Oil & Natural Gas Technology

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Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities

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ABSTRACT

In 2000, Chevron began a project to learn how to characterize the natural gas hydrate deposits in the deepwater portions of the Gulf of Mexico. A Joint Industry Participation (JIP) group formed in 2001, and a project partially funded by the U.S. Department of Energy (DOE) began in October 2001. The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deepwater Gulf of Mexico (GOM). These naturally occurring gas hydrates can cause problems relating to drilling and production of oil and gas, as well as building and operating pipelines. Other objectives of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to determine how the results of this project can be used to assess if, and how gas hydrates act as a trapping mechanism for shallow oil, or gas reservoirs.

During October 2013 – March 2014 Project activities included:

- **Completed the operational plan for the field test of the Hybrid Pressure Coring System (PCS) at the Catoosa Test Facility in Oklahoma. The Hybrid PCS was developed by Aumann & Associates, Inc. (AAI) and was factory acceptance tested in September 2013.**
- **Pro-log, Inc. completed fabrication of the Heavy Van and Service Van, which serve as transport and on-site servicing containers for the Hybrid PCS. The Service Van was delivered and used at the Catoosa Test Facility, and then it was returned to storage at Pro-log, Inc. The Heavy Van remained in storage at Pro-log, Inc.**
- **The field test was conducted November 4 - 13, 2013 at the Catoosa Test Facility in Oklahoma. Following the field test the Hybrid PCS was returned to AAI for further modification.**
- **Following the completion of the field test a preliminary assessment of the results was made by AAI. It was later recommended that a Technical Review Team (TRT) be**

formed to further investigate tool performance and operational issues. TRT was formed on December 3, 2013 and completed their assessment in March 2014.

- **AAI identified and completed some additional modifications to the Hybrid PCS based on field test performance.**
- **The TRT completed their assessment of the field test results and recommended actions to improve future performance.**
- **The Project closed on March 31, 2014, but it includes an additional 90 day post-closeout period to complete final documentation and delivery of the project equipment (by the end of June 2014). The final documentation will include a detailed Phase IIIB technical report and a final integrated report. Because the details of technical activity during October 2013 – March 2014 period will be provided in the Phase IIIB technical report this current Semi-Annual Progress Report is limited to a high level summary.**

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1.0 Introduction

In 2000, Chevron Petroleum Technology Company began a project to learn how to characterize the natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. Chevron is an active explorer and operator in the Gulf of Mexico, and is aware that natural gas hydrates need to be understood to operate safely in deep water. In August 2000, Chevron working closely with the National Energy Technology Laboratory (NETL) of the United States Department of Energy (DOE) and held a workshop in Houston, Texas, to define issues concerning the characterization of natural gas hydrate deposits. Specifically, the workshop was meant to clearly show where research, the development of new technologies, and new information sources would be of benefit to the DOE and to the oil and gas industry in defining issues and solving gas hydrate problems in deep water.

Based on the workshop held in August 2000, Chevron formed a Joint Industry Project (JIP) to write a proposal and conduct research concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. Chevron generated a research proposal which was submitted to DOE in April 2001 under a competitive DOE funding opportunity announcement (FOA). That application was selected for award by DOE under the FOA and Chevron was awarded a cooperative agreement for research based on the proposal.

The title of the project is **"Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities".**

1.1 Objectives

The **primary objective** of this project is to develop technology and data to assist in the characterization of naturally occurring gas hydrates in the deep water Gulf of Mexico (GOM). These naturally occurring gas hydrates can cause problems relating to drilling and production of oil and gas, as well as building and operating pipelines. Other objectives of this project are to better understand how natural gas hydrates can affect seafloor stability, to gather data that can be used to study climate change, and to determine how the results of this project can be used to assess if and how gas hydrates act as a trapping mechanism for shallow oil or gas reservoirs.

1.2 Project Phases

The project is divided into phases. **Phase I** of the project is devoted to gathering existing data, generating new data, and writing protocols that will help the research team determine the location of existing gas hydrate deposits. During **Phase II** of the project, Chevron will drill hydrate data collection wells to improve the technologies required to characterize gas hydrate deposits in the deepwater GOM using seismic, core and logging data. **Phase III** of the project began in September of 2007 and will focus on obtaining logs and if possible cores of hydrate bearing sands in the GOM.

1.3 Research Participants

In 2001, Chevron organized a Joint Industry Participation (JIP) group to plan and conduct the tasks necessary for accomplishing the objectives of this research project. As of March 2014 the members of the JIP were Chevron, Schlumberger, ConocoPhillips, Halliburton, the U.S. Bureau of Ocean Energy Management (BOEM), Total, Japan Oil, Gas and Metals National Corporation (JOGMEC), Reliance Industries Limited, The Korean National Oil Company (KNOC), and Statoil.

1.4 Research Activities

The research activities began officially on October 1, 2001. However, very little activity occurred during 2001 because of the paperwork involved in getting the JIP formed and the cooperative agreement between DOE and Chevron in place. Semi-Annual and Topical Reports have been written that cover the activity of the Project through March 2014.

1.5 Purpose of This Report

The purpose of this report is to document the activities of the Project during October 2013 – March 2014. *It is not possible to put everything into this Semi-Annual report, and there are more technical details that will be provided in the Phase IIIB technical report to be delivered by June 2014. Additionally, many of the important results are included and references to the NEL Project website:*

http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/projects/DOEProjects/CharHydGOM-41330.html/

The discussion of the work performed during this report period is organized by task and subtask for easy reference to the technical proposal and the DOE contract documents.

2.0 Executive Summary

As the Cooperative Agreement was moving toward its conclusion on March 31, 2014, the JIP and DOE have determined that they will focus full attention on the development and testing of an integrated suite of pressure coring and pressure core analysis devices in collaboration with research and development experts in the US Department of Energy, U.S. Geological Service, Georgia Tech, Scripps Institution of Oceanography and other academic institutions as well as Aumann and Associates Inc, Geotek and other and sub-contractors. Other than drilling associated with tool testing at the Catoosa site (Hallett, OK), no other drilling programs will be conducted.

During the reporting period, significant progress was made in the development, field testing, and post-test analysis of the Hybrid Pressure Coring System (PCS).

1) The final design of the Hybrid PCS built by Aumann Associates Incorporated (AAI) has been completed, and a factory acceptance was successfully conducted during September 2013 at AAI's facility in Salt Lake City, Utah.

2) The Heavy Van and Service Van were fabricated by Pro-Log, Inc. and are in storage at New Iberia, Louisiana and ready for delivery.

3) The onshore test of the Hybrid PCS was completed at the Catoosa Test Facility near Hallett, Oklahoma during November 4-13, 2013. Results of the test and tool performance were extensively reviewed and documented by AAI and a Technical Review Team (TRT) which was formed for this purpose.

4) Some post-test modifications to the Hybrid PCS were completed by AAI that were within the scope, budget and timing of this Project. The TRT completed their assessment and issued their results.

5) The Project is scheduled to close on March 31, 2014, but it includes an additional 90 day post-closeout period to complete final documentation and final delivery of the Project Equipment (including the Hybrid PCS, the Service and Heavy Vans, and additional equipment developed during the Project).

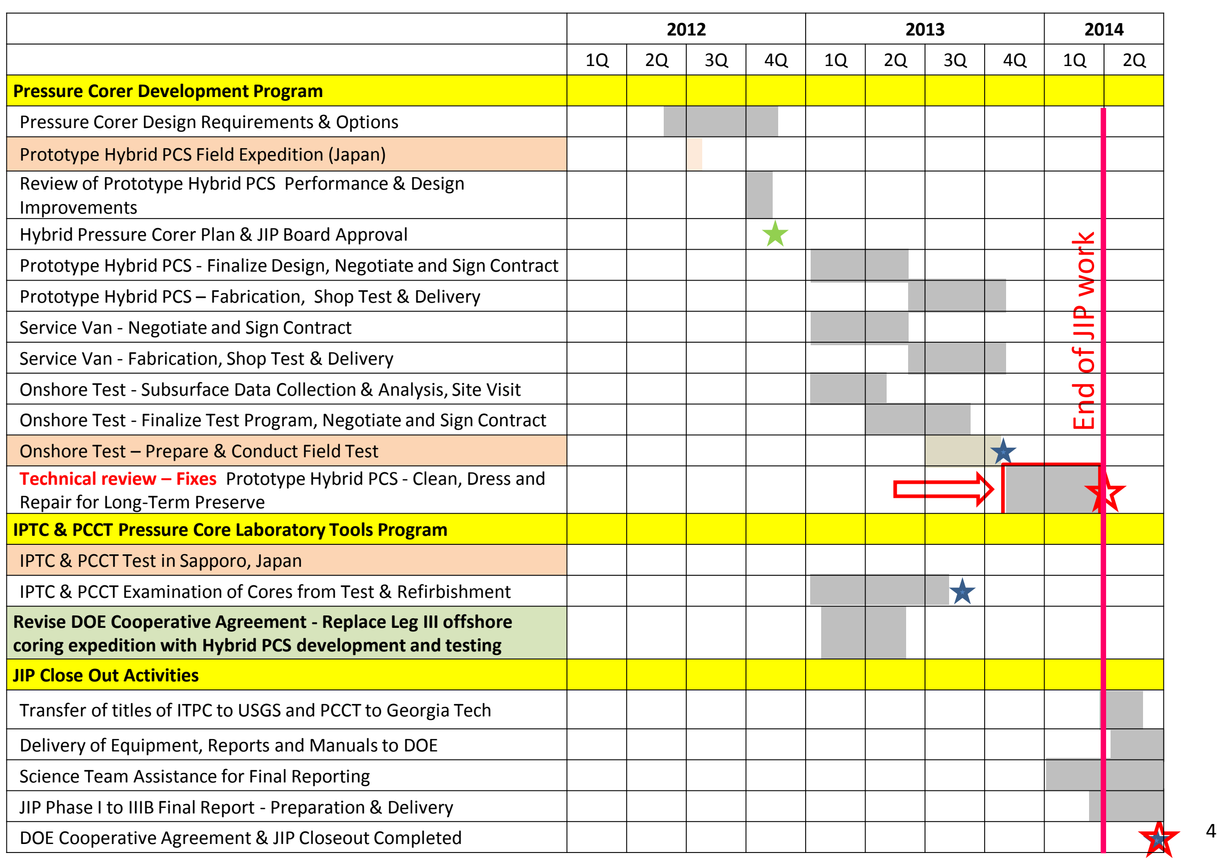
6) Because the final documentation will include a detailed Phase IIIB Technical Report, this current Semi-Annual Progress Report will only include a high level summary of technical activities during the reporting period.

3.0 PHASE III B (Leg III) Activities

As the Cooperative Agreement was moving toward its conclusion on March 31, 2014, the JIP and DOE determined that they will focus full attention for the remainder of this Phase on the development and testing of an integrated suite of pressure coring and pressure core analysis devices in collaboration with research and development experts in the U.S. Department of Energy, U.S. Geological Service, Georgia Tech, Scripps Institution of Oceanography and other academic institutions as well as Aumann and Associates Inc., GeoTek and other contractors.

The Project Schedule below shows the activities that were conducted during the October 2013 – March 2014 reporting period, and it illustrates the activities that are to be completed during the 90 day close-out period.

JIP Project Schedule (Adjustment to Previous Schedule)



3.1 Preparation and execution of the Hybrid PCS field test

Chevron signed a time and materials contract with the Catoosa Test Facility for providing a research test site with drilling rig and 3rd party services for testing the Hybrid PCS. The Hybrid PCS tool was transported to the test site, and the testing commenced on schedule on November 4th. The test was completed on November 13th. Prior to the test the following activities were completed in preparation for the test:

<u>Service and Heavy Vans:</u>
The Service Van was fabricated at Pro-Log's Tenaha, TX facility and was shipped to the Catoosa Test Facility in late October. The Heavy Van was fabricated at Pro-Log's New Iberia, LA facility and was placed into storage after completion in late October. Chevron elected not to use the Heavy Van at the onshore test site due to out of the ordinary onshore loading requirements and associated costs. The Heavy Van is designed for cranes used in offshore loading/unloading operations. Core inspection operations at the onshore test site, which were initially planned for inside the Heavy Van, were performed inside the Catoosa Test Facility's workshop.

<u>Onshore Test Planning and Mobilization:</u>
The onshore test objective was to test the functionality of the Hybrid PCS tool and not its durability in extreme settings. The test site lithology was studied, coring intervals were identified and very hard or abrasive strata were avoided. Extensive discussions with Catoosa Test Facility (CTF) owners were agreed upon which resulted in CTF being a prime contractor with all 3rd party contractors (Weatherford, Core Labs, AAI etc.) being subcontractors to CTF. This contracting plan allowed CTF to conduct the test operation in accordance with their operation and safety protocols at their test site. Chevron performed contract administrative duties with respect to the test program and Management of Change of test program only. A "Hybrid PCS Coring, Testing and Core Handling Plan Catoosa Test Facility" planning document was issued in late October, and a summary of the pre-test operational program was provided in the Semi-Annual Progress Report #41330R25 (April 2013 – September 2013). All materials and services were mobilized in a timely manner and CTF commenced onshore testing as scheduled on November 4th.

<u>Onshore Test Execution:</u>

The onshore test plan was to:

1. Drill to top of Tonkawa sand and cut three cores using the face bit configuration in sand #1.
2. Cut two cores with cutting shoe configuration, one core in sand #1 and one core in sand #3.

The actual result was:

1. Attempted first core in sand #1 with face bit configuration (not tested in Japan) and inner sleeve/core liner collapsed due to high differential pressure between outside diameter of inner sleeve and inside diameter of core liner.

2. Decision was made to switch to cutting shoe configuration as this configuration had already established a proven track record in Japan.

3. Cutting shoe bit face disintegrated after cutting 0.9 feet of core in sand #1. The apparent reason for the failure was presumed to be cutting shoe bit manufacturing detailed design.

4. Made another attempt to core in sand #1 with face bit configuration which resulted in high differential pressures and a collapsed liner again.

5. Decided to test the center bit drill ahead option with the center bit installed in face bit configuration. This achieved a 22 feet/hour rate of penetration (ROP). The onshore test was then concluded.

Due to the problems encountered with the Hybrid PCS, the onshore testing took longer than anticipated and was not completed until November 13th. The detailed operational data will be provided in the Phase IIIB Technical Report. All test operations were completed in a safe manner with no accidents or incidents.

3.2 Preliminary Report on the Performance of the Hybrid PCS during the field test

The onshore test performance of the Hybrid PCS was below expectations. The problems areas fall into 4 categories:

Bit design issues:

- Cutting shoe center bit extended further ahead of main bit than expected.
- Cutting shoe crown disintegrated during first and only attempt with cutting shoe and inner barrel assembly.
- Cutting shoe bit/center bit combination resulted in very slow drilling with ROP of 1 foot/hour for four hours.
- A high differential pressure created during pumping operations with the face bit could be a result of inadequate total flow area of the face bit; however, further investigation is required to draw this conclusion.

Pressure Retention issue:

- Autoclave pressure was not retained during either the dimensional tests or the coring runs even though the ball valve closed and appeared to operate properly. The maximum pressure recorded was around 100 psi.
- The pressure boost from the pressure control section did not occur which was verified by the fish pill recorder data.
- There was evidence that the separator piston moved down prematurely on some tools while they were waiting to be run.
- The return spring jumped coils and jammed on at least one dimensional test which prevented the ball valve from closing.
- The weight of the sinker bar assembly, inner latch, extension rods and pressure control section could push down on the inner tub plug which would release pressure from the autoclave at trapped pressures below 130 psi.

Inner tube and core liner failure:

- The inner tube and core liner collapsed during two face bit runs.
- The inner tube was redesigned with a low strength thin wall stainless steel tube to accomplish the objective (increase clearance between ID of inner tube and OD of core liner and core catchers to eliminate during core transfer to PCATS), of one of the 15 modifications from the Japan tool.
- A review of the reason for high differential pressure between the OD of the inner sleeve and ID of the core liner may be the root cause of failure; however, some changes may have to also be made to the inner sleeve material and/or thickness to be compatible with differential pressures of either a redesigned tool or face bit.

Human error:

- One fish pill recorder was set up incorrectly and failed to record the pressure properly due to inadequate training and practice.
- Two types of parts were discovered to have been manufactured incorrectly due to improper QA and inadequate FAT assembly and checking
- A face bit inner barrel assembly failed to latch due to an assembly error on the rig floor
- AAI service personnel assembled tools incorrectly on three runs
- A premature comment that the pawls had locked under the seal hub was incorrect information which was later correctly identified as directly related to the collapsed inner sleeve/core liner.

There were several Hybrid PCS Test Successes, which include the following:

- Inner and outer latch systems worked extremely well with no failures or wear.
- All inner barrels were assembled correctly in the BHA/Outer barrel.
- Low end drive system was verified to function correctly with no wear on the drive dogs or drive sub.
- Wireline tools functioned as designed with no failures or wear.
- Core transfer tool was effective during the two operations. There was no jamming as was experienced in Japan.
- Pre-run and post-run pressure tests verified that the autoclave sealing systems were effective.
- Upper autoclave seals, ball valve and sleeve valve all appeared to function correctly (mechanically) on many occasions.
- Core liners and other sensitive parts of the inner barrel assembly held up well in consideration of core jamming when liner collapsed.

3.3 Post Test Actions

AAI developed preliminary recommendations which were reviewed and considered as corrective actions to improve overall performance. AAI also performed some preliminary tests which have resulted in some findings that will lead to solutions to the problems. Several of these solutions have been completed within the scope and budget of the Project and will be described in detail in the Phase IIIB technical report.

AAI also followed-up on Chevron's suggestion to bring outside 3rd party consultants to take a fresh look at the problems encountered and understand what their suggestions and recommendations were to overcome performance issues. A December 3rd workshop hosted by AAI in Salt Lake City was attended by the DOE, USGS, Chevron and two 3rd party consultants to better understand the onshore test problems and what the solutions/fixes might be implemented in the short term to correct the issues related to poor performance. A Technical Review Team (TRT) was then formed during the workshop to further investigate tool performance. AAI also committed four members to the team.

3.4 Technical Review Team

Objective:

To help understand the causes behind the performance issues identified during testing at Catoosa Test Facility and determine the necessary actions to improve the performance of the prototype Hybrid PCS tool.

Membership:

- Tom Pettigrew (Team Leader), Principal, Pettigrew Engineering
- Jim Aumann, Principal, Aumann and Associates
- Tim Collett, Co Chief Scientist, United States Geological Survey
- Tom Fate, Coring Subject Matter Expert, Chevron Energy Technology Company
- John Roberts, (Ad hoc member) Technical Director, Geotek
- Available JIP Resources: Harutaka Okayama, JOGMEC; Ludovic Delmar, Halliburton

Results and Recommendations:

The TRT Technical Review Results are summarized in the Table on the following page.

Additionally, the TRT made the following assessment and recommendations:

- Extensive lab testing has taken place to verify solutions to individual operational issues.
- Further full scale testing of the Hybrid PCS could not be carried out due to JIP time and budget limitations.
- Alternatives for further testing (however, outside the scope of the current Project) were identified. These alternatives will be described in more detail in the Phase IIIB Technical Report. These include:
    - Testing at depth from a suitable platform with wireline capability such as IODP or drill ships
    - Testing at depth at suitable facility such as Schlumberger Cameron Testing and Training Facility
    - Testing in a flow loop such as Schlumberger Genesis Testing Facility
    - Laboratory Testing
    - Field Testing by an interested Operator

TRT HPCS Technical Review Results Update

13-Mar-14

Item	TRT Identified Problem Area	TRT Suggested Next Steps and/or Fix	TRT Estimate of Impact on Overall Performance	Review and/or Testing Results	Final Status
1a	Cutting shoe center bit apparent excessive extension.	Design and manufacture length adjuster for the center bit assembly.	Low	A tolerance study of the BHA revealed a tolerance stackup of +/- 0.603" is possible.	A center bit length adjuster has been designed and in fabrication, to be delivered with the HPCS.
1b	Cutting shoe crown disintegration.	Design and manufacture all steel body PDC cutting shoes.	High	Fabrication of all steel body PDC cutting shoes is possible.	All steel body PDC cutting shoe designed and in fabrication. 4 each to be delivered with the HPCS.
1c	Low cutting shoe/center bit penetration rate.	Have representative from bit company analyze cutting shoe center bit to main bit assembly.	Low		Larger total flow area of core bits may increase penetration rate.
1d	High pressure drop in face bit inner barrel assembly.	Analyze flow through assembly and modify to increase flow areas in tight spots.	High	A review of the assembly drawings did not identify any significant flow restrictions. A review of the bit designs revealed that the total flow area of the face bit is 0.98 sq. in. and the cutting shoe bit, with cutting shoe, 1.36 sq. in. Note, 1.8 sq. in. is typical for a 10-5/8" bit.	5 additional nozzles have been added to the face bit to increase the total flow area to 1.84 sq. in. The cutting shoe bit nozzles have been bored out to increase the total flow area to 1.72 sq. in.
2a	Hydrostatic pressure retention failure.	Full function hydrostatic lab tests and engineering study at AAI.	High	Lab tests confirmed that two chambers in the ball valve assembly can result in slow closure with viscous fluids. Developed and successfully tested pressure relief slots. Full function lab tests verified significant pressure reduction (up to 350 psi) do to chamber volume increase if the pressure control section does not supply additional volume.	Pressure relief slots have been added to the existing tools.
2b	Nitrogen pressure boost failure.	Most likely a failure of ball valve closure(See 2-a) or leaky seals (See Item 2-c.) in the pressure control section.	High	Full function lab tests revealed an incorrect operational sequence allowing the sleeve valve to open while the inner tube plug check valve is still open. Additional full function lab tests with a corrected operational sequence functioned correctly. It is a very simple fix to change the operational sequence by deepening a counter bore in the lift sub. This will be implemented in the existing pressure sections.	The operational sequence has been corrected by deepening a counter bore in the lift sub in all the existing pressure sections.
2c	Premature movement of separator piston.	Hydrostatically test the pressure control system seals and sealing systems at AAI. Change compounds, seal design and/or surface finishes and shop test to verify satisfactory performance. Provide new seals, modify parts if necessary.	High	Completed numerous tests that confirmed that the seal selection, materials and design is satisfactory. Several systems were charged and measured over time with no leakage or piston movement. It is believed that the problem may have been the result of a bad or cut seal.	Issue resolved, believed to have been a glitch.
2d	Spring jumping coils/jamming issue.	Investigate adding a counter bore in the flow sleeve to trap the spring. Manufacture and test counter clockwise springs. Revise manual to add a step to check for correct spring operation.	High	A cutting shoe sleeve was modified with a counterbore to trap and center the lower end coil of the ball valve return spring. This not only made assembly easier, it also completely fixed the jamming of the return spring that prevented the ball valve from closing.	All of the cutting shoe sleeves and outer shoes (for the face bit) have been modified.
2e	Concerns over premature release of autoclave pressure due to weight of the sinker bar assembly, etc.	Add locking dogs inside the inner barrel assembly to prevent downward movement until disassembly.	High	Calculations confirmed that it is not possible to release the autoclave pressure with the weight of the sinker bar assembly or upper Hybrid PCS assembly. Lab tests confirmed the calculations.	No additional locking dogs are required.

TRT HPCS Technical Review Results Update

13-Mar-14

Item	TRT Identified Problem Area	TRT Suggested Next Steps and/or Fix	TRT Estimate of Impact on Overall Performance	Review and/or Testing Results	Final Status
3a	Collapse of Inner Tube and Core Liner.	Analyze and hydrostatically test the inner tube and core liner at AAI for collapse strength. Consider increasing the strength of the inner tube if it increases resistance to core liner collapse.	High	Calculations indicate that thin wall inner tube collapse is possible with as little as 300 psi. A thicker 304 SS tube could withstand up to 2000psi.	Thicker wall inner tube design complete. New parts not ordered due to long lead time.
4a	Fish pill pressure recorder set up incorrectly.	Assign responsibility and require proper training ahead of the operation.	Low	AAI personnel have gained experience using the fish pill pressure recorders during lab tests.	No further action required.
4b	Incorrect part manufacture.	Add a QC function to the ordering process.	High	The defective parts were parts that were ordered at the last minute because of an oversight in ordering by AAI management. The late parts delivery prevented the required 100% inspection and FAT of those parts.	No further action required.
4c	Face bit inner barrel assembly failed to latch into the BHA.	Paint color coding on upper assemblies (outer bearing and inner barrel sub).	Medium	Resolved by color coding parts	All pertinent parts have been color coded.
4d	AAI personnel assembled tools incorrectly on three runs.	Require the use and sign off on the run request form.	Medium	Prepare a sign off sheet prior to next operation.	Sign off sheet prepared and added to operations manual.
4e	Premature comment by AAI crew regarding pawls mis-operation.	All personnel except AAI personnel should stay out of the Service Unit. Client should wait for official report before documenting failures.	Low	NA	No further action required.
4f	Insufficient Staff to adhere to protocol and verify correct documentation.	A minimum of 3 Coring Service Technicians, a Records Technician, and 1 rig floor Coring Engineer per 12 hr. shift, plus one overall Coring Supervisor is recommended for all HPCS operations.	High	NA	No further action required.

4.0 Conclusions

Much progress was made during the current reporting period. This included the final planning and execution of the onshore test of the Hybrid PCS. Following the test there was an extensive technical and operational review of the test results. A dedicated Technical Review Team was formed to provide a thorough assessment of the results and make recommendations for further improvements. AAI continued to evaluate the tool performance and test results, and they have made some modifications to the Hybrid PCS within the budget and timeframe of this Project. The Project, the JIP and the Cooperative Agreement have concluded as planned on March 31, 2014. A 90 day project close-out plan has been developed and is in progress. The closeout activities will consist of the reporting on Phase IIIB results together with a compilation of scientific results previously reported in the Phase I, II and IIIA, the transferring of equipment developed under JIP to destinations designated by DOE and the audit activities for year 2013 as required by DOE regulations.

5.0 References

No external references were used for this report.