	7/31/2012	7/17/2012
Deliverable 2 – Project Management Plan	8/14/2012	8/14/2012
Deliverable 3 – Technology Status Report	7/31/2012	7/27/2012
Deliverable 4 – Technology Transfer Plan	7/31/2012	7/27/2012
Deliverable 5 – Phase I Interim Report Draft	4/22/2013	4/22/13
Deliverable 6 – Phase I Interim Report	6/21/2013	6/21/2013
Deliverable 7 – Phase I Interim Progress Materials	7/5/2013	6/7/2013
Deliverable 8 – Phase II Project Management Plan Draft	7/21/2013	8/21/2013
Deliverable 9 – Phase II Project Management Plan	15 days after receiving RPSEA comments	10/9/2013
Deliverable 10 – Draft of Final Technical Report	4/22/2014	-
Deliverable 11 – Approved Final Technical Report	6/21/2014	-
Deliverable 12 – Final Technical Presentation	6/21/2014	-

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Financial Information

- Total Project Cost: $1,066,507
- Subcontractor Cost Share: $268,000
- RPSEA Maximum Share: $798,507
- RPSEA Maximum Share Minus 1% Tech Transfer: $787,842

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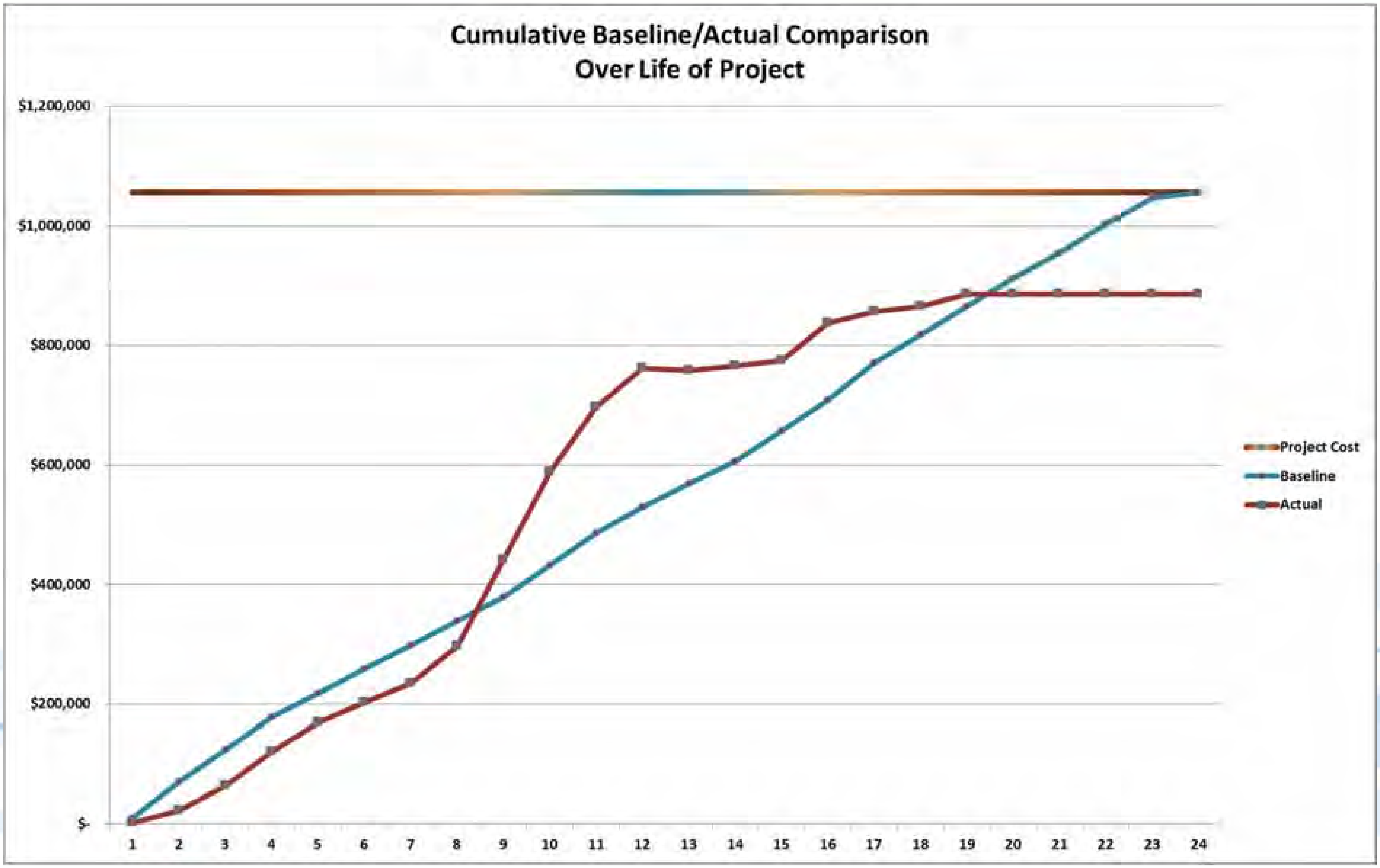
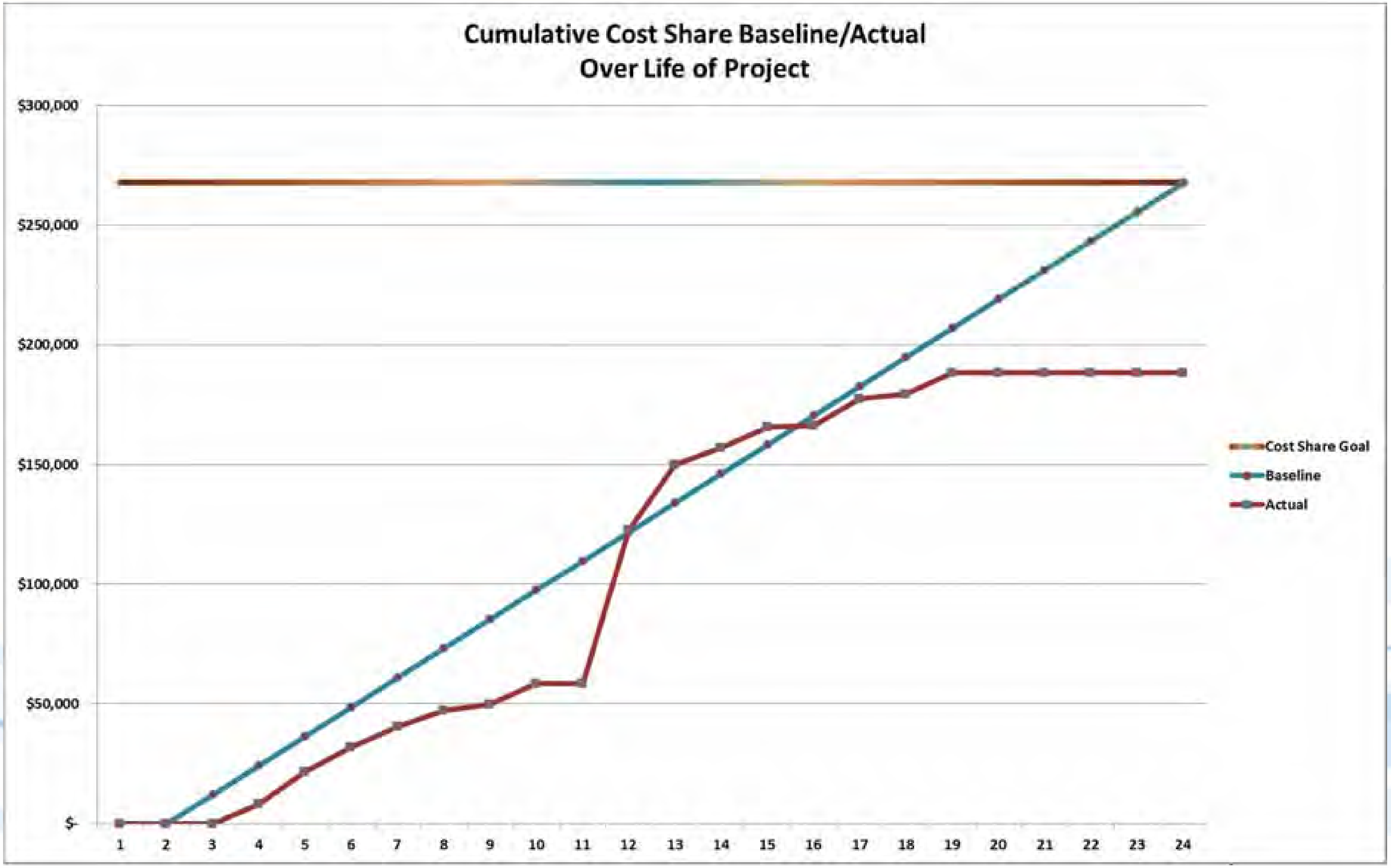
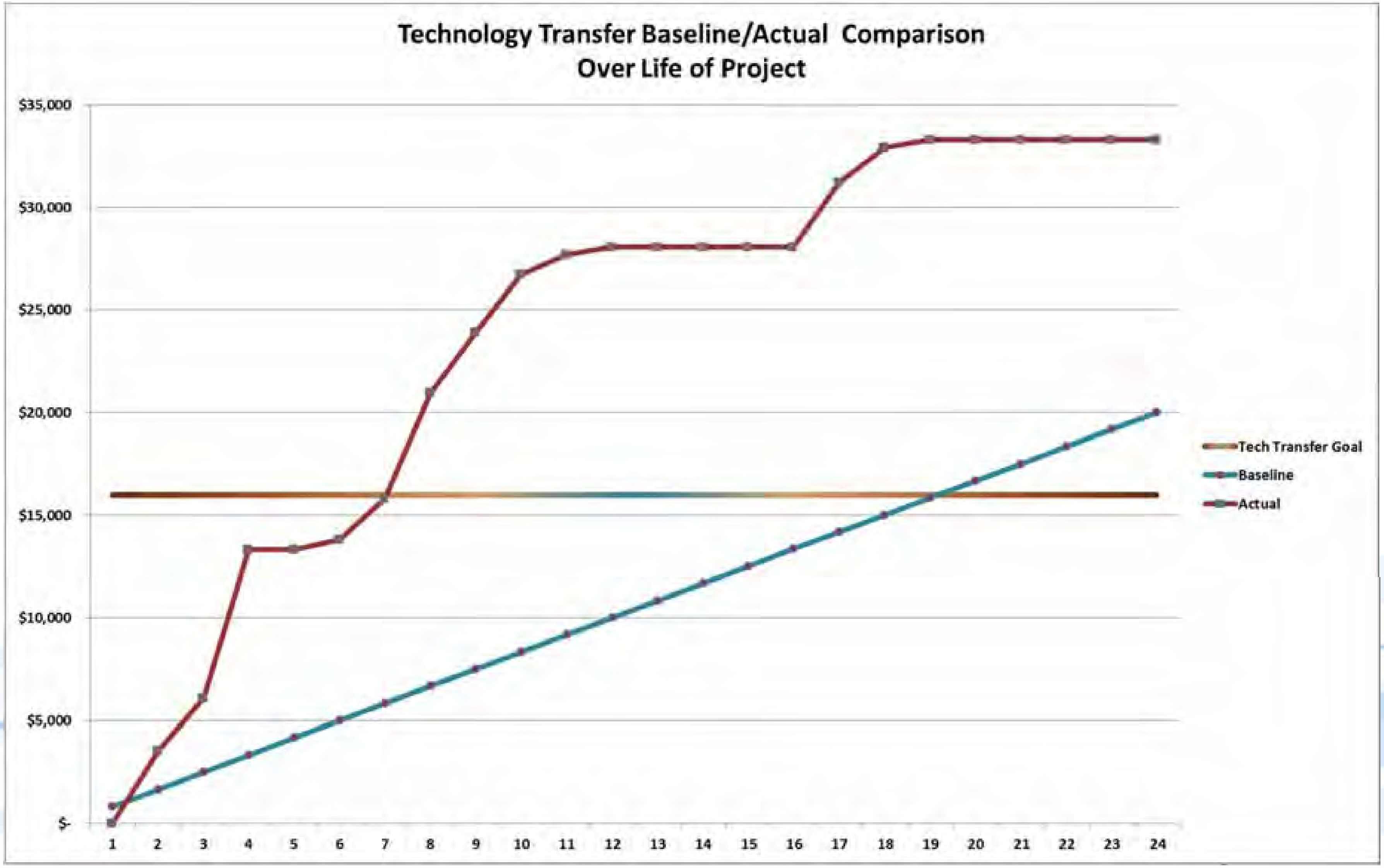
Financial Information - Totals



Financial Information – Cost Share



Financial Information – Technology Transfer



Phase 2 Work Summary

- Continue development of the Finite Element Modeling performed in Phase I
  - ECD, friction pressure, deviated wells
- Compare the developed *COMSOL Multiphysics®* model with results from commercially available simulators
- Key mechanical components identified in Phase I will be analyzed under real-well conditions
  - Switchable crossover
  - Crossover design for liner hangers
  - Float equipment

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Phase 2 Work Summary

- Identify RCPC slurry design considerations compared to conventional deepwater designs
- Prepare a high-level conceptual operation plan to successfully perform a deepwater RCPC job
- Develop a conceptual high-level contingency plan for all major contingency situations in a potential deepwater RCPC application
- Develop a conceptual report which identifies major equipment, software, placement design and techniques in detail

Current Work Status Update - Phase 2 Activities

- Task 12: Numerical Simulations
  - Subcontractor – University of Houston
  - Continued development of simulations and numerical models performed in Phase I

- Task 13: Mechanical Placement Controls
  - Subcontractor- Weatherford
  - Evaluation of mechanical flow requirements and components

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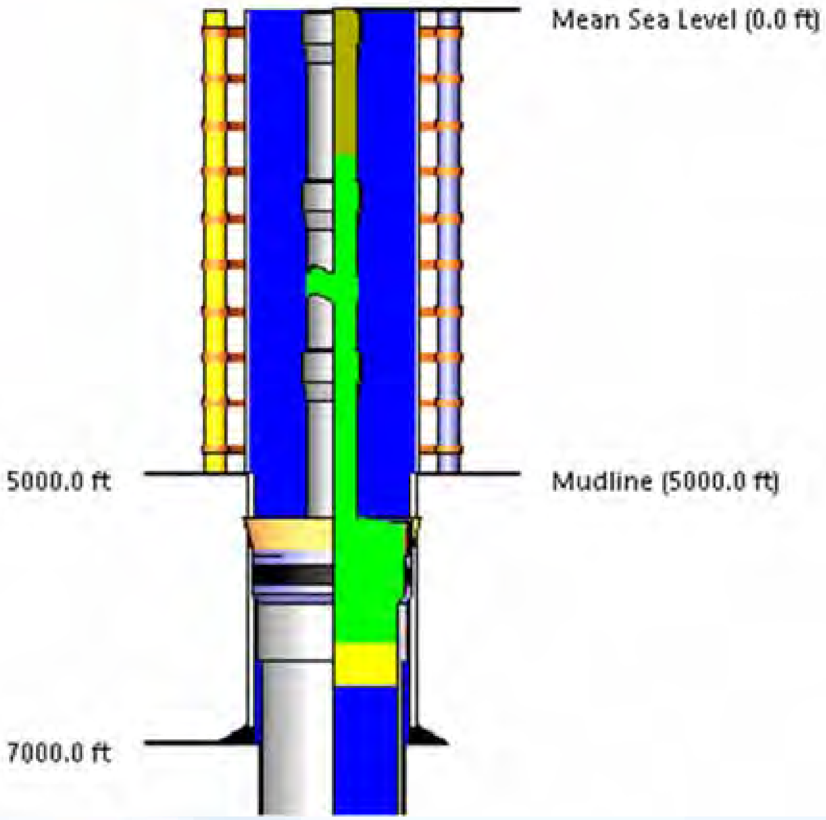
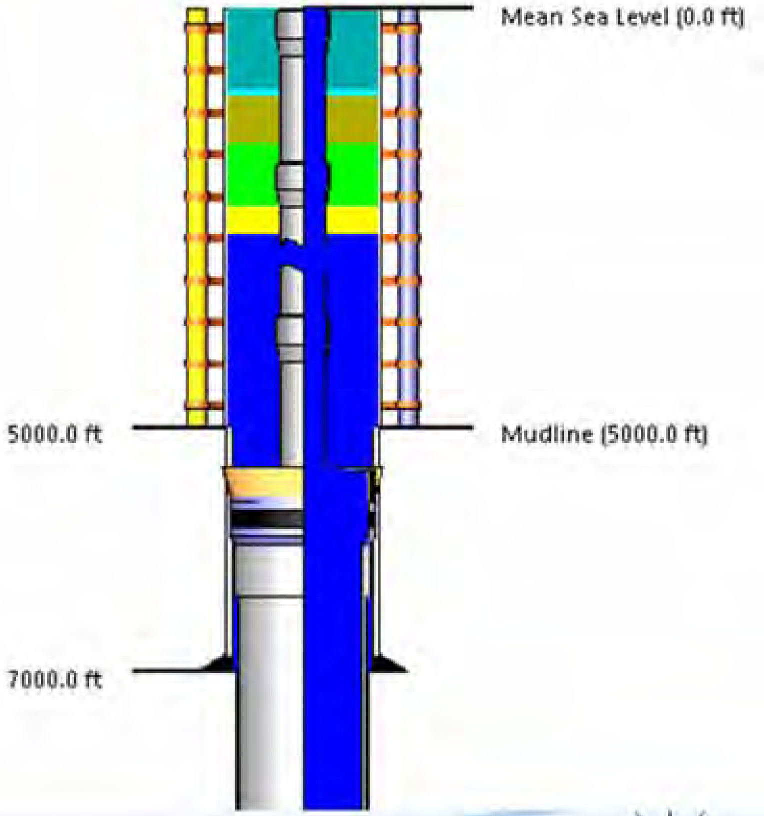
Task 7: Numerical Methods and Simulation



Conventional

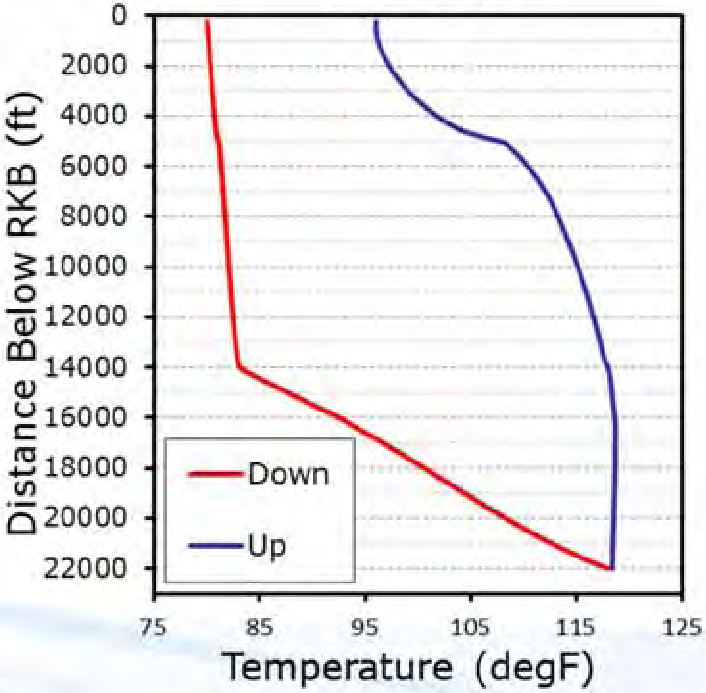


Reverse

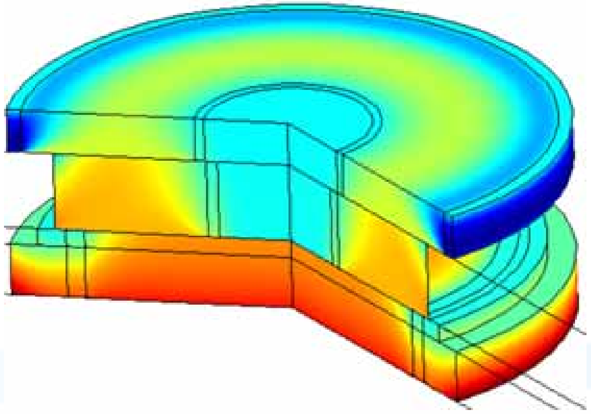
Bottom Hole Circulating Temperatures

- "1-D models cannot reflect the full complexity of the heat transfer process and therefore cannot be expected to provide reliable predictions of down-hole temperatures"[1]

1-D Data



2-D Data



[1]Bittleston, S.H., Schlumberger Cambridge Research, *A Two-Dimensional Simulator To Predict Circulating Temperatures During Cementing Operations*, in *SPE Annual Technical Conference and Exhibition*. 1990, Society of Petroleum Engineers: New Orleans.

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Task 12: New Features in Model

- Includes temperature change in the formation
  - More realistic temperature gradients
  - More similar to WELLCAT's model
- ECDs calculated independently of temperature data
  - Fully integrated calculations are currently being developed
- Temperatures during full cement job modeled, not just mud circulation
- Analyzed conventional placement to verify model

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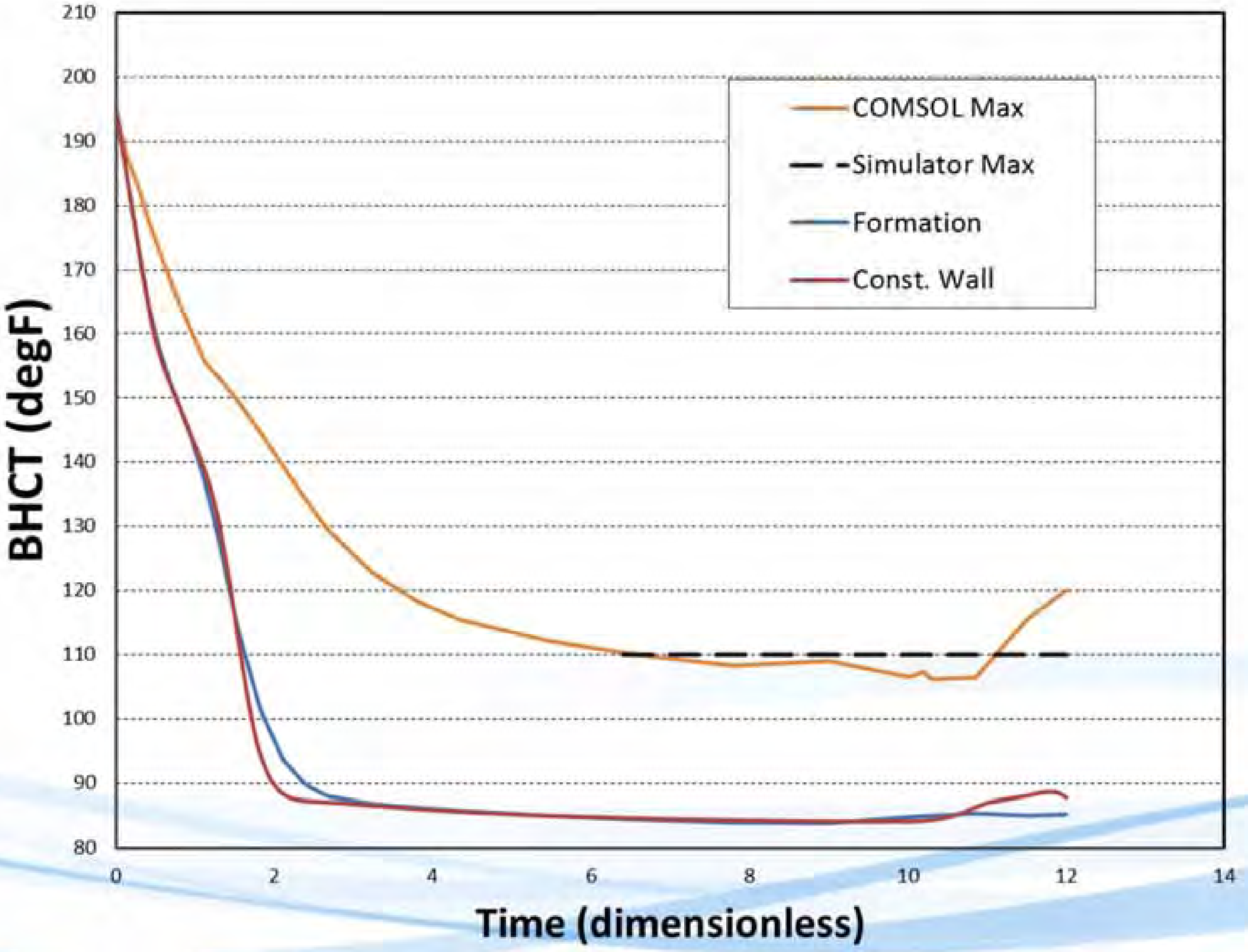
Conventional Placement to Verify COMSOL Model



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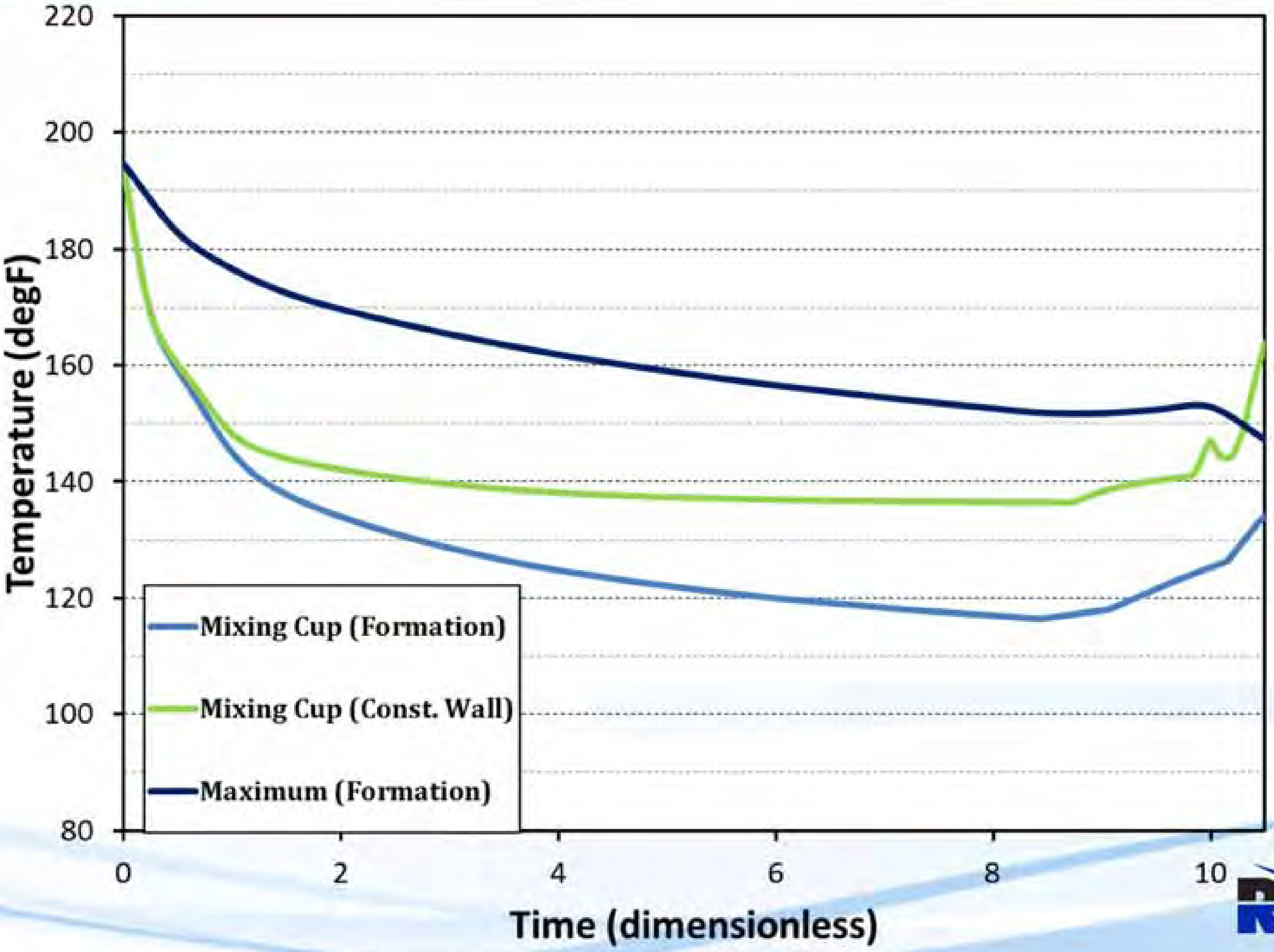
BHCT in Reverse Circulation



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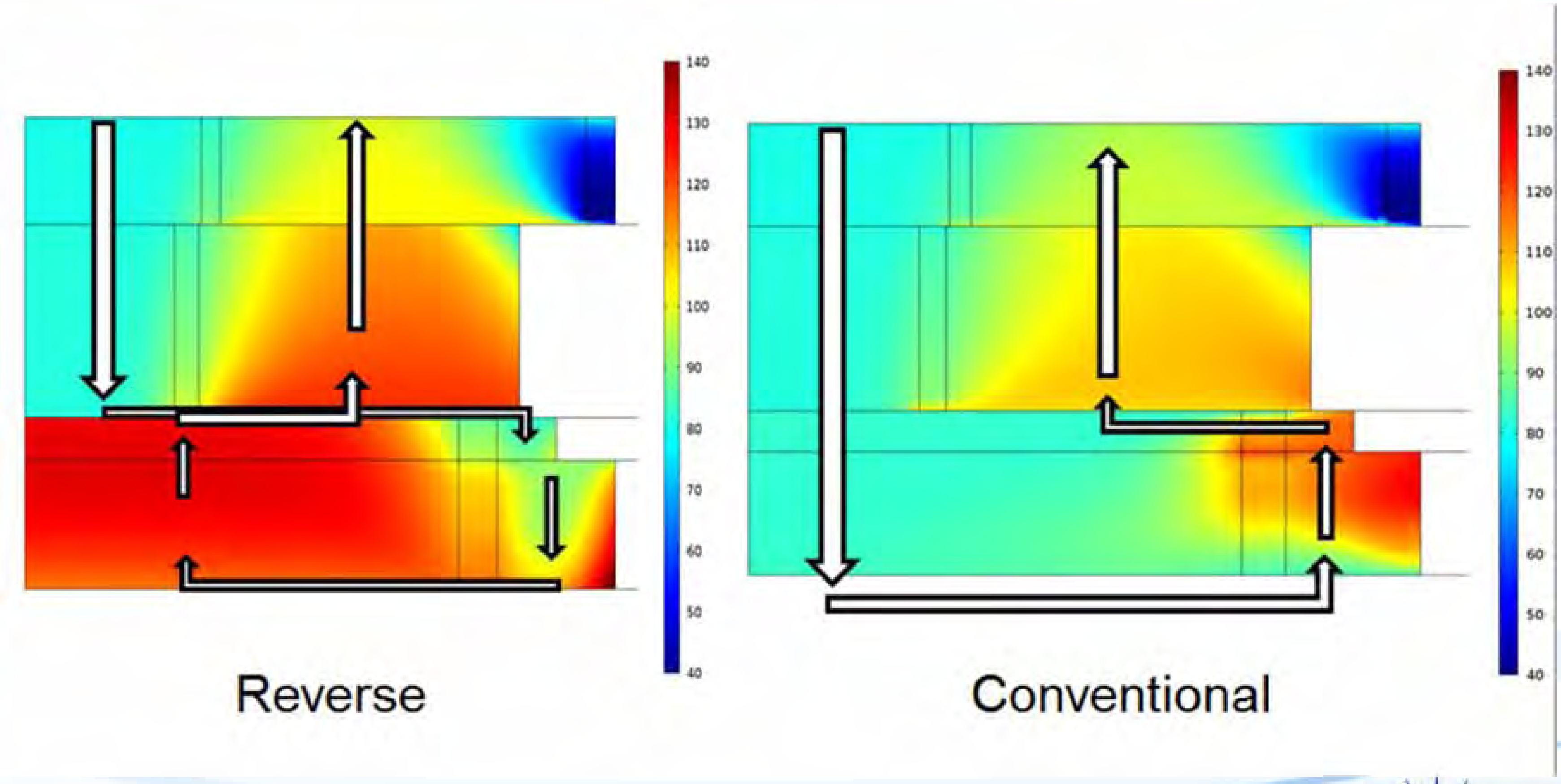
Overall COMSOL Temperature Comparison



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Mechanical Placement Control

- Initial Design Requirements for Mechanical Placement of Cement in a reverse cementing application
  - Reverse cementing system must work with casing run on a work string, e. g. liners, long strings hung off on previously run casing hangers, tie back strings, etc.
  - The system, as a minimum, should allow circulation in the primary direction, e. g. circulation down the work string, through the ID of the casing, and up the annular area between the casing and open hole/previously run casing ID while going in the hole with the casing.
  - The system, as a minimum, should be able to switch from circulation in the conventional direction to the reverse direction, so that all flow down the work string should will be directed to the casing annulus at the top of the casing. A pack-off above the exit ports to keep all flow moving down is activated at this time. Returns are taken taken from the casing ID then diverted above the pack-off into the annular area between the previously run casing ID and the work sting OD

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Mechanical Placement Control

- Initial Design Requirements for Mechanical Placement of Cement in a reverse cementing application Other considerations for the system are how the cement is placed and how to reduce the ECD's to minimum during cementing
  - At least one operator wants a continuous operation. Their vision is to have continuous rotation during the entire procedure, up to setting of the liner hanger. No shutting down rotation. They do not want to even shut down to put a plug container in the system – therefore all pumping is through the top drive
  - One operator doesn't want floating equipment at the bottom of the liner because of the higher ECD's caused by the floating equipment – yet still wants well control when released from the liner hanger
  - No operator wants holes below the liner hanger where cement is injected, therefore all pumping is done above the top of the liner hanger – preferable with the liner hanger un-set

Summary of Mechanical Requirements

- Fluid separation with plugs, balls, darts, etc. during reverse cementing is proving a challenge when consideration of operation of tool systems. All these tend to limit the operation mode of the tools. Therefore the use of “gel” plugs for fluid separation must be considered.
- The crossover system that can be switched on demand is proving a challenge. Designing a system that will work with current drill pipe and liner hangers is needed to meet today’s demand.
- Floating equipment, if used, should be the highest flow rate possible and must stay open during the placement of the cement – closing only after the cement has been placed and the liner hanger set
- When considering continuous operation, no shutting down of rotation during the entire procedure, except to set the liner hanger, requires re-thinking of fluid separation and tool operation.

Other current work in progress

Operational Contingency Planning

- Lost circulation
- Running equipment
- Tool operation
- Pack off at float/shoe area
- Other areas of concern?

RCPC slurry design considerations compared to conventional deepwater designs

- Varies by depth, location of crossover tool, volumes

Viscous pill evaluation for fluid separation downhole

Tech Transfer

Past Tech Transfer 2013

- RPSEA UDW Technology Conference – October 2013

- ABC GOM Ultra-Deep HTHP Conference – November 2013

Planned Tech Transfer 2014

- E&P Magazine Article – March 2013

- OTC – May 2014
  - Session # 030 - RPSEA UDW Research Efforts - Drilling, Interventions, and Weather-related Projects

- RPSEA UDW Conference – October 2014

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