Oil & Natural Gas Technology

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(April 2008 – September 2008)

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 was 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 April 2008 – September 2008, the JIP concentrated on:

- Redesigning a new pressure corer;
- Completed work to publish the special volume on leg 1;
- Planning operations and selecting hole locations for Phase III drilling.

More information can be found on the JIP website.
https://cpln-www1.chevron.com/cvx/gasjip.nsf

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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.

On the basis of 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. The proposal was submitted to NETL on April 24, 2001, and Chevron was awarded a contract on the basis of 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 at least three data collection wells to improve the technologies required to characterize gas hydrate deposits in the deep water GOM using seismic, core and logging data. **Phase III** of the project began in September of 2007 and will focus on obtaining logs and 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 2008 the members of the JIP were Chevron, Schlumberger, ConocoPhillips, Halliburton, the Minerals Management Service (MMS), Total, JOGMEC, Reliance Industries Limited, The Korean National Oil Company (KNOC), and StatoilHydro.

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 contract between DOE and Chevron in place. Several Semi-Annual and Topical Reports have been written that cover the activity of the JIP through March 2008.

1.6 Purpose of This Report

The purpose of this report is to document the activities of the JIP during April 2008 – September 2008. It is not possible to put everything into this Semi-Annual report. However, many of the important results are included and references to the JIP website, https://cpln-www1.chevron.com/cvx/gasjip.nsf, are used to point the reader to more detailed information concerning various aspects of the project. The discussion of the work performed during April 2008 – September 2008 is organized by task and subtask for easy reference to the technical proposal and the DOE contract documents.

2.0 Executive Summary

Chevron formed a Joint Industry Participation (JIP) group to write a proposal and conduct research concerning natural gas hydrate deposits in the deepwater portion of the Gulf of Mexico. The proposal was submitted to NETL on April 24, 2001, and Chevron was awarded a contract on the basis of 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".**

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). **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.

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 at least three data collection wells to improve the technologies required to characterize gas hydrate deposits in the deep water GOM using seismic, core and logging data. Phase III of the project is to collect data on hydrate bearing sands. Both logging and coring operations are planned.

A website has been developed to house the data and information that were collected in the Workshop, as well as other items submitted during the course of this research endeavor. The link to the JIP website is as follows: https://cpln-www1.chevron.com/cvx/gasjip.nsf.

2.1 Hole locations for GC955 and WR313 were selected and a hazard analysis completed. Well bore stability analysis is compete and a final report expected in November 2008.

2.2 Site Selection

Alternative hole locations were selected for GC955 to avoid operations near the rig at GC955..

2.3 Pressure Corer

Analysis of the pressure corer indicates no technical problems with increasing the operating pressure. Final design is being completed and is expected in October 2008.

2.4 Marine and Petroleum Geology JIP Special Volume

Marine and Petroleum Geology will publish the Scientific Results for the 2005 DOE-Chevron Joint Industry Project Gulf of Mexico methane hydrates drilling. Fifteen papers and one overview paper were sent in for publication. The special volume will be published in November of 2008.

3.0 Results and Discussion Phase II

3.1 Task 1.0 – Research Management Plan

Work on this task is complete and has been reported on in previous semi-annual reports.

3.2 Task 2.0 – Project Management and Oversight

Work on this task is complete and has been reported on in previous semi-annual reports.

3.3 Task 3.0 – Validation of New Gas Hydrate Sensors

Work on this task is complete and has been reported on in previous semi-annual reports.

3.4 Task 4.0 – Validation of the Well Bore Stability Model

Work on this task is complete and has been reported on in previous semi-annual reports.

3.5 Task 5.0 – Core and Well Log Data Collection – Area A

Work on this task is complete and has been reported on in previous semi-annual reports.

3.6 Task 6.0 – Data Analysis – Initial Cruise

Work on this task is complete and has been reported on in previous semi-annual reports.

3.7 Task 7.0 – Technical Conference

In order to provide the scientific community with current data from the project, a workshop will be conducted to present all information obtained during the course of the project to industry, academic, government and other interested professionals. This workshop will focus on the opportunities for improving the tools and protocols for effective field investigation of hydrates in the Gulf of Mexico. The output of the workshop will be plans for DOE consideration for acting on specific recommendations arising from this workshop.

Marine and Petroleum Geology will publish the Scientific Results for the 2005 DOE-Chevron Joint Industry Project Gulf of Mexico methane hydrates drilling. Fifteen papers and one overview paper were received and submitted for publication. The special volume will be published in November 2008.

3.8 Task 8.0 – Field Sampling Device Development

In addition to any specific data/tool needs identified in the Task 7 workshop, the acquisition of improved technologies for the acquisition, retrieval and subsequent analysis of samples under in-situ pressure (and possibly temperature) conditions will be pursued. Pressure coring equipment will be evaluated both from the JIP membership and the development of new devices to accomplish these goals (both sample retrieval and extensive analysis of samples in systems capable of minimizing hydrate dissociation and sample alteration from its natural state).

The design of the high pressure coring equipment is complete and a final report is expected in October of 2008. Details of the design are presented in Appendix B which is a copy of the third quarter progress report.

3.9 Task 9.0 – Recommendation for Further Activities

Work on this task is complete and has been reported on in previous semi-annual reports.

4.0 Discussion and Results PHASE III A – Follow on Field Activities Drilling and Logging

Phase III activities are to include work focused on characterization and evaluation of hydrate occurrence within coarse-grained horizons within the Gulf of Mexico. The activities include preparation for these field activities through analyses and technology development, carrying out of the field activities and post field activity analysis and reporting. The field sites selected for Phase III activity are to include specifically locations at Alaminos Canyon 818 as recommended under Phase II Task 9. Field sites (in addition to AC 818) to be included in the investigation will be selected upon mutual agreement of the Recipient and DOE with the intent of testing alternative models of gas hydrate occurrence. Planned activities associated with Phase III are outlined in the task/subtask descriptions to follow.

4.1 Task 1.0 – Research Management Plan

The research management plan was prepared and submitted to the DOE.

4.2 Task 2.0 – Project Management and Oversight

Project Quarters 1 & 2: The project manager appointed by the JIP members held weekly conference calls with the DOE project managers and provided other reports and presentations as required. See Appendix A for a summary of milestones and progress to date.

The JIP Executive Board (EB) approved two new members—the Korean National Oil Company and StatoilHydro—to become members of the JIP.

Members of the EB also attended the site selection drill operations meeting.

The JIP web site is being maintained and a new web site at Scripps is being evaluated.

The chief scientist for the LWD leg was selected and candidates for the coring leg evaluated.

Total DOE project funds are approximately 56% spent and total project funds are 99% spent or obligated for the remaining Phase III A estimated costs.

Project Quarters 3 & 4: The project manager appointed by the JIP members held weekly conference calls with the DOE project managers and provided other reports and presentations as required. See Appendix A for a summary of milestones and progress to date.

The Korean National Oil Company and StatoilHydro became members of the JIP.

The JIP web site is being maintained and a new web site at Scripps is being designed.

Total DOE project funds are approximately 59% spent and total project funds are 92% spent or obligated for the remaining Phase III A estimated costs.

4.3 Task 3.0 – Field Program – Drilling/Logging

Project Quarters 1 & 2: Several meetings were held in Houston between the LWD contractor (Schlumberger), Chevron drilling engineers, and the USGS Chief Scientist for the LWD leg. A design of the LWD tool string has been developed but may change before the cruise.

Safety training for the personnel on the LWD leg has been determined and will be arranged.

Locations for hazard analysis have been selected and hazard analysis will begin in April. See Appendix B for location maps of the holes.

A drill ship has been selected and drilling and logging is being planned for late June into July but could change because of drill ship schedule. In the worse case the ship schedule could slip into late 2008.

Project Quarters 3 & 4: A design of the LWD tool string has been developed that will allow for both tool strings to be used.

Safety training for the personnel on the LWD leg has been determined and conducted.

Locations for hazard analysis have been selected and hazard analysis completed.

The drill ship selected was unable to complete other work in time for this program to conduct drilling in the time we had contracted. The contract was revised and we are now planning on conducting LWD operations under the same terms in the first or second quarter of 2009.

4.4 Task 4.0 – Data Analysis

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

4.5 Task 5.0 – Improved Hydrate Recovery, Detection and Measurement Equipment

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

4.6 Task 6.0 – Detailed Seismic Study of Selected Drilling Locations

Project Quarters 1 & 2: 3-D analysis of GC955 and WR313 is complete and a report from the site selection group is expected in May.

Project Quarters 3 & 4: A draft of the final report for GC955 and WR 313 is compete and is expected in November 2008.

4.7 Task 7.0 – Well Bore Stability

Project Quarters 1 & 2: Analysis of the three sites (AC, GC, and WR) areas has been started and waiting on final well locations to be completed.

Project Quarters 3 & 4: Well bore stability analysis completed for AC and is progress for GC and WR. A final report is expected in November of 2009.

4.8 Task 8.0 – Data on Lab Samples

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

5.0 PHASE III B – FOLLOW ON FIELD ACTIVITIES (CORING) AND FINAL REPORTING

Phase III B activities are to include work focused on characterization and evaluation of hydrate occurrence within coarse grained horizons within the Gulf of Mexico. The activities include preparation for these field activities through analyses and technology development, carrying out of the field activities and post field activity analysis and reporting. The field sites selected for Phase III activity are to include specifically locations at Alaminos Canyon 818 as recommended under Phase II Task 9. Field sites (in addition to AC 818) to be included in the investigation will be selected upon mutual agreement of the Recipient and DOE with the intent of testing alternative models of gas hydrate occurrence. Planned activities associated with Phase III B are outlined in the task/subtask descriptions to follow.

5.1 Task 1.0 – Revised Research Management Plan

Project Quarters 1 & 2: <u>No work accomplished this period</u>.
Project Quarters 3 & 4: <u>No work accomplished this period</u>.

5.2 Task 2.0 – Project Management and Oversight

Project Quarters 1 & 2: <u>No work accomplished this period</u>.
Project Quarters 3 & 4: <u>No work accomplished this period</u>.

5.3 Task 3.0 – Field Program – Coring

Project Quarters 1 & 2: <u>No work accomplished this period</u>.
Project Quarters 3 & 4: <u>No work accomplished this period</u>.

5.4 Task 4.0 – Data Analysis

Project Quarters 1 & 2: <u>No work accomplished this period</u>.
Project Quarters 3 & 4: <u>No work accomplished this period</u>.

5.5 Task 5.0 – Improved Hydrate Recovery, Detection and Measurement Equipment

Project Quarters 1 & 2: <u>No work accomplished this period</u>.
Project Quarters 3 & 4: <u>No work accomplished this period</u>.

5.6 Task 6.0 – Detailed Seismic Study of Selected Drilling Locations

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

5.7 Task 7.0 – Well Bore Stability

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

5.8 Task 8.0 – Data on Lab Samples

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

5.9 Task 9.0 – Technical Conference and Compilation of Scientific Papers

Project Quarters 1 & 2: No work accomplished this period.

Project Quarters 3 & 4: No work accomplished this period.

6.0 Experimental

Experimental work was conducted during the period of this report. Photos and drawings of some of the experimental equipment that was used on the cruise were presented in previous semi-annual reports.

7.0 Conclusions

Drilling targets were identified for AC818, GC955, and WR313. Hazard analysis for the locations was complete.

Drill ship for the LWD was unable to conduct operations in the time specified. The contract was modified to conduct operations in the first or second quarter of 2009.

Redesign of the pressure corer is complete and a final report expected in October 2008.

8.0 References

No external references were used for this report.

9.0 Appendix A, B

APPENDIX A

Milestone Table A1

#	Milestone	Plan date	Progress	Comments
1	Select LWD Locations	Q2 08	Complete. Another block may be selected in October.	Site selection report for GC955 and WR313 is expected in May and will be included in the next semi-annual report. AC818 report was included in Semi-Annual Report 41330R13. An additional location for LWD drilling may be selected in October of 2008 as an alternate to AC818.
2	Complete Design of Pressure Coring Equipment	Q2 08	Design work complete; final report is expected in October.	
3	LWD Selected Locations	Q3 08	LWD locations were selected.	
4	Report on LWD Phase III A Task 3 Deliverable	Q4 08	LWD drilling was delayed until March 2009 due to drill ship schedule.	
5	Complete Research Management Plan	Q1 09		
6	DOE Approval to Proceed to Phase III B	Q2 09		
7	Complete Construction of New Pressure Coring Equipment	Q3 09		
8	Field Test Pressure Coring Equipment	Q4 09		
9	Select Sites for Coring Leg	Q4 09		
10	Conduct a Hazard Analysis of Sites and Apply for Permits	Q2 10		
11	Core Selected Locations	Q3 10		
12	Report on Lab and Coring Data	Q4 10		
13	Final Report	Q4 10		

Appendix B

Development of a High Pressure Temperature Corer (HPTC)

Interim Report

September 30, 2008

PREPARED FOR

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DEVELOPMENT OF A
HIGH PRESSURE TEMPERATURE CORER
INTERIM REPORT

1.0 Introduction

Pressure Temperature Core Sampler (PTCS) and Non-cooled Pressure Temperature Core Sampler (NC-PTCS) were used successfully to recovering methane hydrate samples off the coast of Japan. The design of these tools was carried out by Aumann & Associates, Inc. under contract to JOGMEC and it's predecessor JNOC. The system was designed to a working pressure of 3,500 psi with a 4:1 safety factor on safety critical components.

Chevron Technology Development Corporation requires a pressure coring system for use in a DOE project to recover methane hydrate from deeper zones in the Gulf of Mexico. This will require a new system based on the successful NC-PTCS with the following extended capabilities.

- Increased pressure capability to 5,500 psi.
- The ability to transfer core to analysis equipment while under pressure.

Aumann & Associates, Inc. was contracted by Chevron to modify the design of the NC_PTCS to meet the new requirements.

2.0 Executive Summary

The project is structured in three phases. Following is a summary of the results of the work to date:

2.1 Review Phase

This phase was completed by December, 2007. The NC-PTCS files, reports and drawings were located, collected, reviewed and studied by Jim Aumann and two engineering associates, Chris Johnson and Joel Quinn keeping in mind the new higher pressure and core transfer requirements. Chris Johnson has been an active contributor to the PTCS and NC-PTCS project for many years and was responsible for the successful fixed pin ball valve design. Joel Quinn previously worked on downhole tools for Christensen Diamond Products (now Baker Hughes Inteq) and assisted with the design of the original pressure coring at Christensen. He is also a materials specialist.

During this time, we took the opportunity to add hands on experience to our review when a client ordered a NC-PTCS assembly that we assembled and delivered during August, 2007.

We held a project review and brainstorming meeting and accomplished the following:

1. Jim Aumann presented a PowerPoint presentation on the history of the PTCS and NC-PTCS including the method of operation and design concepts.
2. We brainstormed possible solutions to some of the anticipated challenges.
3. We assigned responsibilities for the initial tasks to be carried out in the Basic Design Phase.

We established contact with Georgia Tech and GeoTech and obtained information regarding the transfer and analysis equipment. At the conclusion of this phase a telephone project review was held. It was decided that the all of the interested parties should attend a review meeting in person before a final design was undertaken. The meeting took place at the conclusion of the Basic Design Phase in April, 2008.

2.2 Basic Design Phase

During the Basic Design Phase, each subsystem and part was analyzed to determine the specific changes needed for both the higher pressure and core transfer requirements. Drawing layouts were prepared using AutoCAD and preliminary calculations were carried out. The preliminary calculations are shown in Appendix A.

As part of the Basic Design Phase more discussions were held between Aumann & Associates, Inc., Fugro GeoConsulting, Inc., GeoTech, Ltd., and Georgia Tech, to identify interface requirements and discuss prior experiences, current methods of core transfer and determine if any existing equipment or design approaches might be applicable to the new HPTC.

This Basic Design Phase was completed by March, 2008 and a project/design review was held at the Fugro offices in Houston, Texas. The following decisions were made:

2.2.1 The working pressure of the system was reduced to 5,000 psi (338 bar), because of concerns about the cost and safety of core transfer and analysis equipment. It was also determined that a working pressure of 5,000 psi would meet operational requirements.

2.2.2 Instead of designing a new core transfer system, AAI should design the new HPTC to be compatible with the Geotech Pressure Core Analysis and Transfer System (PCATS) system.

2.2.3 The HPTC will be made compatible with the PCATS existing flange system for transfer operations.

2.2.4 The size of the HPTC core and liner will be compatible with the PCATS 65mm ID. It is preferred that the HPTC use the same liner (63mm OD) tubing and core catchers as the Fugro Pressure Corer (FPC) if possible.

2.2.5 The successful "Fixed Pin Ball Valve" design used in the NC-PTCS should be used for the HPTC only adjusting for the smaller core size and the higher pressure requirement.

2.2.6 The HPTC will use a bit insert or extended cutting shoe to cut the core instead of a core bit so that the HPTC inner barrel assembly is compatible with the Fugro core bit. In other words, designs of all participating tools will be coordinated so that they use the same BHA. This means that any of the tools can be used without requiring a drill pipe trip.

2.2.7 The length of the HPTC core should be 3.5m (11.5 ft) unless Geotech determines a shorter length is necessary for the new PCATS. (NOTE: Subsequent to the design review meeting AAI and Geotech determined that it would be possible to design the new PCATS to meet the 3.5m (11.5 ft) HPTC core length.

2.3 Detailed Design Phase

Following the design review meeting, the Detailed Design Phase the design commenced. AAI interfaced with Geotech to obtain the interface requirements for the PCATS system and to establish an acceptable core length. Geotech provided AAI with the connector flange and manipulator connection details. AAI interfaced with Fugro to mutually work out a common BHA and bit design. Fugro provided AAI with the drawings for the existing core liner and core catchers. No major obstacles were encountered.

The reduction in core size enabled us to incorporate a few additional modifications and improvements beyond those specified in the original scope of work and the design review meeting:

- 2.3.1 The OD of the inner barrel assembly was reduced to increase the clearance between it and the ID of the drill string.
- 2.3.2 The OD of almost the entire inner barrel assembly was standardized. This will make servicing much easier and eliminate the need to constantly adjust pipe wrenches.
- 2.3.3 The outer core barrel was changed to use standard drill collar connections instead of the proprietary Baker Hughes Inteq core barrel threads. We learned that management at Baker Hughes decided they could no longer support work by or sell to third parties. The use of a standard drill collar thread will also insure that the entire BHA will have the same torsional strength.

The subsystems and components were redesigned and the part designs were finalized based on the scope of work, meeting decisions, interface requirements and design objectives. A full scale integrated layout was prepared, materials and sizes were selected and final calculations carried out. More detailed information is provided in Section 3.

2.4 Current Status

As of this writing, 80% of the individual part drawings have been prepared and are now being checked. An new assembly drawing is being prepared, as a final check, by “assembling” AutoCAD blocks made from the individual part drawings. The assembly drawing is about 70% complete.

Manufacturing cost estimates still need to be obtained. This will be done as soon as the part drawings are checked and complete.

Although it took some additional time to interface and work out the new design requirements, he work will be completed without any increases to the planned budget. It is estimated Phase 3 will be competed by the end of October, 2008.

3.0 Details of the HPTC Design

A schematic drawing of the High Pressure Temperature Corer (HPTC) is shown in Figure 1. The inner barrel assembly of the HPTC, which is run and retrieved using a wireline, consists of the cutting shoe, core catcher, ball valve, insulated inner tube, regulated pressure control system, over-travel spring, bearing and latch assemblies. The outer barrel assembly, is run in the hole on the drill pipe as part of the bottomhole assembly. It consists of the bit with torque drive key, outer barrel and landing seat. Following is a description of the various components and details of the work that was carried out in order to achieve the goals stated above. Since the field proven NC-PTCS was used as a basis for the HPTC design the modification notes at the end of each section refer to the changes that were made based on starting with the NC-PTCS design.

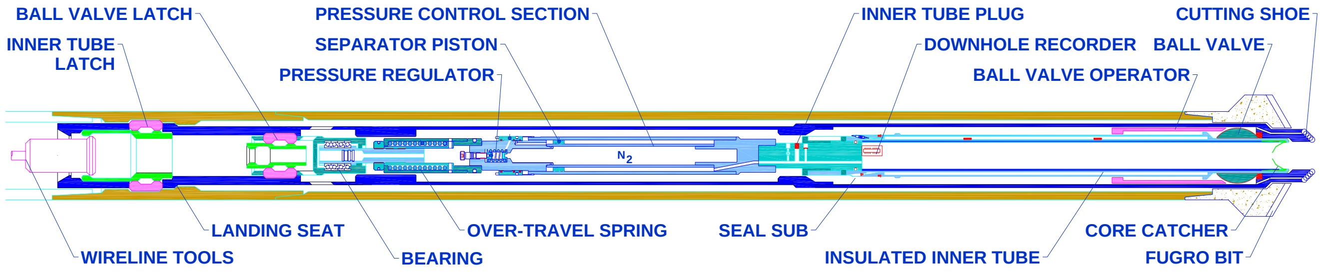


Figure 1, High Pressure Temperature Corer (HPTC) Schematic Drawing

3.1 Latch Systems and Wireline Tools

The HPTC uses two latches that work together to provide the necessary functions and feedback using only the mechanical wireline. The system uses a set of wireline tools that work in conjunction with the latches for setting and retrieving the inner barrel assembly and operating the ball valve. All normal operations are semi-automatic using spring loaded sleeves. Shear pins in the wireline tools are used only to release from the inner barrel assembly as an emergency release device in case of a problem with the HPTC system. Components used with the wireline tools include jars and sinker bars which are normally included with the HPTC equipment. Wireline, rope sockets, etc. are normally supplied by the operator or wireline company along with the wireline unit. The HPTC uses the spacing between the landing shoulder and the end of the spear as well as two different diameter profiles for establishing correct engagement for the desired operation. The same basic tool design is used for all operations, with only spacing tubes and different diameter collets assembled for the particular operation required.

Two latches are contained in the core barrel. The inner barrel latch (the upper latch) locks the inner barrel assembly into the outer barrel assembly while coring. The wireline pulling tool releases this latch to come out of the hole. The ball valve latch (the lower latch) controls the operation of the ball valve and position of the inner tube. The pulling tool engages this latch and pulling on the wireline releases the latch, raises the inner barrel to clear the ball, and then closes the ball.

3.1.1 Inner Barrel Latch

The inner barrel latch locks the inner barrel assembly to the outer barrel assembly. Surface indication of proper operation of the latch is provided through the automatic release of the running tool when the inner barrel assembly lands on the no-go shoulder and the dogs correctly lock into position. The landing shoulder locates the inner barrel assembly in its proper relationship to the outer barrel assembly. The weight of the inner barrel assembly, the holding capability of the latch dogs and pump pressure combine to hold it in position during coring operations.

After the core is cut the inner barrel latch is normally automatically released using the wireline pulling tool. The release occurs when the inner tube reaches the end of its stroke after the release of the ball valve latch and closure of the ball.

Modifications from NC-HPCS to HPTC

- No changes were made to the wireline tools or inner barrel latch or method of operation other than changes to the diameters to reduce and standardize the OD's of the inner barrel assembly.
    - The OD's of the inner barrel latch spring retainer and upper end of the inner barrel latch housing were reduced from 5.625 to 5.375.
    - All of the parts in the inner barrel latch assembly were reduced in diameter.
    - The OD's of the lower end of the inner barrel latch housing, upper barrel, and middle barrel were increased from 5.25 to 5.375.
    - The OD of the inner barrel latch piston was reduced by 0.18.
    - The OD of the inner barrel latch dogs were reduced by 0.125.

3.1.2 Ball Valve Latch

The ball valve latch keeps the inner tube assembly secured relative to the inner barrel assembly and to keep the ball valve locked in the open position while running in the hole and during coring. Once coring is complete the wireline pulling tool is run to the HPTC, where it locks into the ball valve latch piston. The ball valve latch is released by upward pull on the wireline. Continued upward pull on the wireline lifts the inner tube and closes the ball valve, capturing the core at bottom hole pressure. In addition, as stated above, completion of the required upward movement of the inner tube lifts the inner barrel latch piston allowing the dogs to retract and releases the inner barrel assembly from the outer barrel assembly. This allows the inner barrel assembly to be brought to the surface. Again, the operation is designed to be automatic.

Modifications from NC-HPCS to HPTC

- No changes were made to any of the parts in the ball valve latch.

3.1.3 Emergency Release Systems

The inner tube latch incorporates a second wireline tool recess which can also be caught with the pulling tool adjusted for a slightly longer engagement. This feature allows the inner tube latch piston to be caught and the inner barrel latch released without closing the ball valve.

3.1.4 The wireline tools also feature a shear pin which is activated by jarring down with the wireline jar. This is an emergency release device which allows the tool to be released from the latch piston in case some type of malfunction prevents the normal automatic operation.. It can be used, for example, to release the normal pulling tool should the inner barrel latch not release as designed. After the pulling tool is brought to the surface, the emergency pulling tool can be run and a direct release of the inner barrel latch can be attempted. In a worst case, the shear pin release can be used and wireline pulled out of the hole so that the drill string can be pulled without having to cut the wireline or pull it to break it.

Modifications from NC-HPCS to HPTC

- No changes have been made to the wireline tools or emergency release system.

3.1.5 Bearing

A bearing assembly provides for free rotation of the outer barrel relative to the inner tube so that the inner tube and core catchers do not rotate with the bit and outer barrel and damage the core. The bearing provides for a low friction connection for both axial and radial loads. In the axial direction, the bearings provide free rotation in the case of either up or down thrust of the inner tube. Normally the inner tube hangs from the barrel assembly. However, it is possible for the inner tube to develop upward thrust should the core have difficulty entering the core catcher or become jammed in the inner tube. Core jamming can produce axial forces on the bearing equal to the applied weight on the bit. In the radial direction the bearing keeps the upper end of the assembly centered and prevents the top end of the inner assembly from rotating against the outer tubes. The bearing is located just below the latch assembly. Four oil sealed angular contact bearings (three for up thrust and one for down thrust) are used in the HPTC bearing assembly. A floating piston is incorporated into the design to equalize the pressure across the rotating seal preventing a pressure lock and possible high seal friction.

Modifications from NC-HPCS to HPTC

- No changes have been made to the bearing assembly.

3.1.6 Over-travel Spring

The over-travel spring is located in a chamber just below the bearing. The spring is preloaded to provide sufficient force to lift the pressure control section, inner tube and core with enough extra force to apply a controlled force to close the ball without damaging any parts Should the ball valve or inner tube become jammed during closure operations with the wireline, the maximum force that is exerted on the parts is the force provided by the spring rather than the full force of the wireline pull. The spring also compensates for the length adjustment which is made for proper core shoe to cutting shoe spacing. The length adjustment is made with a thread and locknut that is located between the bearing and spring assembly.

Modifications from NC-HPCS to HPTC

- No changes were made to the over-travel spring.

3.1.7 Pressure Maintenance Section

The purpose of the pressure maintenance section is threefold. First, it affords some protection from pressure fluctuations due to thermal changes and/or slow leakage. Second, it can be set to provide a pressure boost to help create an initial seal on the ball valve. Third, it provides for safe release of pressure in the unlikely event that the barrel traps excessive pressure downhole or produces excessive pressure due to heating as, or after, it is brought to the surface. The pressure section contains a pressure transducer to enable the system pressure to be measured after the barrel is brought to the surface. The pressure control section is equipped with externally operable shut-off valves (called bullet valves) and access ports to allow for isolating the pressure control section from the ball valve section before disconnecting them. These same ports also provide for the sampling of core fluids if desired as well as an alternate way to monitor pressure.

A burst disk assembly is incorporated in the inner tube plug to protect the equipment and operators from over-pressure and possibly bursting of the barrel. This "pressure fuse" is calibrated very accurately to any desired pressure. For the HPTC burst discs will be ordered to 6000 psi. This allows for slight over-pressure during core transfer, etc. and still falls well within the safe design range of the inner barrel assembly.

A regulated pressure system is incorporated into the pressure section. The pressure regulator can be set at the surface to provide a small pressure boost when the ball valve closes down hole to help create an initial seal. The regulator section uses a nitrogen reservoir but with a separator chamber and piston to prevent the nitrogen gas from mixing with the core fluids and gasses. The regulator section was evaluated and it was determined that it met the higher pressure requirements without any changes. This includes the accumulator barrel, regulator barrel and separator piston. The bullet valves are used throughout the pressure section needed to be qualified for service at the new higher pressure. A prototype bullet valve with a back-up ring added to the seal design was hydrostatically tested. We were able to repeatedly open and close the bullet valve at a pressure of 7000 psi using Nitrogen and also with water without leakage.

The inner tube plug is located at the top of the inner tube. It joins the pressure maintenance section to the insulated inner tube. It contains a manifold and bullet valves for isolating the pressure chamber from the regulator. It also contains the burst disk, pressure transducer and optional downhole pressure/temperature recorder. The inner tube plug is held in place by six externally removable retaining pins. To transfer the core under pressure, the transfer chamber is screwed into an adapter installed at the top of the crossover sub. A seal surface in the adapter engages a seal inside the crossover sub. The adapter shoulders on the inside to provide a flush surface for core transfer. The pressure in the decompression chamber is equalized to the pressure inside the core barrel. Then the release pins in the crossover sub are unscrewed just enough to free the inner tube plug so the core can be transferred. With this approach the inner tube plug with the downhole recorder and pressure transducer attached are moved into the core transfer chamber along with the core and core liner.

Modifications from NC-HPCS to HPTC

Changes were made to the pressure section to allow for higher working pressure, to reduce the diameter of the core and transferred components and to standardize the OD of the inner barrel assembly.

- The OD of the inner tube plug and all associated features were reduced in diameter to meet the requirements to fit into the 65 mm ID PCATS chamber.
- The inner tube plug was modified to accept the thread at the top of the Fugro core liner. This thread will be used to fasten the liner to the inner tube plug.
- A back-up ring was added to the bullet valve seal.
- The accumulator fill sub was reduced in diameter and lengthened so it would fit inside the reduced diameter seal sub.
- The accumulator and regulator tubes were shortened by 3.5 inches to allow room for the longer accumulator fill sub.
- The seal sub was reduced in diameter to the standardized 5.375 OD. The ID was reduced in diameter to fit the smaller crossover sub.
- We verified that the regulator may be used up to 10,000 psi input pressure and 5000 psi output pressure. No changes were required.

3.1.8 Inner Tube

The inner tube consists of two concentric tubes with an air gap insulation space between them to provide the core with some protection from heating as the inner barrel is pulled to the surface. The air gap insulated space also contains temperature sensors that can be monitored at the surface during cooling or core removal operations. At the surface plugs can be removed and the air gap insulated space filled with liquid to aid in transferring heat while it is being sub-cooled in an ice bath. The entire inner tube will require redesign to prevent the tubes from bursting or collapse in the higher pressure. It may be that a decision will have to be made to choose between a smaller core or the insulated inner tube design.

Modifications from NC-HPCS to HPTC

Changes were made to the inner tube to make it compatible with the increased pressure, the reduced diameter of the core and standardized inner barrel assembly OD.

- The ID of the crossover sub, inner sleeve and outer sleeve extension were reduced from 2.938 in to 2.559 in.
- The wall thickness of the inner sleeve was increased to 0.25.
- The wall thickness of the outer sleeve was increased from 0.225 to 0.375.
- The OD of the outer sleeve and upset diameter on the outer sleeve extension were reduced from 4.687 to 4.312 (to allow for the smaller standardized 5.375 inner barrel OD.
- The OD of the outer sleeve extension was reduced from 3.937 to 3.562.
- The thread and seal sizes were adjusted for the new part diameters.
-

3.1.9 Ball Valve Section

In the NC-HPCS (and HPTC) the inner tube extends through the ball to the bit while running in the hole and during coring. After the core is taken, the wireline engages the latch at the top of the inner barrel assembly and pulls the inner tube up through the ball. After the inner tube clears the ball, the inner tube contacts and lifts the ball valve operator. Continued lifting of the inner tube and operator closes the ball.

3.1.9.1 Ball Valve Operator

The ball valve operator provides a way to insure that the inner tube clears the ball before the ball starts to close. Pivoting link pins between operator and ball translate the linear motion of the wireline into rotational motion to close the ball. The ball valve operator also contains a set of die springs that compensate for length tolerance accumulation and limit the pull on the link pins.

3.1.9.2 Ball Valve

The fixed pin ball valve used for the NC-PTCS is a variation of the original PTCS ball valve with modifications that permit easier assembly and better control of the closed ball position. The ball valve pivot pins provide a way to rotate the ball from the outside of the pressure housing. Internal stops control the full open and full closed position of the ball.

Modifications from NC-HPCS to HPTC

Changes were made make the ball valve section compatible with the increased pressure, the reduced diameter of the core and standardized inner barrel assembly OD. These modifications include:

- The OD of the ball was reduced from 5.000 to 4.625 in.
- The ID of the ball, ball valve seal and operator were reduced from 3.312 to 2.937 in.
- The OD of the ball valve housing, operator housing and ball valve seal sub housing were reduced from 5.594 to the new standardized 5.375.
- The ID of the ball valve housing was reduced from 5.100 to 4.723 while increasing the wall thickness from 0.233 to 0.326 to meet the 5,000 psi HPTC pressure requirement.
- All of the operator parts including the operator and spring carrier were adjusted to work within the other parts. This was generally a reduction in size by 0.187 in.

3.1.10 Core Catchers

The NC-PTCS uses two types of core catchers, a nearly full closing finger (or petal) catcher and a conventional slip type catcher. These core catchers have been successful in reliably recovering hydrate bearing cores. Unfortunately, because the PCATS requires the core liner, core catchers and core to be extracted into the PCATS chamber it is not possible to use the existing NC-PTCS core catchers.

Modifications from NC-HPCS to HPTC

- We incorporated the Fugro spring basket catcher system that screws onto the end of the plastic core liner. The Fugro core catchers have also proven successful in recovering methane hydrate cores.

3.1.11 Extended Cutting Shoe

The NC-PTCS used the main core bit to trim the core. The sub at the bottom of the inner barrel assembly merely contained the ball valve seal and provided guidance for the inner barrel and protection for the core catchers. Because of the requirement to use the HPTC with the Fugro Bit we decided to make this part into what is called a cutting shoe. The design and function is similar to the cutting shoe successfully used for years by the Ocean Drilling Program on their XCB core barrel. The cutting shoe becomes a small core bit that extends through the larger hole in the main bit. The cutting shoe rotates with the main bit to trim the core. The fact that it extends ahead of the main bit can reduce core washing and can improve core recovery. The main challenge was to find a way to transmit the drilling torque to the cutting shoe which is removed with each wireline trip. Fugro also needed a way to transmit the torque and introduced a simple key feature in the ID of the bit. We considered several types of spring loaded arms but ultimately decided to incorporate a simple matching key feature into the OD of the cutting shoe.

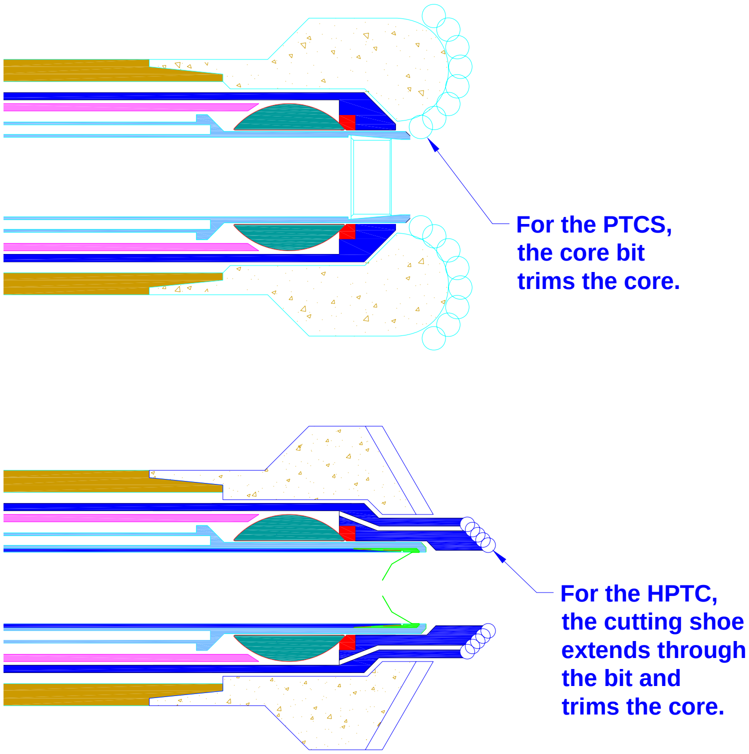


Figure 1, Extended Cutting Shoe Concept

Modifications from NC-HPCS to HPTC

- Modified the existing ball valve seal sub into a cutting shoe with PDC cutters for trimming the core.
- Added a key feature to the OD of this new cutting shoe to transmit the drilling torque from the main bit to the cutting shoe.
- Provided flow ports to cool and clean the cutters on the cutting shoe.

3.1.12 Outer Barrel Assembly

The outer barrel assembly of the NC-PTCS used the Baker Hughes Inteq proprietary 8 x 5 core barrel threads for the outer barrel, subs and core bit which we purchased from BHI. However, recently the BHI management decided to no longer support or sell to third parties. Because of this we investigated using a standard drill collar thread for the outer core barrel and bit connections. We found that this was possible because of the smaller OD of the inner barrel assembly. This will also provide an outer core barrel with a higher torque rating.

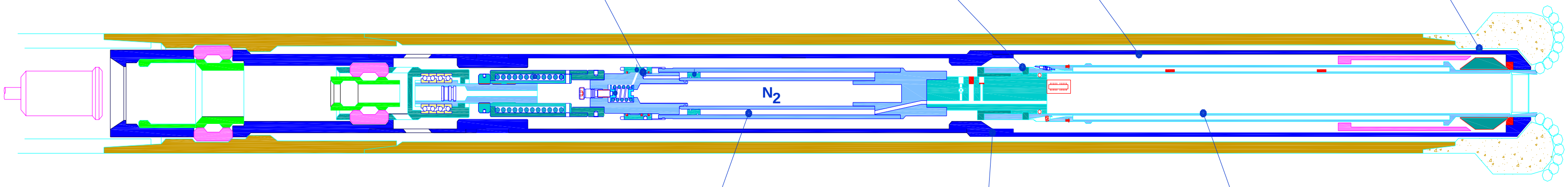
Modifications from NC-HPCS to HPTC

- A 6-5/8 IF thread was selected for the outer core barrel and bit threads.
- A standard PTCS drill collar with the 6-5/8 IF tool joint supplies more flow area when used in conjunction with the HPTC than the standard BHI 8 in x 5 in core barrel.
- A bore back will be used as a way of obtaining a larger ID where needed.
- Minor changes were made to the landing seat. Previously, the landing seat was screwed into the landing sub. The landing seat was changed so that it is now trapped in a bore back between the outer core barrel and the first drill collar. This eliminates one sub and simplifies manufacture of these parts. The landing seat shoulder was also reduced in diameter from 5.625 to 5.500 to allow for the reduced OD of the inner barrel assembly.

Appendix A, Safety Factors NC-PTCS vs HPTC (Prelminary)

Part Name	Part No	Original NC-PTCS Design			Recommendations	
		3500	5500	5000	5000	Changes Required
FIXED PIN BALL VALVE						FIXED PIN BALL VALVE
Ball	10186	6.73	4.28	4.28	4.28	
Ball Valve Housing	10182	4.49	2.86	3.14	3.95	Increase wall by 0.062
Pivot Pin	10181	7.01	4.46	4.91	4.91	No change required
Ball Trunnions	10186	6.73	4.28	4.71	4.71	No change required
Ball (Shear from Contact)	10155	19.42	12.36	13.60	13.60	No change required
TOP SEAL BALL VALVE						
Upper Operator Housing	10571	4.04	2.57	2.83	3.98	Increase wall by 0.094
Ball Valve Housing (Tension)	10561	6.88	4.38	4.80	4.80	No change required
Ball Valve Housing (Hoop)	10561	4.04	2.57	2.83	3.98	Increase wall by 0.094
INNER TUBE						
Inner Sleeve (Burst)	10513	4.03	2.57	2.82	3.98	Increase wall by 0.062
Outer Sleeve (Collapse)	10512	1.38	1.38	1.38	1.38	No change (4:1 not req'd)
INNER BARREL						
Lower Outer Tube	10506	3.91	2.49	2.74	3.98	Increase wall by 0.156
Seal Sub Housing	10507	9.27	5.90	6.49	6.49	No change required
PRESSURE SECTION						
Retaining Pins (Shear)	10607	5.54	3.52	3.88	3.88	No change required
Retaining Pins (Blowout)	10607	7.77	4.95	5.44	5.44	No change required
Bullet Valve (Blowout)	10533	28.11	17.89	19.68	19.68	No change required
Accumulator Barrel (6000psi)	10521	4.84	4.48	4.48	4.16	At 7000 psi, No change
Reservoir Barrel (6000psi)	10520	5.39	5.39	5.39	4.81	At 7000 psi, No change
Sleeve Valve	10524	8.70	5.54	6.09	4.35	At 7000 psi, No change
Parts needing redesign (SF < 4) are shown in yellow.						

Appendix B, Preliminary Safety Factor Review Schematic



Bullet Valves
No change required

Lower Outer Tube
Increase wall 0.156

Retaining Pins
No change required

Ball Valve Housing
Increase wall by 0.062
Ball & Pivot Pins
No change required

Accumulator Barrel
and Reservoir Barrel
No change required

Seal Sub
No change
required

Inner Sleeve
Increase wall by 0.062
Outer Sleeve
No change required

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