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 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.

During October 2012 – March 2013 Project activities included:

- **Completion of the testing of the Instrumented Pressure Test Cell (IPTC) and the Pressure Core Characterization Tool (PCCT) on pressured cores collected in Japan. The test was very successful.**
- **Detailed analyses and identification of design modification options to make improvements on the prototype Hybrid PCS previously developed by Aumann & Associates Inc. (AAI) and used by JOGMEC during their July 2012 hydrate pressure coring expedition offshore Japan.**
- **The selection of pressure corer design options for an improved hybrid PCS for GOM JIP is near completion. Contracting work for the manufacturing of the improved prototype Hybrid PCS has been initiated.**
- **Development of a high level plan for onshore test of the JIP Hybrid PCS. The Catoosa test site has been selected as the onshore test site. Detailed evaluation of for onshore testing program options and contracting work for testing program has begun.**

More information is available on the NETL website: http://www.netl.doe.gov/technologies/oil-gas/FutureSupply/MethaneHydrates/projects/DOEProjects/CharHydGOM-41330.html

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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) 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".**

1.2 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.

1.3 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.

1.4 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 September 2012 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.

1.5 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 September 2012.

1.6 Purpose of This Report

The purpose of this report is to document the activities of the Project during October 2012 – March 2013. *It is not possible to put everything into this Semi-Annual report, however, 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

The Cooperative Agreement is now moving toward its conclusion. 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 contractors. Other than drilling associated with tool testing at the Catoosa site, no other drilling programs will be conducted.

During the reporting period, significant progress in the development of the integrated pressure coring and pressure core analysis devices has been made:

1. The Instrumented Pressure Test Cell (IPTC) and the Pressure Core Characterization Tool (PCCT) were field tested in Sapporo Japan. The Japanese organizations JOGMEC and AIST have very generously extended an invitation for the JIP to field test the IPTC and PCCT at the AIST hydrate laboratory in Sapporo, Japan analyzing some of the methane hydrate pressure cores captured by JOGMEC in July 2012. The field tests of the IPTC and PCCT systems were conducted in the January 2013. The tests were very successful. The IPTC and PCCT performed well and met the design specifications.
2. The development of the Hybrid Pressure Coring System (Hybrid PCS) continued during this reporting period:
   - The available information from the JOGMEC deployment of the hybrid PCS offshore Japan in July 2012 has been reviewed. Nineteen design modification options for the JIP Hybrid PCS were initially identified and presented at the December 2012 Board Meeting (Reference Appendix 4). Further modification review and assessment has narrowed the list to a total of fifteen improvements to be implemented and final design is close to completion. Contracting work has been initiated.
   - Options for onshore test sites have been reviewed. Catoosa site has been selected as the test site. Detailed planning for the onshore test has begun.

3.0 PHASE III B (Leg III) Activities

The Cooperative Agreement is now moving toward its conclusion. The JIP and DOE have 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. No other drilling programs will be conducted.

3.1 Instrumented Pressure Test Cell (IPTC) and Pressure Core Characterization Tool (PCCT) Development

During the previous reporting period, modifications to the Instrumented Pressure Test Cell (IPTC) and construction and shop testing of the Pressure Core Characterization Tool (PCCT) were completed. A joint USGS and Georgia Tech operational test of the IPTC and PCCT was successfully held in June 2012. JOGMEC (a Gulf of Mexico Hydrate Joint Industry Project participant) and AIST (Japan National Institute of Advanced Industrial Science and Technology) organizations have collaborated to extend a very generous invitation to the JIP for USGS and Georgia Tech to conduct field trials of the IPTC and PCCT late in 2012 at the AIST national hydrate laboratory in Sapporo, Japan, analyzing some of the pressurized hydrate cores obtained by JAMSTEC using the prototype Hybrid PCS in July 2012. The invitation was accepted. In January 2013, a team of researchers from the USGS, Georgia Tech, JOGMEC and AIST collaborated to perform the analyzed special hydrate cores retrieved by JOGMEC from the coring expedition in Nankai trough area in 2012. The PCCT system developed for the JIP analyses were used to perform the analyses at AIST laboratory in Sapporo, Japan. The tool performed very well and the analyses were highly successful as reported in a number of information releases. (http://soundwaves.usgs.gov/2013/04/research.html).

The successful field test of the PCCT and the ITPC was the results of very careful planning and execution by USGS and Georgia Tech scientists under the leadership of Dr. Carolyn Ruppel, (Manager of USGS Gas Hydrate Research Project) and Professor Carlos Santamarina (Georgia Tech). Appendix 1 provides a summary of the preparation tasks leading to the field test. Appendix 2 provides a summary of the tasks completed during the field test.

After the field testing program, the USGS and Georgia Tech scientific team prepared two reports. The lessons learned report is reproduced in Appendix 3. The operating manual report outlining elements of a pressure-core analysis program will be issued as a separate technical report in the future.

The scientific work related the development of the PCCT tool has been recently published in Scientific Drilling, No.14, September 2012. The co-authors of the paper are J. Carlos Santamarina, Sheng Dai, Junbong Jang, and Marco Terzariol of Georgia Tech.

3.2 Pressurized Hydrate Coring System

During this reporting period, the focus of the project was also on the development of a prototype Hybrid Pressure Coring System (PCS) for the JIP. The objectives of the development are to produce one Hybrid PCS tool set, to test the tool for functionality and, subsequently, to turn over the prototype tool set, operating procedure and lessons learned from the test to National Energy Technology Laboratory (NETL) or an organization designated by NETL.

As noted in the April to September 2012 semi-annual report, JOGMEC deployed an earlier version of a prototype Hybrid PCS for a hydrate pressure coring expedition in the Nankai Trough offshore Japan in July 2012. The prototype Hybrid PCS was designed and manufactured by AAI. The July expedition was completed with a reportedly good recovery percentage (approximately 70% recovery rate) of pressurized hydrate cores from the prototype Hybrid PCS. However, a number of retrieved cores retained only partial pressure and there were indications that even better performance might be achievable. The JIP Hybrid PCS tool will be based on the similar AAI design of the previous version with fifteen design improvements.

During the fourth quarter of 2012, a number of meetings have been held to develop a list of nineteen potential design improvements for the JIP PCS. The Chief Co-Scientists were consulted in a number of review conference calls. The design criteria, options and recommended system were presented the JIP Executive Board and the Co-Chief Scientists at the Board meeting on December 11, 2012. Excerpts of the presentation to the Board pertinent to the design criteria options were reproduced in Appendix 4. Work on final selection of JIP hybrid design tool options continued in the first quarter of 2013 and the final design, consisting of fifteen design improvements, is nearing its completion. Design improvement #s 6, 7 8 & 11 (Reference Appendix 4) were dropped from consideration for risk of setback, schedule, unsatisfactory performance (in recently fabricated Fugro tool) and the need for third party participation reasons. Contracting work for the final design and manufacturing of the JIP Hybrid PCS tool has begun.

As noted in the previous period report, three options for the coring service van were generated and evaluated. Final selection has been made. The Heavy Van option was selected due to safety and operating requirements. The technical details are described in Appendix 4.

Three options for onshore test sites were also evaluated including visits to two of the sites. The Catoosa site has been selected as the best available site, with an excellent rig and the capability to drill open holes. The site management is very cooperative and eager to conduct the test. Other sites are heavily booked and our schedule uncertainty would have made reserving a time slot elsewhere very difficult. As the objective is to test the functionality of the tool, not its durability in extreme settings, very hard or abrasive strata needs to be avoided. From available technical and log information, there are suitable zones for a coring test of the JIP Hybrid PCS at the Catoosa site. A high level program for the onshore test has been developed. Contracting work for the testing program has been initiated. More details on the Catoosa test site and the test program are provided in Appendix 4.

4.0 Conclusions

The Cooperative Agreement is now moving toward close-out. 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 with research and development experts in the U.S. Geological Service, Georgia Institute of Technology Tech, Aumann and

Associates Inc., GeoTek and other academic institutions and contractors. Other than drilling associated with tool testing at the Catoosa test site, no other drilling programs will be conducted.

Much progress has been made during the current reporting period. The field test of the Instrumented Pressure Test Cell (IPTC) and the Pressure Core Characterization Tool (PCCT) by the scientific team from JOGMEC, AIST, USGS and Georgia Tech, were highly successful. The development of the JIP Hybrid PCS is well underway. The design of the prototype Hybrid PCS tool is near completion. Considerable progress has been made on the planning for the onshore test to be scheduled in the fourth quarter of 2013.

5.0 References

No external references were used for this report.

Appendix 1

Preparation Planning for IPTC and PCCT Field Test in Japan

(excerpts from Report on USGS Gas Hydrates Project Activities under JIP Chevron Technical Assistance Agreement TAA-12-2135/CW928359 prepared by Dr. Carolyn Ruppel, USGS)

This report outlines activities carried out in the first quarter of the federal government's 2013 fiscal year and related to the Chevron Technical Assistance Agreement (TAA) between the US Geological Survey and the DOE/Chevron JIP. Activities detailed here were completed by engineer Bill Winters, technician Dave Mason, engineer Emile Bergeron, physical scientist Bill Waite, and Carolyn Ruppel (manager) of the USGS Gas Hydrates Project, Coastal and Marine Geology Program, Woods Hole, with input from Tim Collett of the Energy Research Program, as appropriate.

Activities and completed actions during the reporting period include:

- Late October: Multi-day science planning meeting with AIST and JOGMEC representatives, held at Georgia Tech and attended by Winters, Waite, and (partially) Ruppel and Collett on the phone. This meeting focused on specifics for the Sapporo activity, including order of operations, order of core analyses, tests to be run on various core sections, distribution of personnel among instrumentation, communication and transfer of physical core pieces in Sapporo, and review of background data acquired by Schultheiss and relevant for decision-making on core processing in Sapporo.
- Late November 2012: AIST brought its version of the IPTC and accumulator to Georgia Tech for a meeting with USGS (Winters, Waite, and Mason) and Georgia Tech personnel. At this meeting, the AIST IPTC was successfully pressurized with no difficulty. As expected, it was verified that the current USGS sensors were not compatible with the AIST IPTC. The final decision was made that the AIST IPTC would be equipped with the original Georgia Tech-built sensors and used for all controlled depressurization tests (mini-production tests), while the Georgia Tech-built IPTC operated by the USGS would be used for physical property characterization and run with the updated sensors.

- Completed the preliminary assembly (PCCT) and operations (IPTC) manual.
- Conducted numerous practice runs on the IPTC at the USGS, with personnel taking turns mastering the IPTC and the electronics. This is critical as the electronics and IPTC device will be operated in different locations during the Sapporo tests.
- Machined additional rods and sensors and retested/recalibrated all sensors. Added safety shims to rods to ensure safe engagement of the drive-rod threads while preventing over insertion into the cores.
- Developed data acquisition protocols for all digital systems.
- Continued refinement of manifolds.
- Sapporo final preparations:
  - Resolved outstanding issues related to interlab communications in Sapporo, length of cables, transport of equipment from freight office to AIST, expected inspections once equipment is assembled in Sapporo, and related matters.
  - Received final, signed entry documents for 4 USGS personnel (Winters, Waite, Bergeron, and Mason) to work at AIST.
  - Received final confidentiality agreement from Japanese counterparts.
  - Shipped all equipment and peripherals to Japan the week of December 24, 2012, following preparation of detailed manifests and completion of other arrangements by the USGS shipping office.

Appendix 2

Summary of PCCT Activities in Sapporo, Japan
January 15-26, 2013

(excerpted from report prepared by Dr. Carolyn Ruppel, USGS)

Overall impression:

The conception, design, and rigorous preliminary laboratory testing of a full suite of unique first-of-a-kind hydrate-bearing Pressure Core Characterization Tools (PCCT) have resulted in the extremely successful field testing of cores recovered from the Nankai Trough offshore Japan.

Highlights:

- The support of the PCCT program by the Chevron/DOE Joint Industry Project resulted in the successful performance of every PCCT system used in Sapporo.
- Careful attention to details and test protocols insured the safe handling and testing of hydrate-bearing sediment cores without injuries or loss of pressure core.
- A profound spirit of cooperation existed between the various research groups, AIST, Georgia Tech, JOGMEC, and USGS as exemplified by the willingness to help each other, discuss new ideas, transfer equipment and supplies, and change test plans as necessary.
- Merging experience-based and analytical research approaches created a stronger field program.

Tool performance:

- P-wave, S-wave, electrical resistivity, and cone strength measurements were recorded in two core sections that were tested in the Instrumented Pressure Testing Chamber (IPTC). This system was completely rebuilt prior to its fourth field deployment in Sapporo.
- Two core sections were tested in the Effective Stress Cell (ESC) to determine stress / deformation response and hydraulic conductivity before and after dissociation, as well as volumetric contraction and gas production during depressurization. Gas volume and hydrate saturation were determined after dissociation.
- Consolidation, creep, and strength studies were performed on three core sections in the Direct Shear Cell (DSC), with concurrent P-wave monitoring. Measurements were repeated be-

fore and after dissociation to determine the sediment response with and without hydrates and the dissociation induced volume contraction.

- Multiple samples from one core section were obtained within the Bio-Sampler and placed into individual bio-reactor cells that were incubated to produce specimens for subsequent biological analysis. At least 60 petri dishes were monitored for 72 hrs.
- The National Institute of Advanced Industrial Science and Technology (AIST) IPTC was used to perform production tests on three core sections using US supplied instrumentation and data logging capabilities.
- A stepper-motor-driven manipulator system (capable of an effective 0.1 mm resolution) was critical in removing pressure cores from their original storage chambers and positioning them along a string of chambers, ball valves, clamps, and test devices as specified in individual core test plan. Additional untested cores were transferred from their original pressure vessels into other chambers for longer-term storage.
- Used in conjunction with the manipulator, a cutter system made well-defined, precise, and clean cuts through pressure core liner and sediment, enabling samples of predetermined length to be tested in other PCCT devices or placed into storage chambers.
- Two separate high- and low-pressure pump and manifold systems independently pressurized, maintained pressure, and depressurized the manipulator/core string and individual test devices as required by individual core test plans.

International team studying gas hydrates in Japan, January 2013.

Front row, kneeling: **Jun Yoneda** (Japan's National Institute of Advanced Industrial Science and Technology [AIST]). Front row, standing, left to right: **Yoshihiro Konno** (AIST), **Jiro Nagao** (AIST), **Marco Terzariol** (Georgia Tech), **William Winters** (USGS), **Junbong Jang** (Georgia Tech), **Kiyofumi Suzuki** (Japan Oil, Gas and Metals National Corporation [JOGMEC]), **Sheng Dai** (Georgia Tech), **Tetsuya Fujii** (JOGMEC), and **Emile Bergeron** (USGS). Back row, standing, left to right: **William Waite** (USGS), **Efthymios Papadopoulos** (Georgia Tech), **David Mason** (USGS), and **Carlos Santamarina** (Georgia Tech). Photograph courtesy of **William Winters**, USGS.

Appendix 3

Lessons Learned: PCCT Analyses of Japanese Pressure Cores in Sapporo, January 2013

(Reproduced from technical report prepared by the USGS and Georgia Tech)

The inclusion of elements on this list does not imply that these items were problems in Sapporo. They are listed here merely as high-level takeaway messages that should not be forgotten for future programs. This document should be used in conjunction with the summary transmitted to the JIP after the completion of the Sapporo activity.

Pre-arrival:

1. Create map of refrigerated and non-refrigerated work areas, including layout of utilities.
2. Ensure adequate compressed air, water and electrical supplies, temperature maintenance, and gas venting.
3. Agree on test plan for each core.

Safety:

1. Anyone has authority to stop the work at any time for safety reasons.
2. Do not rush; core processing speed will increase with proficiency.
3. Have a plan in case of accidental core depressurization or equipment failure.
4. Overhead double hoist system or equivalent is necessary to prevent injuries and ensure safe movement of heavy equipment and cores.
5. If working in shifts, hand off at clear breaks in the analyses, not according to the clock.
6. Have wall mounted safety/procedural charts and get oral confirmation from all workers in the area prior to opening/closing valves, disconnecting pressure lines, or moving the core.

General operations:

1. Prior to testing real pressure cores: (a) tighten all threaded components; (b) have second, experienced person recheck fittings; (c) check connections for leaks; (d) ensure entire system has been pressurized and checked.
2. Prefit devices with appropriately rated eyes for lifting with hoist system.
3. Ensure that every device and bridge has a fill and drain port.
4. Never “over open” a ball valve. Exposed ball valve lip can hamper core movement.

5. Coupler rings and O-rings should be removed and cleaned after each operation
6. Maintain a real-time equipment performance log for each device, probes, etc. and backup digital data daily, including keeping a copy offsite.
7. Know rules for disposal of saltwater and sediment at operations site.
8. Maintain a large (200L) reservoir of saltwater in the cold room for filling and pressurizing PCCT devices.

IPTC-specific:

1. Device operator and electronics operator should face each other.
2. Work in pairs when operating the IPTC: (a) one person sets calipers for drill/probe insertion, the another operates the drill/probe; (b) each person checks independently to ensure that probes are retracted beyond the inner wall prior to core advancement
3. Drive arms: (a) double check tightness and consider improvements; (b) clean after each core is tested and check condition of bearing assemblies; (c) recheck probe position relationships after each test.
4. Be gentle when inserting probes into hydrate-bearing sediments and always ensure that probe end location is known before closing probe ball valve.
5. Double check response of each probe (particularly resistivity probe) prior to testing a real core.
6. Use contact shear-wave probe, not normal sensor, in cemented sediments.
7. For seismic measurements, choose a probe frequency that avoids noise amplification and carefully match probe frequencies/orientations at paired port locations.

Other Devices:

1. Make every effort to keep PCCT testing devices proximal to manipulator.
2. Electronics for manipulator must be within sight of the motor or a mirror system to permit real-time observation of motor’s action.
3. “Listen” to core barrel for auditory clues about grabber and core movement when using manipulator.
4. Check the manipulator ball valve for a lip/roughness after each use.
5. Inspect and, if necessary, replace cutter blade after each use on sand-bearing sediments
6. Stabilize manipulator string during cutting.

(USGS High-Level List) Necessary changes/replacements for IPTC post-Sapporo:

1. Purchase Agilent Technologies digital storage oscilloscope ($2200).
2. Purchase two double-acting high-pressure ISCO syringe pumps for IPTC to replace Rice high-pressure pumps ($20-$30K total).
3. Replace and recalibrate IPTC probes as needed and purchase additional sensors.
4. Resolve whether USGS should be independent and purchase an overhead hoist system or whether this will normally be supplied at operations site.
5. Determine whether Glydrings should be replaced with O-rings in IPTC to improve performance.
6. All electronics boxes need to be refurbished/shielded and/or replaced to reduce electronic noise. Ensure availability of duplicate boxes as backup during field operations.
7. Devise method for mounting manifolds, particularly those for the manipulator and IPTC.
8. If IPTC will be used for controlled production testing in the future, need access to gas and water collection system.

Appendix 4
JIP Prototype Hydrate Pressure Coring System

1. Design Criteria, Options and Recommendations

Prototype Hydrate Pressure Corer Design Criteria

The prototype hydrate pressure corer and system must meet the customer's requirements (DOE) within available funding. Trade-offs will be required. DOE desired criteria:

- An Aumann & Associates Hybrid PCS similar to those ordered by JOGMEC and JAMSTEC, noting that the results achieved by these devices in the July hydrate coring expedition were by scientific hydrate coring standards promising given the tool's early stage of development.
- Incorporating design modifications from lessons learned in July from the JOGMEC and JAMSTEC versions of the prototype Hybrid PCS
- Compatible with PCATS, IPTC and PCCT analytical equipment
- Meeting design criteria for pressure core retrieval at expected GOM sites such as GC 955 and WR 313.
- Having a PDC face bit configuration for coring hard, hydrate cemented sands
- Having a PDC cutting shoe configuration for coring softer sediments such as seals, interbedded sediments, etc.
- Able to work in 5 ½" OD x 4 ¼" ID drift drill pipe (bored out IODP and standard industry drill pipe)
- Carefully tested at an onshore drill test site, choosing the best coring depths for function tests and assessments of design improvements while avoiding hard or abrasive strata that might damage the pressure corer
- Note exceeding the remaining JIP funds (including all other required project deliverables such as close-out reports, etc.)

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Prototype Hydrate Pressure Corer Options

- Immediately after the September JIP Board meeting options other than the Hybrid PCS were once more investigated but quickly ruled out. There is no industry interest in designing and building a complex, one-off, high-specification downhole tool within the limited budget. No companies had devices 'in the works.'
- Most importantly, the DOE has a strong preference for an Aumann & Associates JOGMEC/JAMSTEC design Hybrid PCS with improvements based on recent lessons learned. An improved Hybrid PCS would to ensure commonality of components, operational experience with the JOGMEC and CDEX Hybrid PCS's.
- The JIP team therefore held extensive meetings with Aumann & Associates in October and November to investigate the root causes of the July coring difficulties and to brainstorm potential solutions in order to potentially improve the 69% pressure core recovery rate.
  - *It is worth noting that during Leg III planning the JIP team felt that achieving even a 50% recovery rate would have been a significant accomplishment.*
- From extensive JIP meetings with Aumann & Associates a number of modifications were developed and listed, many focusing on the pressure control section. Each will be investigated and (as appropriate) incorporated into the JIP improved prototype Hybrid PCS.
- Many factors likely contributed to pressure control problems, and not all likely at the same time. One key realization by the JIP team is that at the final moment of the ball valve closure there occurs a split-second increase in the internal volume of the autoclave, causing a roughly 600-800 psi pressure drop in the autoclave. This pressure drop should be more than compensated for by the pressure control section's nitrogen reservoir, regulator and sleeve valve. Root cause analysis identified a number of potential causes that could have led to pressure leakage or total loss, with just two examples being:
  - *Potential of the ball valve when closed to be temporarily cracked open and in effect act as a check valve causing bleeding out of the pressure being added from the pressure control system before the ball valve reclosed*
  - *A small check valve installed in the autoclave to bleed drilling fluid into the autoclave during the temporary pressure drop was at times blocked open, subsequently bleeding out all pressure in the autoclave.*
  - *Significant amounts of cuttings and debris at times packing the ball valve and ball valve actuating spring, perhaps due to the pressure corer being close to or at the bottom hole during retrieval or cuttings coming up around the cutting shoe.*

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Recommended System: JIP Improved Prototype Hybrid PCS

1. Hybrid PCS Base Platform similar to JOGMEC and JAMSTEC
2. PDC face bit configuration with wireline center drilling plug to enable coring of the hard, hydrate cemented sands at GC 955 and WR 313
3. PDC cutting shoe configuration (JOGMEC type) for coring of softer or interbedded sediments and also capable of running certain other IODP tools.
4. Capability for single or double stacked core catchers (e.g. basket over collet) to efficiently break and hold cores ranging from hard to soft compositions
5. Custom IODP-type outer barrel and bottom hole assembly design (as nearly identical to the Chikyu as possible) for use on any IODP or industry rig
6. Float Valve in drill string for enhanced safety
7. Design improvements for investigation and possible use (as detailed on the next three pages):
   - 7 pressure control section improvements
   - 1 diagnostics capability improvement
   - 3 core transfer improvements
   - 2 core capture improvements
   - 2 pressure corer maintenance improvements
   - 4 pressure corer operations improvements

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Design Improvements – To Be Investigated (1)

#	Modification	Objective
1	Add filtration system to the autoclave check valve, so that it doesn't clog open after bleeding drilling fluid into the autoclave.	**Improve Pressure Maintenance:** Prevent check valve plugging and pressure loss through the check valve
2	Develop a fast acting auxiliary valve for pressure control section to compensate for pressure draw down during ball valve closure	**Improve Pressure Maintenance:** Prevent pressure drop that occurs as the ball valve closes by adding pressure to compensate for the slight increase in volume of the sealed autoclave.
3	Add an accumulator option for the pressure control section	**Improve Pressure Maintenance:** Potentially simpler, more robust design
4	Add a spring or detent to the sleeve valve to prevent the possibility of premature opening from downhole vibration, etc.	**Improve Pressure Maintenance:** Keeps the sleeve valve at the top position to enable a full stroke and maximum pressure increase.
5	Change the winding direction in the ball valve closure spring for easier assembly and less chance of internal spaces filling with mud	**Improve Pressure Maintenance:** Smoother, more reliable closure of the ball valve with less chance of mud clogging the spring
6	Re-evaluate the size and function of the pressure control section considering the characteristic of nitrogen to behave differently from the perfect gas law under high pressure and low temperature	**Improve Pressure Maintenance:** At high pressure and low temperature a larger volume of nitrogen is required to provide the same force that it does at ambient pressure and temperature.
7	Consider use of argon or other gas with properties closer to the perfect gas law than nitrogen	**Improve Pressure Maintenance:** Argon or other gases are known to more closely follow the perfect gas law than nitrogen – perhaps avoiding design changes to the existing pressure control section

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Design Improvements – To Be Investigated (2)

#	Modification	Objective
8	Add fish pill capability to measure the nitrogen reservoir temperature and pressure	**Improved Diagnostics:** Comparison of nitrogen reservoir data with data from the other fish pills
9	Increase core liner and core catcher clearances with inner tube and / or redesign the core liner to catcher thread	**Improved Core Transfer:** Avoid core liner becoming jammed in the inner tube due to dissociation, etc.
10	Increase clearance in transfer barrel and seal surfaces	**Improved Core Transfer:** Avoid core liner catching or sticking
11	Add a sleeve to the pawl release tool that would trap the pawls and pawl spring in the recess in the seal sub and prevent the possibility of jamming during extraction to PCATS.	**Improved Core Transfer:** Avoid core liner catching or sticking
12	Design a liner length adjuster between the inner tube plug and core liner	**Improve Core Capture / Pressure Maintenance:** The core liners had varying lengths outside specifications and therefore potential for degraded core capture or pressure loss if pushed against the ball valve. A liner length adjuster would compensate for any core liner length differences
13	Design basket catchers with a variety of sheet metal thicknesses (thicker = stiffer basket, thinner = more flexible basket)	**Improved Core Capture:** Options to match basket catcher flexibility better capture harder or softer sediments
14	Reduce the inner latch piston ID to prevent jamming with the wireline tool	**Improved Operations:** Avoid jamming

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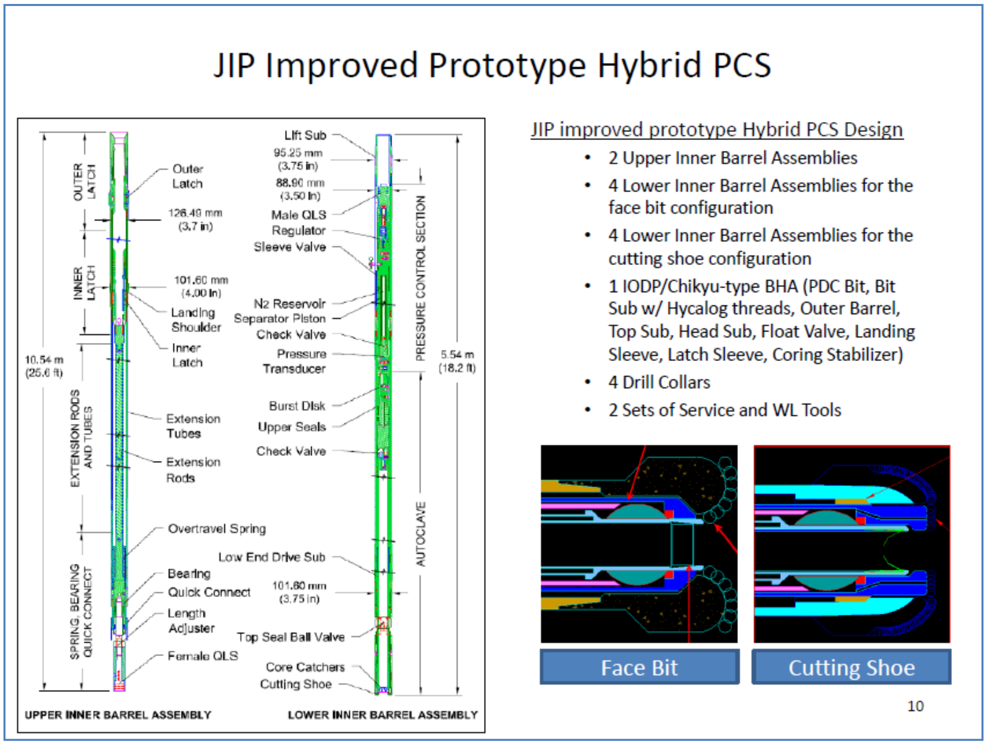
Design Improvements – To Be Investigated (3)

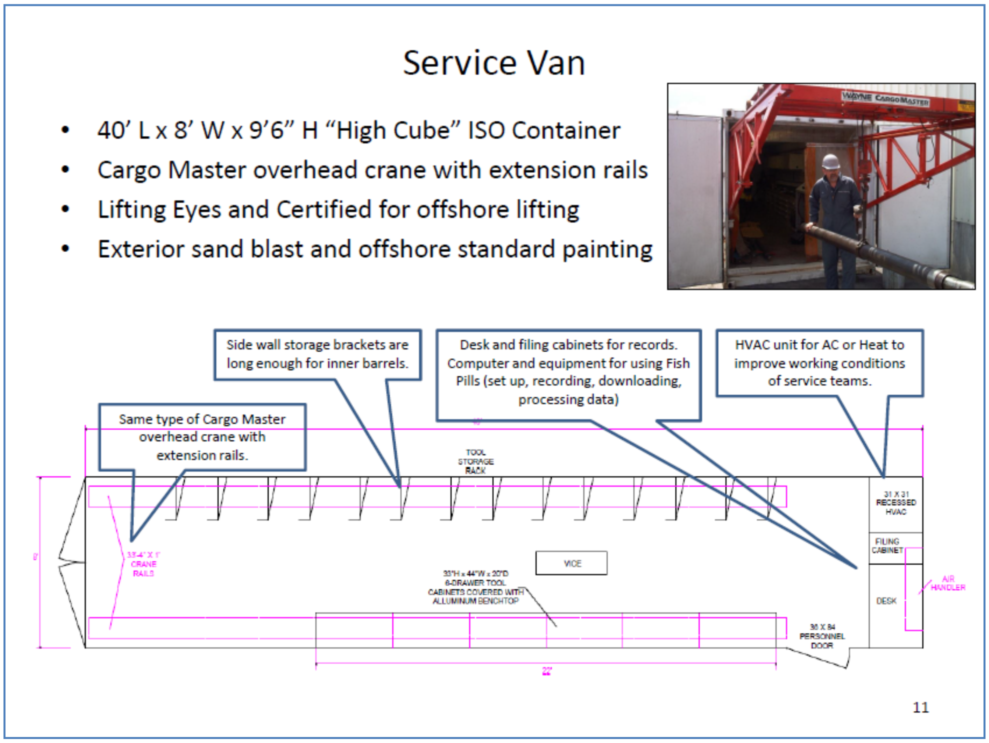
#	Modification	Objective
15	Modify the outer latch housing garter spring grooves to increase strength	**Improved Operations:** Improved latching
16	Mill the QLS alignment markings and possibly increase clearances	**Improved Operations:** Milling for easy identification of alignment indicators and smoother, faster operations; increased clearances to prevent occasional jams or alignment and stab problems because of tight fit.
17	For bullet valves requiring high torque replace Allen wrench fitting with hex bit sockets and ratchets.	**Improved Operations:** Faster, more reliable bullet valve securing especially under high pressure.
18	Add flats and / or knurling or no-mar wrenches for easier, safer assembly in the service van. Provide pipe wrenches with teeth milled off to use on parts with the flats. Re-check make-up torque charts.	**Improved Maintenance:** Avoid damage to the pressure corer during assembly / disassembly due to improper tool placement, improper tool choice or improper torque.
19	Revert to the original Hybrid PCS three piece latch housing to simplify manufacture	**Improved Maintenance:** Simpler assembly

Note:
While all of the above potential design improvements will be studied, not all of them will necessarily be implemented in the improved JIP prototype Hybrid PCS. The main take-away of the JIP Team from the root cause analysis and design improvement discussions is that the JOMEC / JAMSTEC prototype Hybrid PCS design does not appear to require major changes. A series of small design improvements is believed to be sufficient to measurably improve the pressure core recovery rate.

9

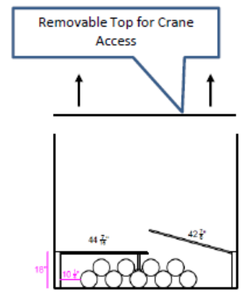

JIP Improved Prototype Hybrid PCS
OUTER LATCH
Outer Latch
126.49 mm (3.7 in)
INNER LATCH
101.60 mm (4.00 in)
Landing Shoulder
Inner Latch
10.54 m (25.6 ft)
EXTENSION RODS AND TUBES
Extension Tubes
Extension Rods
Overtravel Spring
SPRING, BEARING QUICK CONNECT
Bearing
Quick Connect
Length Adjuster
Female QLS
Lift Sub
95.25 mm (3.75 in)
88.90 mm (3.50 in)
Male QLS
Regulator
Sleeve Valve
N2 Reservoir
Separator Piston
Check Valve
Pressure Transducer
PRESSURE CONTROL SECTION
5.54 m (18.2 ft)
Burst Disk
Upper Seals
Check Valve
AUTOCLAVE
Low End Drive Sub
101.60 mm (3.75 in)
Top Seal Ball Valve
Core Catchers
Cutting Shoe
UPPER INNER BARREL ASSEMBLY
LOWER INNER BARREL ASSEMBLY
JIP improved prototype Hybrid PCS Design
• 2 Upper Inner Barrel Assemblies
• 4 Lower Inner Barrel Assemblies for the face bit configuration
• 4 Lower Inner Barrel Assemblies for the cutting shoe configuration
• 1 IODP/Chikyu-type BHA (PDC Bit, Bit Sub w/ Hycalog threads, Outer Barrel, Top Sub, Head Sub, Float Valve, Landing Sleeve, Latch Sleeve, Coring Stabilizer)
• 4 Drill Collars
• 2 Sets of Service and WL Tools
Face Bit
Cutting Shoe
10

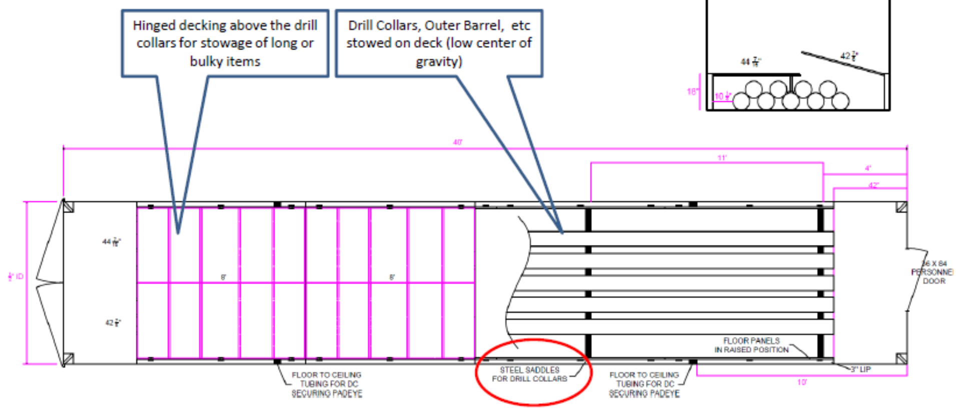
2. Selection of Service Van Options – Heavy Van Option Selected



Heavy Van

- 40’ L x 8’ W x 8’ H
- DNV 2.7-1 Open Top Container, 40,000 lbs MGW
- Lifting Eyes and Certified for offshore lifting
- Exterior sand blast and offshore standard painting





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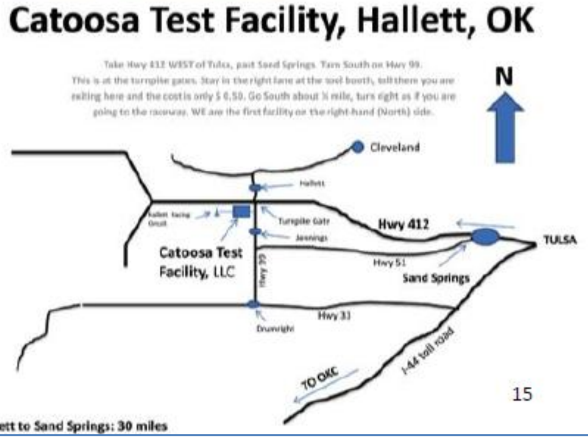
3. Catoosa Test Site and High Level Onshore Test Program

Catoosa Testing Facility, Hallet, OK

- Former Amoco and GRI site at Catoosa, recently purchased by NOV and relocated to nearby Hallet for better variety of geologic formations.
- Wellbore data (logs, cores) at the new site are being examined along with other near-by industry wells to get best picture of subsurface conditions in order to optimize the onshore drilling test.
- Rig 11 is optimal for the test, a top drive rig with 107 ft double mast derrick, situated on a pivoting rail system. This allows the rig to pivot with pipe in the derrick from one wellbore to another very quickly with no down time.
- The data acquisition unit for Rig 11 uses the Sperry-Sun Drilling Services' Integrated System for Information Technology and Engineering (INSITE™), which allows for real-time data that can be viewed from the rig or data acquisition room.
- Large 120 foot by 90 foot warehouse and office complex with 4 self-contained offices, an electronics lab, a large conference room and a huge full service machine shop, equipped with a 5 ton overhead crane open to customer use.



Preliminary Onshore Test Program

	Rig Activities
Monday Day 1	Morning rigup
	Move rig to proper well slot
	Rig up circulating system
	Pressure test all connections
	Rig up BOP and test
	Rig up open hole drilling BHA
	Rig maintenance and shutdown
Tuesday Day 2	Morning Rigup
	Mix spud mud
	Spud well, drill to 600 ft
	Rig maintenance and shutdown
Wednesday Day 3	Morning rigup
	Spud well, drill to 1,000 ft
	Circulate well clean
	Dummy trip
	Circulate well to coring mud
	POOH
	Rig maintenance and shutdown
Thursday Day 4	Morning rigup
	Pick up core bbl with cutting shoe drill bit
	Pick up drill collars and double of drill pipe
	Rig up wireline
	Run inner barrels with no accumulator pressure, check mechanical fit
	Circulate at full coring pressure 5-10 minutes
	Rig up and pull inner barrel
	Test remaining inner barrels
	POOH with outer barrel inspect for damage and washouts
	Rig maintenance and shutdown
Friday Day 5	Morning rigup
	RIH tag bottom
	Rig up wireline
	Pull and check pressure holding on two autoclaves without drilling
	Run inner barrel for core #1
	Cut cutting shoe bit core #1 check core recovery and pressure holding
	Cut cutting shoe bit core #2 check core recovery and pressure holding
	Cut cutting shoe bit core #3 check core recovery and pressure holding
	Cut cutting shoe bit core #4 check core recovery and pressure holding
	POOH with cutting shoe bit assembly
	Rig maintenance and shutdown
Saturday	
Sunday	

Monday Day 6	Morning rigup
	RIH with bit
	Circulate well clean
	POOH
	Pick up core bbl with face drill bit
	Pick up drill collars and double of drill pipe
	Rig up wireline
	Run inner barrels with no accumulator pressure, check mechanical fit
	Circulate at full coring pressure 5-10 minutes
	Rig up and pull inner barrel
	Test remaining inner barrels
	Run and latch center bit plug
	Circulate at full coring pressure 5-10 minutes
	POOH with outer barrel inspect for damage and washouts
	Rig maintenance and shutdown
Tuesday Day 7	Morning rigup
	Pick up face bit outer barrel and inner barrel
	RIH tag bottom
	Face bit core #1 check core recovery and pressure holding
	Pull off bottom
	Run center bit plug
	Drill
	Pull center bit plug
	Run inner barrel
	POOH
	Rig maintenance and shutdown
Wednesday Day 8	Morning rigup
	RIH
	Face bit core #2 check core recovery and pressure holding
	Pull off bottom
	Run center bit plug
	Drill
	Pull center bit plug
	Face bit core #3 check core recovery and pressure holding
	Face bit core #4 check core recovery and pressure holding
	POOH lay down barrel
	Rig maintenance and shutdown
Thursday Day 9	Morning rigup
	Lay down coring equipment
	Clean out derrick, demob rig
	Contingency
Friday Day 10	Contingency
Saturday	
Sunday	
Monday Day 11	Contingency
Tuesday Day 12	Contingency

Planned Test Days: 9; Contingency Days: 3 (weather, tool problems, etc.) 16