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Phase IIIB Topical Report
Report #41330R27

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 deep water portion of the Gulf of Mexico (GOM). In August 2000 Chevron worked closely with the National Energy Technology Laboratory (NETL) of the United States Department of Energy (DOE) and held a workshop in Houston, Texas to define issues concerning the characterization of natural gas hydrate deposits. Specifically, the workshop was meant to 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. Following this workshop, Chevron formed a Joint Industry Project (JIP) in 2001 to write a proposal to conduct research on natural gas hydrate deposits in the deep water portion of the Gulf of Mexico. That proposal was selected for award by the DOE, and Chevron was awarded a cooperative agreement for research based on the proposal (DOE Award: DE-FC26-01NT41330). The title of the project is "Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Exploration and Production Activities".

Since 2001 the JIP has engaged in a multiyear effort to develop technology and collect data to assist in the characterization of gas hydrates in the deep water Gulf of Mexico. Other JIP members include ConocoPhillips, Schlumberger, Halliburton, Japan Oil Gas and Metals National Corporation, U.S. BOEM, Total, Reliance Industries Ltd., Korean National Oil Company, and Statoil.

During the project's first phase (Phase I), the JIP performed technical investigations into the occurrence, nature, and implications of gas hydrate in the Gulf of Mexico. Results included the development of seismic modelling and interpretation methods to identify and characterize hydrate deposits in deep water environments, a series of laboratory investigations to determine the impact of gas hydrate occurrence on sediment physical properties, identification of geohazards and well bore stability issues, and development of drilling and coring methods through hydrate intervals. Several workshops and conferences were held to share the results and to plan the subsequent phases of the project.

In next phase (Phase II) the JIP completed the project's first offshore drilling expedition in 2005 (Leg I) consisting of drilling, logging, and coring operations in fine-grained sediments at five locations in two GOM areas. The program collected an outstanding suite of well-logs and borehole seismic through the hydrate stability zone and collected over 200 meters of core. Leg I demonstrated the viability of pre-drill techniques and technologies used for hydrate identification and characterization, and it demonstrated the ability to safely drill and operate in areas of hydrate occurrence.

Following on the success of Phase II the project moved to Phase III, which included a second offshore drilling expedition (Leg II). During this expedition extensive Logging While Drilling (LWD) data were

acquired from additional GOM locations in order to further evaluate hydrate drilling hazards, to provide information on gas hydrate resource potential, and to develop plans for a third offshore expedition (Leg III) that focused on hydrate coring. Planning for Leg II began in 2005 with the evaluation of numerous sites prospective for the occurrence of gas hydrate at high saturations. Three sites were ultimately selected, and the Leg II drilling program was completed in 2009. Given program budgets, Leg II focused on LWD collection to confirm gas hydrate occurrence – with coring deferred to a later Leg. The Leg II operation obtained extensive LWD data from seven drilling locations at three GOM areas.

Encouraged with Leg II results, the JIP planned to continue the drilling and coring program in a follow-up Phase (Phase IIIB) to obtain pressurized cores and to characterize hydrates at as close to in-situ conditions as possible. The plan for Phase IIIB included a Leg III offshore expedition to twin some of the previous wells drilled in order to collect extensive continuous pressure cores, wireline logs, wireline pressure profiles and fluid samples from gas hydrate bearing sand horizons. These pressure cores would be cut with a customized core barrel to retain in-situ pressure during the acquisition, retrieval, and transportation operation. Early versions of pressure coring tools were developed by industry prior to Phase III, but the JIP placed a focus on further development and testing of a pressure coring system in Phase III. Extensive work on the pressure coring system ramped-up in 2010 when Aumann & Associates (AAI) proposed the development of a High Pressure Temperature Corer (HPTC) for the JIP. A design and manufacturing contract for HPTC was awarded to AAI by the JIP in 2011. Following field testing of a related AAI prototype Pressure Coring System in Japan in July 2012, the design of the JIP system was changed to a Hybrid Pressure Core System (Hybrid PCS) and AAI was awarded a contract to design and manufacture the Hybrid PCS. Early in November 2013, the Hybrid PCS was tested for functionality at an onshore test at the Catoosa Test Facility in Hallett, Oklahoma. Several performance issues were observed during the Catoosa test. A technical review was subsequently conducted and the root causes of performance issues were identified. AAI has since upgraded the Hybrid PCS to rectify the performance issues observed at Catoosa, but the revised system has not undergone field-based testing.

In addition to further development of pressure coring tools, work was also conducted in Phase IIIB to further develop the measurement systems that could be used to analyse the pressure cores under in-situ pressure conditions. This work was conducted by two collaborating research teams of scientists over many years: the USGS and the Georgia Institute of Technology. These teams have successfully developed the Instrumented Pressure Test Cell (IPTC) and the Pressure Core Characterization Tool (PCCT) systems. These systems have the capability to perform a number of analyses of hydrate core properties under in-situ pressure conditions. Early designs were tested in 2005 during the Leg I expedition. More recent field testing of the systems has been successful on pressured cores collected offshore Japan in January 2013.

Phase IIIB also included the planning of a Leg III drilling expedition to collect hydrate pressure cores in offshore GOM. Preliminary planning work was completed by several project science teams in early 2010. However, after the Macondo well incident in GOM in 2010, a team of Chevron scientists and the Chevron Deepwater Drilling Operations Group completed a detailed assessment of drilling plans, well designs, and safety considerations. It was determined by this group that GOM deep water drilling operations by Chevron would require the use of a sixth generation deep water drillship. Largely because of the cost for this type of drilling program the Leg III expedition was not pursued in this project.

The project was concluded in May 2014. Final delivery of equipment and reports was completed by the end of the 90 day close-out period, which concluded in August 2014. This Topical Report provides the detailed documentation of the Phase IIIB activities and results that were completed between January 2010 and May 2014.

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EXECUTIVE SUMMARY

In 2001 Chevron formed a Joint Industry Project (JIP) group to conduct research on natural gas hydrate deposits in the deep water portion of the Gulf of Mexico (GOM). 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 subsequently Chevron was awarded a cooperative agreement for the hydrate research based on this 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 project was funded and started in October 2001. At the project completion in May of 2014 total project funding was approximately $50MM ($35MM from the DOE and $15MM from the JIP). Over a period of 12 years the project completed a wide scope of hydrate scientific research, technology development, and technology testing / application. The project included drilling, logging, coring, acquisition and analysis of hydrate data and samples, development of analytical methods, and construction, testing and delivery of coring equipment and tools. The project included 10 JIP member companies and 20 subcontractors, including Universities, Oil and Gas Industry Service companies, Suppliers, Manufacturers, and Government Agencies. Data obtained by the project enabled over 180 technical reports / publications and over 120 technical presentations at industry forums. Thirty five University or College students contributed directly to the project and received educational funding. The project was concluded in May 2014, and the technical results are available on the DOE-NETL Methane Hydrates Website in the form of Semi-Annual Reports, Topical Reports, and other related documentation. This current report is the Phase IIIB Topical Report that provides detailed documentation of the Phase IIIB activities and results that were completed between January 2010 and May 2014.

The key tasks that were identified and completed for this Project Phase include the following:

- Project Management and Oversight
- Improved Prototype Hydrate Recovery and Measurements Equipment
    - Further development and testing of the Instrumented Pressure Test Cell (IPTC) and Pressure Core Characterization Tool (PCCT)
- Prototype Pressure Coring Equipment Design Update, Development and Testing
    - Development of High Pressure Temperature Corer (HPTC)
    - Development and testing of Hybrid Pressure Coring System (HPCS)

    - Catoosa onshore test of the HPCS
    - Technical Review Team (TRT) analysis of test results and recommendations
    - Additional modifications to the HPCS post-Catoosa test
- Preliminary Planning Study of a Potential Marine Pressure Coring Expedition

INTRODUCTION

In 2000 Chevron began to frame a project to characterize the natural gas hydrate deposits in the deep water Gulf of Mexico (GOM). Chevron is an active explorer and operator in the Gulf of Mexico and was aware that natural gas hydrates needed to be better understood in order to operate safely in deep water. In August 2000 Chevron worked with the National Energy Technology Laboratory (NETL) of the United States Department of Energy (DOE) to conduct a workshop in Houston, Texas that identified and discussed the key issues concerning the characterization of natural gas hydrate deposits. Specifically, the workshop was meant to show where research, the development of new technologies, and new data collection and analysis would be beneficial to the DOE and to the oil and gas industry in defining issues and solving natural gas hydrate problems in deep water.

In 2001 Chevron formed a Joint Industry Project (JIP) group to write a proposal and to conduct research on natural gas hydrate deposits in the deep water GOM. Chevron generated a research proposal which was submitted to the DOE in April 2001 under a competitive DOE funding opportunity announcement (FOA). That application was selected for an award by the 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”. The project was funded in October 2001, and in December 2001 additional workshops were held to identify the project sub-teams and to develop the high level project phases and tasks, which are illustrated and summarized in Figure 1.

Since 2001, the JIP engaged in a multiyear effort to develop technology and collect data to assist in the characterization of gas hydrates in the deep water GOM. The JIP members include ConocoPhillips, Schlumberger, Halliburton, Japan Oil Gas and Metals National Corporation (JOGMEC), U.S. Bureau of Ocean Energy Management (BOEM), Total, Reliance Industries Ltd., Korean National Oil Company (KNOC), and Statoil. Since its initiation the JIP project work continued over three main phases:

<u>Phase I:</u> During the first phase, the JIP performed technical investigations into the occurrence, nature, and implications of natural gas hydrates in the GOM. Planning for an offshore

expedition to collect hydrate data was also conducted. During the period March - May 2002 a series of technical workshops were held to define the detailed project scope, key tasks, work plan, and schedule. The project governance and technical teams responsible for completing the work were also established. Subsequent workshops were held to identify the project subcontractors and to initiate plans for drilling site selection and drilling operations.

Phase II: During the second phase, the JIP completed the first offshore expedition in 2005. This Leg I expedition consisted of drilling, logging and coring operations in fine-grained sediments at five drilling locations in two GOM areas. The expedition collected an excellent suite of well-logs and borehole seismic through the hydrate stability zone. Over 200 meters of core was recovered and a 60 meter thick, gas-hydrate-bearing interval was identified. The data obtained from Phase I and Phase II activities, including the Leg I offshore expedition, demonstrated the potential for gas hydrate characterization using industry-standard seismic data, and it demonstrated the ability to safely drill and operate in areas where modest to low saturations of gas hydrate might occur in the fine-grained sediments that typify the GOM.

Phase III: Phase III was established as two distinct sub-phases:

- Phase IIIA – Activities under this sub-phase included a second offshore expedition (Leg II) to obtain extensive Logging While Drilling (LWD) data from additional locations in the GOM with a focus on areas anticipated to have higher saturation hydrate occurrence in coarse grained sediments. Planning began in 2005 and the Leg II expedition was completed in 2009. The Leg II expedition obtained extensive LWD data from seven drilling locations at three GOM areas. Leg II successfully demonstrated the occurrence of gas hydrates at medium to high saturations in reservoir-quality sands in the GOM. The hydrate deposits were found in close accordance with pre-drill predictions, demonstrating the validity of the hydrate exploration and appraisal tools and techniques used in finding, delineating, and characterizing targeted accumulations. Also in this phase, systems for handling and analyzing pressured cores were further developed.

- Phase IIIB - The Phase IIIB activities included the technology development of pressure coring equipment suitable for characterizing and evaluating hydrates at *in-situ* conditions in the GOM. Design alternatives for a functioning pressure coring device were developed, and a prototype pressure coring tool was built and tested. The systems for handling and analyzing pressured cores were continued to be refined. These systems were successfully tested on pressured, hydrate-containing cores obtained by JOGMEC (a JIP member) in 2012 during an expedition offshore Japan. A preliminary planning study for a potential marine pressure coring acquisition expedition in the GOM (Leg III) was also competed in order to determine the drilling requirements and cost.

Throughout all project phases regular project reporting included Semi-Annual Reports and Topical Reports. A final Project Summary Report was prepared and delivered in 2014. That report contains the extensive reference and technical publication list for the entire project. The reports for the Phase IIIB period are summarized in Table 1, and they are available on the DOE-NETL Methane Hydrates Website.

Figure 1: Project Phases and Key Activities.

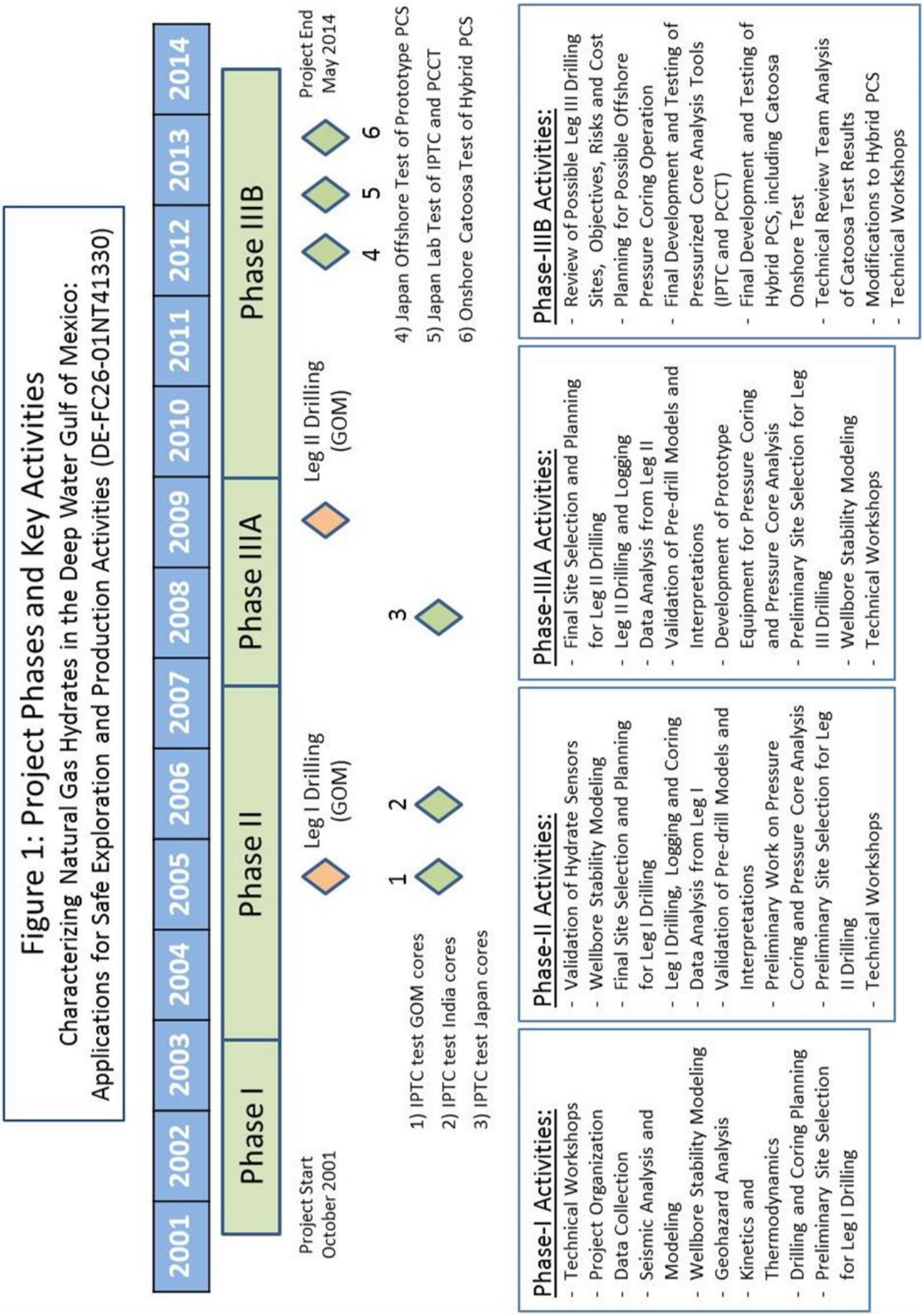

Table-1: Listing of Semi-Annual and Topical Reports for Phase IIIB (January 2010 – May 2014).

Report #	Report Type	Start Date	End Date	Phase	Topics Included in the Report
41330R18	Semi-Annual Report	Oct-09	Mar-10	Phase III	continued data analysis from Leg II drilling, prepare publications to share results, planning for future coring and Leg III drilling
41330R19	Semi-Annual Report	Apr-10	Sep-10	Phase III	planning for Leg III drilling, discussion of drilling moratorium impacts, discussion of coring tool development and bottom hole assembly design.
41330R20	Semi-Annual Report	Oct-10	Mar-11	Phase III	description of information sharing from Leg II drilling (website with log data, publication with full results), discussion of drilling moratorium impacts, update on pressure coring tool development
41330R21	Semi-Annual Report	Apr-11	Sep-11	Phase III	discussion of new well planning procedures post moratorium, update on timing of Leg III, proposed "block organization" for Leg III, use of PCATS and HPTC in Japan tests, HPTC/PCATS testing
41330R22	Semi-Annual Report	Oct-11	Mar-12	Phase III	detailed discussion regarding new drilling regulations and well design, discussion of pressurized coring, discussion of funding issues related to increased drilling costs and requirements, continued development of the IPTC/PCCT
41330R23	Semi-Annual Report	Apr-12	Sep-12	Phase III	completed modifications to IPTC and construction of PCCT, discussion of project funding and pace, completed lab testing of IPTC and PCCT, discussion of testing prototype Hybrid PCS by JOGMEC, evaluated options for service vans.
41330R24	Semi-Annual Report	Oct-12	Mar-13	Phase III	completion of testing of IPTC and PCCT on pressurized cores in Japan, design modifications to Hybrid PCS, onshore test planning for Catoosa site
41330R25	Semi-Annual Report	Apr-13	Sep-13	Phase III	completion of Hybrid PCS system and factory testing, planning for onshore test of Hybrid PCS at Catoosa, delivery of reports on IPTC and PCCT successful tests
41330R26	Semi-Annual Report	Oct-13	Mar-14	Phase III	completion of the Hybrid PCS onshore test at Catoosa, fabrication of service vans and heavy vans, Technical Review Team assessment of Hybrid PCS test results, Project close-out planning
41330R27	Topical Report: Phase IIIB Topical Report	Jan-10	May-14	Phase III	detailed report on the development of the IPTC and PCCT, development of the HPTC and Hybrid PCS, planning and design of an offshore Hydrate pressure coring operation, Catoosa onshore test of the Hybrid PCS, Technical Review Team findings and post-test modifications to the Hybrid PCS

Phase IIIB Tasks:

The key tasks that were identified for Phase IIIB included the following:

- Project Management and Oversight
- Improved Prototype Hydrate Recovery and Measurements Equipment
  - Further development and testing of the Instrumented Pressure Test Cell (IPTC) and Pressure Core Characterization Tool (PCCT)
- Prototype Pressure Coring Equipment Design Update, Development and Testing
  - Development of High Pressure Temperature Corer (HPTC)
  - Development and testing of Hybrid Pressure Coring System (HPCS)
  - Catoosa onshore test of the HPCS
  - Technical Review Team (TRT) analysis of test results and recommendations
  - Additional modifications to the HPCS post-Catoosa test
- Preliminary Planning Study of a Potential Marine Pressure Coring Expedition

Phase IIIB Results Summary:

Phase IIIB activities were originally focused on the planning of offshore drilling expedition Leg III to collect hydrate pressure cores at a number of selected locations in the GOM that were previously drilled and logged in Phase IIIA (Drilling Leg II). Activities also included technical work on the development and testing of pressurized coring equipment and continued work on hydrate core testing & analysis equipment.

Prototype Pressure Core Handling / Analysis Equipment

The development and enhancement of prototype Pressure Core Handling / Analysis equipment was initiated and completed by two teams of scientists from the United States Geological Survey and Georgia Institute of Technology. Two systems to analyse pressure cores taken under in-situ conditions have been successfully developed: the Instrumented Pressure Test Cell (IPTC) (enhanced from the IPTC version originally created during Phase II of the project) and the Pressure Core Characterization Tool (PCCT). The systems have the capability to perform a number of analyses on the pressured hydrate cores under in-situ pressure conditions. A field test of these tools was successfully accomplished at the AIST national hydrate laboratory in Sapporo, Japan, in January 2013. The IPTC and PCCT equipment have been delivered to the Department of Energy (DOE), and subsequently the title was transferred to USGS Woods Hole (IPTC) and Georgia Institute of Technology (PCCT) where these equipment systems now reside.

Prototype Pressure Coring Equipment Design, Development and Testing

Technical work to update and improve a hydrate pressurized coring system was initiated by the JIP in Phase III. In 2011 the JIP funded Aumann and Associates, Inc. (AAI) to development a High Pressure Temperature Corer (HPTC) for the JIP. The HPTC specifications included a longer core barrel allowing for more efficient coring operations and increased core diameter to enable improved device robustness and reliability.

Subsequent to the contract award to AAI, the Chevron Drilling Group reviewed deep water drilling protocols and determined that the large diameter of the HPTC design would not be compatible with the drill pipes to be employed by Chevron deep water drill rigs. While it would be possible to make modifications to the HPTC design and the drill pipes, these changes would be complex and difficult. In June 2012, JOGMEC was successful in the acquisition of hydrate pressure cores offshore Japan using a pressurized core system built by AAI for JOGMEC that employed a smaller core barrel. In April, 2013, AAI was contracted by the JIP to build a Hybrid Pressure Core System (Hybrid PCS) based on the Japanese pressurized core barrel with additional refinements from lessons learned from JOGMEC coring experiences. The manufacturing of the Hybrid PCS was completed and factory acceptance tested in September 2013. A Heavy Van and Service Van were also constructed at this time. These vans serve as transport and on-site servicing containers for the Hybrid PCS.

In November 2013 the Hybrid PCS was field tested for functionality at Catoosa Test Facility in Hallett, Oklahoma. A number of performance issues were observed during the Catoosa test. A technical review was subsequently conducted and the root causes of performance issues were identified. AAI completed modifications to the Hybrid PCS to rectify the performance issues observed at Catoosa, but the modified system that includes these changes was not further field tested prior to the close of the Project. The Hybrid PCS, the Service Van, the Heavy Van and associated drilling and coring equipment were delivered to the DOE storage facility in Morgantown, West Virginia in June 2014.

Preliminary Planning Study of a Potential Marine Pressure Coring Expedition

The preliminary planning and design of a Leg III drilling expedition to collect pressure cores of hydrates offshore GOM was initiated in late 2009. A Leg III Science Field Organization Team was established and the kick-off meeting was held in January 2010. This team included scientists and engineers from Chevron, academia, industry, DOE, USGS and BOEM. Additional teams and contractors (such as Geotek and Aumann and Associates) were also very involved in the expedition planning. Issues with compatibility of the drill pipe and the HPTC pressure corer were identified and discussed. A series of meetings were held in first half of 2010 to address this issue, as well as to develop the technical scope and scientific objectives of the Leg III drilling and coring expedition. However, the planning for Leg III and other Phase IIIB work was significantly impacted by the GOM Drilling Moratorium that was announced in May 2010 as a result of the Macondo well incident. Prior to the moratorium the project team had been ramping up preparations for the planned 2011 Leg III expedition. Shortly after the moratorium was announced the Leg III preparations were put on hold to wait for lifting of the moratorium and to get post-moratorium clarification and assessment of regulatory, legislative, permitting, operational, and commercial changes in GOM drilling.

Following the GOM Macondo well incident, a team of Chevron scientists and the Chevron Deepwater Drilling Operations Group completed a detailed evaluation of new drilling and safety requirements for deep water drilling and coring. The evaluation included a scoping study, a front end engineering study, a drilling and coring safety review, and a detailed time and cost estimate of an offshore operation to obtain hydrate pressure cores. The main conclusions of the study were:

1) Offshore drilling and pressure coring of hydrates carry inherent considerable safety risks as hydrate accumulations are considered drilling hazards. The study showed that there are many risk factors in a pressure coring operation with an experimental prototype pressure coring tool. To provide adequate safeguards, a sixth generation deep water drill ship should be deployed for the Leg III pressure coring operation.

2) Time and cost estimate of the Leg III pressure coring operation using a sixth generation deep water drillship would be expensive as the operational cost would exceed $1MM/day. The total cost of a nominal three well program would exceed $40MM.

Due to the high cost of this potential offshore operation a decision was made to not pursue the Leg III expedition. Instead, the Hybrid PCS was field tested at the onshore test facility at Catoosa.

Phase IIIB Topical Report Organization:

This Topical Report is a compilation of several separate reports that were developed for each of the primary tasks. Each task report has its own introduction, table of contents, report text, and appendices.

This Topical Report is organized into the following sections:

- Section-1 is the introductory and overview section.
- Section-2 is the Task Report for the development of the improved prototype Hydrate Core Recovery and Measurements Equipment. It was prepared by Carlos Santamaria (Georgia Tech

University) and is titled: *“Development of the Instrumented Pressure Test Cell (IPTC) and the Pressure Core Characterization Tool (PCCT)”*

- Section-3 is the Task Report for the development of High Pressure Temperature Corer (HPTC). It was prepared by Jim Aumann and Chris Johnson (Aumann & Associates) and is titled: *“Redesign of the High Pressure Temperature Corer (HPTC)”*. This report was previously issued in November 2012. The copy included here is unchanged from that version.
- Section-4 is the Task Report for the development and testing of Hybrid Pressure Coring System (HPCS). It was prepared by Jim Aumann (Aumann & Associates) and is titled: *“Development and Testing of the Hybrid Pressure Coring System (HPCS)”.*
- Section-5 is the Task Report for the Catoosa onshore test of the Hybrid PCS. It was prepared by a team that included Jim Aumann (Aumann & Associates), Tom Pettigrew (Pettigrew Engineering), Tom Fate and Sam Chase (Chevron), and Carlos Santamaria (Georgia Tech University). It is titled *“Catoosa Onshore Test of the Hybrid PCS”.*
- Section-6 is the Task Report for the Catoosa Test Technical Review Team’s analysis of test results, recommendations, and additional modifications made to the Hybrid PCS after the Catoosa test. It was prepared by a team that included Tom Pettigrew (Pettigrew Engineering), Jim Aumann (Aumann & Associates), Tim Collett (USGS), Tom Fate (Chevron), and John Roberts (Geotek). It is titled: *“Technical Review Team Final Report Following Onshore Testing at Catoosa Test Facility, November 3-13, 2014.”*
- Section-7 is the Task Report for the preliminary planning study of a Potential Marine Pressure Coring Expedition in the deep water Gulf of Mexico. It was prepared by Jim Mounteer (Argon Energy) and Tom Fate (Chevron), along with contributions from the Chevron Deepwater GOM Drilling Team. It is titled: *“Planning and Design of Offshore Hydrate Pressure Coring Operation”.*

SECTION 2
PHASE IIIB TOPICAL REPORT #41330R27

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

Carlos Santamarina (Georgia Tech)

GOM Deepwater Gas Hydrate
Joint Industry Project
DOE Award DE-FC26-01NT41330

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INTRODUCTION

In 2009, the Gulf of Mexico Hydrate Joint Industry Project (JIP) conducted an offshore drilling and logging operation (called Leg II) into various hydrate formations at various offshore locations in Green Canyon, Atwater and Walker Ridge areas. Quality log data with good stratigraphic and hydrate properties information were obtained from these wells. Given the success of the logging operations for hydrate, the JIP started to develop a plan for a Leg III coring operation to acquire offshore hydrate pressure cores of hydrates and to analyze these pressure cores for hydrate properties under in situ conditions. The planning work for the Leg III coring operation would consist of three main components: development of a functioning pressure coring device, detailed engineering of the offshore coring operation, and development of a system to analyze the pressure cores under in situ pressure conditions. The three main components must be fully compatible with each other for an overall viable system.

Two systems to analyze the pressure cores under in situ conditions have been successfully developed by two teams of scientists from the United States Geological Survey and Georgia Institute of Technology: the Instrumented Pressure Test Cell (IPTC) and the Pressure Core Characterization Tool (PCCT). The USGS team was led by Dr. Carolyn Ruppel and the Georgia Institute of Technology team was led by Professor Carlos Santamarina. The systems have the capability to perform a number of analyses on the pressured hydrates cores under in situ pressure conditions. A field test of the hydrate pressured cores systems was successfully accomplished at the AIST National Hydrate Laboratory in Sapporo, Japan, in January 2013. This report documents the development of the IPTC and PCCT systems.

EVOLUTION OF THE PRESSURE CORE CHARACTERIZATION TOOLS

The following is a brief historical summary of the evolution of pressure core characterization tools. Summary by Carolyn Ruppel (USGS Woods Hole) and Carlos Santamaria (Georgia Tech University):

- Between 1995 (ODP Leg 164) and early 2000s (e.g., IODP Exp. 204): Pressure core tools advanced rapidly (JNOC corer, Hyacinth, Fugro)

- By 2003: No way to interrogate multiple physical properties of hydrate-bearing sediments recovered in pressure cores, but could X-ray the cores with Geotek instrumentation. Becoming clear that depressurizing the cores destroyed sediment structure and made it impossible to obtain meaningful physical measurements.

- 2004: We proposed (to the DOE/Chevron JIP) building an instrument that could receive a pressure core and measure its seismic, strength, and electrical properties. Met with Geotek in Atlanta to discuss plans.

- 2005: First deployment of the Instrumented Pressure Testing Chamber (IPTC) on DOE/Chevron JIP pressure cores from Gulf of Mexico (obtained in Leg 1 expedition). Proposed and were funded for development of effective stress cell by Joint Oceanographic Institutions (IODP) and DOE/Chevron JIP.

- 2007-08: Georgia Tech analyzed pressure cores from NGHP (India) & UBGH 1 (Korea).

- 2009: IPTC informally transferred to USGS Gas Hydrates Project in Woods Hole.

- 2010: Georgia Tech proposed development of suite of other tools (e.g., shear cell, bio cell) to interrogate cores and of the manipulator and cutter to move and trim pressure core.

- 2011: With DOE/Chevron JIP support, Georgia Tech commenced building the new tools and the manipulator and cutter, and the USGS automated and updated aspects of the IPTC and revised sensors to handle coarse-grained sediments.

- 2012: Technology transfer within JIP—AIST built its own IPTC.

- 2013: Georgia Tech and the USGS deployed the full suite of Pressure Core Characterization Tools (PCCT) in Sapporo in collaboration with JAMSTEC and AIST.

Responsibilities between the USGS Woods Hole and Georgia Tech University were spilt as follows:

<u>USGS Woods Hole:</u>

- 5 personnel
- IPTC Refinements included:
    - Electronics
    - High pressure manifolds
    - New sensor development
    - Digital data acquisition
    - Operations manual
    - Containerized shipping

<u>Georgia Tech University</u>

- 4 personnel (additional 5 in Sapporo)
- PCCT Developments included:
    - Manipulator
    - Cutter – two types
    - Shear stress cell
    - Effective stress cell
    - Biological cell
    - Controlled depressurization cell

1. DEVELOPMENT OF THE INSTRUMENTED PRESSURE TEST CELL (IPTC) SYSTEM

The IPTC was the first pressure core characterization device developed in what has become the Pressure Core Characterization Tools (PCCT's). Components of PCCT's are illustrated in Appendix-1. The assembly and operations manuals are provided in Appendices 2 and 3.

The IPTC consists of a 316 stainless steel pressure chamber with ports to provide access to the sediment core. The IPTC's wall thickness (t= 12.5 mm) can sustain a fluid pressure of ~36 MPa. The inside diameter (din= 65 mm) of the IPTC accommodates pressure cores recovered by the Fugro pressure coring system and with the help of an auxiliary tube, HYACE rotary (pressure) cores. The IPTC is designed to ensure workability, safety, and geometric compatibility with peripheral devices and instrumentation.

The IPTC pressure chamber has two parallel rows of 4 instrumentation arms, each consisting of a stainless steel rod (L= 300 mm, d= 8 mm), a driver, a rod guide, and a ball valve. Three of the instrumented rod pairs contain transducers that are introduced into the sediments using the mechanical advancing driver through holes previously made with a drilling rod, which occupies the first access port closest to the point at which the core is introduced into the IPTC. Instrumented rods penetrate into the pressurized chamber through 25.4-mm-diameter rod guides. A ball valve lies between the rod guide and the chamber to permit tool replacement or repair while the system is under pressure. Flat ball bearings between the instrumented rods and drivers minimize friction, facilitate drilling of holes, and prevent the rotation of direction-dependent transducers. The length of the rod guide is designed to allow complete retrieval of instrumented rods so the ball valve can be closed, preserving the pressure in the chamber.

P-wave and S-wave velocities, electrical conductivity, and undrained shear strength of the sediment core are sequentially measured through the 3 instrumentation ports arrayed along the IPTC beyond the drilling port.

- *P- and S-wave measurements*: rod endings are trimmed into 6 mm outside diameter tips to facilitate introduction of transducers into drilled holes. P-wave measurements are conducted with miniature pinducer barrels. Bender elements are used for S-wave measurements. The bender elements, which are 10 mm long and 4 mm wide, stick out at the end of rods to attain optimal transducer-sediment coupling for signal generation and detection. For both the P- and S-wave measurements, noise control is based on signal stacking (typically 1024 signals). To determine velocities, we pick first arrivals from stacked waveforms.

- *Electrical conductivity*: is measured using the single-wedge electrical needle probe that sticks out 2.5 cm ahead of the rod.
- *Strength*: is measured using a specially designed, 60° cone-shaped stud. A full-bridge strain gauge circuit is mounted on the inner wall of the cone tube so that the cone effectively acts as a load cell. Finally, the cone resistance qc is a function of the unknown sediment undrained shear strength Su.

The development of the IPTC has been published by Yun, Narsilio, Santamarina and Ruppel [1]. Refer to the table below for references regarding the IPTC.

IPTC Topic	Reference
IPTC *Development*	Yun, T., Narsilio, G. A., Santamarina, J. C., and Ruppel, C. (2006). "Instrumented Pressure Testing Chamber for Characterizing Sediment Cores Recovered at In Situ Hydrostatic Pressure." Marine Geology, Vol. 229, pp. 285-293.
Gulf of Mexico *Deployment*	Yun, T., Narsilio, G. A., Santamarina, J. C., and Ruppel, C. (2006). "Instrumented Pressure Testing Chamber for Characterizing Sediment Cores Recovered at In Situ Hydrostatic Pressure." Marine Geology, Vol. 229, pp. 285-293.
Krishna-Godavari Basin (India) *Deployment*	Yun, T. S., Fratta, D., and Santamarina, J. C. (2010). "Hydrate-Bearing Sediments from the Krishna-Godavari Basin: Physical Characterization, Pressure Core Testing, and Scaled Production Monitoring." Energy & Fuels, Vol. 24, No. 11, pp. 5972-5983.
Ulleung Basin, (Sea of Japan) *Deployment*	Yun, T. S., Lee, C., Lee, J.-S., Bahk, J. J., and Santamarina, J. C. (2011). "A pressure core based characterization of hydrate-bearing sediments in the Ulleung Basin, Sea of Japan (East Sea)." Journal of Geophysical Research, Vol. 116, No. B2.

2. DEVELOPMENT OF THE PRESSURE CORE CHARACTERIZATION TOOL (PCCT) SYSTEM

As of today, our comprehensive pressure core characterization system includes core manipulation tools and characterization chambers. Tools have been selected to obtain complementary information relevant to science and engineering needs, with emphasis on the measurement of parameters used in hydro-thermo-mechanical analyses. All tools are designed following key guidelines and objectives: simple and robust systems, portable components for fast deployment, modular design for maximum flexibility, standard dimensions and parts for affordable construction and maintenance, rust-resistance for seawater environment, capability of maintaining and operating at pressure, ability to impose effective stress, and safety for monitoring of hydrate dissociation and gas production during controlled depressurization, heating or fluid exchange (such as with liquid CO_2). The modular design allows any two tools/chambers to be coupled through an identical flange-clamp system.

Manipulator	Longitudinal position control of core position Internal telescopic screw system (stroke=2.6m) external stepper motor with sub-millimeter resolution
IPTC	Described above
Subsampling cutters	Saw type: linear saw blade Guillotine type
Effective stress chamber	Effective stress Fluid conductivity
Direct shear chamber	Effective stress Double direct shear (maximum shear displacement: 15 mm)
Sub-sampling Tool for Biological Studies	A large number of sub-specimens from a single core segment
Controlled depressurization chamber	Information of the core lithology Self-drilling thermocouples

The operating manual for the PCCT system is reproduced in Appendices 2 and 3. The PCCT development results have been previously reported and published in 2012. [2, 3]

3. FIELD TESTING OF IPTC AND PCCT SYSTEMS

3.1 FIELD TESTING OF IPTC

The IPTC was deployed on three occasions: Gulf of Mexico (spring 2005), Krishna-Godavari Basin (India – fall 2006) and Ulleung Basin (Sea of Japan – fall 2008).

Gulf of Mexico: The IPTC was deployed for the first time during spring 2005 drilling in the Gulf of Mexico as part of the ChevronTexaco Joint Industry Project on Methane Hydrates. The focus area for the KC151 drilling lies in ∼1322 m of water on a structural ridge that forms the edge of a salt withdrawal mini-basin. The pressure core was maintained at ∼ 14 MPa fluid pressure throughout the recovery and analysis period, the ambient air temperature in the laboratory van in which the IPTC was operated was ∼ 7 to 8 °C or lower. To ensure that the sediment core remained within the stability field for gas hydrate in case any were present, ice was packed around the IPTC. The results of the test in the Gulf of Mexico were published in 2006 [4].

Krishna-Godavari Basin: three pressure cores were tested at an onshore facility in Singapore (cores were maintained under∼13MPa fluid pressure for 3 months). The test program included the measurement of elastic wave velocity, shear strength, and electrical conductivity, followed by fast depressurization of the sub-sampled core round. The results of this field test were published in 2010 [5].

Ulleung Basin: Seven pressure cores were recovered during the UBGH Expedition01 (four Fugro Pressure Cores-FPC and three HYACE Rotary Cores-HRC). The IPTC-based characterization took place within the core storage facility at the Korea Institute of Geoscience and Mineral Resources between February 10-16, 2008. The working temperature varied 3°C–5°C throughout the testing period. Six of seven recovered pressure cores were subjected to the IPTC-based characterization. Three cores were then selected for controlled depressurization within the IPTC. P and S wave velocities, electrical conductivity, temperature and the amount of produced gas were continuously measured during depressurization. The results of this field test were published in 2011 [6].

3.2 FIELD TESTING OF COMPLETE PCCT SYSTEM

The field testing of the PCCT system was successfully completed on pressured cores collected offshore Japan at the ASIT (Japan National Institute of Advanced Industrial Science and Technology) in Sapporo, Japan in 2012 . The pressure-core specimens were collected using the Hybrid Pressure-Coring System (Hybrid PCS) operated from the Chikyu deep ocean-drilling vessel. Eight of the cores were recovered at close to in-situ pressure and transported to AIST in Sapporo. The core was extracted from the PCS under pressure, X-rayed by Geotek, Inc., and cut into ~1.2 m sections that were transferred to storage chambers pressurized to 20 MPa.

PCCT devices were deployed in AIST's cold room (4°C) laboratories in Sapporo, and the pressure cores were transferred from storage to undergo analysis. The PCCT were operated at 10 MPa during testing of the cores.

The Effective Stress Chamber (ESC). Within the ESC, specimens were confined within a flexible membrane and subjected to an effective stress of ~3MPa, equivalent to what they experienced in situ due to the weight of overlying sediments. Small-strain stiffness, compressibility, hydraulic conductivity, volume contraction upon dissociation, and hydrate saturation were measured.

The Direct Shear Chamber (DSC). The DSC was used to measure specimen compressibility and shear strength under the in-situ effective stress (~3MPa), before and after hydrate dissociation. Additionally, P-wave velocity and temperature data were gathered throughout the loading, shearing, and dissociation process. The DSC data were also analyzed to study creep and volume compaction upon dissociation.

Sub-sampling Tool for Biological Studies. This tool was used to collect and transfer multiple subsamples to bioreactors without contaminating them, while maintaining pressure and temperature conditions for hydrate stability. Nutrients for microorganisms were injected into the bioreactor using a high-pressure syringe. Cell counts were made, and the effects of depressurization rate on post-sampling biological activity were investigated.

In addition, monitored depressurization tests conducted in individual PCCT chambers provided precise estimates of hydrate saturation and valuable geophysical information that can be used in the interpretation of data from future field production projects.

The success of the field testing of the PCCT has been published in 2013 [7]. The details of the field testing have also been in reported in the Semi-annual Progress Reports #41330R24 and #41330R25 [8, 9]. Some of the field testing results are also summarized in Appendix-4.

4. SUMMARY

The PCCT system is very flexible and can be readily extended to accommodate more devices and measurements, or even experiments that require single or repeated access to the specimen. For example, the addition of more access ports and transducers would permit us to construct electrical resistivity tomographic images of cores.

PCCTs can be used to measure mechanical, thermal and hydraulic parameters, and to monitor changes due to variations in pressure, temperature, and fluid exchange, to sample sediments or pore fluids, or to conduct micrological investigations.

Pressure-core technology can be effectively used to retrieve natural hydrate-bearing sediments under in situ conditions. A decade ago, pressure cores could be X-rayed and then depressurized to estimate the volume of hydrate that had been present. With the development of the full suite of PCCT tools, it is now possible to measure a much more comprehensive suite of mechanical, hydraulic, electrical, and biological properties, as has been done successfully for these pressure cores from the Nankai Trough.

In addition to pressure core testing, comprehensive characterization programs should include sediment index properties analyzed within the framework of available data for natural hydrate bearing sediments, and test with remolded specimens with synthetic hydrate. Pressure core technology can also be deployed to study other gas rich hydrocarbon formations such as deep-sea sediments, coal bed methane, and gas shales.

REFERENCES

1. Yun, T., Narsilio, G. A., Santamarina, J. C., and Ruppel, C. (2006). "Instrumented Pressure Testing Chamber for Characterizing Sediment Cores Recovered at In Situ Hydrostatic Pressure." Marine Geology, Vol. 229, pp. 285-293.
2. Santamarina, J. C., Dai, S., Jang, J., and Terzariol, M. (2012). "Pressure core characterization tools for hydrate-bearing sediments." *Scientific Drilling*, 14, pp. 44-48.
3. The PCCT Development Team (Georgia Tech: Santamarina, J.C., Dai, S., Jang, J., Terzariol, M., and Papadopoulos, E.; USGS: Winters, W.J., Mason, D., Waite, W., and Bergeron, E.). (2012). “Pressure core characterization tools to enhance gas hydrate field programs.” *Fire in the Ice*, 12(2), pp. 7-9.
4. Yun, T., Narsilio, G. A., Santamarina, J. C., and Ruppel, C. (2006). "Instrumented Pressure Testing Chamber for Characterizing Sediment Cores Recovered at In Situ Hydrostatic Pressure." Marine Geology, Vol. 229, pp. 285-293.
5. Yun, T. S., Fratta, D., and Santamarina, J. C. (2010). "Hydrate-Bearing Sediments from the Krishna-Godavari Basin: Physical Characterization, Pressure Core Testing, and Scaled Production Monitoring." Energy & Fuels, Vol. 24, No. 11, pp. 5972-5983.
6. Yun, T. S., Lee, C., Lee, J.-S., Bahk, J. J., and Santamarina, J. C. (2011). "A pressure core based characterization of hydrate-bearing sediments in the Ulleung Basin, Sea of Japan (East Sea)." Journal of Geophysical Research, Vol. 116, No. B2, pp. 0-Citation B02204.
7. The Sapporo Scientific Team (Georgia Tech: Dai, S., Jang, J., Terzariol, M., Papadopoulos, E., and Santamarina, J.C.; AIST: Konno, Y., Yoneda, J., and Nagao, J.; JOGMEC: Suzuki, K. and Fujii, T.; USGS: Winters, W.J., Mason, D., Waite, W., and Bergeron, E.). (2013). “Pressure core analysis tools used to characterize hydrate-bearing sediments from the Nankai Trough.” *Fire in the Ice*, 13(2), pp. 19-22.
8. “DOE Semi-annual Progress Report #41330R24 (October 2012 – March 2013)” NETL Methane Hydrates Web Site.
9. “DOE Semi-annual Progress Report #41330R25 (April 2013 – September 2013)” NETL Methane Hydrates Web Site.

APPENDIX 1
COMPONENTS OF PRESSURE CORE CHARACTERIZATION TOOLS

Components of Pressure Core Characterization Tools

for the analysis of:

hydrate-bearing sediments
gas-charged sediments
gas shales
coal

Pressure Core Characterization Tools <u>PCCTs</u>

Portable manipulator (MAN)
Core cutting tools (SAW and GUI)

Instrumented pressure testing chamber (IPTC)
Effective stress cell with flexible wall confinement (ESC)
Controlled de-pressurization (CDP)
Direct shear chamber (DSP)
Bio-sampling and reactor chambers (BIO)

General specifications:

Nominal core length: 1m
Core/liner diameter: ID=57 mm; OD=63 mm
Devices capable of undertaking 35MPa (5000 psi)
Operation <21MPa (<3000psi)
Portable + Modular Design

Instrumentation → Properties

Pre-production testing

Temperature & pressure (inside the core)

P-wave & S-wave velocity

Compressibility under zero-lateral strain

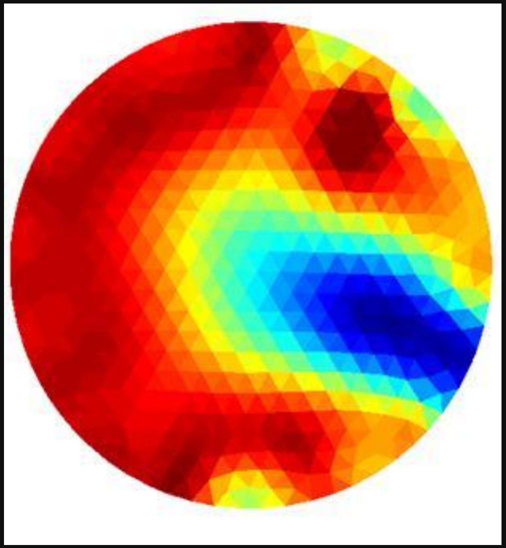
Shear strength (penetration and direct shear)

Electrical conductivity

Hydraulic conductivity

Thermal conductivity

Pore fluid sampling (without dissociation)



Production monitoring

Most properties above

Additional:

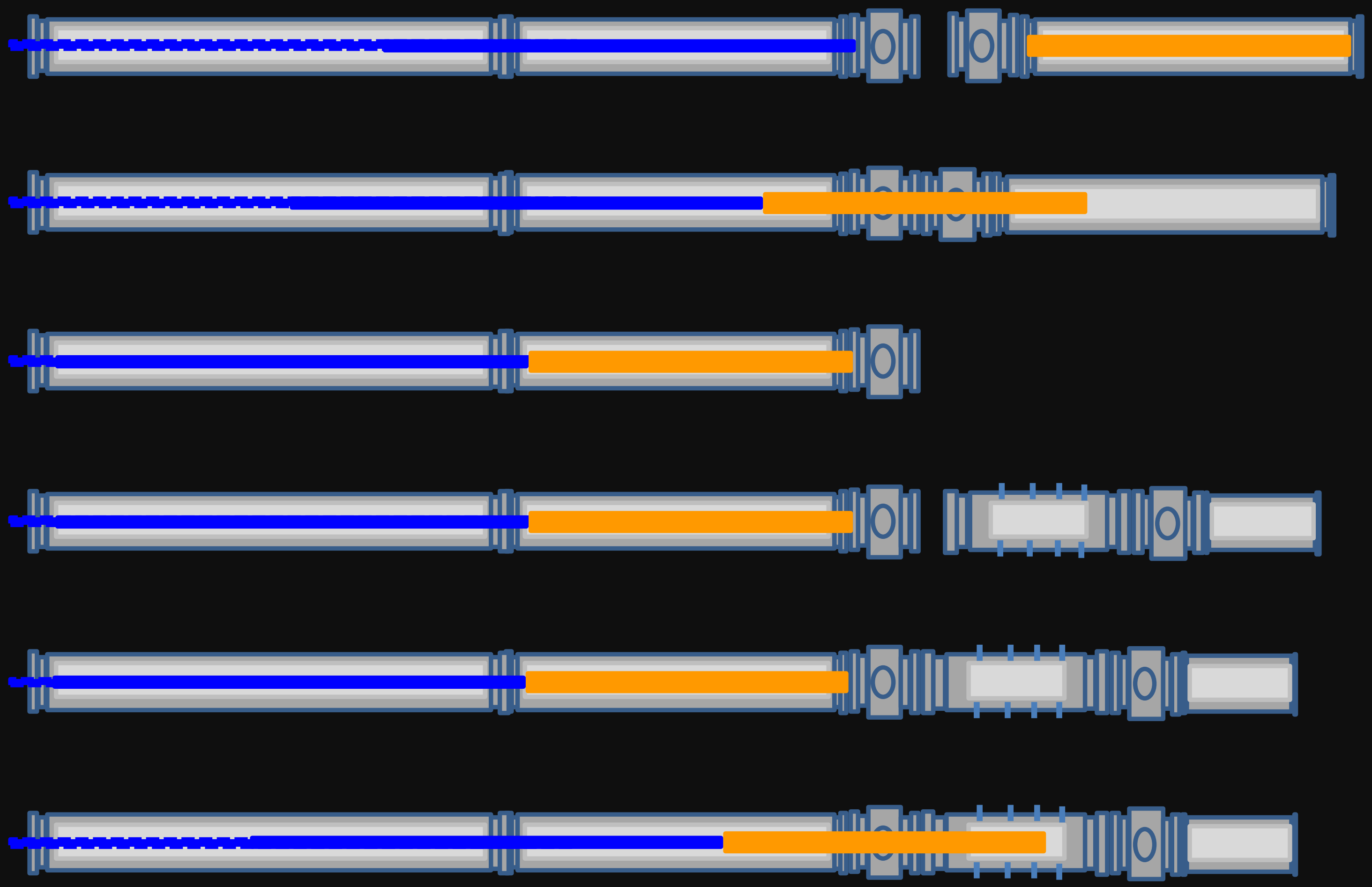
volume contraction upon dissociation

Post-dissociation properties

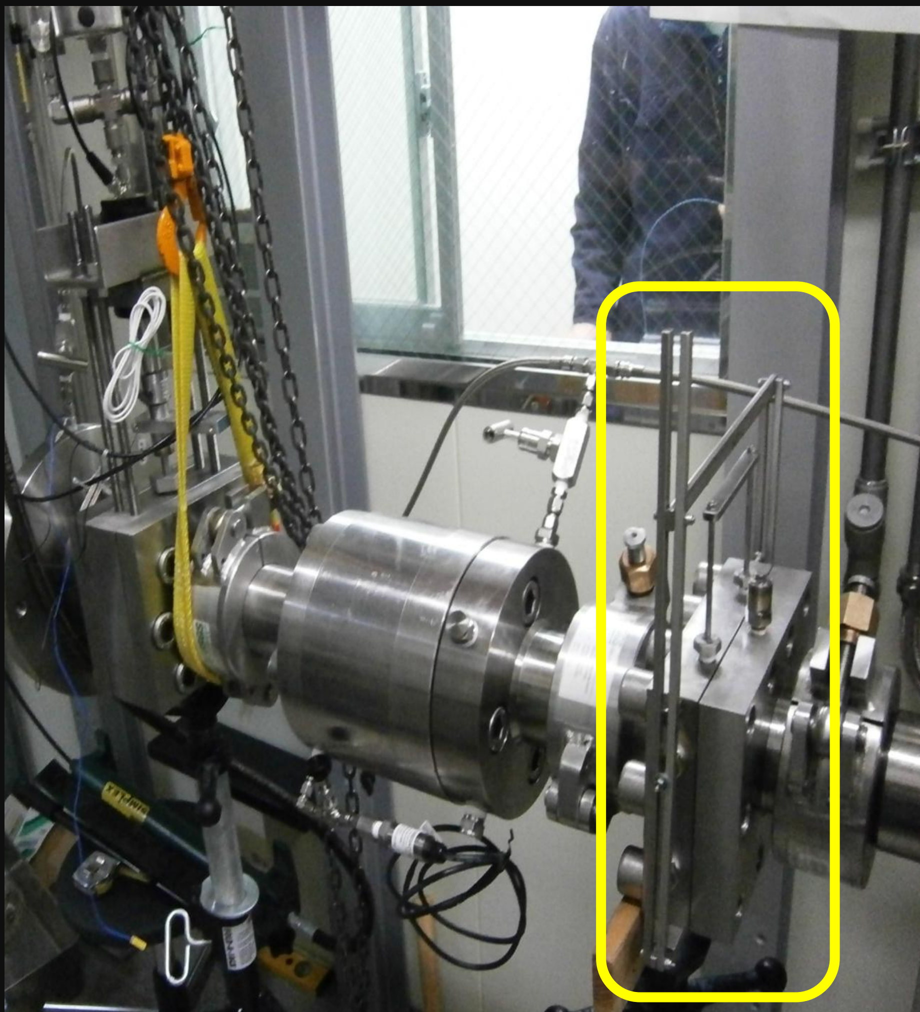
All above

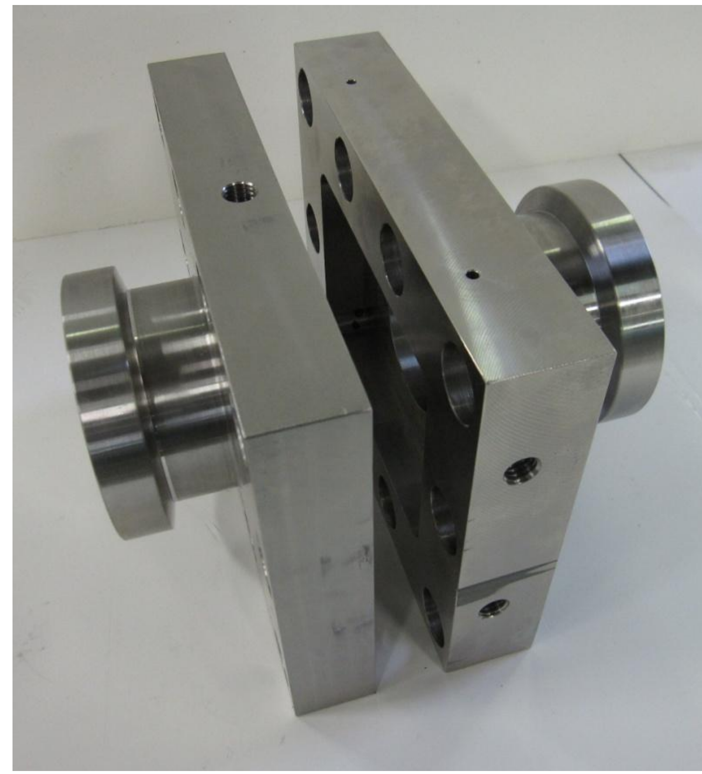
Manipulator MAN

click on image to play movie

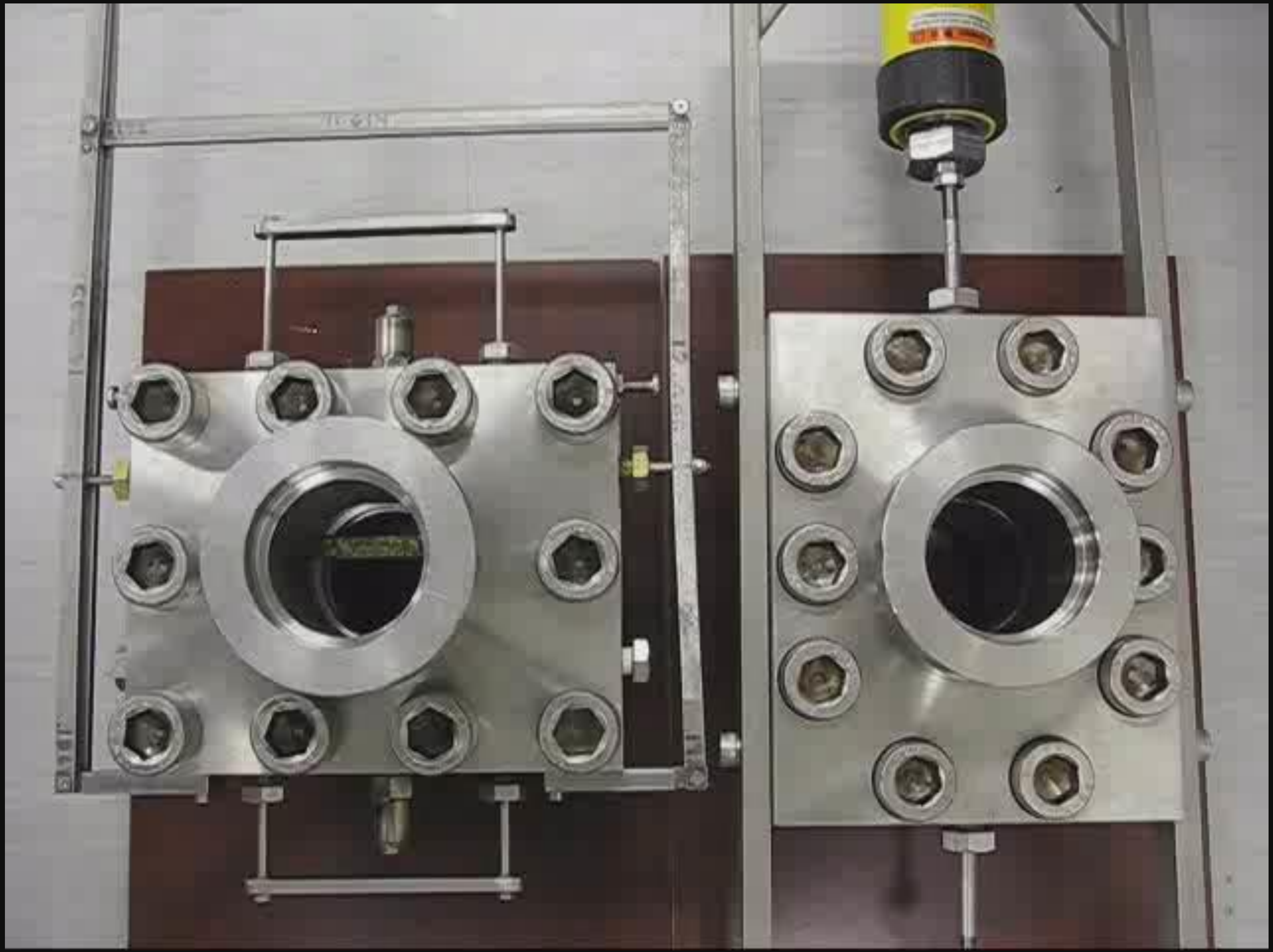


Cutters CUTs





Cutters CUTs



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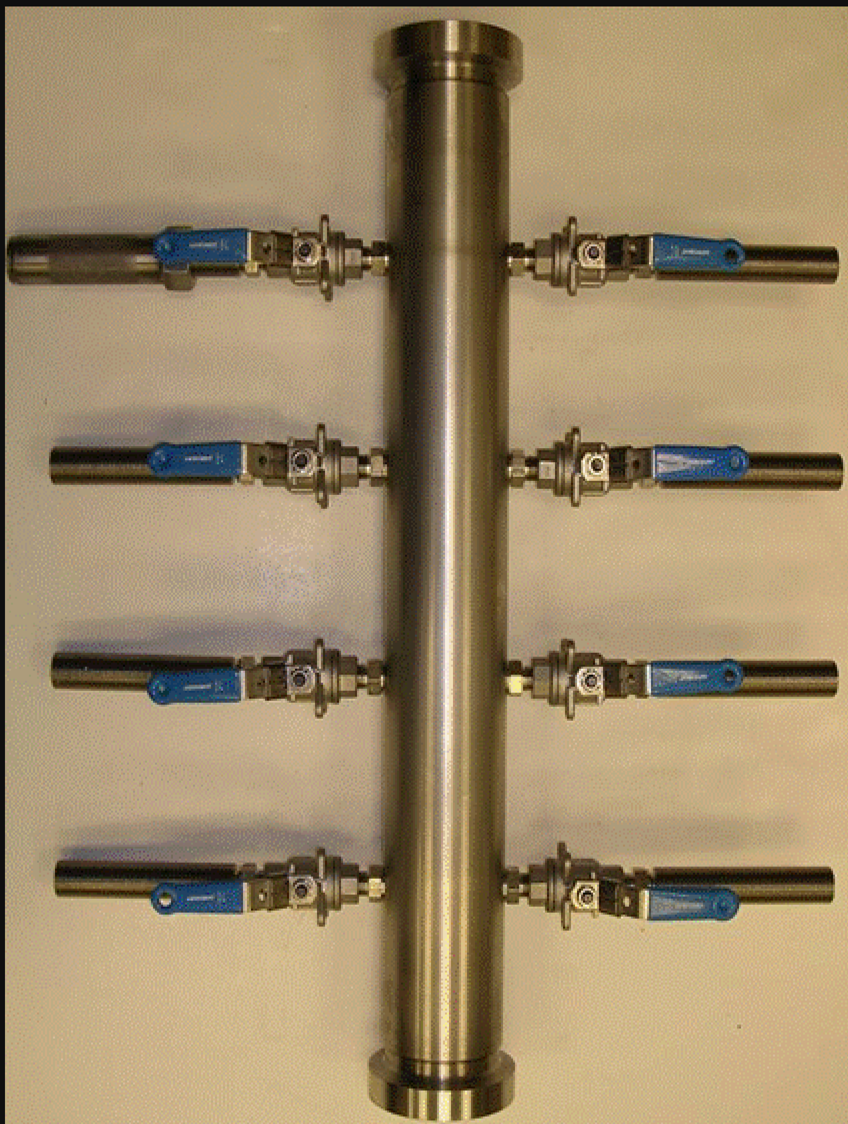
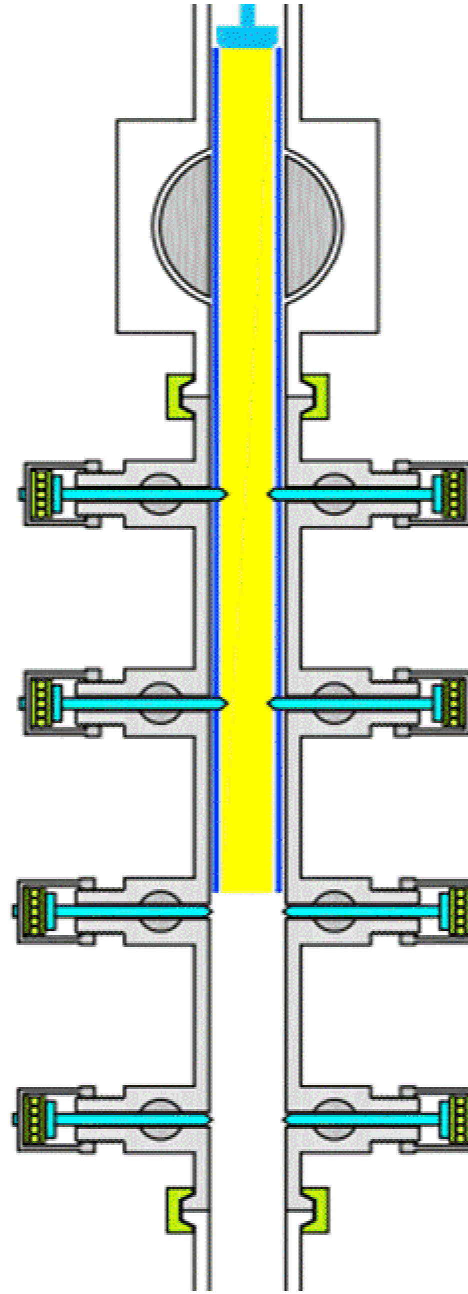
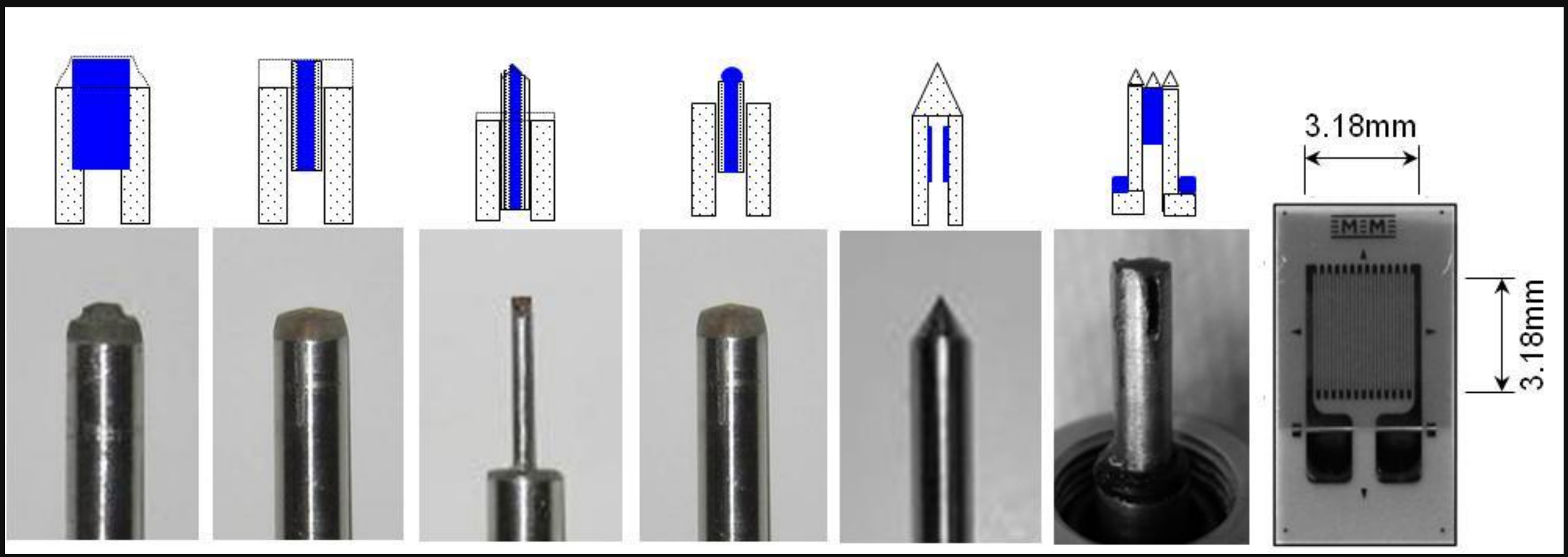
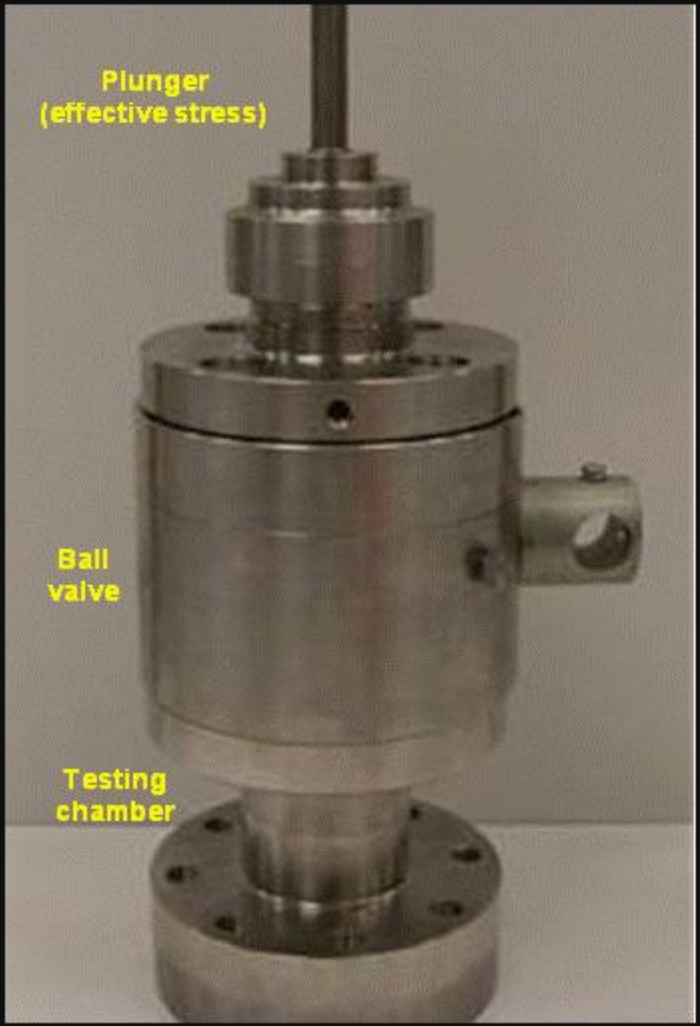
IPTC

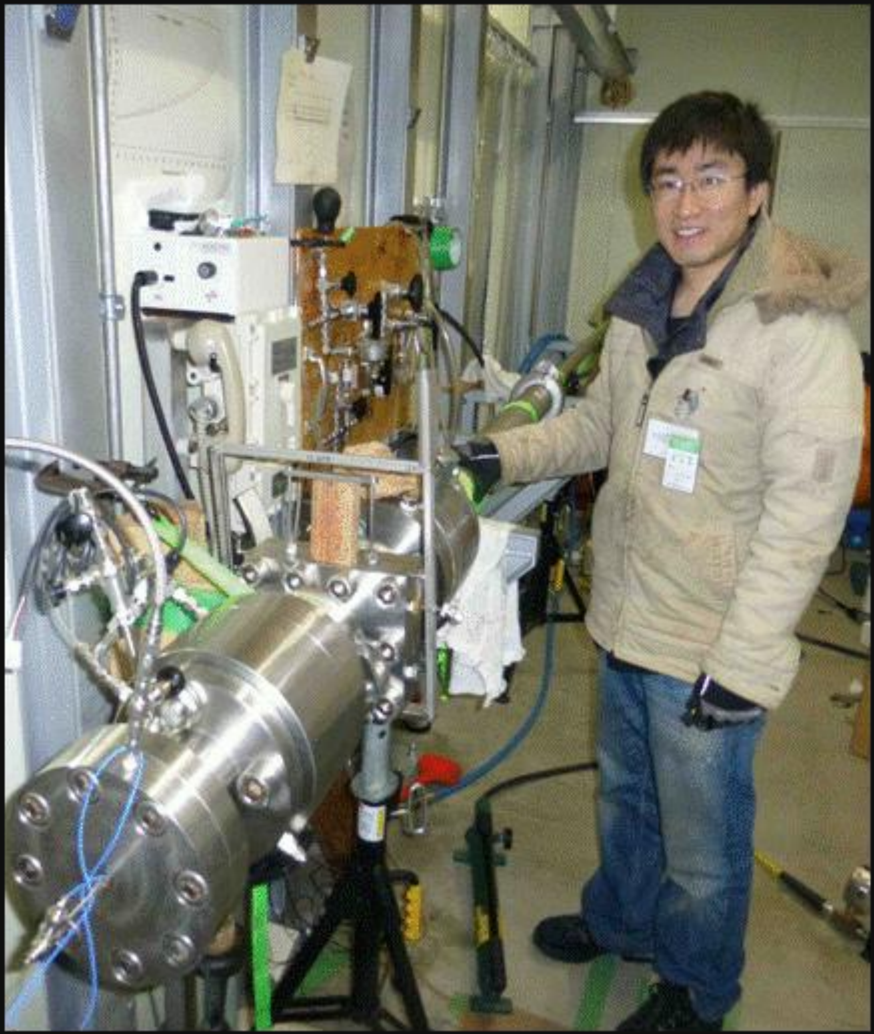





3.18mm
3.18mm

ESC Effective Stress Chamber

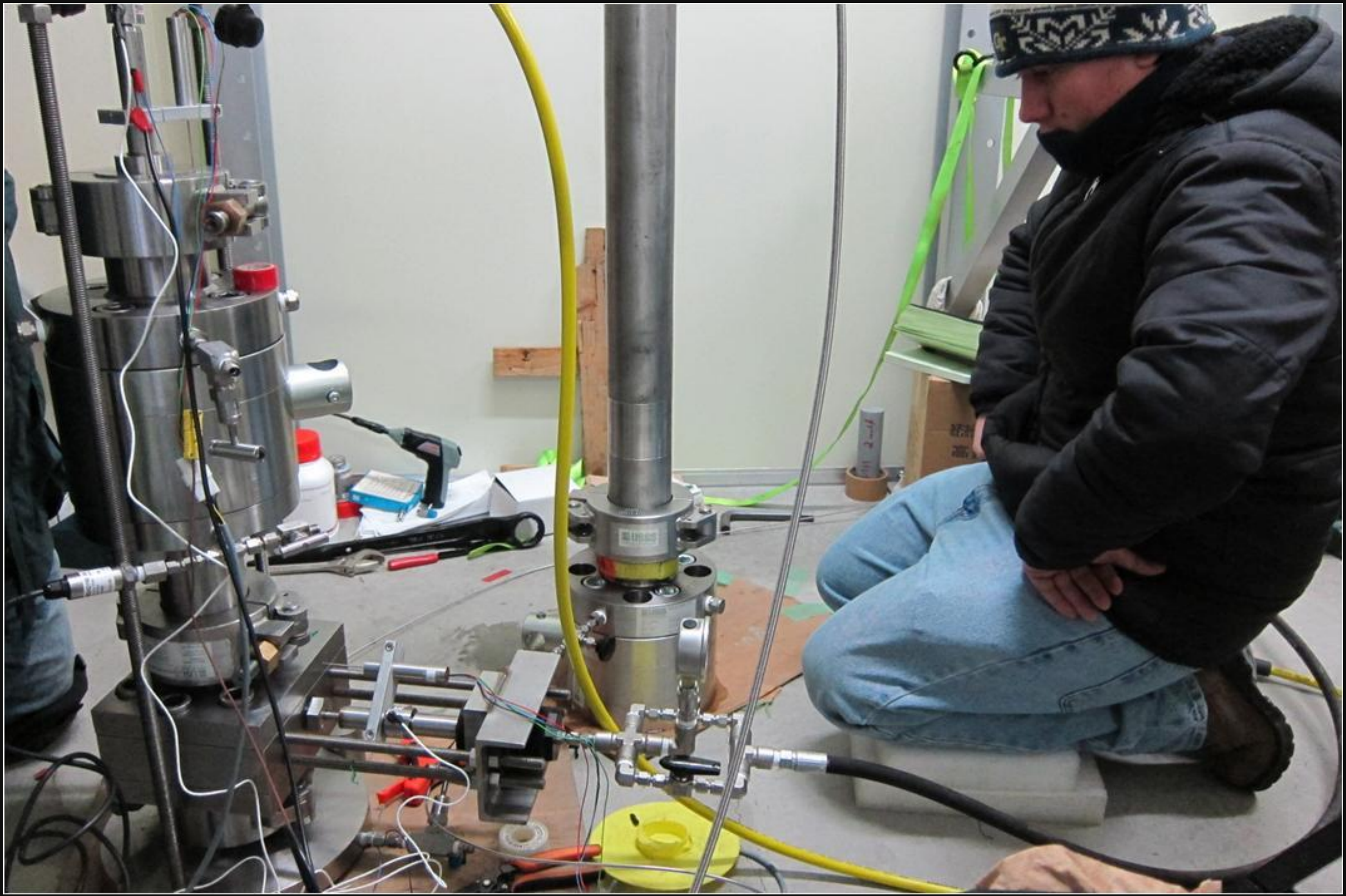




ESC Effective Stress Chamber

click on image to play movie

DSC Direct Shear Chamber



DSC Direct Shear Chamber

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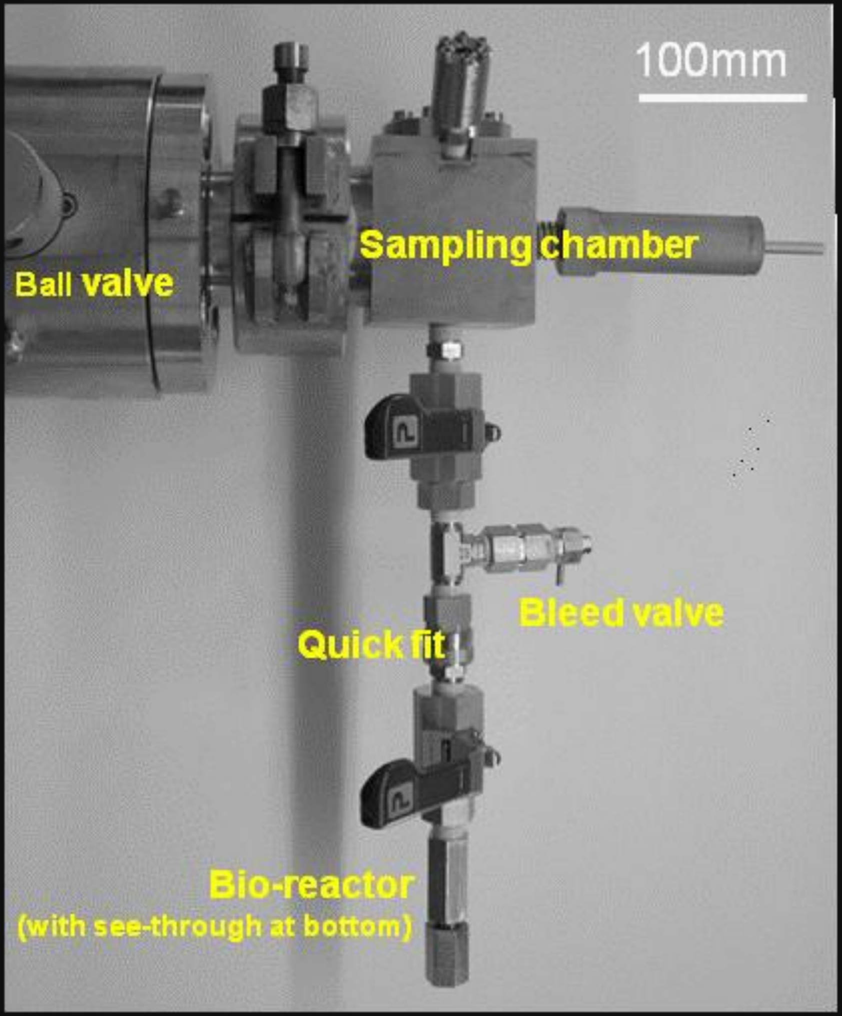
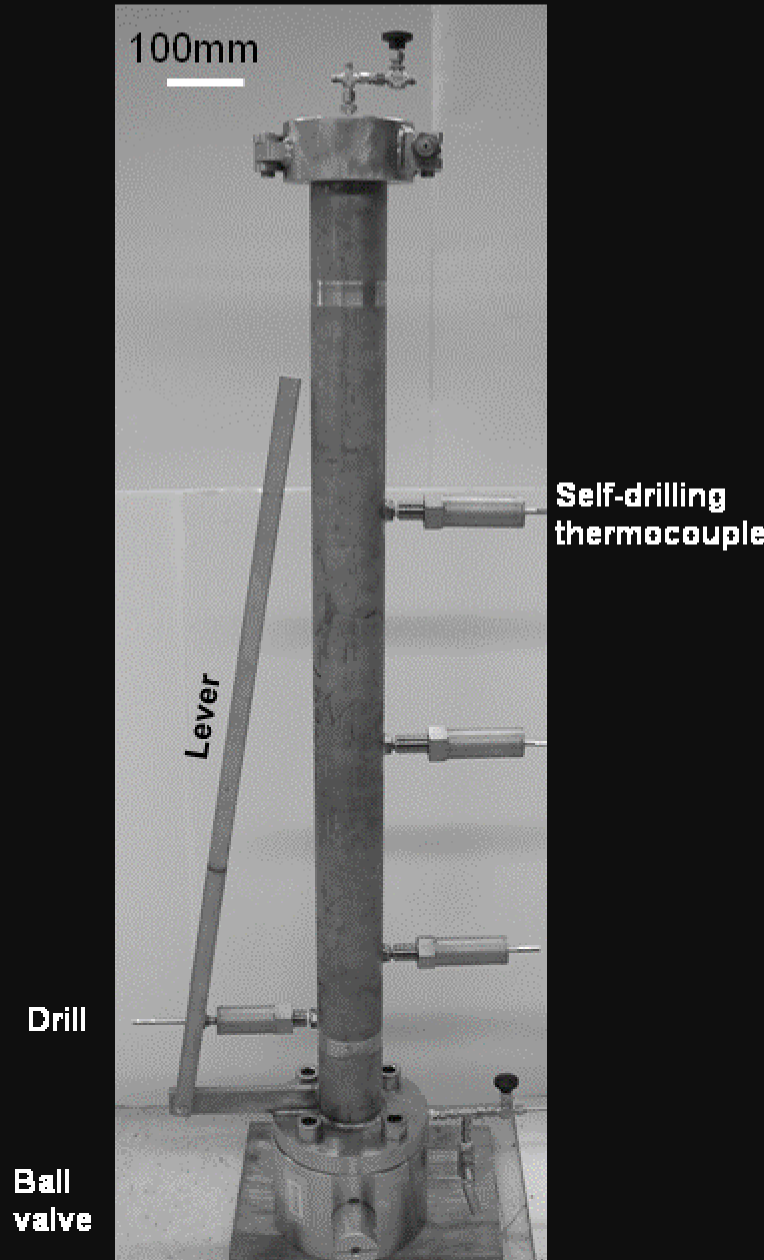
BIO Chamber

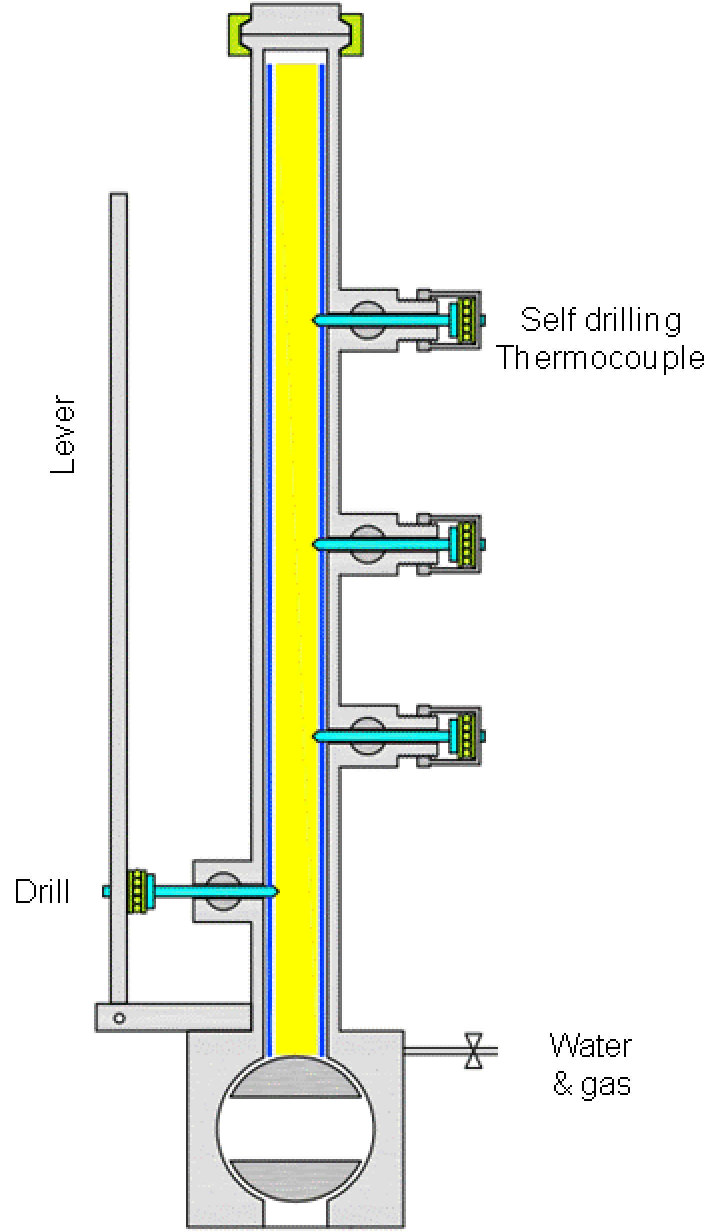

100mm
Sampling chamber
Ball valve
Bleed valve
Quick fit
Bio-reactor
(with see-through at bottom)

BIO Chamber

click on image to play movie

Controlled Depressurization Chamber





Controlled Depressurization Chamber

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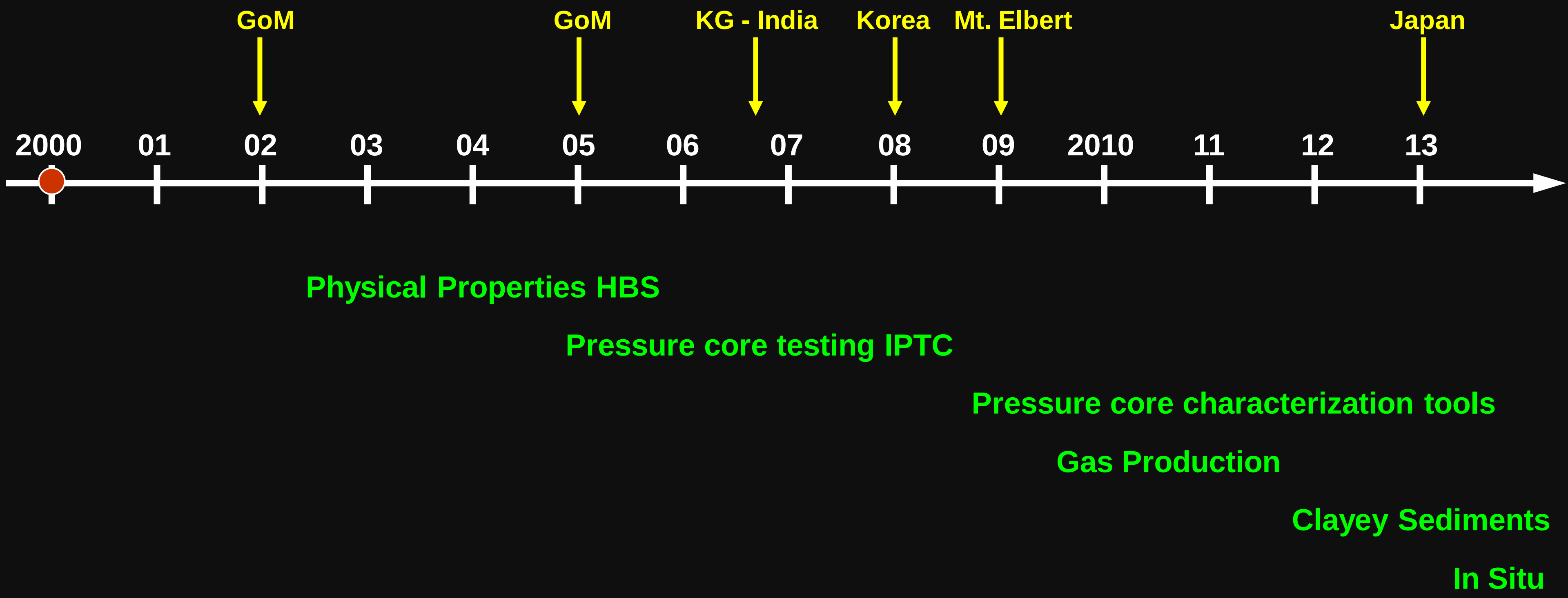
Study of Hydrate Bearing Sediments



Sediment Characterization - Strategy

Index properties

Reconstituted specimens at proper σ'

without hydrate

with hydrate

any core

Pressure cores within stability field

without σ' control

reloaded to in-situ σ'

production studies

pressure cores

In-situ tests

APPENDIX 3
PRESSURE CORE CHARACTERIZATION TOOLS –
PRE-DEPLOYMENT OPERATIONS MANUAL

Chapter 2
Infrastructure

Overview

This chapter of the operating manual outlines elements of a pressure-core analysis program that need to be handled prior to deploying the Pressure Core Characterization Tools (PCCT) in the field. The chapter is divided into five sections:

1. *Safety and Environmental Protection*: addresses local safety requirements that will determine high-level strategies for how the PCCT program will be set up and operated. A key factor that depends on local safety protocols is whether the measurement electronics can be collocated with the measurement devices.
2. *Science Planning*: addresses what the measurement and reporting expectations are, and what the scheduled time allotted for the program will be. Key factors: agreeing on the number, location and type of measurements and subsamples to be taken along each core, establishing access to depressurized material, and setting a schedule for how many days each core is expected to require for analysis.
3. *Infrastructure*: addresses components of the field program that are expected to be in place prior to the PCCT deployment, given the need to handle heavy objects, high-pressure flammable gasses, large fluid volumes in a temperature-controlled environment. Key factors: workspace dimensions and configurations, along with requirements for power, gas-handling, fluid-handling and heavy-lifting needs.
4. *Personnel*: addresses how many people are required in total by detailing how many people are needed for each element in the complete PPCT program. Key factor: 4 USGS, 5 Georgia Tech personnel were present in Japan.
5. *Shipping and Equipment Overview*: provides guidance for the safe and timely transport of the PCCT devices and support gear. Key factors: A shipping agent and extended lead-times for shipping were critical for timely, accurate transport. Also included in this section is a short list of unexpectedly helpful items that each device would benefit from having on hand.

Each section contains details that were important for the successful operations at AIST in Sapporo, Japan during January 2013, illustrated with photos taken by William Winters (USGS).

1. Safety and Environmental Protection

1.1. To reinforce that safety is paramount above all else, establish the rules for safe operations during the initial planning meetings.

- Abide by local and organizational safety protocols.
  - Establish whether pressurized cells and electronics must be separated.
  - Design a safe-venting system for methane released from intentionally dissociated gas hydrate.
  - Ensure general airflow is sufficient to handle methane released from accidental gas hydrate dissociation.
  - Establish a disposal plan for wastewater and sediment/water mixes.

- Establish working temperature so appropriate safety gear, including eye protection and clothing, can be procured.
- Establish working pressure.
  — Pressure vessels must have adequate safety ratings/inspections/ maintenance and be equipped with pressure relief devices.
  — Plumbing lines must have their blow-off valves properly set.

1.2. Onsite operational safety and core integrity:

- Reinforce that anyone has authority to stop the work at any time for safety reasons.
- Scheduling: establish science plan that balances completion goals with allotted time.
  — Do not push beyond normal endurance limits (late night operations). This can be especially tempting during first and last operational days.
  — If working in shifts, hand off at clear breaks in the analyses, not according to the clock.
  — Do not rush; core processing speed will increase with proficiency.
- Safety-related procedures and equipment design
  — Have wall mounted safety/procedural charts (Fig. 2.1) and get oral confirmation from all workers in the area prior to opening/closing valves, disconnecting pressure lines, or moving the core. These are the activities most likely to endanger the core integrity and oversight has proven critical. Do not leave chambers pressurized overnight without cause.
  — Have device-specific plans in case of accidental core depressurization or equipment failure.

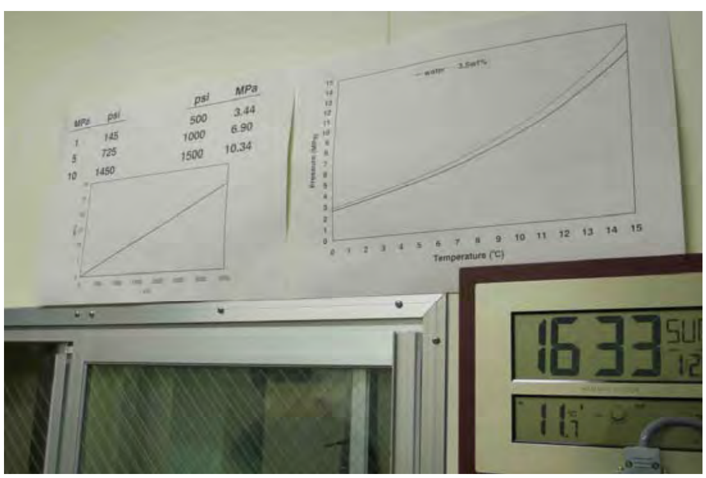


Figure 2.1. Wall charts of pressure conversion factors and gas hydrate stability (AIST, Sapporo, Japan). Synchronized digital clocks, one facing the electronics room and one facing the cold room, are used for note recording.

2. Science Planning

2.1. Core test plan: Agree on individual core test plan prior to arrival on site. Final adjustments to the plan must be completed prior to loading a pressure core into the manipulator.

- Establish overall goals, emphasis, and focus of the test program.
  - Establish pressure and temperature requirements for pressure-core testing in relation to in situ conditions and gas-hydrate stability.
- Use PCATS X-radiographs to map sections designated for PCCT testing.
  - Cores that have been stored vertically may be slightly different than shown in X-radiographs (voids may be filled…).
  - Establish cut locations with suitable sample sizes for PCCT cells. Verify subsample locations with device operators and science leads.
    - Effective Stress Cell (ESC): 7 cm
    - Direct Shear Cell (DSC): 17 cm
    - Biology Cell (BIO): 17 cm
    - IPTC:
      - Up to the Storage Chamber length (~120 cm) when connected to a Manipulator and Extension/Storage Chamber.
      - Up to the length of the chamber (~65 cm) when isolated for a production test.
  - Establish IPTC hole locations with the following rules:
    - No holes in ESC specimen.
    - No resistivity or cone strength IPTC measurements in the shear band zones of the DSC. Spreadsheet is useful for inputting DSC dimensions and calculating no-penetration zones. P and S-wave measurements (typically within the first and last 4.5 cm of the specimen) are possible with consent from the DSC operator.
    - Maintain 13.59 cm spacing between IPTC holes. Half spacing can be utilized if time permits.
    - Print "cut sheets" for each core to use for verifying subsample sizes, subsample acquisition order (needed for verifying device readiness and scheduling) prior to loading a core into the manipulator.
- Establish the core location in the storage chamber (were spacers used?)
  - Geotek spacers (Fig. 2.2) used during initial storage of the Nankai Trough cores tested at the AIST facility, Sapporo, Japan were very effective and provided an almost constant free-edge location of the core for all tested cores.

Figure 2.2. Black spacers (center of photograph) used in Nankai Trough pressure cores to uniformly position the free core end, thereby facilitating liner grabbing.

- Plan on conducting a post-mortem of the depressurized core with examination/documentation of the IPTC probe holes, if possible.
- Establish a post-cruise protocol for geotechnical/sedimentological testing of core subsections to provide base line data for interpreting the measurements made at pressure.

2.2. Schedule: Assume 3 days per core for full analysis.

- Day 1: Core loading
  - IPTC analysis
  - Day's end review and verification of PCCTs schedule based on IPTC program.
- Day 2: PCCT processing
  - Core cutting
  - PCCT operation
  - Production monitoring/PCCT dissociation
- Day 3: Recovery and preparation
  - Device clean-up, parts replacement
  - Initial data review
  - Lessons learned discussion
  - Confirmation of scientific program for upcoming core.

2.3. Reporting in the field

- Photographs
  - Generate a signature list for people consenting to be photographed.
  - Helpful to have a central repository for submitting select photographs, with permission. Photos need to be in folders identified by photographer so citations at a later time will be possible.
- Hand-written notes
  - Individuals should have small notebooks/pen for real-time notes.
  - Each station should have a clipboard/pen for real-time notes.
- External updates – to contain at least what was agreed upon prior to departing for the field.
  - Daily update containing safety summary and tools used.

- Core updates once a core is fully processed that identifies the data streams acquired.
- Project update compiling core updates, all lessons learned (compilation of individual notebook entries and group discussions), and the post-fieldwork analysis plan.

3. Infrastructure

3.1. Location

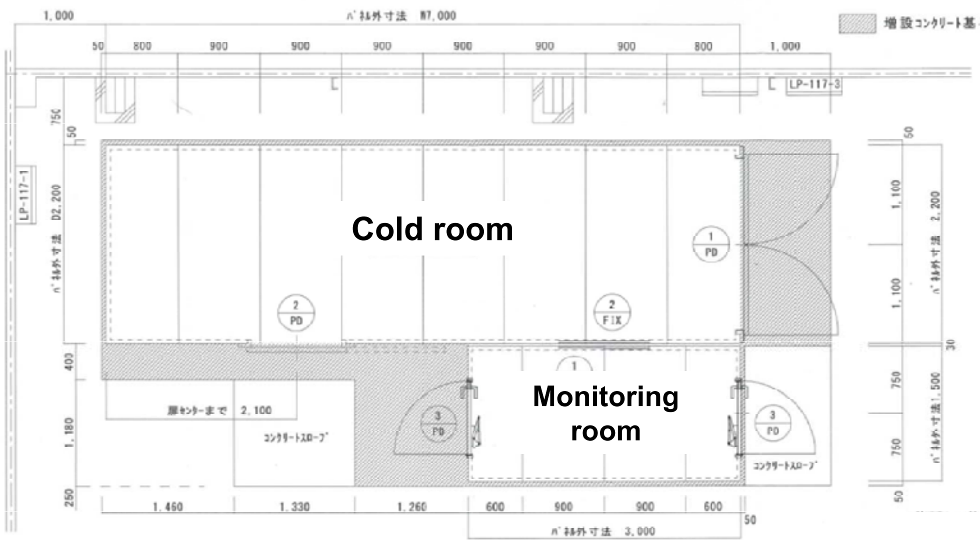
- Land-based laboratory setting in Sapporo, Japan worked very well. Shipboard operations reduce availability of space/facilities and increase electrical noise/power issues.
- Long-term core storage facility must be close to the refrigerated test location and needs syringe-pump pressure maintenance for the stored cores between the time of their initial storage and their testing.
- Testing facility should not have set closing times because some measurements are long-duration. Closing times increase safety concerns due to a rush to finish tasks.
- Lunch and dinner catering/boxed meals/delivery would be helpful. With many different tests running concurrently, people have breaks at different times, and will often need to be recalled to duty quickly.
- Housing should either be within walking distance, or easily reached by cab/transit at any hour of the day or night. Given the long hours, if some subset of the research group has a break, they should be able to reach their resting spot rapidly. Commuting time is wasted time.

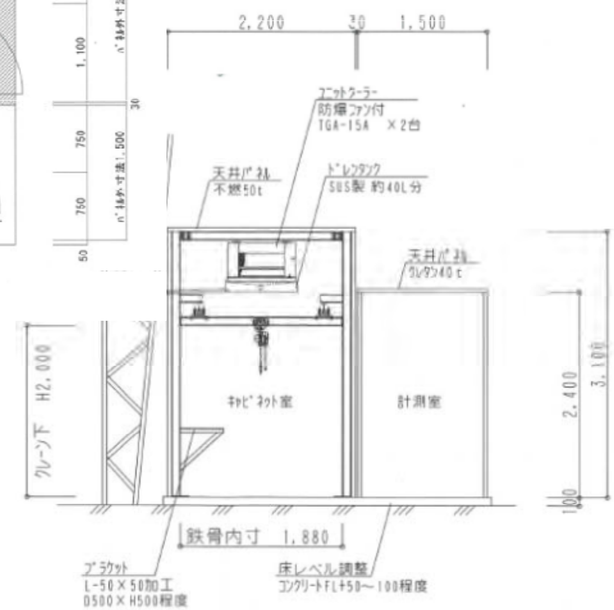
3.2. Refrigerated work area

- Dimensions
  - Cold room of 7 m x 2.2 m (22.9 x 7.2 ft) was sufficient for the manipulator and IPTC. The DSC chamber was also used in the room with little difficulty at AIST, Sapporo, Japan (Fig. 2.3-2.5). The length was tolerable, but doubling the width would allow the ESC and Bio chambers to be operated in the same space, along with all of the electronics. Alternative could be a 12.8-13.7 m (42-45 ft) refrigerated van or space. Height should allow for a crane system with a 2.5 m (8 ft) chain fall. Having all PCCT chambers set to operate in a single space is very important for limiting sensitive chamber transport and making more efficient use of tools and supplies. Environmental displays set according to local requirements. O_2 and CH_4 were continually monitored and displayed for the AIST, Sapporo cold room (Fig. 2.6).
  - Electronics space, if separated from the cold room (see below)

A

Equipment container





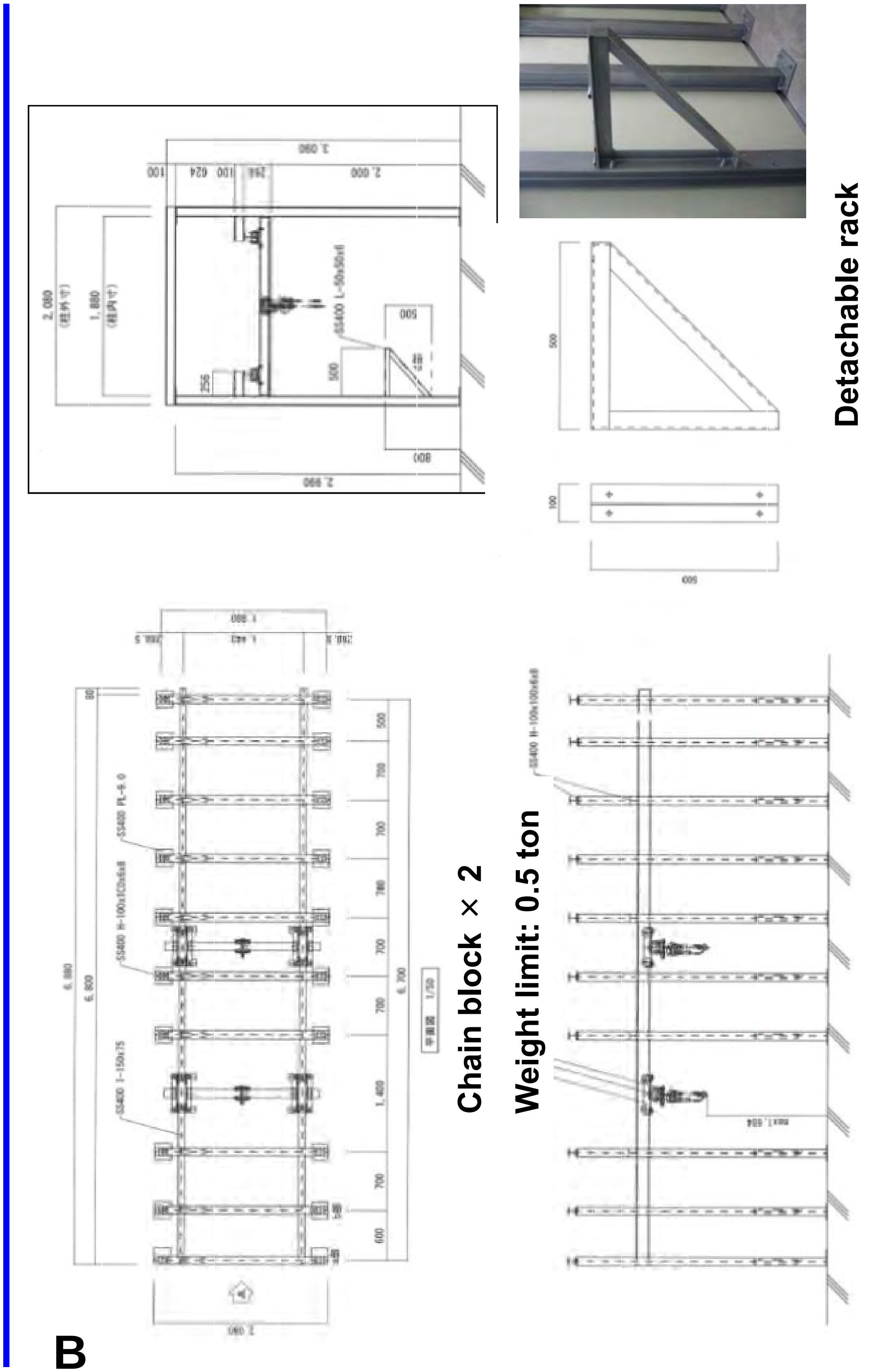
□Status: Completion

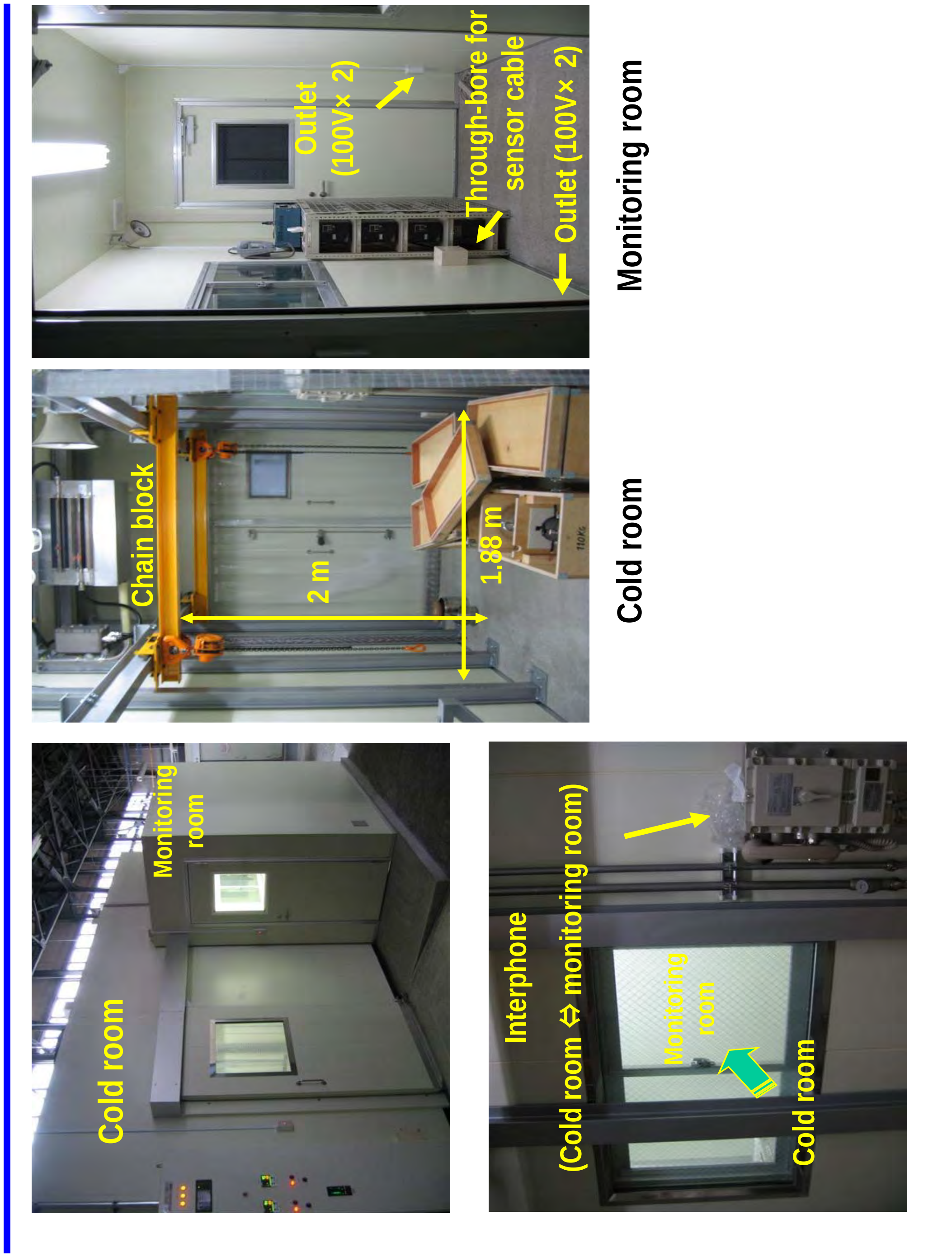
□Specs:

✓Explosion protection (certified High Pressure Gas Safety Law)

✓Temperature control: +5 – +15 ℃ (±1 ℃)

✓Electricity available in monitoring room (100 V × 4)


Detachable rack
Chain block × 2
Weight limit: 0.5 ton
B



C

Figure 2.3A-C. Schematics and photographs of the refrigerated test facility in Sapporo, Japan that was designed by JOGMEC and AIST (figure supplied by AIST/JOGMEC).

Figure 2.4. Front view of the refrigerated van used at AIST, Sapporo, Japan showing environmental conditions monitoring panel (left), sliding door (center), and the attached electronics area (right).

Figure 2.5. Side view of the refrigerated van used at AIST, Sapporo, Japan showing the door to the electronics room (left) and the double doors leading into the refrigerated work area (right).

Figure 2.6. Part of the environmental conditions monitoring panel showing O_2 (left) and CH_4 (right) levels in the refrigerated work area.

- Configuration
  - One of the short walls should have double doors with hanging clear-plastic strips (Fig. 2.7) to allow core-storage chambers to be brought in.

Figure 2.7. Refrigerated work area at AIST, Sapporo, Japan showing moveable plastic curtains used for reducing temperature fluctuations when outer doors are opened.

  - Configure remaining space in a horse-shoe arrangement with open central area for walking and moving gear, manipulator string along one long wall, PCCT devices along the opposite long wall, cold saltwater reservoir along the remaining short wall (Figs. 2.8-2.9).

Figure 2.8. Refrigerated work area at AIST, Sapporo, Japan showing (left to right): window looking into the electronics area, custom cart for transporting pressure cores, yellow double overhead hoist system, manipulator string, Direct Shear Cell (far end of van), orange seawater tank, AIST IPTC, and wall-bracket supports.

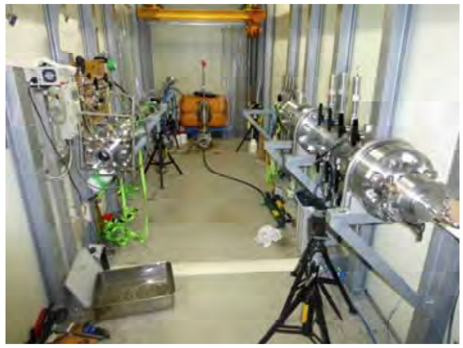


Figure 2.9. Layout in the refrigerated work space at AIST, Sapporo, Japan showing (left to right): intrinsically-safe phone used to communicate with the electronics area, manipulator string (note the wall support brackets), Direct Shear Cell (far end of van), orange seawater tank, yellow double overhead hoist system, US IPTC, and AIST IPTC.

- Separating the devices from the electronics reduces crowding for the manipulator and IPTC and protects sensitive gear from spray from leaks or decoupled devices, but communications between the electronics and device operation areas must be unfettered.
- Option 1: Electronics *in* the operational cold room
  - Manipulator string and IPTC could be separated from the electronics and manipulator controls by a 1.2 m (4 ft) protective partition rather than a full wall.
  - PCCT workstations would have their electronics along the wall, to the side of each device. Table with 1 m x .5 m (3.25 x 1.75 ft) top surface and lower shelf for each station will suffice for the electronics.
- Option 2: Electronics *outside* the operational cold room (Fig. 2.10)
  - Electronics room should be a minimum 2 x 6 m (6.5 x 20 ft) space to accommodate all PCCT systems, but preferably the electronics space would run the complete length of the cold room, with glass between the electronics and the cold room.
  - Open communication is essential.
    - Wireless headsets/microphones (preferred)
    - Hands-free, built-in microphones and speakers (workable)
    - Direct-line phone (minimum requirement) would need 3 total for the IPTC, Manipulator and active PCCT device.

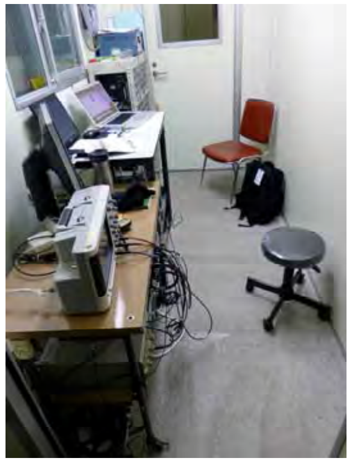


Figure 2.10. Electronics area at AIST, Sapporo, Japan. Note the window and telephone (upper left corner) allowing visual and voice communication with the refrigerated work area.

- Electrical Requirements
  - The manipulator stepper motor requires 120 V, though either 50 or 60 Hz AC power is fine. If 120 V not available, USGS has a 100 V to 120 V transformer available that was able to run the Manipulator in Sapporo.
  - Manipulator eye port requires a high-intensity battery-driven light source (50-60 Hz, 100-120 V AC).
  - Whether the electronics are in or out of the operational cold room, power should be distributed, with wall-mounted power outlets, two per station (6 stations). Preferably 120 V, 60 Hz.
  - Uninterruptible Power Supplies (UPS), one per station (500 watts)
- Temperature Requirements: Working temperature of 5 °C (41 °F) was adequate. Temperature fluctuation <±1°C preferred.
- Device Manipulation Requirements
  - Ramp access between permanent storage room and testing facility.
  - Fitted carts for pressure vessel transport. These may need to be customized for each site depending on core storage device (Fig. 2.11).

Figure 2.11. Transporting a pressure core using a custom-rolling cart.

— Independent overhead cranes with a 2.5 m (8 ft.) chain fall significantly improve device manipulation and alignment (Figs. 2.12-2.13).

Figure 2.12. Yellow double overhead hoist system (upper left) being used to support a PCCT device in the cold room at AIST, Sapporo, Japan. The window separating the cold room from the electronics room (center) and the intrinsically safe telephone used to communicate with the electronics room (right) are also shown in the photograph.

Figure 2.13. Close up view of the overhead hoist system used in the cold room.

— Wall-mounted brackets (Fig. 2.14) and rubber shims/step blocks worked very well for supporting the manipulator string. 1 m (39.5 in) centers, on the bracket spacing was acceptable. 1 m (39.5 in) height to the bracket top was acceptable.

Figure 2.14. Wall brackets support the US IPTC (left) and the AIST IPTC (right).

- Fluid Handling Requirements
  — 200 L plastic container (or two 100 L containers) (Fig. 2.15) is needed as a saltwater reservoir held at cold-room temperatures for filling devices and storage vessels.

Figure 2.15. Siphoning water into the orange seawater container in the cold room.

- These may be cheaper to purchase than ship.
- Salt needed to match testing salinity (Fig. 2.16).

Figure 2.16. Container of sea salts used to create seawater at AIST, Sapporo, Japan.

- Water should be stored in the cold room for a day or two prior to testing to reach test temperature, or could be wheeled into the test area from having been cooled in the long-term core storage area.

- Floor drains, sediment traps, and running water for cleaning and draining the devices.
- Compressed air for driving the high-pressure Rice pump (or substitute portable air compressor): High capacity, 20 gallon minimum, 9-11 cfm flow, 120 psi. (Rice high-pressure pump requires 60-100 psi).

- Gas Handling Requirements: Gas vent line for releasing flammable gasses without passing the gas through a non-explosion-proof vent fan.

3.3. Non-refrigerated work area

- Dimensions: 4 m x 6 m (minimum).
- Adjacent to refrigerated work space.
- Adequate lighting is required.
- Electrical Requirements: 100-120 V, 50-60 Hz AC Power for electronics/soldering.
- Running water/sink with sediment trap capacity for water/sediment disposal.
  - Industrial mop and bucket on casters (purchased on site)
- Chairs and two workbenches or desks for electrical and device maintenance.
- Toolbox and IPTC gun box storage and access area.

3.4. Meeting/break room for discussion and respite from the cold.

- Whiteboards
- Tables
- Chairs
- Meeting room should be secure for leaving clothing-type gear overnight.

3.5. Lavatories: need to be proximal, preferably without requiring special gear to access (e.g., North Slope)

4. Personnel

4.1. PCCT Personnel: Minimum complement: 4 USGS, 5 GaTech.

- Pressure core storage chamber movement (3). These are bulky enough to require one person to push the cart, and two to guide/stabilize/handle the strapping (Fig. 2.17).

Figure 2.17. Moving a pressure-core chamber.

- Manipulator (1 GaTech, 2 GaTech/USGS) (Figs. 2.18-2.19)
  - Controller (1)
  - Position verification (2: tape measure operator; spreadsheet operator)
  - During operation, a position verifier can monitor whether the motor is moving and verify motor revolution count during precision operations.

Figure 2.18. Manipulator string in the cold room at AIST, Sapporo, Japan with the Direct Shear Cell attached on the near end and the stepper motor that controls core movement located at the far end. William Waite (USGS) views the operation from the electronics room through a window (upper left).

Figure 2.19. Measuring the manipulator string prior to moving a pressure core into the AIST IPTC (foreground).

- Cutter (1 GaTech, 2 GaTech/USGS/Other) (Fig. 2.20)
  - Controller (1): Needs to be someone with a feel for the correct behavior of the cutter blade, proper tension and loading, proper activator-arm and core-grabber tightening.
  - Saw (3): Cutting worked well with a rotation between the person moving the saw, the person applying a load to the blade and someone resting/marking the progress. One of these three can be the controller.

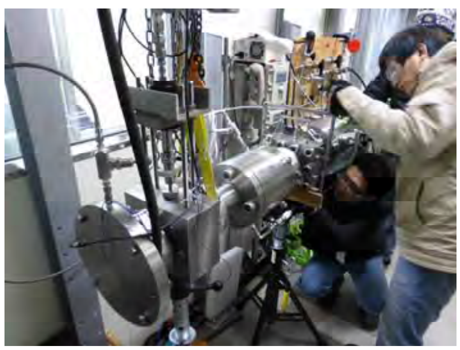


Figure 2.20. Cutting a core section prior to transferring it into the Direct Shear Cell (DSC) (left).

- IPTC (4 USGS, 1 GaTech) (Figs. 2.21-2.22)
  - Device operator (2: mechanical controller; electrical controller)
  - Movers/plumbing/repairs (2)
  - Manipulator operator (1)
  - During operation, the movers and manipulator operator will also act as second hands/brains for the mechanical and electrical controllers.

Figure 2.21. Complete manipulator string containing an extension chamber, the US IPTC, and manipulator (left to right) viewed by personnel in the electronics room.

Figure 2.22. Opening a ball valve, prior to transferring a pressure core section into the US IPTC (foreground).

- Effective Stress (2 GaTech + 2 movers/plumbers) (Fig. 2.23)
  - Manipulating the device requires 2 movers and 1 device controller.
  - Operating the device requires 2 operators for pressure management.

Figure 2.23. Working with the Effective Stress Cell.

- Direct Shear (2 GaTech + 2 movers/plumbers) (Fig. 2.24)
  - Manipulating the device requires 2 movers and 1 device controller.
  - Operating the device requires 2 operators for pressure management.

Figure 2.24. Operating the Direct Shear Cell in the main cold room.

- Bio (2 GaTech + 2 movers/plumbers) (Fig. 2.25)
  - Manipulating the device requires 2 movers and 1 device controller.
  - Operating the device requires 1 operator + 1 additional present for safety (Bio is the only chamber pressurized with gas).

Figure 2.25. Operating the Bio sampler system.

5. Shipping and Equipment Overview

5.1. Use of a facilitator is highly recommended on international projects.
5.2. Balance cost with time needed for delivery.
5.3. Allow time for customs inspection, if needed.
5.4. Provide adequate time on government shipments to obtain three bids.
- Weights and sizes of pallets/containers are needed to procure bids.
- Pallets must be non-wooden for international travel.

5.5. Manifest must be externally approved prior to shipper pick up; allow extra time for this.
5.6. Manifest for Sapporo is listed separately. In addition, the following items should be considered for the warm-room electronics and device maintenance work area:
- Soldering station and supplies.
- Corded and battery drills and bits.
- Wooden V-blocks or similar for supporting pressure chambers and PCCT test devices during cleaning and maintenance.
- Selection of Swagelok fittings and piping, including English-to-Metric conversions.

5.7. The following warm room station supplies can also be copied for the cold room, with one table/shelf station per PCCT device, including the Manipulator.
- Pegboard for hanging tools
- Power strip (preferably 2)
- Vacuum grease
- Paper towels
- Q-tips and other dedicated swabbers to clean the IPTC and various other chambers.
- 4 C-clamps and straps for securing device (8 for manipulator string).
- Hangable wrench set, including small and large adjustable wrench.
- Hex wrench sets (metric and US), including M24 wrench.
- Vice grips
- Screw Driver (flathead)
- Tape (Teflon or sticky)
- Clipboard/pen/sharpie for notes
- Scissors
- Sedimentologic items (loupe…)
- Drip pans (various sizes)
- Leatherman pliers
- Hand-pump pressure washer to clean equipment.
- 5-gallon buckets (with liners) for use as waste baskets.
- Flashlight
- Thumb drive for data backup
- Wall-mounted charts for hydrate stability and MPa/psi conversion.

APPENDIX 4
SUMMARY OF FIELD TESTING OF PCCT AND IPTC

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

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 a 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 before 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 plans. 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.

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

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.
2. Purchase two double-acting high-pressure ISCO syringe pumps for IPTC to replace Rice high-pressure pump.

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.

APPENDIX 2
PRESSURE CORE CHARACTERIZATION TOOLS – ASSEMBLY AND OPERATIONS MANUAL

Pressure Core Characterization Tools

Assembly and Operation Manuals

Team: J. Carlos Santamarina (PI)
Sheng Dai
Junbong Jang
Marco Terzariol

Georgia Institute of Technology
Atlanta, Georgia

January 2014

Contents

Note: * E. Papadopoulos helped with electronics (MAN and all other tools)

**The IPTC chamber has been retrofitted by USGS collaborators W. Winters, D. Mason, W. Waite, and E. Bergeron who also designed and built the pressure control panels.

Key references:

Santamarina, J. C., Dai, S., Jang, J., and Terzariol, M. (2012). "Pressure Core Characterization Tools for Hydrate-Bearing Sediments." Scientific Drilling, Vol. 14, pp. 44-48. http://pmrl.ce.gatech.edu/papers/Santamarina_2012a.pdf

Yun, T., Narsilio, G. A., Santamarina, J. C., and Ruppel, C. (2006). "Instrumented Pressure Testing Chamber for Characterizing Sediment Cores Recovered at In Situ Hydrostatic Pressure." Marine Geology, Vol. 229, pp. 285-293. http://pmrl.ce.gatech.edu/papers/Yun_2006e.pdf

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Manipulator MAN

Introduction - Purpose

	Slide #
Purpose • Move specimen with mm-precision under in situ *P-T* conditions.	
General description • Major chambers: storage chamber + screw chamber. • The screw system inside of the screw chamber includes: 2.656m-long 3/4" acme screw, C-tube, C-key, and grabber. • The screw system is controlled by the step motor.	AS-MAN 1

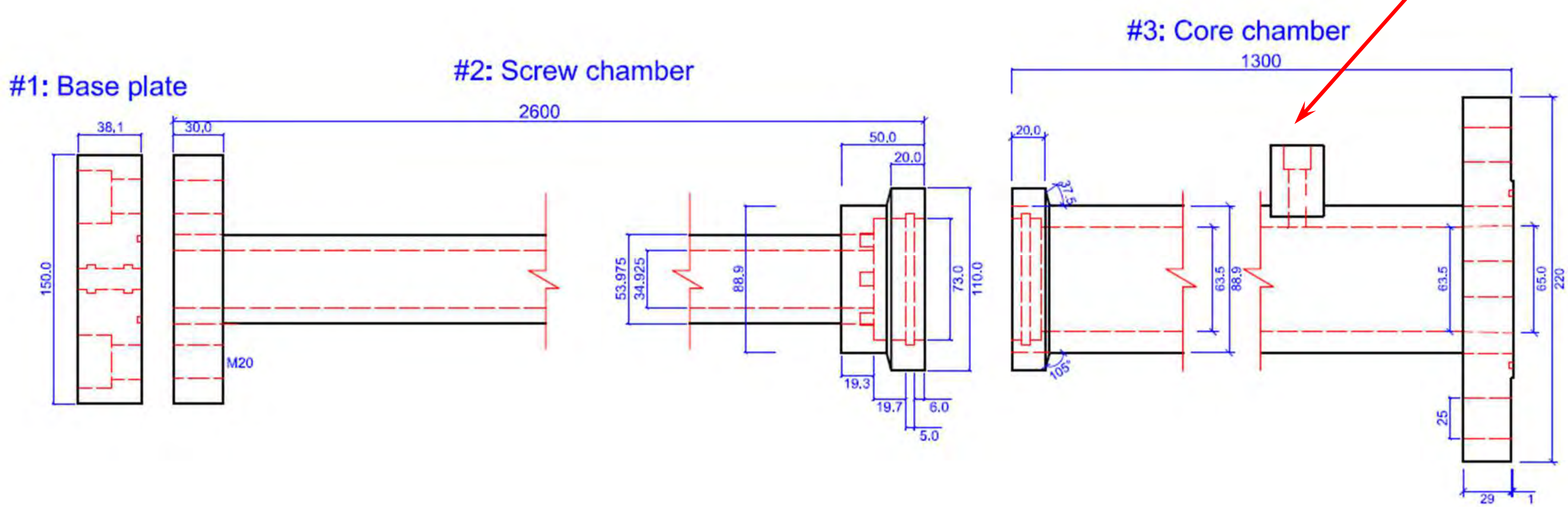
Assembly

	Slide #
Assembly of the screw system 1. Screw the C-tube onto the screw. 2. Let the screw shaft go through the base plate of the screw. chamber and use the C-key to fix the other end of the screw system onto the screw chamber. Caution: the screw does not directly sit on the base plate, but on a thrust bearing (1/2"-ID, 1-7/32 "-OD, 9/16"-thickness, McMaster 60715K11). 3. Lock the screw shaft outside of the base plate. 4. Install the grabber onto the C-tube using a shear pin.	AS-MAN 2
Sequential assembly 1. Install see-through windows on the storage chamber. 2. Connect the screw chamber and the storage chamber using quick connector. 3. Install the step motor on the extruded screw shaft. 4. Install flexible lens camera to monitor core movement through the see-through window during operation.	AS-MAN 3
Controller 1. Connect the stepper motor to the STAC5 controller through the screw terminal connector. 2. Connect the controller to the computer through the RJ45 connector. 3. Connect the controller to 110V 60Hz power outlet through the screw terminal connector.	AS-MAN 4
Software 1. Install ST configurator software to computer (www.applied-motion.com). 2. Install the Q programmer software (www.applied-motion.com). 3. Start the ST configurator software.	AS-MAN 5

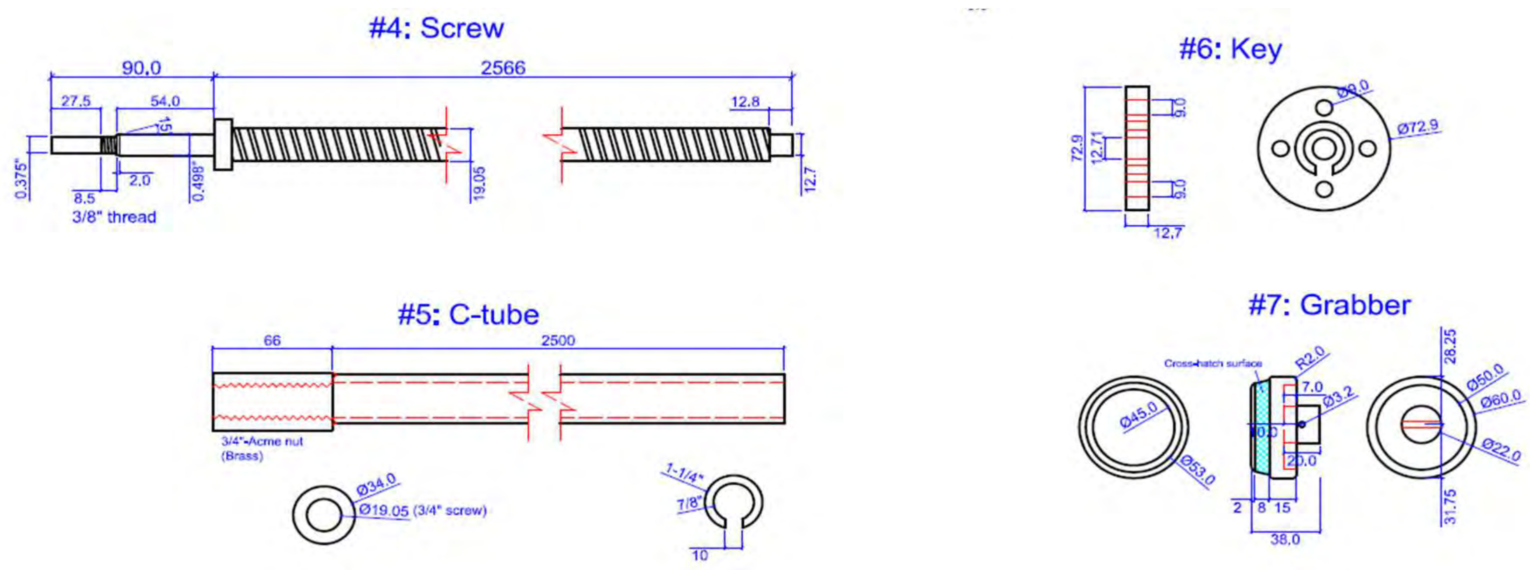
4. Configure the IP on the STAC5 software to match the IP on the controller (Default 10.10.10.10). The Controller's IP can be changed by using the rotary switch at the back of the device. 5. Upload the drivers for the controller on the software by choosing the right drivers from the list. 6. Choose from the list the stepper motor that will be used (default setup comes with HT34-497). Choose the Parallel setup for the stepper motor if connected to 110V outlet. 7. Choose Q programmer from the Motion tab on the ST configurator. 8. Open the Q programmer software and refer to the operating manual for command reference manual for the list of possible commands.	
Cautionary Measures 1. The controller will always input the correct amount of displacement but this is not the actual amount that the grabber displaces. There can be discrepancies between the top due to 3 reasons: • Slack • Insufficient torque • End of stroke 2. Make sure the grabber does not hit the end of the manipulator or core chamber, and does not move behind the screw chamber. The first may result in considerable damage to the chamber, while the second may prevent the grabber from moving forward.	

AS-MAN 1

See-through



AS-MAN 2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10
#6: Key
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12,71
9,0
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#7: Grabber
Cross-hatch surface
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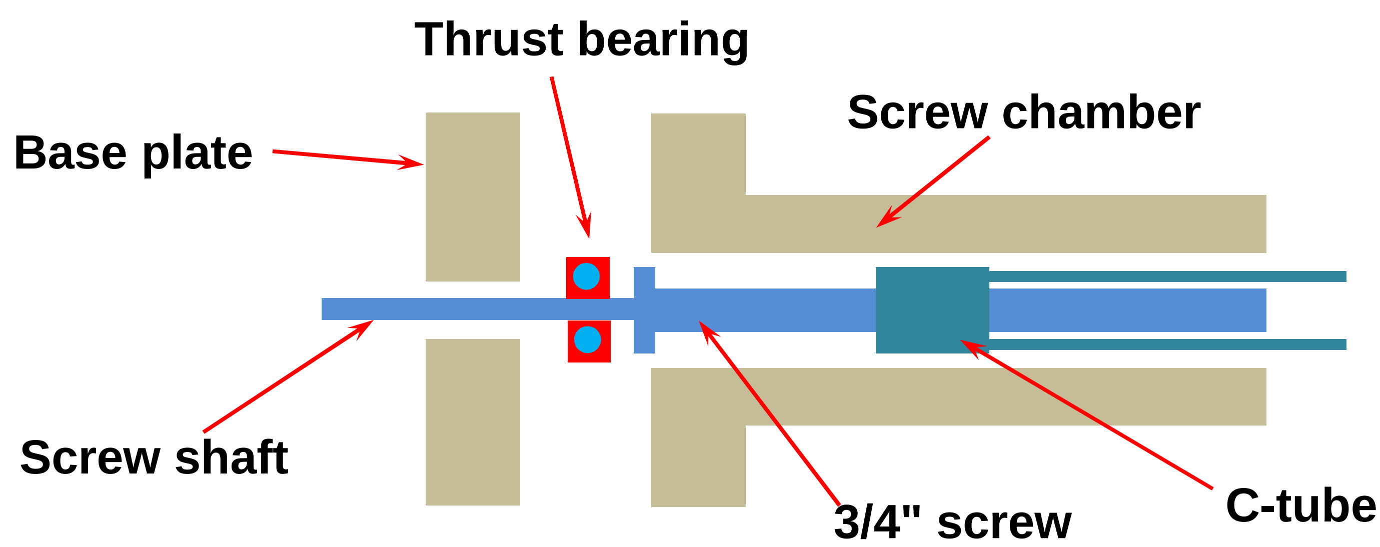
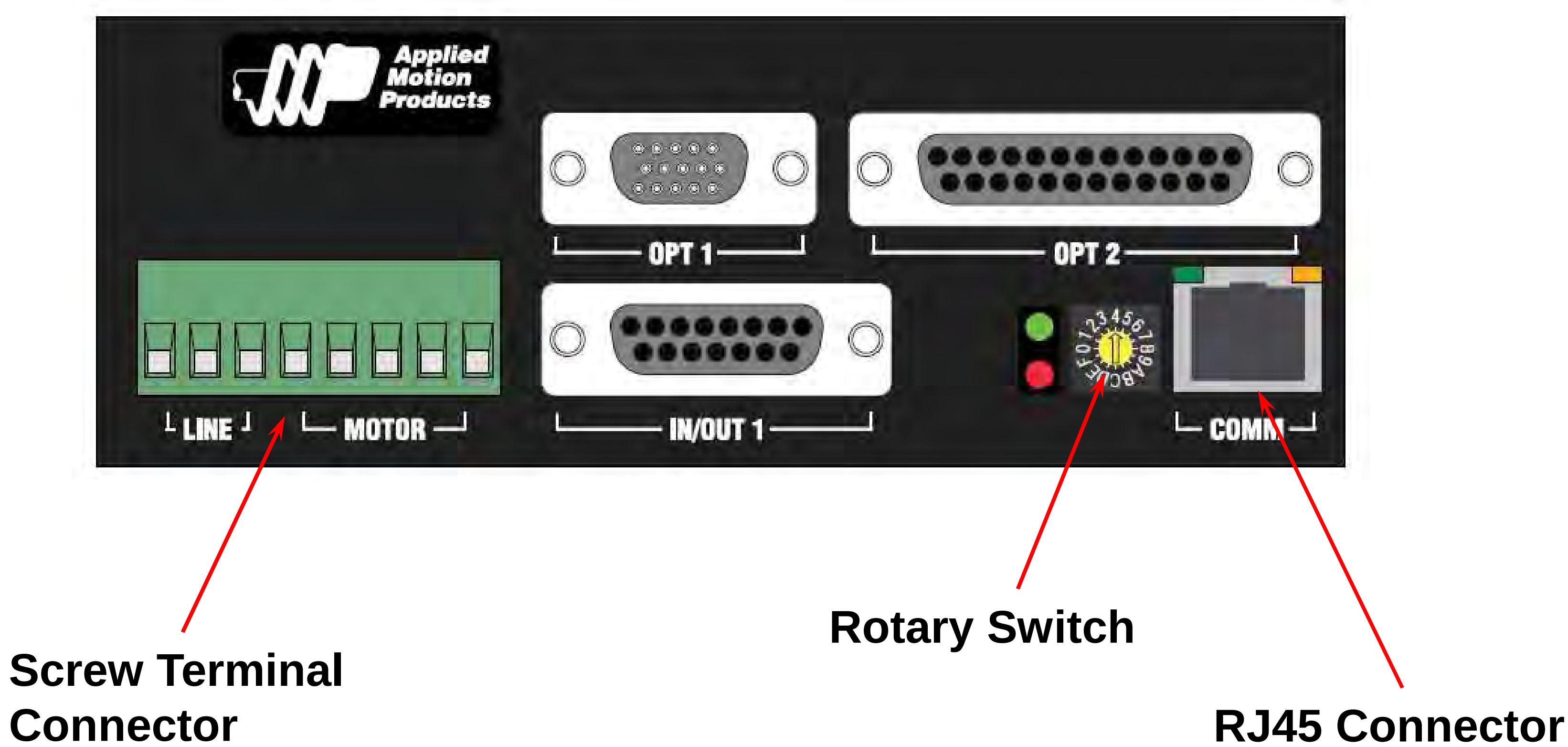

Thrust bearing
Base plate
Screw chamber
Screw shaft
3/4" screw
C-tube

AS-MAN 3

AS-MAN 4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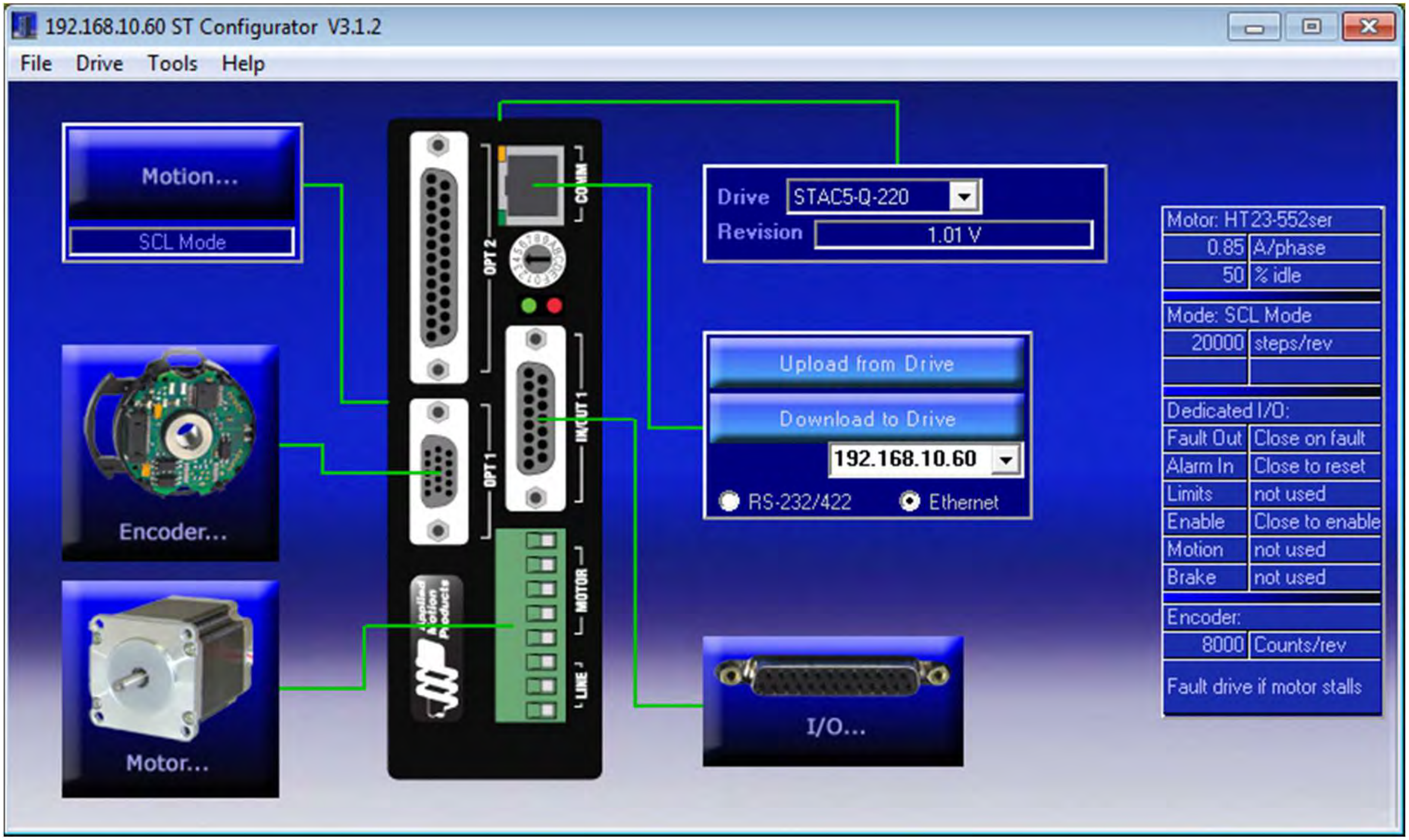
AS-MAN 5



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Revision
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RS-232/422
Ethernet
I/O...
Motor: HT23-552ser
0.85 A/phase
50 % idle
Mode: SCL Mode
20000 steps/rev
Dedicated I/O:
Fault Out Close on fault
Alarm In Close to reset
Limits not used
Enable Close to enable
Motion not used
Brake not used
Encoder:
8000 Counts/rev
Fault drive if motor stalls

Cutter: SAW

Introduction - Purpose

	Slide #
Purpose Sub-sample specimens with desired length under in situ *P-T* conditions	
General description • The SAW has 3 major parts: the chamber, the saw system, and the external frame. • The chamber has two pieces: one with a square cavity to house the saw system; and the other has a cylindrical cavity to house a pair of clamps. • The saw system includes a cutting saw blade, a saw frame, and 3 rods to manipulate the frame. • The external frame is designed to apply reciprocating movement of the saw system through the saw frame rods.	AS-SAW 1

Assembly

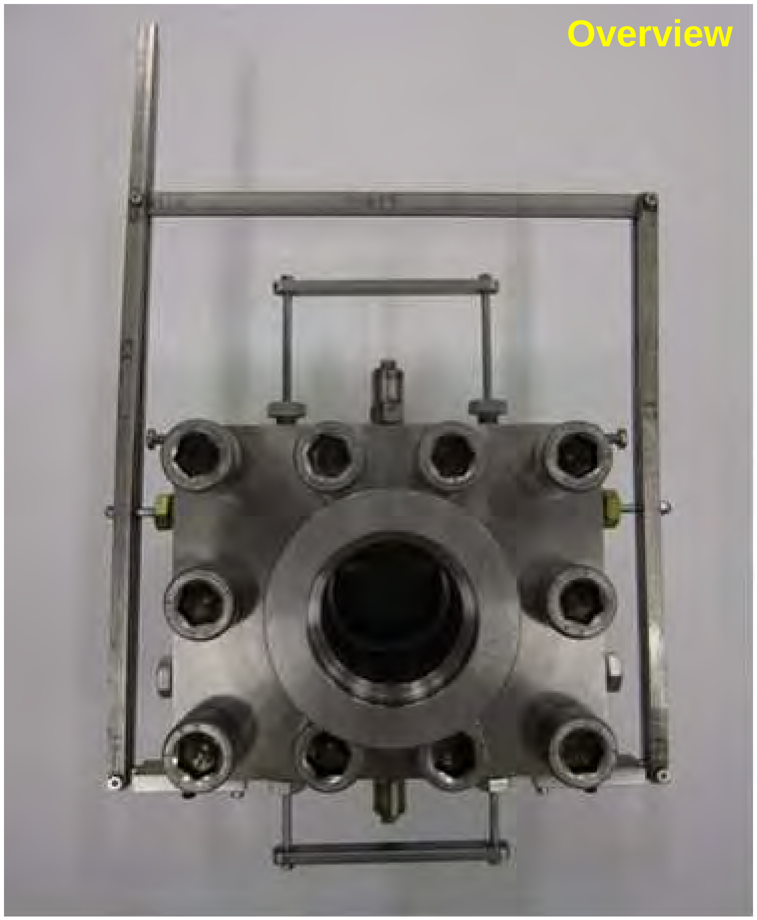
	Slide #
Assembly of the saw system 1. The saw frame has two pieces with different thicknesses, connected using M4 screws. Washers are used as spacers between both pieces to house the saw blade in between. 2. Place the saw frames together with the saw blade into the saw chamber; use a 1ft-long 3/16" stainless steel rod to go through the chamber and the frame; use two 1/16" shear pins to lock the frame onto the frame rod. 3. Install the two vertical key rods onto the saw chamber and also use 1/16" shear pins to lock the blade keys on them. 4. Adjust the position of the keys to lock the saw blade using nuts on the keys. Keep the two keys vertical and fix this position using external handles. Note – to replace the blade: 1. Unscrew the upper frame (thinner one); 2. Loose the two key rods and adjust the direction of the keys to let the saw blade out. 3. Replace with a new blade and follow step 4 above.	AS-SAW 2
Assembly of the external frame 1. After assembling the saw system in the saw chamber and the clamps in the clamp chamber, use ten M20 screws to tight the two chamber pieces. 2. The external frame contains: 2 pivots, 2 long vertical bars, 2 short vertical bars, and 1 horizontal bar.	AS-SAW 3

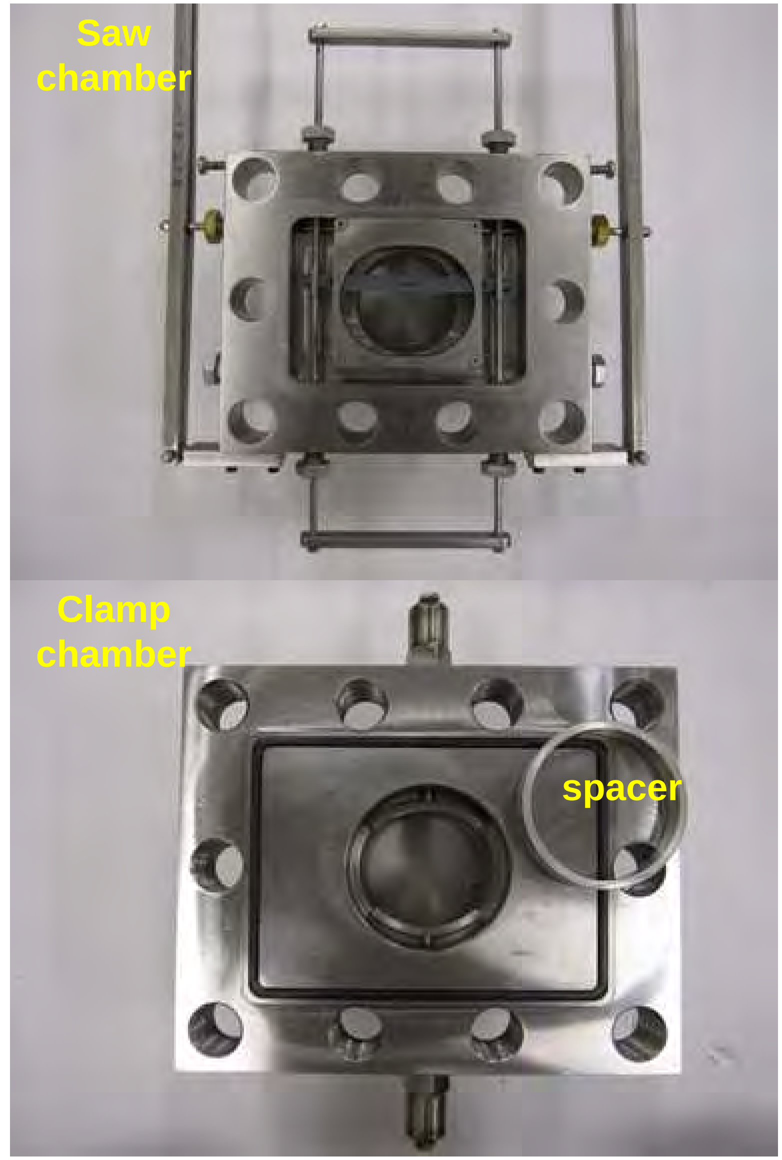
3. The external frame is designed to move the saw system by PULLING rather than PUSHING the saw frame rod. Note: 1. All bars are connected using M4 screws. 2. There is a spacer for the clamp chamber (AS-SAW 1) to allow MAN passing by smoothly.	

Operation

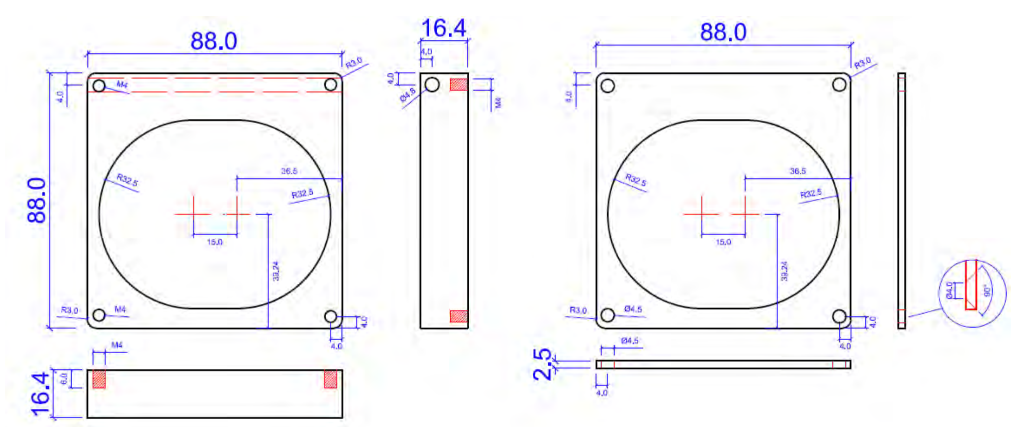
	Slide #
Cutting using the saw 2. Uplift the saw blade (through vertical saw frame rods) to the very top, in order to clear the space for core to pass through. 3. Once the specimen is positioned by the manipulator, clear the spacers. Use external frame to apply reciprocal cutting and while gradually lower the saw blade (through saw frame) downwards to saw the core.	OP-SAW 1

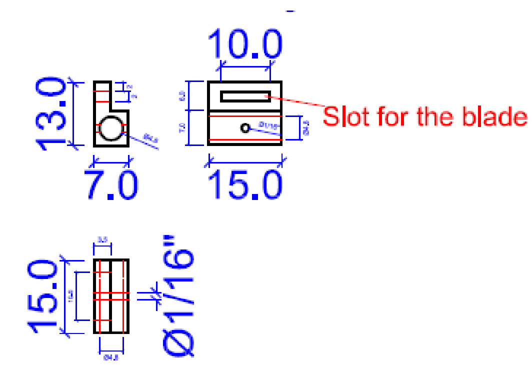
AS-SAW 1

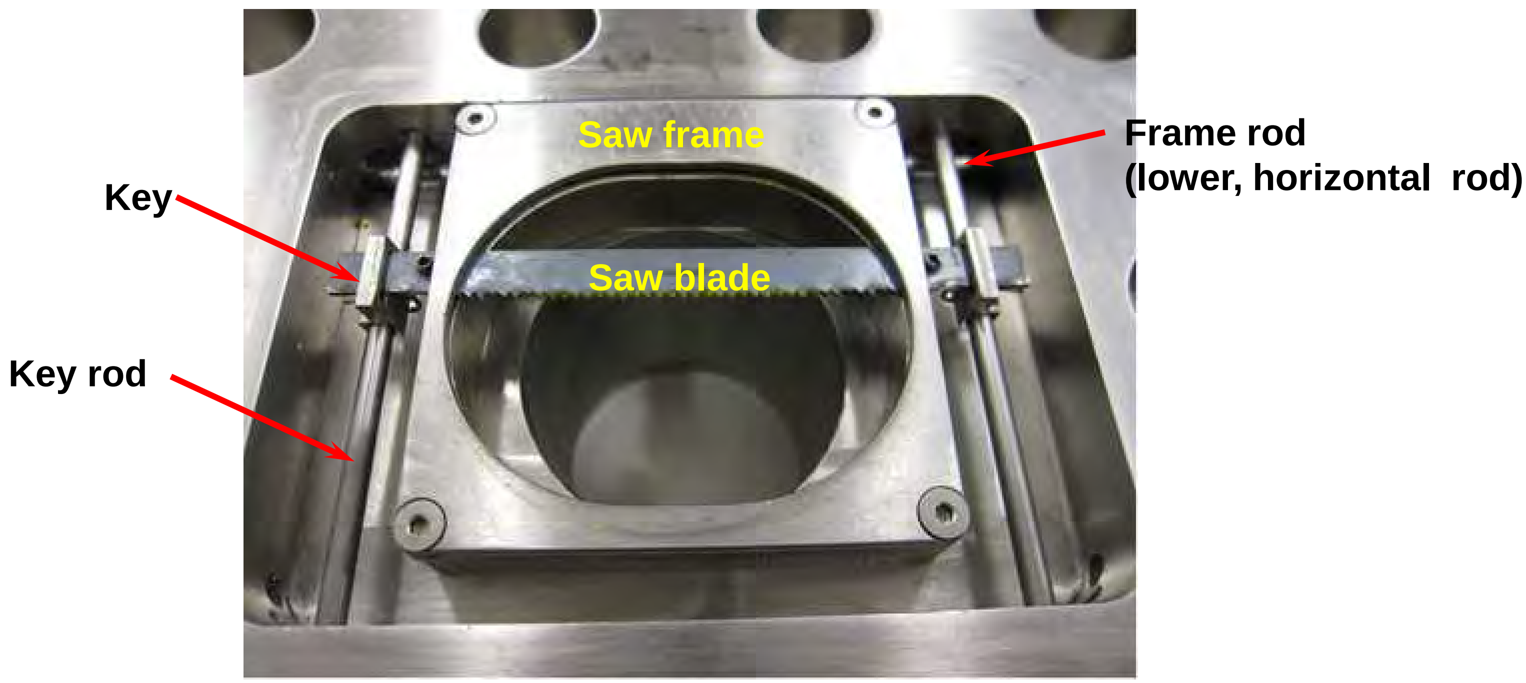




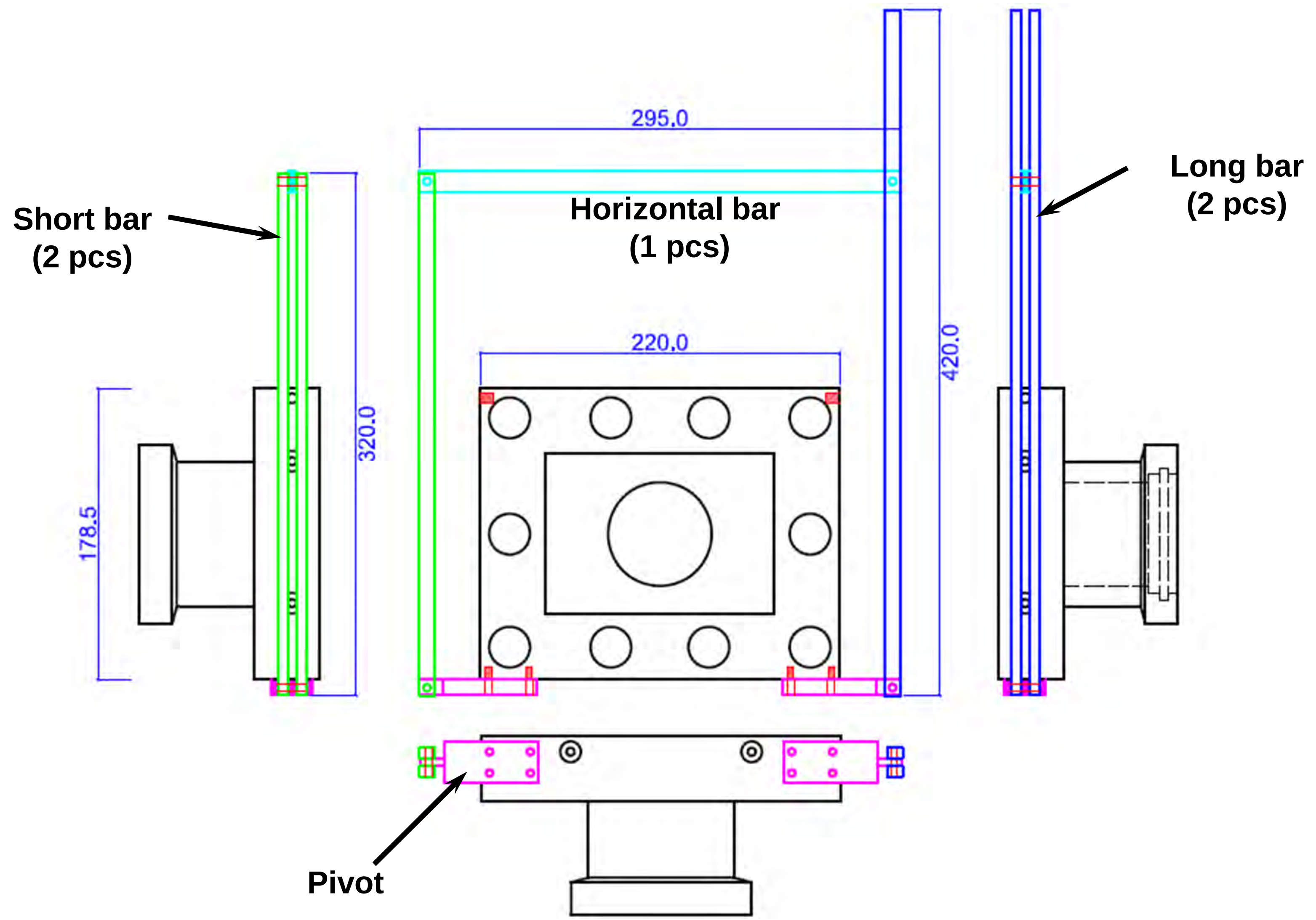
AS-SAW 2


88.0
16.4
88.0
16.4
88.0
2.5


10.0
13.0
7.0
15.0
Slot for the blade
15.0
Ø1/16"

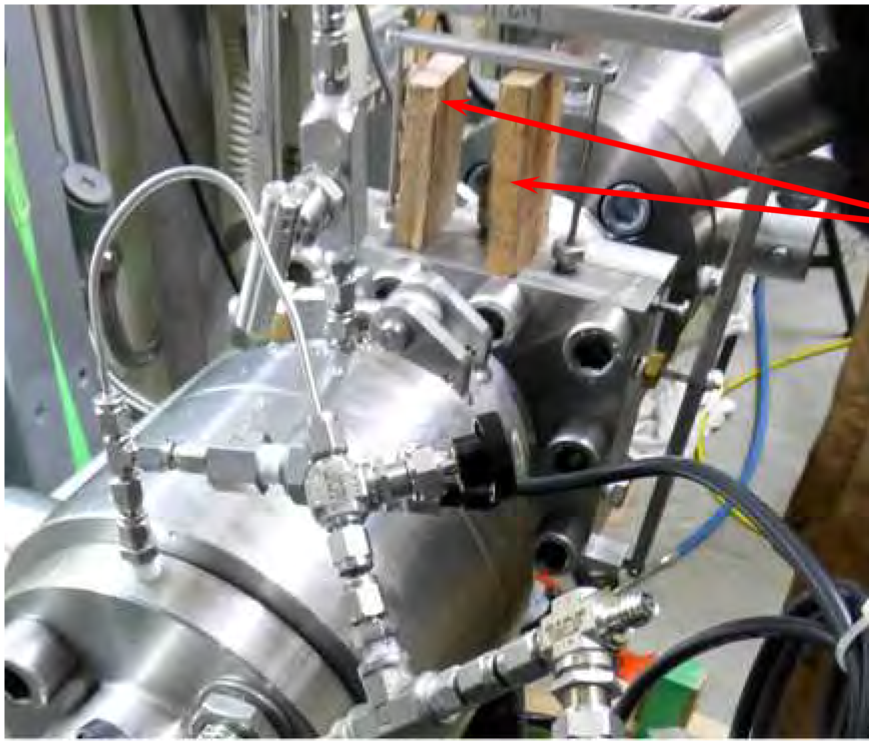

Saw frame
Saw blade
Key
Key rod
Frame rod
(lower, horizontal rod)

AS-SAW 3



Short bar
(2 pcs)
Horizontal bar
(1 pcs)
Long bar
(2 pcs)
Pivot
295.0
220.0
320.0
420.0
178.5

OP-SAW 1



Spacer – before positioning the specimen

Cutter in operation

Cutter: Guillotine

Introduction - Purpose

	Slide #
Purpose The guillotine is a sub-sampler for pressurized samples.	
General description: The chamber consists of the chamber itself (GUI chamber), the cap (GUI top), two sets of blades, an external reaction frame and two sets of ENERPAC cylinders	AS-GUI 1

Assembly

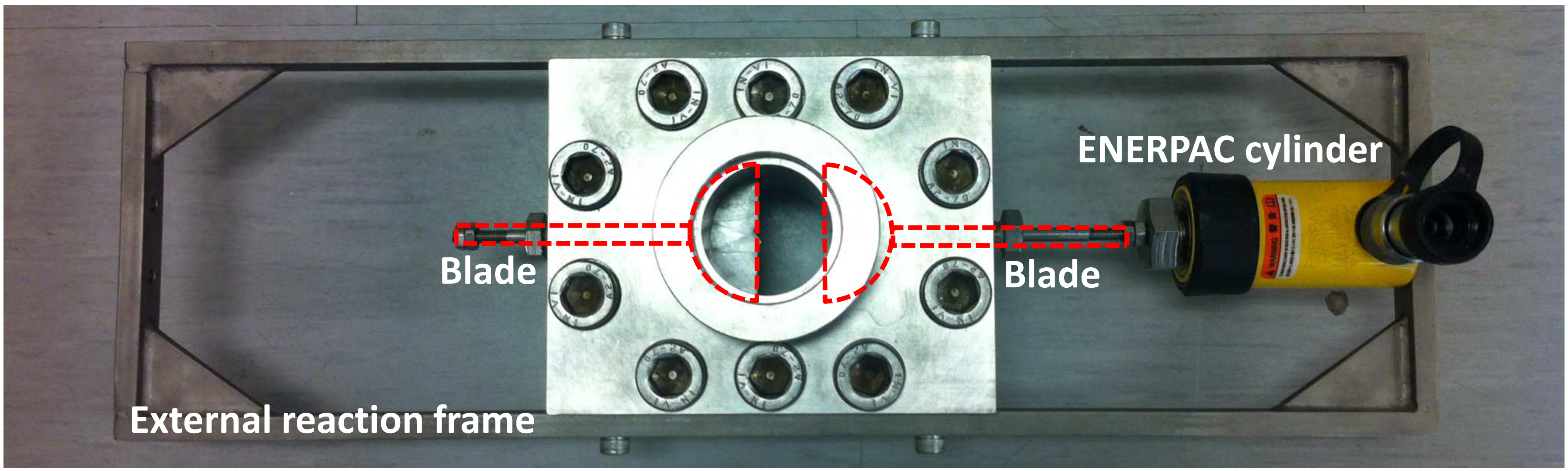
	Slide #
General Assembly 1. Insert 5/16” rod into M16 screw 2. Install o-ring taking into account that the screws in the front of the 5/16” rod can shear it, therefore the o-ring should be “screwed” until passes the threaded length 3. Place the blade into the GUI chamber 4. Insert 5/16” rod into the GUI chamber and screw the blade 5. Retract the blade until it sits against the wall of the chamber 6. Screw the M16 screws. Take into account it has to be screwed to the end (until touches metal to metal) in order to allow a correct alignment of the rod and the screw holes. The blade must run smoothly. 7. Repeat step 1 to step 6 with the second blade 8. Approach both blades to the middle of the chamber and mark on the exterior part of the plunger its position in order to recognize its location during operation 9. Align the GUI chamber and GUI top and screw 10 of M24 screws 10. Assemble external frame and attach it to the GUI chamber with four M10 screws 11. Install the 2 Enerpac cylinders as shown in AS-GUI 3 Note: O-ring material is Buna-N	AS-GUI 2 AS-GUI 3
Assembly to MAN 1. Couple with MAN from one side and any PCCT on the other side. With the help of couplers, it is possible to couple to MAN the same way it is done with each chamber (in the figure is shown only 2 screws of the 10 needed to operate). 2. Fill the chamber with water and pressurize. Check for leaks 3. Once the pressures on the MAN and GUI matches, the ball valve can be opened	AS-GUI 4

Operation

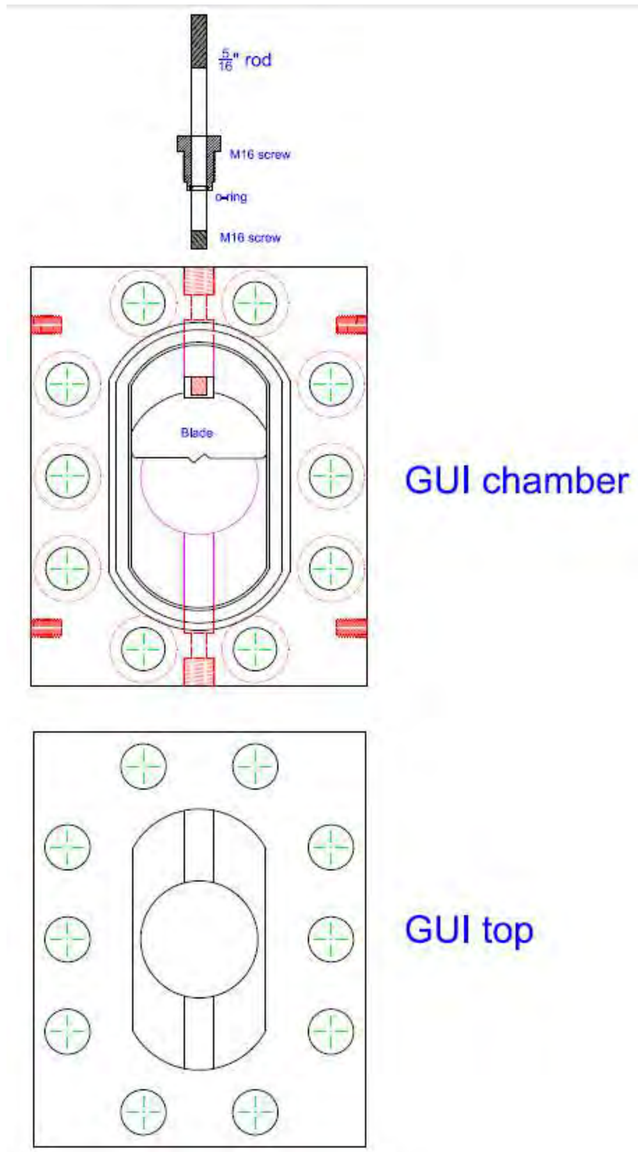
	Slide #
Sub-sampling 1. Move the specimen with MAN to the position where it has to be sub-sampled 2. To cut the sample, both cylinders must acted together at low speed. 3. Check the marks of the position of the blades (step 7 on the assembly) in order to prevent the blades from smashing each other 4. Once sub-sampled, retract the cylinders and the blades.	(no figure)

AS-GUI 1

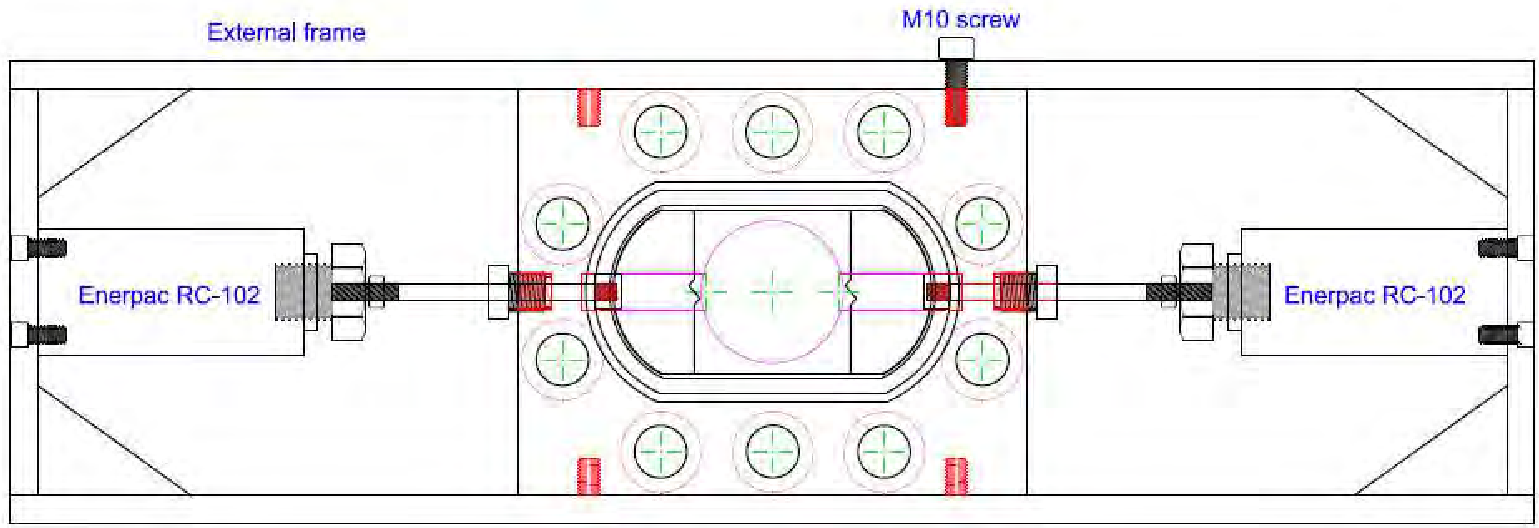
GUI chamber



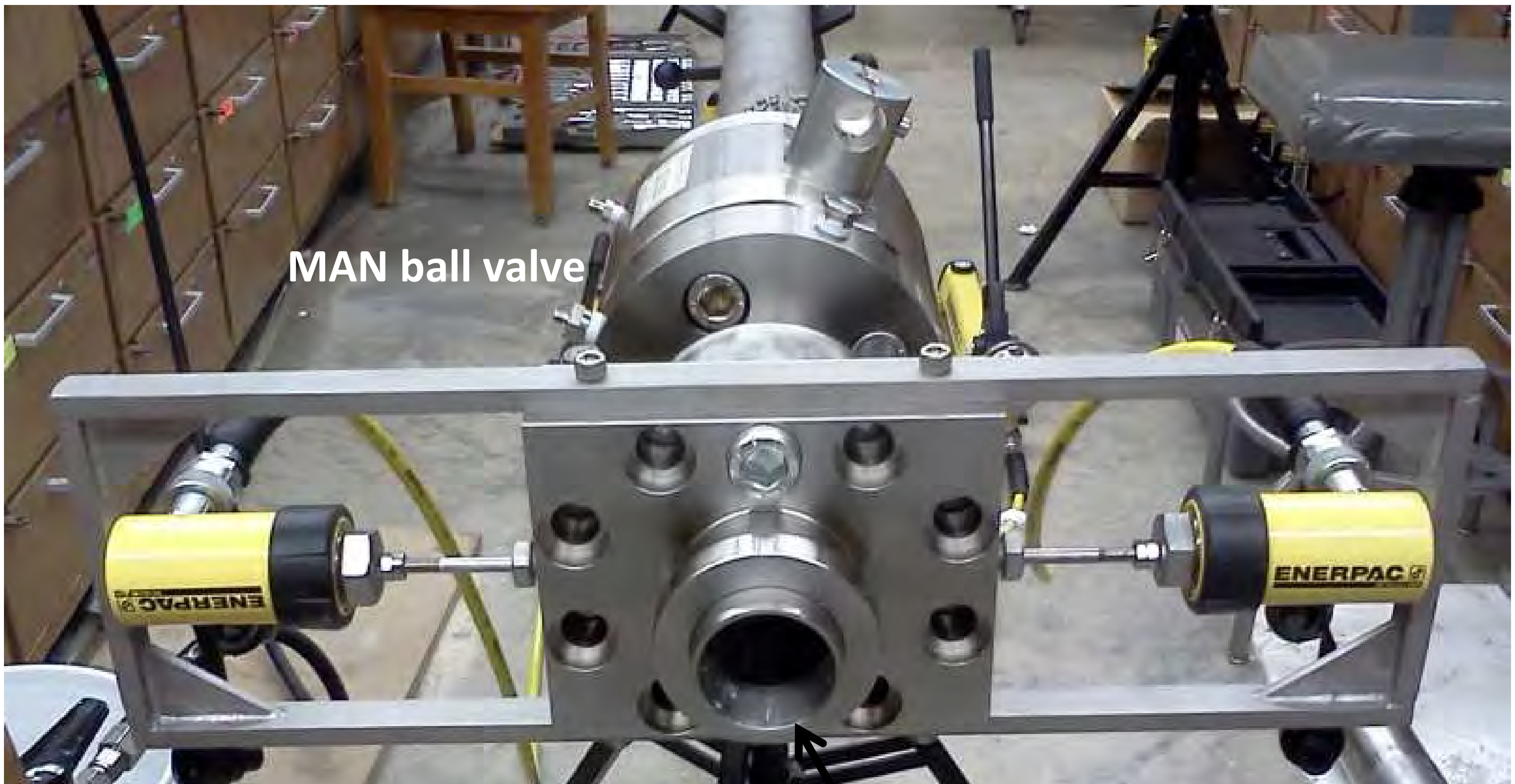
AS-GUI 2



AS-GUI 3



AS-GUI 4



Coupler

Instrumented Pressure Testing Chamber IPTC

Introduction - Purpose

	Slide #
Purpose The IPTC is a high pressure chamber able to test pressurized samples under no in-situ effective stress.	
General description The chamber consists of 3 parts: the chamber itself; 8 access ports and its instrumented rods; and an extension chamber. The IPTC is able to drill, and measure: elastic waves, undrained shear strength and electrical conductivity. It can be easily coupled with any PCCT (Pressure Core Characterization Tool).	AS-IPTC 1

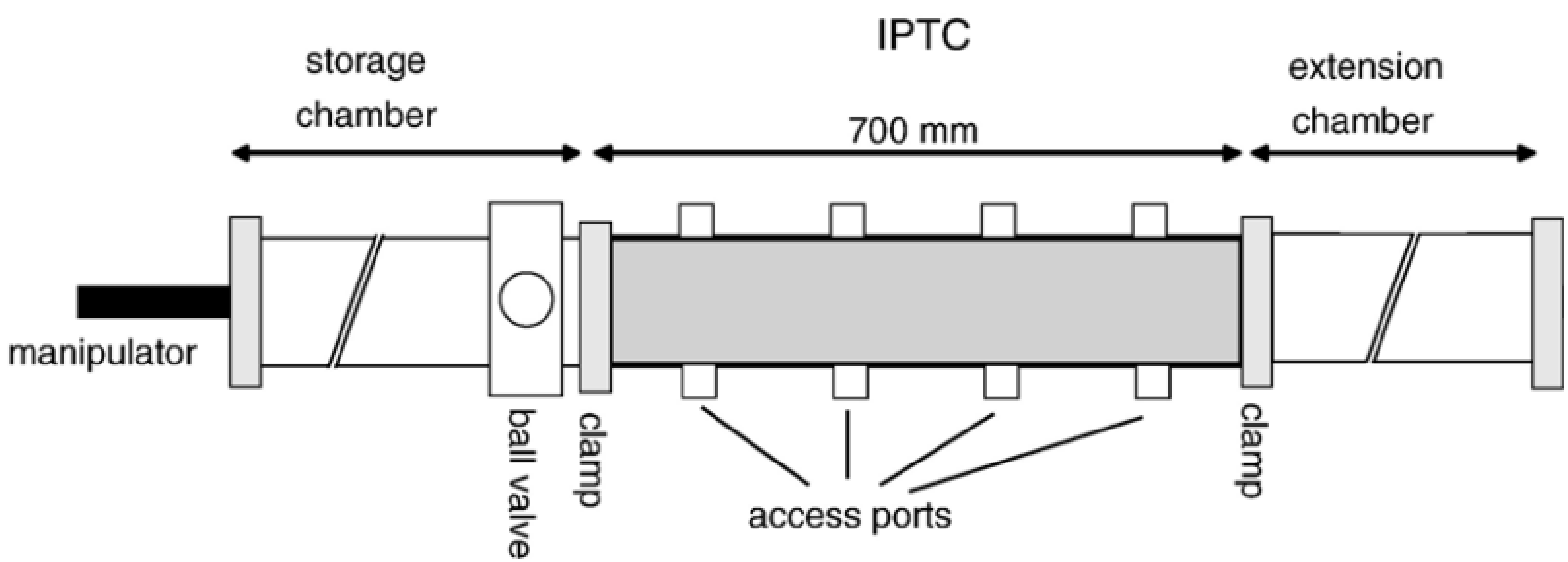
Assembly

	Slide #
Assembly of the instrumented ports 1. Screw connectors 1 and 2 to the ball valve 2. Place ball bearing on the instrumented rod 3. Place the driver on the instrumented rod as shown in figure 4. Screw the rod guide in to the driver and instrumented rod 5. Place o-ring in the rod guide 6. Screw the rod guide (along with the driver and instrumented rod) to the connector 1 Note: O-ring material is Buna-N	AS-IPTC 2
Assembly of the chamber 1. Screw the ports to the chamber following the order shown in the figure. Being V_p the P-wave transducer, V_s the bender elements, S_u undrained strength probe and s_{el} the electrical probe. 2. Mark the position of the rod above the ball valve and “testing position” (this will help to realize the location of each rod at each moment) 3. The MAN will be coupled to the left of this configuration. 4. The extension chamber will be coupled to the right.	AS-IPTC 3

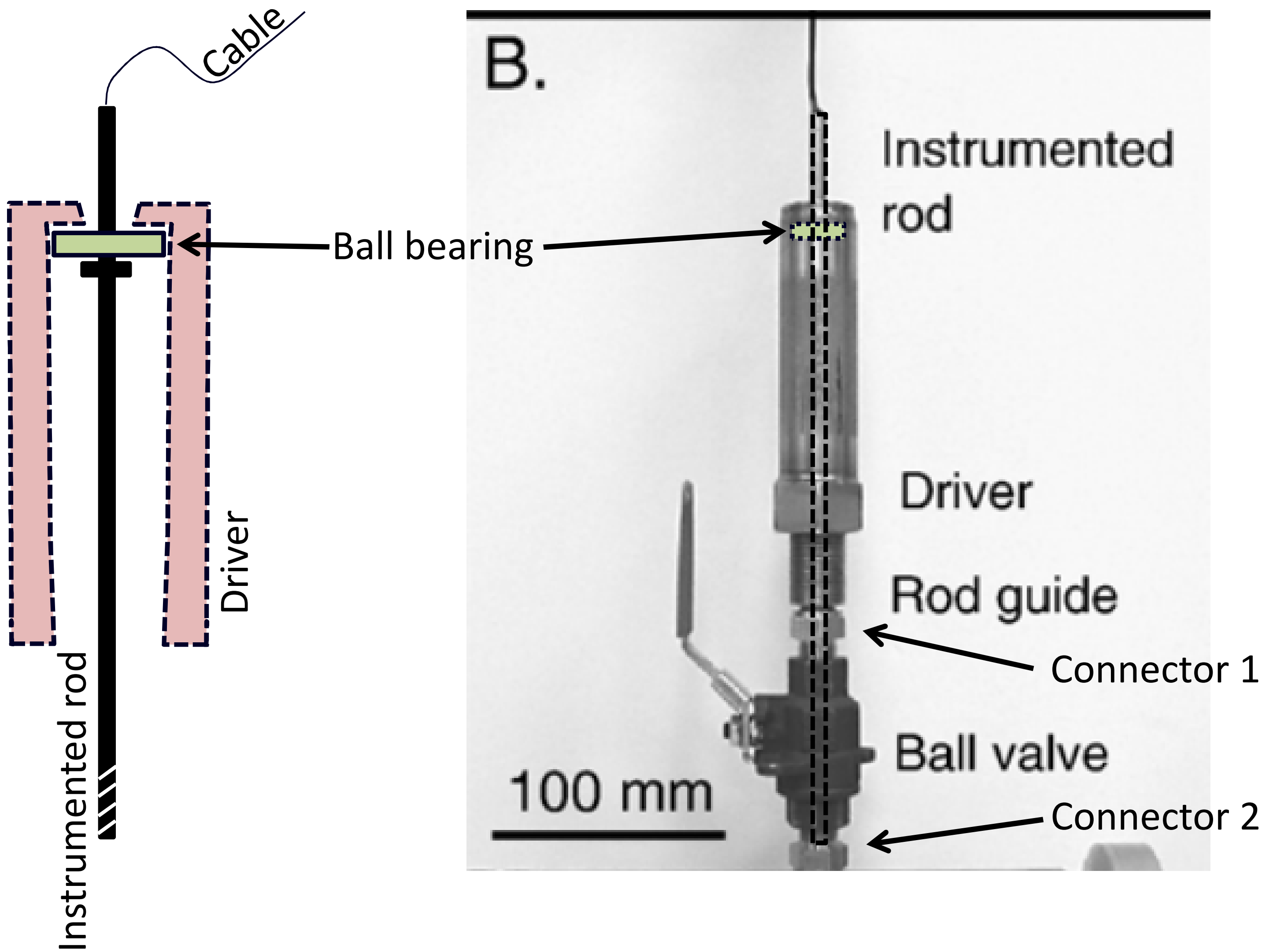
Operation

	Slide #
Early steps 1. The instrumentation peripherals are schematized in the figure 2. Couple the IPTC and extension chamber to the MAN 3. Fill with water and pressurize until it matches the pressure in the storage chamber 4. Open ball valve (figure AS-IPTC 1) and move the specimen to the IPTC	OP-IPTC 1 AS-IPTC 1
Testing 1. Once selected the testing planes, displace the specimen with the MAN until the plane matches with the position of the drilling port. 2. Drill with both rods to the desired depth 3. Retract both drilling rods 4. Move the specimen until the testing plane matches with the next position of instruments (in the first iteration: P-waves) 5. Conduct the respective measurements 6. Retract rods 7. Drill to the desired depth with the drilling rods 8. Repeat step 3 to 6 until the whole specimen is tested	OP-IPTC 2
After measurements 1. Once all measurements are done, retract all rods to the mark above the ball valve position (step 2 on the chamber assembly) 2. Close all ball valves 3. Retract the specimen to the storage chamber 4. Close MAN ball valve 5. Depressurize the IPTC	

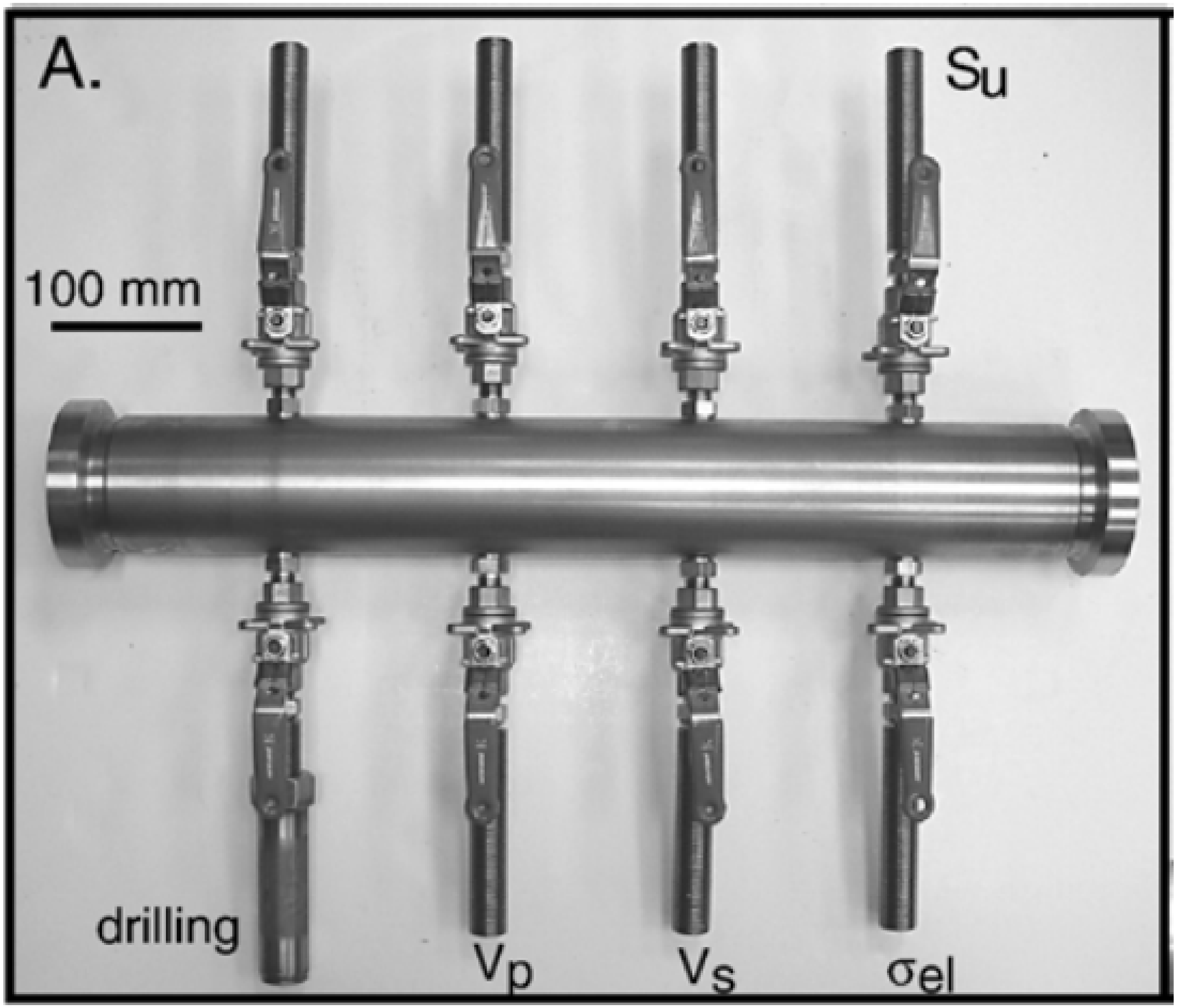
AS-IPTC 1


IPTC
storage
chamber
700 mm
extension
chamber
manipulator
ball valve
clamp
access ports
clamp

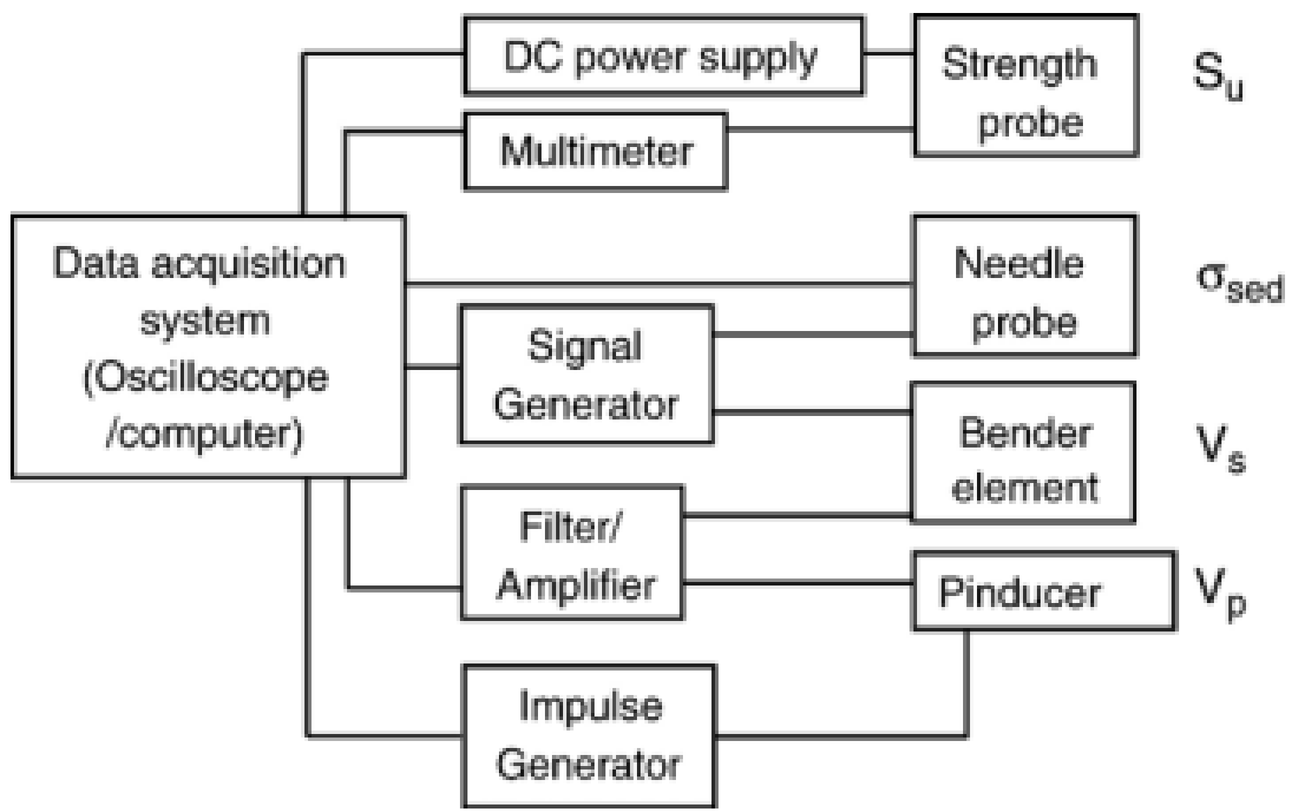
AS-IPTC 2


Cable
Ball bearing
Driver
Instrumented rod
B.
Instrumented
rod
Driver
Rod guide
Connector 1
Ball valve
Connector 2
100 mm

AS-IPTC 3

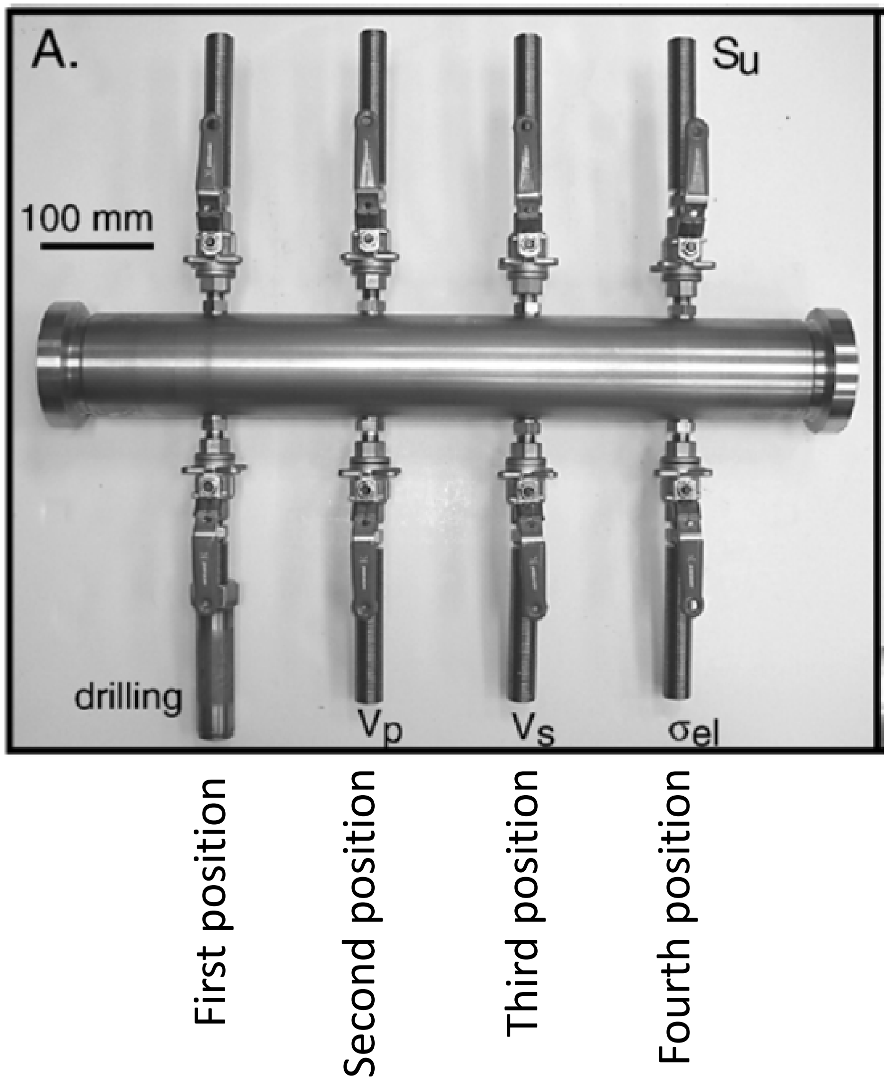


OP-IPTC 1



DC power supply
Strength probe
S_u
Multimeter
Data acquisition system (Oscilloscope /computer)
Needle probe
σ_{sed}
Signal Generator
Bender element
V_s
Filter/ Amplifier
Pinducer
V_p
Impulse Generator

OP-IPTC 2


A.
100 mm
Su
drilling
Vp
Vs
σel
First position
Second position
Third position
Fourth position

Controlled Depressurization Chamber (CDC)

Introduction - Purpose

	Slide #
Purpose CDC maintains the geological formation of hydrate bearing sediment and measures dissociated gas volume for the hydrate saturation while the core is dissociating.	
General description CDC houses 1.2 m long core and has three self-drilling thermocouples and one drill to make holes on the liner. The leverage system of the drill helps to reduce operation effort. The 2-L water storage and 55-L gas storage collects water and dissociated gas.	AS-CDC 1

Assembly

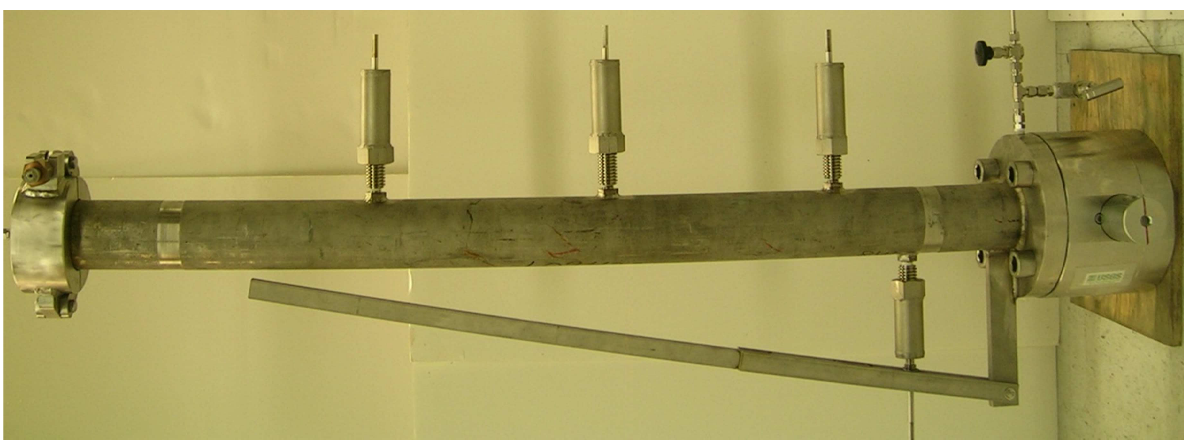
	Slide #
Assemble the flange on the ball valve	
1. House an O-ring (OA1) on the O-ring groove of the flange	AS-CDC 2
2. Tighten M24 screws	AS-CDC 3
Assemble self-drilling thermocouples	
1. Place an O-ring (OA2) on the O-ring groove of the self-drilling thermocouple guide screw	AS-CDC 2 AS-CDC 3
2. Use two acme-threaded nuts to tighten the self-drilling thermocouple guide screw	AS-CDC 4
3. Unscrew the two nuts and insert the self-drilling thermocouple rod	
4. Place a thrust bearing (A1) on the circular shoulder of the self-drilling thermocouple rod	
5. Assemble the hand driver	
6. Repeat above for two others: assemble from the port close to the flange	
Assemble the drilling system	
1. Place an O-ring (OA2) on the O-ring groove of the drilling guide screw	AS-CDC 2 AS-CDC 3
2. Use two acme-threaded nuts to tighten the guide rod of the self-drilling thermocouple	AS-CDC 4
3. Unscrew the two nuts and insert a self-drilling rod	
4. Assemble the hand driver	
5. Place a washer (A2) and a thrust bearing (A1) on smaller circular shoulder of the rod	
6. Connect the drilling rod lever arm to the chamber with a screw (A3, A4)	
Assemble the main chamber cap	
1. Place an O-ring (OA3) on the groove of the main chamber	
2. Close the cap and C-clamp	AS-CDC 2

Assemble the gas storage and water storage 1. Place an O-ring (OA4 for the water storage, OA5 for the gas storage) on the groove of the lid and the bottom 2. Use threaded rod, washers, and nuts to assemble	AS-CDC 3 AS-CDC 5 AS-CDC 6
Caution • Be sure that the minimum engagement during operations (25 mm for the hand-driver and 2.5 mm for the locking nail) • Be sure that the self-drilling thermocouple rod and locking nail does not intrude the passage while a sub-core moves	

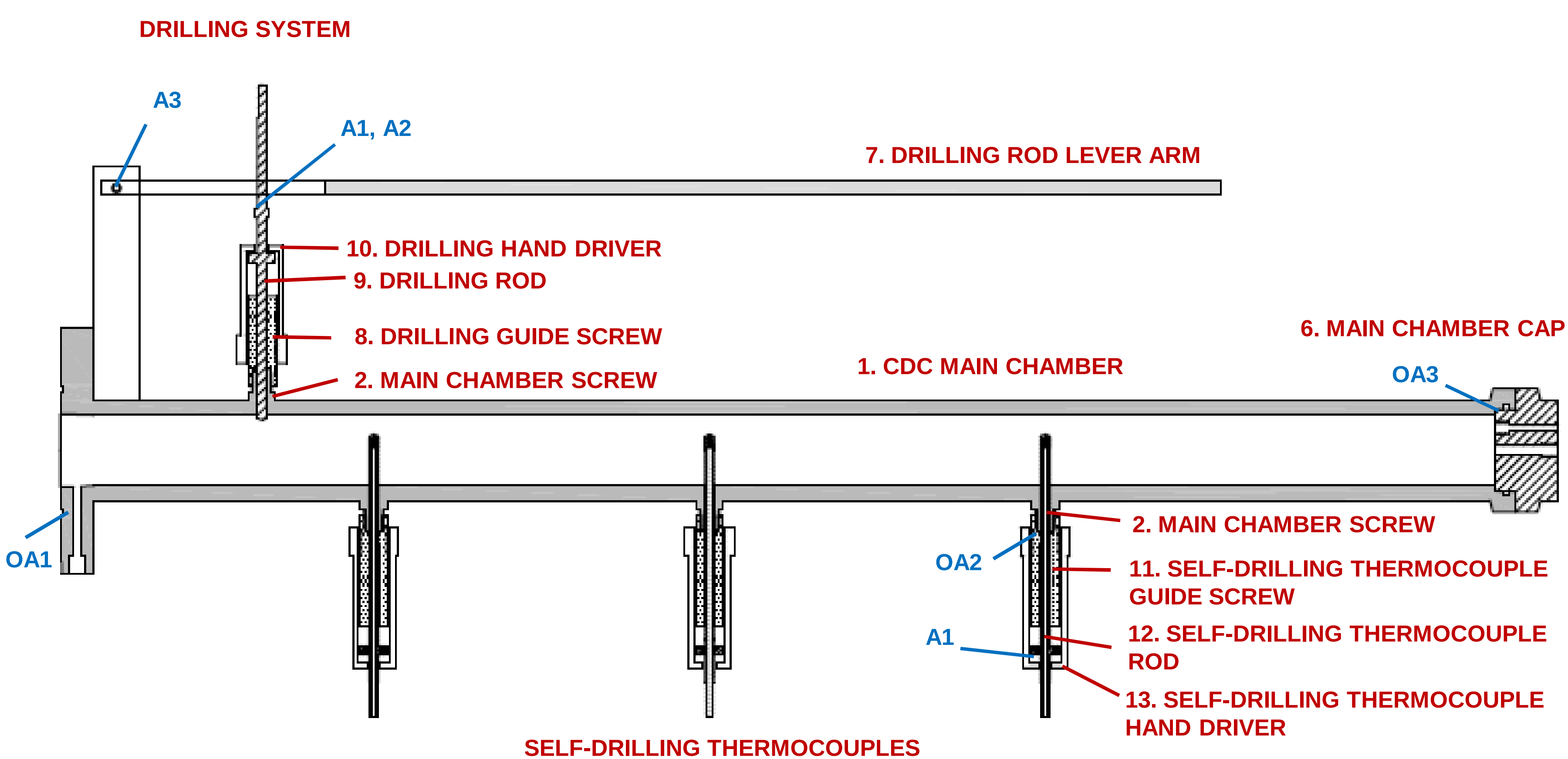
Operation

	Slide #
Early steps Connect electronics and tubing	
Depressurization 1. Fill water in the chamber through the fitting on the cap until the port on the flange drains water 2. Perforate holes on the liner by using the drilling system while transferring the core 3. Insert self-drilling thermocouples by rotating the rod and hand driver 4. Place a thermocouple in the thermo-drilling rod cavity until it touches the tip 5. Open the needle valve to dissociate gas. 6. Monitor chamber pressure, chamber temperature, and the weight of gas storage.	OP-DSC 1
Caution • Be sure that the minimum engagement length of thread connections during operations (25 mm for the hand-driver and 2.5 mm for the locking nail) • Do not apply high pressure to acrylic storages: the maximum pressure is 35 kPa (5 psi) for the gas storage, and 210 kPa (30 psi) for the water storage.	

AS-CDC 1



AS-CDC 2



- KEEP THE CLEARANCE OF THE LINER PASSAGE AT THE BEGINNING.
- MOVE DRILLING ROD LEVER ARM ONLY TO MAKE HOLE THROUGH A LINER.
- TO TIGHTEN THE GUIDE SCREWS USE TWO ACME NUTS.

AS-CDC 3

No.	Item	O.D.	I.D.	Th.
A1	Thrust bearing	16 mm	8 mm	5 mm
A2	Thick washer	24 mm	8.4 mm	2.0 mm
A3		0.25" hex bolt, washer, and nut		
A4		5/18 0.25" nut and washer		
OA1	O-ring	107 mm	101 mm	3 mm
OA2	O-ring	10.5 mm	7.5 mm	1.5 mm
OA3	O-ring	80 mm	72 mm	4 mm
OA4	O-ring	3.875"	3.625"	0.125"
OA5	O-ring	10"	9.75"	0.125"

All O-rings are buna-N.

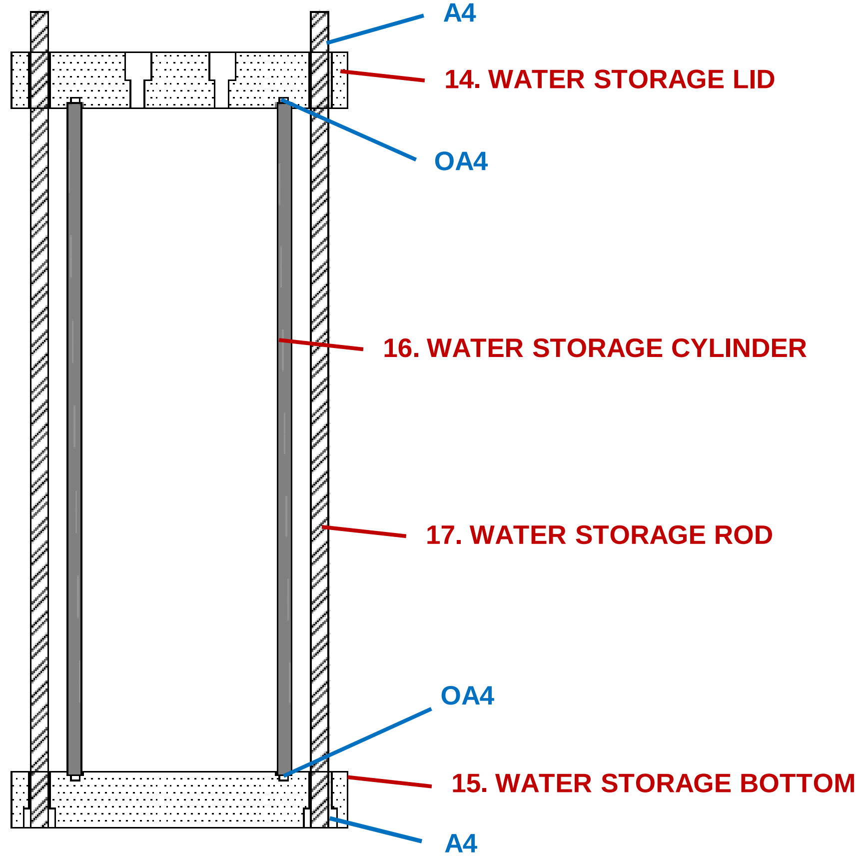
AS-CDC 4

SELF-DRILLING THERMOCOUPLE

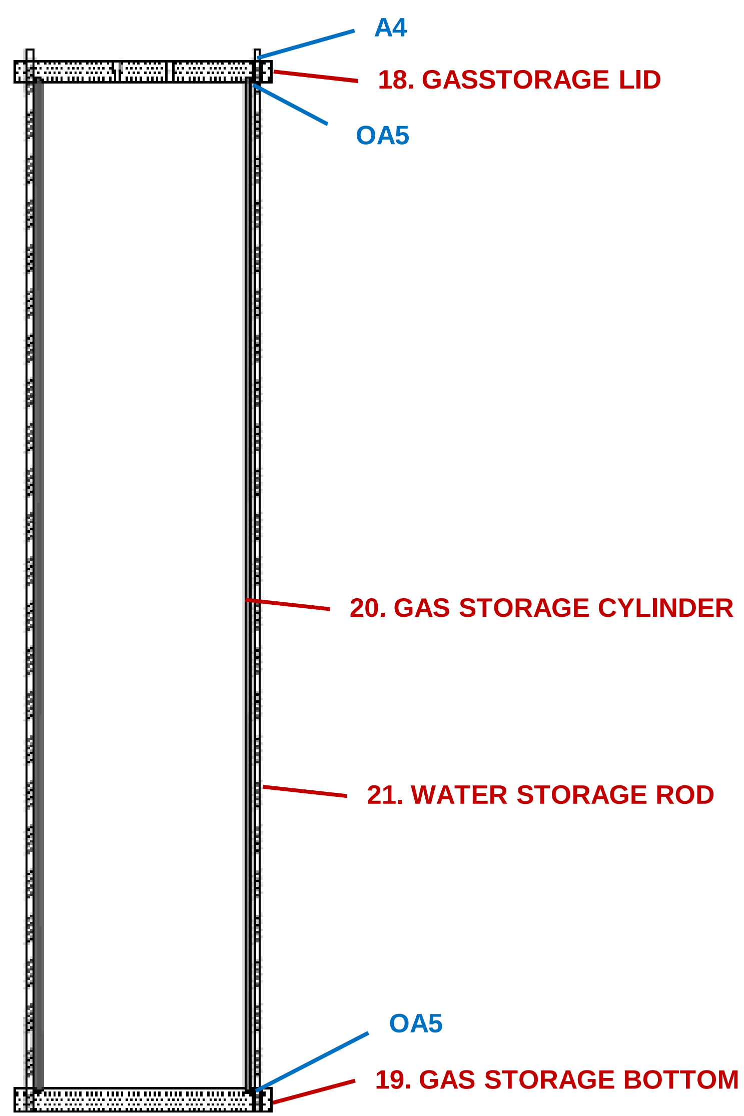
DRILLING SYSTEM

TWO 1"-ACME-THREAD-NUTS

AS-CDC 5


A4
14. WATER STORAGE LID
OA4
16. WATER STORAGE CYLINDER
17. WATER STORAGE ROD
OA4
15. WATER STORAGE BOTTOM
A4

AS-CDC 6



A4
18. GASSTORAGE LID
OA5
20. GAS STORAGE CYLINDER
21. WATER STORAGE ROD
OA5
19. GAS STORAGE BOTTOM

Effective Stress Chamber

Introduction - Purpose

	Slide #
Purpose: • Characterization of natural hydrate-bearing sediments under in-situ *P*-*T*-*σ*' conditions. • Measured properties include: *P*, *T*, stress-volume response, V_p, *k*, and gas production.	
General description The chamber has mainly 5 parts: loading plunger, membrane cell, main chamber, ball valve, and external reaction frame.	AS-ESC 1
Details of loading plunger (#1, #2), membrane cell (#3), and main chamber (#4, #5, #6).	AS-ESC 2

Assembly

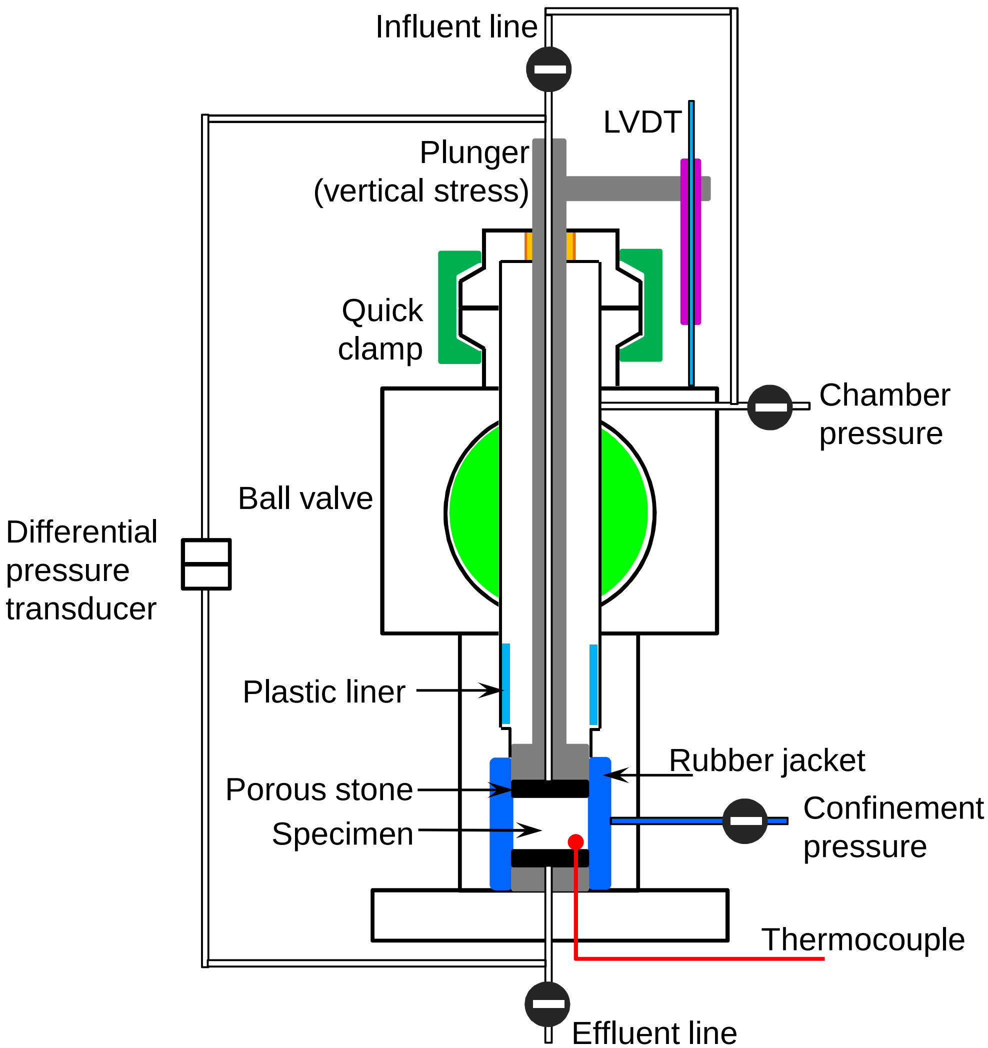
	Slide #
Assembly of the membrane cell 1. The membrane cell consists of 3 stainless steel cylinders and a 2"-diameter rubber membrane. 2. The membrane should cover the inside of the middle cylinder (which has a 1/6" NPT hole) and be flipped over at the two ends to cover the outside of the middle cylinder. 3. The other two cylinders are inserted into the middle cylinder and tightly squeeze the membrane. 4. Cut off the part of the membrane that outside the cylinder. 5. Place the membrane cell into the main chamber (#4 in Slide AS-ESC 2). Use a 1/16"-NPT tubing to go through the side weldolet on the main chamber and connect with the membrane cell. 6. The 1/16"-NPT tubing is sealed by an o-ring and a back-up ring between the weldolet and a weldolet nut. Note: 1. The tested maximum differential pressure for the membrane within the cell is ~1MPa. 2. To replace the membrane: (1) unscrew the weldolet nut; (2) unscrew the 1/16"-NPT tubing; (3) take the membrane cell out of the main chamber; (4) take apart the 3 cylinders and replace the membrane.	AS-ESC 3
Assembly of the loading plunger and pedestal 1. The plunger is connected with the loading pad using 3 screws and one O-ring in between for sealing. 2. Similarly, the pedestal (#5) is connected with the bottom plate (#6) using 4 M4 screws and an O-ring in between for sealing.	AS-ESC 4

Note: There are two sets of loading pad-pedestal, for measuring hydraulic conductivity and P-wave velocity respectively.	
Sequential assembly 1. From bottom up: Bottom plate (with pedestal) → Main chamber (with membrane cell) → Ball valve → Standard flange → Loading plunger (with loading pad). 2. Place the assembled chamber within the reaction frame. 3. Install peripherals: electronics, valves, and pumps.	

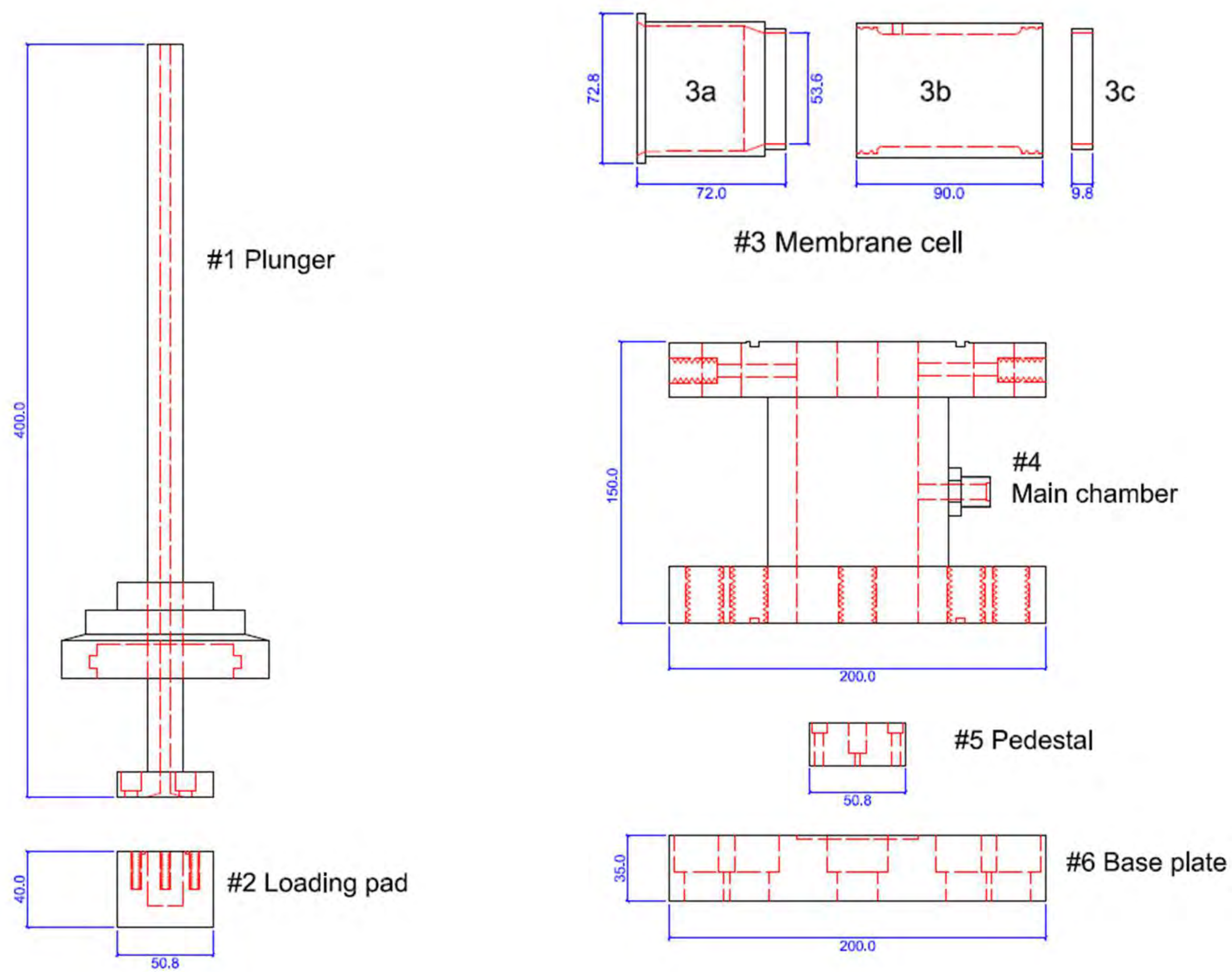
Operation

	Slide #
Early steps 1. Push the core out of plastic liner into the membrane cell using the plunger. 2. Restore in-situ effective stress condition until sediment consolidation completes. Note: During the pressurization of the chamber, make sure the valve that connects the membrane cell and the chamber is open, i.e., the chamber pressure and the confinement pressure are equal to avoid membrane rupture.	
Hydraulic Conductivity Test 1. Close the valve between membrane cell and the chamber to isolate the confinement pressure from the chamber pressure. 2. Slightly increase the confinement pressure (recommend 0.1MPa increase) to avoid boundary flow and not rupturing the membrane. 3. Extract the fluid at a constant rate q from the effluent line and meanwhile measuring the differential pressure Δu at the top and bottom of the core. 4. Hydraulic conductivity is computed as $k = qL/(A\ \Delta u)$, where L and A are the length and cross section area of the testing specimen.	AS-ESC 1

AS-ESC 1


Influent line
LVDT
Plunger
(vertical stress)
Quick
clamp
Chamber
pressure
Ball valve
Differential
pressure
transducer
Plastic liner
Rubber jacket
Porous stone
Specimen
Confinement
pressure
Thermocouple
Effluent line

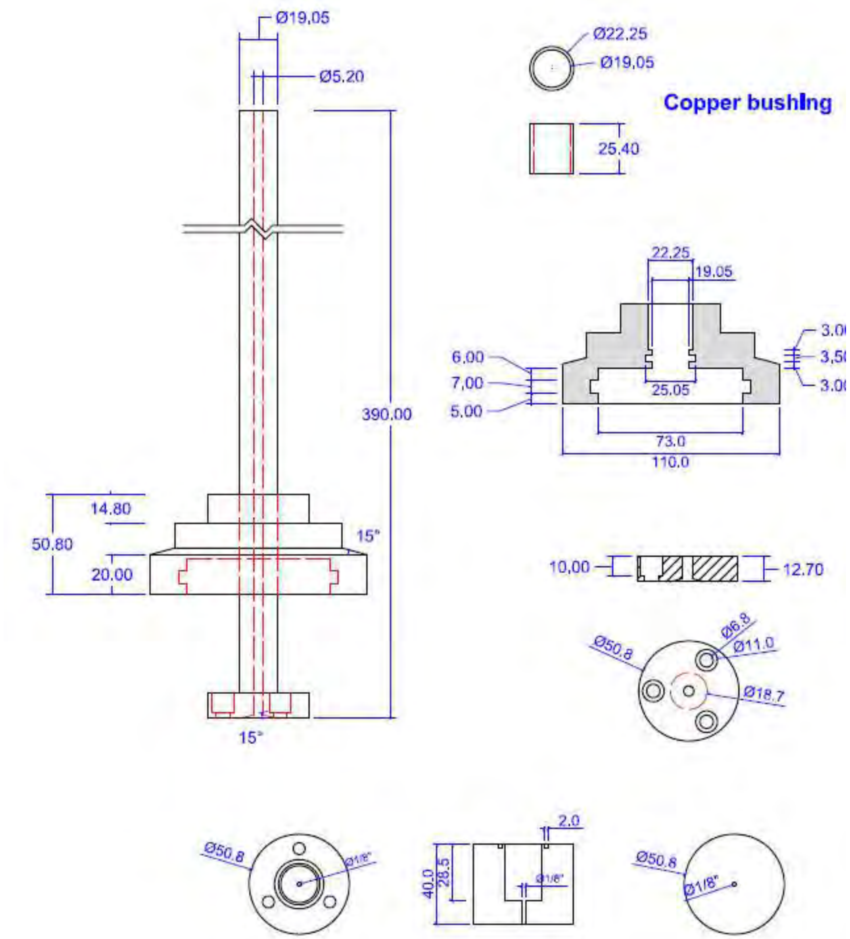
AS-ESC 2



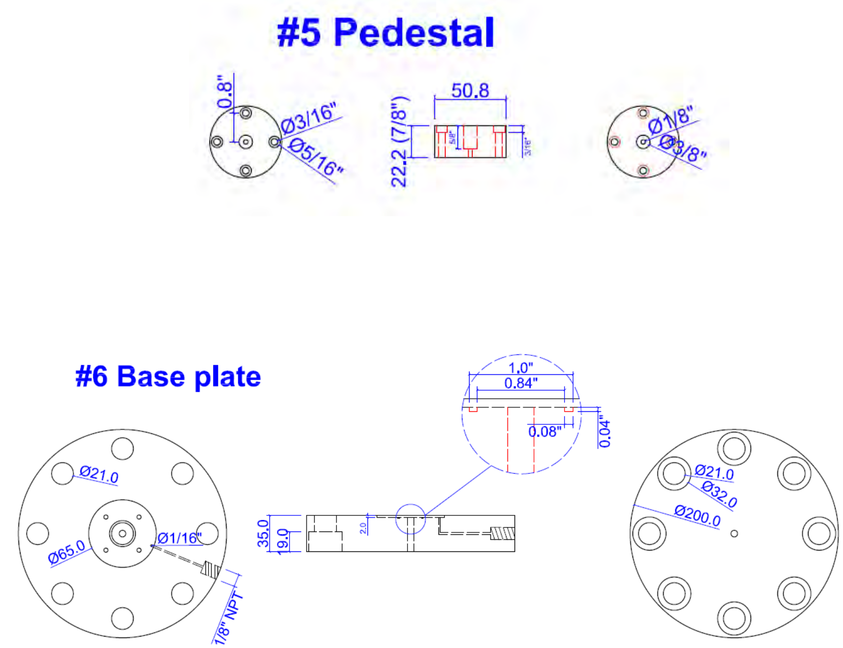
400.0
#1 Plunger
40.0
50.8
#2 Loading pad
72.8
3a
53.6
72.0
3b
90.0
3c
9.8
#3 Membrane cell
150.0
#4
Main chamber
200.0
#5 Pedestal
50.8
35.0
#6 Base plate
200.0

AS-ESC 3

AS-ESC 4



Loading plunger



Pedestal and Bottom plate

Direct Shear Chamber

Introduction - Purpose

	Slide #
Purpose The Direct Shear Chamber is the one that determines the shear strength of the pressurized samples.	
General description The chamber consists in (from top to bottom) a vertical plunger (blue in the figure) and a cap; a ball valve; the liner trap; and the shear box. Sensors: force (vertical and shear), displacement (vertical and shear), thermocouples, and piezocrystals (P-wave).	AS-DSC 1

Assembly

	Slide #
Assembly of the shear force plunger 1. Screw the shear frame (C shape) to the shear cylinder 2. Screw connector 1 to the shear cylinder 3. Screw the load cell (10 klbs) pointing to the chamber, meaning that looking from the top in front of the chamber it is possible to read the label in the load cell 4. Screw connector 2 to the load cell 5. Screw plunger to connector 2 6. Insert LVDT connector through connector 2 and plunger and tight 7. Insert 1" screw to the plunger 8. Insert o-ring (size 4x8mm)in the plunger in the housing provided in the screw 9. Screw the 4 threaded rods to the middle chamber 10. Assembly positioner: screw the 5/16" bolt into 9/16" bolt and insert o-ring (size 2.4x4.6mm) in the housing (similar to 1" screw) 11. Screw positioner to the middle chamber 12. Connect the green pump hose (including by-pass connectors) to the rear connection in the shear cylinder Notice that you will have two parts: first the middle chamber with 4 threaded rods and the positioner, and second the reaction frame, from the cylinder to the shear plunger Note: O-ring material is Buna-N	AS-DSC 2 AS-DSC 3

Step	Ref.
Assembly of the bottom plate 1. Screw (4) ½”-13 screws to the bottom 2. House the o-rings (1/16” x ½”) on the piezocrystal, thermocouple and regular screws 3. Screw the piezocrystal screw on the top 4. Screw the thermocouple screw on the top 5. Screw a regular screw on the top 6. Cables from the piezocrystal and thermocouple must go through 1/8” hole in the plate 7. Connect ¼” needle valve	AS-DSC 4
Assembly of the vertical plunger 1. Insert the cap o-ring (3x24mm) on the groove 2. Insert shaft through the cap 3. Screw the instrumented screw into the base 4. House the o-rings (1/16” x ½”) on the instrumented screw 5. Insert cables from the instrumented screw into the shaft 6. House the o-ring (2x20.5mm) in the base 7. Screw the base to the shaft with (3) M6 screws Note: O-ring material is Buna-N	AS-DSC 5
General Assembly (part 1) 1. Place bottom plate in a horizontal surface and in a spill proof container 2. Place o-ring (4x72mm) on the chamber bottom and couple it in the bottom plate 3. Clamp with a c-clamp and adjust it 4. Place middle chamber on top. Make sure 4.5 diameter thick o-ring (specially made) is placed on chamber bottom 5. Place the shearing ring (red in figure) on the middle chamber. Screw the positioner until the shearing ring is placed against the wall 6. Place the chamber top with o-ring (4.5 mm thick) on top of the middle chamber 7. Screw 6 long M24 bolts on the chamber top 8. On the 4 threaded rods (1/2” rods in the assembly of the middle chamber), place four ½” nuts and washers 9. Insert the shearing frame on to the threaded rods until the shearing plunger touches the shearing ring (the result is showed in figure 1) 10. Screw 1” screw to the middle chamber with 1 ½” wrench 11. Secure the position of the shearing frame with 4 new washers and nuts (1/2” nuts). Use the 4 washers and nuts from the step 10 to the lock position	AS-DSC 6

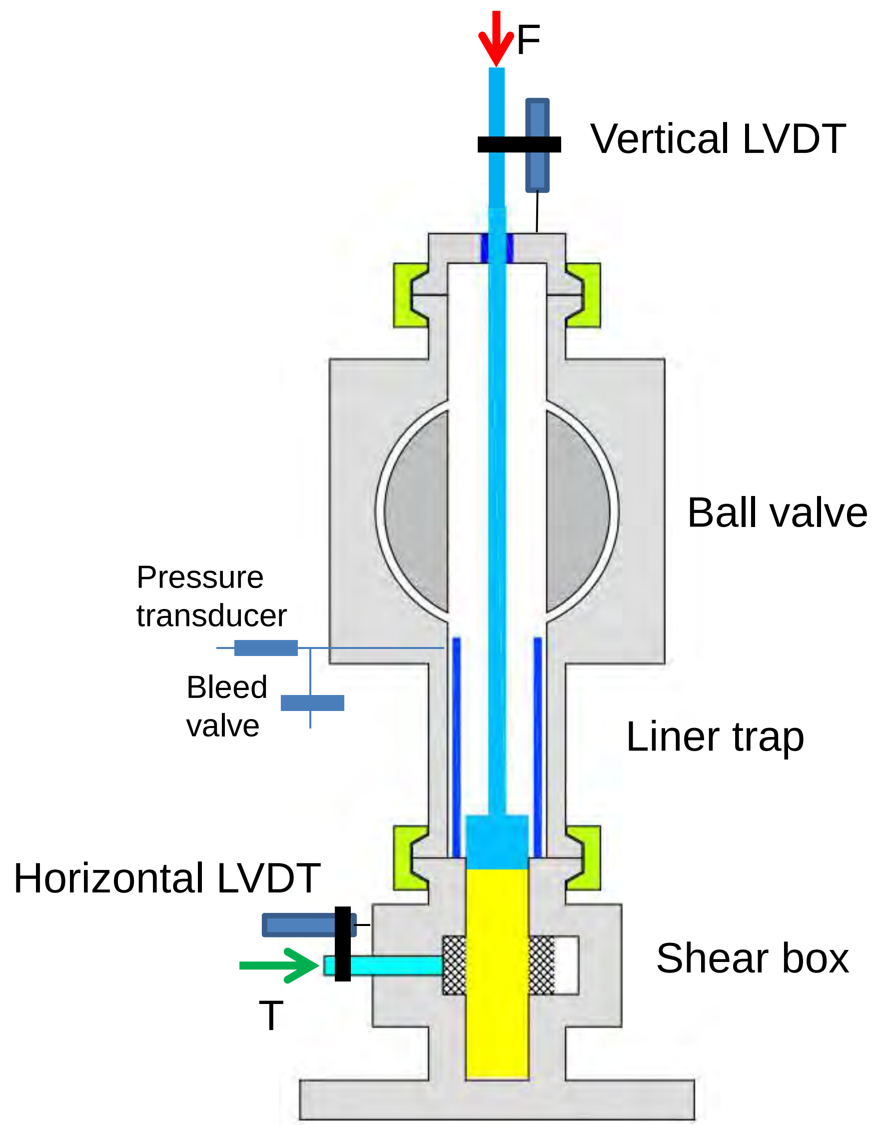
General Assembly (part 2) 1. Place the funnel on the top of the chamber top (o-ring -4x72mm- is needed to couple) 2. Pour water in the chamber and use a wrench to move the shearing ring forward and backward in order to remove air bubbles from the system 3. Place the liner trap and couple with the chamber top 4. Place the ball valve and make sure the port from the liner trap is not aligned, might bring problems with the operation. Screw the ball valve to the liner trap (4) M24 screws. Connect the pressure transducer on the top of the liner trap 5. Pivoting on point A, rotate the ball valve and liner trap until the ball valve faces to the back side 6. Re-adjust the 6 long M24 screws on the shear chamber 7. Place a c-clamp in point A and adjust it 8. Place the top flange and screw with 4 M24 screws to the ball valve. Make sure the connector in the flange does not interfere with the operation of the ball valve and the position of the 5/8" threaded rods. Use the aluminum pipe to align flange with ball valve 9. Pour water until it reaches the middle of the ball valve 10. Place a coupler in the flange. Make sure o-ring (4x72mm) is placed 11. Close the ball valve	AS-DSC 7
Final assembly before operations 1. Once loaded with the specimen and the chamber verticalized, screw the (2) 5/8" threaded rods and place (2) 5/8" nuts (one each rod – that will be the sitting of the bar 2) 2. Pour water until the top of the coupler of the top flange 3. Screw the 5 klbs load cell to bar 2 pointing up, meaning that the label of the load cell can be read from the front of the chamber 4. Screw the shaft of the vertical plunger to load cell 5. Install bar 2 with load cell and plunger through the two threaded rods and insert it into the chamber until the plunger touches the ball valve (the ball valve will be closed) 6. Close the plunger cap and place c-clamp. Make sure the o-ring is already installed in the plunger cap 7. Place the rest of 5/8" nuts as shown 8. Place bar 1 as shown and screw two 5/8" nuts on top of the bar 1 9. Place and screw saddle with two M8 screws onto bar 2 10. Place LVDTs on the plunger and shear plunger	AS-DSC 8

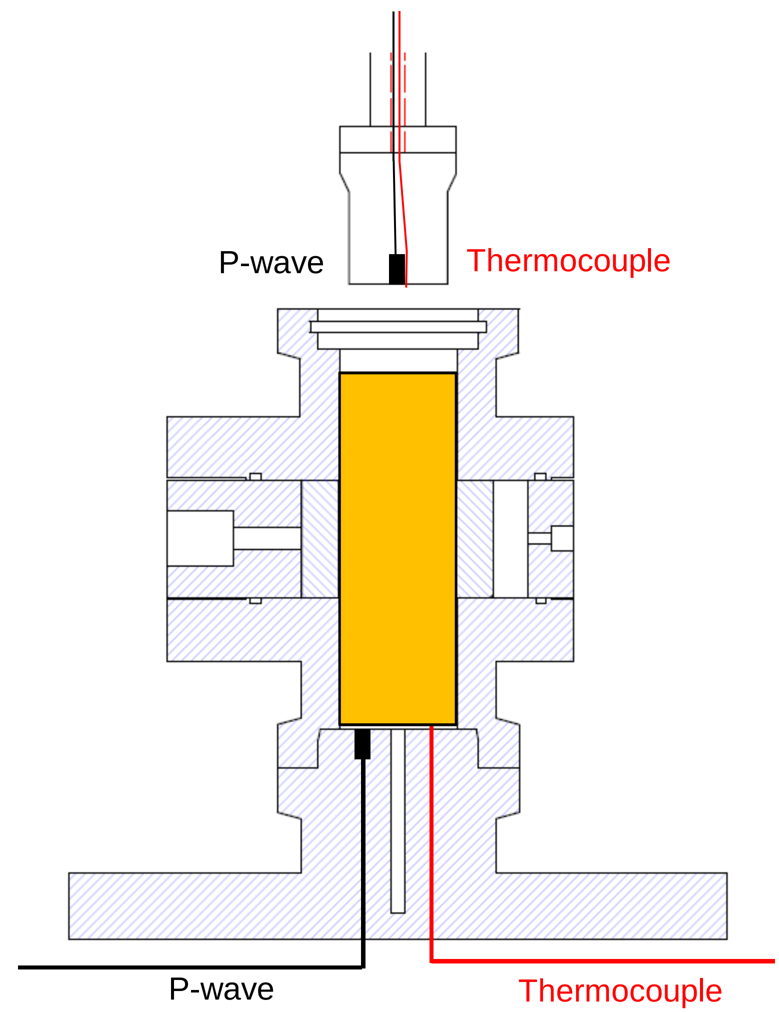
Operation

	Slide #
Early steps 5. Instrumentation peripherals are shown in the figure 6. Connect the water pressure transducer and bleed valve; and check for leaks 7. Once the top cap and chamber are pressurized, the ball valve can be opened 8. By means of the vertical plunger and helped by the Enerpac cylinder, lower the vertical plunger until touching the specimen 9. Extrude the sample from the plastic liner and house it in the shear chamber 10. Once the specimen has touched the pedestal in the shear chamber, shoot first attempt of P-waves and check reception and reading from the LVDTs and load cells 11. Gradually load the specimen until desired final load recording P-waves on different stages (physically criteria applies at choosing load stages) 12. Once reached to final load, relaxing test can take place , where the load is reapplied to the desired final load several times until the change is engineering insignificant	OP-DSC 1
Shear Test 5. After applying target stress for shear tests, check connections and sensors of forces, displacements and pressure 6. Un-screw the internal screw in the positioner (15 turns should be enough) – Important: do not unscrew the external screw 7. Close the ball valve in by-pass connection 8. Apply pressure to the shear cylinder, monitor for horizontal displacement and pressure in the gauge 9. Shear the specimen on 1mm spaced steps. After each step, let the specimen to relax. Repeat until the end of the run is reached 10. Retract the horizontal plunger by open the retention valve in the green pump and open the ball valve in the by-pass connection 11. Unload the vertical plunger 12. Screw the internal screw in the positioner until the internal ring is back in its initial position	OP-DSC 2
Dissociation test 1. Connect the steel hose to the DSC and the other extreme to a top connection on an intermediate chamber. Connect lower connection of the intermediate chamber to high pressure pump. The intermediate chamber works as a buffer so there is no gas fluid in the connection to the ISCO pump. 2. Extract fluid from the ISCO pump at constant flow 3. Monitor water pressure and temperature from the chamber. 4. Stop the test when water pressure is atmospheric pressure and temperature is room temperature	OP-DSC 3

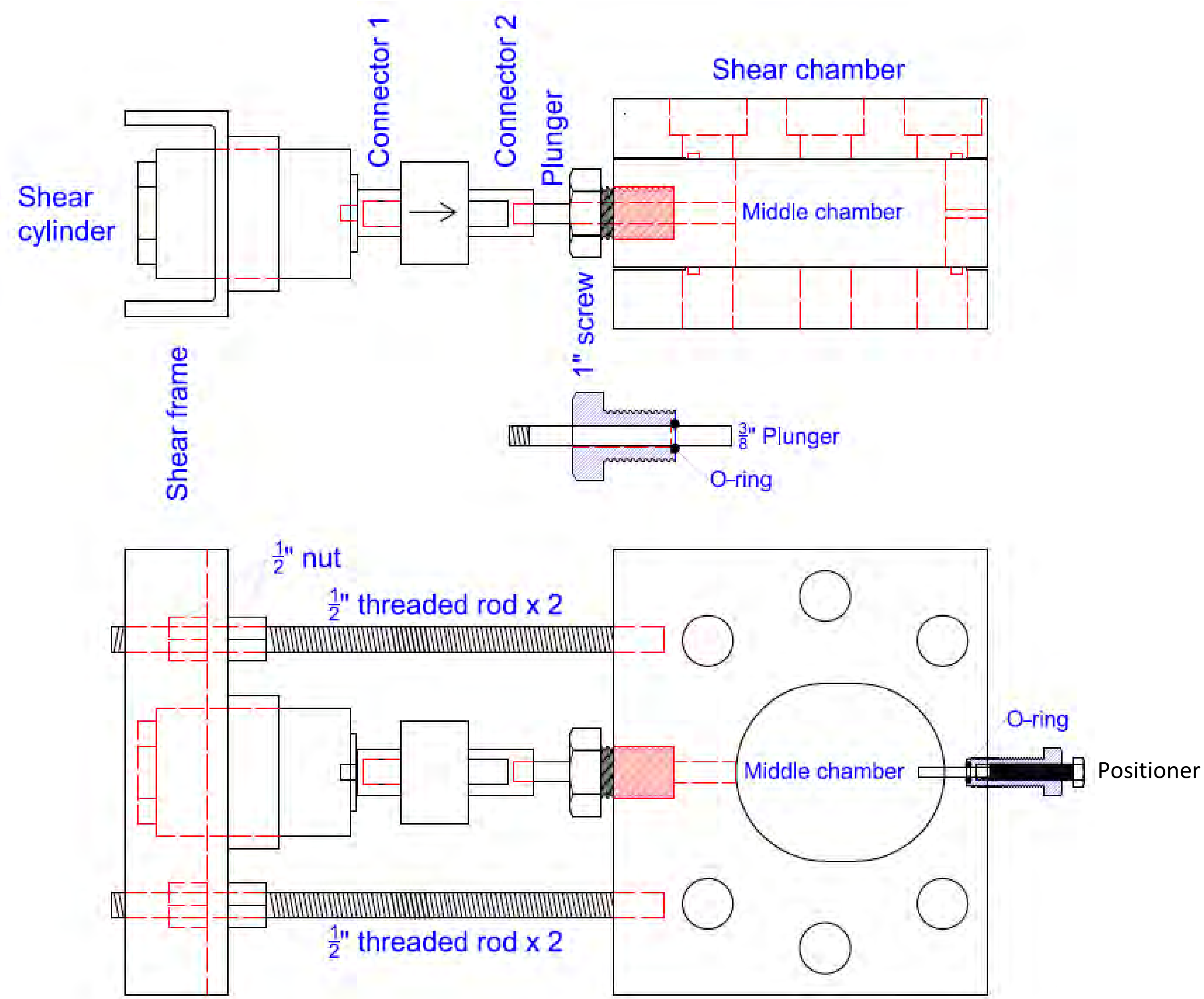
5. Release the methane gas safely	
Recompression test and shear test after dissociation 1. Reload the specimen as a standard compression test to the maximum capacity of the chamber monitoring forces and displacements 2. Unload the specimen to vertical stress and reload the target stress to perform a new shear test 3. Repeat steps on ”Shear test” title 4. Reload to the maximum capacity of the frame and repeat step 3 5. Unload the specimen (stress) following the inverse steps shown in the “Assembly” section 6. Recover the specimen from the chamber	(no figure)

AS-DSC 1


F
Vertical LVDT
Ball valve
Pressure
transducer
Bleed
valve
Liner trap
Horizontal LVDT
Shear box
T

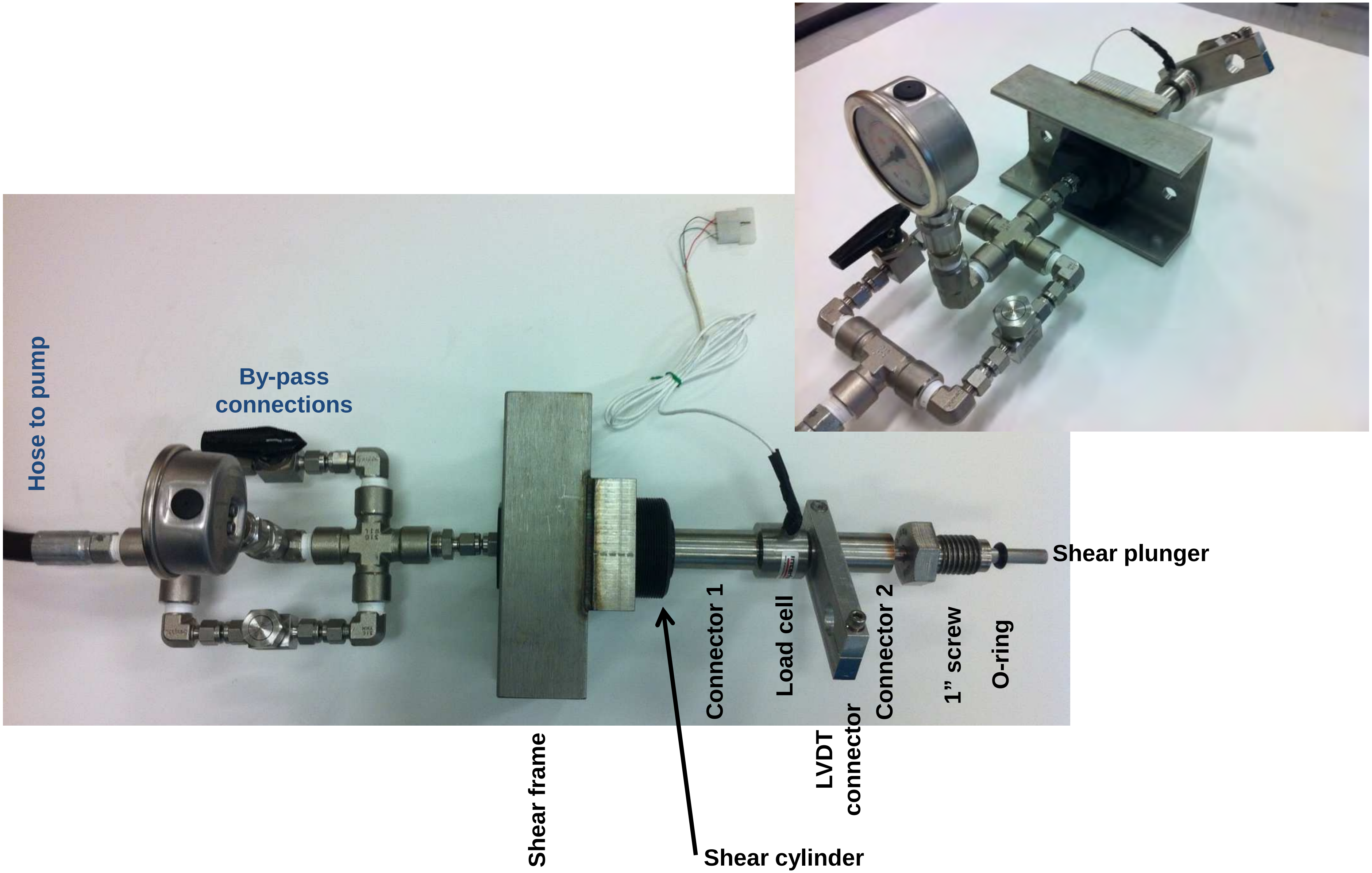

P-wave
Thermocouple
P-wave
Thermocouple

AS-DSC 2

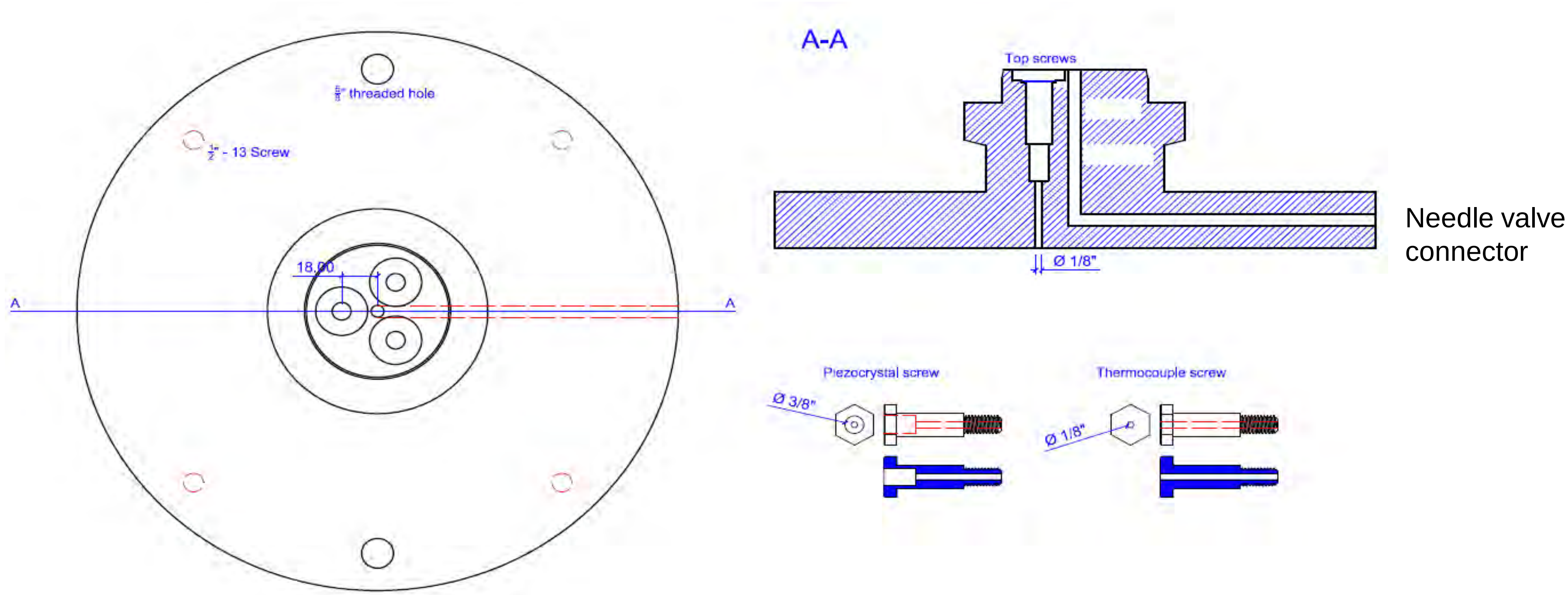


Shear chamber
Middle chamber
Connector 1
Connector 2
Plunger
Shear cylinder
1" screw
Shear frame
3/8" Plunger
O-ring
1/2" nut
1/2" threaded rod x 2
Middle chamber
O-ring
Positioner
1/2" threaded rod x 2

AS-DSC 3

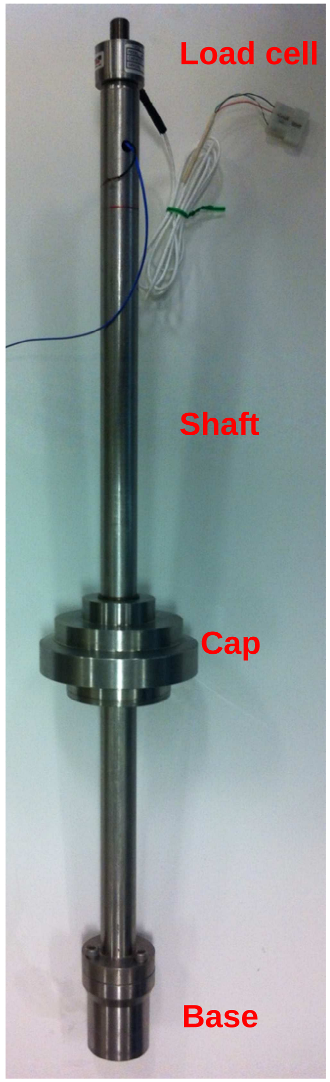

Hose to pump
By-pass connections
Shear frame
Shear cylinder
Connector 1
Load cell
LVDT connector
Connector 2
1" screw
O-ring
Shear plunger

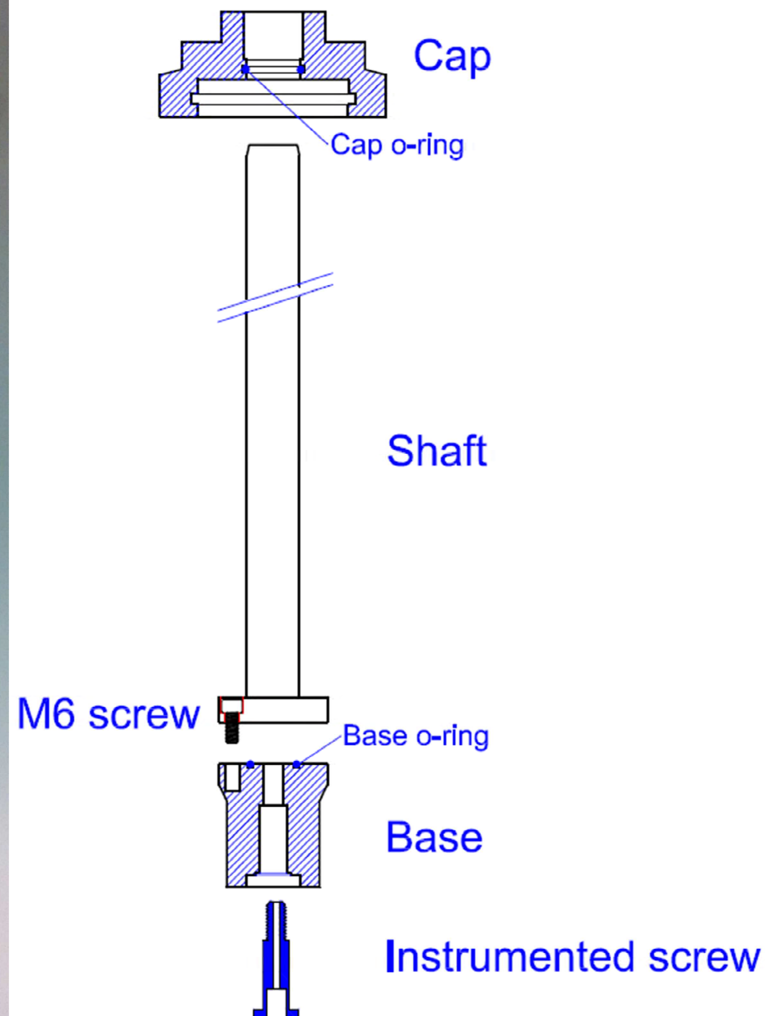
AS-DSC 4



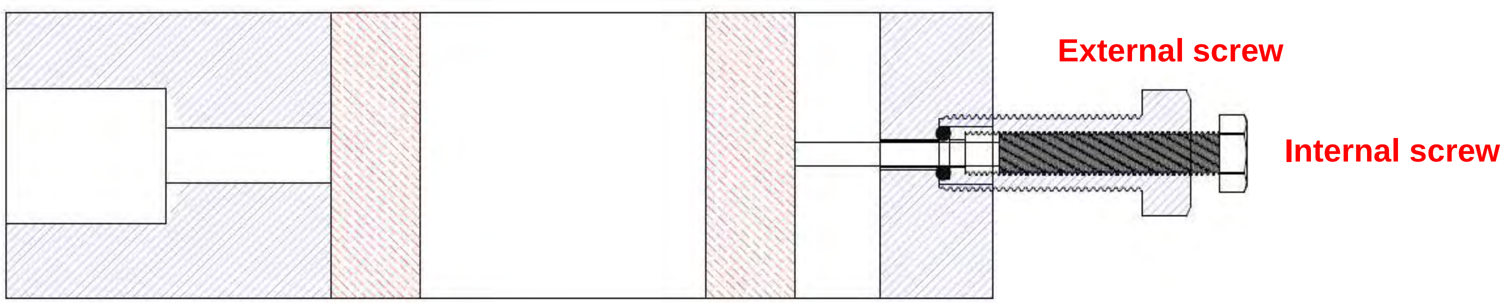
Note: O-ring material is Buna-N

AS-DSC 5

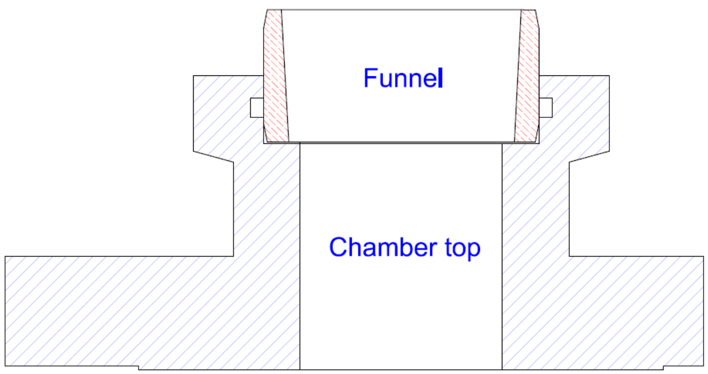

Load cell
Shaft
Cap
Base

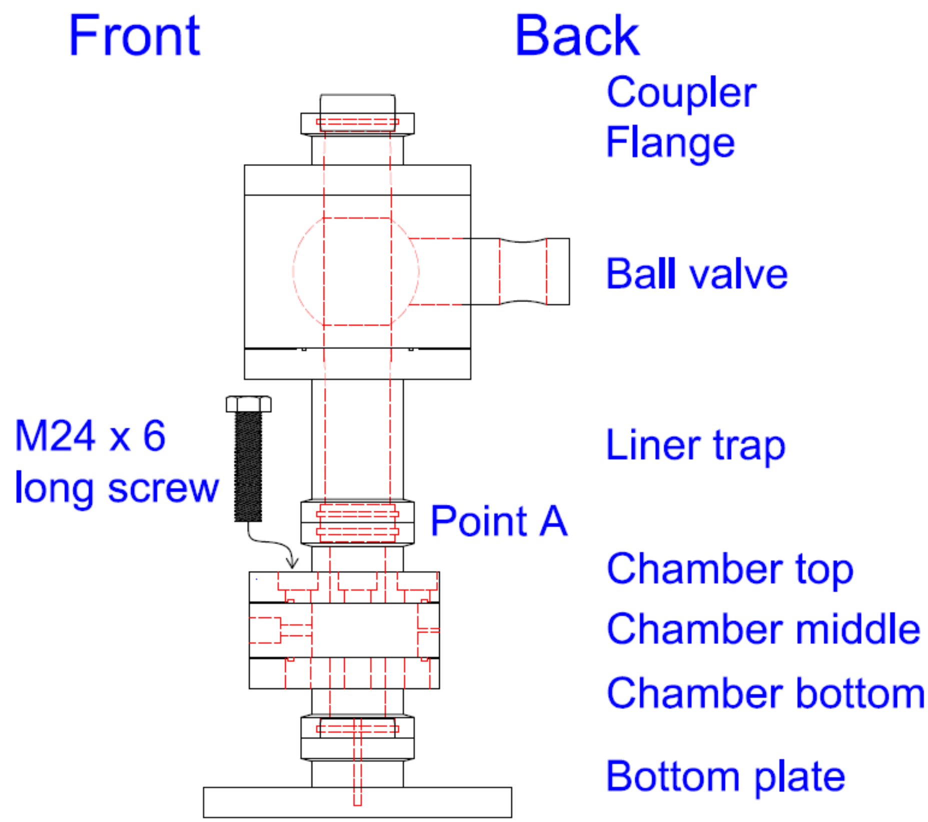

Cap
Cap o-ring
Shaft
M6 screw
Base o-ring
Base
Instrumented screw

AS-DSC 6

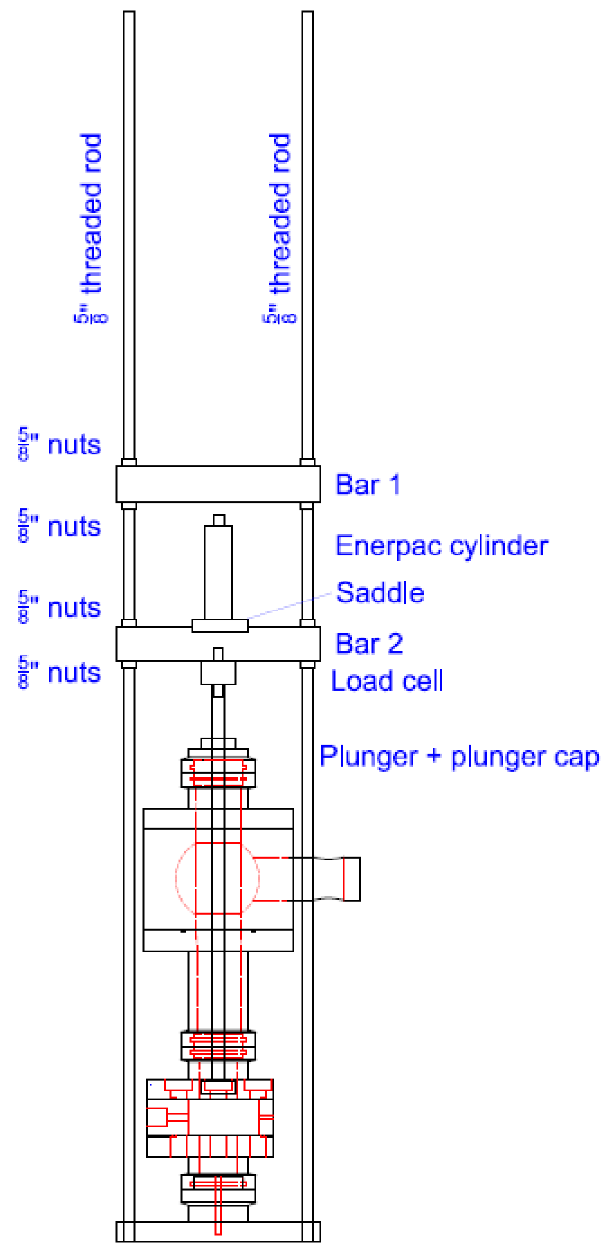


AS-DSC 7


Funnel
Chamber top

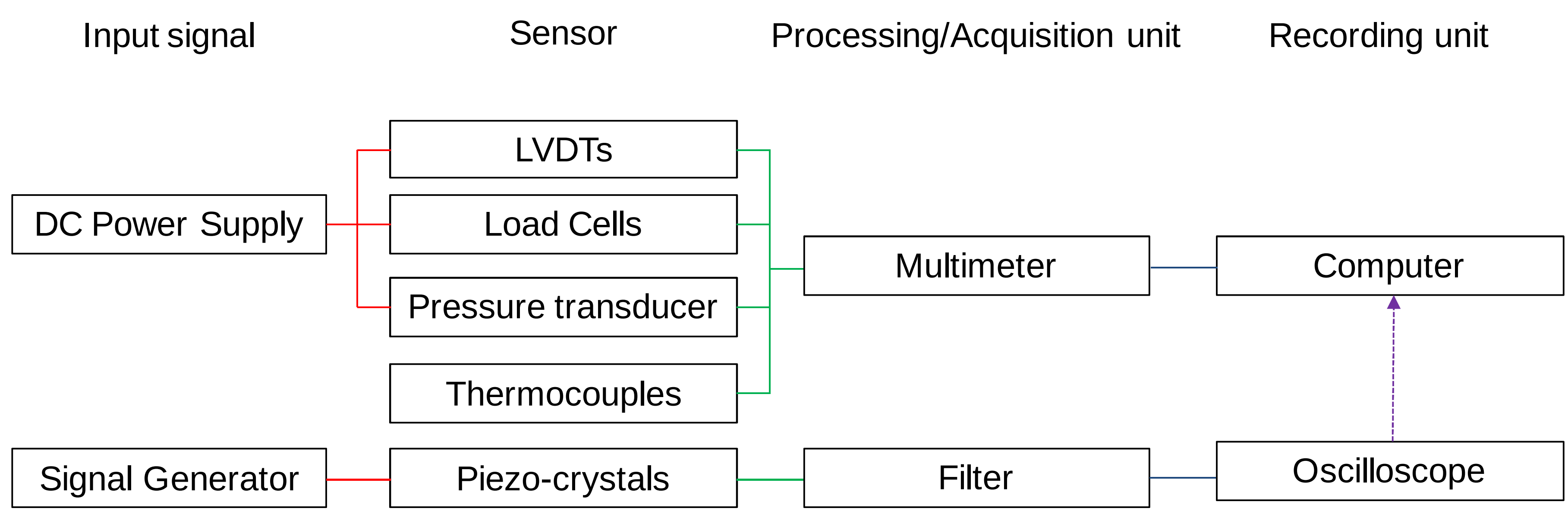

Front
Back
Coupler
Flange
Ball valve
M24 x 6
long screw
Liner trap
Point A
Chamber top
Chamber middle
Chamber bottom
Bottom plate

AS-DSC 8

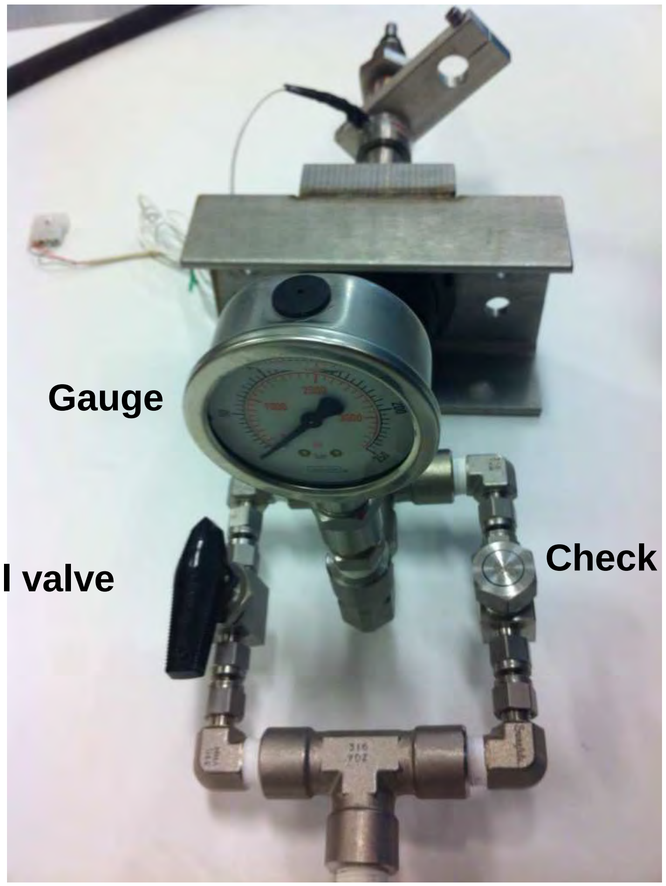


5/8" threaded rod
5/8" threaded rod
5/8" nuts
5/8" nuts
5/8" nuts
5/8" nuts
Bar 1
Enerpac cylinder
Saddle
Bar 2
Load cell
Plunger + plunger cap

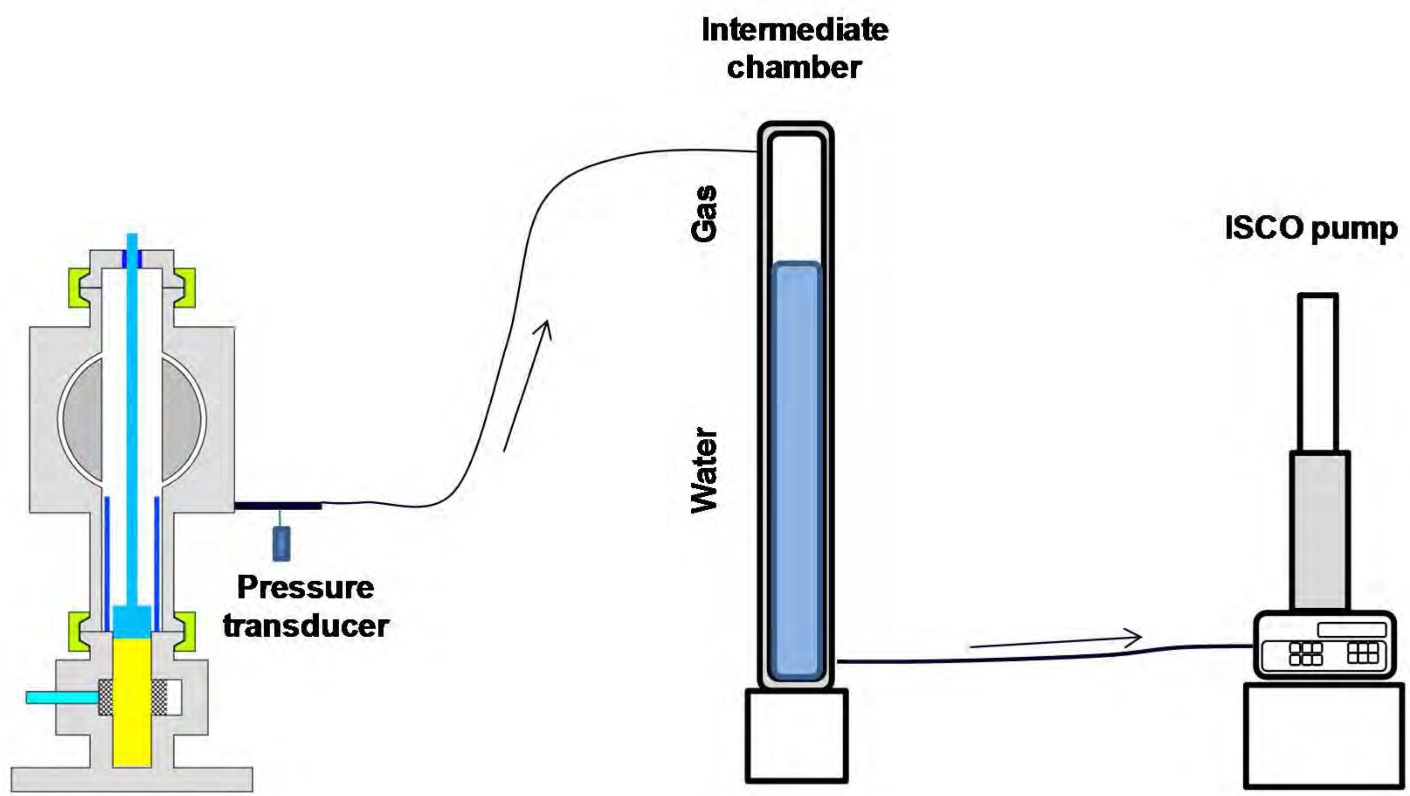
OP-DSC 1


Input signal
Sensor
Processing/Acquisition unit
Recording unit
LVDTs
DC Power Supply
Load Cells
Multimeter
Computer
Pressure transducer
Thermocouples
Signal Generator
Piezo-crystals
Filter
Oscilloscope

OP-DSC 2



OP-DSC 3



Intermediate chamber
Gas
Water
ISCO pump
Pressure transducer

Chamber for Biological Studies

Introduction - Purpose

	Slide #
Purpose Collect soil sub-samples from hydrate bearing sediments for biological studies without dissociation and measure hydrate saturation	
General description The bio-subsampling chamber (BIO) consists of a flange with a self-drilling thermocouple and locking nails, the sampling chamber, a soil sampling rod, and bio-reactors	AS-BIO 1

Assembly

	Slide #
Assemble the flange on the ball valve 1. House an O-ring (OB1) on the O-ring groove of the flange 2. Tighten M24 screws	 AS-BIO 2 AS-BIO 3
Assemble the self-drilling thermocouple 1. Place an O-ring (OB2) on the O-ring groove of guide rod 2. Use two 1"-acme-thread-nuts to tighten the self-drilling thermocouple guide screw on the self-drilling thermocouple connector 3. Unscrew the 1"-acme-thread-nuts and insert the self-drilling thermocouple rod 4. Place a thrust bearing (A1) on the circular shoulder of the self-drilling rod 5. Assemble the self-drilling thermocouple hand driver	 AS-BIO 2 AS-BIO 3 AS-BIO 4
Assemble locking nails 1. House the O-ring (OB3) on the groove of the nail guide screw, and tighten it on the flange 2. Screw the locking nail into the nail guide screw	 AS-BIO 2 AS-BIO 3 AS-BIO 4
Assemble the soil sampling 1. Place an O-ring (OB2) on the O-ring groove of a guide rod 2. Use two 1"-acme-thread-nuts to tighten the scraper rod guide screw 3. Insert the scraper rod 4. Insert the shear pin (B3) of the scraper head through the sapphire window hole. 5. Stack two PVC washers (B2), coated in vacuum grease, on the shoulder of scraper rod. If the PVC washer is larger than the acme nut hole, trim the washer. 6. Connect a needle valve on the tube fitting of the scraper rod	 AS-BIO 2 AS-BIO 3 AS-BIO 4
Assemble the sapphire window 1. Place two O-rings (OB4 and OB5) on grooves 2. Put the sapphire window (B4) and a sealing washer (B5) on it	AS-BIO 2 AS-BIO 3 AS-BIO 5

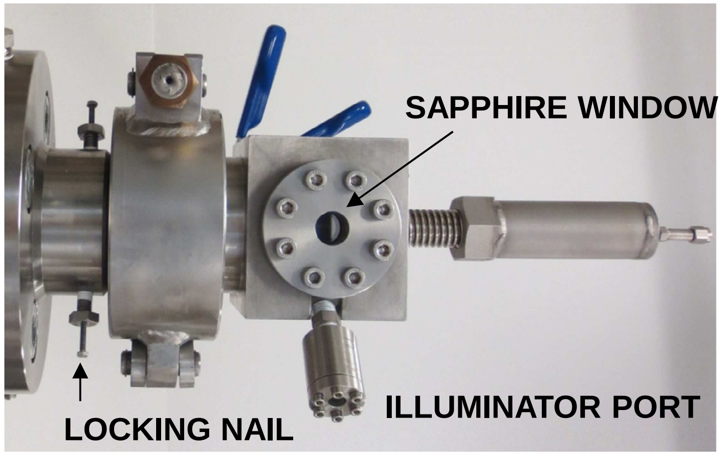
3. Fix the sapphire window with screws (B6) **Assemble the illuminator port** 1. Place an O-ring (OB8), polycarbonate disk (B7), and a sealing washer (B8) in order 2. Use screws (B8) to tighten them **Assemble the bio-reactors connected permanent fittings** 1. Place an O-ring (OB5) in the groove and cover it with a backup ring (OB6) 2. Place a sealing washer and polycarbonate disk in the bio reactor bottom 3. Screw the bio-reactor bottom on the bio-reactor **Assemble the flange and the BIO chamber** 1. Place O-rings (OB9, OB10) on each O-ring groove 2. Insert a coupler between the flange and BIO chamber 3. Close it with a C-clamp	AS-BIO 2 AS-BIO 3 AS-BIO 5 AS-BIO 2 AS-BIO 3 AS-BIO 6 AS-BIO 2 AS-BIO 3
Note • Permanent fittings on the BIO chamber are all NPTs Caution: • Be sure that the minimum engagement between the guide rod and the nut is 25 mm for the hand-driver and 2.5 mm for the locking nail • Be sure that the self-drilling thermocouple rod and locking nail does not intrude the passage while a sub-core moves	AS-BIO 7

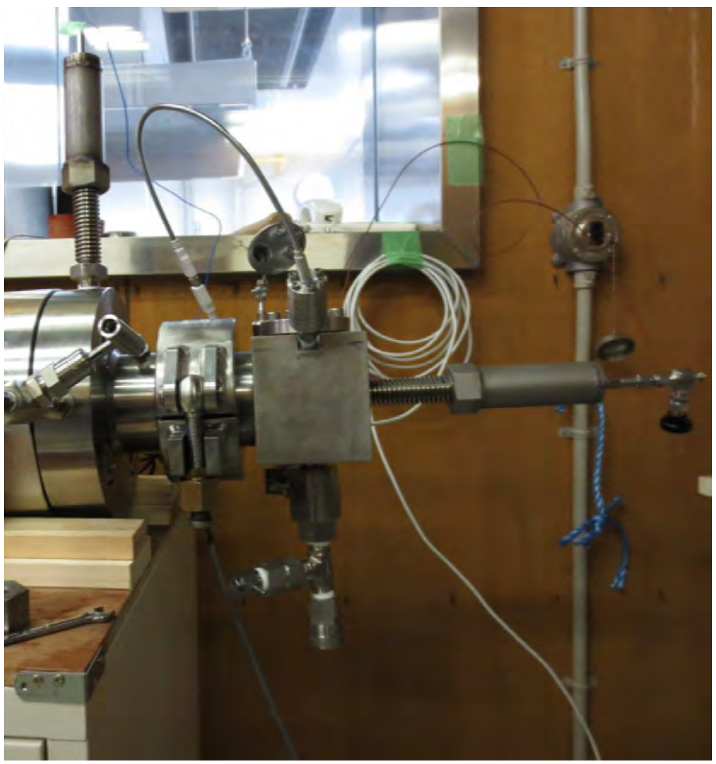
Operation

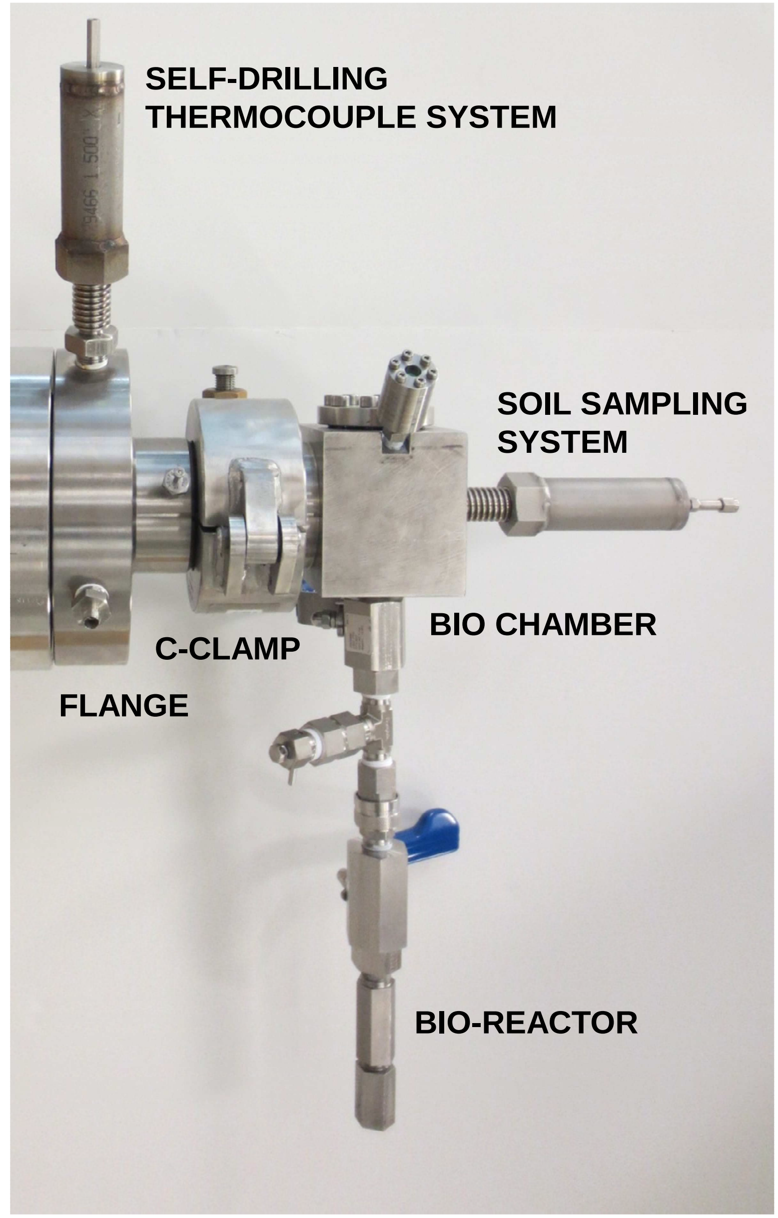
	Slide #
Early steps • Minimum specimen length is 17 cm • Prepare a manifold system to preserve bio-reactors and pressurization system • Connect sensors	OP-BIO 1 OP-BIO 2 AS-BIO 1
Sub-sampling 1. Use flange ports to fill the chamber with inert gas (i.e., argon). 2. Insert the self-drilling thermocouple rod while rotating the rod and hand driver 3. Install a thermocouple into the self-drilling thermocouple cavity until it reaches the bottom of the cavity. 4. Screw locking nails into the chamber. 5. Collect soil specimens by using the soil sampling system: use a 10 mm wrench on the hex-nut of the scraper rod to scrape the soil surface. 6. Drop collected soils into the bio-reactor: the cavity of the scraper head can be aligned with a mark on the scraper rod 7. The maximum travel length of the scraper rod should be 6cm, and the distance between the locking nails and the specimen	OP-BIO 1

face should be 14 cm 8. Inject nutrients or liquid by using the high pressure syringe through the scraper rod 9. The volume of the bio-reactor should be 15 ml, the volume of the T-shape fitting for the quick connector should be 30 ml, and the scraper rod passage should be 5 ml; when fully packed, the scraper head should hold 3 ml of soil 10. Release the pressure of the T-shaped fitting through the bleed valve before disconnecting the quick-connector 11. Close the bleed valve 12. Connect separated bio-reactor onto the manifold.	
Dissociation test 1. Displace argon gas in the chamber with water 2. Connect the gas storage filled with water 3. Open the needle valve connected with the gas storage to depressurize the chamber 4. Measure the pressure and the temperature of the chamber and the weight of discharged water from the gas storage	OP-BIO 1
Caution: • Be sure that the minimum engagement length of thread connections during operations (25 mm for the hand-driver and 2.5 mm for the locking nail) • Check the bleed valve before and after operating the quick-connector • When interconnecting the quick-connector, confirm that the connection is tight • Do not look directly inside the chamber through the sapphire window or other ports: use a reflector such as a mirror	

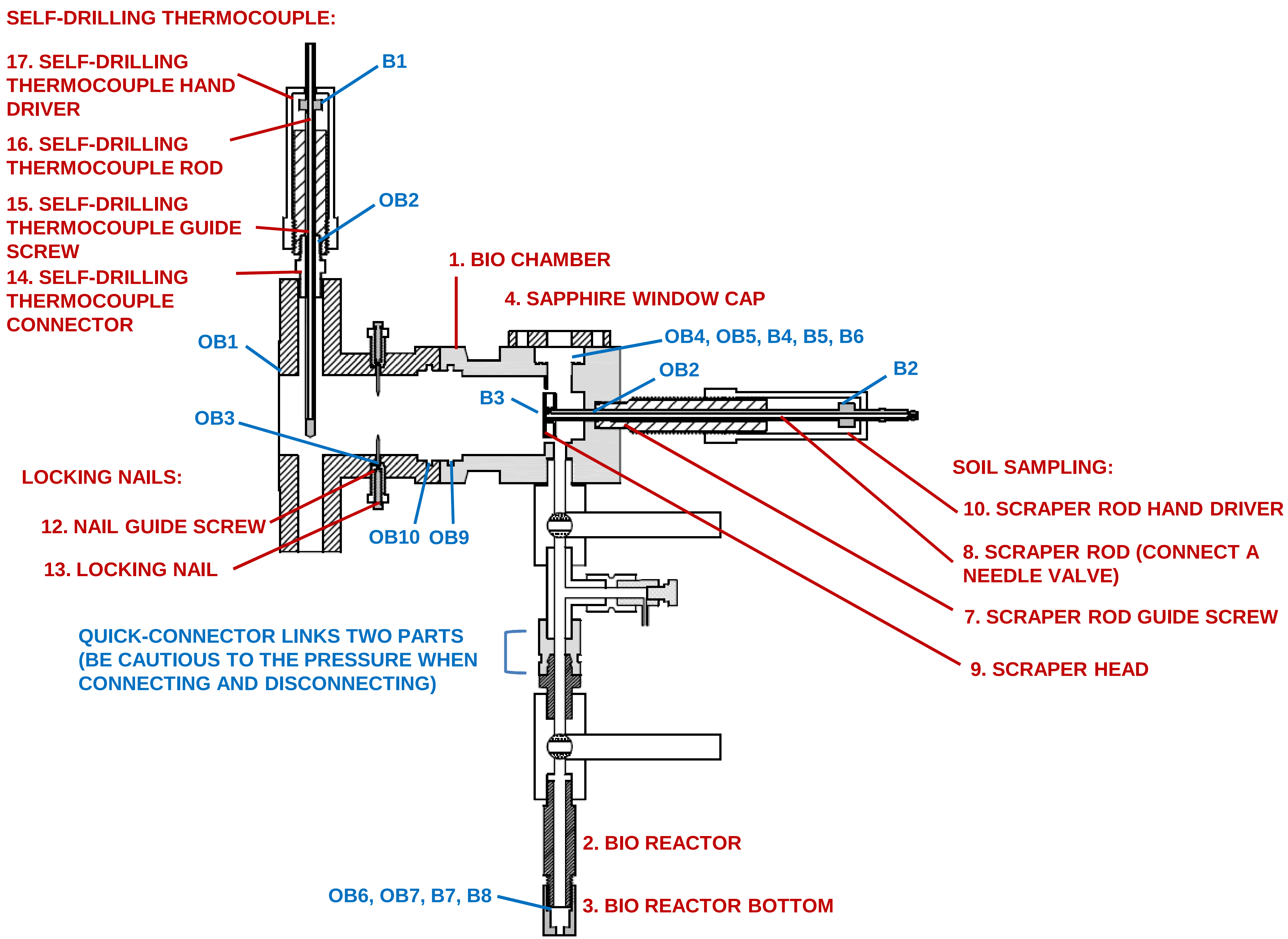
AS-BIO 1


SAPPHIRE WINDOW
LOCKING NAIL
ILLUMINATOR PORT




SELF-DRILLING
THERMOCOUPLE SYSTEM
SOIL SAMPLING
SYSTEM
BIO CHAMBER
C-CLAMP
FLANGE
BIO-REACTOR

AS-BIO 2



SELF-DRILLING THERMOCOUPLE:
17. SELF-DRILLING THERMOCOUPLE HAND DRIVER
16. SELF-DRILLING THERMOCOUPLE ROD
15. SELF-DRILLING THERMOCOUPLE GUIDE SCREW
14. SELF-DRILLING THERMOCOUPLE CONNECTOR
B1
OB2
OB1
OB3
LOCKING NAILS:
12. NAIL GUIDE SCREW
13. LOCKING NAIL
OB10
OB9
1. BIO CHAMBER
4. SAPPHIRE WINDOW CAP
OB4, OB5, B4, B5, B6
OB2
B2
B3
SOIL SAMPLING:
10. SCRAPER ROD HAND DRIVER
8. SCRAPER ROD (CONNECT A NEEDLE VALVE)
7. SCRAPER ROD GUIDE SCREW
9. SCRAPER HEAD
QUICK-CONNECTOR LINKS TWO PARTS (BE CAUTIOUS TO THE PRESSURE WHEN CONNECTING AND DISCONNECTING)
2. BIO REACTOR
3. BIO REACTOR BOTTOM
OB6, OB7, B7, B8

AS-BIO 3

No.	Item	O.D.	I.D.	Th.
B1	Thrust bearing	16 mm	8 mm	5 mm
B2	PVC washer	1"	7/16"	0.06"
B3	Shear pin	2 mm		
B4	Sapphire window	40 mm		12 mm
B5	Sealing washer	1.5"	1"	0.062"
B6	M8 screw			
B7	Polycarbonate	5/8"		1/2"
B8	Sealing washer	5/8"	5/16"	0.062"
B9	M4 screw			
OB1	O-ring	95.9 mm	84.5 mm	5.7 mm
OB2	O-ring	10.5 mm	7.5 mm	1.5 mm
OB3	O-ring	13/64"	5/64"	1/16"
OB4	O-ring	29 mm	24 mm	2.5 mm
OB5	O-ring	37 mm	32 mm	2.5 mm
OB6	O-ring	9/16"	7/16"	1/16"
OB7	Back-up ring	0.563"	0.327"	0.118"
OB8	O-ring	5/8"	1/2"	1/16"
OB9	O-ring	80 mm	72 mm	4 mm
OB10	O-ring	82 mm	72 mm	6 mm

All O-rings are buna-N.

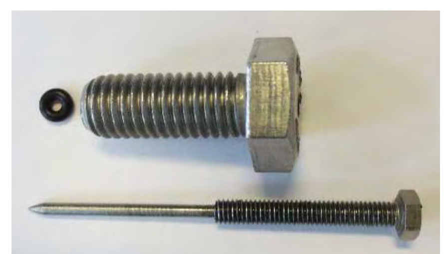
AS-BIO 4

SELF-DRILLING
THERMOCOUPLE

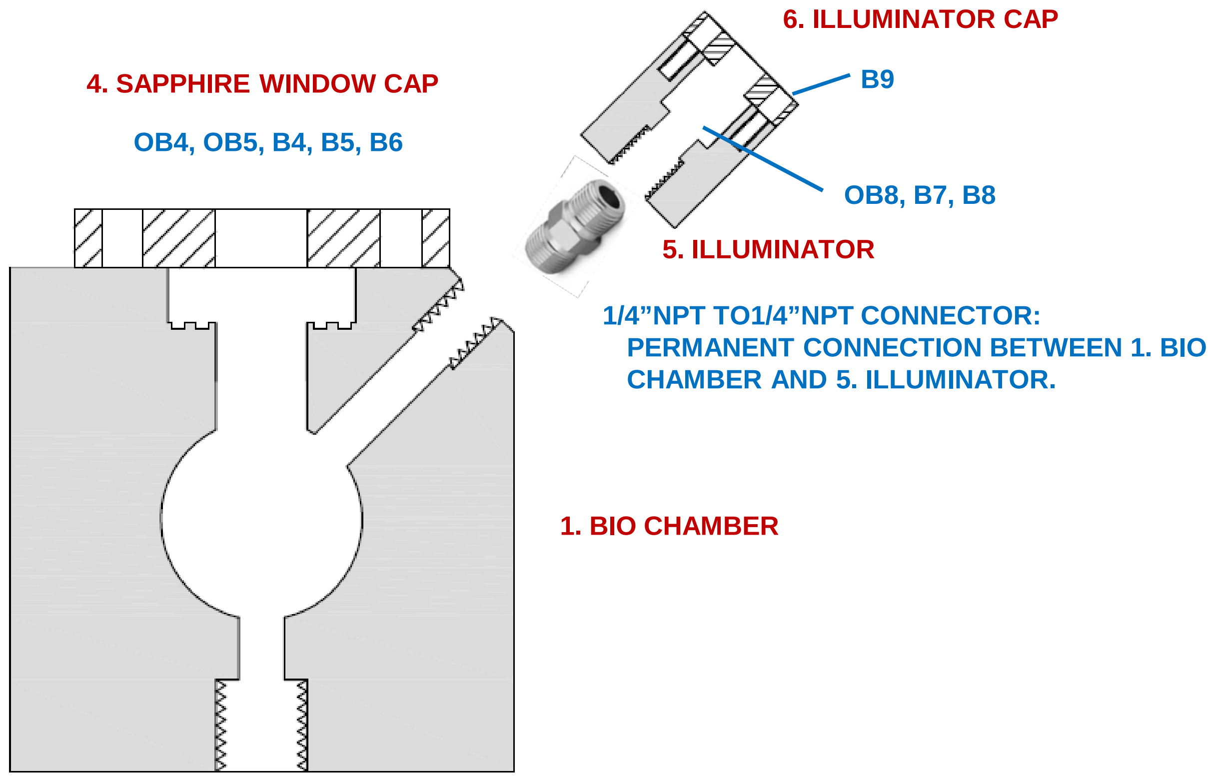
SOIL SAMPLING

TWO 1"-ACME-THREAD-NUTS

LOCKING NAIL



AS-BIO 5

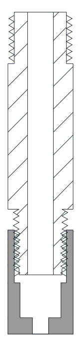

6. ILLUMINATOR CAP
4. SAPPHIRE WINDOW CAP
OB4, OB5, B4, B5, B6
B9
OB8, B7, B8
5. ILLUMINATOR
1/4”NPT TO1/4”NPT CONNECTOR:
PERMANENT CONNECTION BETWEEN 1. BIO
CHAMBER AND 5. ILLUMINATOR.
1. BIO CHAMBER

AS-BIO 6

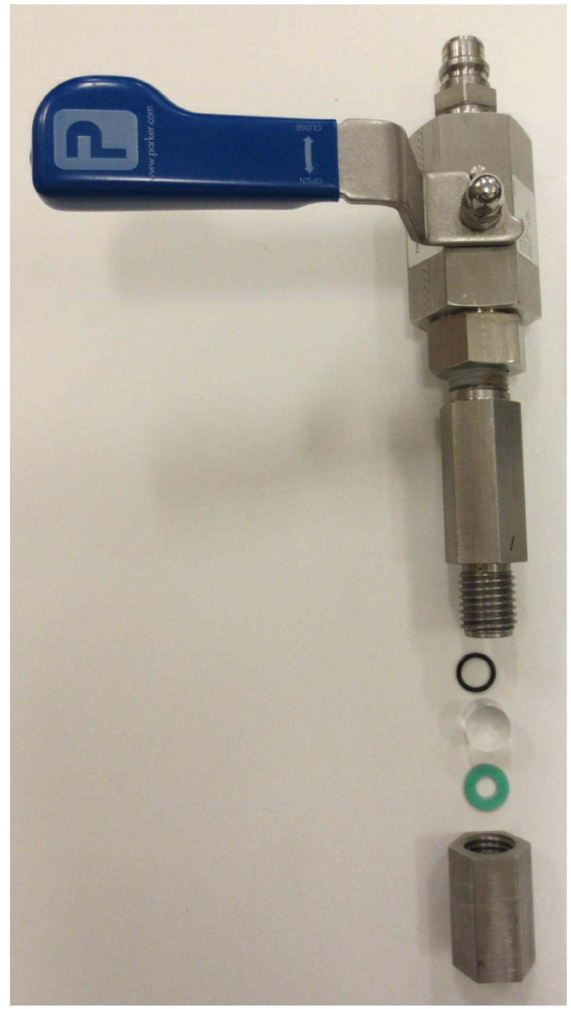
FIXED ON BIO-REACTOR PERMANANTLY

QUICK CONNECT STEM 1/2” NPT

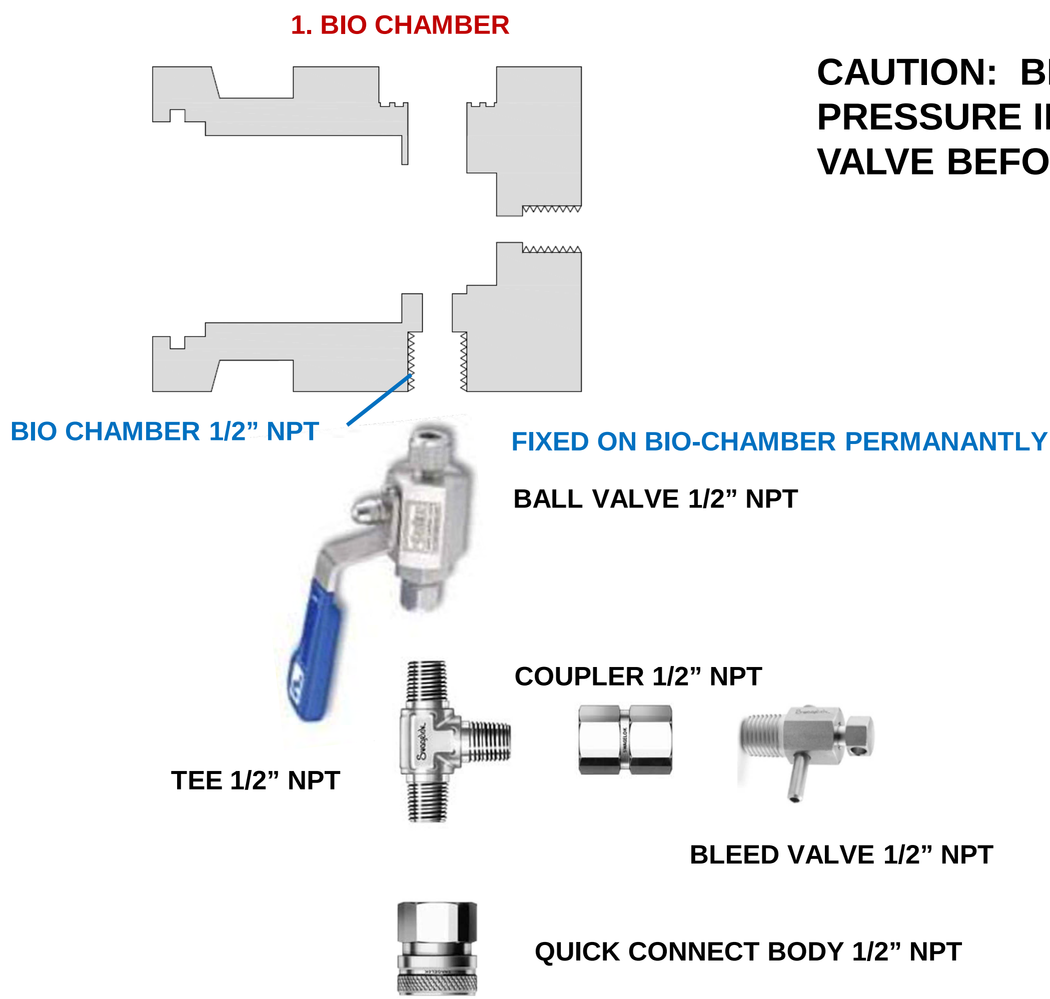
BALL VALVE 1/2” NPT



BIO REACTOR 1/2” NPT

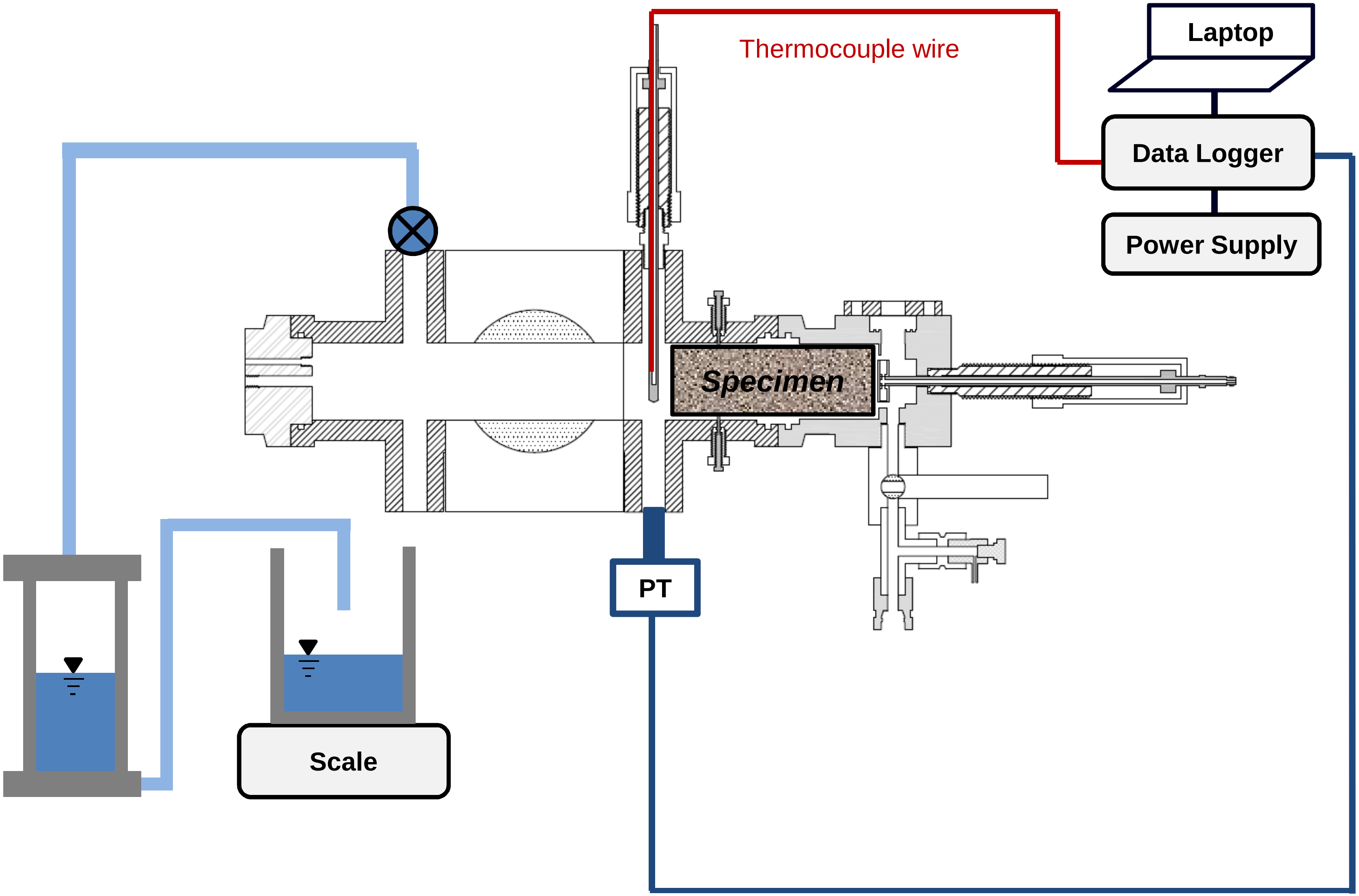


AS-BIO 7

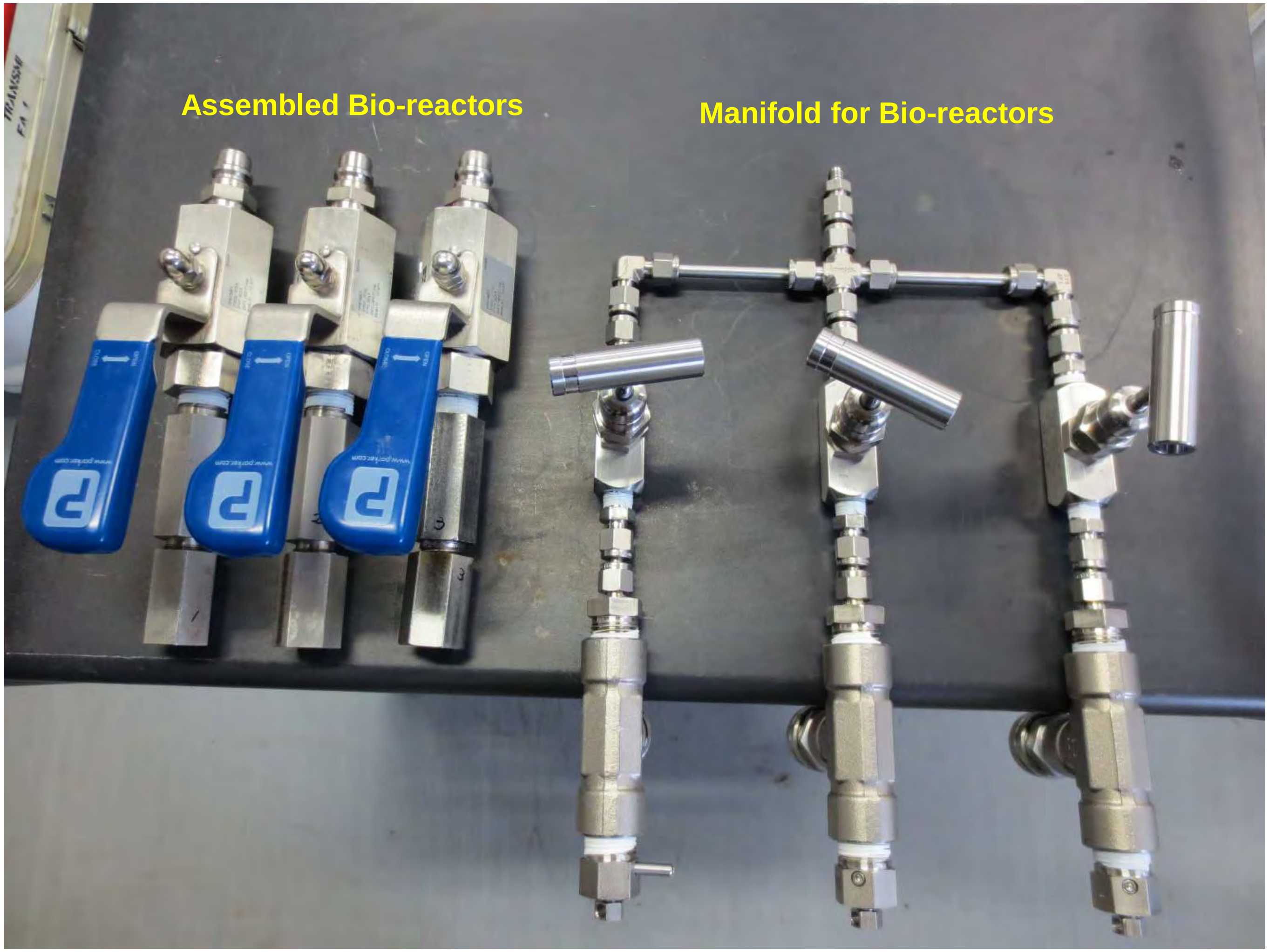


CAUTION: BE SURE TO RELEASE THE PRESSURE IN THE TEE THROUGH THE BLEEING VALVE BEFORE DISENGAGING QUICK CONNECT.

OP-BIO 1


Thermocouple wire
Laptop
Data Logger
Power Supply
Specimen
PT
Scale

OP-BIO 2



SECTION 3
PHASE IIIB TOPICAL REPORT #41330R27

Redesign of the High Pressure Temperature Corer (HPTC)

James Aumann and Chris Johnson (Aumann & Associates)

GOM Deepwater Gas Hydrate
Joint Industry Project
DOE Award DE-FC26-01NT41330

November 2012

Redesign of the
High Pressure Temperature Corer (HPTC)
Final Report

Services Agreement CW821566

November 29, 2012

PREPARED FOR

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A Division of Chevron U.S.A. Inc.

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TABLE OF CONTENTS

Redesign of the High Pressure Temperature Corer (HPTC) Final Report

Introduction

The High Pressure Temperature Corer (HPTC) was developed under contract K19259 JT between Chevron Energy Technology Company and Aumann & Associates, Inc. This contract was entered into as a task under the “Gulf of Mexico Hydrate Joint Industry Participation Agreement” (“JIP Agreement”) and funded by the United States Department of Energy (“DOE”) under Solicitation No. DE-PS26-01NT40869, Methane Hydrates. As specified in the contract and contract revisions, the HPTC was designed with the following primary features and specifications.

- Based on the successful wireline retrievable NC-PTCS design
- Operate in the special 6-5/8 NC-PTCS drill pipe and drill collars
- Maximum Operational Pressure: 5000 psi with a safety factor of 4:1
- Compatible with the Pressure Core Analysis and Transfer System (PCATS)
- Cutting shoe design that would allow the installation of a liner and the Fugro coring tools
- Core Size: Compatible with a 65mm transfer chamber x 11.5 ft long

The design work for the HPTC was completed in 2009. As the JIP began developing plans for a field test and the actual GoM operations it became apparent to the JIP that it would be desirable to make several changes to the HPTC. These changes are needed because of recently developed operational decisions and the need to increase efficiency by reducing the number of drill pipe trips.

Also, the core liner, liner threads and core catcher design incorporated in the HPTC were developed by others for the Fugro pressure coring tools. Previous experience has shown there have been failures of the liner, liner threads and catchers which sometimes prevent the core from being transferred to the PCATS. It is not clear if the damage occurs while coring or during core extraction. The problem could be worse with the longer cores produced by the HPTC. The JIP indicated it would like to conduct an investigation into the core liner material, liner thread design and core catchers to see if there might be stronger and more reliable options.

In summary, the operational changes, decisions and new requirements include:

- The need to core at depths up to 11,000 ft with pressure up to 5,500psi.
- The use of 7-5/8 OD x 6-5/8 ID high torque casing in place of the special large bore drill pipe.
- The elimination of the need to be able to run the Fugro pressure coring tools in the same BHA.
- Use Baker Hughes Inteq (BHI) PDC bits instead of a Fugro bit.
- The desire to use the BHI 8 x 5 HT outer barrel assembly components.
- Be able to run large diameter wireline logging tools without making a pipe trip. This results in a need for a 5.875 hole through the main bit.
- Drill to, or between core points without making a pipe trip. This requires the development of a center bit option.

- The desire to take conventional cores using BHI standard 6 x 4 core barrel components including the Hydrolift core catcher system.
- Study and evaluate past failures and investigate a more robust liner and liner thread.
- Develop a variety of core catchers that could be used in case problems are encountered using the Fugro basket catchers.

These requirements were structured into a contract with the following tasks:

- Redesign to Operate in Casing with BHI 8 x 5 HT coring BHA
- Redesign for 5.875 ID in Main Bit
- Redesign for 5,500 psi
- Improved Liner, Liner Thread
- Improved Core Catchers
- Conventional Core Barrel Option
- Center Bit Option
- Prepare Manuals

The results of the engineering work required to incorporate these changes into the HPTC is described in this report. The report assumes that the reader is already familiar with the work described in the HPTC Development Final Report. This report is structured according to the above tasks.

1.0 Redesign to Operate in 7-5/8 Casing with BHI 8 x 5 HT Coring BHA Components

To meet these requirements required the resizing of the HPTC latch assembly and the redesign of the outer core barrel assembly. Because of the similarities between the PTCS and the requirements of this task, we decided to start with the PTCS latch design and modify it rather than attempt to modify the smaller HPTC latch assembly developed under the previous contract. Also, the PTCS design already incorporated components from a BHI 8 x 5 coring BHA although not the HT connections.

1.1 Redesign the latch assembly to land in a larger bore.

As stated above, since this task required landing in a bore even larger than the original PTCS, we decided to start with the original PTCS latch housing rather than the smaller HPTC latch housing developed under the previous contract. We also decided to modify three of the six latch dogs to serve as a landing spider rather than increase the diameter of the landing shoulder. The landing dogs provide the no-go stop and position the latch dogs in the proper location adjacent to the groove in the landing sleeve. The redesigned latch is shown in Figure 1. The spider concept provides several benefits:

1. The working diameter can easily be changed to accommodate other drill pipe bores by simply changing the landing and latch dogs and requires no change to any of the other latch components.
2. The spider concept eliminates the need for extensive milling of flow slots because the spider concept provides sufficient flow area.

3. Using the same dog pockets in the latch body for both the landing dogs and the latch dogs insures an accurate location of the latch dogs with respect to the recess in the latch sleeve.

In the original HPTC design, an inside shoulder was added to the latch dogs to keep them from possibly falling out on the rig floor. In the current design spring pins pressed into the latch housing are used instead. They will achieve the same end result but at a much lower cost. Slots are provided in the dogs around the pins to allow the dogs to still to move in and out. This change will also allow the dogs to be changed without disassembling the latch spring retainer and piston. The same spring pins are used to hold the new landing dogs. The landing dogs do not have slots and are not free to move in and out but fixed in position to provide a firm landing shoulder. The Buna-N o-rings were also replaced by metal extension (garter) springs. ***NOTE: The new landing dog idea was abandoned in favor of the Baker Hughes proposed bottom landing bit system which made a landing shoulder in the latch unnecessary. The Baker Hughs bottom landing drive system is proprietary and could not be described in detail in this report. Contact Baker Hughes for design details.***

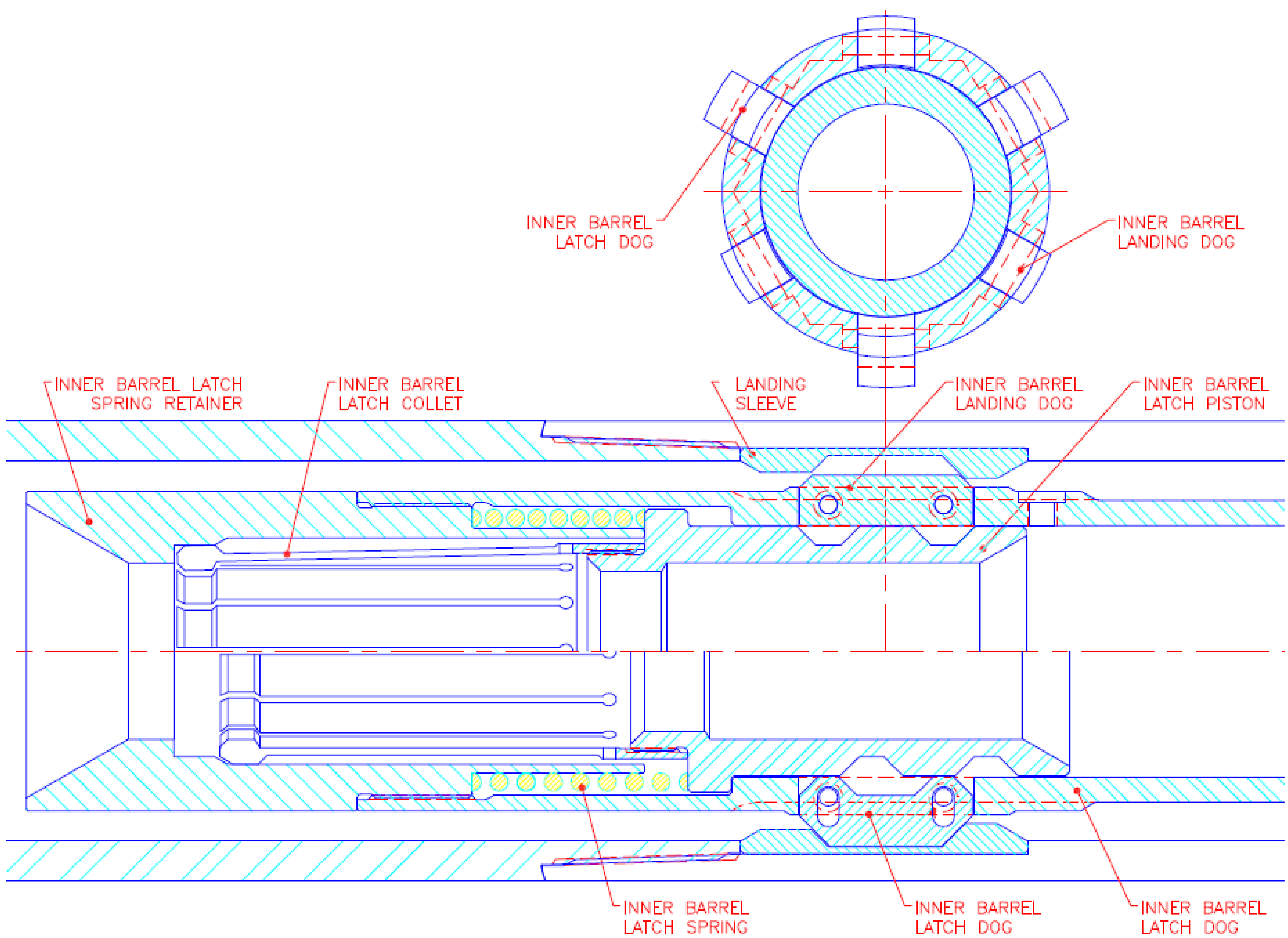


Figure 1, Redesigned latch. Note the new fixed landing dogs shown in the upper section.

1.1.2 Redesign for the Baker Hughes 8 x 5 HT connection.

To determine the required latch assembly component diameters we started with the Baker Hughes HT connection box bore ID and worked inwards from there to arrive at the required diameters for the other components and see if a 5.875 diameter pass through bore could be achieved without altering latch component proportions. The Baker Hughes HT connection is a double shouldered connection making up in the ID as well as the OD. Our preferred solution for the landing sleeve was to allow it to be sandwiched between the surfaces of the inner shoulder and carry the stress of the internal shoulder. This meant that the recess in the landing sleeve could not be larger than the internal box bore or the stress in that part would be increased in the thinner wall area. Therefore, we set the latch sleeve recess equal to the box bore ID. This coincidentally resulted in pass through bore of 6.000 in and provides a standard 0.125 drift allowance for the 5.875 proposed cutting shoe OD.

1.1.3 BHI proposed that they had a design for a bit to bit torque transmission system. Their idea also included a bottom landing inner barrel assembly which eliminated the need for a landing shoulder on the latch assembly.

1.1.4 We designed new lifting clamp and latch lock system to fit the redesigned latch housing. The new lifting clamp is based on the successful and field proven system used for the Chikyu IODP coring tools.

1.1.5 The increased diameter afforded by the change to casing and BHI BHA components allowed us to incorporate more of the original NC-PTCS field proven components with fewer modifications.

1.1.6 We used the additional space provided by the larger casing ID and BHI BHA as an opportunity to increase the diameter of some of the inner barrel components to provide for a safer and more reliable operation. This includes a safer retaining pin design and air gap insulation space closer to the original NC-PTCS design.

2.0 Increase the ID of the Bit to 5.875 in.

This change is to allow larger diameter logging tools to pass through the bit using the drill pipe or casing as a logging riser without the necessity of making a DP trip. This will enable a cored hole to be logged without drilling a new hole or attempting to re-enter the cored hole. This should result in greatly reduced rig time and cost per well.

2.1 A feasibility study was conducted to determine if a 5.875 hole in the main bit is possible considering the effects on the HPTC inner barrel assembly and cutting shoe design. BHI proposed a nested main bit to cutting shoe torque transmission system. This eliminated the need to provide a torque transmission system in the latch assembly and eliminates the drilling torque from being applied to most of the inner barrel assembly threaded connections. Their idea also included a bottom landing bit-to-bit inner barrel assembly which eliminated the need for a landing shoulder on the latch assembly. The bottom landing and bit-to-bit torque transmission system made the large hole concept feasible.

2.2 This same bottom landing and bit-to-bit torque transmission system was incorporated into the center bit system for drilling ahead.

2.3 Aumann & Associates personnel worked closely with Baker Hughes designers in developing the bits and provided guidance in the main bit and cutting shoe designs and cutting shoe body dimensions and also in selecting the cutting shoe thread. AAI personnel also carefully checked their drawings and inserted bit profiles into the layout and assembly drawing to verify proper fit with the HPTC components.

2.4 Design layouts were prepared in AutoCAD in full scale to verify the fit and functionality of the components.

2.5 The working drawings were prepared directly from the models in the full scale layouts. Assembly drawings were prepared by making blocks from the working drawings and assembling the blocks in the assembly drawing. We create the model of all close fitting parts are drawn to maximum material in order to more easily see if there are any interference fit issues.

3.0 Increase Operating Pressure to 5,500 psi

The HPTC was designed for a working pressure of 5000 psi with a 4:1 safety factor based on gas pressure vessel design. The pressure maintenance section is already designed to 7000 psi with a safety factor of 4:1 so it can be used as is. Redesign to 5,500 psi required the following:

3.1 All of the main pressure chamber parts and ball valve components were re-evaluated and redesigned where necessary. These include the double wall insulated inner tube (inner and outer tubes, inner tube extension, inner tube plug and crossover sub), and the ball valve components (ball valve housing, operator housing, and seal sub). Calculation sheets are provided in the Appendix.

3.2 Trade-off's between the diameters were carefully considered in light of the changes to the latch and larger hole through the bit.

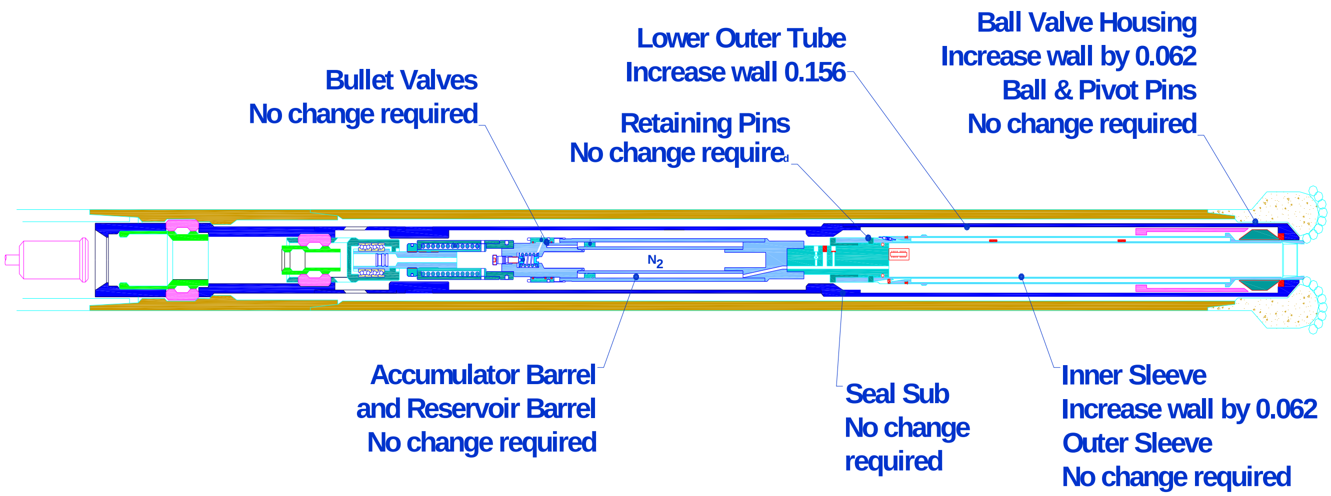


Figure 2, Final design changes required to meet the 5500psi working pressure requirement.

3.3 Design layouts were prepared to verify the fit and functionality of the components.

3.4 The changes were documented in the part and assembly drawing.

4.0 Improved Liner And Liner Thread

This task was originally included in the scope of work because it had been reported that a number of pressure coring runs had been unsuccessful because of failure of the liner thread. The liner thread had been developed in conjunction with the Fugro pressure coring tools. It incorporates a unique double tapered thread with an internal shoulder which is intended to provide a design for the relatively weak PVC that maximizes the strength under the last engaged thread. Further investigation and interviews with Fugro and Geotek personnel revealed that they had come to the conclusion that it was not the thread that had been responsible for the failed runs but that other components in those tools that incorporated this thread had failed or functioned improperly and those failures led to the failure of the liner thread.

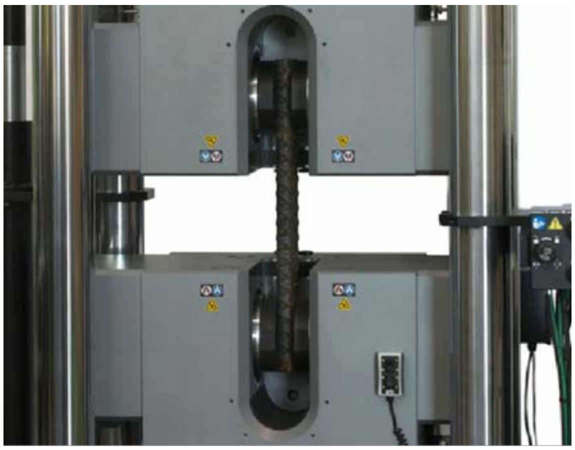
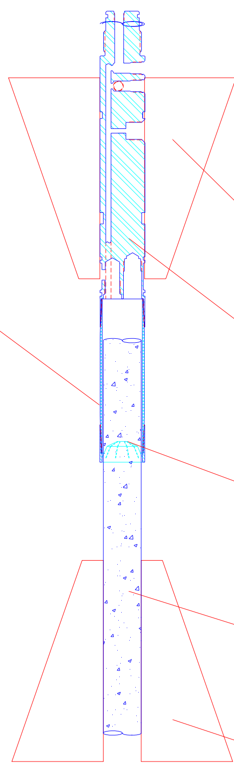


Figure 3, Instron Tensile Test Machine

In order to verify the thread and liner had adequate strength, we manufactured a simple tensile test fixture using a short section of PVC core liner threaded onto an inner tube plug at the top end and a core catcher at the bottom end. An 18” long simulated core made of plaster of Paris was inserted into the basket catcher. This assembly was placed in an Instron Tensile Testing Machine at American Testing Laboratory. The core was gripped in the lower jaw of the Instron Test Machine and the inner tube plug was gripped by the upper jaw. Tension was applied and measured and the liner, core



Instron Tensile Test Machine set up for pull testing PVC core liner and liner thread catchers and core observed. Tension was applied until the core slipped through the serrated basket catcher and the serrated basket catcher finally inverted. This occurred at about a 3000 lb load which is believed to be more than the strength of methane hydrate in tension. It also meant that the PVC core liner and core liner thread were stronger than the baskets in the basket catchers and therefore, the liner thread did not require further investigation.

5.0 Improved Catcher

As with all the coring systems, core catchers allow the core to enter easily but prevent the core from falling out during the trip out of the hole or, in the case of the HPTC, at least until the core liner is retracted and the ball valve closed. The following core catchers were designed into the HPTC:

5.1.1 Basket Catcher

The basket catcher is very similar to a mining type core catcher. It has a series of spring steel sheet metal fingers pointing up that fold open to allow the core to enter but collapse inward when the core pushes them down. This prevents the core from sliding back out. This is the catcher that has been traditionally been used in coring systems with the ability to transfer to PCATS under pressure.

Figure 4, Basket Catcher

5.1.2 Flapper Catcher

The flapper catcher was developed especially for coring in very soft sediment. The design is a downsized version of the IODP HPCS flapper core catcher. It provides a nearly full closure catcher. The flapper is curved and is cut from a piece of tubing so it matches the curve of the body. The flapper hinge ears are also machined out of the tubing. The ears engage a slot in the body. As the core enters, the flapper rotates into a matching recess in the catcher housing until it is flush with the ID of the housing. This allows the core to enter freely. As the core starts to slide out, the flapper closes to a 45 degree angle and seats against the internal wall of the core catcher housing and fully closes off the tube. A cantilever spring on the back of the flapper pushes the top of the flapper into the core to start the closing action. A thin sleeve is slid on from the pin end to the body to contain the flapper in its recess and prevent core washing. The mating part below keeps the sleeve from sliding off.

The body is a female core liner thread on the top and male core liner thread on the bottom and is five inches long shoulder to shoulder. I can be used alone with a blank core liner end on the bottom or used in tandem with a basket core catcher. If it is not used, a 5" core liner extension or slip catcher must be installed instead.

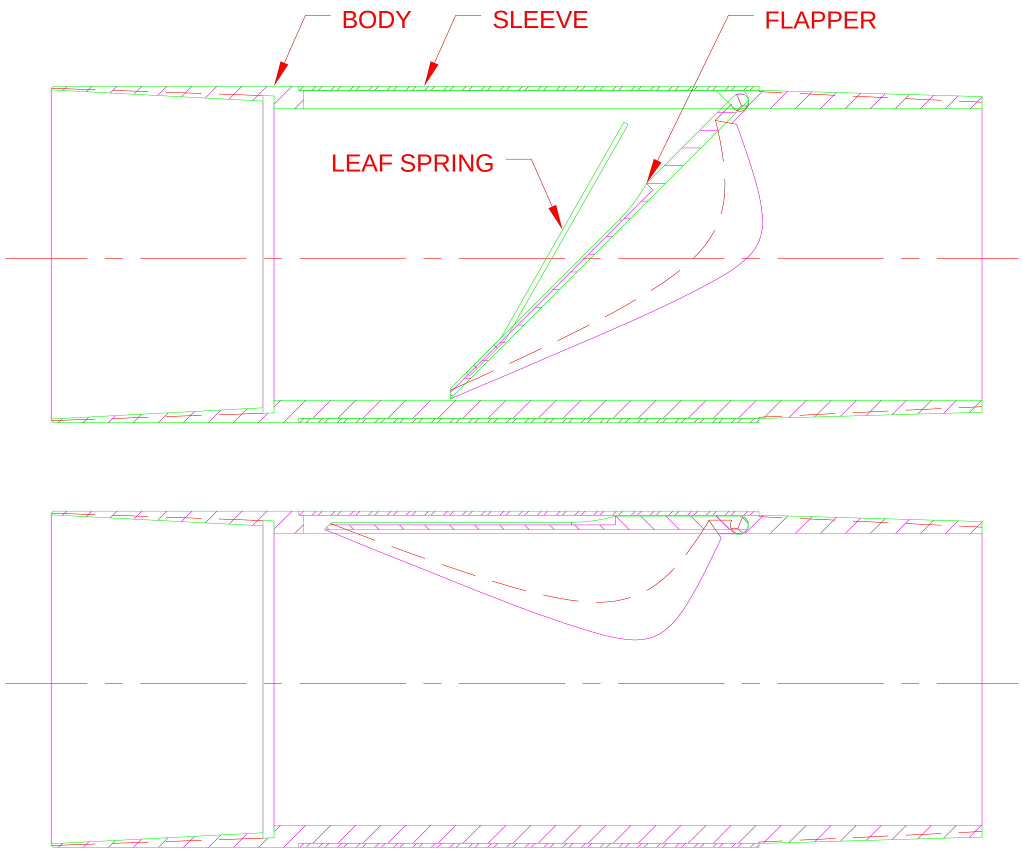
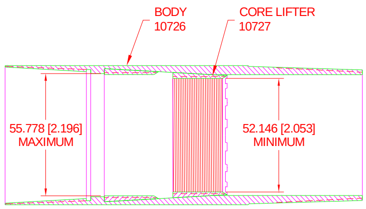


Figure 5, Flapper Core Catcher. Bottom fully open, top closed.

5.1.3 Slip Catcher

The slip catcher is similar to typical oil field core catchers. Slip (or spring) style core catchers are very similar to slips used to hold the drill pipe in the rotary table. The slip ring is called a core lifter. It is a tapered cylindrical wedge cut through longitudinally on one side. This allows the core lifter to expand when pushed up to permit movement of the core in the upward direction but, should the core start to slide out; the core lifter is pulled down with the core and compressed by the tapered mating surface. This locks the core lifter tightly onto the core to prevent it from sliding out. The core lifter is machined to a slightly smaller diameter than the core so it must expand as the core slides through it. This provides moderate gripping action to prevent from sliding backwards through it as the liner is pulled up through the ball valve after coring. A fine thread machined into the ID of the core lifter to provide even more friction between the core and core lifter.



The slip had to be designed extremely thin and with a very shallow taper in order to fit it into the limited space available. However, it can still accommodate an undersized core as small as 2.053 OD and can expand sufficiently to freely pass an oversize core up to 2.196 OD.

The spring catcher body has the same OD, length and threads as the 5" core liner extension. If the spring catcher is used, the liner extension is removed so that the overall length of the liner assembly remains the same.

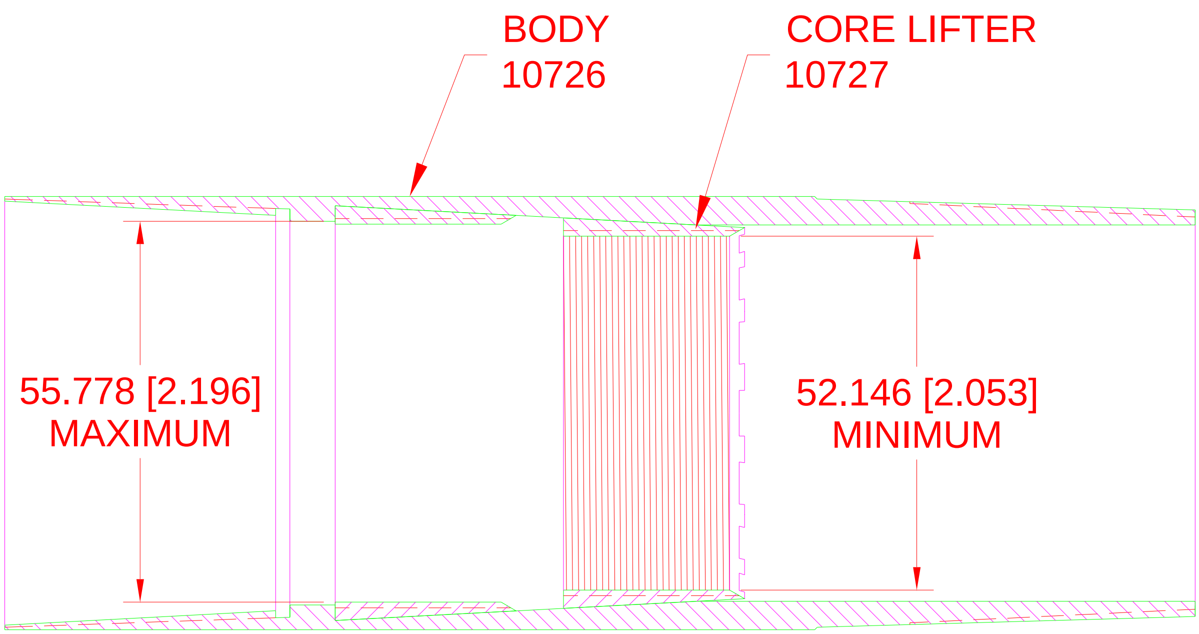


Figure 6, Slip Core Catcher for the HPTC.

APPENDIX A – Calculations

HPTC
BALL VALVE BALL (10786) - SHEAR FROM TRUNION

Required: Modify existing PTCS design for:
5000 psi working pressure with 4:1 safety factor for gas. $\text{Press} := 5000 \cdot \text{psi}$

Mat'l: 15-5 PH or 17-4 PH heat treated to H900 $\sigma ys := 170000 \cdot \text{psi}$

$$\text{DiaSeal} := 3.68 \cdot \text{in}$$

$$\frac{\pi}{4} \cdot \text{DiaSeal}^2 \cdot \text{Press} = 5.318 \times 10^4 \, \text{lbf}$$ Pressure Force on Ball

$$\text{DiaTrun} := 1.37 \cdot \text{in}$$

$$\frac{\pi}{4} \cdot \text{DiaTrun}^2 \cdot 2 = 2.948 \, \text{in}^2$$ Shear Area - Trunnions

$$\frac{\frac{\pi}{4} \cdot \text{DiaSeal}^2 \cdot \text{Press}}{\frac{\pi}{4} \cdot \text{DiaTrun}^2 \cdot 2} = 1.804 \times 10^4 \, \text{psi}$$ Shear Stress

$$\frac{\sigma ys \cdot 0.5}{\frac{\frac{\pi}{4} \cdot \text{DiaSeal}^2 \cdot \text{Press}}{\frac{\pi}{4} \cdot \text{DiaTrun}^2 \cdot 2}} = 4.712$$ Safety Factor

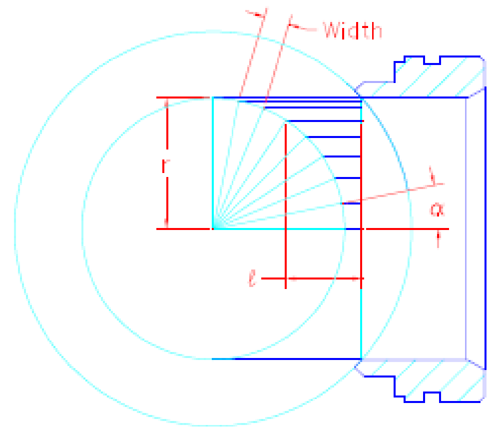
HPTC
BALL VALVE BALL (10786) - SHEAR ON THE CLOSED BALL

Required: Modify existing PTCS design for:
5000 psi working pressure with 4:1 safety factor for gas. $Press := 5000 \cdot psi$

Material: 15-5 PH or 17-4 PH heat treated to H900 $\sigma ys := 170000 \cdot psi$

Assume, all pressure load is taken by ball (none by trunnions)

The shear area of the ball is irregular as it interfaces with the hole through the ball. Use Simpson's formula for calculating irregular areas. The technique divides the area into equal width segments. the length of each segment is measured or calculated. The area of each sebment is calculated and summed using the formula. Divide a quadrant of the shear circle into 8 segments and multiply the result by four to obtain the total area.



$DiaSeal := 3.68 \cdot in$

$r := 1.656 \cdot in$ The radius of the hole through the ball.

$\alpha := \frac{90 \cdot deg}{8}$ $\alpha = 11.25\,deg$ The angle of each segment.

$Width := \frac{2 \cdot \pi \cdot r}{32}$ $Width = 0.325\,in$ The length of the arc of the segment.

$l_0 := 0.216 \cdot in$ The length from the hole to the edge of the ball at the shear line.

$i := 1, 2 .. 8$

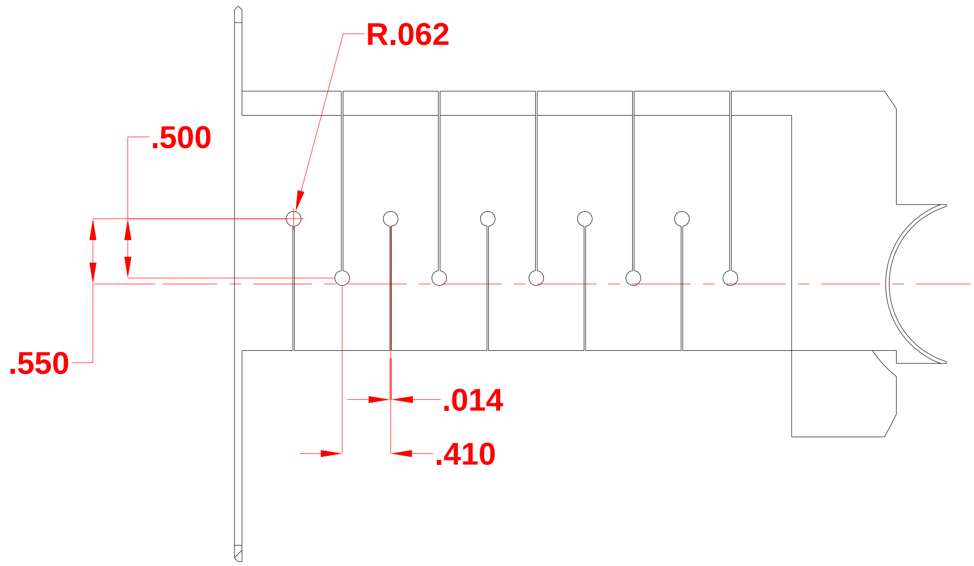
$l_i := r \cdot (1 - \cos(i \cdot \alpha)) + l_0$ The lengths of segments 1 through 8.

$A_{shear} := 4 \cdot \frac{Width}{3} \cdot \left[\left(l_0 + l_8\right) + 4 \cdot \left(l_1 + l_3 + l_5 + l_7\right) + 2 \cdot \left(l_2 + l_4 + l_6\right) \right]$ $A_{shear} = 8.509\,in^2$

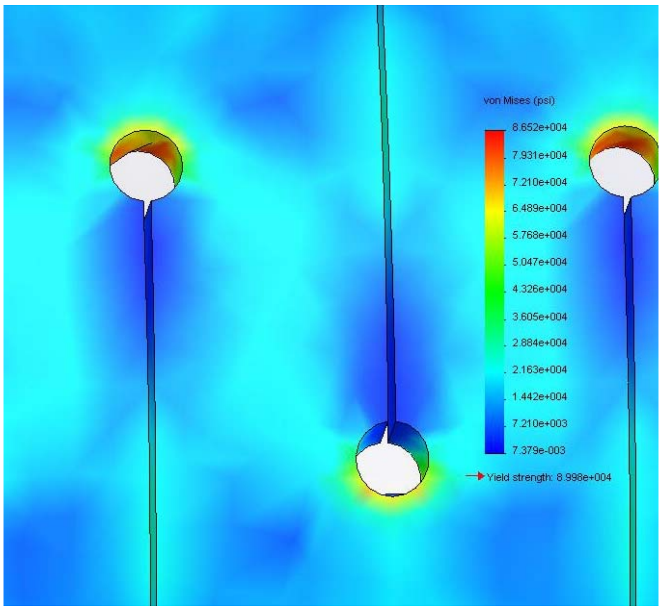
$$\frac{\frac{\pi}{4} \cdot DiaSeal^2 \cdot Press}{A_{shear}} = 6.25 \times 10^3\,psi$$ Shear Stress

$$\frac{\sigma ys \cdot .5}{\frac{\pi}{4} \cdot DiaSeal^2 \cdot Press} = 13.6$$ Safety Factor

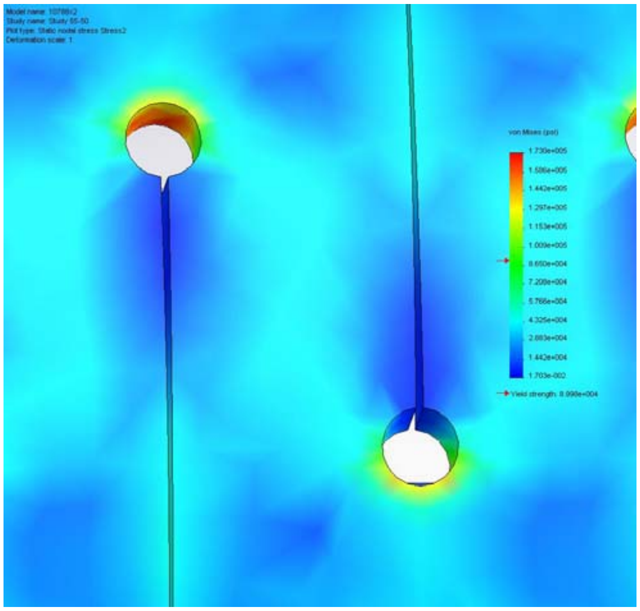
HPTC
Ball Valve Spring Retainer, 10788
Calculations by Finite Element Analysis (FEA)



Spring Retainer final configuration recommendations based on the FEA shown below.



Resultant force at .020 deflection = 581 lbs by FEA.



Resultant force at .040 deflection = 1161 lbs by FEA.

HPTC
Operator Housing, 10764

Required: Modify existing PTCS design for:
1. 5000 psi working pressure with 4:1 safety factor for gas.
2. Reduce OD to 5.375 for more clearance and to standardize.
3. Reduce ID for higher pressure and smaller core (smaller ball valve).

Given :

$P := 5000psi$

$OD := 5.375in$

$\sigma y := 110000\frac{lbf}{in^2}$ Yield stress of 4142 at Rc 28-32

Solve by trial and error:

$ID := 4.125 \cdot in$ $Wall := \frac{OD - ID}{2}$ $Wall = 0.625\,in$

$\sigma hoop := P \cdot \left(\frac{OD^2 + ID^2}{OD^2 - ID^2}\right)$ $\sigma axial := \frac{ID^2 \cdot P}{OD^2 - ID^2}$ $\sigma radial := -P$

$\sigma hoop = 1.933 \times 10^4\,psi$ $\sigma axial = 7.164 \times 10^3\,psi$ $\sigma radial = -5 \times 10^3\,psi$

$$\sigma equiv := \frac{2^{.5}}{2} \cdot \left[\left[(\sigma hoop - \sigma axial)^2 + (\sigma hoop - \sigma radial)^2 + (\sigma axial - \sigma radial)^2\right]^{0.5}\right]$$

$\sigma equiv = 21069\,psi$

$SF := \frac{\sigma y}{\sigma equiv}$ $SF = 5.221$

HPTC
BALL VALVE PIVOT PIN (10181)

Required: Check existing PTCS design for:
5000 psi working pressure with 4:1 safety factor for gas. $\text{Press} := 5000 \cdot \text{psi}$

Mat'l: 15-5 PH or 17-4 PH heat treated to H900 $\sigma ys := 170000 \cdot \text{psi}$

$$\text{DiaPin} := .87 \cdot \text{in}$$

$$\frac{\pi}{4} \cdot \text{DiaPin}^2 \cdot \text{Press} = 2.972 \times 10^3 \, \text{lbf}$$ Pressure Load on Pin

$$.365\text{in} \cdot (.25\text{in} - .015\text{in}) \cdot 2 = 0.172 \, \text{in}^2$$ Shear area on pin ears

$$\frac{\frac{\pi}{4} \cdot \text{DiaPin}^2 \cdot \text{Press}}{.365\text{in} \cdot (.25\text{in} - .015\text{in}) \cdot 2} = 1.733 \times 10^4 \, \text{psi}$$ Shear Stress

$$\frac{\sigma ys \cdot .5}{\frac{\frac{\pi}{4} \cdot \text{DiaPin}^2 \cdot \text{Press}}{.365\text{in} \cdot (.25\text{in} - .015\text{in}) \cdot 2}} = 4.906$$ Safety Factor

HPTC

INNER SLEEVE, INNER TUBE (10713)

Required: Modify existing PTCS design for:

1. 5000 psi working pressure with 4:1 safety factor for gas.
2. Reduce OD to 5.375 for more clearance and to standardize.
3. Reduce ID if necessary for higher pressure.

Given :

$P := 5000\text{psi}$

$OD := 3.062\text{in}$

Solve by trial and error:

$\sigma y := 120000 \frac{\text{lbf}}{\text{in}^2}$ Yield stress of 4142-4145 at Rc 32-36

$ID := 2.559 \cdot \text{in}$ $\quad Wall := \frac{OD - ID}{2}$ $\quad Wall = 0.251\,\text{in}$

$\sigma hoop := P \cdot \left(\frac{OD^2 + ID^2}{OD^2 - ID^2} \right)$ $\quad \sigma axial := 0 \cdot \text{psi}$ $\quad \sigma radial := -P$

$\sigma hoop = 2.816 \times 10^4\,\text{psi}$ $\quad \sigma axial = 0\,\text{psi}$ $\quad \sigma radial = -5 \times 10^3\,\text{psi}$

$$\sigma equiv := \frac{2^{.5}}{2} \cdot \left[\left[(\sigma hoop - \sigma axial)^2 + (\sigma hoop - \sigma radial)^2 + (\sigma axial - \sigma radial)^2 \right]^{0.5} \right]$$

$\sigma equiv = 30965\,\text{psi}$

$SF := \frac{\sigma y}{\sigma equiv}$ $\quad SF = 3.875$

HPTC
OUTER SLEEVE, 10712 - COLLAPSE

Required: Modify existing PTCS design for:
1. 5000 psi working pressure. Note that a 2:1 safety factor is adequate because collapse of t tube would not result in personnal injury.
2. Reduce OD for adequate clearance with the lower outer tube.
3. Reduce ID for higher pressure and smaller core (smaller ball valve).

Given :

$P := 5000psi$

Material : Alloy Steel, AISI 4140, 4142 or 4145 oil quenched and tempered to Rc 32-36

Hardness $Rc := 31.5$ Correlates to Tensile Strength $\sigma t := 140000 \cdot ps$ (psi)

Assume Yield to Tensile Ratio of 0.875

Material Yield Strength $\sigma y := 0.875 \sigma t$

$\sigma y = 122500\,psi$

Outer Diameter $Do := 4.25 \cdot in$

Inner Diameter $Di := 3.625 \cdot in$

Thickness $t := \dfrac{Do - Di}{2}$ $t = 0.313\,in$

Diameter to Thickness $r := \dfrac{Do}{t}$ $r = 13.6$

Using API RP 7G Equation for Pipe Collapse
Transition Zone between Elastic and Plastic Range
For 105 ksi Minimum Material with
D/t Ratio between 20.70 to 26.89

$A := 2.053$ $B := 0.0515$

$$P_c := \sigma y \cdot \left[\left(\frac{A}{\frac{Do}{t}} \right) - B \right] \qquad P_c = 12183\,psi$$

$$SafetyFactor := \frac{P_c}{P} \qquad SafetyFactor = 2.437$$

HPTC
OUTER SLEEVE, 10712 - COLLAPSE

Required: Modify existing PTCS design for:
1. 5000 psi working pressure. Note that a 2:1 safety factor is adequate because collapse of this tube would not result in personnal injury.
2. Reduce OD for adequate clearance with the lower outer tube.
3. Reduce ID for higher pressure and smaller core (smaller ball valve).

Given :

$P := 5000psi$

Material : Alloy Steel, AISI 4140, 4142 or 4145 oil quenched and tempered to Rc 32-36

Hardness $Rc := 31.5$ Correlates to Tensile Strength $\sigma t := 140000 \cdot ps$ (psi)

Assume Yield to Tensile Ratio of 0.875

Material Yield Strength $\sigma y := 0.875\sigma t$

$\sigma y = 122500\,psi$

Outer Diameter $Do := 4.25 \cdot in$

Inner Diameter $Di := 3.625 \cdot in$

Thickness $t := \frac{Do - Di}{2}$ $t = 0.313\,in$

Diameter to Thickness $r := \frac{Do}{t}$ $r = 13.6$

Using API RP 7G Equation for Pipe Collapse
Transition Zone between Elastic and Plastic Range
For 105 ksi Minimum Material with
D/t Ratio between 20.70 to 26.89

$A := 2.053$ $B := 0.0515$

$$P_c := \sigma y \cdot \left[\left(\frac{A}{\frac{Do}{t}}\right) - B\right] \qquad P_c = 12183\,psi$$

$$SafetyFactor := \frac{P_c}{P} \qquad SafetyFactor = 2.437$$

HPTC

OUTER SLEEVE EXTENSION, 10705 - COLLAPSE

Required: Modify existing PTCS design for:

1. 5000 psi working pressure. Note that a 2:1 safety factor is adequate because collapse of this tube would not result in personnal injury.
2. Reduce OD for adequate clearance with the lower outer tube.
3. Reduce ID for higher pressure and smaller core (smaller ball valve).

Given :

$P := 5000psi$

Material : 15-5PH or 17-4PH age hardenened to H900

$\sigma y := 170000 \cdot psi$ Material Yield Strength

Outer Diameter $Do := 3.5625 \cdot in$

Inner Diameter $Di := 3.188 \cdot in$

Thickness $t := \frac{Do - Di}{2}$ $t = 0.187\,in$

Diameter to Thickness $r := \frac{Do}{t}$ $r = 19.025$

Using API RP 7G Equation for Pipe Collapse Transition Zone between Elastic and Plastic Range:
For 105 ksi Minimum Material with
D/t Ratio between 20.70 to 26.89

$A := 2.053$ $B := 0.0515$

$$P_c := \sigma y \cdot \left[\left(\frac{A}{\frac{Do}{t}}\right) - B\right] \qquad P_c = 9589\,psi$$

$$SafetyFactor := \frac{P_c}{P} \qquad SafetyFactor = 1.918$$

HPTC
LOWER OUTER TUBE (10706)

Required: Modify existing PTCS design for:
1. 5000 psi working pressure with 4:1 safety factor for gas.
2. Reduce OD to 5.375 for more clearance and to standardize.
3. Reduce ID if necessary for higher pressure.

Given :

$P := 5000psi$

$OD := 5.375in$

Solve by trial and error:

$\sigma y := 120000 \frac{lbf}{in^2}$ Yield stress of 4142-4145 at Rc 32-36

$ID := 4.500 \cdot in$ $Wall := \frac{OD - ID}{2}$ $Wall = 0.438\,in$

$\sigma hoop := P \cdot \left(\frac{OD^2 + ID^2}{OD^2 - ID^2} \right)$ $\sigma axial := \frac{ID^2 \cdot P}{OD^2 - ID^2}$ $\sigma radial := -P$

$\sigma hoop = 2.844 \times 10^4\,psi$ $\sigma axial = 1.172 \times 10^4\,psi$ $\sigma radial = -5 \times 10^3\,psi$

$$\sigma equiv := \frac{2^{.5}}{2} \cdot \left[\left[(\sigma hoop - \sigma axial)^2 + (\sigma hoop - \sigma radial)^2 + (\sigma axial - \sigma radial)^2 \right]^{0.5} \right]$$

$\sigma equiv = 28956\,psi$

$SF := \frac{\sigma y}{\sigma equiv}$ $SF = 4.144$

HPTC
Seal Sub, 10707

Required: Modify existing PTCS design for:
1. 5000 psi working pressure with 4:1 safety factor for gas.
2. Reduce OD to 5.375 for more clearance and to standardize.
3. Reduce ID for higher pressure and smaller core (smaller ball valve).

Given :

$P := 5000psi$

$OD := 5.375in$

$\sigma y := 170000psi$ For 17-4 PH SS heat treated to H900

Solved by trial and error. Note: Smaller ID required than needed for adequate safety factor in order to seal against the smaller crossover sub.

$ID := 4.125 \cdot in$ $\quad Wall := \dfrac{OD - ID}{2}$ $\quad Wall = 0.625\,in$

$\sigma hoop := P \cdot \left(\dfrac{OD^2 + ID^2}{OD^2 - ID^2} \right)$ $\quad \sigma axial := \dfrac{ID^2 \cdot P}{OD^2 - ID^2}$ $\quad \sigma radial := -P$

$\sigma hoop = 1.933 \times 10^4\,psi$ $\quad \sigma axial = 7.164 \times 10^3\,psi$ $\quad \sigma radial = -5 \times 10^3\,psi$

$$\sigma equiv := \frac{2^{.5}}{2} \cdot \left[\left[(\sigma hoop - \sigma axial)^2 + (\sigma hoop - \sigma radial)^2 + (\sigma axial - \sigma radial)^2 \right]^{0.5} \right]$$

$\sigma equiv = 21069\,psi$

$SF := \dfrac{\sigma y}{\sigma equiv}$ $\quad SF = 8.069$

HPTC

10607 RETAINING PINS

GIVEN:

$P := 5000 \cdot psi$ Working pressure

$D_{plug} := 2.56 \cdot in$ Seal diameter of the Plug to be retained

$D_{pin} := 0.620 \cdot in$ Retaining Pin diameter

$L_{pin} := .19 \cdot in$ Retaining Pin engagement length

$n := 6$ Number of retaining pins

$S_u := 210000 \cdot psi$ Ultimate stress of the pin material, BeCu

$S_y := 145000 \cdot psi$ Yield stress of the material

$\tau_y := .5 \cdot S_y$ $\quad \tau_y = 72500\,psi$ Yield stress in shear

CHECK THE RETAINING PIN SHEAR STRENGTH:

$$A_{plug} := \pi \cdot \frac{D_{plug}^{2}}{4} \qquad A_{plug} = 5.147\,in^2$$

$F_{plug} := A_{plug} \cdot P$ $\quad F_{plug} = 25736\,lbf$ The force pushing on the IT plug due to pressure P

Calculate the shear area of the pins:

$$A_{shear} := n \pi \cdot \left(\frac{D_{pin}}{2}\right)^2 \qquad A_{shear} = 1.811\,in^2$$

Calculate the shear stress and factor of safety:

$$\tau := \frac{F_{plug}}{A_{shear}} \qquad \tau = 1.421 \times 10^4\,psi$$

$$SF_{shear} := \frac{\tau_y}{\tau} \qquad SF_{shear} = 5.103$$

Calculate the bearing stress and factor of safety:

$$A_b := n \cdot D_{pin} \cdot L_{pin} \qquad A_b = 0.707\,in^2 \qquad D_{pin} \cdot L_{pin} = 0.118\,in^2$$

$$S_{bearing} := \frac{F_{plug}}{A_b} \qquad S_{bearing} = 3.641 \times 10^4\,psi$$

$$SF_{bearing} := \frac{S_y}{S_{bearing}} \qquad SF_{bearing} = 3.982$$

Check the thread engagement is adequate to prevent the threads from shearing off under pressure.

$L_{thread} := .103in$

$F_{pin} := D_{pin}^{2} \cdot \frac{\pi}{4} \cdot P$ $\qquad F_{pin} = 1510\,lbf$

$D_{pitch} := .700 \cdot in$ for a 3/4-16UNF thread.

$A_{thread} := \pi \cdot D_{pitch} \cdot L_{thread} \cdot 0.5$ $\qquad A_{shear} = 1.811\,in^{2}$ The shear area.

$\tau_{thread} := \frac{F_{pin}}{A_{thread}}$ $\qquad \tau_{thread} = 13329\,psi$

$SF_{thread} := \frac{\tau_y}{\tau_{thread}}$ $\qquad SF_{thread} = 5.439$

Finally, check how much torque it will take to turn the pins to remove them under pressure. First calculate the force created by the seal on the pin, then use the screw jack formula to determine the required torque:

$p := \frac{1 \cdot in}{16}$ $\qquad p = 0.063\,in$ Thread pitch

$\mu := .08$ Coefficient of friction

$r := \frac{D_{pitch}}{2}$ Calculated pitch radius of thread

$T := F_{pin} \cdot r \cdot \frac{2 \cdot \pi \cdot \mu \cdot r + p}{2 \cdot \pi \cdot r - \mu \cdot p}$ $\qquad T = 57.413\,in \cdot lbf$ To screw in under pressure

$T := F_{pin} \cdot r \cdot \frac{2 \cdot \pi \cdot \mu \cdot r - p}{2 \cdot \pi \cdot r + \mu \cdot p}$ $\qquad T = 27.19\,in \cdot lbf$ To remove under pressure

PTCS/HPTC
10607 LARGE BULLET VALVE

GIVEN:

$P := 5000 \cdot psi$ Working pressure

$S_u := 210000 \cdot psi$ Ultimate stress of the pin material, BeCu

$S_y := 145000 \cdot psi$ Yield stress of the material

$\tau_y := .5 \cdot S_y$ $\tau_y = 72500\, psi$ Yield stress in shear

$D_{oring} := 0.562in$ $D_{thread} := .687in$ $L_{thread} := .26in$

Calculate the force generated by the pressure acting on the o-ring seal:

$$P_{force} := P \cdot \frac{\pi}{4} \cdot D_{oring}{}^2 \qquad P_{force} = 1240\, lbf$$

Calculate the shear area of the threads.:

$$A_{shear} := \pi \cdot D_{thread} L_{thread} \cdot .6 \qquad A_{shear} = 0.337\, in^2$$

Calculate the shear stress and factor of safety:

$$\tau := \frac{P_{force}}{A_{shear}} \qquad \tau = 3684\, psi$$

$$SF_{shear} := \frac{\tau_y}{\tau} \qquad SF_{shear} = 19.681$$

HPTC
10721 Accumulator Barrel

$P := 7000 \frac{lbf}{in^2}$ Assumes using a booster pump to charge the Nitrogen reservoir.

$\sigma y := 170000 \frac{lbf}{in^2}$ Yield stress of 17-4PH at H900

$OD := 4.25 in$ Accumulator Barrel OD

$ID := 3.56 \cdot in$ Accumulator Barrel ID

$\sigma hoop := P \cdot \left(\frac{OD^2 + ID^2}{OD^2 - ID^2} \right)$ $\sigma axial := \frac{ID^2 \cdot P}{OD^2 - ID^2}$ $\sigma radial := -P$

$\sigma hoop = 3.993 \times 10^4 psi$ $\sigma axial = 1.646 \times 10^4 psi$ $\sigma radial = -7 \times 10^3 psi$

$$\sigma equiv := \frac{2^{.5}}{2} \cdot \left[\left[(\sigma hoop - \sigma axial)^2 + (\sigma hoop - \sigma radial)^2 + (\sigma axial - \sigma radial)^2 \right]^{.5} \right]$$

$\sigma equiv = 40638 psi$

$SF := \frac{\sigma y}{\sigma equiv}$

$SF = 4.183$

HPTC
10720 Reservoir Barrel

$P := 7000 \frac{lbf}{in^2}$ Assumes using a booster pump to charge the Nitrogen reservoir.

$\sigma y := 170000 \frac{lbf}{in^2}$ Yield stress of 17-4PH at H900

$P := 7000 \frac{lbf}{in^2}$ (Assume could use 6,000 psi N2 bottle + charege pump)

$\sigma y := 170000 \frac{lbf}{in^2}$ Yield stress of 17-4PH at H900

$R_{OD} := 2.625in$ Reservoir OD

$R_{ID} := 2.125 \cdot in$ Reservoir ID

$\sigma hoop := P \cdot \left(\frac{R_{OD}{}^2 + R_{ID}{}^2}{R_{OD}{}^2 - R_{ID}{}^2} \right)$ $\sigma axial := 0psi$ $\sigma radial := -P$

$\sigma hoop = 3.362 \times 10^4 psi$ $\sigma axial = 0 \, psi$ $\sigma radial = -7 \times 10^3 psi$

$$\sigma equiv := \frac{2^{0.5}}{2} \cdot \left[\left[(\sigma hoop - \sigma axial)^2 + (\sigma hoop - \sigma radial)^2 + (\sigma axial - \sigma radial)^2 \right]^{0.5} \right]$$

$\sigma equiv = 3.761 \times 10^4 psi$

$SF := \frac{\sigma y}{\sigma equiv}$

$SF = 4.52$

HPTC
ACCUMIULATOR AND RESERVOIR VOLUME CALCULATIONS

$R_{OD} := 2.625in$ Reservoir OD

$R_{ID} := 2.125 \cdot in$ Reservoir ID

$Lres := 18.44in$ Reservoir Length

$Lpis := 1.75in$ Separator Piston Length

$OD := 4.25in$ Accumulator Barrel OD

$ID := 3.56 \cdot in$ Accumulator Barrel ID

$Lacc := 21.38in$ Accumulator Length

$Vends := 13.5in^3$

Accumulator Volume

$$Vres := \left[\frac{\pi}{4} \cdot \left(R_{ID}^2\right) \cdot Lres\right] + Vends$$

$$Vacc := \frac{\pi}{4} \cdot \left(ID^2 - R_{OD}^2\right) \cdot (Lacc - Lpis)$$

$Vres = 78.899\,in^3$

$Vacc = 89.158\,in^3$

$Pres := 7000psi$ Initial pressure in the reservoir

$$Pend := \frac{Pres \cdot Vres}{Vacc + Vres}$$

$Pend = 3286psi$ Pressure at end of accumulator stroke

$$V5000 := \frac{Pres \cdot Vres}{5000psi} - Vres$$

$V5000 = 31.559\,in^3$ Accumulator volume where pressure reaches 5000 psi

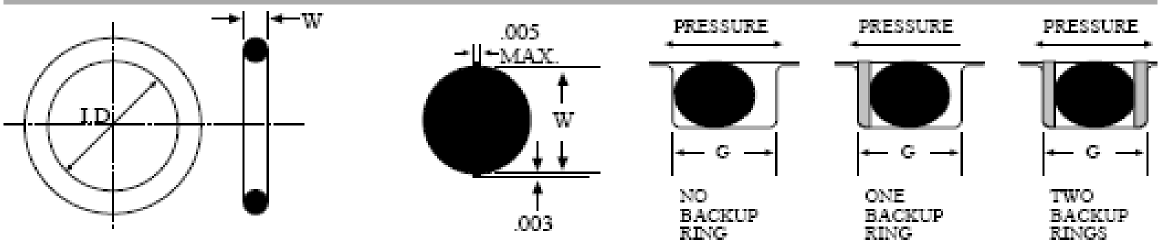
APPENDIX B – Specification Cut Sheets

1. O-ring Design Chart (HydroPak)
2. Fugro Core Catcher,W16-55-05-04/0
3. Fugro Core Liner, W16-55-05-02/0
4. Sensotec Model NK Portable Display for Pressure Transducers
5. Sensotec Flush Diaphragm Pressure Transducer, Model A205
6. Tescom Model 44-1100 Pressure Regulator
7. Fike ½ 100 Rupture Disk Holder
8. Victaulic Snap-Joint Couplings

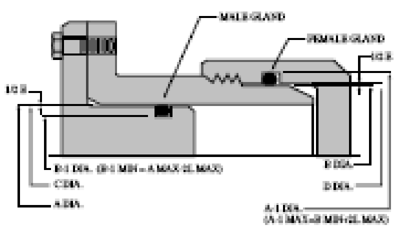
O-Ring Design Chart (HydroPak)

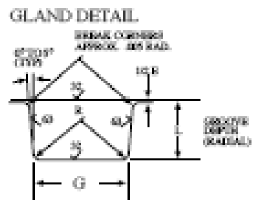
O-RINGS

O-RING GLAND DIMENSIONS



O-Ring Gland Design For Static Seals

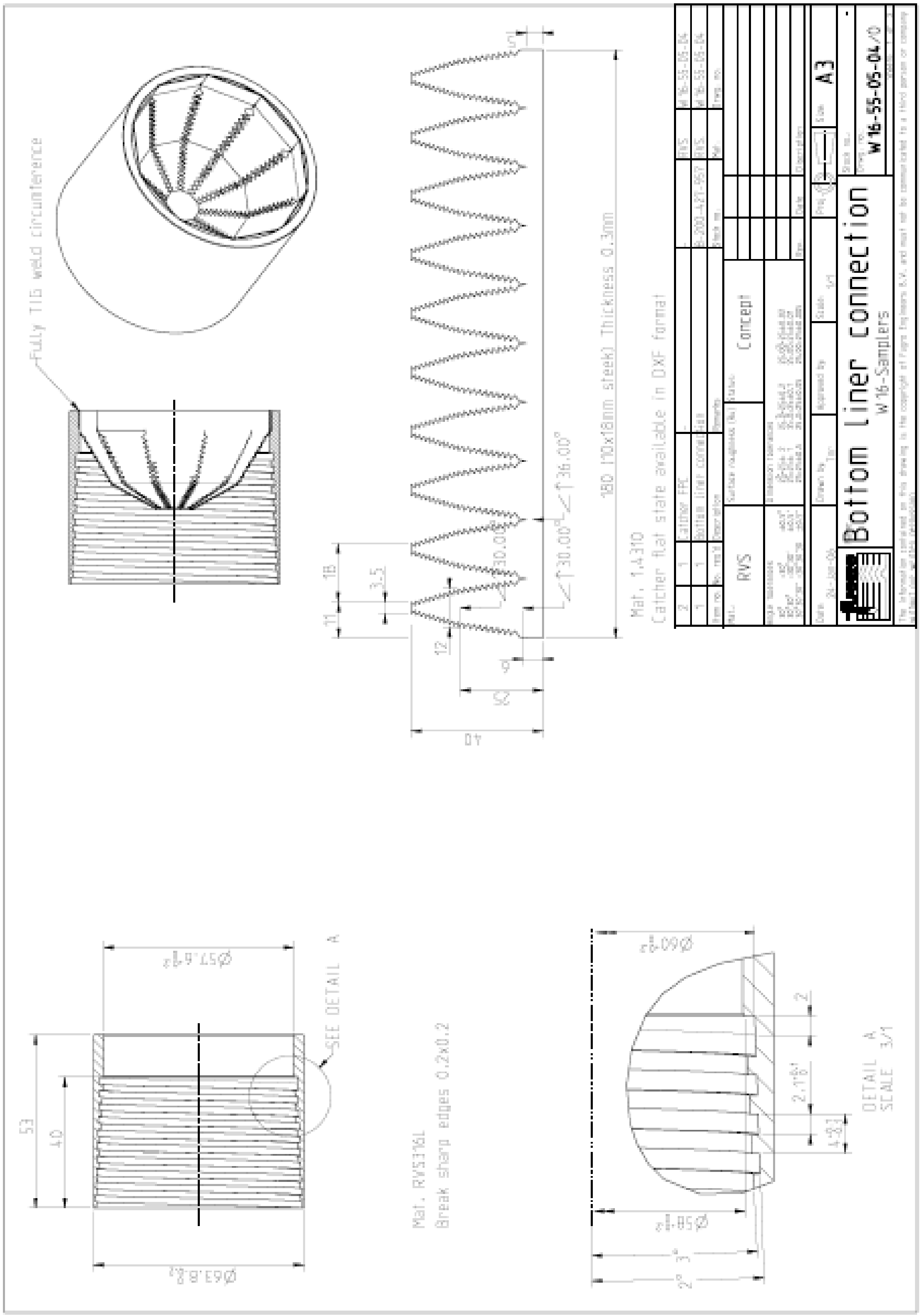




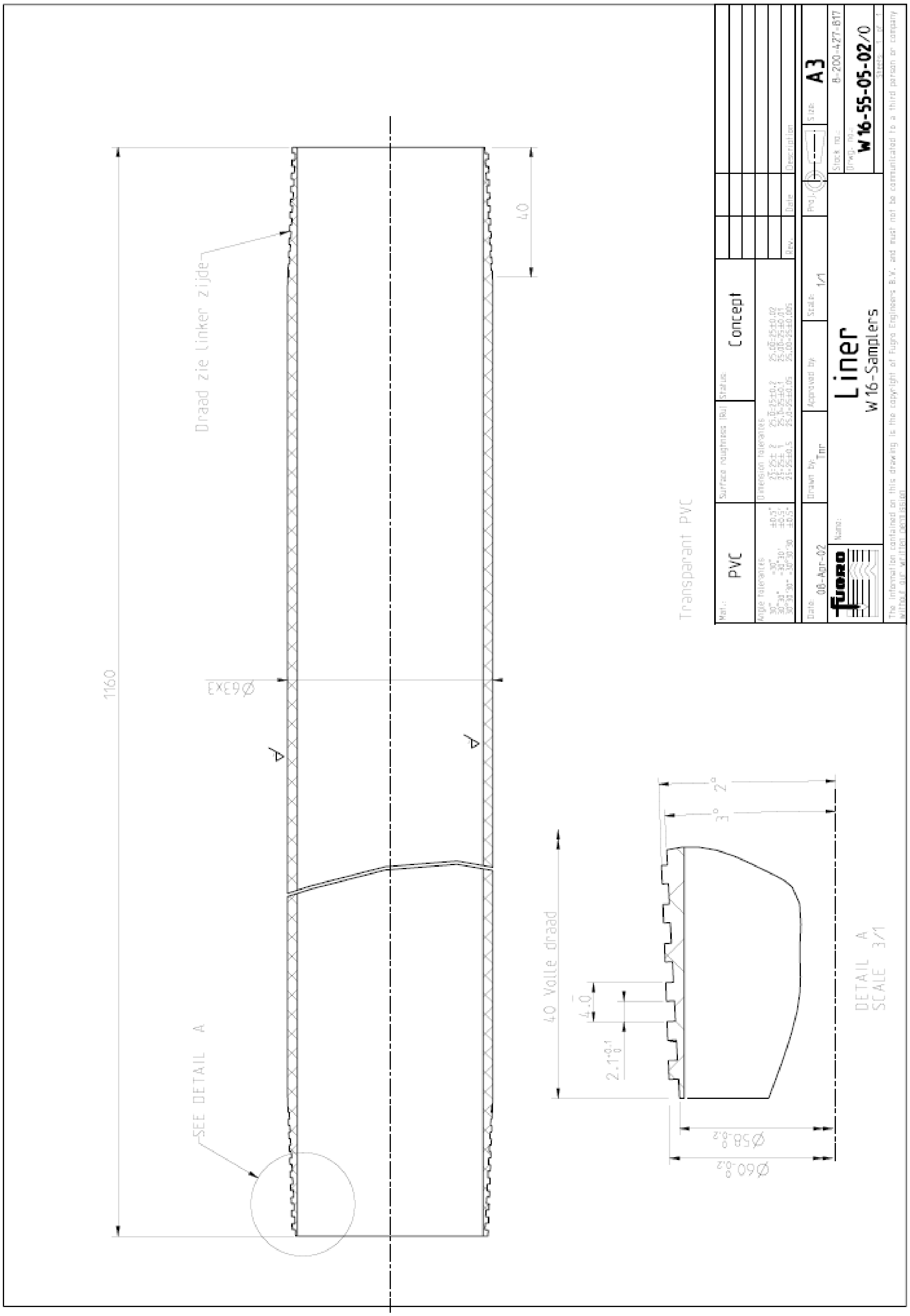
A – Bore Dia. (male gland)
A-1 – Groove Dia. (female gland)
B – Tube OD (female gland)
B-1 – Groove Dia. (male gland)
C – Plug Dia. (male gland)
D – Throat Dia. (female gland)
E – Diametrical Clearance

W O-RING CROSS SECTION	L GROOVE DEPTH		SQUEEZE				E DIAMETRICAL CLEARANCE MAX.	G GROOVE WIDTH ± .005			R GROOVE RADIUS	ECCEN-TRICITY MAX.
			RADIAL		AXIAL			NO BACKUP RIN	ONE BACKUP RING	TWO BACKUP RINGS		
	RADIAL	AXIAL	INCHES	%	INCHES	%						
.070	.050-.052	.050 -.054	.015-.023	22-23	.013-.023	19-32	.004	.095	.140	.207	.005-.015	.002
.103	.081-.083	.074-.080	.017-.025	17-24	.020-.032	20-30	.005	.142	.173	.240	.005-.015	.002
.139	.111-.113	.101-.107	.022-.032	16-23	.028-.042	20-30	.006	.189	.210	.277	.010-.025	.003
.210	.170-.173	.152-.162	.032-.045	15-21	.043-.063	21-30	.006	.283	.313	.413	.020-.035	.004
.275	.226-.229	.201-.211	.040-.055	15-20	.058-.080	21-29	.007	.377	.410	.540	.020-.035	.00

Fugro Core Catcher, W16-55-05-05/0



Fugro Core Liner, W16-55-02/0



Sensotec Model NK Portable Display for Pressure Transducers

Honeywell

Model NK

Portable LCD Display/Signal Conditioner

DESCRIPTION

The Model NK portable instrument features a full 4 1/2 digit LCD display and is designed for use in remote field operations as a portable calibrator or readout device. Shunt calibration offers the operator quick field setup with a minimum of warm-up. A peak/ hold feature is optional.

FEATURES

- Strain-gage/bridge-based transducer input
- 4-1/2 digit LED display
- Battery powered
- Analog output option
- Not RoHS compliant

Model NK

GENERAL SPECIFICATIONS

Characteristic	Measure
Number of channels	1
Material	Deep drawn Aluminum case

ENVIRONMENTAL SPECIFICATIONS

Characteristic	Measure
Temperature, operating	0 °C to 54 °C [32 °F to 130 °F]
Temperature, storage	-29 °C to 66 °C [-20 °F to 150 °F]
Power requirement	Batteries - 4 "D" cells

TRANSDUCER INTERFACE SPECIFICATIONS

Characteristic	Measure
Transducer excitation	4 Vdc
Types of inputs accepted	0.5 mV/V to 4 mV/V
Transducer bridge range	350 ohm
Pushbutton shunt cal	Yes
Calibration method	Manual
Electrical connection type	PT02A-10-6S1
Zero balance	± 15 % of full scale (min.)
Noise and ripple	30 microvolts

AMPLIFIER CHARACTERISTICS SPECIFICATIONS

Characteristic	Measure
Full scale outputs available	0 V to 1 V (optional)
Output impedance	< 1 ohm (optional)
Non-linearity	±0.02 % of full scale (max.)
Drift, zero	±5 mV (max.)
Drift, span	±5 mV (max.)
Stability, zero	0.1 % of full scale/year
Stability, span	0.1 % of full scale/year
Frequency response	1000 Hz
Span adjustment, fine	±15 % of range
Span adjustment, coarse	100 % of range
Zero adjustment, fine	±15 % of range
Zero adjustment, coarse	100 % of range
Short circuit protection	Yes

DIGITAL DISPLAY CHARACTERISTICS SPECIFICATIONS

Characteristic	Measure
Number of display characters	4-1/2
Conversion/second	1.5
Scaling	0-19999
Scaling method	Zero and span adjustment
Max. display count	19999
Polarity indications	Yes
Programmable decimal points	Yes
Display size	10,2 mm [0.4 in]
Overrange indication	Yes
Resolution	1/20000
Type	LCD
Max. sensitivity	0.1 microvolt/count
Peak/hold	Yes (optional)

PHYSICAL CHARACTERISTICS SPECIFICATIONS

Characteristic	Measure
Weight	1,4 kg [3 lb]

POWER SUPPLY SPECIFICATIONS

Characteristic	Measure
Power requirements	4 "D" cells

FRONT PANEL SPECIFICATIONS

Characteristic	Measure
Digital display	4-1/2 digits LCD
Environmentally sealed	Weatherproof case

OPTION CODES

	Many range/option combinations are available in our quick-ship and fast-track manufacture programs. Please see http://sensing.honeywell.com/TMsensor-ship for updated listings.
Input	52c. 10 mV/V to 40 mV/V
Output	56e. 0 Vdc to 1 Vdc
Special features	58c. Peak/hold 58m. Knob zero and span adjustments

Flush Diaphragm Pressure Transducers

Model A-105 and A-205

UNITIZED FLUSH DIAPHRAGM

15 TO 15,000 PSI

STAINLESS STEEL

Model A-105

Model A-205

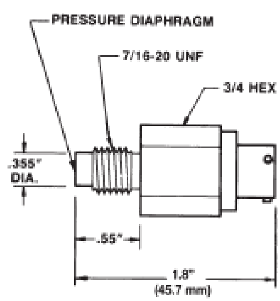
Models A-105, A-205 Subminiature Pressure Transducers are manufactured with a unitized stainless steel diaphragm. The advantage of this type of design is that a thin diaphragm and heavy sidewalls are made from one piece of stainless steel. This unitized diaphragm is rugged, but at the same time can be made thin enough to measure low pressures. Available pressure ranges span from 15 to 15,000 psi. These models can be used in corrosive fluid environments. Models A-105 and A-205 have welded stainless steel electrical connectors as an integral part of the transducer body. A-105's and A-205's are recommended for applications involving rough handling or where a completely hermetically sealed transducer is required.

Dimensions

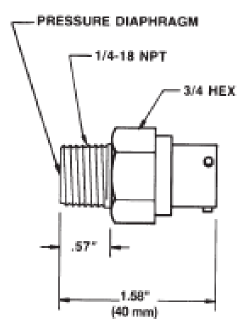
Model A-105 (Order Code AP311)
Model A-205 (Order Code BP312)

*Stocked ranges (in bold) for Models A-105 only.

Available Ranges* (All Models)
15; 25; 50; 75; 100; 150; 200; 300; 500; 750; 1000; 1500; 2000; 3000; 5000; 7500; 10,000; 15,000 psi



Model A-105



Model A-205

Options (See Appendix)

Temperature compensated 1b, 1c, 1f
Premium Options: 1d, 1e, 1g, 1h, 1i
Accessories: Mating connectors and connector/cable assemblies

	Models		Pressure Threads
	A-105	Order Code AP311	7/16-20 UNF
	A-205	Order Code BP312	1/4-18 NPT

		Low Pressure Ranges	**High Pressure Ranges**
PERFORMANCE	Pressure Ranges	<100 psi (1 bar to 7 bar)	100 to 15,000 psi (10 bar to 1000 bar)
	Non-Linearity and Hysteresis (max)*	1% F.S.	+/-0.5% F.S.
	Non-repeatability (max)*	1% F.S.	+/-0.1% F.S.
	Output (standard)*	.1mV/psi (@ 5VDC)	2mV/V
	Resolution	Infinite	Infinite
ENVIRONMENTAL	Temperature, Operating	-65° to 300° F (-54° to 150° C)	-65° to 300° F (-54° to 150° C)
	Temperature, Compensated	60° to 160° F (15° to 71° C)	60° to 160° F (15° to 71° C)
	Temperature Effect		
	–Zero (max)*	0.001mV/° F (0.0018mV/° C)	0.01% F.S./° F (0.018% F.S./° C)
	–Span (max)*	0.002mV/° F (0.0036mV/° C)	0.02% Rdg./° F (0.036% Rdg./° C)
ELECTRICAL	Strain Gage Type	Bonded foil	Bonded foil
	Excitation (calibration)	5VDC	5VDC
	Excitation (acceptable)	Up to 5VDC or AC	Up to 5VDC or AC
	Insulation Resistance	5000 megohm @ 50VDC	5000 megohm @ 50VDC
	Bridge Resistance	350 ohms	350 ohms
	Shunt Calibration Data	Included	Included
	Wiring Code (std)		
	A-105/A-205	#2 (See Pg. AP-8)	#2 (See Pg. AP-8)
	Electrical Termination (std)		
	A-105/A-205	PTIH-10-6P or equiv. (Hermetic stainless)	PTIH-10-6P or equiv. (Hermetic stainless)
	Mating Connector (not incl.)		
	A-105/A-205	PT06A-10-6S or equiv.	PT06A-10-6S or equiv.
MECHANICAL	Media	Gas, Liquid	Gas, Liquid
	Overload-Safe	100% over capacity	50% over capacity
	Overload-Burst	400% over capacity	400% over capacity
	Pressure Port		
	A-105	7/16-20 UNF male	7/16-20 UNF male
	A-205	1/4-18 NPT male	1/4-18 NPT male
	Dead Volume	Flush diaphragm	Flush diaphragm
	Wetted Parts Material	17-4 PH Stainless	17-4 PH Stainless
	Type	Gage	Gage
	Weight	1-2 oz.	1-2 oz.
	Case Material	17-4 PH Stainless	17-4 PH Stainless
IN-LINE AMPLIFIERS	Outputs Available	0-5VDC, 4-20mA (≥50 psi) 0-1VDC (<50 psi)	0-5VDC, 4-20mA

NOTES *Unit of measure in specifications is different for low ranges than high ranges.

General Information

How to order (See Pg. AP-19)
Gage/Absolute pressure selection flow chart (See Pg. PR-1)

Tescom Model 44-1100 Pressure Regulator

Specifications

❑ Operating Parameters

pressure rating per criteria of ANSI/ASME B31.3	
maximum rated inlet pressure:	
stainless steel	10,000 PSIG
brass	6,000 PSIG
outlet pressure ranges	0-500, 0-800, 10-1500, 15-2500, 25-4000, 50-6000 PSIG
design proof pressure	150% of maximum rated inlet
leakage	bubble-tight
operating temperature	-65° F to +165° F (-55° C to +75° C)
flow capacity	C_V = .06
maximum operating torque	35 in.-lb. (3.95 Nm)

❑ Media Contact Materials

body	brass, 303 or 316 Stainless Steel
filter:	
brass body	40 Micron (nominal) - bronze
SST body	15 Micron (nominal) - 316 SST
main valve seat	Vespel®
vent valve seat	CTFE
seals	Buna-N
back-up rings	Teflon®
remaining parts	300 Series Stainless Steel

For other materials and modifications, please consult factory.

❑ Cleaning .... CGA 4.1 and ASTM G93 (Intermediate Level)

❑ Weight .... 4.75 lbs. (2.15 kg)

Pressure Conversion 14.5 PSIG = 1 bar 145 PSIG = 1 MPa

Vespel® and Teflon® are registered trademarks of Du Pont.

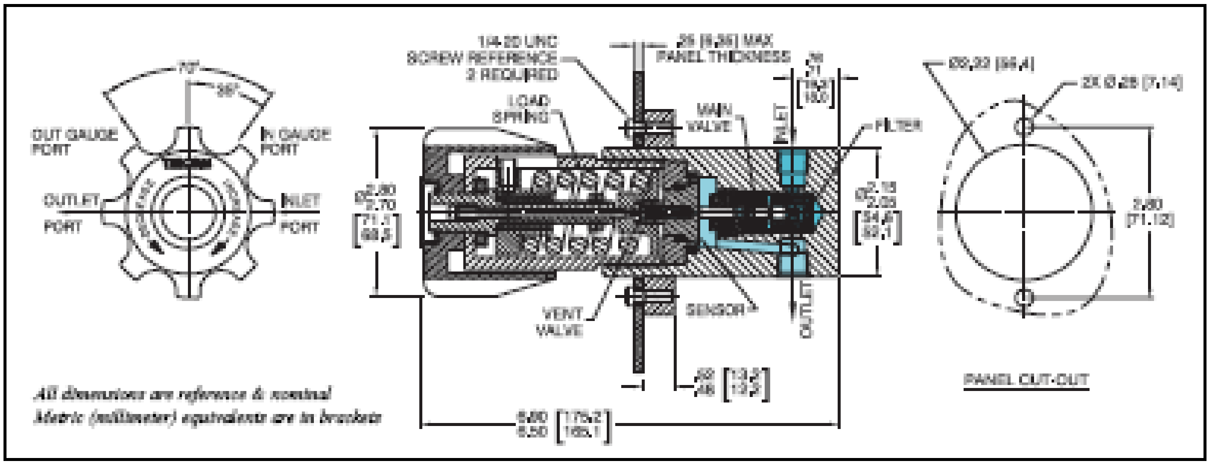
Advantages

- Removable valve assembly module permits easy repair
- Excellent sensitivity through a wide range of pressure settings
- Extra safety and reliability of piston style sensor
- Unbalanced stem assists positive shut-off
- Inlet & outlet gauge ports standard
- Available in brass or Stainless Steel
- Regulator vents to zero PSIG in all pressure ranges
- Numerous modifications available

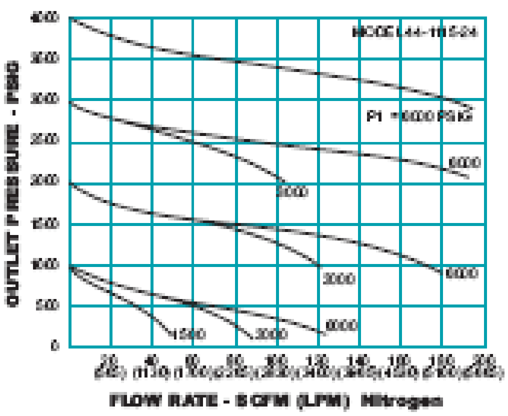
TESCOM CORPORATION

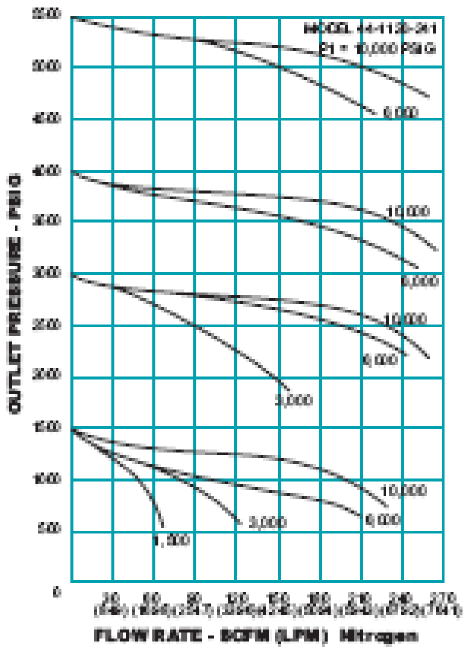
Global technical support & distribution • Design & manufacturing facilities in the U.S., Germany & Asia

44-1100 Series High Pressure



Flow Charts





Part Number Selector

example part number:

44-11	1	1	-	2	4

BASIC SERIES	BODY MATERIAL	OUTLET PRESSURE RANGE	PORT TYPE	PORT SIZE
44-11	1 – Brass 2 – 303 Stainless Steel 6 – 316 Stainless Steel	1 – 0-500 PSIG 2 – 0-800 PSIG 3 – 10-1500 PSIG 4 – 15-2500 PSIG 5 – 25-4000 PSIG 6 – 50-6000 PSIG	2 – NPT	4 – 1/4"

Repair Kits, Accessories & Modifications *may be available for this product. Please contact factory for more information.*

WARNING! Do not attempt to select, install, use or maintain this product until you have read and fully understood the Tescom Safety, Installation & Operation Precautions.

NOTE: Product availability and specifications contained herein are subject to change without notice. Consult local distributor or factory for potential revisions and/or service related issues.

TESCOM CORPORATION
INDUSTRIAL CONTROLS DIVISION

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Form No. 332 Rev. 1/03 Printed 1/03 5M Printed in U.S.A.

Fike ½ 100 Rupture Disk Holder

SCREW TYPE SERIES

DESCRIPTION

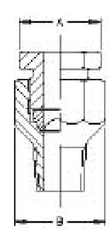
The typical Screw Type Rupture Disc Holder (without rupture disc) is a three-piece unit consisting of a base (inlet), holddown ring, and an outlet nut. When assembled, with rupture disc in place, the crown of the disc protrudes into the holddown ring. The base and holddown ring grip the rupture disc while the outlet nut provides the compression necessary to create a metal to metal seal.

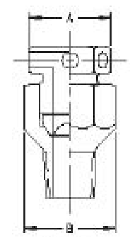
Fike's Screw Type Rupture Disc Holders are confined to the 1/2 inch nominal disc size. They are available in four styles: (1) ½30, (2) ½100, (3) S½10, (4) ½SP10. All these styles may be applied to a pressure system, or set-up, through standard NPT connections.

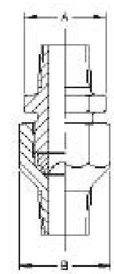
½30 SCREW TYPE HOLDER

The ½30 Screw Type Rupture Disc Holder utilizes the 30° angular seating arrangement and is designed for use with Fike's Conventional Prebulged P and CPV Series Rupture Discs. This style of Screw Type Holder is reusable and limited to a maximum pressure of 3000 PSIG. Standard ½30 Screw Type Holder dimensions and configurations, with assembly letter designations, may be located in the table below.

Assembly No.	Connections		Hex Size Across Flats		Overall Height
	Inlet	Outlet	A	B	
1/2-30SA-12	1/4 NPT	Free	1-1/8	1-1/4	2-5/16
1/2-30SA-10	1/2 NPT	Free	1-1/8	1-1/4	2-5/16
1/2-30SB-15	1/4 NPT	1/2 NPT	1-1/8	1-1/4	3-1/8
1/2-30SB-10	1/2 NPT	1/2 NPT	1-1/8	1-1/4	3-1/8
1/2-30SM-12	1/4 NPT	Muffled	1-1/8	1-1/4	2-1/2
1/2-30SM-10	1/2 NPT	Muffled	1-1/8	1-1/4	2-1/2


1/2 30 SA


1/2 30 SM

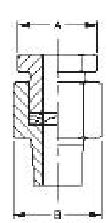

1/2 30 SB

½100 SCREW TYPE HOLDER

The ½100 Screw Type Rupture Disc Holder utilizes the flat seating arrangement which is characteristic of, and for use with, Conventional Prebulged or Scored Rupture Discs. This style of holder is reusable and has a maximum pressure rating of 10,000 psig. Special holders, similar to the ½100 type, can be furnished in other nominal sizes and for pressure up to 100,000 psig. Standard ½100 Screw Type Holder dimensions and configurations, with assembly letter designations, are located in the table below.

Standard material of construction for the ½30 and ½100 Rupture Disc Holders is 316 stainless steel. Other materials may be specified.

Assembly No.	Connections		Hex Size Across Flats		Overall Height
	Inlet	Outlet	A	B	
1/2-100SA-12	1/4 NPT	Free	1-1/8	1-1/4	2-1/8
1/2-100SA-10	1/2 NPT	Free	1-1/8	1-1/4	2-1/8
1/2-100SB-15	1/4 NPT	1/2 NPT	1-1/8	1-1/4	2-15/16
1/2-100SB-10	1/2 NPT	1/2 NPT	1-1/8	1-1/4	2-15/16
1/2-100SM-12	1/4 NPT	Muffled	1-1/8	1-1/4	2-5/16
1/2-100SM-10	1/2 NPT	Muffled	1-1/8	1-1/4	2-5/16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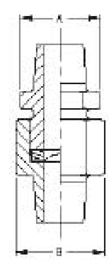
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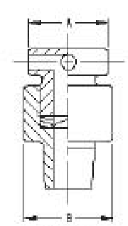

1/2 100 SM

Form No. R.1.38.01-1

Victaulic®

IPS CARBON STEEL PIPE GROOVED COUPLINGS **06.09**

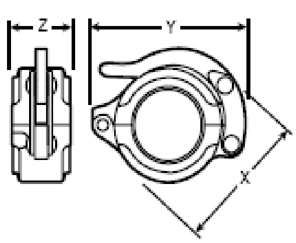
Style 78 Snap-Joint® Coupling

PRODUCT DESCRIPTION

Style 78 Snap-Joint couplings are designed for quick disconnect service. Mated housings are hinged with an attached locking handle for assembly. Housings through 4" (100 mm) size have a smooth outer surface. Larger sizes have cross-ribbed design for added strength.

Sizes 1 - 1½" (25 - 40 mm) are supplied with steel link handles. Sizes 2 - 4" (50 - 100 mm) are supplied with a cast handle (steel link-type handle available on request). Sizes 5 - 8" (125 - 200 mm) are supplied with a cast handle only.

DIMENSIONS



Pipe Size		Max. Work Pres.	Max. End Load	Allow. Pipe End † Sep.	Deflect. Fr. C_L †		Dimensions Inches/millimeters			Aprx. Wgt. Each
Nominal Diameter In./mm	Actual Out. Dia. In./mm	PSI* kPa	Lbs.* N	In. mm	Per Cplg. Deg.	Pipe In./Ft. mm/m	X	Y	Z	Lbs. kg
1 25	1.315 33,4	300 2065	410 1825	0 - 0.06 0 - 1,6	2° – 43′	0.57 48	2.75 70	3.25 83	1.75 44	0.8 0,4
1¼ 32	1.660 42,2	300 2065	650 2890	0 - 0.06 0 - 1,6	2° – 10′	0.45 38	3.13 79	3.75 95	1.88 48	1.1 0,5
1½ 40	1.900 48,3	300 2065	850 3780	0 - 0.06 0 - 1,6	1° – 56′	0.40 33	3.50 89	4.50 114	1.88 48	1.7 0,8
2 50	2.375 60,3	300 2065	1,330 5920	0 - 0.06 0 - 1,6	1° – 31′	0.32 26	4.00 102	4.75 121	1.88 48	1.7 0,8
2½ 65	2.875 73,0	300 2065	1,950 8680	0 - 0.06 0 - 1,6	1° – 15′	0.26 22	4.75 121	5.88 149	1.88 48	2.5 1,1
3 80	3.500 88,9	300 2065	2,885 12840	0 - 0.06 0 - 1,6	1° – 2′	0.22 18	5.38 137	6.25 159	1.88 48	2.8 1,3
4 100	4.500 114,3	300 2065	4,770 21225	0 - 0.13 0 - 3,2	1° – 36′	0.34 28	6.88 175	7.75 197	2.13 54	5.5 2,5
5 125	5.563 141,3	300 2065	7,290 32440	0 - 0.13 0 - 3,2	1° – 18′	0.27 23	8.75 222	9.50 241	2.13 54	9.8 4,4
6 150	6.625 168,3	300 2065	10,350 46060	0 - 0.13 0 - 3,2	1° – 5′	0.23 18	9.88 251	10.63 270	2.13 54	10.7 4,9
8 200	8.625 219,1	300 2065	17,500 77875	0 - 0.13 0 - 3,2	0° – 50′	0.18 14	12.25 311	13.00 330	2.38 60	15.3 6,9

*† Refer to notes on page 2.

Refer to Victaulic Pocket Handbook I-100 for special safety precautions when used for concrete pumping.

SECTION 4
PHASE IIIB TOPICAL REPORT #41330R27

Development and Testing of the Hybrid Pressure Coring System (HPCS)

Aumann & Associates

GOM Deepwater Gas Hydrate
Joint Industry Project
DOE Award DE-FC26-01NT41330

August 2014

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Development and Testing of the Hybrid Pressure Coring System Final Report

August 22, 2014

Prepared for
Chevron Energy Technology Company
Under
Service/Purchase Contract CW1094939

TABLE OF CONTENTS

Development and Testing of the Hybrid Pressure Coring System

Background

The High Pressure Temperature Corer (HPTC) was developed under contract K19259 JT between Chevron Energy Technology Company and Aumann & Associates, Inc. This contract was entered into as a task under the "Gulf of Mexico Hydrate Joint Industry Participation Agreement" ("JIP Agreement") and funded by the United States Department of Energy ("DOE") under Solicitation No. DE-PS26-01NT40869, Methane Hydrates. As specified in the contract and contract revisions, the HPTC was designed with the following primary features and specifications.

- Based on the successful wireline retrievable NC-PTCS design
- Operate in the special 6-5/8 NC-PTCS drill pipe and drill collars
- Maximum Operational Pressure: 5000 psi
- Compatible with the Geotek Pressure Core Analysis and Transfer System (PCATS)
- Cutting shoe design that would allow the removal of an inner bit to make it possible to run other size coring tools or larger logging tools through the bit.
- Core size compatible with a 65mm x 11.5 ft long transfer chamber

The design work for the HPTC was completed in 2009. As the JIP began developing plans for a field test and the actual GoM operations it became apparent to the JIP that it would be desirable to make several changes to the HPTC. These changes were needed because of operational decisions and the desire to increase efficiency by reducing the number of drill pipe trips by logging through the drill pipe and to incorporate Baker-Hughes core bits and outer core barrel components to make it possible to interchange with their conventional coring tools without making a drill pipe trip.

The operational changes and requirements included:

- The need to core at depths up to 11,000 ft with pressure up to 5,500pai.
- The use of 7-5/8 OD x 6-5/8 ID high torque casing in place of the special large bore drill pipe.
- The elimination of the need to be able to run the Fugro pressure coring tools.
- Use Baker Hughes Inteq (BHI) PDC bits instead of a Fugro bit.
- The desire to use the BHI 8 x 5 HT outer barrel assembly components.
- Be able to run large diameter wireline logging tools without making a pipe trip. This results in a need for a 5.875 hole through the main bit.
- Drill to, or between core points without making a pipe trip. This requires the development of a center bit option.
- The desire to take conventional cores using BHI standard 6 x 4 inner barrel components including the Hydrolift core catcher system.
- Study and evaluate past failures and investigate a more robust liner and liner thread.

- Develop a variety of core catchers that could be used in case problems are encountered using the Fugro basket catchers.

The design work for the changes was completed by Aumann & Associates, Inc. during 2011. Four prototype tools and associated wireline tools and special service tools were manufactured, assembled and functionally shop and final acceptance tested and, a set of service equipment was procured.

Small Diameter Pressure Corer

By the conclusion of the HPTC contract, Aumann & Associates, Inc. had developed and tested a considerably smaller version of a wireline retrievable pressure coring system, called the Hybrid PCS, for Japanese clients. That system is designed to operate in 4-1/8 ID drill pipe and the standard IODP BHA. They Hybrid PCS also has the ability to transfer to the PCATS under pressure for analysis. The PTCB has a pressure rating of 5000 psi and recovers a 2.00 inch diameter x 11.5 ft (3.5m) long core. The Hybrid PCS tools were manufactured and field tested on land in November, 2011, and subsequently used in operations offshore Japan in July and August, 2012. The significant results of those operations include:

- The tools functioned correctly and the ball valve fully closed except in two runs where the PVC core liner broke due to a core jam and the core liner stuck in the open ball preventing it from closing.
- Eight of the eighteen runs resulted in recovery of full pressure and four more runs with significant pressure resulting in a pressure performance of 67%.
- Overall core recovery was 69% compared to only 20% using conventional coring tools.
- Approximately 25 meters of good quality methane hydrate bearing core were successfully transferred to and analyzed in PCATS under pressure. (See Figure 1.)

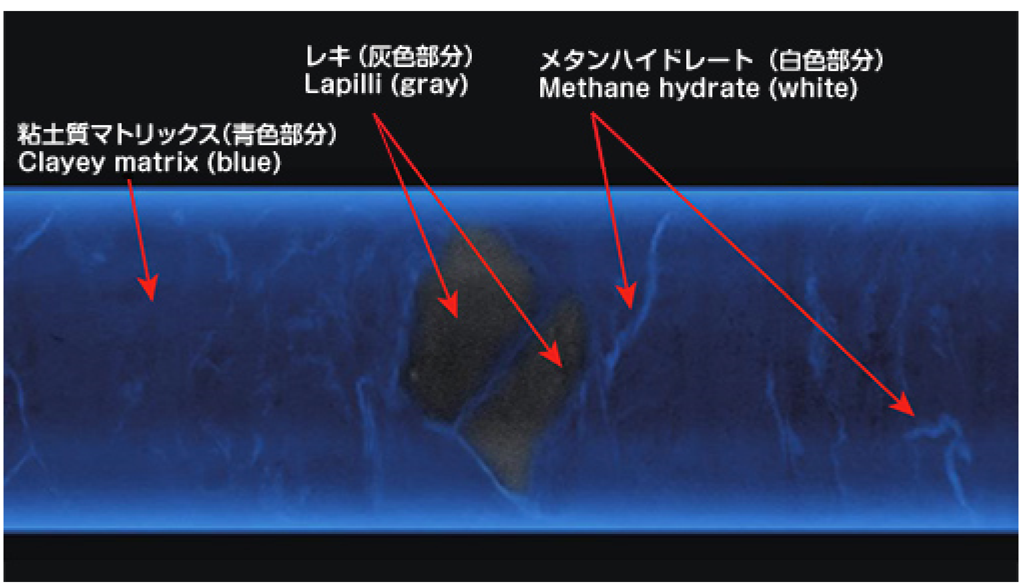


Figure 1, Section of good core x-ray image during PCATS analysis.

- There were no major failures of the coring tools or service tools.
- However, there were a number of issues that were identified and reported during the Hybrid PCS field test and operations in Japan including failure of the system to recover boosted pressure consistently and other reliability and efficiency issues.

These issues were reviewed in a meeting with Chevron on February 26, 2013 at Aumann & Associates, Inc. offices. Fifteen of them were selected by the JIP project management to be included in a Hybrid PCS system being developed for the JIP GoM project under Contract CW1094932 signed on June 1, 2013. The required Kick-off Meeting was held on June 3, 2013 at the AAI offices in Salt Lake City, Utah with Jim Aumann (AAI), David Whitaker, Cung Vu (Chevron), Rob Russell (Chevron), Sam Chase (Chevron) in attendance.

What follows in this report is a description of the original Hybrid PCS followed by an in depth description of the 15 recommended changes and details of the implementation of those changes. Additional sections cover the manufacturing, quality assurance, final acceptance and field tests.

Introduction to the Original Hybrid PCS

The Hybrid PCS was developed to become part of the suite of coring tools used in the IODP standard 5-1/2 drill pipe with a 4.125 inch bore. It was designed to be used in the standard IODP marine BHA and used interchangeably with other IODP tools. As part of the project, existing pressurized coring systems were studied in an attempt to discover the best features that might be incorporated into the new Hybrid PCS. The systems evaluated included:

Non-cooled Pressure Temperature Core Sampler (NC-PTCS)

This system was designed and produced for JOGMEC from 1998 through 2003. It is based on ball valve technology and is run in special large bore drill pipe and BHA. It is a rotary coring system that is deployed and retrieved using a wireline. It recovers a 2-5/8 inch diameter x 11.5 ft long core. The NC-PTCS was successful in recovering methane hydrate bearing cores in operations offshore Japan in March-April, 2004. It is probably the most successful pressure coring tool developed to date.

High Pressure Temperature Corer (HPTC)

This system was developed for the U.S. Department of Energy under contract to Chevron as part of the GoM JIP. The HPTC was designed using the NC-PTCS as a basis but was improved to include the ability to transfer core under pressure to the Geotek Pressure Core Analysis and Transfer System (PCATS). It still requires special large bore drill pipe or a casing used as drill pipe and a special BHA assembly.

IODP Pressure Core Sampler (PCS)

The PCS was developed in the late 1970's and has been used by IODP-USIO on the JOIDES Resolution with some success for over 25 years. The PCS is deployed by pumping down the drill pipe and is wireline retrievable. It incorporates a conventional ball valve. The relatively small 4.125 ID bore in the IODP drill pipe and BHA coupled with a conventional ball valve results in a small 1.500 diameter by 1m long core size. It has no transfer capability. The PCS has been used successfully but with mixed results when it comes to reliability.

Fugro HYACE Rotary Corer (HRC) and Fugro Piston Corer (FPC)

Both Fugro pressure coring systems are wireline deployable and retrievable. They incorporate a curved flapper valve and are able to transfer the core under pressure to the Geotek Pressure Core Analysis and Transfer System (PCATS). They both recover an approximately 2-1/8 inch diameter x 1 m long core. The Fugro curved flapper provides a larger core than is possible using a conventional ball valve or conventional flat flapper valve. With both tools wireline manipulation retracts the inner tube and triggers and closes the flapper valve. Both tools recover a one meter long pressurized core. The HRC is a rotary corer driven by a downhole mud motor. The FPC is a powered by a combination piston and hammer drill. Should the piston stop penetrating before the end of its stroke, a hammer drill is energized. These tools are quite complex because they incorporate a down hole mud motor or hammer drill. These complexities coupled with the easily contaminated flapper valve design have proven somewhat unreliable in use.
The table below summarizes the specifications of the tools evaluated in the development of the original Hybrid PCS.

TABLE 1, PRESSURE CORE SYSTEM SPECIFICATION COMPARISON

System	Core OD		Core Length		Max Pressure		Min Drill Pipe Bore		Comments
	(in)	(mm)	(ft)	(m)	(psi)	(MPa)	(in)	(mm)	
IODP PCS	1.575	40.00	3.28	1.00	10000	68.9	4.125	104.78	No core liner, Compatible with ESCS/HPCS BHA. Uses an accumulator for pressure compensation.
JOGMEC NC-PTCS	2.625	66.68	11.5	3.50	3500	20.7	5.906	150.01	
DOE HPTC	2.244	57	11.5	3.5	5000	34.5	6.625	168.28	Based on NC-PTCS
FUGRO HRC	2.00	51	3.28	1.0	3000	20.7	4.125	104.78	Mud motor driven rotary corer. Transfers under pressure to PCATS. Operates in the Fugro BHA but nearly compatible with ESCS/HPCS BHA.
FUGRO FPC	2.125	53.98	3.28	1.0	3626	25	4.125	104.78	Piston and hammer drill system. Transfers under pressure to PCATS. Operates in the Fugro BHA but nearly compatible with ESCS/HPCS BHA.
Hybrid PCS with Top Seal Ball Valve	1.875 to 2.00	47.6 to 51.0	11.5	3.50	5000	34.5	4.125	104.78	Simple rotary corer with a ball valve. Liner and core transfers under pressure to PCATS. Compatible with ESCS/HPCS BHA.

TABLE 2, PRESSURE CORE SYSTEM FEATURE COMPARISON

	Valve	Closure Trigger	Closure Power	Pressure Maintenance	Liner	Transfer Under Press	Core Cutter
PCS	Ball	Drop Ball	Mud Press	Accumulator	No	No	Cutting Shoe
PTCS	Ball	Wireline	Wireline	N2 Regulated	Yes	No	Core Bit
HPTC	Ball	Wireline	Wireline	N2 Regulated	Yes	Yes	Cutting Shoe
HRC	Curved Flapper	Unknown	Spring	Accumulator	Yes	Yes	Rotary Mud Motor
FPC	Curved Flapper	Unknown	Spring	Accumulator	Yes	Yes	Hammer Drill
Hybrid PCS	Ball Top Seal	Wireline	Spring	N2 Regulated	Yes	Yes	Cutting Shoe

Original Hybrid PCS

The Hybrid PCS is a unique combination of the concepts and technology taken from each of the systems previously described. The overview of the Hybrid PCS inner barrel assembly is shown in the following figure.

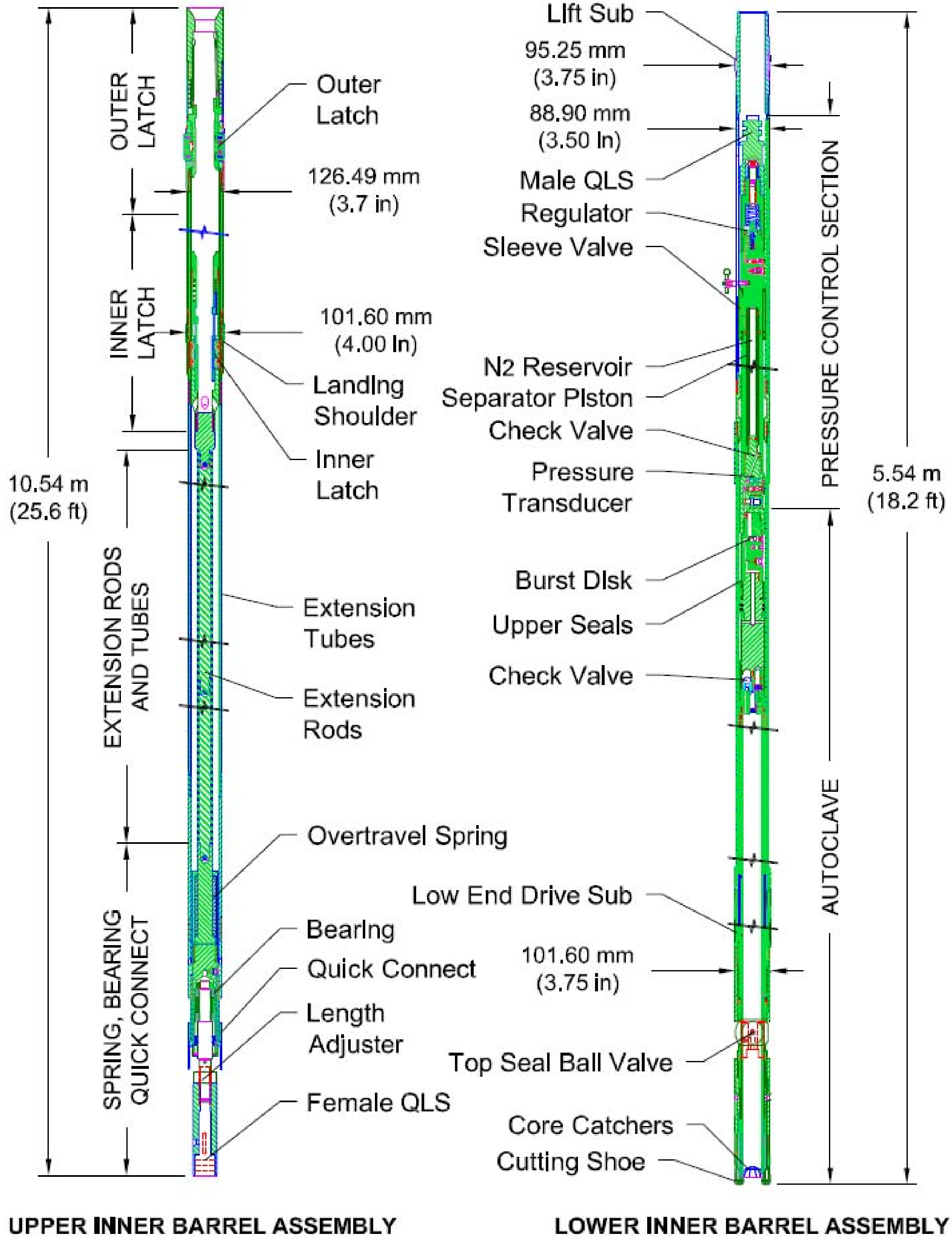


Figure 2, Overview of the Original Hybrid PCS Inner Barrel Assembly

The Hybrid PCS tool was designed to work in the IODP 5-1/2 drill pipe with a 4-1/8 in bore and land in the standard IODP ESCS bottom hole assembly (BHA). It is a conventional rotary coring system driven by the rotating drill pipe. The Inner Barrel Assembly is wireline deployed and retrieved. The Hybrid PCS inner barrel assembly was designed in two halves that can be assembled or disassembled vertically on the rig floor. This makes picking up and laying down the autoclave safer and more efficient.

The Upper Inner Barrel Assembly contains the latch assembly with inner and outer latches, extension tubes and rods, over travel spring, sealed inner bearing, optional sealed outer bearing, length adjuster, and quick connects for the extension tubes and rods that easily connect these components to their mating parts in the Lower Inner Barrel Assembly.

The Lower Inner Barrel Assembly contains the mating quick connects (to attach the extension tubes to the lift sub, and rods to the pressure control section), pressure control section, and the pressure retaining autoclave.

Upper Inner Barrel Assembly

Latch System

The Hybrid PCS uses two latches that work together to provide the necessary functions and feedback using only the mechanical wireline. The inner (lower) latch locks the inner assembly in position inside the outer assembly `for coring. The outer (upper) latch locks the PTCB into the BHA during the coring operations. There are three wireline tools that are used in conjunction with the Hybrid PCS latch system. The wireline tools use the same body as the wireline tools on the PTCS and HPTC. The tube and collet diameters have been modified to fit the smaller diameters in the Hybrid PCS latch section. The three wireline tools are shown in the figures below:

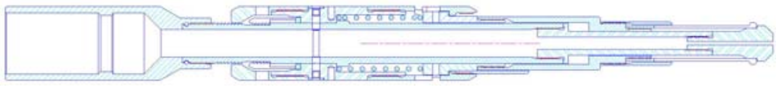


Figure 3. Running Tool

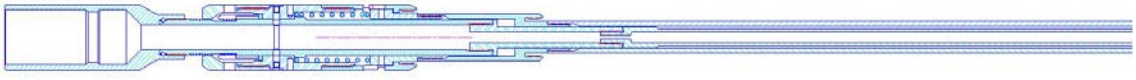


Figure 4, Pulling Tool

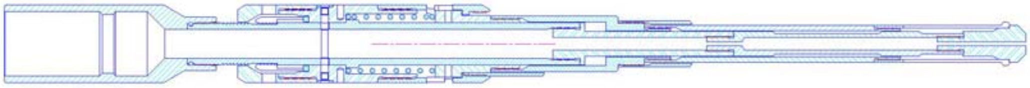


Figure 5, Emergency Pulling Tool

The running tool is used to run the tool into the hole and set the inner barrel assembly in the BHA. The pulling tool is used to latch onto the inner latch after coring. Upward pull with the wireline then activates it to close the ball. It then automatically releases the outer latch and allows the inner barrel assembly to be pulled to the surface. The emergency pulling tool can be used to release the outer latch without releasing the inner latch, and pull the tool from the hole in an emergency situation for example, in case the inner assembly becomes jammed. These components are described in more detail below.

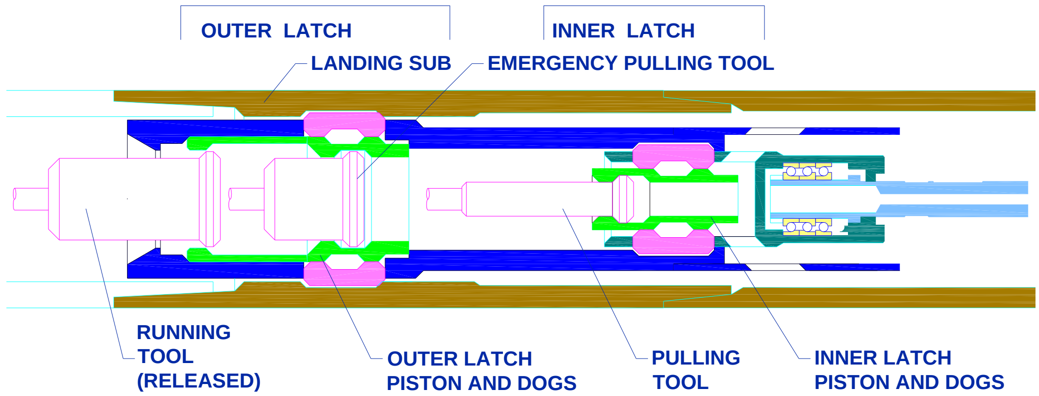


Figure 6, Latch Section and Wireline Tool Function

Outer Latch

The outer 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 in a groove in the landing sub. A 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.

Inner Latch

The inner latch keeps the inner tube assembly secured relative to the outer assembly to keep the ball valve locked in the open position while running in the hole and during coring. Once coring is complete the pulling tool is run to the PTCS, where it locks into the inner latch piston. The inner 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, 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. The bearing assembly, accumulator section, and inner tube assembly are connected to the bottom end of the inner latch. Thus, they all move when then inner latch assembly is moved.

Wireline Tools

When an inner barrel assembly is run into the hole, prior to coring, the running tool is inserted into the top end of the latch assembly. A collet on the end of the running tool engages the outer latch collet at the top of the latch housing. The weight of the entire tool is carried through this connection. This weight keeps the inner barrel latch piston pulled up against the spring. In this position, the upper latch dogs are pulled into recesses in the latch housing, allowing the tool to be lowered into the drill pipe. When the large diameter of the latch housing contacts the landing shoulder in the BHA, the weight comes off the pulling tool and outer latch piston allowing the outer latch piston to move down, pushed by the spring. This downward movement of the piston pushes the dogs into the cavity in the upper end of the BHA. In the assembly drawing the inner barrel assembly is shown latched into the BHA,

When an inner barrel assembly is to be retrieved, the pulling tool is attached to the end of the wireline. The smaller diameter collet on the end of this tool passes through the upper latch assembly and engages the shoulder on the latch piston of the inner latch assembly. Pulling up on the wireline, then pulls up the latch piston, against the spring force, and allows the dogs to drop into the recesses on the piston. This releases the inner latch. Further pulling on the wireline pulls the inner latch assembly up against the outer latch piston to move it upward allowing the dogs in the upper latch to drop into the recesses on the piston, and unlatching the tool from the BHA for retrieval to the surface.

Emergency Release Systems

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

The wireline tools also features a shear pin which is activated by jarring down with a wireline Spang jar. This is an emergency release device which allows the wireline tool to be released from the latch assembly 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 outer 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.

Extension Rods and Extension Tubes

The extension rods and extension barrels connect the latch assembly to the over travel spring and bearing. They are needed because the HPCS, EPCS and ESCS have inner barrel assemblies designed to recover 9.5 m cores. The PTCB does not require nearly as much length even with the pressure control section and bearing/spring section. The rods and tubes allow us to use the shorter PTCB in the much longer ESCS/EPCS/ESCS BHA. The extension rods are exactly the same length as the extension tubes and can be removed without changing the function of the assembly for easier and more convenient horizontal function testing at the surface.

Baring, Length Adjuster and Over Travel Spring

A bearing assembly provides for free rotation of the outer barrel relative to the inner tube so that the inner tube and core catcher does not rotate with the bit and outer barrel and damage the core. The bearings provide 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. 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 at the bottom of the extension rods. Four oil sealed angular contact bearings are used in the Hybrid PCS 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. The over travel spring is a highly preloaded compression spring. This spring compensates for the tolerances in lengths of all the parts. It also compensates for length changes due to the length adjustment capability built into the lower end of the bearing assembly. The function is simple. When the parts run out of travel the spring compresses to provide the extra travel needed by compressing the spring instead of overloading parts or running out of travel. Also, high tensile forces can be generated as the core is being broken. This spring will stretch to allow the core catcher to bottom out in the cutting shoe and prevent high tensile forces from being applied to the PVC core liner. The threaded length adjuster provides a way to adjust the length of the inner assembly so that the core shoe has the proper clearance from the cutting shoe. A lock nut is used to secure the connection once the length has been set.

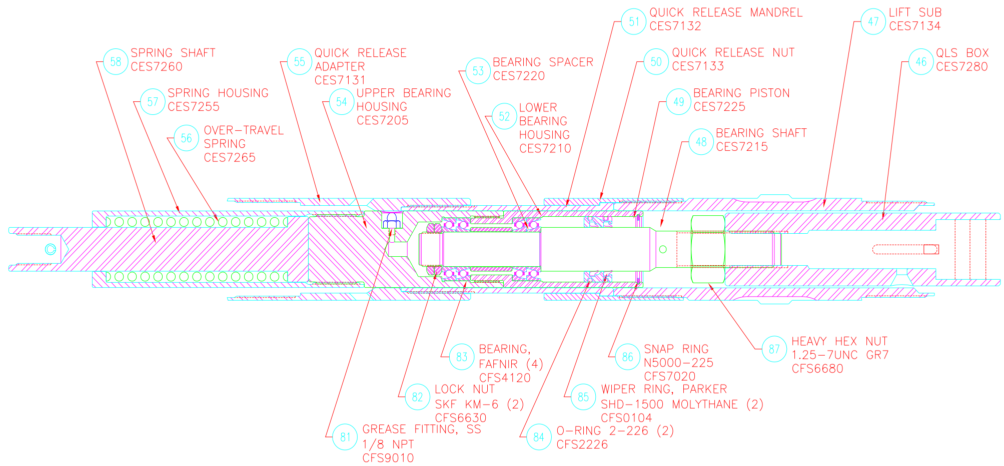


Figure 7, Bearing, length adjuster and over travel spring.

Optional Outer Bearing

An optional Outer Bearing Assembly can be installed in the extension tubes in the top assembly. It is used when the face bit or punch coring system will be used. The Outer Bearing decouples the outer tubes in the inner barrel assembly from the rotation of the BHA and can reduce inner tube rotation and increase core recovery and quality during punch and face bit coring. It is installed in place of the inner tube sub. The Outer Bearing Assembly is also oil sealed and pressure compensated. It is unique in that it has a hole through it to allow the extension rods to pass through it. It can be left in the upper assembly for all types of coring for convenience but serves no purpose while coring with a cutting shoe because in that case the outer tubes are rotated by the drive sub.

Female QLS

The Female Quick Lock System (QLS) is the lowest component of the Upper Inner Barrel Assembly and the Male QLS is at the top of the Lower Inner Barrel Assembly. The QLS provides a quick and easy way to connect and disconnect the inner components of the upper and lower inner barrel assemblies on the rig floor vertically in the mouse hole. The QLS transfers tension, compression and torque without having to make up a threaded connection. To make up the connection they are simply stabbed and rotated 90 degrees relative to each other. To disconnect a pin punch is inserted into a hole in the side of the female QLS and pushed down. This releases an internal locking plate. The male and female QLS can then be rotated 90 degrees and pulled apart.

Quick Release Adapter, Mandrel and Nut

The quick release components provide a way to quickly assemble the upper and lower outer components vertically on the rig floor. The upper section is simply stabbed into the lift sub and a sleeve called a nut is rotated to secure the connection. This avoids having to turn the entire assembly being suspended from the lifting clamp. The connection does not have keys and is not designed to transmit torque.

Lower Inner Barrel Assembly

The Lower Inner Barrel Assembly has two sections, the pressure control section and the autoclave. The pressure section provides a nitrogen charged pressure regulated system to maintain pressure on the autoclave after the core is recovered and the ball is closed. The autoclave contains the pressurized core. The autoclave utilizes a so called Top Seal Ball Valve as the main closure valve for the autoclave at the bottom where the core enters. This concept, originally developed and demonstrated on earlier versions of the PTCS uses a positively actuated ball as the pressure chamber closing mechanism. The name Top Seal Ball Valve comes from the fact that the pressure chamber seal is located above the ball valve (i.e. on the "top" side of the ball), thus the ball itself is located outside of the pressure chamber. This arrangement allows the ball to be as large as the OD of the tool itself (the ball does not need to be contained inside the pressure housing), and therefore this also allows the maximum core size possible with a ball valve type closure. The lower inner barrel assembly is positioned in the BHA such that the cutting shoe extends slightly (approximately one half to one inch) past the face of the bit.

Pressure Control Section

The purpose of the pressure 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 an accumulator effect for moderating pressure increases due to heating, etc.. (*Note: A burst disk is also provided in the attached autoclave assembly and acts as a safety fuse against overpressure for the entire assembly 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 without connecting hoses or opening valves. The pressure control section is equipped with externally operable shut-off valves and ports to allow for isolating the pressure control section from the ball valve section before disconnecting them. Ports and internal valves also provide for the sampling of core fluids if desired as well as an alternate way to monitor pressure in case of pressure transducer failure. The pressure regulator is set at the surface. It can be set to provide a pressure boost when the ball valve closes downhole to help create an initial seal at very low differential pressure. The regulator section uses a nitrogen reservoir but includes a separator piston to prevent the nitrogen gas from mixing with the core fluids and gasses.

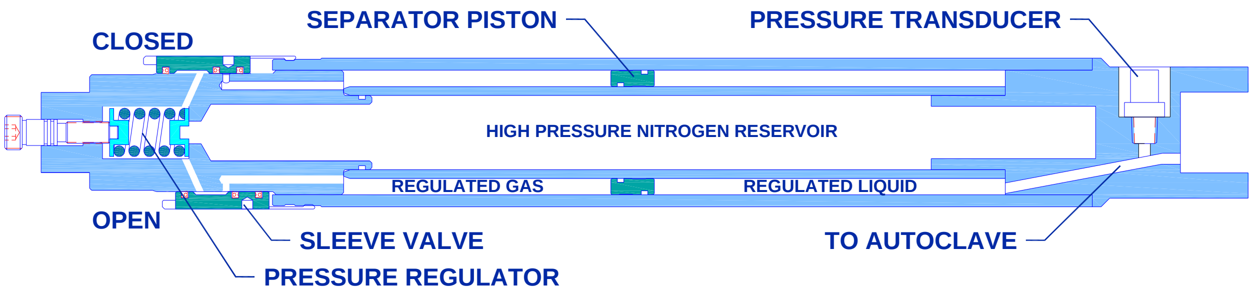


Figure 8, Pressure Control Section

Autoclave

The autoclave pressure chamber is formed by a high strength stainless steel tube terminating with a ball valve at the bottom and a seal sub and so called inner tube plug at the top. The inner tube plug provides several important functions. It provides for free rotation without seal friction during coring but moves into the sealed position to close off the top of the pressure chamber after the core is cut. The top of the core receiving tube, called the core liner, is connected to the inner tube plug. Thus, when the inner tube plug is pulled up, the liner and any core within it, move up as well. A steel inner tube that supports the core liner is also attached to the inner tube plug.

During coring operations the liner and core catcher extend into the cutting shoe. In this case, the pawls are held in collapsed position under an extension on the inner tube collet release sleeve. This sleeve is held in position by a tight fit over the two inner tube plug seals. Two grooves in the ID of this sleeve assure that the sleeve is positioned properly.

The pawls consist of three segments of a ring, machined with special angles to allow them to function as stops for the inner tube plug when the pressure chamber is closed. These pawls have an external groove on the bottom to allow an o-ring to be installed. This o-ring keeps the bottom ends of the pawls pulled tightly against the OD of the inner tube plug. A circular recess on the ID of the pawls, at the upper end, allows a circular leaf spring to be inserted under the pawls. This leaf spring pushes the upper end of the pawls outward. During coring, the inner tube collet release sleeve is positioned over the pawls and prevents the pawls from being pushed outward by the spring.

As the inner tube plug is pulled up and passes into the seal sub, the inner tube collet release sleeve contacts the bottom edge of the seal sub. As the inner tube is pulled up further, the pawls are pulled into the cavity at the lower end of the seal sub. This cavity diameter keeps the pawls in the compressed position. The inner tube collet release sleeve is pushed along the OD of the inner tube plug as the inner tube plug is pulled further into the seal sub. When the top end of the pawls reach the large cavity inside the seal sub, the leaf spring under the top end of the pawls pushes that end of the pawls out so that they engage the cavity in the seal sub, At this point, the inner tube (and attached liner and inner tube) are locked against any further motion. It is in this position that the tool is retrieved to the surface.

The inner tube plug contains a check valve to allow fluid to escape as core is pushed into the liner. It also contains a pressure port that allows the core chamber to be connected to the pressure control section. An internal valve allows this pressure supply line to be isolated as the tool is being serviced before the autoclave is separated from the pressure control section above. A burst disk in the inner tube plug protects against overpressure.

Once the tool is at the surface, the upper assembly (latches and bearing) is separated on the rig floor. The lower assembly is brought to the service unit where the autoclave is isolated and separated from the pressure control section. Adapters needed for transfer to the PCATS are installed. The autoclave is connected to the PCATS system, the connection chamber pressurized and the actuator on the PCATS is advanced. A pawl release sleeve on the end of the actuator pushes under the top end of the pawls, and forces the pawls up into the cavity on the seal sub. This releases the inner tube plug from the seal sub. At the same time that the pawl release sleeve pushes under the pawls, the collet on the pulling tool engages the buttress threads on the end of the inner tube plug. This allows the actuator on the PCATS system to pull on the inner tube plug to bring it into the PCATS chamber. As the inner tube plug is pulled further into the seal sub, the chamfer on the end of the inner tube collet release sleeve slides under the taper on the end of the inner tube collet. This releases the inner tube collet from the inner tube plug, allowing the inner tube plug, liner and core to be pulled into the PCATS, leaving the inner tube inside the autoclave. A more detailed description of the components is provided in the following paragraphs.

Burst disk

A burst disk assembly is incorporated into the autoclave section to protect the equipment and operators from over-pressure and possibly bursting of the barrel. This "pressure fuse" is calibrated very accurately to a burst pressure of 5500 psi. This allows for slight over-pressure during core transfer, etc. and still falls well within the safe design and test range of the inner barrel assembly.

Check Valve

A check valve is incorporated at the top of the core chamber in the inner tube plug. The purpose of the check valve is to keep drilling fluids from entering the inner tube from above while still allowing fluid above the core to exit as the core enters the core liner. This eliminates a potential hydraulic lock inside the inner tube that could prevent more core from entering.

Inner Tube

A steel inner tube is attached via a collet to the inner tube plug. It provides support for the PVC core liner. The inner tube also pulls the ball valve release sleeve as the wireline is lifted to activate and close the ball after the core is cut. A collet at the top end of the inner tube provides a way to release the inner tube from the inner tube plug and core liner as the core is being transferred to PCATS.

Low End Drive Sub

This low end drive sub has four slots on the O.D. to engage the four drive dogs in the low end drive assembly. Two of the slots are open in the counter-clockwise direction to allow for easier dog engagement. The other two slots are double sided to restrain any backlash toque. The drive dogs lock the inner tube and outer barrel together to transmit the drilling torque to the cutting shoe.

Top Seal Ball Valve

The main valve that closes the lower end of the autoclave uses a so called Top Seal Ball Valve concept. The name "Top Seal" ball valve comes from the fact that the pressure chamber seal is located above the ball valve (i.e. on the "top" side of the ball), thus the ball itself is located outside of the pressure chamber. This arrangement allows the ball to be as large as the OD of the tool itself (the ball does not need to be contained inside the pressure housing). The larger ball allows for a larger hole through it and therefore, provides the maximum core size possible with a ball valve type closure. A large highly preloaded spring is used to close the ball after the core has been cut. A collet is used as a trigger to keep the ball in the open position during coring. A sleeve, pulled by the wireline pulling tool, is withdrawn from under the collet which releases the spring to close the ball. To maximize core size the steel inner tube is terminated just above the ball valve so that only the clear PVC plastic liner passes through the hole in the open ball. This feature provides additional area for an even larger diameter liner and core. The liner and core catcher designs were be based on the Fugro tools with only the liners being lengthened and the diameter of the core catcher and liner downsized from 2-1/8 in to 2 in to suit the smaller core. The core length was maintained at 11.5 ft like the NC-PTCS and HPTC and new PCATS II capabilities.

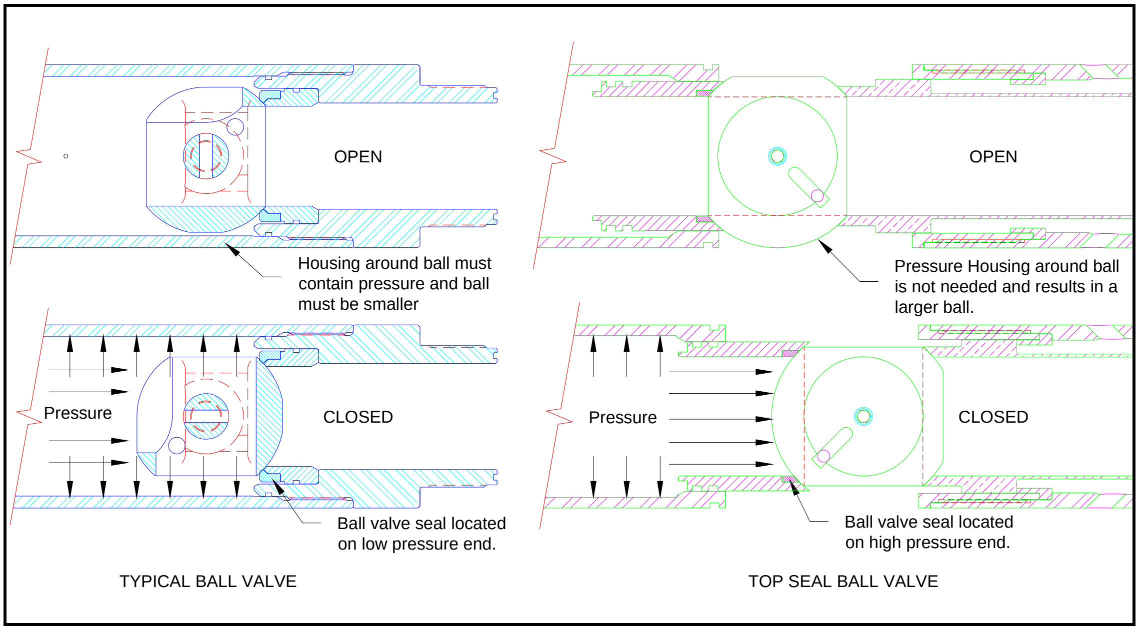


Figure 9, Traditional Ball Valve (left) compared to Top Seal Ball Valve concept (right).

Core liner

A transparent PVC core liner is contained in the inner tube and passes through the ball and into the cutting shoe. The liner is attached to the inner tube plug via a special tapered thread. The liner provides a continuous smooth bore for easy core entry. The liner is pulled with the inner tube plug during extraction to PCATS. The core catcher is attached to the lower end of the core liner using the same special tapered thread. Small holes drilled half way through the core liner wall provide a way for axial movement and rotation to be observed by x-ray scan while being manipulated in the PCATS system.

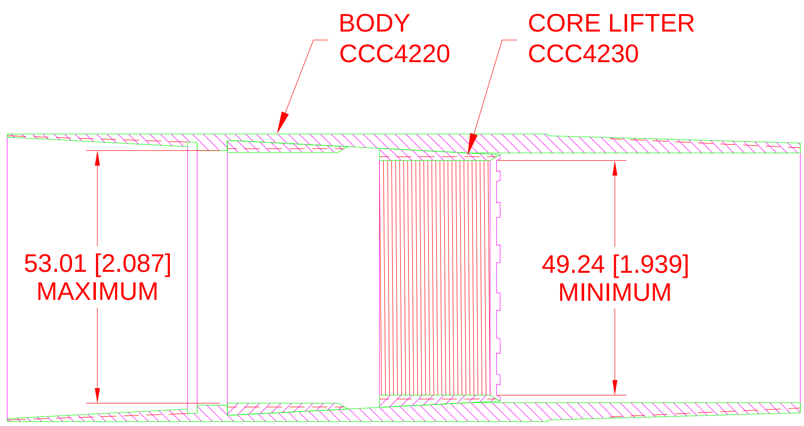
Core Catchers

Core catchers allow relatively free entry of the core into the core liner in the inner tube but prevent it from exiting when the core barrel is lifted off bottom. There are three core catcher options for the Hybrid PCS. The basket core catcher is shown in the photo. The thin sheet metal blades spring open to allow the core to enter but spring closed to prevent the core from sliding out. There is also a conventional slip type catcher and a full closing flapper catcher for very soft formations. The basket catcher can be used alone or in conjunction with one of the other two.

Figure 10. Hybrid PCS Basket Core Catcher

Spring Core Catcher

A spring (or slip) catcher is an option for the Hybrid PCS. The tapered surface was designed into the middle of a 5" long liner spacer. A male and female double tapered core liner thread are at each end so it can be easily added or removed. When it is used, the slip catcher takes the place of a 5" core liner spacer. The slip catcher body is made from stainless steel to ensure a smooth surface for the tapered spring ring to slide against. A shallow 5 degree taper was incorporated because of the extremely limited wall thickness. The shallow taper and core lifter length provide a grip range of from 1.94 in to 2.087 inches in diameter. A very fine thread is machined on the ID of the spring catcher to help grip the core. There are no internal threads in the spring catcher body. The spring catcher is simply squeezed and inserted into the body and it snaps into the enlarged tapered bore.



Flapper Core Catcher

The flapper catcher was modeled after the flapper catcher used on the HPCS. Besides being down sized for the 2 inch core the design was reduce in thickness to fit the kerf available in the Hybrid PCS liner thickness. In addition, there was not adequate space available to permit a slide in installation into a core catcher housing so an integral housing was developed with a slip-on outer sleeve to prevent core washing, protect the flapper and provide a surface for the cantilever spring that initiates closure of the flapper. When it is used, the flapper catcher takes the place of a 5" core liner spacer. The flapper core catcher is normally used with the punch shoe option. It can be run with or without the basket catcher.

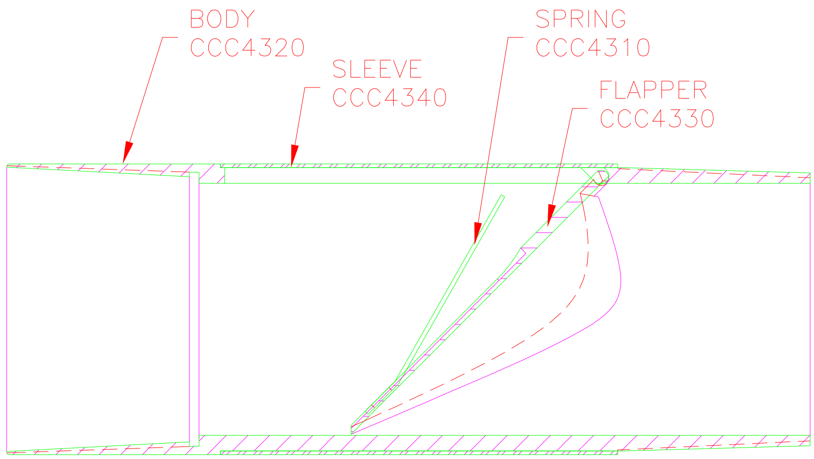


Figure 11, Hybrid PCS Flapper Catcher

Cutting Shoe

In order to be compatible with the ESCS BHA, a secondary inner bit, called a cutting shoe, is required. A torque transmission system is also required to transfer drilling torque from the BHA to the cutting shoe. The existing low end drive system already contained in the CDEX IODP Extended Shoe Coring System (ESCS) BHA, as used on the DV Chikyu, was incorporated for this purpose. The Hybrid PCS cutting shoe is an adaptation of the ESCS cutting shoe with a reduced ID to cut the smaller core size.

The cutting shoe is installed at the very end of the lower inner tube assembly. It is a small core bit that rotates with the main bit and does the actual core cutting. Small nozzles are designed into the cutting head to provide fluid for cooling the cutters and washing the cuttings away. The cutting shoes for the Hybrid PCS utilize polycrystalline diamond compacts (PDC) cutters. The cutting shoe sleeve is screwed into the ID of the cutting shoe which guides the drill fluid to keep it away from the core liner and core and directs it to the nozzles on the face of the cutting shoe.

Figure 12, Main bit and cutting shoe.

Optional Punch Shoe

A "punch" shoe option is also available. It has no cutters but simply punches into the formation like a cookie cutter. Rotation is not desired when the punch cutting shoe is used. Therefore the outer bearing must be installed and the drive sub replaced with a slick sub so rotation and torque is not transferred to the shoe.

Optional Face Bit

An optional so called Face Bit can be installed in place of the normal ESCS/HPCS bit. The face bit has a 2" bore and cuts the core as in a c conventional coring system. In this case the cutting shoe is replaced with a plain shoe. The outer bearing is also installed when using the Face Bit.

Ball Follower and Return Spring

The ball follower and return spring maintain the ball in the fully up or open position to prevent the ball from rubbing on the liner while coring.

Cutting Shoe Sleeve

The cutting shoe sleeve is threaded into the cutting shoe. It provides an annular channel to enable drilling fluid to be directed to the jets in the cutting shoe without washing the core.

Design Modifications

The following design change recommendations and improvements resulted from the JOGMEC and CDEX/JAMSTEC corer 2012 field testing and operations and were subsequently incorporated as deliverables in the Hybrid PCS development project.

1. Add check valve filtration system (possibly sintered filter) so it does not clog open after bleeding drilling fluid into the autoclave. The check valve is an optional item housed in the pressure control section. It provides a way for fluid to enter but not exit the autoclave after the ball valve closes. It was added because there is an autoclave chamber volume increase when as the inner tube plug continues to move up after the ball valve closes. If the pressure control section fails to provide a pressure boost, than the pressure in the autoclave will drop in proportion to the volume increase as the Inner Barrel Assembly is brought to the surface. The check valve is designed to eliminate this effect. However, in the past the check valve has often been contaminated with drilling mud and either sticks open or plugs. Adding a filter is intended to prevent the contamination. A standard sintered filter was selected that fits in the space in front of the check valve and replaces a portion of a washer that was used to hold the check valve in place.

2. Develop a fast acting last second auxiliary valve for autoclave or pressure control section to prevent pressure draw down during ball valve closure and IT plug movement. A design was developed that incorporates a spring loaded mandrel, detent and spring loaded sliding sleeve valve, called a pawl carrier, into the lower inner tube plug. (See Figure 13.) The detent is modeled after the very reliable latch dogs. The detent prevents motion between the mandrel and inner tube plug during coring. The sliding sleeve valve allows drilling mud to continue to enter the autoclave after the ball closes and the upper seals are engaged. When the pawls spring out in the cavity in the seal sub, continued upward motion pushes the sleeve valve against its spring to the closed position and seated against the inner tube plug. At this point the upper seals have stopped moving.

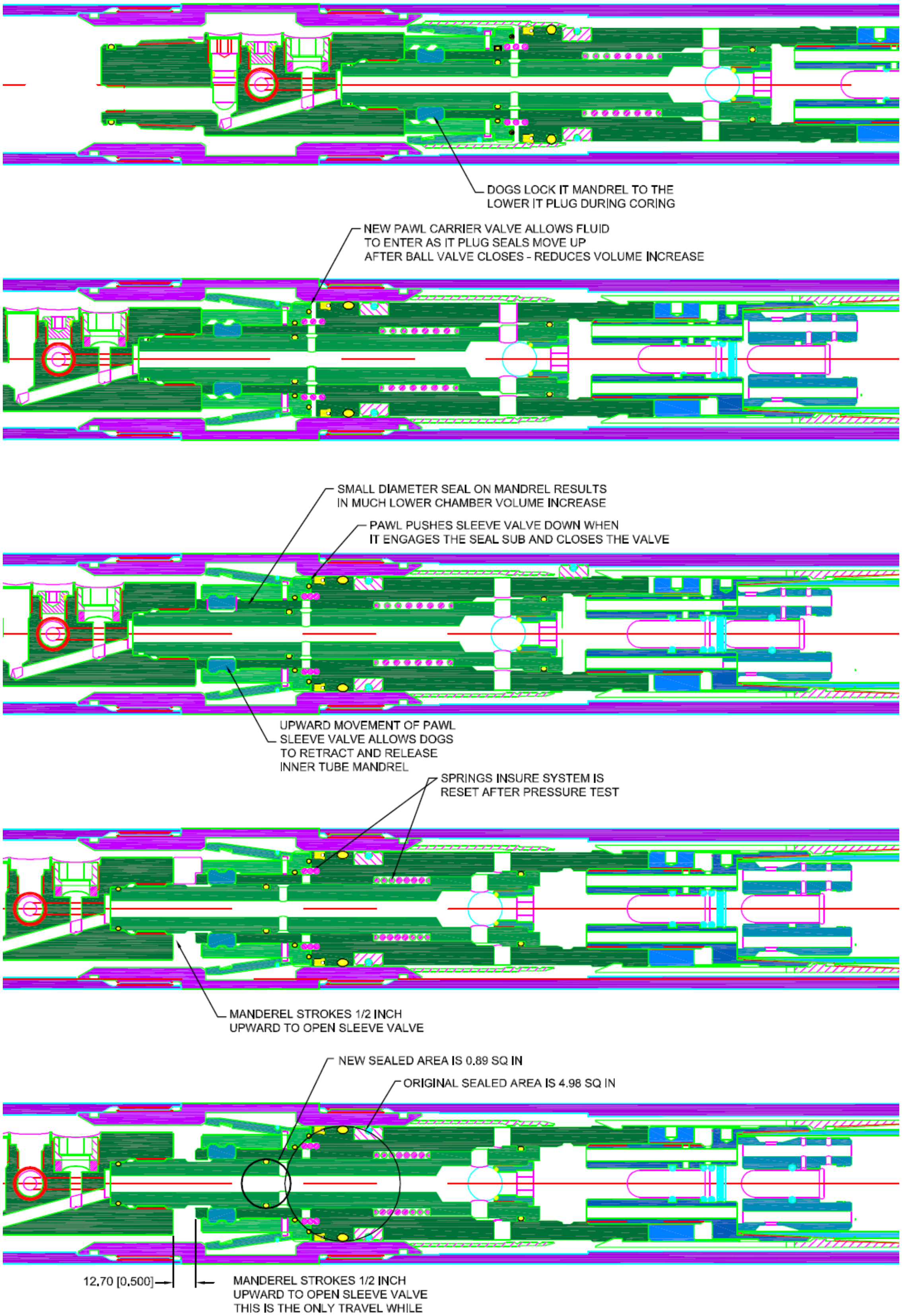


Figure 13, New Inner Tube Fast Acting Valve operation

The dogs are released by the movement of the pawl carrier and the mandrel is released from the inner tube plug allowing the components above it to continue to move up along with the mandrel to open the sleeve valve in the pressure control system and release the outer latch from the BHA. However, during this final motion, only the much smaller mandrel seal moves. This results in very little volume change to the autoclave.

The table lists the calculated volume change results for the original design and design with the fast acting valve. The reduction in chamber volume increase is due to the smaller diameter mandrel moving instead of the main upper seals. Calculations show that the 10 times smaller increase in the autoclave volume should lower the pressure reduction from 600 psi to less than 100 psi even without an active pressure regulated nitrogen supply or accumulator.

Table 3, New Inner Tube Fast Acting Valve Performance

Event	Original IT Plug			New IT Plug		
	Area	Distance	Volume	Area	Distance	Volume
	sq in	in	cu in	sq in	in	sq in
Chamber Sealing to End of Motion	4.98	0.806	4.01	0.895	0.5	0.45

The spring under the mandrel provides for automatic resetting of the system after the pressure inside the autoclave is bled down. This is necessary so that the required pre-deployment pressure test can be carried out and the autoclave can be reset for coring without disassembly.

An optional lockout washer is also provided that can be installed between the pawl carrier and upper inner tube plug to deactivate the new fast acting valve. When the lockout washer is installed it virtually returns the inner tube plug to its previous function without the fast acting valve.

As an added bonus, the new pawl carrier provides a way to easily replace the pins that hold the pawls in place. This has been nearly impossible to do in the original inner tube plug design because the pins were inserted into blind holes in the inner tube plug itself. With the improved design, the pin holes go all the way through to the ID. The pawl carrier can be disassembled and the pins easily pushed out through the ID and replaced.

3. Add an accumulator option for the pressure control section
The accumulator option was copied from the original PTCS that has a similar option. The conversion can be easily made by removing the separator piston and reservoir barrel and installing an accumulator piston. (See Figure 14.) The gas side of the accumulator is normally charged with about half the expected bottom hole pressure. This provides an accumulator volume and pressure cushion of about half of the chamber volume with pressure going from full bottom hole

pressure to half of the bottom hole pressure in case of leakage or volume changes in the autoclave. With the accumulator option there is no further pressure compensation once the accumulator piston reaches the bottom end of the chamber.

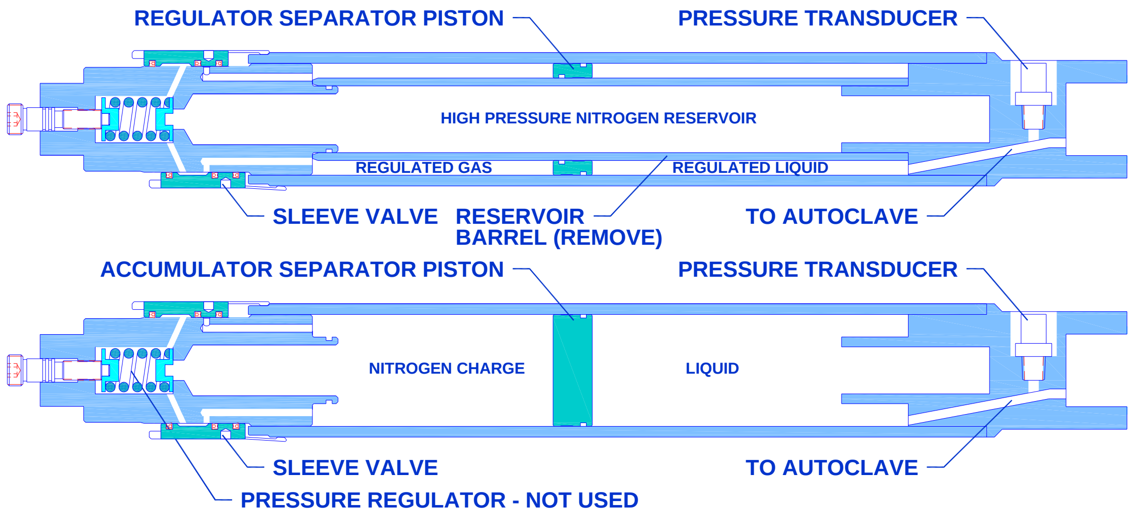


Figure 14, Pressure regulated (top) to accumulator conversion option (bottom).

4. Add a detent or spring to the sleeve valve to prevent the possibility of premature opening.
   This modification was modeled after the filed proven sleeve valve used in the PTCS. It was downsized to fit the Hybrid PCB Accumulator Barrel and designed to fit the existing turned down OD on the accumulator barrel. It consists of curved finger spring detents added to the lower end of the sleeve valve. The leaf springs bump up against the upset on the outer diameter of the Accumulator Barrel. The sleeve valve is securely locked in place until it bumps against the bottom of the lift sub which provides sufficient force to make the detents expand and jump up onto the larger diameter on the Accumulator Barrel. We used our own curved leaf spring MathCad template to design it to be sure the leaves would not be overstressed. The MathCad calculation sheet is provided in the Appendix of this report.

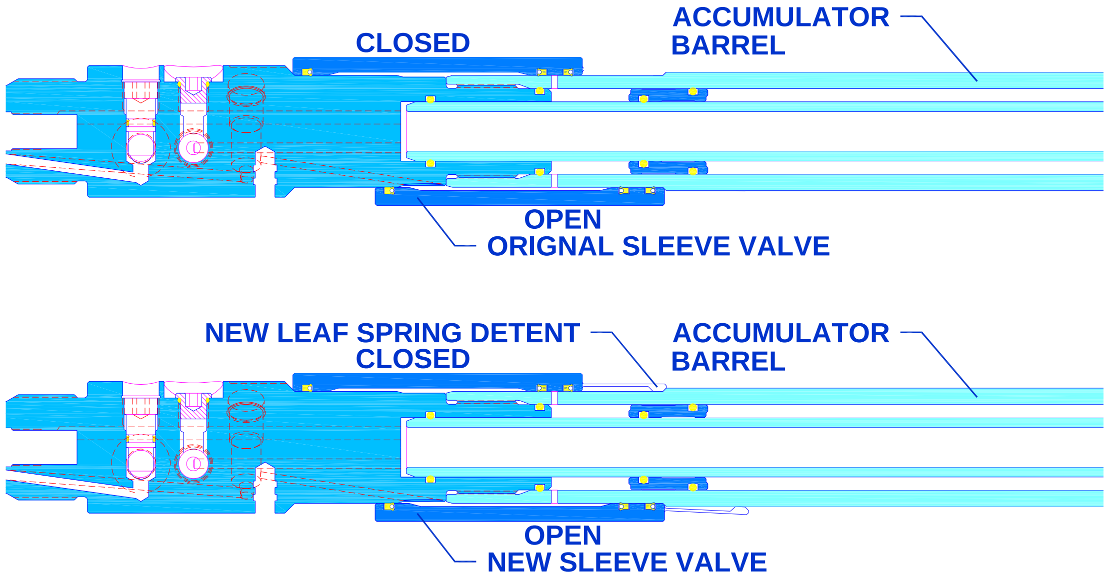


Figure 15, New Sleeve Valve Detent

5. Change winding direction in the ball valve closure spring for easier assembly.
   This was easily done by a change to the drawing. However, we also learned that the wrong thread had been ordered on the spring loading tool. The new springs were ordered and tested. There was no longer a tendency for the spring to jumped coils and bind up going in the top of the drive sub. This makes assembly much safer and more efficient. The springs supplied with the tools and spare parts are all wound in the new counter-clockwise direction.

6. Increase core liner and core catcher clearances with Inner Tube and/or redesign the core liner to catcher thread.
   The problem with the original Hybrid PCS was that in previous operations, the core liner would occasionally become stuck in the PCATS during transfer. This requires a lot of manipulation and time and in one case, the PCATS was damaged and in one other case a pressure core was lost because it had to be depressurized to get it free. A thorough investigation of the design revealed several issues:

a) The core catchers and liner extensions were specified to be slightly larger than the core liner. This left a sharp edge facing up on the upper end of the core catcher and extensions that could easily get hung up on any shoulder inside the Hybrid PCS or PCATS. This was fixed by making the core liners OD to match the OD of the core catchers.

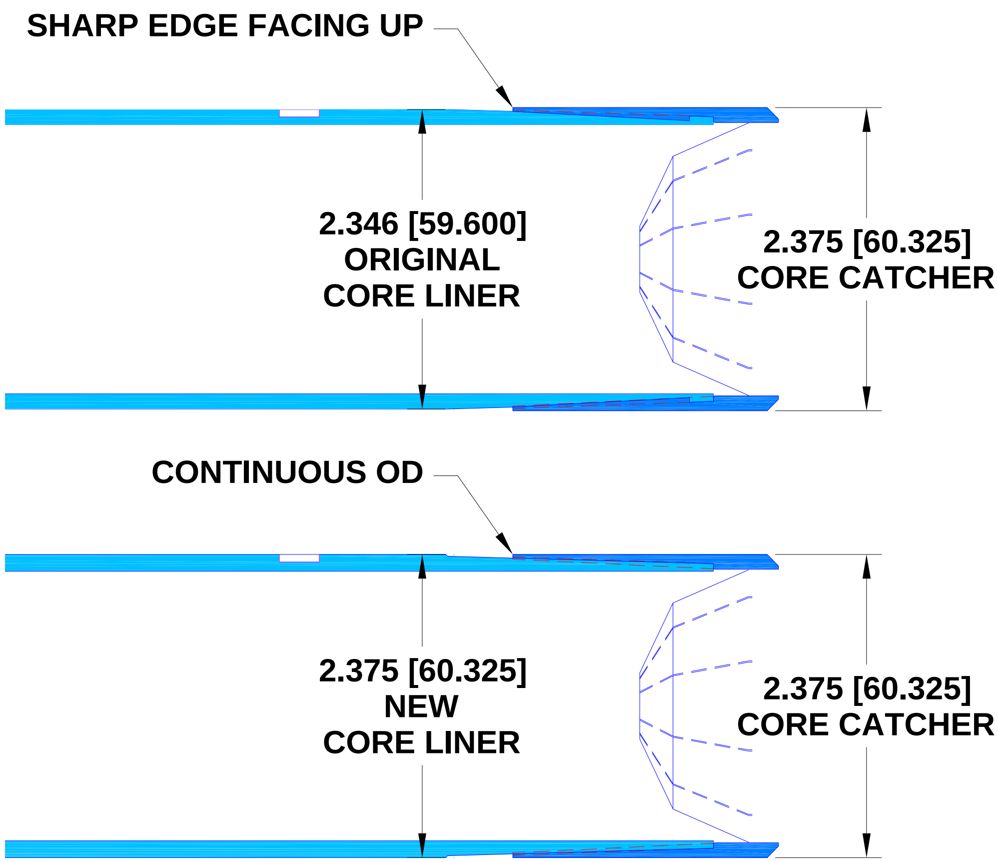


Figure 16, Improvement 1 for smooth transfer to PCATS.

b) The OD of the core liner length adjuster nut was dimensioned 2.515 +/-0.005 and it must travel through the 2.520 +/0.005 ID of the seal sub during transfer to PCATS. This combination can result in an interference fit of 0.005 making it impossible to transfer the inner tube to the PCATS. The seal sub ID was changed to 2.520/2.522 and the length adjuster nut was changed to 2.500 +/-0.005 resulting in a 0.015 minimum diametric clearance between the two parts. Note that this error had been discovered during the Japanese operation and fixed during that time.

c) The original inner tube had a specified ID of 2.385/2.390 and the core liner had an OD of 2.375 +/-0.010. This also had the possibility of an interference fit. In addition because of the relatively long (11.5 ft) length and operating in a dirty environment made it likely that there could be a problem with core extraction. To fix this problem, the Inner Tube was changed to use a stainless steel tube that had a stock inside diameter of 2.406 which provided the additional clearance that was needed. In addition, the original inner tube was made from carbon steel which was prone to corrosion. The new stainless steel inner tube eliminated any problem with corrosion buildup as well.

d) NOTE: Geotek also made changes to eliminate some sharp shoulders inside PCATS that could have been partially responsible for some of the difficulty with core transfer.

7. Increase clearance in transfer barrel and seal surfaces.
The purpose of the Transfer Barrel is to cover and seal the holes in the ball valve housing for pressure tests and during core transfer to PCATS. In field tests and previous operations, it was difficult to slide the Transfer Barrel over the Extension Sub and Ball Valve Housing. The effect was largely due to the long contact area. This was corrected by enlarging the bore in the middle of the Transfer Barrel. The seal diameter was not changed. In Figure 17 below, the original Transfer Barrel with tight clearances is shown in the upper half of the drawing and the improved Transfer Barrel is shown in the lower half. Calculation sheets for the Transfer Barrel with the larger bore are provided in the Appendix. The factor of safety is still 4 with the specified yield strength of 135Ksi.

Figure 17. Improved Transfer Barrel for easier assembly and disassembly.

8. Design a length adjuster between the inner tube plug and core liner. Note: The identified need for a pressure relief hole to the recorder holder has been replaced by the redesigned length adjuster included in this modification.
A length adjuster was needed in the autoclave to compensate for tolerance stack-up in the inner tube assembly and especially the plastic Core Liner. A length adjuster was incorporated into the Upper Inner Barrel Assembly but, in practice it did not prove practical or efficient to make the adjustment in that assembly. This improvement was implemented by shortening the Lower Inner Tube Plug and adding a threaded sleeve and a lock nut similar to a normal core barrel length but on a much smaller scale. The threaded nut also included a thin sleeve that covers the recess between the threaded sleeve and Lower Inner Tube Plug. This was done to prevent the loose Pawls or Pawl Spring from dropping into the recess and

jamming during core transfer to PCATS. As part of this improvement, the recorder holder was moved to the length adjuster which is more easily accessible and also eliminates the pressure trap that damaged the downhole recorders during operations.

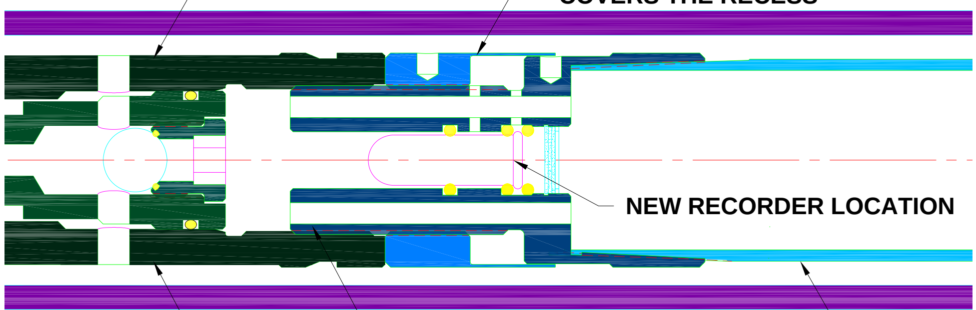


Figure 18, Core Liner Length Adjuster.

9. Design basket catchers with basket thickness options

   The basket core catchers are manufactured from standard gage stainless steel sheet that can be purchased in a variety of thicknesses (gages). The laser cut program works on any thickness that might be used for a basket catcher. It is only necessary to specify the gage of the material on the purchase order. No changes were required the documentation. In the end Chevron management decided to purchase the standard basket thickness and not a variety of thicknesses.

10. Reduce the inner latch piston ID to prevent jamming with wireline Pulling Tool

    During operations in Japan it was discovered that the core of the wireline pulling tool could become jammed into the inner latch piston because tolerances could result in a press fit. The bore in the end of the inner latch piston was 1.45 +/- 0.010 (1.440/1.460) and the core on the wireline pulling tool is 1-7/16 +/- 1/64 (1.415/1.447). The initial solution implemented was to reduce the diameter of the inner latch piston to 1.250 so the core of the wireline pulling tool core could not enter that bore. However, tests with the reduced diameter inner latch piston revealed that this change rendered the shear pin release feature inoperable because the end of the pulling tool core must be free to move down in order to shear the shear pin in the pulling tool to release it. Therefore, instead of reducing the ID of the inner latch piston, it was increased to 1-1/2 +/-1/64. This provides a minimum clearance of 0.03125. This prevents the jamming and also allows the shear pin release to function normally. Drawing CES7114 Rev 3 is provided in the appendix.

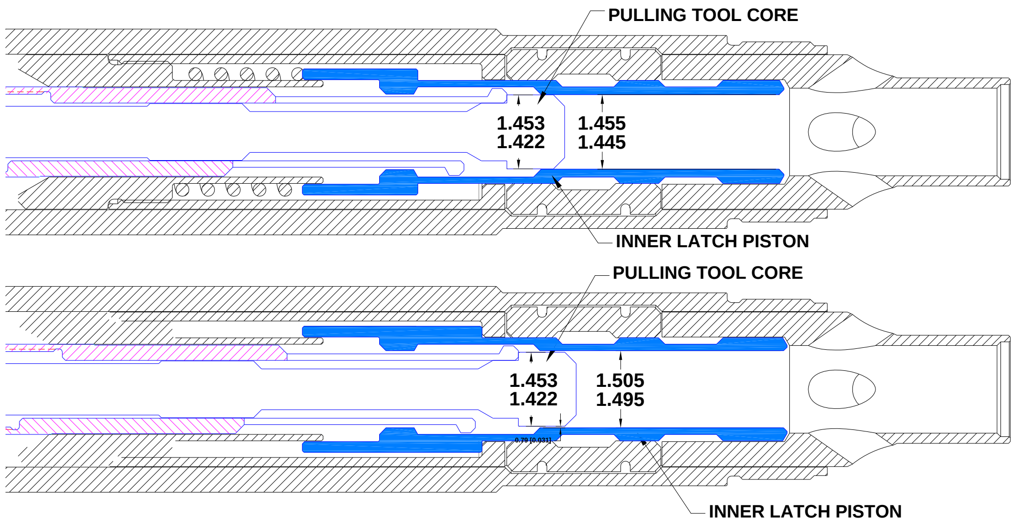


Figure 19, Inner Latch Piston ID (original top, improved bottom)

11. Modify outer latch housing garter spring grooves to increase strength.

    The garter springs are required to retract the dogs while tripping the inner barrel assemblies to keep the dogs from dragging on the drill pipe ID. The garter springs must be housed below the OD of the housing. The original design incorporated a lathe turned groove to do this. The groove must be deep enough so that the garter spring still applies inward force when the dog is completely retracted. With a lathe turned groove and six dog windows there was not much material left. Although the resulting strength was sufficient for the applied axial and torsional loads we did not anticipate the possibility that someone might overstress the area by applying make-up torque through this weak section which occurred while preparing the tools for an operation. In order to avoid this in the future, we decided to improve the design to make it more robust. First, only three dogs were specified and used. The six dog windows were specified to provide a way to machine them using wire EDM. However, this is no longer required since it is easy to machine them using NC milling machines. Second, the grooves were changed to from a simple round lathe turned groove to a "D" profile (See Figure 20.) with the flat part of the "D" in the area of the dog windows. The flat part of the "D" provides the required deep groove adjacent to the dog window and the round part of the "D" leaves much more material and results in higher tensile and torsional strength to the part. The tensile and shear area increases from 0.324 sq in in the original configuration to 1.812 sq in with the new "D" profile design or six times the area and strength. The effective moment arm is also increased and the resulting much elongated shape much more resistant to failure in torsion. The function of the garter springs is not compromised except for having to negotiate a tighter radius in the corners of the "D" shape. Note that a larger blend radius was specified for the corners of the "D". The new profile was lab tested successfully.

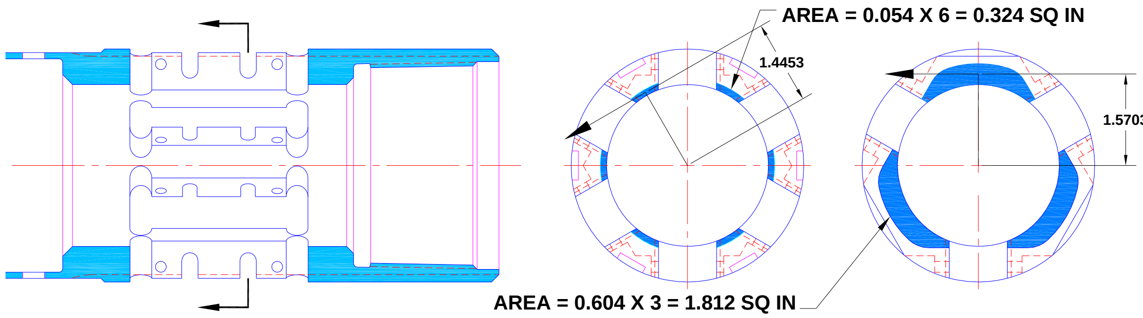


Figure 20, Outer Latch Housing with stronger garter spring grooves, original left, improved right.

12. Milled QLS alignment markings and possibly increase clearances
    This was a simple matter of specifying milled alignment marks on the drawings of the male and female QLS parts. It was decided not to increase clearances. Entry bevels were added to the holes on the QLS female. Revised drawings are provided in the Appendix.

13. For bullet valves requiring high torque replace allen wrench fitting with hex bit sockets and ratchets.
    The hex bit sockets and ratchets were ordered and provided.

14. Add flats and/or knurling or no-mar wrenches for easier, safer assembly. Provide pipe wrenches with teeth milled off to use on parts with the flats. Recheck make-up torque charts.
    An attempt was made to fabricate toothless flat jaw wrenches from heavy duty pipe wrenches. This failed miserably and the jaws simply slipped off the flats on the parts when torque was applied. Instead commercial flat jaw "monkey" wrenches were located and ordered and provided. "Monkey" wrenches have toothless flat jaws but they are cast at an angle to the handle which keeps them locked to the flats.

    Make-up torque charts were checked during the last operation and several errors were found in the formulae in the spreadsheet. Corrections were made and new torque charts were placed in the manuals.

15. Revert to the original Hybrid PCS three piece latch housing (CES7116/CES7113 instead
    This was done as an aid in manufacturing. The drawings still existed. Only the part list had to be changed. This change was added to the contract before signing. The parts were ordered and provided using the three piece design.

    Progress on the above tasks were reported in the Bi-weekly Reports and on a tracking spreadsheet. Approvals on design concepts and design decisions were received by email or during project review meetings.

Center Bit Assembly Design

A Center Bit Assembly was required as part of the contract deliverables but, not listed as one of the above engineering tasks. In an attempt to maximize the reliability and reduce complexity, we used as many parts common to the Hybrid PCS as possible in the design of the Center Bit Assembly. The entire Outer Latch Assembly was incorporated as well as the Quick Connect. The extension tube design was also borrowed from the Hybrid PCS with only the length adjusted. The Center Bit Assembly also incorporated the field proven drive sub, CES4005, as used on the ESCS tools we supply to CDEX/MQJ for use on DV Chikyu. The Center Bit Assembly details are provided on Drawing Number AES7060.

Two optional center bits were designed. One center bit fits the 3.800 ID of the cutting shoe bit and the second center bit fits the 2.000 ID in the face bit. Both center bits were designed and manufactured by Scorpion Engineering. They have been supplying our cutting shoes and center bits for many years. These small bits have a tungsten carbide matrix and incorporate PDC cutters. Both bits utilize the same thread that fits the bit sub in the Center Bit Assembly.

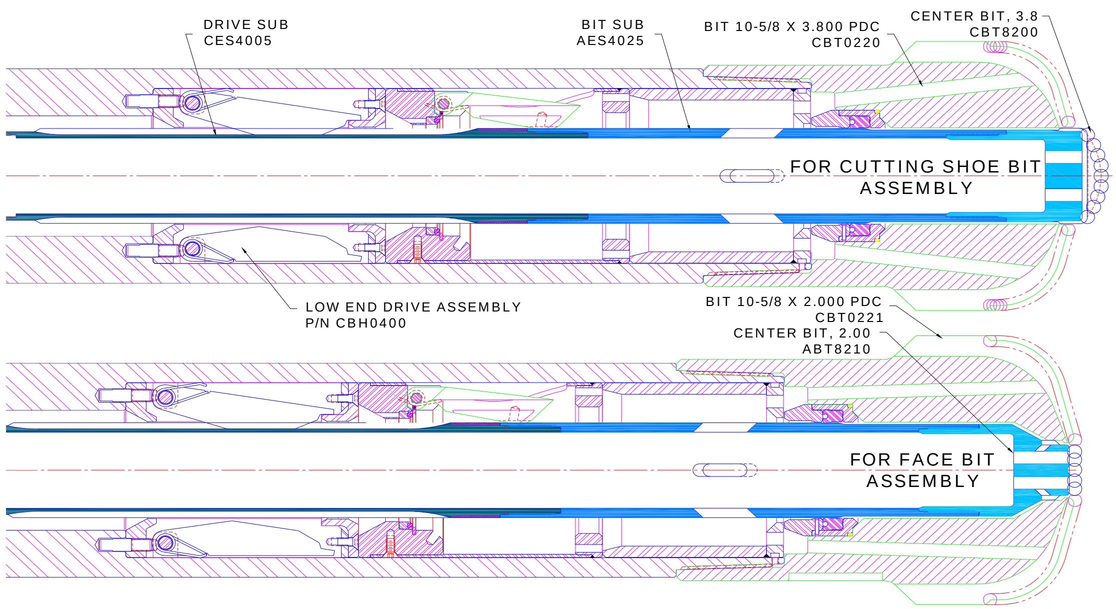


Figure 21, Center Bit Assembly, Top – Cutting Shoe Assembly, Bottom – Face Bit Assembly

Manufacturing and Quality Assurance

An Inspection and Test Plan was developed based on the template provided in the contract. The plan was discussed and approved at the Project Kick-off meeting held at the AAI offices in Salt Lake. The Inspection and Test Plan provides a structure for easily identifying tasks and assigning responsibilities. A copy is provided in the Appendix.

A new AAI manufacturing and quality assurance specification, ASP1000, was prepared to include the Chevron contract requirements regarding manufacture and quality assurance. A copy of ASP1000 is contained in the appendix. Kick-off Meetings were held in person with the management at Able Machine and Engineering, Aerospace Tooling and Loveridge Machine the week of June 10th and with American Machine the following week and by phone conference with Houston Downhole Tool. Specification ASP1000 was reviewed in detail during these meetings.

A list of the potential suppliers was provided to Chevron management. Mr. Sam Chase and/or Rob Russell visited most of the suppliers and approved the following list:

- Able Machine and Engineering – Hybrid PCS custom parts
- Aerospace Tooling and Machine – Hybrid PCS custom parts
- American Machine and Engineering – Hybrid PCS custom parts
- Houston Downhole Tool and their subcontractors including:
    - Alco Tool – Hybrid PCS 17-4 SS outer tubes
    - Reamco, Inc. – drill collar machining and carbide inserts on stabilizers
    - Taylor Oilfield Mfg – BHA component machining
    - Timken/BSI – Source for BHA 4145H Alloy Steel and trepanning
- Loveridge Machine Company – Hybrid PCS custom parts
- May Manufacturing – Cast and machine Lifting Clamps

Sources for purchased items included:

- Atlas Copco Secoroc LLC – Bits and cutting shoes
- Century Spring – Stock springs
- Gulf Coast Seal – Seals
- Honeywell Sensing and Control - Transducers
- Hydrapak, Inc. – Seals
- McMaster-Carr – Fasteners and hardware
- Rust Automation – Tescom regulator parts and Fike burst disks
- Salt Lake Bolt and Nut - Fasteners
- Scorpion Engineering, Inc. – Cutting shoes and center bits
- SKF Machined Seals – Seals

- Spring Works – Custom springs
- Suhm, Inc. – Custom springs

A full list with contact information and addresses is provided in the Appendix. Proposed part assignments were initially reported to Chevron for approval in a spreadsheet. Final assignments are shown in the QA Report.

Some purchase orders were prepared and issued immediately for most of the parts for Hybrid PCS tools, BHA components and spare parts because only a few of the parts required modifications and quotes had already been obtained from the suppliers. Other purchaser orders were issued soon after the modifications and center bit assembly design were completed. All purchase orders included the requirement to meet the new Specification ASP1000. A spreadsheet was prepared showing the status of each part. This spreadsheet was continuously updated and included with each of the Biweekly Reports that were distributed via email.

AAI incorporated a live rather than paper document control system. This was done by saving only the latest versions of drawings (in AutoCAD and Adobe .pdf format) in a special computer “folder” on the AAI server. All old or obsolete drawings were moved to a separate “obsolete” folder. In this way, only the latest approved versions of drawings were available to print or email and only these were used in the ordering process. A list of the latest versions of drawings could be obtained by printing out the directory of that folder.

AAI collected post heat treated samples from project ferrous steel materials that were purchased in a non-heat treated condition and subsequently heat treated. These samples were retained for conducting possible future tensile tests. One sample was collected for each heat treat batch. These samples were stamped with the same serial number as the parts that used that material and stored in a crate in the utility closet in the service van. A catalogue of the material test coupons is included in the Quality Assurance Records and the index of this report.

The Quality Assurance Record was compiled and contains the material certifications, inspection reports, and Material Rejection Reports for each part. The report is organized by purchase order number and then the item number on the purchase order. This is also used as the serial number for the parts. An index was prepared and is available sorted by Serial Number and Part Number so that records can be easily located. A two volume hard copy of the Quality Report with the indices was placed in the file cabinet in the service van. An electronic copy of the same material was copied onto the hard drive of the service van computer. AAI retained one hard copy in its files and one electronic copy on the AAI server. A copy of the Quality Assurance Record Index is provided in the Appendix of this report.

Mr. Rob Russell, Chevron QA Representative, conducted frequent audit visits to AAI subcontractor machine shops and sometimes witnessed dimensional inspections at subcontractor's facilities prior to the shipment of completed parts to AAI.

Dome discrepancies occurred during the manufacturing and quality assurance process.

1. The contract budget and deliverables were taken from the AAI submitted budget but structured differently, rearranged and modified. Also, some additional spare parts were listed in the body of the contract instead of with the spare parts section. AAI did not adequately compare and check their proposal with the actual contract and used the original AAI submitted budget list for ordering parts. This resulted in some parts not being ordered or ordered late when the discrepancy was discovered. This in turn, caused two parts to get through the process with inadequate QA because they were rushed through manufacturing when it was discovered they were missing and had to be completed in time for the field test. Errors on one of these parts was discovered during the Catoosa field test and corrected at a local machine shop under the direction of AAI personnel. The cost of missing parts was deducted from the contract total.

2. AAI's contracted machine shop management did not adequately disseminate AAI (Chevron) purchase order QC requirements to shop QC and/or production staff. Three of the subcontractor machine shop's purchasing personnel were not aware of material country of origin requirement and ordered materials that originated in countries outside USA or Defense Federal Acquisition Regulation Supplement (DFARs) approved countries. A limited number of parts were manufactured from countries deemed non-reliable such as Czech Republic, Romania, and China. This was in non-compliance with Chevron's requirement that raw materials be sourced from reliable western countries or equivalent. It was determined that non-reliable sourced materials would require additional chemical analysis to verify the material composition and sample retention for possible future tensile testing to verify material heat treatment compliance. There were exceptions where the Chevron representative determined the material would be acceptable for use without the additional testing on low stressed components. In one case AAI reordered the parts to be made with the correct materials. A chart of parts manufactured with non-compliant materials and with the resolution for each part is provided in the Appendix.

3. During the course of manufacture we received several notices of manufacturing errors. These were handled using our standard Material Variance Report form. The supplier provides the information concerning the defect and an AAI Engineer reviews the information and makes a disposition with instructions to "Use as is", "Rework", or "Scrap" the part(s). The Material Variance Reports become a permanent record and are included in the Quality Assurance Records. No serious issues were identified except for one

part where the supplier voluntarily scrapped the parts and manufactured replacements.

4. Towards the end of the manufacturing phase, one machine shop determined that it had taken on too much work and would not be able to complete the orders in the allotted time. AAI attempted to balance the workload by transferring some of the parts to other machine shops. However, it was too late and, in the end, late deliveries from several suppliers delayed assembly and final acceptance tests.

Assembly and Final Acceptance Tests

Assembly was started on September 18, 2013 and final acceptance tests were conducted over the period of September 19 through October 10, 2013. Final Acceptance Tests (FAT) were conducted on four autoclaves, four pressure sections, two upper assemblies and one center bit assembly. Three test procedures were used during the FAT:

1.1 Procedure CES001, Autoclave Pressure Test

This procedure includes the proof pressure test at 7500 psi (1.5 times the 5000 psi working pressure), a leak test at the working pressure of 5000psi and a low differential pressure test designed to test the ball valve seal at pressure conditions simulating slowly coming out of the hole. This procedure was conducted on each of the three autoclave assemblies.

1.2 Procedure CES002, Pressure Control Section Pressure Test

This procedure includes a proof pressure test at 10,500 psi (1.5 times the nitrogen working pressure of 7000 psi), a leak test at working pressure and a test to verify the performance of the regulator at several set points. This procedure was conducted on each of the three pressure control sections.

1.3 Procedure CES003, Horizontal Function Test

This procedure verifies the correct operation of the wireline tools, latches, bearing and over travel spring in the upper assembly and also function testing of a fully assembled Inner Barrel Assembly.

The tests were conducted at the Aumann & Associates, Inc. All of the tools passed their respective FAT’s. The full results of the FAT and the data sheets were provided in the Hybrid PCS (PCTB) Final Acceptance Test Report issued October 16, 2013.

Packing and Shipping for the Field Test

Chevron decided it would be more cost effective to ship the service van directly from Prolog to the Catoosa Test Facility and ship the tools, field test spare parts and service tools separately from AAI to the Catoosa Test Facility. Therefore AAI procured shipping crates and loaded the tools, field test spare parts and service tools into the crates and shipped to the Catoosa Test Facility during the last week in October. The bottom hole assembly, drill collars and crossover subs that had been stored at Houston Downhole

Tool in Tomball, Texas were likewise shipped by truck rather than using the heavy van because of the additional cost that would have been incurred to hire a crane to load it and the extra transportation cost for moving the heavy van itself.

The operations and results of the Catoosa Field Test are covered in Sections 5 and 6 of the Phase IIIB Topical Report.

At the end of the Catoosa field test, the bottom hole assembly, drill collars and crossover subs were returned to Houston Downhole Tool. All of the other AAI supplied tools and equipment were packed in the service van. Small parts and spare parts were packed in the cabinet drawers and larger tubes and assemblies were placed on the pipe racks and securely fastened using web type tie down straps.

Bottom Hole Assembly Inspection and Repair

The bottom hole assembly components, drill collars and subs were inspected for damage and cracks at Houston Downhole Tool. This included Head Sub, Top Sub, Landing Saver Sub, two Crossover Subs, the Lift Sub, Stabilized Modified Long Bit Sub, Coring Stabilzier, Seal Bore Outer Core Barrel and four Outer Core Barrels (drill collars). The Inspection Reports are provided in Appendix D of this report.

Figure 22, Damaged Pin Thread

The pin thread on the very bottom thread of the Seal Bore Outer Core Barrel was found to be damaged. This appeared to have been done during offloading without the use of a thread protector. We elected to repair it by grinding off the mushroomed portion and removing burrs by polishing. This was done because the only other options were to completely re-cut the thread or shorten the pin. Because this part must have a controlled length, it would have had to be scrapped. The repaired damage should not impact its function or life.

The threads in the boxes on three CBH1030-0, Outer Core Barrels (drill collars) and one CBH5065-0, Coring Stabilizer were galled. The threads were chased and the shoulders moved back to provide the proper gaging after the re-cut. Re-cutting the Outer Core Barrels only shortened them by 1/4 inch but still left them within the tolerance range. The coring stabilizer was also shortened by about 1/4 inch but left it slightly shorter than the specified length. However, this will have no effect on its function or life.

There were no cracks found in any of the BHA components. All were repainted; the threads re-coated with thread dope and thread protectors installed. Cost for the inspection and rework of the BHA was $3,315.00.

Bits

The bits were inspected by the manufacturer, Atlas Copco. They found damaged PDC cutters on the cutting shoe bit and no damage on the face bit. Photos below show the damaged cutters. A inspection report is provided in Appendix D2 of this report.

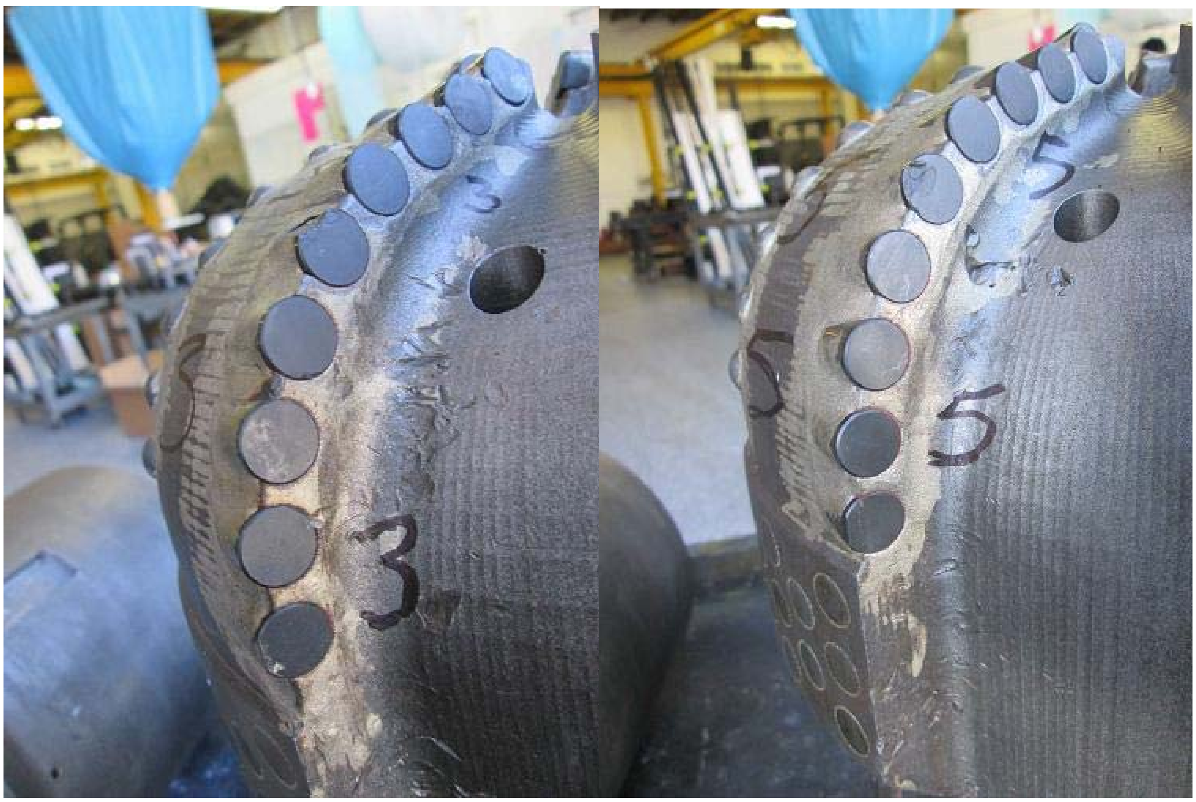


Figure 23, Damage PDC cutters on the blades 3 and 5 of the cutting shoe bit.

Repairs were made by Atlas Copco. Slightly damaged cutters were removed, rotated and braised back on. Severely damaged cutters were replaced. The bit should function like a new bit with the repairs that were made.

Inner Barrel, Center Bit Assemblies and Wireline Tools

The inner barrel assemblies and center bit assembly were completely disassembled at AAI and inspected for wear and damage. Other than expendable items such as seals, core liners and basket catchers, there was no wear observed on any parts and only superficial wear on the coatings and some minor corrosion. The only significant damage to any parts was what was reported in the Field Test Report. The field test damage consisted of a failed cutting shoe and two collapsed inner tubes and liners. The service van was also cleaned and inspected. Some damage was discovered on the exterior at the rear of the unit.

Cutting Shoes

During the Field test at Catoosa a Cutting Shoe crown apparently came off and disintegrated during the first and only coring test of the cutting shoe inner barrel assembly.

Closer inspection of the cutting shoe also revealed that the shank did not have the agreed upon design which would provide a steel stop for both the cutting shoe insert and the core catcher, resulting in those items stopping against the matrix, which is relatively weak in tension.

Figure 24, Cutting Shoe with missing crown.

AAI hired Royce Anthon, a metallurgical consultant with extensive experience in diamond bit metallurgy, to evaluate the bond between the matrix and steel bit blank of the cutting shoe. His study was not conclusive but he suspected the matrix material used by the manufacturer is not compatible with the 17-4 PH stainless steel bit shank because of a significant difference in the coefficient of thermal expansion between the two materials. AAI requested and obtained a metallurgical section of a new cutting shoe in the bond area prepared to confirm and verify the metalurgist’s hypothesis. A apparent void area can be seen in the section in the area between the crown and shank showing an imperfect bond but this is not serious enough by itself to explain the complete disintegration of the matrix crown.

Figure 25, Cutting shoe crown with section removed for analysis.

AAI met with representatives of Atlas Copco, manufacturers of steel bodied bits. They agreed to provide a quotation for manufacturing all-steel body PDC cutting shoes. With their product, no matrix would be used in the manufacture of the all-steel body PDC cutting shoes and, since the all-steel body PDC cutting shoe will not be furnaced, standard heat treated alloy steel can be used for the shank. The PDC cutters are brazed directly into the steel body which avoids the problems associated with a matrix construction altogether. The new design is shown in the drawing below. Note that tungsten carbide matrix is traditionally used in diamond bit construction to provide a high erosion and abrasion resistant surface. This is not needed in bits and cutting shoes used for coring relatively soft sediments encountered in methane hydrate formations. New steel body cutting shoes were manufactured to replace the four allocated to the autoclaves and also to replace the cutting shoes provided as spare parts. The new design also provides large round nozzles that may reduce plugging and includes larger waterways in front of each PDC cutter that may provide better cleaning.

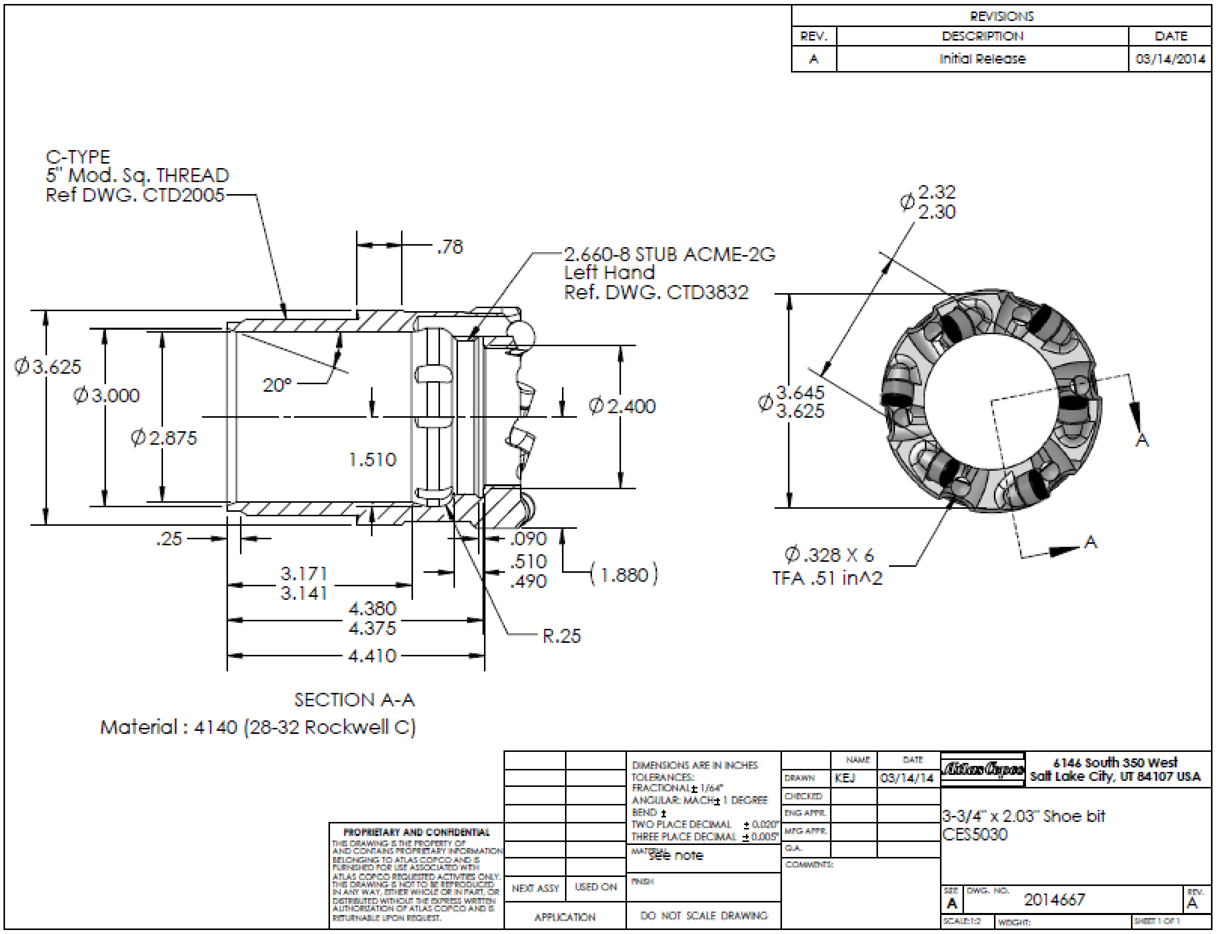


Figure 26, All-steel body PDC cutting shoe design

Collapsed Inner Tube Liners

During Runs 2: Face Bit Dimensional Test #1, at Catoosa the When the mud pump was engaged to initiate circulation, a pressure spike of 860 psi was observed. Circulation was established for 30 min. Note that the dimensional tests were intended to be circulation and function tests in the casing with no coring attempted. The PCTB was then recovered on wireline without incident. Upon inspection of the PCTB, it was discovered that the liner and inner tube had collapsed, preventing the ball valve from closing. On Run 13: Face Bit Core #2 Coring began at a depth of 1,158 ft with 8,000 – 16,000 lb weight on bit, 240 – 250 gpm flow rate and observed pump pressure as high as 440 psi. When brought to the surface, it was discovered that the liner and inner tube had again collapsed.

Figure 27, Collapsed inner tube from face bit Dimensional Test #1.

The inner tube had been redesigned in order to provide more clearance between the ID of the inner tube and OD of the core liner to eliminate sticking during core transferring the core to PCATS. As part of this redesign a low strength thin wall stainless steel tube was selected because it provided the necessary increased ID for more clearance and also corrosion resistance at a low cost. This change may have contributed to the implosion although the unusually high pressure generated by the face bit was probably the real culprit since the inner tubes did not implode during the cutting shoe bit runs.

That being said, it was determined that there was sufficient room in the autoclave to provide a significantly thicker and stronger inner tube that would be more robust and more resistant to collapse even in the presence of unwanted pressure spikes. Unfortunately, there was not sufficient time to design, manufacture and test replacement inner tubes in time for the cutoff date of the project. One stock thin wall replacement inner tube was provided by AAI during the field test at Catoosa. That leaves one autoclave without an inner tube. New replacement thicker inner tubes should be manufactured and tested prior to any operations that included the face bit option.

Damage to the Service Van

The Service Van was apparently stabbed with a forklift either during placement or while being moved or loaded following the field test. AAI inspected the damage and believed the damage to be superficial and not structural.

Figure 28, Damage to Service Van from apparent fork lift stab.

Aumann & Associates obtained approval from Chevron and repaired the damage. The following photos show the damaged area after the repairs were made.

Figure 29, Repaired Service Van

Additional Modifications

A Technical Review Team (TRT) was assembled following the Catoosa Field Test to study and evaluate the test results and make recommendations for improvements. Additional lab tests were also conducted. Based on the recommendations made by the TRT and approved by Chevron, prototype parts were modified and/or manufactured and successfully lab tested. It is believed that those improvements will result in significantly improved performance. The improvements were implemented to the entire project inventory including assemblies and spare parts. All modified parts were re-coated with Manganese Phosphate when required by the drawing specifications. Please refer to the separate TRT Final Report for more information.

e) Final Packing and Shipping.

The tools were nearly completely disassembled and parts and subassemblies placed in sealed in plastic bagging material with desiccant to prevent corrosion during long term storage. Where possible, parts were placed in the cabinet drawers. Longer parts and subassemblies were placed on the tool racks and tied to the structure using web tie downs.

Bound copies of the operation and service manuals were placed in the file cabinet in the service van. A copy of the QA Report was also placed in the file cabinet. Copies of the packing lists were placed in sealed pouches on the outside and inside the service van. An electronic copy of these documents was loaded onto the laptop computer and placed in the filing cabinet. The required heat treatment test coupons were placed in a crate in the HVAC closet. A copy of the packing list that lists the location of each part is provided in Appendix E of this report.

APPENDICES

A. MathCad Sleeve Valve Detent Calculation Sheets
- A1 - Sleeve Valve Collet Calculations
- A2 - AHT4041, Transfer Barrel with thinner wall Calculations

B. Revised Drawings
- B1 - Drawing CES7330 Rev 4, Sleeve Valve
- B2 - Drawing CES7519, Ball Valve Spring

C. Manufacturing and Quality Specifications
- C1, ASP1000, Manufacturing and Quality Specification
- C2, List of Manufacturers and Sources of Purchased Parts
- C3, Inspection and Test Plan
- C4, Quality Report Index

D. Post Field Test Inspection Reports
- D1, BHA Inspection Documents
- D2, Bit Inspection Report

E. Packing List

Appendix A1, CES7330, Sleeve Valve Collet Calculations

SLEEVE VALVE COLLET, CES7330

(Cantilevered Leaf Spring)

GIVEN:

$\delta := \left(\frac{2.625 \cdot in - 2.5 \cdot in}{2}\right)$ $\delta = 0.062 \cdot in$ (required deflection)

$L := 4 \cdot in$ (length of leaf)

Material: 4140 steel OQ&T to 28-34 Rc with the following properties:

$E := 28 \cdot 10^6 \cdot psi$ $S_y := 90000 \cdot psi$

Calculate the allowable bending and tensile working stress with a safety factor of 4.

$S_w := \frac{S_y}{4}$ $S_w = 2.25 \times 10^4 \cdot psi$

THE VARIABLES ARE:

$D := 2.81 \cdot in$ Outside diameter of the collet

$d := 2.69 \cdot in$ Inside diameter of the collet

$n := 12$ Number of fingers on the collet

$R := \frac{D}{2}$ $R = 1.405 \cdot in$ Resulting Outside Radius of the collet

$r := \frac{d}{2}$ $r = 1.345 \cdot in$ Resulting Inside Radius of the collet

The Area of the Section, A, Moment, M_x; and Momemt of Inertia, I_x, and distance from the neutral axis to the extreme fiber, y, are calculated as follows:

$$A := \int_r^R \int_{\frac{\pi}{2}-\frac{\pi}{n}}^{\frac{\pi}{2}+\frac{\pi}{n}} r \, d\theta \, dr \qquad A = 0.043 \cdot in^2$$

$$M_x := \int_r^R \int_{\frac{\pi}{2}-\frac{\pi}{n}}^{\frac{\pi}{2}+\frac{\pi}{n}} r^2 \cdot \sin(\theta) \, d\theta \, dr \qquad M_x = 0.059 \cdot in^3$$

$$I := \int_{\frac{\pi}{2}-\frac{\pi}{n}}^{\frac{\pi}{2}+\frac{\pi}{n}} \int_r^R r^3 \cdot \sin(\theta)^2 \, dr \, d\theta \qquad I = 0.08 \cdot in^4$$

Calculate the y the distance from the neutral axis:

$y_o := \frac{M_x}{A}$ $y_o = 1.36 \cdot in$

Translate the Moment of Inertia to center on the neutral axis from the centers of the axis:

$$I_x := I - M_x \cdot y_o$$

$$I_x = 2.111 \times 10^{-5} \cdot in^4$$

Find the distance from the neutral axis to the extreme fiber in the leaf:

$$y_1 := \cos\left(180 \cdot \frac{deg}{n}\right) \cdot r \qquad y_1 = 1.299 \cdot in$$

$$y := y_o - y_1 \qquad y = 0.06 \cdot in$$

The general deflection equation for a cantilever beam is:

$$\delta = \frac{P \cdot L^3}{3 \cdot E \cdot I_x}$$

Rearrange terms and solve for the maximum allowable load, P:

$$P := \frac{3 \cdot \delta \cdot E \cdot I_x}{L^3} \qquad P = 1.732 \cdot lbf \qquad \text{for one finger}$$

$$P_{total} := n \cdot P \qquad P_{total} = 20.78 \cdot lbf \qquad \text{for "n" fingers}$$

Check that the bending stresses are acceptable:

$$S := P \cdot L \cdot \frac{y}{I_x} \qquad S = 1.982 \times 10^4 \cdot psi$$

$$FS := \frac{S_y}{S} \qquad FS = 4.542$$

Check the maximum safe tensile load.

$$A_{total} := A \cdot n \qquad A_{total} = 0.518 \cdot in^2$$

$$P_{allow} := S_w \cdot A_{total} \qquad P_{allow} = 11663 \cdot lbf$$

Appendix A2, AHT4041, Transfer Barrel Calculations

Hybrid PCS
AHT4041, Transfer Barrel
4.25 OD x 3.75 ID 17-4 PH SS

$P := 5000 \frac{lbf}{in^2}$ $P = 34.474\,MPa$ Working pressure

$\sigma y := 135000 \frac{lbf}{in^2}$ $\sigma y = 930.792\,MPa$ Yield stress of 4140 OQT to 135Ksi Yield

$OD := 4.375 in$ $OD = 111.125\,mm$

$ID := 3.781 \cdot in$ $ID = 96.037\,mm$

$\sigma hoop := P \cdot \left(\frac{OD^2 + ID^2}{OD^2 - ID^2} \right)$ $\sigma axial := \frac{ID^2 \cdot P}{OD^2 - ID^2}$ $\sigma radial := -P$

$\sigma hoop = 3.451 \times 10^4\,psi$ $\sigma hoop = 237.929\,MPa$

$\sigma axial = 1.475 \times 10^4\,psi$ $\sigma axial = 101.728\,MPa$

$\sigma radial = -5 \times 10^3\,psi$ $\sigma radial = -34.474\,MPa$

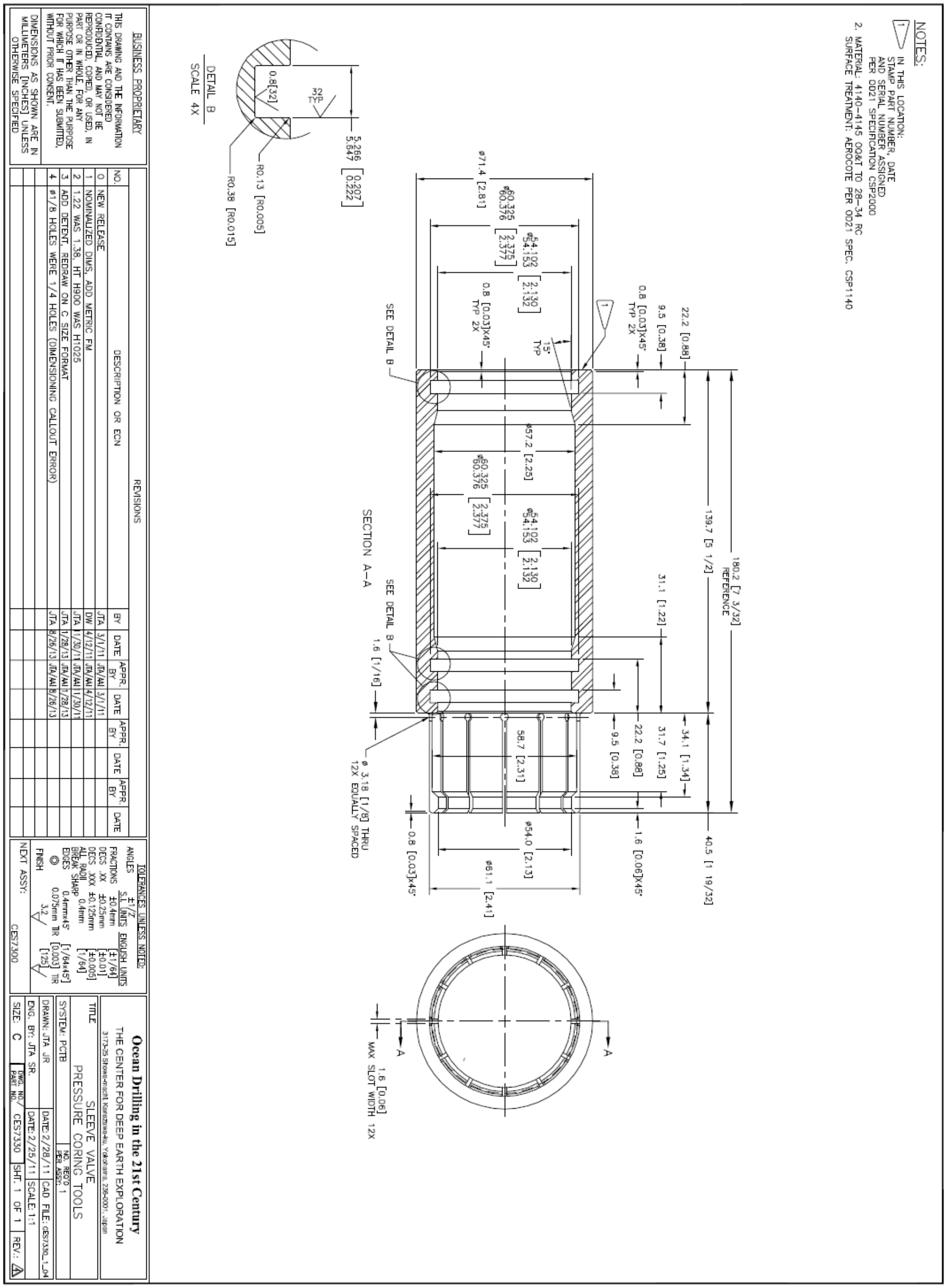
$$\sigma equiv := \frac{2^{.5}}{2} \cdot \left[\left[(\sigma hoop - \sigma axial)^2 + (\sigma hoop - \sigma radial)^2 + (\sigma axial - \sigma radial)^2 \right]^{.5} \right]$$

$\sigma equiv = 3.422 \times 10^4\,psi$ $\sigma equiv = 235.908\,MPa$

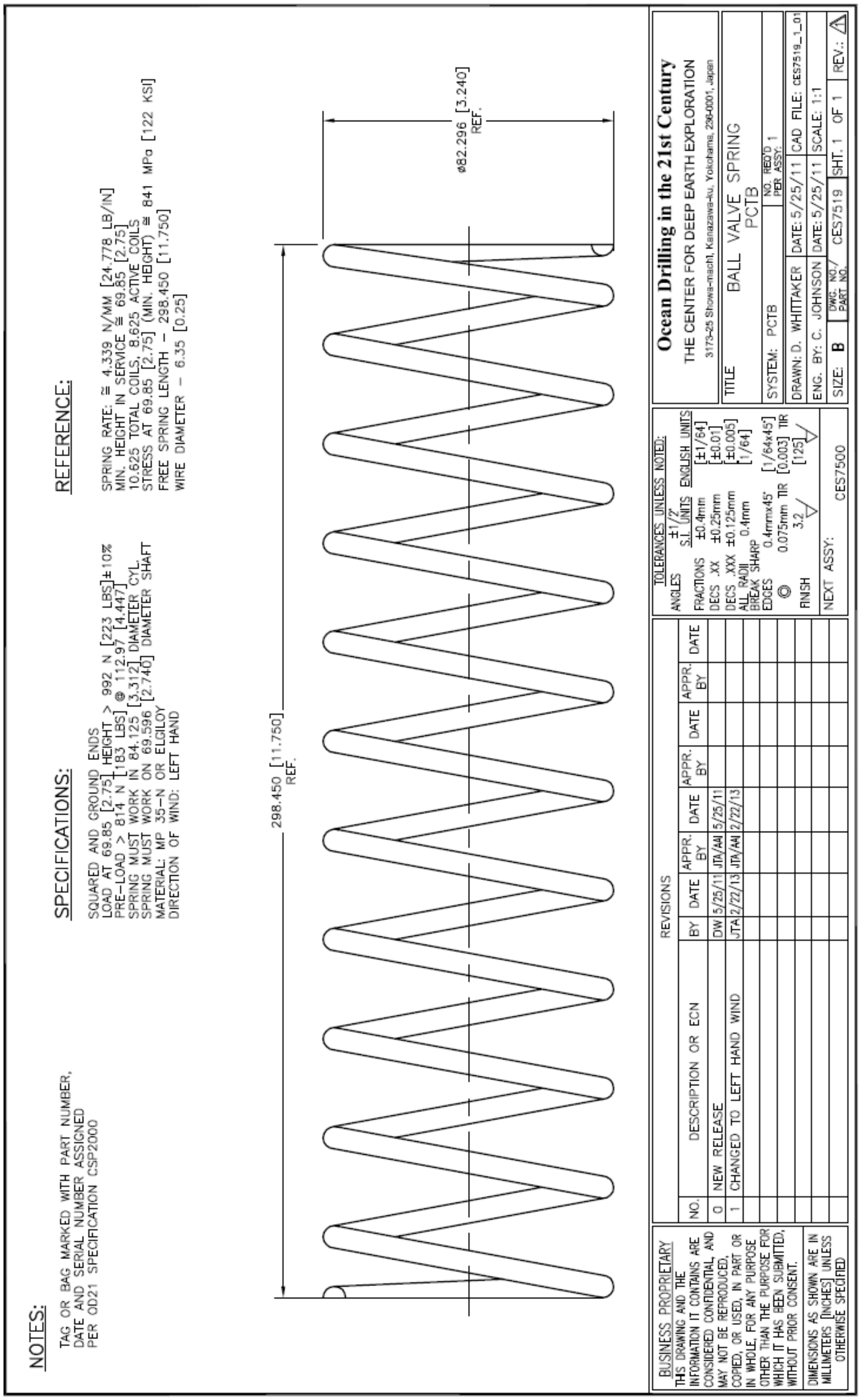
$SF := \frac{\sigma y}{\sigma equiv}$

$SF = 4$

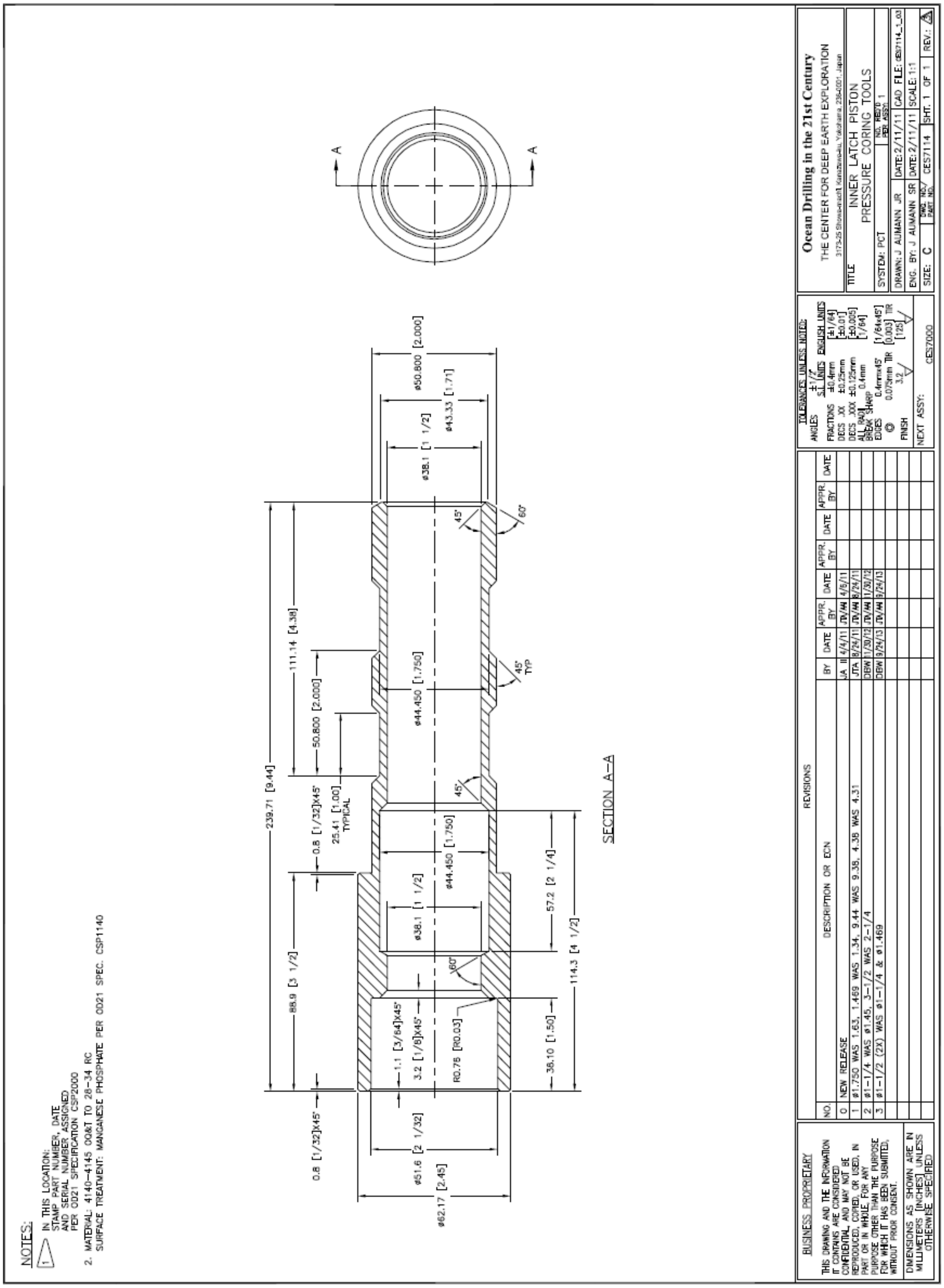
Appendix B1, Drawing CES7330 Rev 4, Sleeve Valve



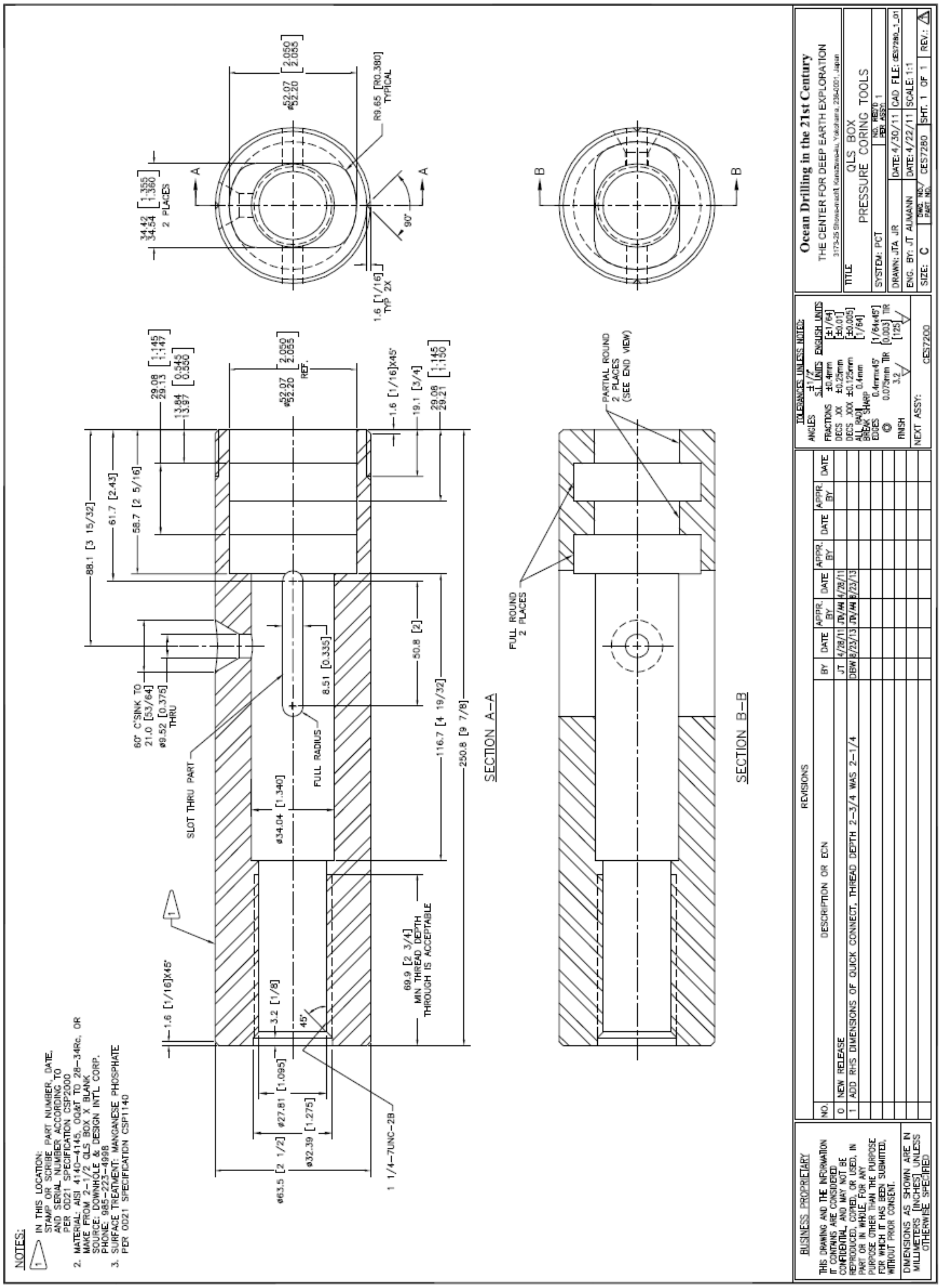
Appendix B2, CES7514 Rev 1, Ball Valve Spring



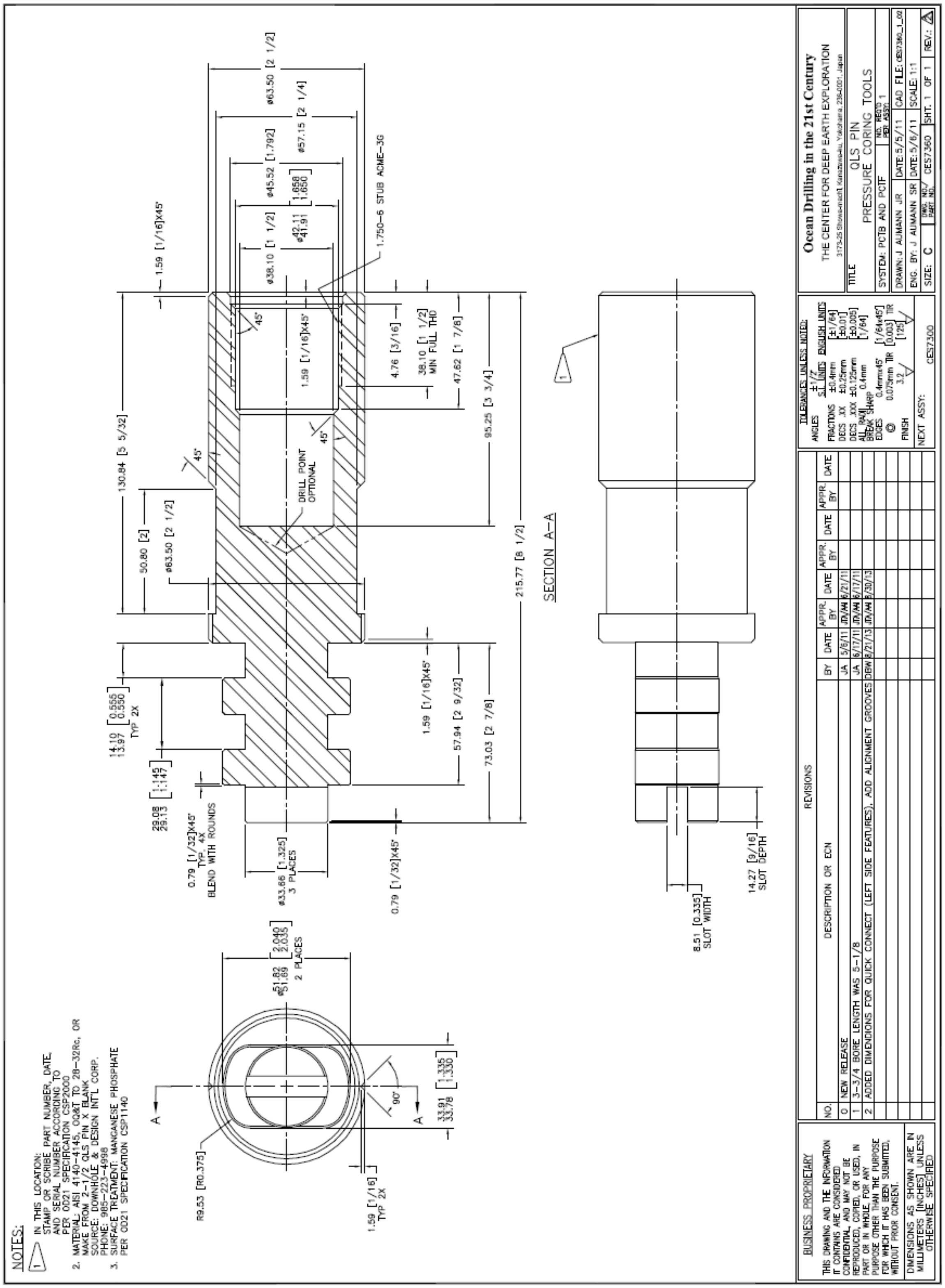
Appendix B3, CES7114 Rev 3, Inner Latch Piston



Appendix B4, CES7280, QLS Box



Appendix B5, CES7360, QLS Pin



Appendix C1, ASP1000, Manufacturing Specification

Aumann & Associates

Phone: 801.631.2874 2698 South Redwood Rd Suite N; West Valley City, Utah 84119 Email: Jim@AumannInc.com

Title:	Specification:	Revision:
General Manufacturing and Quality Specification	ASP1000	1

1.0 General Description

This specification covers general manufacturing quality control, finishing procedures and certifications for custom manufactured parts.

2.0 Quality Control Inspection

2.1 All parts must be inspected for conformance to drawing specifications and tolerances in an inspection area separate from the fabrication area and by personnel qualified to perform such inspections. The person conducting the inspection must be different from those who fabricated the parts.

2.2 Supplier shall notify AAI a minimum of two days before inspections are scheduled. Supplier and its client shall have an opportunity to witness inspection(s) and/or review inspection documents.

2.3 Inspection(s) and certification(s) shall be complete and verified by AAI prior to acceptance and delivery.

2.4 Calibration for all measurement and/or test equipment used for verification purposes shall be current.

2.5 An inspection report shall be furnished with each batch of parts delivered. It shall provide a written record of each actual measurement taken to verify the part complies to the dimensions and tolerances specified on the drawing(s). This means 100% inspection of each dimension on each part. The inspection report can be in the form of a marked up print or a chart.

2.6 The inspection report will also contain the date of the inspection, the inspector(s) name(s), measurement or test equipment used and date(s) of next calibration.

2.7 Any part found to be out of compliance with the dimensions and tolerances specified on the drawing(s) or specification(s) shall be clearly marked and quarantined. A Material Variance Report (MVR) provided by AAI shall be completed by manufacturer and forwarded to AAI by email, fax or hand carried. AAI engineering personnel will make a determination to scrap, rework or use the part as is. The completed and approved MRR will become a permanent part of the inspection report. Any marking shall be removed from the part(s) after successful rework or if the designation was “Use as is”.

3.0 Surface Treatment

Where a particular surface treatment is indicated on the drawing, purchase order or other documentation for a given part or assembly, the following specifications and procedures apply. Where there is not a requirement for a surface treatment, a rust inhibitor shall be applied if appropriate.

Conventional Paint: Clean parts in accordance with paint manufacturer’s recommendation. Paint exterior with a two-coat quality marine system which includes a metal-rich primer and tough topcoat. Color to be as specified on the purchase order.

Epoxy Paint: See Specification CSP1020.

Xylan 1425 Coating: See Specification CSP1120.

Sermaguard 1150 or Xylan 1052: See Specification CSP1125.

Manganese Phosphate Coating: See Specification CSP1140

4.0 PART IDENTIFICATION

All parts must be marked in the location indicated on the drawing with the part number (including latest "dash" revision number), the month and year of fabrication and the serial number as indicated by the Purchase Order. Part marking shall be in accordance with specification CSP2000.

5.0 MATERIALS

All materials must be sourced from U.S or Western mills. Materials from third world countries are not acceptable except in extreme case by an approved waiver in advance using a Material Variance Request (MVR).

6.0 CERTIFICATIONS

6.1 Chemical analysis: Certification of chemical analysis is required for all materials supplied by the vendor, including steels, non-ferrous metals, and alloys.

6.2 Heat treating: Certification is required for all treated parts from the vendor performing the heat treating operation. All parts heat treated must be identified by quantity, part number, order date, and checked for conformance to the appropriate specification.

6.3 Physical properties: Certification of physical properties (tensile strength, yield strength, elongation, hardness, impact or others as required by the purchase order) is required for any part with a rotary shouldered connection. Specific requirements are detailed in Specification CSP5010 for drill collars and subs and CSP6050 for outer core barrels. These specifications are referenced on the drawings or purchase order where required. Certification of tensile strength, elongation, and hardness shall be provided for parts manufactured from commercially pre heat treated material. Vendor heat treated parts require certification of hardness after heat treatment. In addition vendor heat treated parts must be delivered with test coupons suitable for conducting tensile and impact tests in the future. The test coupon shall be cut from the same lot of material as the parts and heat treated with the parts. Note that test coupons are required for each lot of material used and each batch of heat treated parts. Test coupons for parts made from solid bar stock shall be 6 inches long. Test coupons for parts made from tubing or with a predominantly tubing form shall be supplied with a piece of tubing or manufactured to a similar wall thickness and shall be 10-12 inches long. As an option the vendor may supply the certified post heat treat tensile, yield, and elongation values in place of the test coupon(s). Vendor heat treated parts with this requirement shall be so noted on the drawing and/or purchase order. Test coupons shall be stamped with the same serial number as the parts.

6.4 Testing: Tensile properties shall be determined by tests on specimens conforming to the requirements in the current ASTM A370. Charpy Impact testing shall conform to ASTM A370 and ASTM E23 testing procedures. Unless otherwise noted, the orientation of charpy sample shall be longitudinal with the "V" notch perpendicular to the outside diameter (surface) of the material. Also, the impact tests shall be performed at 0° C (32° F) unless specified otherwise.

7.0 API SPECIFICATION REQUIREMENTS

7.1 Where applicable, all drill string components must meet American Petroleum Institute Specification 7, "Rotary Drilling Equipment," (current revision).

7.2 API threads are to be fabricated and checked using only hardened and ground, API Ring and Plug thread gages with calibration certified to API Spec. 7 Reference Master gages within the last three years.

An authorized representative of AAI must approve any deviation from this specification.

Aumann & Associates
Phone: 801.631.2874 2698 South Redwood Rd Suite N; West Valley City, Utah 84119 Email: Jim@AumannInc.com

Title:	Specification:	Revision:
General Manufacturing and Quality Specification	ASP1000	1

Approved by: ______________________________ *Date:* Jan 17, 2013
James T. Aumann
Senior Engineering Supervisor

______________________________ *Date:* ______________.
Drilling Engineer

______________________________ *Date:* Jan 17, 2013 .
Manager

Revisions:

No.	Description or ECN	By	Date	Appr. By	Date	Appr. By	Date
0	New Release	JTA	01/17/13	JTA	01/13/13		
1	Added 5.0 Materials, and test coupon size details.	JTA	07/13/13	JTA	07/13/13		

Appendix C2, List of Manufacturers and Sources of Purchased Parts

Able Machine and Engineering – Hybrid PCS custom parts
Dan Smith
272 Berger Ln
Salt Lake City, UT 84107
Phone: 801.268.6766 Fax: (801) 268-0330

Aerospace Tooling and Machine – Hybrid PCS custom parts
Perry Salm
2190 West 1700 South
Salt Lake City, UT 84104
Phone: (801) 972-1279 Fax: (801) 972-1296

American Machine and Engineering – Hybrid PCS custom parts
J.R. Calkins
2440 S. 3200 W. #5
West Valley City, UT 84119
Phone: (801) 973-0494 Fax: (801) 908-0122

Anaheim Custom Extruders – Plastic extruded tubing for core liners
Angie Rivas
4640 East LaPalma Ave
Anaheim, California 92807
Phone: (800) 229-2760 Fax: (714) 693-9531

Houston Downhole Tool
Julie Braue'
11010 Mahaffey
Tomball, TX 77375
Phone: (281) 875-0404 Fax: (281) 875-0505

Loveridge Machine Company – Hybrid PCS custom parts
Dennis Loveridge
4097 South West Temple
Murray, UT 84107
Phone: (801) 262-1414 Fax: (801) 261-1818

May Manufacturing – Cast and machine Lifting Clamps
Mike May
454 West 600 North
Salt Lake City, UT 84103
Phone: (801) 531-8931 Fax: (801) 521-0641

Sources for purchased items included:

Atlas Copco (formerly New Tech, Inc.)
Mark Jones
6146 South 350 West
Salt Lake City, UT 84107
Phone: (801) 281-1682

Century Spring – Stock springs
222 East 16th St.
Los Angeles, CA 90015
Phone: (800) 237-5225 Fax: (213) 749-3802
Order via: http://www.centuryspring.com

Gulf Coast Seal – Seals
Aaron Carter
9119 Monroe Rd
Houston, TX 77061
Phone: (713) 910-7700 Fax: (713) 910-6600

Honeywell Sensing and Controls - Transducers
Banu Turkoglu
2080 Arlingate Lane
Colombus OH 43228
Phone: (614) 850-5000 Fax: (614) 850-1111

Hydrapak, Inc. – Seals
3532 W Galaxy Park Place
West Jordan, UT 84088
Phone: (801) 973-7325 Fax: (801) 973-7440

Industrial Gasket & Shim Co. (IGS) – Ball valve shims
Kelli Hunt
PO Box 368
Meadow Lands, PA 15347
Phone: (724) 222-5898

Kepner Products Company – Check valves
Dave Takata
995 N. Ellsworth Avenue
Villa Park, IL 60181
Phone: 630-279-1550 Fax: 630-279-9669

McMaster-Carr – Fasteners and hardware
Order online at: http://www.mcmaster.com

Rust Equipment Company – Tescom regulator parts and Fike burst disks
Jeff Taggart

8070 South 1300 West
West Jordan, UT 84088
Phone: (801) 566-7878

Bolt and Nut Supply – Fasteners
2212 S West Temple
Salt Lake City, UT 84115
Phone: (801) 486-0088

QD Tech, Inc. – Core catcher baskets
3245 West 2400 South
Salt Lake City, UT 84119
Phone: (801) 558-5262 Fax: (941) 954-4656

Quality Plating – Manganese Phosphate coating and anodizing
Glenn Fassmann
533 West 400 South
Salt Lake City, UT 84101
Phone: (801) 355-7424 Fax: (801) 355-7820

Scorpion Engineering – Cutting shoes and center bits
Scott Evans
5654 West Axel Park Rd.
West Jordan, UT 84088
Phone: (801) 838-9655 Fax (888)266-5448

SKF Machined Seals – Seals
3443 North Sam Houston Parkway West Ste.
Houston, TX 77086
Phone: 800.589.5563 Fax: 440-720-1502

Spring Works Utah – Springs
Ron Mongeon
976 West 850 South
Woods Cross, UT 84087
Phone: (801) 298-0113 Fax: (801) 292-8006

Suhm Spring Company – Springs
Jim Howell
14650 Heathrow Forest Parkway
Houston, TX 77032
Phone: (713) 224-9293 Fax: (713) 224-9418

Appendix C3, Inspection and Test Plan

Supplier: Aumann & Associates Inc.	**Customer:** Chevron	**ITP No.:** 1001	**Rev. No.:** 0
PO / Contract No.: CW1094939	**Service(s) Provided:** Development of Hybrid PCS	**AAI Acceptance / Date:** 05/30/2013 Name / Signature: Jim Aumann President	**Purchaser Acceptance/ Date:** 05/30/2013 Name / Signature: Purchaser Senior QA/QC Specialist

No.	Activity	Requirement / Dwg No.	Supplier Responsible Party	Record(s) Produced / Verifying Document(s)	Comments / Required Certification
1.	Review contract	Purchaser Supplier Contract	Jim Aumann President	Contract Review Comments	Purchaser Supplier Interface as needed
2.	Generate project engineering drawings	Purchaser Supplier Contract	Jim Aumann President David Whittaker Asst. Engineer	Engineered drawing	Design lessons learned/ proposed modifications to be Purchaser reviewed/approved prior to incorporation into engineered drawings
3.	Generate document control registry update as required	Purchaser Supplier Contract	Jim Aumann President David Whittaker Asst. Engineer	Document control registry	Distribute original registry and updates to Purchaser
4.	Conduct Contract Kick Off Meeting	Purchaser Supplier Contract	Jim Aumann President David Whittaker Asst. Engineer Chevron Representative	Kick Off Meeting MOM	Purchaser Attendance
5.	Issue procurement documents to subcontractors	Purchaser Supplier Contract Engineered Drawings	Jim Aumann President David Whittaker Asst. Engineer	Procurement documents	Ensure Purchaser requirements are defined in procurement documents issued to subcontractors
6.	Select subcontractors, proceed with fabrication	Historical relationship with reliable subcontractors	Jim Aumann President David Whittaker Asst. Engineer	Procurement documents Subcontractor Listing	Distribute original subcontractor listing and updates to Purchaser.
7.	Witness subcontractor inspections prior to subcontractor machine part shipment to Supplier	Engineered Drawings	Jim Aumann President David Whittaker Asst. Engineer Chevron Representative	Subcontractor Inspection Record	Subcontractors shall provide minimum two (2) day notice to Supplier to attend all final inspections (including dimensional) at subcontractor shop prior to shipping. Purchaser option to witness or visit subcontractors with notice to Supplier and concurrence.
8.	Receive and review quality records from subcontractors	Procurement Documents	Jim Aumann President David Whittaker Asst. Engineer Brandy Lynn Nevaree Clerk Chevron Representative	Subcontractor Quality Records	Verify records are complete, accurate, country source of origin Purchaser Review

No.	**Activity**	**Requirement / Dwg No.**	**Supplier Responsible Party**	**Record(s) Produced / Verifying Document(s)**	**Comments / Required Certification**
9.	Assemble JIP Hybrid PCS Pressure Corer System	Engineered Drawings, Service Manual	Jim Aumann President David Whittaker Asst. Engineer Chevron Representative	Engineered Drawings	Assemble all configurations (each upper inner barrel with all four lower inner barrels, all bit configurations, etc.) Purchaser Witness
10.	Verify fish pill fit and function	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
11.	Test and verify fish pill reader and fish pill laptop software functions	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
12.	Emergency pulling connection tool test	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
13.	Running tool connection test include latch system	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
14.	Pulling tool connection test	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
15.	Bearing assembly test	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
16.	Over travel spring test	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
17.	Pressure test autoclave horizontally	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
18.	Pressure test pressure control system	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
19.	Verify pressure control section transducer function	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
20.	Horizontal dry function tests including ball valve closing test	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Witness
21.	Verify catcher core extraction function (PCATS Extraction Function)	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Core extraction of inner tube plug & liner core, core catchers from autoclave (PCATS extraction simulation), verify accu*rate* space for length differences, catcher ODs/edge finish precludes catching on PCATS equipment during transfer.

No.	Activity	Requirement / Dwg No.	Supplier Responsible Party	Record(s) Produced / Verifying Document(s)	Comments / Required Certification
22.	Prepare corer, commissioning spares, manuals, liners, tools, consumables, etc., for onshore drilling site testing	Engineered Drawings Supplier Test Procedure	As Above	Supplier Test Record	Purchaser Review
23.	Dependent upon van logistics and contract scope: Receive, prepare, load service & heavy vans Mobilize to onshore drilling test site	Industry working standard	As Above	Supplier Shipping Documentation	Prepare, load corer, tools, test spares, consumables, manuals, etc., ship to onshore drilling test site Purchaser Review
24.	Execute onshore drilling site test Demobilize to supplier shop	Engineered Drawings Manuals Purchaser Supplier Contract Purchaser Onshore Drilling Test Program Supplier Procedures	As Above	Onshore Drilling Test Performance Records	Purchaser Witness and Review
25.	Receive service & heavy van at supplier shop	Industry working standard	As Above	Supplier Shipping Documentation Storage & Preservation Procedure	Unpack, prepare service & heavy van for packing, shipment, & long term storage of corer, spare parts, tools, project documentation, etc. Purchaser Review
26.	Assembly/ catalog post-drilling replacement consumables, post-delivery spares	Engineered Drawings Purchaser Supplier Contract	As Above	Storage & Preservation Procedure Parts & spares Listing	Purchaser Review
27.	Compile/ catalog /label spare material samples for post contract test coupon machining and testing	Engineered Drawings Purchaser Supplier Contract	As Above	Spare Material Listing	Purchaser Review One material sample shall be collected for materials: That are not purchased in a heat treated condition but are heat treated by subcontractors (this includes all pressure retaining parts subcontractor coated parts Material sample size shall be adequate to machine to test coupon dimensions for tensile, etc., testing. Samples shall be labeled traceable to part, preserved for long term service van storage Purchaser Review

No.	Activity	Requirement / Dwg No.	Supplier Responsible Party	Record(s) Produced / Verifying Document(s)	Comments / Required Certification
28.	Compile / catalog operating procedures, assembly/repair manuals, quality records, all other turnover documentation	Engineered Drawings Purchaser Supplier Contract Purchasers Engineering Specification	As Above	Manuals Drawings QA Records	Records to be delivered are defined in Purchasers Engineering specification
29.	Prepare tools, spares, parts for crating, long term preservation, storage and shipping inside service and heavy van	Purchaser Supplier Contract Storage & Preservation Procedure	As Above	Preserved equipment and inventory	Include spare part preservation and storage plan in delivery Purchaser Witness and Review
30.	Inspect service and heavy van interiors/exteriors prior to loading.	Purchaser Supplier Contract Storage & Preservation Procedure	As Above	Damage Report (if any)	Vans clean, dry, no damage/ cracks, door / locking devices/handles function. Purchaser Witness
31.	Pack all Contract materials (corer, spare parts, tools, consumables, etc.) preserved for long term storage, and project documentation into vans	Purchaser Supplier Contract Storage & Preservation Procedure	As Above	Purchaser Supplier Contract	Purchaser Witness and Review
32.	Verify vans loaded contents adequate securing/ protection for transport and long term storage	Purchaser Supplier Contract Storage & Preservation Procedure	As Above	Purchaser Supplier Contract	Purchaser Witness
33.	Prepare shipping documentation	Engineered Drawings Purchaser Supplier Contract	As Above	Shipping documentation and inventory	Purchaser Review
34.	Purchaser Shipping Inspection	Purchaser Supplier Contract Storage & Preservation Procedure	Chevron Representative	Purchaser Supplier Contract	Purchaser Witness
35.	Turnover to Purchaser of service and heavy van packed with corer, tools, equipment, quality records, manuals, documentation, etc.	Engineered Drawings Purchaser Supplier Contract Scope	As Above	Shipping Documentation	Purchaser receipt of all documents, drawings, etc. and Purchaser final review, inspection, acceptance, closing doors and locking up the two loaded out vans at SLC. After Purchase final acceptance Purchaser bears the responsibility, cost and risk of transport to the final destination

NON U.S.SOURCED MATEREIAL

Part No.	Description	Qty	Supplier	P.O.	Material Origin if not U.S.	Test Coupon Requirement Based Upon Material Origin/Service Stress	Additional Testing Conducted
CES7101	Outer Latch Spring Retainer	3	Loveridge	A1521-1	Czech Republic - NC	None - low service stress	
CES7103	Outer Latch Collet	4	Loveridge	A1521-2	Italy - coupon not available	None - Italy acceptable DFAR	
CES7315	Accumulator Barrel	4	Aerospace	A1520-28	Italy 17-4 to be HT after mfg. no extra test coupon req'd	None - Italy acceptable DFAR	
CES7744	Liner Length Adjuster	8	Able	A1522-11	Mexico	None - low service stress	
CES7526	Segment Pawl Set of 3	9	Aerospace	A1520-31	Slovenia (to be HT after mfg. no extra test coupon req'd	Required - high service stress Chemical certification req'd using shavings mechanical test after PWHT	Chemical certification conducted by American Metalurgical Testing
CES7622	Housing Extension	4	Loveridge	A1521-12	Czech Republic	None - low service stress	
CES7535	Punch Shoe	1	Able	A1522-21	Turkey Heat Number 124012	Moderate service stress, determine if same mill/ HT # as CES 7271, 7272, if matl. available, chem. &/or mech. test	Chemical certification conducted by American Metalurgical Testing
CES7271	Upper Housing, Outer Bearing	2	Able	A1522-24	Turkey Heat No. 124012,	Low service stress. See Comment for CES 7535	
CES7272	Lower Housing, Outer Bearing	2	Able	A1522-25	Turkey Heat No. 124012,	Low service stress. See Comment for CES 7535	

CBH0410	Body, Low End Drive	1	Aerospace	A1520-40	Czech Republic "4340"	Switched to USA material	
CBH0415	End Cap, Low End Drive	1	Aerospace	A1520-42	Czech Republic "Any Steel"	None - low service stress	
CBH0150	Base Ring and Shroud	1	Aerospace	A1520-45	Czech Republic "Mild Steel"	None - low service stress	
CBH0610	Bit Seal Retainer	1	American	A1523-4	Czech Republic	None - low service stress	
CBH0620	Bit Seal Gland	1	American	A1523-5	Czech Republic	None - low service stress	
AHT4042	Transfer Sub	2	Aerospace	A1520-48	Italy - NC	None - Italy acceptable DFAR	
CHT4063	Ball Resetting Spacer	2	American	A1523-8	Czlech Republic	None - low service stress	
CSB1203	Ratchet Housing, WL Tools	3	Loveridge	A1521-14	Turkey - coupon not available Heat 111308	Low service stress. See comment CSB 1215	
CSB1207	Spring Housing, WL Tools	3	Loveridge	A1521-15	Turkey - coupon not available	Low service stress. See comment CSB 1215	
CSB1215	Collet Base, WL Tools	3	Loveridge	A1521-16	Turkey Heat 122064	Determine if same mill as CSB 1203, 1207, if coupon available chem. &/or mech. test, low service stress	Chemical certification conducted by American Metalurgical Testing

Appendix C4, Quality Report Index by Part Number

Aumann & Associates, Inc.
2698 South Redwood Rd Suite N
West Valley City, UT 84119
(801) 631-2874 Fax: (801) 886-9040
Email: jim@aumanninc.com

Hybrid PCS
Chevron Contract No.CW1094939
Quality Assurance Records
Sort by Part Number

Serial Number		PO			Inspct.	Mat
PO #	Item	Mfg	Qty	Description	Rep	Certs
A1532	1	Honeywell	6	Pressure Transducer Model A-205 10,000 psi		
A1530	5	Aero-Space	1	Inner Tube Sub, 61" Long	YES	YES
A1530	7	Aero-Space	1	Bit Sub, Center Bit Assembly	YES	YES
A1520	34	Aero-Space	4	Housing, High Pressure PCTB	YES	YES
A1520	47	Aero-Space	2	Transfer Barrel, PTCB II	YES	YES
A1520	48	Aero-Space	2	Transfer Sub, PCTB II	YES	YES
A1520	44	Aero-Space	1	Body, Float Vavle	YES	YES
A1536	1	Able	5	Body, Float Valve	YES	YES
A1522	31	Able	5	Seal Retaining Ring, Float Valve	YES	PP
A1522	36	Able	5	Flapper, std Float Valve	YES	YES
A1520	45	Aero-Space	1	Base Ring/Shroud, Float Valve	YES	YES
A1540	1	American Machine	3	Float Valve Spacer	YES	YES
A1520	40	Aero-Space	1	Body, Low End Drive	YES	YES
A1520	41	Aero-Space	16	Drive Pin, Low End Drive	YES	YES
A1520	42	Aero-Space	1	End Cap, Low End Drive	YES	YES
A1520	43	Aero-Space	6	Drive Dog, Low End Drive	YES	YES
A1521	13	Loveridge	16	Hinge Pin, Lowe End Drive	YES	YES
A1523	4	American Machine	3	Bit Seal Retainer	YES	YES
A1523	5	American Machine	3	Bit Seal Gland, Bit Seal Assembly	YES	YES
A1517	1	Houston Downhole	1	Head Sub	YES	YES
A1540	2	American Machine	3	Blank Landing Shoulder Insert	YES	YES
A1517	2	Houston Downhole	1	Top Sub	YES	YES
A1517	6	Houston Downhole	4	Outer Core Barrel, Controlled Length	YES	YES
A1517	3	Houston Downhole	1	Landing Saver Sub	YES	YES
A1520	38	Aero-Space	3	Replaceable Seat, Landing Saver Sub	YES	YES
A1520	39	Aero-Space	3	Simple Latch Sleeve, ESCS	YES	YES
A1517	4	Houston Downhole	1	Seal Bore Outer Core Barrel	YES	YES
A1517	7	Houston Downhole	1	10-5/8 Coring Stabilizer	YES	YES
A1517	5	Houston Downhole	1	Stabilized Modified Long Bit Sub, 10-5/8	YES	YES
A1542	1	Atlas Copco	2	Bit, PDC, 10-5/8" OD X 3.800" ID, add 5ea 15/32 ports	YES	YES
A1522	19	Able	75	Body, Basket Core Catcher, PCTB	YES	YES
A1522	22	Able	10	Body, Slip Core Catcher	YES	YES
A1522	23	Able	10	Core Lifter, Slip Core Catcher	YES	YES
A1520	35	Aero-Space	10	Flapper Catcher Body, 2 " Core, Hybrid PCTB	YES	YES
A1520	37	Aero-Space	10	Flapper, 2" Core, Hybrid PCTB	YES	YES
A1520	36	Aero-Space	10	Sleeve, Flapper Core Catcher	YES	YES
A1533	1	Anaheim	80	Core Liner,RPVC, Clear	YES	YES
A1522	13	Able	10	Core Liner Extension, PCTB	YES	YES
A1522	35	Able	2	Core Liner Extension, 2", PCTB	YES	YES
A1520	11	Aero-Space	4	Inner Tube, PCTB, Threat Only	YES	YES
A1530	4	Aero-Space	2	Inner Tube,Sub, 131" Long	YES	YES
A1520	12	Aero-Space	4	Inner Tube Sub, 15.4 Long, Thread Only	YES	YES
A1530	6	Aero-Space	3	Low End Drive Sub	YES	YES
A1521	1	Loveridge	5	Outer Latch Spring Retainer, PCT	YES	YES
A1521	2	Loveridge	6	Outer Latch Coolet, PCT	YES	YES
A1520	2	Aero-Space	5	Outer Latch Upper Housing	YES	YES
A1520	5	Aero-Space	5	Inner Latch Spring Retainer, PCT	YES	YES
A1520	4	Aero-Space	5	Middle Latch Housing	YES	YES
A1520	6	Aero-Space	5	Inner Latch Piston, PCT	YES	YES
A1520	8	Aero-Space	18	Inner Latch Dog	YES	YES
A1520	7	Aero-Space	5	Lower Latch Housing	YES	YES
A1522	1	Able	5	Inner Latch Housing, PCT	YES	YES
A1520	9	Aero-Space	5	Rod Adapter	YES	YES
A1520	10	Aero-Space	4	Estension Rod,106 in, PCTB	YES	YES
A1520	13	Aero-Space	5	Quick Release Adapter	YES	YES

CERT = Certificate of Compliance
PP = Standard Purchased Part - None Required

Aumann & Associates, Inc.
2698 South Redwood Rd Suite N
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Hybrid PCS
Chevron Contract No.CW1094939
Quality Assurance Records
Sort by Part Number

Serial Number		PO			Inspct.	Mat
PO #	Item	Mfg	Qty	Description	Rep	Certs
A1520	14	Aero-Space	5	Quick Release Mandrel	YES	YES
A1521	3	Loveridge	5	Quick Release Nut	YES	YES
A1520	22	Aero-Space	6	Lift Sub, PTCB	YES	YES
A1520	23	Aero-Space	6	Middle Barrel, PCTB	YES	YES
A1520	1	Aero-Space	7	Outer Latch Piston, Large Dia Drill Pipe	YES	YES
A1520	3	Aero-Space	27	Outer Latch Dog, Large Dia DP, PCTB	YES	YES
A1520	17	Aero-Space	5	Upper Swivel Housing	YES	YES
A1520	19	Aero-Space	5	Lower Housing, Swivel Assy, PCT	YES	YES
A1520	21	Aero-Space	5	Bearing Shaft, Swivel Assy, PCT	YES	YES
A1520	18	Aero-Space	5	Bearing Spacer, Swivel Assy, PCT	YES	YES
A1520	20	Aero-Space	6	Piston, Swivel Assy, PCT	YES	YES
A1520	16	Aero-Space	4	Spring Housing, Swivel Assy, PCTUpper Swivel Housing	YES	YES
A1520	15	Aero-Space	4	Spring Shaft, Swivel Assy, PCT	YES	YES
A1522	24	Able	2	Upper Housing, Outer Bearing	YES	YES
A1522	25	Able	2	Lower Housing, Outer Bearing	YES	YES
A1522	26	Able	2	Shaft, Outer Bearing	YES	YES
A1522	27	Able	2	Spacer, Outer Bearing,	YES	YES
A1522	28	Able	4	Piston, Outer Bearing	YES	Brass NR
A1522	29	Able	2	Bearing Shaft Adapter	YES	YES
A1522	30	Able	2	Length Adjustment Nut	YES	YES
A1530	3	Aero-Space	5	QLS 2-1/2" Latch Plate	YES	YES
A1530	1	Aero-Space	4	QLS Box, PCTB	YES	YES
A1522	4	Able	6	Accumulator Sub, PCTB	YES	YES
A1522	3	Able	6	Reservor Barrel	YES	YES
A1520	28	Aero-Space	6	Accumlator Barrel	YES	YES
A1522	2	Able	8	Sparator Piston	YES	Brass NR
A1521	5	Loveridge	5	Sleeve Valve Sub, PCT	YES	YES
A1520	27	Aero-Space	6	Sleeve Valve	YES	YES
A1521	4	Loveridge	6	Regulator Sub, PCT With Thread Calculations	YES	YES
A1520	25	Aero-Space	6	Pressure Adjust Screw (Same as 10526C)	YES	YES
A1520	26	Aero-Space	6	Regulator Lock Nut	YES	YES
A1520	24	Aero-Space	6	QLS Pin, PCT	YES	YES
A1522	6	Able	8	Transducer Cap, PCT	YES	YES
A1522	5	Able	21	Check Valve Backup Washer, PCT	YES	Brass NR
A1522	12	Able	8	Collet Release Sleeve	YES	YES
A1522	15	Able	7	Collet, Ball Valve Spring, PCTB	YES	YES
A1522	14	Able	5	Release Sleeve, PCTB	YES	YES
A1521	9	Loveridge	5	Drive Sub, PCTB	YES	YES
A1522	17	Able	8	Ball, PCTB	YES	YES
A1550	1	Suhm	8	Return Spring, PCTB	COMP	COMP
A1522	16	Able	6	Seal Carrier, PCTB	YES	YES
A1521	10	Loveridge	16	Pivot Screw, PCTB	YES	PP
A1521	7	Loveridge	88	Collapsing Detent, PCTB	YES	YES
A1550	2	Suhm	6	Ball Valve Spring, PCTB, Left Hand Wound	COMP	COMP
A1520	33	Aero-Space	10	Vented Rabbit, PCTB	YES	YES
A1520	31	Aero-Space	10	Segment Pawl, Set of 3	YES	YES
A1520	30	Aero-Space	16	Spring, Pawl	YES	YES
A1520	32	Aero-Space	10	Check Valve Plug, PCTB	YES	YES
A1520	29	Aero-Space	12	Burst Disk Hold Down	YES	YES
A1521	6	Loveridge	94	Large Bullet Valve	YES	YES
A1522	20	Able	3	Outer Shoe, 2 inch Core, PCTB	YES	YES
A1522	21	Able	1	Punch Cutting Shoe, PCTB	YES	YES
A1646	1	S & K	3	Punch Cutting Shoe, PCTB	YES	YES
A1522	7	Able	5	Seal Sub, High Pressure PCTB	YES	YES
A1517	8	Houston Downhole	4	Outer Tube, PCTB	YES	YES

CERT = Certificate of Compliance
PP = Standard Purchased Part - None Required

Aumann & Associates, Inc.
2698 South Redwood Rd Suite N
West Valley City, UT 84119
(801) 631-2874 Fax: (801) 886-9040
Email: jim@aumanninc.com

Hybrid PCS
Chevron Contract No.CW1094939
Quality Assurance Records
Sort by Part Number

Serial Number		PO			Inspct.	Mat
PO #	Item	Mfg	Qty	Description	Rep	Certs
A1521	11	Loveridge	4	Ball Follower, High Pressure PCTB	YES	YES
A1522	18	Able	6	Cutting Shoe Sleeve, PCTB	YES	YES
A1521	12	Loveridge	4	Housing Extension, High Pressure PCTB	YES	YES
A1522	8	Able	4	Upper Inner Tube Plug, PCTB II	YES	YES
A1523	1	American Machine	6	Lower Innwer Tube Plug	YES	YES
A1521	8	Loveridge	4	Inner Tube, PCTB	YES	YES
A1521	18	Loveridge	4	Inner Tube, PCTB	YES	YES
A1523	2	American Machine	4	Mandrel, IT Plug	YES	YES
A1522	9	Able	7	Pawl Carrier, PCTB II	YES	YES
A1522	10	Able	40	Inner Tube Plug Dog	YES	YES
A1522	11	Able	8	Limer Length Adjuster	YES	YES
A1523	3	American Machine	4	Lock Nut, Liner Lenth Adjuster	YES	YES
A1541	2	Able	4	IT Plug Lockout Washer	YES	YES
A1541	3	Able	4	QLS Spacer	YES	YES
A1522	34	Able	12	Latch Bolt= Inner Barrel Clamp	YES	YES
A1531	1	May	6	Lifting Clamp Body Set, 3-1/2"	YES	YES
A1522	32	Able	12	Hinge Pin, Inner Barrel Clamp	YES	YES
A1522	33	Able	12	Latch Pin, Inner Barrel Clamp	YES	YES
A1531	2	May	4	Lifting Clamp Body Set, 3-3/4"	YES	YES
A1523	6	American Machine	2	Pawl Release Sleeve, PCTB	YES	YES
A1541	4	Able	2	Inner Tube Pulling Tool, PCTB	YES	YES
A1520	46	Aero-Space	2	Transfer Adapter	YES	YES
A1523	10	American Machine	2	Inner Latch Relase Tool, PCT	YES	YES
A1541	5	Able	3	Latch Lock Clamp (modified purchased part)	YES	PP
A1523	9	American Machine	2	Cap, Ball Valve Resetting Tool	YES	YES
A1523	8	American Machine	2	Spacer, Ball Valve Restting Tool, HPCTB	YES	YES
A1541	1	Able	2	IT Plug Wrench Sleeve	YES	YES
A1523	7	American Machine	2	Washer Set, BV Install Tool, PCT	YES	YES
A1530	2	Aero-Space	3	QLS Pin, Wireline Tools	YES	YES
A1520	55	Aero-Space	3	Mandrel (10423B)	YES	YES
A1521	14	Loveridge	3	Ratchet Housing (Note: Identical to 10427 Rev-.Samp With PN CSB12	YES	YES
A1520	56	Aero-Space	3	Ratchet Sleeve (10390A)	YES	YES
A1520	57	Aero-Space	3	Shear Pin (10426)	YES	YES
A1520	58	Aero-Space	28	Shear Pin (10425)	YES	YES
A1521	15	Loveridge	3	Spring Housing	YES	YES
A1520	59	Aero-Space	3	Collet Housing (10422-)	YES	YES
A1521	16	Loveridge	3	Collet Base	YES	YES
A1540	3	American Machine	1	Core, Running Tool, PCT	YES	YES
A1520	49	Aero-Space	1	Collet, Running Tool, PCT	YES	YES
A1520	50	Aero-Space	1	Mandrel Adapter	YES	YES
A1520	51	Aero-Space	3	Collet Adapter, PCT	YES	YES
A1540	4	American Machine	1	Core, Emergency Pulling Tool	YES	YES
A1520	52	Aero-Space	1	Collet, Emergency Pulling Tool, PCT	YES	YES
A1520	53	Aero-Space	1	Core, Pulling Tool	YES	YES
A1520	54	Aero-Space	1	Collet Extension, Pulling Tool	YES	YES
A1517	10	Houston Downhole	1	Lift Sub w/7"OD x 18 Degree Top Upset f/5-1/2 DP Elevators, with 8-1	YES	YES
A1542	2	Atlas Copco	1	Bit Breaker, 13.5 square, 10-5/8" bits, 17,500 ft-lbs	PP	PP
A1517	9	Houston Downhole	2	X-Over Sub, 8.25OD X 4.25ID with XT57 Box up X 6-5/8 FH Mod Pin D	YES	YES

CERT = Certificate of Compliance
PP = Standard Purchased Part - None Required

Aumann & Associates

Client: Chevron Corporation **Date:** June 25, 2014
System: Hybrid PCS (PCTB) **Prepared:** DB Whittaker

Post Heat-Treated Parts - Test Coupon Catalogue

Part Number	Part Name	Testable?
AHT4041	Transfer Barrel	YES
CBH0120	Flapper, Float Valve Assembly	YES
CBH0410	Body, Low End Drive	YES
CBH0412	Drive Pin, Low End Drive	YES
CBH0420	Drive Dog, Low End Drive	YES
CBH0430	Hinge Pin, Low End Drive	YES
CBH1075	Replaceable Seat	YES
CCC4330	Flapper, Flapper Core Catcher	YES
CCL1020	Core Liner Extension, 5 in	NO
CES7101	Outer Latch Spring Retainer	YES
CES7210	Lower Housing, Swivel	YES
CES7275	PISTON, OUTER BEARING	NO
CES7306	Accumulator Sub, HPCTB	YES
CES7310	Reservoir Barrel	YES
CES7315	Accumulator Barrel	YES
CES7325	Sleeve Valve Sub	YES
CES7335	Regulator Sub	YES
CES7365	Pressure Transducer Cap	NO
CES7508	Drive Sub	YES
CES7511	Ball	YES
CES7526	Segment Pawl	YES
CES7527	Pawl Spring	YES
CES7529	Check Valve Plug	YES
CES7534	Outer Shoe, PCTB	YES
CES7535	Punch Shoe, PCTB	YES
CES7602	Seal Sub	YES
CES7605	Outer Tube, HPCTB	YES
CES7610	BV Housing, HPCTB	YES
CES7701	Upper Inner Tube Plug, PCTB II	YES
CES7714	Lower Inner Tube Plug, PCTB II	YES
CES7743	Inner Tube Plug Dog, PCTB II	NO
CHT4011	Inner Tube Pulling Tool, HPCTB	YES
CHT4020	Transfer Adapter	YES
CSB1204	Ratchet Sleeve (10390)	YES

Appendix D1, BHA Inspection Reports

P.O. BOX 397
YOUNGSVILLE, LOUISIANA 70592
2809 YOUNGSVILLE HWY.
337-856-9001 • FAX 337-856-7564

IOS INSPECTION OILFIELD SERVICES™

Field Inspection Report

No. 168292

For: Houston Down hole | Location: | Rig | Job No. | Date 2/19/14

	Serial No.	Description of Tool	Pin	Box	I.D. Pin	Pin O.D.	Box O.D.	Length	Fishing Neck	B.S.R.
1	A1517-06-1	Outer Core Barrel	ok	DS01						
2	A1517-06-2	Outer Core Barrel	ok	DS01						
3	A1517-06-3	Outer Core Barrel	ok	ok						
4	A1517-06-4	Outer Core Barrel	ok	DS01						
5	A1517-04-1	Seal Bore O.C.B.	DT	DS						
6	A1517-05-1	Stab Mod Long bit Sub	ok	DS ok						
7	A1517-07-1	Coring Stabilizer	ok	ok DS						
8	A1517-01-1	Head Sub	ok	ok						
9	A1517-02-1	Top Sub	ok	ok						
10	A1517-03-1	Landing Saver Sub	ok	ok						
11	A1517-09-1	X-Over Sub	ok	ok						
12	A1517-09-2	X-Over Sub	ok	ok						
13	A1517-10-1	Lift Sub	ok	—						
14										
15										
16										
17										
18										
19										
20										

Inspection Performed	Specification	Version	Date
✓ Visual			
✓ Mech./Dimensional			
✓ Wet Mag. Particle			
Dry Mag. Particle			
Ultrasonic			
Dye Penetrant			
Other:			

Lead Gage ____
Taper Gage ____
UT Unit ____
Mag Coil ____
Batch Strength ____ ml/100ml
Coil Amps ____
UV Meter ____
Blacklight Intensity ____

Summary
PO# 140255

Julie Brauer

Cesar Torres
inspector

2
Level

Note: BB = Boreback / RG = Relief Groove

TAYLOR OILFIELD MFG., INC.
14401 Interdrive East
Houston, TX 77032
Phone: 281-442-4084
Fax: 281-449-8479

THREAD INSPECTION REPORT
TAPERED THREADS

Length After Rework
382 1/4"

Vendor Name: Houston Downhole		Date: 3/05/14
Part Description: 8 1/4 Outer Core Barrel Seal		
Serial #: A1517-04-1		WO #: 147061

	LEFT HAND SIDE	RIGHT HAND SIDE
THREAD CONNECTION TYPE	PIN ☐ BOX ☑ 6 5/8 FH Mod	PIN ☐ BOX ☐
OPERATION EXECUTED	CHASE ☑ REFACE ☐ NEW ☐ RECUT ☐	CHASE ☐ REFACE ☐ NEW ☐ RECUT ☐
TAPER MEASUREMENT OVER	1" .166 inch; 2" /inch	1" /inch; 2" /inch
THREAD LEAD / HEIGHT	.001 / .147	
THREAD PROFILE	GOOD ☑ BAD ☐	GOOD ☐ BAD ☐
BEVEL DIA.	7.890 /inch	/inch
GAUGE STAND-OFF	GAUGE SERIAL # M-22912; STANDOFF IN ☑ OUT ☐ .010 inch	GAUGE SERIAL #; STANDOFF IN ☐ OUT ☐ inch
PIN CONNECTIONS	PIN LENGTH. inch; RELIEF GROOVE DIA. inch; RELIEF GROOVE WIDTH inch	inch; inch; inch
BOX CONNECTIONS	THREAD LENGTH 6.500 inch; BOREBACK DIA. inch; C'BORE DIA. 6.812 inch; C'BORE DEPTH .625 inch	inch; inch; inch; inch

[signature]

COMMENTS:	INSPECTED BY: DA

TAYLOR OILFIELD MFG., INC.
14401 Interdrive East
Houston, TX 77032
Phone: 281-442-4084
Fax: 281-449-8479

THREAD INSPECTION REPORT
TAPERED THREADS

Length After Rework 360-3/16"

Vendor Name: Houston Downhole			Date: 3/12/14	
Part Description: 8 1/4 outer Core Barrels				
Serial #: S/N A1517-06-1			WO #: 147064	
DA	LEFT HAND SIDE		RIGHT HAND SIDE	
THREAD CONNECTION TYPE	PIN ☐ 6 5/8 F.H	BOX ☑	PIN ☐	BOX ☐
OPERATION EXECUTED	CHASE ☑ NEW ☐	REFACE ☐ RECUT ☐	CHASE ☐ NEW ☐	REFACE ☐ RECUT ☐
TAPER MEASUREMENT OVER	1" 2"	inch /inch	1" 2"	/inch /inch
THREAD LEAD / HEIGHT				
THREAD PROFILE	GOOD ☐	BAD ☐	GOOD ☐	BAD ☐
BEVEL DIA.	7.890	/inch		/inch
GAUGE STAND-OFF	GAUGE SERIAL # U-22902 STANDOFF IN ☑ OUT ☐	.006 inch	GAUGE SERIAL # STANDOFF IN ☐ OUT ☐	inch
PIN CONNECTIONS	PIN LENGTH / RELIEF GROOVE DIA. / RELIEF GROOVE WIDTH	inch / inch / inch		inch / inch / inch
BOX CONNECTIONS	THREAD LENGTH	6 1/16 inch		inch
	BOREBACK DIA.	inch		inch
	C'BORE DIA.	6.815 inch		inch
	C'BORE DEPTH	.625 inch		inch

[signature]

COMMENTS:	INSPECTED BY: DA

TAYLOR OILFIELD MFG., INC.
14401 Interdrive East
Houston, TX 77032
Phone: 281-442-4084
Fax: 281-449-8479

THREAD INSPECTION REPORT
TAPERED THREADS

Length After Rework 360-1/4"

Vendor Name: Houston Downhole		Date: 3/12/14
Part Description: 8 1/4 outer Core Barrels		
Serial #: S/N A1517-06-2		WO #: 147064
	LEFT HAND SIDE	**RIGHT HAND SIDE**
THREAD CONNECTION TYPE	PIN ☐ BOX ☒ 6 5/8 FH	PIN ☐ BOX ☐
OPERATION EXECUTED	CHASE ☒ REFACE ☐ NEW ☐ RECUT ☐	CHASE ☐ REFACE ☐ NEW ☐ RECUT ☐
TAPER MEASUREMENT OVER	1" ___ inch; 2" ___ /inch	1" ___ /inch; 2" ___ /inch
THREAD LEAD / HEIGHT	___ ___	___ ___
THREAD PROFILE	GOOD ☐ BAD ☐	GOOD ☐ BAD ☐
BEVEL DIA.	7.890 /inch	/inch
GAUGE STAND-OFF	GAUGE SERIAL # M-22; STANDOFF IN ☒ OUT ☐ .009 inch	GAUGE SERIAL #; STANDOFF IN ☐ OUT ☐ ___ inch
PIN CONNECTIONS	PIN LENGTH — inch; RELIEF GROOVE DIA. — inch; RELIEF GROOVE WIDTH — inch	inch; inch; inch
BOX CONNECTIONS	THREAD LENGTH 6 1/16 inch; BOREBACK DIA. inch; C'BORE DIA. 6.840 inch; C'BORE DEPTH .625 inch	inch; inch; inch; inch
COMMENTS:		INSPECTED BY: [signature]

TAYLOR OILFIELD MFG., INC.

14401 Interdrive East
Houston, TX 77032
Phone: 281-442-4084
Fax: 281-449-8479

THREAD INSPECTION REPORT
TAPERED THREADS

Length After Rework
360-3/16"

Vendor Name: Houston Downhole		Date: 3/12/14
Part Description: 8¼ outer Core Barrels		
Serial #: S/N A1517-06-4		WO #: 14 7064

	LEFT HAND SIDE	RIGHT HAND SIDE
THREAD CONNECTION TYPE	PIN ☐ BOX ☒ 6 5/8 REG	PIN ☐ BOX ☐
OPERATION EXECUTED	CHASE ☒ REFACE ☐ NEW ☐ RECUT ☐	CHASE ☐ REFACE ☐ NEW ☐ RECUT ☐
TAPER MEASUREMENT OVER	DA 1" .166 inch; 2" /inch	1" /inch; 2" /inch
THREAD LEAD / HEIGHT		
THREAD PROFILE	DA GOOD ☒ BAD ☐	GOOD ☐ BAD ☐
BEVEL DIA.	7.890 /inch	/inch
GAUGE STAND-OFF	GAUGE SERIAL # M-22912; STANDOFF IN ☒ OUT ☐ .004 inch	GAUGE SERIAL #; STANDOFF IN ☐ OUT ☐ inch
PIN CONNECTIONS	PIN LENGTH — inch; RELIEF GROOVE DIA. — inch; RELIEF GROOVE WIDTH — inch	inch; inch; inch
BOX CONNECTIONS	THREAD LENGTH 6 1/16 inch; BOREBACK DIA. inch; C'BORE DIA. 6.815 inch; C'BORE DEPTH .625 inch	inch; inch; inch; inch
COMMENTS:		INSPECTED BY: DA

TAYLOR OILFIELD MFG., INC.
14401 Interdrive East
Houston, TX 77032
Phone: 281-442-4084
Fax: 281-449-8479

THREAD INSPECTION REPORT
TAPERED THREADS

Length After Rework
39-1/2"

Vendor Name: HOUSTON DOWNHOLE		Date: 03-16-14
Part Description: 8 1/4" CORING STABILIZER		
Serial #: A 1517-07-1		WO #: 0147064

	LEFT HAND SIDE	RIGHT HAND SIDE
THREAD CONNECTION TYPE	6 5/8 FH PIN ☐ BOX ☒	PIN ☐ BOX ☐
OPERATION EXECUTED	CHASE ☒ REFACE ☐ NEW ☐ RECUT ☐	CHASE ☐ REFACE ☐ NEW ☐ RECUT ☐
TAPER MEASUREMENT OVER	1" .166 inch; 2" /inch	1" /inch; 2" /inch
THREAD LEAD / HEIGHT	— .148	
THREAD PROFILE	GOOD ☒ BAD ☐	GOOD ☐ BAD ☐
BEVEL DIA.	7 7/8 /inch	/inch
GAUGE STAND-OFF	GAUGE SERIAL #: M-22912; STANDOFF IN ☒ OUT ☐ 0.003 inch	GAUGE SERIAL #; STANDOFF IN ☐ OUT ☐ inch
PIN CONNECTIONS	PIN LENGTH inch; RELIEF GROOVE DIA. inch; RELIEF GROOVE WIDTH inch	inch; inch; inch
BOX CONNECTIONS	THREAD LENGTH 7 3/8 inch; BOREBACK DIA. — inch; C'BORE DIA. 6 13/16 inch; C'BORE DEPTH 5/8 inch	inch; inch; inch; inch

3.

COMMENTS:

INSPECTED BY: DA

TAYLOR OILFIELD MFG., INC.
14401 Interdrive East
Houston, TX 77032
Phone: 281-442-4084
Fax: 281-449-8479

THREAD INSPECTION REPORT
TAPERED THREADS

Length After Rework 47-7/8"

Vendor Name: HDH		Date: 3/4/14	
Part Description: 8 1/4 Crossover			
Serial #: A1517-09-1		WO#: 146951	
	LEFT HAND SIDE	**RIGHT HAND SIDE**	
THREAD CONNECTION TYPE	PIN ☐ BOX ☑ 5 1/2 FH	PIN ☐ BOX ☐	
OPERATION EXECUTED	CHASE ☐ REFACE ☐ NEW ☑ RECUT ☐	CHASE ☐ REFACE ☐ NEW ☐ RECUT ☐	
TAPER MEASUREMENT OVER	1" .166 inch 2" /inch	1" /inch 2" /inch	
THREAD LEAD / HEIGHT	-.001 .121		
THREAD PROFILE	GOOD ☑ BAD ☐	GOOD ☐ BAD ☐	
BEVEL DIA.	6 23/32 /inch	/inch	
GAUGE STAND-OFF	GAUGE SERIAL # L-19285 STANDOFF IN ☑ OUT ☐ .007 inch	GAUGE SERIAL # STANDOFF IN ☐ OUT ☐ inch	
PIN CONNECTIONS	PIN LENGTH inch; RELIEF GROOVE DIA. inch; RELIEF GROOVE WIDTH inch	inch; inch; inch	
BOX CONNECTIONS	THREAD LENGTH 5 3/8 inch; BOREBACK DIA. NA inch; C'BORE DIA. inch; C'BORE DEPTH 5/8 inch	inch; inch; inch; inch	
COMMENTS:		INSPECTED BY: TA	

Appendix D2, Bit Inspection Report

Atlas Copco

Dull Grade Evaluation

Due Date: 3-Mar-14

Bit Information	
Customer	
Contact	Jim Aumann
Date Received	26-Feb-14
Received From	Jim Aumann
PO / Ticket No	
Size & Style	10.625 SC513
Part Number	2012330
Serial Number	121009
Work Order	121009 RP1
Additional HF Repair Area (in^2)	

Body Repair	
Cutter Pockets to Repair	0
Weld Cutter Pocket Rebuild	0
Flame Spray Cutter Pocket Rebuild	0
Gage Cutter Hardface Buildup	0
Blades to Repair	0
Blades - Remove HF	0
Blades - Add HF	0
Blades - Cutter Exp Mod	0
Blade - Cutter Web Mod	0
Weld Repair Body Cracks	0
Gage Pads to Repair	0
Chamfer Pads to Repair	0

Nozzle Repair	
Nozzle Cavities to Repair	0
HF Nozzle Bores	0
Nozzle Cracks to Repair	0
Nozzles to Braze In	0

Cutter Repair	R	T	S	W	A	P
Face PDC	4	0	14	0	0	0
Gage PDC	0	0	0	0	0	0
Back-Up Face	0	0	0	0	0	0
Back-Up Gage	0	0	0	0	0	0
Updrill PDC	0	0	0	0	0	0
Gage Insert #1	0	n/a	n/a	n/a	n/a	n/a
Gage Insert #2	0	n/a	n/a	n/a	n/a	n/a
Cutters to Spin	14	OK				
Cutters to Replace	4	OK				
Change Cutter Type	0	OK				

Face PDC

Blade	1			2			3			4			5			6		
	D	C	R	D	C	R	D	C	R	D	C	R	D	C	R	D	C	R
1	-	-	-	CC	S	-	-	-	-	-	-	-	CC	S	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	CC	S	-	-	-	-
3	CC	R	-	CC	S	-	CC	S	-	-	-	-	-	-	-	BC	R	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	BC	R	-	-	-	-	-	-	-	-	-	-	CC	S	-	BC	R	-
6																		
7																		
8																		
9																		
10																		

Blade	7			8			9			10			11			12		
	D	C	R	D	C	R	D	C	R	D	C	R	D	C	R	D	C	R
1	-	-	-	-	-	-	CC	S	-	CC	S	-						
2	-	-	-	-	-	-	CC	S	-									
3	-	-	-	CC	S	-	-	-	-	CC	S	-						
4	-	-	-	-	-	-	CC	S	-									
5	-	-	-	-	-	-	CC	S	-	CC	S	-						
6																		
7																		
8																		
9																		
10																		

Blade	Gage PDC 1			Gage PDC 2			Back-Up Fa 1			2			3			4			5		
	D	C	R	D	C	R	D	C	R	D	C	R	D	C	R	D	C	R	D	C	R
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

D = Damage Code	
BC =	Broken Cutter
CC =	Chipped Cutter
CR =	Cracked Cutter
EA =	Eroded Alloy
EC =	Eroded Carbide
G =	Ground Gage Cutter
LC =	Lost Cutter
WC =	Worn Cutter
—— =	No Wear

C = Cutter Code	
A =	Alloy Only - Don't Spin
S =	Spin
R =	Replace
I =	Pull & Inventory
P =	Pull & reinstall
W =	Warranty - Pull, Spin & Alloy
T =	Change Cutter Type
— =	Leave Cutter Set

R = Pocket Repair Code	
X =	Pocket Repair Required
H =	Gage Cutter Hardface Buildup
W =	Weld Pocket Rebuild
F =	Flame Spray Pocket Rebuild

Cutter Type Color Code	
(clear)	PDC - 1313 Premium Grade 1 - AC
	PDC - 1308

Appendix E, Packing List

Aumann & Associates, Inc.
2698 S Redwood Rd, Suite N
West Valley City, UT 84119
801.631.2874 phone
801.886.9040 fax

Hybrid PCS Tools and Spare Parts

PACKING LIST
June 27, 2014
Chevron Contract No. CW1094939

CHEVRON/ DOE JIP - HYBRID PCS Tools & Spare Parts Packing List

Per Ass'y	Part No.	rev	Description	# Ass'y	# Cntr Bit Ass'y	# OP Sp	# F.T. Sp	Total Ordered	Used	Short	Total Count	Location in Service Unit
	AES7010	**1**	**HYBRID-PCS (PCTB) CORING SYSTEM**									
1	**CES7100**	**1**	**LATCH ASSEMBLY**									
1	CES7101	1	Outer Latch Spring Retainer	2	1	0	0	3			3	E4
1	CES7103	2	Outer Latch Collet	2	1	1	0	4			4	E4
1	CES7102	-	Outer Latch Spring, Century S-3169	2	1	2	2	7	2		5	E4
1	CES7154	0	Outer Latch Piston, Large Bore	2	1	0	2	5			5	E4
1	CES7107	3	Outer Latch Upper Housing	2	1	0	0	3			3	A-1 (RACK)
3	CES7155	0	Outer Latch Dogs, Large Bore	6	3	6	6	21			21	E2
2	CES7106	-	Extension Spring, Century 5193	4	2	8	4	18	8		10	E1
1	CES7113	0	Middle Latch Housing	2	1	0	0	3			3	A-1 (RACK)
1	CES7111	1	Inner Latch Spring Retainer	2		0	0	2			2	E3
1	CES7112	-	Inner Latch Spring, Century 3110	2		2	2	6			6	E3
1	CES7114	2	Inner Latch Piston	2		0	0	2			2	E3
1	CES7116	1	Lower Latch Housing	2		0	0	2			2	A-1 (RACK)
3	CES7115	0	Inner Latch Dogs	6		3	0	9			9	E2
1	CES7117	0	Inner Latch Housing	2		0	0	2			2	E3
1	CES7118	1	Rod Adapter	2		0	0	2			2	E2
2	CES7120	2	Extension Rod, 106 long	4		0	0	4			4	D-5 (RACK)
2	CES3502	0	Inner Tube, 106 in long	4	3	0	0	7			7	D-5 (RACK)
1	CES3503	0	Inner Tube Sub, 15 in long	0	1	1	0	2			2	B-3 (RACK), B-5 (RACK)
1	CES7131	0	Quick Release Adapter	2	1	0	0	3			3	B-3 (RACK), A-5 (RACK), E3
1	CES7132	1	Quick Release Mandrel	2	1	0	0	3			3	B-3 (RACK), A-5 (RACK), E3
1	CES7133	0	Quick Release Nut	2	1	0	0	3			3	B-3 (RACK), A-5 (RACK), E3
6	CFS8827	-	Roll Pin, 3/16 dia x 1-1/2 Lg, 420 SS	12		30	30	72	30		42	E1
2	CFS2140	-	O-Ring, 2-140, Buna-N, 70 Duro	4		24	20	48	20		28	C3
3	CFS8864	-	Roll Pin 3/8 dia X 1.5 lg, 420SS	6		36	15	57	9		48	E1
1	**CES7200**	**0**	**SWIVEL/OT SPRING ASSEMBLY**									
1	CES7260	6	Spring Shaft	2		0	0	2			2	A-5 (RACK)
1	CES7255	3	Spring Housing	2		0	0	2			2	A-5 (RACK)
1	CES7265	-	Over Travel Spring, Century 73049	2		2	2	6			6	A-5 (RACK) Assy, E2 Spare
1	CES7205	1	Upper Housing, Swivel	2		1	0	3			3	A-5 (RACK) Assy, E3 Spare
1	CES7220	0	Bearing Spacer	2		1	0	3			3	A-5 (RACK)
1	CES7210	0	Lower Housing, Swivel	2		1	0	3			3	A-5 (RACK) Assy, E3 Spare
1	CES7225	1	Bearing Piston	2		2	0	4			4	A-5 (RACK) Assy, E2 Spare
1	CES7215	2	Bearing Shaft	2		1	0	3			3	A-5 (RACK) Assy, E2 Spare
1	CES7280	0	QLS Box	2		0	0	2			2	A-5 (RACK)
1	CES7281	0	QLS 2-1/2 Latch Plate	2	1	0	0	3			3	A-5 (RACK) Assy, E2 Spare
1	CES7282	0	QLS Latch Spring, 11966	2	1	4	0	7			7	A-5 (RACK) Assy, E2 Spare
1	CFS6810	-	Pipe Plug, 1/8 NPT, Sk Hd Cap, SS	2		4	2	8	2		6	A-5 (RACK) Assy, E1 Spare
2	CFS6630	-	Bearing Lock Nut, SKF KM-6	4		4	2	10	2		8	A-5 (RACK) Assy, E1 Spare
4	CFS4120	-	Bearing, Fafnir, 6006	8		12	4	24			24	A-5 (RACK) Assy, C3 Spare
2	CFS2226	-	O-Ring, 2-226, Buna-N, 70 Duro	4		16	10	30	5		25	A-5 (RACK) Assy, C3 Spare
2	CFS0104	-	Wiper Ring, Parker SHD-1500 Molythane	4		16	10	30	10		20	A-5 (RACK) Assy, E1 Spare
1	CFS7020	-	Snap Ring, Int, N5000-225 SS	2		8	5	15			15	A-5 (RACK) Assy, E1 Spare
1	CFS6680	-	Heavy Hex Nut, 1.25-7UNC GR7	2		2	2	6			6	A-5 (RACK) Assy, E2 Spare
1	**CES7300**	**3**	**PRESSURE CONTROL SECTION**									
1	CES7134	2	Lift Sub, PTCB	4	1	0	0	5			5	B4
1	CES7135	2	Middle Barrel, PCTB	4		0	0	4			4	A-3 (RACK)
1	CES7360	1	QLS PIN	4		0	0	4			4	A-1 (RACK)
1	CES7749	0	QLS Spacer	4		0	0	4			4	A1
1	CES7350	0	Adjustment Screw (AAI 10526)	4		1	1	6			6	A-1 (RACK) Assy, A1 Spare
1	CES7355	1	Regulator Lock Nut	4		1	1	6	1		5	A-1 (RACK) Assy, A1 Spare
1	CES7335	2	Regulator Sub	4		0	0	4			4	A-1 (RACK)
1	CES7325	5	Sleeve Valve Sub	4		0	0	4			4	A-1 (RACK)
4	CES7531	0	Bullet Valve (AAI 10533)	16		32	8	56			56	A1
1	CES7330	2	Sleeve Valve	4		0	0	4			4	A-1 (RACK)
1	CES7320	1	Separator Piston	4		2	0	6			6	A1
1	CES7315	4	Accumulator Barrel	4		0	0	4			4	A-1 (RACK)
1	CES7310	3	Reservoir Barrel	4		0	0	4			4	A-1 (RACK)
1	CES7306	7	Accumulator Sub, HPCTB	4		0	0	4			4	A-1 (RACK)
1	CES7381	1	Backup Washer	4		10	5	19	5		14	A2
1	CES7375	0	#6 SAE Ported Plug, SS	4		50	10	64	4		60	A3

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Hybrid PCS Tools and Spare Parts

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June 27, 2014
Chevron Contract No. CW1094939

CHEVRON/ DOE JIP - HYBRID PCS Tools & Spare Parts Packing List

Per Ass'y	Part No.	rev	Description	# Ass'y	# Cntr Bit Ass'y	# OP Sp	# F.T. Sp	Total Ordered	Used	Short	Total Count	Location in Service Unit
1	CES7365	1	Pressure Transducer Cap	4		1	1	6			6	A-1 (RACK) Assy, A1 Spare
2	CFS2016	-	O-Ring, 2-016, Buna-N, 70 Duro	8		100	20	128			128	C3
1	CFS2222	-	O-Ring, 2-222, Buna-N, 70 Duro	4		50	10	64			64	C3
4	CFS7006	-	Snap Ring, Internal, N-5000-068 SS	16		50	10	76			76	A1, A2
4	CFS8013	-	Backup Ring, 8-013 Split Teflon	16		300	60	376	20	240	116	C3
4	CFS2013	-	O-Ring, 2-013, Buna-N, 70 Duro	16		100	20	136	20		116	C3
3	CFS6860	-	Plug, #6 SAE, 6-HP5ON, SS	12		10	4	26			26	A1, A3
1	CFS9120	-	Ball Lock Pin, 3/8" OD x 1-1/4 Lg, Modified	4		1	1	6			6	E2
3	CFS1800	-	Rod Seal S07-P, 2.125 - #537586	12		150	30	192	30		162	C2
2	CFS2216	-	O-Ring, 2-216, Buna-N, 70 Duro	8		100	20	128			128	C3
3	CFS2220	-	O-Ring, 2-220, Buna-N, 70 Duro	12		150	30	192	30		162	C3
1	CFS2206	-	O-Ring, 2-206, Buna-N, 70 Duro	4		50	10	64	17		47	C3
1	CFS9940	-	Sintered Filter, 1/2 Dia x 0.063 thick, 40 Micron, 3	4		50	10	64			64	A2
1	CFS2012	-	O-Ring, 2-012, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS2109	-	O-Ring, 2-109, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS9930	-	Cartridge Check Valve, Kepner #2203C-3-5	4		20	10	34			34	A1
1	CFS2217	-	O-Ring, 2-217, Buna-N, 70 Duro	4		50	10	64			64	C3
1	CFS9910	-	P.Transducer, Sensotec A205 060-0281-22G-04	4		2		6			6	A-1 (RACK) Assy, A5 Spare
1	**CES7370**	**1**	**REGULATOR KIT, 10,000PSI**									
1	CFS9700	-	Filter Assembly, STD (316 SST), Tescom 6666	4		4	2	10			10	A-1 (RACK)Assy, A1 Spare
1	CFS9701	-	Spring, Tescom 1437	4		2	2	8			8	A-1 (RACK)Assy, A1 Spare
1	CFS9702	-	Main Valve, Tescom 1037-2	4		4	2	10			10	A-1 (RACK)Assy, A1 Spare
1	CFS9703	-	Vespel Seat, Tescom 1036-7	4		4	2	10	1		9	A-1 (RACK)Assy, A1 Spare
1	CFS9704	-	Retainer Seat, Tescom 1035-2	4		4	2	10			10	A-1 (RACK)Assy, A1 Spare
1	CFS9705	-	Connector, (17-4), Texcom 1034-8	4		4	2	10			10	A-1 (RACK)Assy, A1 Spare
1	CFS9706	-	Sensor, Backup, Tescom 1031-2	4		4	2	10			10	A-1 (RACK)Assy, A1 Spare
1	CFS9707	-	Sensor, 1/2 303 SST, Tescom 9619-2	4		4	2	10			10	A-1 (RACK)Assy, A1 Spare
1	CFS9708	-	Spring, 1.48,2.10,3170, Van Stl 10,000psi, Tescom 1051	4		4	2	10			10	A-1 (RACK)Assy, A1 Spare
2	CFS9709	-	Spring Pad, Tescom 7186-1	8		2	2	12			12	A-1 (RACK)Assy, A1 Spare
1	CFS9710	-	Valve Body, Tescom 1038-2	4		2	2	8	1		7	A-1 (RACK)Assy, A1 Spare
1	CFS2014	-	O-Ring, 2-014, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS2113	-	O-Ring, 2-113, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS2116	-	O-Ring, 2-116, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS2122	-	O-Ring, 2-122, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS8014	-	Backup Ring, 8-014 Split Teflon	4		50	10	64	10		54	C3
1	CFS8113	-	Backup Ring, 8-113 Split Teflon	4		50	10	64	10		54	C3
1	CFS8122	-	Backup Ring, 8-122 Split Teflon	4		50	10	64	10		54	C3
1	**CES7600**	**0**	**AUTOCLAVE**									
1	CES7602	2	Seal Sub, HPCTB	4		1		5			5	B3
1	CES7701	1	Upper Inner Tube Plug, PCTB II	4				4			4	B2
1	CES7714	0	Lower Inner Tube Plug, PCTB II	4		2		6			6	B2
1	CES7741	1	Mandrel, PCTB II	4				4			4	B2
1	CES7742	2	Pawl Carrier, PCTB II	4				4			4	B2
4	CES7743	1	Inner Tube Plug Dog, PCTB II	16		16		32			32	B1
1	CES7744	1	Liner Length Adjuster, PCTB II	4		2	2	8			8	B2
1	CES7745	1	Lock Nut, PCTB II	4				4			4	B2
1	CES7746	0	Pawl Carrier Spring, PCTB II, S-126	4		6	2	12			12	B1
1	CES7747	0	Plug Mandrel Spring, PCTB II	4		6	2	12			12	B1
1	CES7748	1	Lockout Washer, PCTB II	4				4			4	B2
2	CES7531	0	Bullet Valve (AAI 10533)	8		16	4	28			28	A1
1	CES7530	0	Burst Disk Holddown	4		4	4	12			12	B1
1	CES7527	0	Pawl Spring	4		8	4	16			16	B1
1	CES7526	2	Segment Pawl, (set of 3)	4		4	1	9			9	B1
1	CES7503	4	IT Collet Release Sleeve, PCTB	4		4		8			8	B2
11	CES7518	2	Collapsing Detent PCTB (11 per set)	44		44		88		44	44	B1
1	CES7529	1	Check Valve Plug	4		4	2	10			10	B1
1	CES7523	1	Rabbit, PCTB	4		4	2	10	1		9	A2
1	CCL1020	0	Core Liner Extension, 5 in	4		4	4	12	5		7	A3
1	CCL1030	0	Core Liner Extension, 2 in			4	4	8			8	A3
1	CES7605	0	Outer Tube, HPCTB	4				4			4	C-2 (RACK), C-3 (RACK)
1	CES7720	0	Inner Tube, PCTB II	4			1	5	2		3	C-2 (RACK), C-3 (RACK)
1	CES7508	4	Drive Sub, PCTB			5		5			5	B5
1	CES7507	3	Release Sleeve, PCTB	4		1		5			5	B4

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1	CES7506	3	Collet, Ball Valve Spring, PCTB	4		1		5			5	B4, B3
1	AES7610	2	BV Housing, HPCTB	4				4			4	C-2 (RACK), C-3 (RACK)
1	CES7519	0	Ball Valve Spring	4		2		6			6	B5
1	CES7525	2	Shim Pack, PCTB	4		4	2	10			10	B3
1	CES7515	4	Seal Carrier, PCTB	4				4			4	B3
1	CES7517	1	Ball Valve Seal, PCTB	4		50	10	64	10		54	C2
2	CES7516	1	Pivot Screw, PCTB	8		4	4	16			16	C-2 (RACK), C-3 (RACK), B1
1	CES7511	2	Ball, PCTB	4		2		6			6	C-2 (RACK), C-3 (RACK), B5
1	CES7609	2	Ball Follower, PCTB II	4				4			4	B3
1	CES7513	0	Return Spring	4		2	2	8	1		7	B4
1	CES7622	2	Housing Extension	4				4			4	B3
1	CES7612	3	Cutting Shoe Sleeve, PCTB II	4				4			4	B3
1	CCL1010	3	Core Liner, PCT	4		70		74	10		64	H-1 THRU H-5 (RACK), D-1 (RACK)
1	CCC4100	1	Basket Catcher, 2.000 Core, PTCB	4		70		74	2		72	A3
1	CES5110	0	Cutting Shoe, PTCB, PDC 3.8 OD x 2.00 ID			6		6			6	A5
1	CES7533	1	Keyless Drive Sub, PCTB	4				4			4	C-2 (RACK), C-3 (RACK)
1	CES7534	0	Outer Shoe, PTCB, 2.00 ID	4				4			4	A4
1	CES7535	1	Punch Shoe, PTCB, 3.8 OD x 2.00 ID			4		4			4	A4
1	CFS2222	-	O-Ring, 2-222, Buna-N, 70 Duro	4		50	10	64		60	4	C3
2	CFS7006	-	Snap Ring, Internal, N-5000-068 SS	8		100	20	128		120	8	A1
2	CFS8013	-	Backup Ring, 8-013 Split Teflon	8				8			8	C3
2	CFS2013	-	O-Ring, 2-013, Buna-N, 70 Duro	8		200	40	248		240	8	C3
1	CFS6860	-	Plug, #6 SAE, 6-HP5ON, SS	4		3	3	10		6	4	A1
1	CFS2014	-	O-Ring, 2-014, Buna-N, 70 Duro	4				4			4	C3
1	CFS9915	-	Burst Disk, Fike 1/2-100SM-5500	4		8	2	14	4		10	A2
1	CFS9920	-	Burst Disk Ring, Fike 1/2-100SM	4		4	2	10			10	A2, B1
1	CFS3906	-	O-Ring, 3-906, Buna-N, 90 Duro	4		50	10	64			64	C3
1	CFS2140	-	O-Ring, 2-140, Buna-N, 70 Duro	4		50	10	64	10		54	C3
3	CFS8803	-	Roll Pin, 1/8 Dia X 3/8 Lg, 420SS	12		150	30	192	36	28	128	B1
1	CFS1805	-	Rod Seal S07-P 2.183 - #542155	4		50	10	64	10		54	C2
1	CFS2330	-	O-Ring, 2-330, Buna-N, 70 Duro	4				4			4	C3
1	CFS2136	-	O-Ring, 2-136, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS2015	-	O-Ring, 2-015, Buna-N, 70 Duro	4				4			4	C3
1	CFS4210	-	Ball, SS, 3/4 dia., #9291K38	4		8	2	14			14	A2, B1
2	CFS2207	-	O-Ring, 2-207, Buna-N, 70 Duro	8				8			8	C3
1	CFS9900	-	Press/Temp Recorder, Star ODI 3000 TD	4		4	2	10			10	UNDER DESK
1	CFS7005	-	Retaining Ring, Int, SS, DIN 472	4				4			4	A2
3	CFS9905	-	Filter, 20x1mm, SS Mesh	12				12			12	A2
1	CFS2151	-	O-Ring, 2-151, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS2234	-	O-Ring, 2-234, Buna-N, 70 Duro	4		50	10	64	10		54	C3
3	CFS2232	-	O-Ring, 2-232, Buna-N, 70 Duro	12		150	30	192	30		162	C3
2	CFS8908	-	Dowel Pin 1/4 dia X 1/2 long, SS	8		8	8	24			24	A2, C-2 (RACK), C-3 (RACK)
1	CFS2231	-	O-Ring, 2-231, Buna-N, 70 Duro	4				4			4	C3
1	CFS2128	-	O-Ring, 2-128, Buna-N, 70 Duro	4		50	10	64	10		54	C3
1	CFS2211	-	O-Ring, 2-211, Buna-N, 70 Duro	4				4			4	C3
-	-	-	**CORE CATCHER OPTIONS, PCTB**									
2	CCC4110	0	Blank Liner End	4		16	4	24		20	4	A3
1	**CCC4200**	**0**	**SLIP TYPE CORE CATCHER**									
1	CCC4220	0	Body, Slip Type Core Catcher			20		20		10	10	A2
1	CCC4230	0	Core Lifter, Slip Type Core Catcher			36		36		26	10	A2
1	**CCC4300**	**0**	**FLAPPER CORE CATCHER**									
1	CCC4320	0	Body, Flapper Catcher			10		10			10	A2
1	CCC4340	0	Sleeve, Flapper Catcher			10		10			10	A2
1	CCC4310	0	Spring, Flapper Catcher			10		10			10	A2
1	CCC4330	0	Flapper, Flapper Catcher			10		10			10	A2
1	**CES7270**	**0**	**OUTER BEARING ASSEMBLY**									
1	CES7271	1	UPPER HOUSING, OUTER BEARING	2				2			2	E4
1	CES7272	0	LOWER HOUSING, OUTER BEARING	2				2			2	E4
1	CES7273	1	SHAFT, OUTER BEARING	2				2			2	E4
1	CES7274	0	SPACER, OUTER BEARING	2				2			2	E4
1	CES7275	0	PISTON, OUTER BEARING	2		2		4			4	E4, E2
1	CES7276	0	SHAFT ADAPTER, OUTER BEARING	2				2			2	E4
1	CES7277	0	LOCK NUT, OUTER BEARING	2				2			2	E4
1	CFS9010	-	Grease Fitting, 1/8 NPT, SS	2				2			2	E4
1	CFS6810	-	Pipe Plug, 1/8 NPT, 316 SS, #4452K541	2				2			2	E4
2	CFS6635	-	Bearing Lock Nut, 2.157-18UN-2A	2		4		6			6	E4, E2
4	CFS4130	-	Bearing, 80x55x13, #71911	8		8	4	20			20	E4, E1
1	CFS2234	-	O-Ring, 2-234, Buna-N, 70 Duro	2			16	18	16		2	E4, C3

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1	CFS0107	-	Wiper Ring, 2.5 ID Molythane, #9403K74	2			16	18			18	
1	CFS7030	-	Snap Ring, Int. N5000-312	2			8	10			10	E4, E1
1	CFS0108	-	Wiper Ring, 2.0 ID Molythane, #9403K69	2			16	18			18	E4, E1
1	CBH1000	0	HPCS OUTER BARREL ASSEMBLY									
1	CBH1010	5	Head Sub	1				1			1	Heavy Van (Houston)
1	CBH1018	2	Blank Landing Shoulder Insert	1				1			1	Heavy Van (Houston)
1	CBH1020	2	Top Sub	1				1			1	Heavy Van (Houston)
1	CBH1070	2	Landing Saver Sub	1				1			1	Heavy Van (Houston)
1	CBH1075	3	Replaceable Seat	1				1			1	Heavy Van (Houston)
1	CBH2045	2	Simple Latch Sleeve (used with Low End Drive)	1				1			1	Heavy Van (Houston)
1	CBH3000	4	Seal Bore Outer Core Barrel	1				1			1	Heavy Van (Houston)
1	CBH5058	0	Stabilized Modified Long Bit Sub, 10-5/8 Blades	1				1			1	Heavy Van (Houston)
4	CBH7100	0	Drill Collars, 8-1/2 x 4-1/4 w/6-5/8 FH Mod	4				4			4	Heavy Van (Houston)
1	CBH5056	0	Coring Stabilizer, 10-5/8 x 8-1/2 x 4-1/4 w/6-5/8 F	1				1			1	Heavy Van (Houston)
1	CBH0400	3	Low End Drive Assembly									
1	CBH0410	3	Body	1				1			1	G-5 (CRATE)
4	CBH0412	2	Drive Pins	4		4		8			8	G-5 (CRATE), E2
1	CBH0415	3	End Cap	1				1			1	G-5 (CRATE)
4	CBH0420	3	Drive Dogs	4		4		8			8	G-5 (CRATE), E2
4	CBH0430	3	Hinge Pin	4		4		8			8	G-5 (CRATE), E2
4	CBH0440	2	Torsion Spring	4				4			4	G-5 (CRATE)
4	CFS6350	-	Cap Screw, Hx Skt Flt Hd, 5/16-18UNC x 19.05 [3	4				4			4	G-5 (CRATE)
1	CBH0100	3	Float Valve Assembly									
1	CBH0115	2	Seal Retaining Ring	1				1			1	G-5 (CRATE)
1	CBH0106	7	Torsion Spring	1				1			1	G-5 (CRATE)
1	CBH0107	3	Hinge Pin	1				1			1	G-5 (CRATE)
1	CBH0110	4	Body	1				1			1	G-5 (CRATE)
1	CBH0120	4	Flapper	1				1			1	G-5 (CRATE)
1	CBH0125	2	Plexiglass Rod	1				1			1	G-5 (CRATE)
1	CBH0140	3	Seal	1				1			1	G-5 (CRATE)
1	CBH0150	4	Base Ring and Shroud	1				1			1	G-5 (CRATE)
4	CFS6350	-	Cap Screw, Hx Skt Flt Hd, 5/16-18UNC x 19.05 [3	4				4			4	G-5 (CRATE)
1	CBH0600	3	Bit Seal Assembly									
1	CBH0610	2	Bit Seal Retainer	1				1			1	G-5 (CRATE)
1	CBH0620	2	Bit Seal Gland	1				1			1	G-5 (CRATE)
1	CFS1600	-	Parker 4615 5000-3750-687 Deep Polypak	1				1			1	G-5 (CRATE)
1	CFS2249	-	O-Ring, 2-249, Buna N, 70 Duro	1				1			1	G-5 (CRATE)
3	CFS8805	-	Roll Pin, 1/8" Dia x 5/8" Lg	3				3			3	G-5 (CRATE)
2	CFS7150	-	Spiral Retaining Ring	2				2			2	G-5 (CRATE)
1	CBH0198	1	Float Valve Spacer	1				1			1	G-5 (CRATE)
1	CBT0221	1	CORE BIT, PDC, 10-5/8 OD X 2 ID	1				1			1	H-5 (CRATE)
1	CBT0220	2	CORE BIT, PDC, 10-5/8 OD X 3.8 ID	1				1			1	OPPOSITE H-5 (CRATE)
1	AES7060		CENTER BIT ASSEMBLY									
1	AES3504	0	Inner Tube Sub, 61" Long		1			1			1	D-5 (RACK)
1	CES4005	5	Drive Sub		1			1			1	A-3 (RACK)
1	AES4025	0	Bit Sub		1			1			1	A-3 (RACK)
1	CBT8200	1	Center Bit 3.75 OD		1			1			1	A4
1	ABT8210	0	Center Bit 2.00 OD		1			1			1	A4
1	AES7290	0	CENTER BIT LENGTH ADJUSTER									
1	AES3506	0	Inner Tube Sub, 7 in	1				1			1	
1	CES7276	0	Shaft Adapter, Outer Bearing	1				1			1	
1	CES7277	0	Lock Nut, Outer Bearing	1				1			1	
1	AES7279	0	Length Adjuster Adapter	1				1			1	
2	CHT4000	1	UPPER TRANSFER ASSEMBLY									
1	CHT4005	2	Pawl Release Sleeve	2				2			2	B2
1	CHT4011	1	Inner Tube Pulling Tool, HPCTB	2				2			2	B2
1	CHT4020	1	Transfer Adapter	2				2			2	A4
1	CFS2232	-	O-Ring, 2-232, Buna-N, 70 Duro	2				2			2	C3
2	AHT4040	0	LOWER TRANSFER ASSEMBLY									
1	AHT4041	0	Transfer Barrel	2				2			2	A4
1	AHT4042	0	Transfer Sub	2				2			2	A4
1	CFS2154	-	O-Ring, 2-154, Buna-N, 70 Duro	2		50	10	62	10		52	C3
1	CFS2240	-	O-Ring, 2-240, Buna-N, 70 Duro	2				2			2	C3
2	-	-	HANDLING TOOLS									
1	CFS9711	-	Tescom Fixture - Clamping Tool, 6557-3	2				2			2	A1
1	CHT3000	0	Core Barrel Dolly	1				1			1	UNDER BENCH TOP
1	CHT4014	0	Accumulator Sub Test Plug	1				1			1	A1
1	CHT4040	0	Inner Latch Release Tool	2				2			2	E2

Aumann & Associates, Inc.
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Hybrid PCS Tools and Spare Parts

PACKING LIST
June 27, 2014
Chevron Contract No. CW1094939

CHEVRON/ DOE JIP - HYBRID PCS Tools & Spare Parts Packing List

Per Ass'y	Part No.	rev	Description	# Ass'y	# Cntr Bit Ass'y	# OP Sp	# F.T. Sp	Total Ordered	Used	Short	Total Count	Location in Service Unit
1	CHT4050	2	Latch Lock Clamp, 3 inch	2				2			2	E2
1	CHT4055	0	Release Handle, Running & Pulling Tool	2				2			2	D3
1	CHT4070	1	Sleeve Valve Tool	2				2		1	1	D1
1	CHT4080	-	No-Mar Wrench 3.75 inch	2				2			2	D5
1	CHT4085	0	Inner Tube Sleeve Wrench Adapter	2				2			2	B2
1	CHT4095	-	24" Hex Wrench	2				2			2	D5
1	CHT4180	0	Cutting Shoe Protector	2				2			2	A5
1	CHT4185	0	Bearing Protector	2				2			2	E3
2	**CHT4190**	**0**	**BALL VALVE INSTALL TOOL**									
1	CHT4193	0	Washer Set	2				2			2	A-3 (RACK)
1	CHT4192	0	3/4-6 ACME Rod, 4 FT	2				2			2	A-3 (RACK)
1	CHT4063	0	Ball Resetting Spacer	2				2			2	A4
1	CHT4062	1	Ball Resetting Cap	2				2			2	A4
1	CFS6660	-	3/4 Washer, Brass	2				2			2	A-3 (RACK)
2	CFS6490	-	3/4-6 ACME Nut, Brass	4				4			4	A-3 (RACK)
2	**CHT2050**	**1**	**Inner Barrel Lifting Clamp, 3-1/2" Assembly**									
1	CHT2051	1	Body, Lift Clamp	2				2			2	E5
1	CHT2052	1	Door, Lift Clamp	2				2			2	E5
1	CHT2053	0	Hinge Pin	2				2			2	E5
1	CHT2054	0	Latch Pin	2				2			2	E5
1	CHT2020	2	Latch Bolt	2				2			2	E5
1	CFS6461	-	Hex Flange Nut, 5/8-11UNC, GR 8, Blk Steel	2				2			2	E5
1	CFS8050	-	Roll Pin, 1/8 Dia x 3/4 Lg, 420 SS	2				2			2	E5
1	CFS7050	-	5/8" External Spiral Retaining Ring	2				2			2	E5
1	CFS7055	-	3/4" External Spiral Retaining Ring	2				2			2	E5
2	CHT2015	-	4 Ft Chain, Gr 80 Alloy Steel, 3/8" Trade Size	4				4			4	E5
1	CHT2016	-	Sling Link, 3/4" Dia Alloy Steel	2				2			2	E5
2	CHT2017	-	Nonremovable Shackle, 3/8" Chain Size	4				4			4	E5
4	CHT2018	-	Nonremovable Gr 100 Fig-8 Connector, 3/8" Cha	8				8			8	E5
2	**CHT2150**	**1**	**Inner Barrel Lifting Clamp, 3-3/4" Assembly**									
1	CHT2151	1	Body, Lift Clamp	2				2			2	E5
1	CHT2152	1	Door, Lift Clamp	2				2			2	E5
1	CHT2053	0	Hinge Pin	2				2			2	E5
1	CHT2054	0	Latch Pin	2				2			2	E5
1	CHT2020	2	Latch Bolt	2				2			2	E5
1	CFS6461	-	Hex Flange Nut, 5/8-11UNC, GR 8, Blk Steel	2				2			2	E5
1	CFS8050	-	Roll Pin, 1/8 Dia x 3/4 Lg, 420 SS	2				2			2	E5
1	CFS7050	-	5/8" External Spiral Retaining Ring	2				2			2	E5
1	CFS7055	-	3/4" External Spiral Retaining Ring	2				2			2	E5
2	CHT2015	-	2 Ft Chain, Gr 80 Alloy Steel, 3/8" Trade Size	4				4			4	E5
1	CHT2016	-	Sling Link, 3/4" Dia Alloy Steel	2				2			2	E5
2	CHT2017	-	Nonremovable Shackle, 3/8" Chain Size	4				4			4	E5
4	CHT2018	-	Nonremovable Gr 100 Fig-8 Connector, 3/8" Cha	8				8			8	E5
1	**CSB1300**	**0**	**WIRELINE TOOLS**									
1	CSB1311	1	Core. Running Tool, PCT	1				1			1	F-5 (RACK)
1	CSB1312	1	Collet, Running Tool, PCT	1		1		2			1	F-5 (RACK)
3	CSB1313	1	Mandrel Adapter	3				3			3	F-5 (RACK)
3	CSB1314	0	Collet Adaper, PCT	3				3			3	F-5 (RACK)
1	CSB1321	1	Core, Emergency Pulling Tool, PCT	1				1			1	F-5 (RACK)
1	CSB1322	1	Collet, Emergency Pulling Tool, PCT	1				1			1	F-5 (RACK)
1	CSB1331	1	Core, Pulling Tool, PCT	1				1			1	F-5 (RACK)
1	CSB1332	1	Collet, Pulling Tool, PCT	1		1		2			1	F-5 (RACK)
1	CSB1333	0	Collet Extension, Pulling Tool	1				1			1	F-5 (RACK)
3	CSB1201	0	QLS Pin, Wireline Tools	3				3			3	F-5 (RACK)
3	CSB1202	B	Mandrel, PCT (10423)	3				3			3	F-5 (RACK)
3	CSB1203	-	Ratchet Housing 10427)	3				3			3	F-5 (RACK)
3	CSB1204	A	Ratchet Sleeve (10390)	3				3			3	F-5 (RACK)
3	CSB1205	-	Shear Pin Sleeve (10426)	3				3			3	F-5 (RACK)
3	CSB1206	0	Shear Pin (10425)	3		25	10	38	8		30	F-5 (RACK)
3	CSB1207	-	Spring Housing (10424A)	3				3			3	F-5 (RACK)
3	CSB1208	B	Spring (10386)	3				3			3	F-5 (RACK)
3	CSB1209	-	Collet Housing (10422)	3				3			3	F-5 (RACK)
3	CSB1215	-	Collet Base (10421)	3				3			3	F-5 (RACK)
6	CFS8825	-	Roll Pin, 3/16 x 1-1/4" Lg, 420 SS	6		25	20	51		45	6	F-5 (RACK)

SECTION 5
PHASE IIIB TOPICAL REPORT #41330R27

Catoosa Onshore Test of the Hybrid Pressure Coring System (HPCS)

Prepared by multiple contributors including:
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GOM Deepwater Gas Hydrate
Joint Industry Project
DOE Award DE-FC26-01NT41330

November 2013

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Testing of Hybrid PCS Development

Test Planning and Preparation

Site Selection

From the outset of the program, the need for a comprehensive test of the Hybrid Pressure Coring System (HPCS) core barrel was recognized as a necessity. The initial plan was to have a full scale mockup of a coring operation to test not only the barrel, but also the interfaces to the PCCT tool and the IPTC tool. This proved to be logistically cumbersome and very expensive, so the program was scaled back to a realistic test of the core barrel itself.

It was also a desire of the team to try to replicate the hydrate formations wherever possible so that the function of the entire coring system could be tested by cutting hydrate cores with the tools. A potential offshore operation was considered at one point. However, cost and logistical complexity steered the team to a more economical solution to use land facilities.

A review of potential land facilities was undertaken. In the Gulf Coast region the team found several facilities that had the capability to perform the test in a cased hole environment. There were two Schlumberger sites, one at Cameron and one in Sugarland, which had a cased hole rig. These were used heavily by Schlumberger for training and for testing newly developed directional and LWD tools. Franks Casing also had a shallow well that was used for training purposes for their tools, as did Baker. All of these facilities were intended for private work, but they could book time as available to outside groups, like JIP's. Concerns were the availability of the sites to meet the project schedule, and that the test would be run in a cased hole environment.

It was thought that a test could be conducted in a cased hole environment if a "synthetic hydrate formation" could be created. Work was undertaken to develop cement slurry having the same general properties as a partially saturated hydrate formation. The plan was to fill the interval with the slurry, then cut "synthetic formation" cores to confirm the mechanical integrity of the barrel. After problems occurred attempting this procedure during a Quality Assurance Test in Japan, this option was dropped. After the Japanese field test proved problematic, it was determined that a conventional well bore with actual formation to drill/core was desired.

As the manufacturing of the HPCS equipment progressed it became apparent that we needed a 10 day period between mid-October and mid-November 2013 to perform the test. During this time the rig at the Cameron facility was down. The Genesis rig was fully booked until Q1 2014, except for single days at a time for the period we desired the test. The Baker and Franks wells were unavailable for our use during October-November 2013.

The alternative site chosen was a new Catoosa Test Facility located just outside Jennings, Oklahoma. It had several advantages:

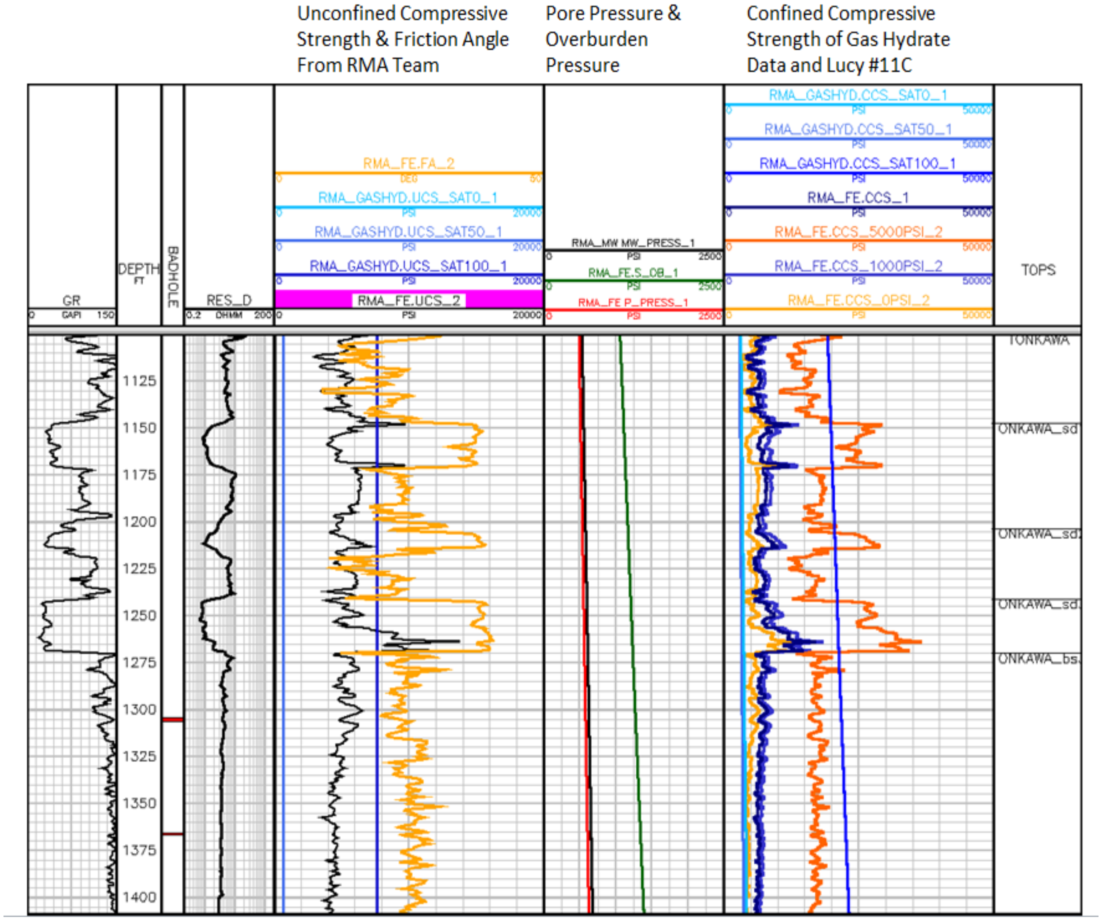
- It was located in a site where rock formations could be drilled anywhere from 725 feet (casing shoe) to about 3,500 feet (sedimentary basement). The test could then be conducted in an open-hole environment vs. cased hole.
- The test site could be booked in advance.
- Catoosa was able to offer their facility 10 days in October with a first refusal for the first 2 weeks of November, which was ideal for our work schedule.
- They were familiar with conducting tests of research tools.
- Catoosa had all necessary permitting in place for their operations.
- They could offer most if not all services required on a pass through basis from local providers, minimizing the logistics and expense of shipping additional equipment to the location from Houston.

The Catoosa rig was custom built for research drilling and testing. It has a substructure that can rotate around a circular track allowing multiple wells to be drilled from the rig. Each well in turn had a conductor set below the water and surface sediments, and can be sidetracked in many directions. Geological control is very good as there are many penetrations in the strata.

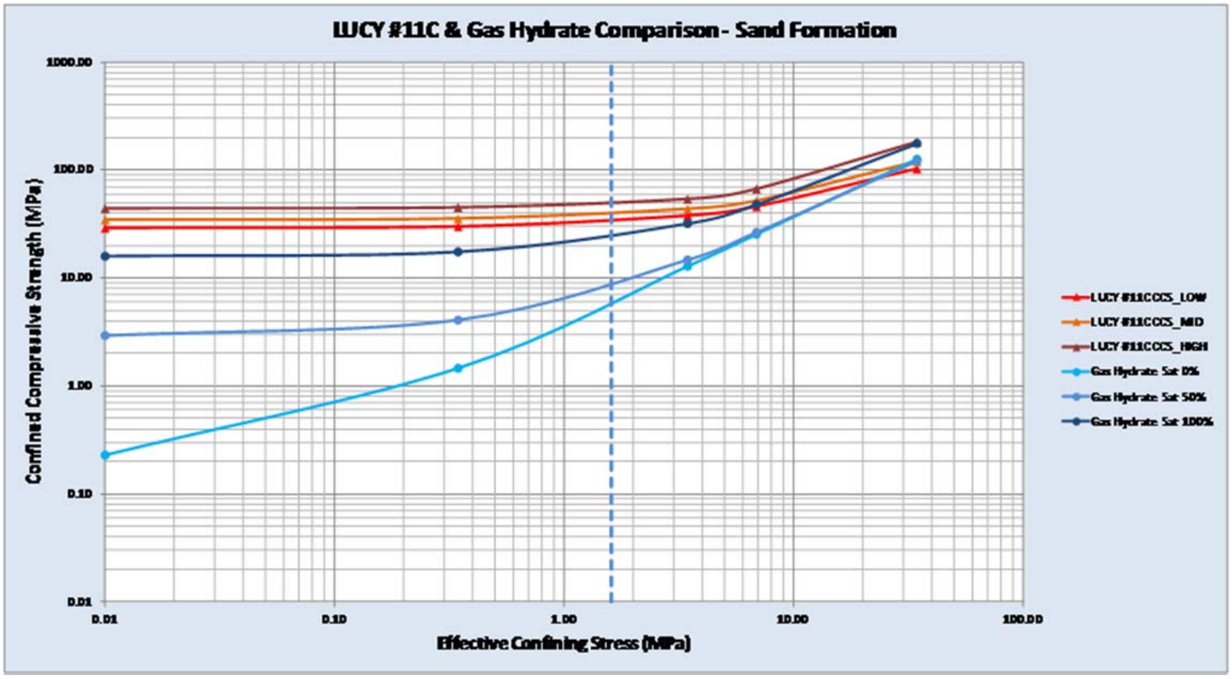
Because the wells are in a non-hydrocarbon area, and there is no evidence of pressure, well control was not a significant issue. The rig is treated from a regulatory perspective like a manufacturing and R&D facility, so permits, licenses etc. are not a significant requirement.

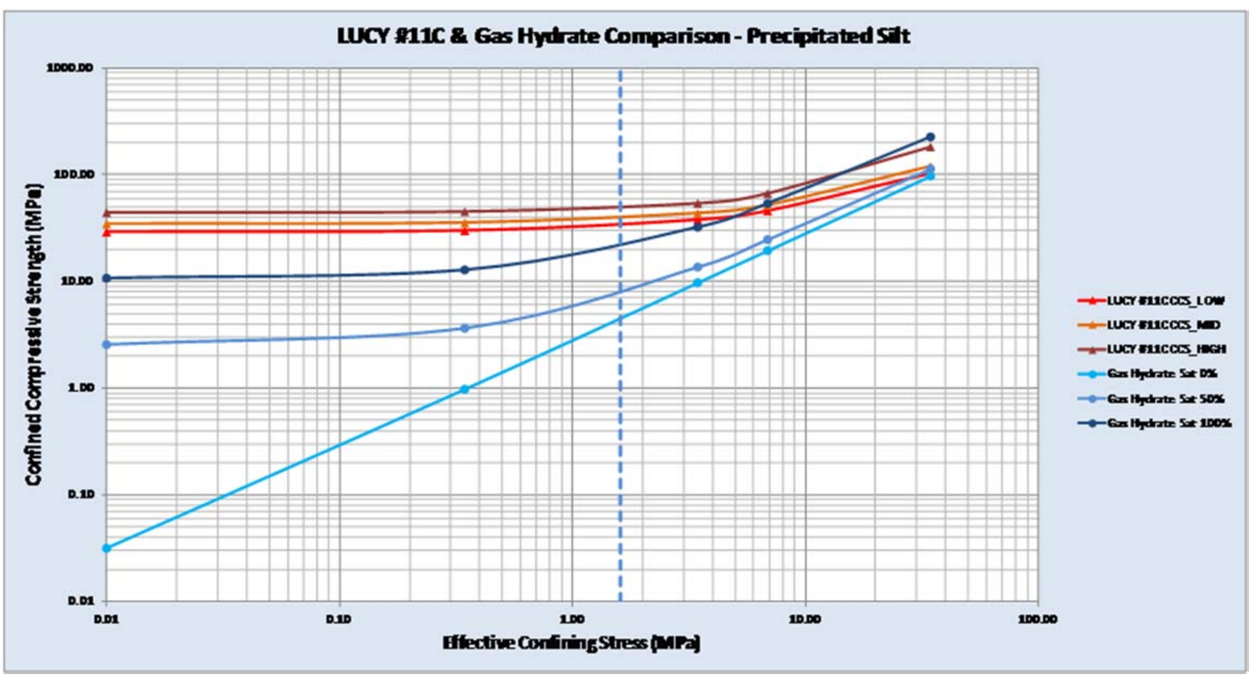
The facility is zero discharge, and all cuttings and liquids from the well are handled by a third party EPA approved waste management firm. The Catoosa Facility was uniquely set up to handle the type of work we planned.

In order to quantify the ability of the hydrate core head to cut the rock formations at Catoosa, a study was completed on the target Tonkawa Sand group at the Lucy well site. Log data and ROP data were reviewed and an estimation of the confined and unconfined compressive strengths was determined. This is shown in the log section below.



In order to evaluate the ability of our bit design to cut these formations, an analysis was made between a typical Tonkawa sand interval compared to an estimate of the hardness of sand with varying degrees of hydrate saturation. These charts are shown below for sand and silt. The conclusion reached is that the formations at the Catoosa Test Site are a lot older and harder than one would expect in an offshore marine environment, but that a fully saturated hydrate core can have strengths of the same order of magnitude as the Tonkawa Sand. Although the relative compressive strength is 2-3 times that of a fully saturated hydrate core (see charts below), the bit manufacturer expressed no concern as to the ability of their bits to drill these formations.


LUCY #11C & Gas Hydrate Comparison - Sand Formation
Confined Compressive Strength (MPa)
Effective Confining Stress (MPa)
1000.00
100.00
10.00
1.00
0.10
0.01
0.01
0.10
1.00
10.00
100.00
LUCY #11CCCS_LOW
LUCY #11CCCS_MID
LUCY #11CCCS_HIGH
Gas Hydrate Sat 0%
Gas Hydrate Sat 50%
Gas Hydrate Sat 100%


LUCY #11C & Gas Hydrate Comparison - Precipitated Silt
Confined Compressive Strength (MPa)
Effective Confining Stress (MPa)
1000.00
100.00
10.00
1.00
0.10
0.01
0.01
0.10
1.00
10.00
100.00
LUCY #11CCCS_LOW
LUCY #11CCCS_MID
LUCY #11CCCS_HIGH
Gas Hydrate Sat 0%
Gas Hydrate Sat 50%
Gas Hydrate Sat 100%

The primary goal of the Catoosa Test was to evaluate the coring tools in a real well bore environment. Testing included makeup and running of the core barrel in various configurations into the drilled well bore. In addition to fit testing and simulated usage, five complete cores were planned to be taken. The field test was designed to see if all the tools would work together and if the service and heavy lift vans would meet the expectations of the design team. All of the tests were planned to evaluate the functionality of the tools, not to test them to their design limits or to verify the operational ranges of the tools.

Contracting and Cost

After the selection of the Catoosa Test Facility (CTF) was made, the Project Team Drilling Consultant began communications with site management to understand how they typically structured their contracts, including costs. CTF typically rents their clients the use of an undrilled hole or an existing wellbore from surface locations around the existing rig pad. Also rented is the site drilling rig and associated mud pumping equipment, their standard drill pipe and bits, and a complete drilling crew for a published day-rate. CTF also provides drilling mud, fuel, special personnel call-out, and accommodations for their clients in accordance with published unit rates. CTF also has a partnership agreement with Oklahoma Tool Company in Drumright for other downhole tools and equipment that may be needed. Unit rates for using Oklahoma Tool Company's equipment are part of CTF's contracts. If additional materials or services are desired by the client, such as wireline services, core analysis, or specialty equipment, the client is typically responsible for contracting these services directly while using the site. All hands-on work activity at CTF's site is required to comply with CTF's safety plan and safe work practices.

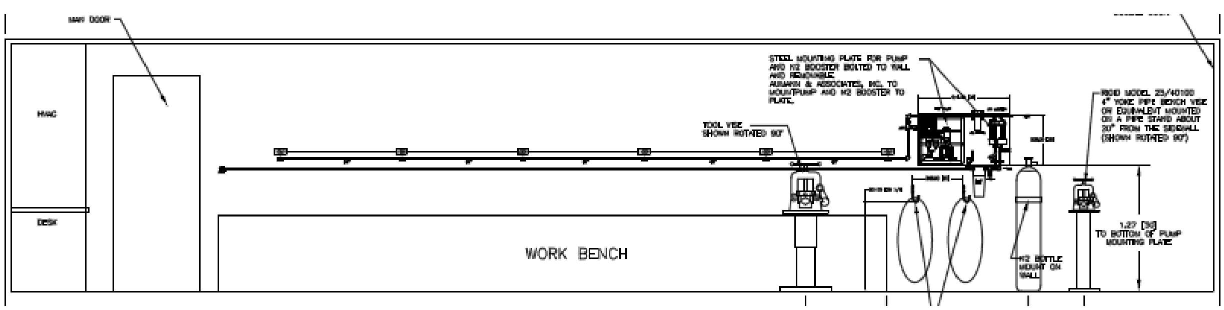
Further discussions occurred between all parties regarding contracting and operator responsibilities. The final contracting strategy put all services under contracts with CTF directly, thereby making CTF completely responsible for the safety of all work performed on their property. Chevron would only bring in observers to witness CTF's execution of the hands-on work performed by either CTF's crew or the subcontractors. Chevron provided the technical requirements for the test and obtained informal quotations for materials and services. These were provided to CTF, who ultimately establish the service contracts. Additionally, the Hybrid PCS Coring, Testing and Core Handling Plan was developed by Chevron, and it was used to communicate technical service and material requirements for the HPCS Test. A mutually agreeable contract was signed by both parties in September, 2013.

The operational plan provided in this report is a high level summary. It is only intended to serve as a guide to how a contractor could plan to drill, core and test a Hybrid Pressure Coring System and how the recovered cores could be inspected, processed and handled. This plan was shared with other contractors, administrators, observers and visitors to the test facility in order to describe the scope of work and services that could be performed. Although portions of this plan are included in the technical requirements of Chevron's contract with CTF, this plan, as a whole, is not part of and nor shall it be construed to be part of the CTF contract.

The estimated cost of the testing program prior to commencement of the test was $480,000. This estimate was based on 7 testing days with an additional 2 contingency days (approximately 144 rig time hours at 16 hours/day). The actual cost at contract close-out was $496,000 which included a claim of $11,060 for damaged drill pipe. The actual test took place over 8 days, 2 of which were 24 hour days for a total of 135.5 hours of rig time.

Service Van and Heavy Van Design and Manufacturing

The design of existing service and heavy transport vans was reviewed. The two vans ranged from 20 to 33 feet long. The 33 foot van was used to transport the inner barrels, drill collars and outer barrel (over 30 feet long). This presented a potential safety concern due to the cumbersome method used to load the large and heavy objects into the van. Once the drill collars and outer barrels were in the van there was no room for personnel to safely work. It was decided to build a 40 foot long service van for extra work space and a 40 foot long heavy transport van for transport of the heavy drill collars and outer barrel. The service van had an extra vice installed in the front for increased ease of pressure section servicing and a desk with computer in the rear for fish pill servicing. Racks were installed along the entire length of one wall for storage and shipment of the inner barrels. The heavy transport van has a false floor, the drill collars and outer barrel are stored beneath the floor in racks secured by chain tongs. Lighter equipment can be stored above the false floor. The roof of the transport van is removable for ease of access by a crane. The service van can be stored on top of the transport van for security.



Chevron issued a purchase order for the fabrication of one heavy transport van and one service van to ProLog Inc. The service van was constructed at the ProLog Tenaha, Texas facility. The primary ProLog New Iberia, Louisiana plant undertook fabrication of the heavy transport van.

ProLog purchased foreign containers and modified them as needed to produce each van. The vans were then outfitted to contract requirements. Gonsoulin Consulting Engineers of New Iberia Louisiana was contracted by ProLog to complete the containers ISO Container Lift Analysis Report including van load test criteria. Additional design interfacing was completed with Aumann & Associates to ensure that the vans satisfied field service needs.

The service van scope of work included installing interior floors and wall siding, work bench, cabinets, overhead electrical crane, pipe racks, C vises, freezer door, N2 pump booster wall steel mounting plate, mounting brackets, and other utilities. The heavy transport van scope of work also included the provision of spreader bars, lifting slings, interior tie down straps and tubing. Both vans were exterior painted by local subcontractors. NDE, electrical or other specialty trade scope not completed internally by ProLog was subcontracted.

ProLog builds to industry standards. Work process procedures such as qualified welding procedures are on file. Workmanship at the Tenaha and New Iberia locations was very satisfactory. Chevron completed two quality surveillance visits to the Tenaha facility and one to New Iberia. A final shipping inspection was undertaken on the Tenaha manufactured service van. Desk drawers, bench cabinets, van plastic curtain doors, exterior Cargo Master crane structure, side and main rear entrance doors, AC, all tested functionally acceptable.

Due to the existing work load during the service van fabrication period, ProLog's Tenaha fabrication yard was required to source additional manpower to complete the van on schedule. Overall, the ProLog scope of work was successfully executed. Quality records, including the ISO Container Lift Analysis Report, van lift test resulting, and lifting lug NDE reports, were turned over with the van upon project completion.

Once fabrication was completed on both vans, the service van was shipped to the Catoosa Test Facility in Jennings, OK to support testing of the Hybrid Pressure Coring System, while the heavy transport van went into long term storage at the New Iberia fabrication yard. Both vans were delivered to the DOE storage facility in Morgantown, West Virginia at the conclusion of the overall project, in July 2014.

While using the service van at the Catoosa Test Facility, two deficiencies were discovered:

1) Instead of the specified heat pump for space cooling and heating of the van's interior during working conditions, it was discovered that only an air-conditioner unit was installed and hence there was no heating capability. ProLog was contacted about the deficiency and corrected this non-conforming item, with Chevron's concurrence, by installing a ceiling-hung 42-amp electric unit heater for space heating. The unit heater was hung in a location such that it did not interfere with other van components. Although not as aesthetically pleasing as a heat pump, the unit heater has greater heating capacity and should work better, especially in colder climates. ProLog traveled with a small crew to Jennings, OK to complete this installation.

2) It was noted that the power cord for the traveling crane draped down during operation to the point where it was creating a potential safety hazard for the work crew and it was exposed to potential damage by getting caught on one of the service vices. The original design called for the power converter and battery to be wall mounted in the rear of the van and that the large diameter 12-volt cord would run in the draped fashion between the converter and the crane motor. After testing was complete at the Catoosa Test Facility, the service van was shipped to Aumann & Associates' workshop in Salt Lake City where the Hybrid Pressure

Coring System underwent further testing and modifications. During the van's tenure in Salt Lake City, Aumann & Associates modified the method in which the crane gets its power by mounting the power inverter and battery on the crane trolley adjacent to the crane's motor and running 120-volt power to the inverter through a coiled cord of smaller diameter than the draped 12-volt cord. The coiled cord remains high and out of the way of workers and other equipment thereby minimizing the risk of damage. This has proved to be a far better design than the original installation.

One additional problem was discovered during inspection at Aumann & Associates following the field test. The rear of the service van was apparently stabbed with a forklift either during placement or while being moved or loaded following the field test at the Catoosa Test Facility. There was a hole in the skin in the lower rear wall, a significant dent and the post on the rear was bent as well. We believed the damage was superficial and not structural but, recommended it be repaired prior to shipping to the DOE. Aumann & Associates obtained approval from Chevron and repaired the damage. The following photos show the damaged area after the repairs were made.

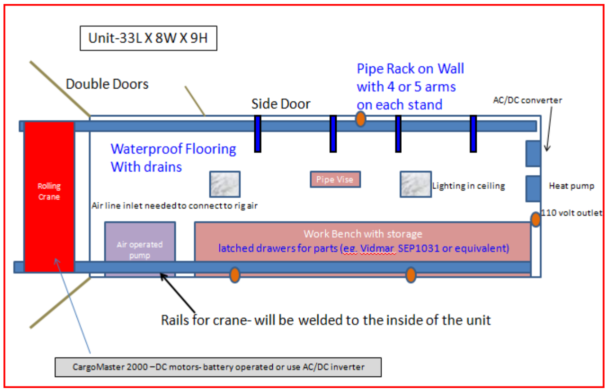
The heavy transport van is primarily designed for use at offshore locations where pedestal cranes are commonly used for moving components in and out of the van which has a removable top for this purpose. Trying to use the heavy transport van for onshore transport of the outer barrel and drill collars presented logistical problems that were harder to overcome than simply using readily available forklifts to load the components on flatbed trucks for shipment. For this reason, the heavy transport van was not used for shipping the bottom-hole assembly to the Catoosa Test Facility.




Operational Plan

Coring Equipment and Vans

Coring equipment is normally contained in two offshore containers. One is the service unit with tool spares and work areas required for servicing and repairs to the tools used to cut the cores. This unit is as shown below



The skid should be spotted such that the crane trails can be extended over the catwalk to allow the inner barrel to be picked up and transferred into the service unit. Lifting tackle is shipped with the unit providing a matched set of slings, and necessary spreader bar for safe lifting. All attachment points and slings are proofed and tested to 2.5 times the nominal gross allowable weight for offshore lifting.

HYDRATE CORING SERVICE UNIT

Service Unit	Nominal Dimensions 40ft x 8 ft x 8 ft 6"			
Inner barrels		**Wt each**	**Weight**	
upper	2	300	600 lb	
Lower	4	400	1,600 lb	
Tools and Other Portable Equipment			2,000 lb	Est
Spares Supplies and Misc			2,000 lb	Est
Estimated Variable Weight			**6,200 lb**	
Vice/Cabinets/Crane/ AC/Permanent Equipment			10,850 lb	Est
40 ft Unit Empty Tare wt			9,150 lb	
Estimated Loaded Weight			**26,200 lb**	

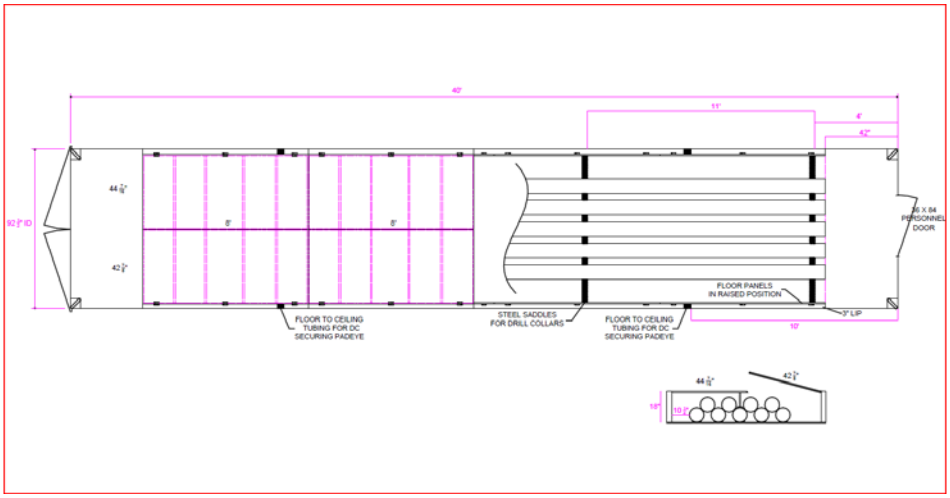
The unit should be visually inspected prior to unloading to assure the crane will not exceed its rated capacity

The service van unit requires the following service connections:

- Electricity: 480 30 amp switchable to 240v -60 amp capacity
- Air: 90 psi inlet pressure, @ 40scf per minute capacity
- Water: nominal 45 psi inlet pressure ½” or 5/8” line
- Grey Water discharge: as needed for sinks and wash-water only

The second container is the heavy lift van designed to carry the outer core barrel, drill collars and other accessories used to support the coring operations. It is a 40 foot container with a removable roof to allow the outer core barrel, drill collars and other bulky items to be loaded.

The floor is removable allowing access to racks to store collars and other equipment and to strap them for shipping. The heavy lift container can be used after the tools have been removed as a work area for the inspection and cutting of core. There is a drop down work table built into the interior wall of the container for this purpose



HYDRATE CORING HEAVY LIFT UNIT

Heavy Van	**Nominal Dimensions 40ft x 8 ft x 8 ft 6"**				
				Weight	**Dia**
Bit Sub, Outer Barrel, Top Sub, Head Sub			34 ft	5,500 lb	8.25"
Coring Stabilizer, 9-7/8 x 8-1/2 x 4-1/4 ID				480 lb	
Drill Collars (Recommend 4 min)		4	30 ft	16,600 lb	8.25"
Packing Strapping & Misc				500 lb	
			Estimated Variable Weight	23,080 lb	
Decking Bracing and Other Fixed Gear				1,000 lb	
40 ft Unit Empty Tare wt				9,150 lb	
			Estimated Loaded Weight	33,230 lb	
			Max wt (ISO Transport)	67,197 lb	
			Max Wt (Offshore Transport)	34,310 lb	

rev: Jul 13

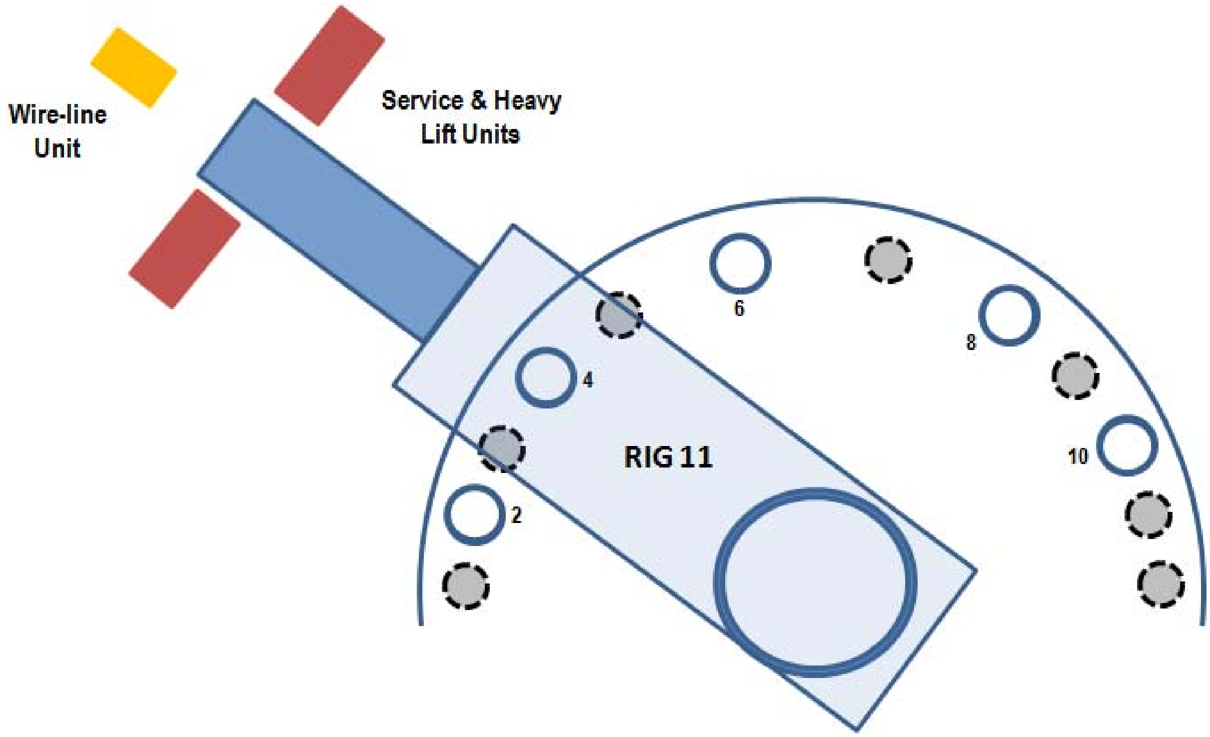
The heavy lift van doubles as a secondary workspace for the analysis of core and preparation for shipping after it has been removed from the wireline barrel in the service van.

Due to program timing and late deliveries, the heavy lift van was not used for the Catoosa Test. The drill collars and other coring equipment were shipped separately.

The heavy van unit requires the following service connections:

- Electricity: heavy duty extension cord with 2 outlets, rated for 110v @20A (total)
- Lighting: portable workspace lighting if needed for night work

Typical layouts at the rig for the coring units is as shown below



Preferred Layout for Slot 4

Crates will be marked as to their storage location (i.e., indoors or outdoors). All crates should be stored in a dry location off the ground and covered from possible rain exposure. CTF will inspect each crate externally on delivery for shipping damage, and report any damage or shortages to Chevron in a timely manner. The main core barrel and drill collars may be stored outside on suitable pipe racks pending use. All collar stock will be handled with suitable slings and a spreader bar, or by forklift. No hooks are to be used on tubular material in handling.

In advance of the start of coring operations, Aumann & Associates should be mobilized to unpack and inspect all materials and load out the service van in preparation for the testing program. Because of its anticipated weight when loaded, it is recommended that the unit be spotted on location where it will be utilized and loaded from that point. At the same time utilities and services (Electricity, Air, and Water) should be rigged up for use. All services in the van should be carefully checked and any deficiencies reported to Chevron so they can be corrected

During coring operations the heavy lift van will be utilized for inspection of the cores cut, and preparation for shipping. This work will be performed by Core Labs. They will bring necessary equipment with them for that purpose. The Heavy lift unit has a fold down workspace to support this effort. They will however need electricity for the cut-off saw, and a workspace light for the evening hours. In the event of rain or inclement weather, the removable roof can be reinstalled once collars and other materials have been removed. Optionally a tarp should be available to rig a temporary rain shelter if needed

Demobilization

At the conclusion of operations, Chevron will arrange and CTF will supervise the loading and securing of all materials into the heavy lift and service vans. Prior to shipping, a visual inspection by both Aumann and Associates and CTF will be made. Once both are satisfied that the containers have been packed in a safe and workmanlike manner, the doors will be locked, and the equipment loaded onto transport carriers.

Well-Site Operations - Drilling to Correlation Point

1. Move rig over Slot 4, and rig up for operations. Prior to the commencement of work, the tong line indicator is to be calibrated to assure that over torqueing of drill string components does not occur. CTF will check calibration of gauges sensors and other indicators to ensure that all are working properly.
2. Rig up bell nipple to the 13-3/8 conductor and check for leaks.
3. Mix pits full of un-weighted polymer gel mud having the following properties

   Mud Wt. 8.4-8.8 (no barite)
   PV: as low as practical
   YP: 10-15
   Gels: 0/5
   Water loss: no control

   A full API Mud check will be required twice each day. A listing of the mud products added to the system each 24 hours will be maintained and a copy of the checks and inventory will be provided to Chevron

4. Hold a pre-job safety meeting, outlining required work activities to be undertaken and note same in the official report.
5. Pick up 12-1/4" bit and BHA as needed to drill out cement from conductor.
6. RIH and tag cement. Break circulation and displace well bore to mud.
7. Drill cement as required to 13-3/8 shoe estimated to be at 748 ft. Circulate bottoms up prior to starting sidetrack so that cuttings to cement ratio can be easily observed.
8. POOH and pick up motor and orienting sub align scribe to bit face and RIH. Orient to nudge well away from existing wellbores (Take into consideration motor reactive torque) Take care to not rotate pipe in order to preserve orientation.

9. Nudge well to sidetrack. Nudging assembly should be tripped for additional stabilization once 100% formation returns are seen. It is important that the well be sidetracked into fresh formations prior to 9,50 ft. RT. Ensure that angles are maintained at 5 degrees or less at 950 ft.
10. Drill with a constant weight and RPM, to maximize the contrast of different formation types. We will correlate from the Lucy 11 log and we expect to have at least 4 good markers as we drill.

CORRELATION POINT	Rotary Depth	Distance To CP1
TOP LOVELL	803’	346’
Limestone Marker One	1000’	149’
Limestone Marker Two	1051’	98’
TOP TONKAWA	1096’	47’
First Core Point	1049’	0’

11. At 1075’, stop drilling and the team should check the correlation to the Lucy offset. The marker at 1051’ can also be confirmed by the general decrease in ROP coincident with the lithology change. Once we have an agreed depth for the top of the Tonkawa, resume drilling at constant wt. RPM.
12. The Hard lime streak at the Tonkawa top should reduce ROP from 100 to 5 ft. per hour. Once the ROP has dropped confirming the Lime, drill through the lime and as soon as ROP increases stop drilling. Circulate samples as required to confirm marker depth.
13. Once the Tonkawa Marker has been verified, measure out of the hole to confirm depth. Catoosa supplied drill pipe and BHA components will no longer be required. Lay down Drill pipe and all BHA components as required. Clean floor for further operations.
14. Rig up 5-1/2” slips, elevators and running tools.
15. Do a joint count of all 5-1/2” pipe on the lease, remove protectors on the rack, clean and visually inspect all threads for galling or seal area damage. Drift all pipe to 4.125” using a long tubing drift mandrel. Tally and number each joint. Re-dope with fresh dope and reinstall protectors prior to pickup.

<u>QA on Face Bit Core Barrel</u>

1. Hold a pre-job safety meeting, outlining required work activities to be undertaken and note same in the official report.
2. Pick up and assemble the 8.25” outer core barrel as directed by AAI personnel and in accordance with the AAI Hybrid PCS Operation Manual. Use collar clamps at all times. If basket slips are used rope handles closed to prevent the barrels from slipping in the

hole. For the first run, a 10-5/8" face bit assembly will be utilized. Driller will measure and record the length and fishing OD of all equipment run through his rotary table.

3. Before running in the hole with the outer core barrel assembly, conduct a space out procedure by running several inner barrel assemblies into the outer core barrel assembly. A modified wireline tool can be attached to a tugger and used instead the Weatherford wireline equipment for these tests. The procedure is described fully in the AAI Operation Manual. This must be done at the surface in order to pick up and view the space between the core catcher and bit or cutting shoe.
4. After the space out procedure is complete, pick up stabilizers and drill collars as directed. Again all pipe is new so double breaks will be needed. Tally and caliper all pipe.
5. Once BHA has been picked up, record the BHA wt in mud, and note same on reports.
6. Run pipe from the derrick as required to put bit just inside the conductor shoe with a tool joint at the rotary table. Circulate bottoms up while rotating at 80-100 rpm pumping at 600 gpm and working pipe to simulate open hole operations.
7. Rig up Weatherford wireline unit, and run a 4.125 dummy to the bit to confirm proper operation and depth calibration. Ensure that an air stripper or other line wiper is used on all pulling operations
8. Hold a pre job safety meeting to brief crews on wireline operations to be undertaken.

The coring system has two upper sections denoted A and B. There are four lower sections denoted 1 through 4. The AAI service staff will prepare core barrels and center bit assemblies to be run into and retrieved from the wellbore.

Planned Tests for Face Bit Assembly

	UPPER BARREL USED	LOWER BARREL USED	Accumulat or Set point (psi)	Test Name	TEST REPORT FORM
Face Dimensional test 1	*A*	*1*	*0*	***1-A-1***	*DIMENSIONAL*
Face Dimensional test 2	*B*	*4*	*0*	***2-B-4***	*DIMENSIONAL*
Face Dimensional test 3	*A*	*2*	*0*	***3-A-2***	*DIMENSIONAL*
Face Dimensional test 4	*B*	*3*	*0*	***4-B-3***	*DIMENSIONAL*
Face Pressure Control Test 1	*B*	*1*	*1000*	***5-B-1***	*DIMENSIONAL*
Face Pressure Control Test 2	*A*	*4*	*1000*	***6-A-4***	*DIMENSIONAL*

For each run, use the following procedure (Refer to the AAI Hybrid PCS Operation Manual for more details and illustrations.)

a) Pick up the upper and lower inner barrel assemblies from the catwalk using a tugger and assemble them in a mouse hole according to AAI instructions.
b) Lift the fully assembled inner barrel assembly from the mouse hole using a tugger and lower it into the drill pipe.

c) Rig wireline installing the AAI running tool on the Weatherford female quick connect system (QLS).
d) Using the wireline, stab the AAI running tool into the top of the AAI inner barrel assembly.
e) Pick up the AAI inner barrel assembly a few inches using the wireline winch. Remove the lifting clamp from the inner barrel assembly.
f) Remove the latch lock clamp from the upper inner barrel assembly.
g) Run the inner barrel assembly to bottom on the wireline. NOTE: The inner barrel assembly will automatically latch into the BHA when the inner barrel assembly lands in the BHA. This should also automatically release the wireline tools.
h) Pull the wireline tools out of the drill pipe and rack back same.
i) Install top drive and pick up drill pipe assembly
j) Break circulation and circulate at 200 gpm while rotating at 100 rpm for 10 minutes
k) Stop circulating, set drill pipe in slips and rig wireline installing the AAI pulling tool on the Weatherford Female QLS.
l) Weatherford will retrieve inner barrel by setting down on the inner barrel assembly. AAI pulling tool should automatically latch into the inner barrel assembly when weight is set down. No jarring or manipulation is required.
m) Once the inner barrel assembly is at surface install a lifting clamp on the upper inner barrel assembly. Set the lifting clamp on the drill pipe shoulder and release and remove the wireline tools.
n) Pick up the inner barrel assembly using a tugger attached to the lifting clamp and move the inner barrel assembly to a mouse hole. Clean the inner barrel assembly with a wash hose as it is being picked up out of the drill pipe.
o) Disassemble and lay down the upper and lower inner barrel assemblies according to instructions by AAI personnel (See Hybrid PCS Operation Manual for more details).
p) Move the lower inner barrel assembly to the Service van using a crane or forklift for disassembly, inspection and maintenance by AAI personnel .
q) Note the barrel combination tested, the pump rate and rpm, and the line weight to latch and unlatch the barrel.
r) Following the dimensional and pressure control tests on the inner barrel, POOH with the Outer barrel, and break as directed so that it can be inspected for any signs of washout or abnormal wear.
s) Once inspection has been completed, pick up core barrel assembly as requested by an AAI representative. The face bit plug is to be installed allowing the core bit to be utilized as a drilling bit.

This procedure will be repeated a total of six times to test all four combinations of inner barrel, and to test proper operation of the core barrel pressure control system.

Notes:

- Runs one through four are designed to check the fit of tools in the core barrel. There is no need for any pressure in the accumulator section, so all runs will be non-pressured. The autoclave section however could have trapped hydrostatic pressure of 300-400 psi inside
- Runs five and six will be conducted using the same test procedure. Crews need to be aware that the upper assembly will contain a chamber charged with approximately 1,500- 2,000 psi of gas pressure. When the barrel is retrieved the lower autoclave section (the part that holds the core) could have liquid pressures approaching 1,000 psi on the inner chamber. Prior to runs five and six hold a toolbox session with all the crews, where they are to be advised by an AAI representative on the safe handling procedure for a pressurized core barrel. All subsequent runs with the core barrel will involve pressurized barrels.
- Safety warning: Keep hands and all other body parts away from the opening in the ball valve housing at all times while handling the lower inner barrel assembly. If the ball valve is in the open position it could slam closed unexpectedly powered by a powerful spring. This could result in serious injury.

Face Bit Drill and Core Operations

Hold a pre job safety meeting with all involved personnel outlining required work activities to be undertaken and note same in the official report.

Operations will involve running the core barrel to bottom drilling to the first core point, retrieving the inner plug, and then cutting three ten foot wireline cores. Following this the outer core barrel will be tripped and broken down for inspection by the AAI team members.

Note: all wireline trips in and out while the bit is in the open hole shall be carried out while circulating 50 to 100 gpm using a circulation head and wiper or snubbing unit.

Face Bit Drill and Core Tests

	UPPER BARREL USED	**LOWER BARREL USED**	**Pressure regulator set point (psi)**	**Test Name**	**TEST REPORT FORM**
Face Bit Plug Drill Record	*C*	*5*		***7-D-I***	*DRILL*
Core Run #1 Face Bit	*A*	*3*	*1000*	***8-C1-A3***	*CORING*
Core Run #2 Face Bit	*B*	*2*	*1000*	***9-2C-B2***	*CORING*
Core Run #3 Face Bit	*A*	*1*	*1000*	***10-C3-A1***	*CORING*

1. Run Core barrel BHA on drill pipe to approximately 1,000 ft. Rotate, wash and ream to bottom. Once bottom has been tagged, mark pipe and reconcile any difference in tally.

2. Begin drilling with light weights to break in bit and establish a good bottom pattern. Circulate to maintain annular velocity in the casing of 125-150 ft. per minute. Use 80-100 RPM for drilling.
3. First core point will be in the top of the main Tonkawa sand group located at approximately 1,150 FBRT, 47 ft. below the limestone marker. Once at core point mark pipe, and pick up off bottom. Circulate and condition mud as required to clean hole for coring.
4. With pipe in slips rotating at 5-10 rpm to avoiding any sticking, run wireline, jars, sinker bars and emergency pulling tool to retrieve the bit plug.
5. Pick up and assemble the PCTB inner barrel assembly in the mouse hole using a tugger as directed by AAI personnel. Move this assembly to the drill pipe using a tugger. Pick up with the wireline, jar, sinker bar and running tool and run in hole. The inner barrel assembly should automatically latch into the BHA and automatically release the wireline tools when it lands in the BHA.
6. POOH with wireline while circulating, and rack back same.
7. Pick up drill string and break circulation at low strokes.
8. Circulate, tag bottom, mark pipe and cut core number one from 1,150ft - 1,160ft. Chevron coring subject matter expert will be on floor at all times while coring. He will advise on proper weight RPM and pump rate to be used for coring. Mark each foot for reference.
9. Once core has been cut, break core as advised, pick up off bottom and circulate as needed to clear cuttings away from BHA vicinity (Bottoms up if time allows.).
10. Set pipe in slips, and rotate at 5-10 rpm while rigging up wireline
11. RIH with wireline, jar, sinker bar and pulling tool, land and latch onto inner barrel assembly, and retrieve same
12. Release the wireline tools, move inner barrel assembly to mouse hole using a tugger and disassemble and lay down upper and lower inner barrel assemblies.
13. Move lower inner barrel assembly to the service van where AAI personnel will disassemble, inspect and dress it.
14. Cut additional cores from 1,160-1,170, and 1,180-1,190. A total of three 10 ft. cores will be cut.
15. Once final core has been cut, circulate as required, pump slug and POOH. Rack back drill pipe and collars, and break down core barrel as directed for inspection.

Note: If there is any tendency for sticking, while running and retrieving wireline, the core barrel should be pulled back into the conductor shoe during wireline operations. Submit required reports to Chevron upon completion of this phase of operations

QA Tests on Insert Bit Core Barrel

1. Hold a pre-job safety meeting, outlining required work activities to be undertaken and note same in the official report.
2. Pick up the 8.25 in core barrel as directed. Use collar clamps at all times. If basket slips are used rope handles closed to prevent the barrels from slipping in the hole. Pick up the 10-5/8" insert bit assembly. Driller will measure and record the length and fishing OD of all equipment run through his rotary table.
3. Pick up stabilizers and drill collars as directed. Tally and caliper all pipe.
4. Once BHA has been picked up, record the BHA wt in mud, and note same on reports.
5. Run pipe from the derrick as requires to put bit just inside the conductor shoe with a tool joint at the rotary table. Circulate bottoms up while rotating at 80-100 rpm pumping at 600 gpm and working pipe to simulate open hole operations.
6. Rig up Weatherford wireline unit, and run a 4.125 dummy to the bit to confirm proper operation and depth calibration. Ensure that an air stripper or other line wiper is used on all pulling Operations
7. Hold a pre job safety meeting to brief crews on wireline operations to be undertaken.

The coring system has two upper sections denoted A and B. There are four lower sections denoted 1 through 4. All of which have been tested in the previous section. Here two tests will be run with the insert drilling extension utilizing the A and B upper sections and two of the lower sections The AAI service staff will prepare core barrels to be run into and retrieved from the wellbore.

Planned Tests for Insert Bit Assembly

	UPPER BARREL USED	**LOWER BARREL USED**	**Pressure regulator set point (psi)**	**Test Name**	**TEST REPORT FORM**
Insert Dimensional test 1	*A*	*4*	*0*	***11-A4***	*DIMENSIONAL*
Insert Dimensional test 2	*B*	*3*	*0*	***12-B3***	*DIMENSIONAL*

For each run, use the following procedure. Refer to the AAI Hybrid PCS Operation Manual for more details and illustrations.

a. Pick up the upper and lower inner barrel assemblies from the catwalk using a tugger and assemble them in a mouse hole according to AAI instructions.
b. Lift the fully assembled inner barrel assembly from the mouse hole using a tugger and lower it into the drill pipe.
c. Rig wireline installing the AAI running tool on the Weatherford female quick connect system (QLS).
d. Using the wireline, stab the AAI running tool into the top of the AAI inner barrel assembly.

e. Pick up the AAI inner barrel assembly a few inches using the wireline winch. Remove the lifting clamp from the inner barrel assembly.
f. Remove the latch lock clamp from the upper inner barrel assembly.
g. Run the inner barrel assembly to bottom on the wireline. NOTE: The inner barrel assembly will automatically latch into the BHA when the inner barrel assembly lands in the BHA. This should also automatically release the wireline tools.
h. Pull the wireline tools out of the drill pipe and rack back same.
i. Install top drive and pick up drill pipe assembly
j. Break circulation and circulate at 200 gpm while rotating at 100 rpm for 10 minutes
k. Stop circulating, set drill pipe in slips and rig wireline installing the AAI pulling tool on the Weatherford Female QLS.
l. Weatherford will retrieve inner barrel by setting down on the inner barrel assembly. AAI pulling tool should automatically latch into the inner barrel assembly when weight is set down. No jarring or manipulation is required.
m. Once the inner barrel assembly is at surface install a lifting clamp on the upper inner barrel assembly. Set the lifting clamp on the drill pipe shoulder and release and remove the wireline tools.
n. Pick up the inner barrel assembly using a tugger attached to the lifting clamp and move the inner barrel assembly to a mouse hole. Clean the inner barrel assembly with a wash hose as it is being picked up out of the drill pipe.
o. Disassemble and lay down the upper and lower inner barrel assemblies according to instructions by AAI personnel (See Hybrid PCS Operation Manual for more details).
p. Move the lower inner barrel assembly to the Service van using a crane or forklift for disassembly, inspection and maintenance by AAI personnel.
q. Note the barrel combination tested, the pump rate and rpm, and the line weight to latch and unlatch the barrel

This procedure will be repeated a total of two times to test each combination of inner barrel.

<u>Insert Drill and Core Operations</u>

Hold a pre job safety meeting with all involved personnel outlining required work activities to be undertaken and note same in the official report.

Operations will involve running the core barrel from the shoe to bottom and cutting a ten foot wireline core, then running the insert plug in the bit and drilling to 1,250’. A final core will be cut. Once the barrel has been tripped to surface it will be broken down for inspection by the AAI team members.

Insert Bit Drill and Core Tests

	UPPER BARREL USED	LOWER BARREL USED	Pressure regulator set point (psi)	Test Name	TEST REPORT FORM
Core Run #4 Insert Bit	*A*	*2*	*1000*	***13-C4-A2***	*CORING*
insert plug and drill Report				***14-D-2***	*DRILL*
Core Run #5 Insert Bit	*B*	*1*	*1000*	***15-C5-B1***	*CORING*

1. Run Core barrel to approximately 1,150 FBRT. Wash and ream to bottom. Once bottom has been tagged, mark pipe and reconcile any difference in tally.
2. With pipe in slips rotating at 5-10 rpm to avoiding any sticking, run wireline the jars and sinker bars, and retrieve the bit plug.
3. Pick up wireline core barrel as directed, and run in hole latching same. POOH with wireline and rack back same.
4. Pick up BHA and break circulation at low strokes.
5. Circulate to bottom mark pipe and cut core number four from 1,190ft – 1,200ft. Chevron coring subject matter expert will be on floor at all times while coring. He will advise on proper weight RPM and pump rate to be used for coring. Mark each foot for reference
6. Once core has been cut, break core as advised, pick up off bottom and circulate as needed to clear cuttings away from BHA vicinity.
7. Set pipe in slips, and rotate at 5- 10 rpm while rigging up wireline.
8. RIH with wireline with pulling tool, latch onto core barrel, and retrieve same.
9. Release pulling tool from inner barrel assembly and move inner barrel assembly to the mouse hole using the tugger.
10. Disassemble and lay down the upper and lower inner barrel assembly in the mouse hole.
11. Install the center bit plug on the center bit lower assembly. Assemble the center bit upper and lower assembly in the mouse hole using a tugger and move same to the drill pipe.
12. RIH with wireline with running tool and land in the BHA. Running tool should automatically release from the center bit assembly. POOH with wireline.
13. Begin drilling with light weights to break in bit and establish a good bottom pattern. *Take caution until any core plug has been drilled and the entire bit face is on bottom to avoid damage to the center insert*. Circulate at full strokes to maintain annular velocity in the casing of 125- 150 ft. per minute. Use 80-100 RPM for drilling. Drill to 1,250 FBRT to test bit function. Once drilling is complete, pick up off bottom and circulate to clear cuttings away from the BHA (Bottoms up if time permits.)
14. Set pipe in slips, and rotate at 5-10 rpm while rigging up wireline

15. RIH with wireline with emergency pulling tool and latch onto center bit assembly and, retrieve same. NOTE: Use circulating head and circulate during all wireline operations while BHA is in open hole.
16. Release emergency pulling tool when inner barrel assembly is landed on drill pipe.
17. Move center bit assembly to the mouse hole using a tugger.
18. Disassemble and lay down upper and lower center bit assembly using a tugger.
19. Assemble upper and lower inner barrel assembly in the mouse hole and move this assembly to the drill pipe using a tugger.
20. Pick up inner barrel assembly with the wireline and running tool as directed, and run in hole latching same. POOH with wireline and rack back same.
21. Pick up BHA and break circulation at low strokes.
22. Circulate to tag bottom, mark pipe and cut core number five from 1,250ft – 1,260ft. Chevron coring subject matter expert will be on floor at all times while coring. He will advise on proper weight RPM and pump rate to be used for coring. Mark each foot for reference.
23. Once core has been cut, break core as advised, pick up off bottom and circulate as needed to clear cuttings away from BHA vicinity (Bottoms up if time permits.)
24. Set pipe in slips, and rotate at 5- 10 rpm while rigging up wireline.
25. RIH with wireline and pulling tool and latch onto core barrel, and retrieve same.
26. Land inner barrel assembly on the drill pipe and release pulling tool from inner barrel assembly. Move inner barrel assembly to the mouse hole using the tugger.
27. Disassemble and lay down the upper and lower inner barrel assembly in the mouse hole using a tugger.
28. Break circulation and circulate bottoms up while decision is made to terminate program.

Note: If there is any tendency for sticking, while running and retrieving wireline, the core barrel should be pulled back into the conductor shoe during wireline operations.

Submit required reports to Chevron upon completion of this phase of operations.

Post Drilling Operations

Once decision has been made to terminate operations all pipe should be prepared for back loading.

1. Pump heavy slug and POOH. Wash pipe inside and outside on trip out.
2. Lay down all pipe applying fresh dope and protectors as it is laid down.
3. Lay down all drill collars and BHA components.
4. Rig out and release Weatherford.
5. Rig out and release Core Labs.
6. Load core transport container in the Georgia Tech Transport.

Once the last core has been cut and prepared for transport, rig out the work area in the heavy shipping container, lift floors and place drill collars and the outer core barrel in their cradles and strap down for shipping. Once visually inspected by AAI Representative floors may be closed and decking strapped down.

The AAI team will be responsible under direction and supervision of CTF to prepare the service van for Transport. All materials will be in proper storage and strapped down as needed for transport.

As noted in the Mob/Demob section the service van load will be much heavier than it was on receipt. Ensure that a crane with proper load capacity for the lifts being anticipated. Have trucks scaled before and after loading to have an accurate weight for the trailer upon delivery to its final destination.

Core Handling and Packaging

Planned Operational Summary

During the field test, it is planned to cut a total of 50 feet of core. Based on previous work with this design of core barrel it can be expected that recovery will be in excess of 70% (35 feet). Cores will be cut in nominal 10 foot lengths using the wireline retrievable pressure core barrel. After the core is cut, the wireline retrievable inner core barrel will be extracted and the lower inner barrel assembly transferred from the floor to the service van where it will be picked up utilizing the service van crane assembly.

Note: the core barrel assembly has internal pressures that can exceed 1,000 psi while in use. Only trained personnel are permitted near the barrel until it is rendered safe

Once in the service van, the pressures in the inner barrel will be read, the pressure will be bled off the system in stages at approximately 1Mega Pascal (145 psi) per minute average until the inner barrel containing the core is at atmospheric pressure. The core will then be extracted to a transfer tube and moved from the service van to the heavy lift van, where further processing will occur.

In the heavy lift van the core will be inspected, and cut into transport sized pieces of approximately 3-1/2 foot lengths. After photographing, the ends plugs will be installed if necessary and the ends capped. These will be places in transport containers supplied by Georgia Tech for the purpose

Safety

- Steel-toed footwear hard hats and eye protection is required to be worn at all times while working in or around the service or Heavy lift Vans.
- Use caution around high pressure fluids and especially around gasses that may be present during pressure testing or in the recovered core.
- Use a locked loop when lifting with a lift strap whenever possible.
- Use care in balancing parts from an open loop lift strap or when using the spinning buggy.
- Work efficiently but don't rush. Being in a hurry can cause an accident.
- Only necessary people are in the unit and that all people follow all AAI safety requirements and instructions
- Always hold a pre job safety meeting so that all in attendance are aware of potential hazards.

Depressurization and Core Extraction

Reading of pressures and extraction of the core will be performed in the Core Service Trailer. All work will be performed by representatives of Aumann and Associates, under the direction of the Catoosa Test Facility. Visitors may view work being done but only to the extent approved by either AAI and/or CTF.

If any job steps need to be altered or cannot be accomplished safely the “Stop-Work Authority” shall be exercised. “Stop-Work” can be exercised by every worker, observer, or visitor as the situation warrants. Work will not resume until alterations have been agreed upon or the unsafe condition has been remedied.

Autoclave Pressure Blow Down (Service Van)

1. Pressure bleeding shall be completed in a safe environment, including as needed the use of a suitable portion of the service test bay, cordoned off as needed to warn and protect nonessential personnel in the event of a pressure leak.
2. Non-authorized personnel shall be restricted from the test area by use of suitable barriers or other adequate means to ensure controlled access to the immediate test area.
3. Devices used to measure test pressure (pressure transducers, pressure read out boxes, dial gauges, or other) shall be calibrated and suitably correlated. Dial gauge range shall be not less than 1.0 times nor greater than four times the test pressure. Gauges shall be marked with gradations of a minimum of 1 PSIG or 1% of full range, whichever is greater. Digital gages are recommended.
4. Examination shall be made of the autoclave/pressure section to verify there are no visible conditions that would prevent bleeding down of the autoclave section.
5. Connect to the pressure transducer to the calibrated read out box to read the system pressure inside the autoclave. Monitor and record the pressure once per minute for a period of five minutes (5 min).
6. Connect the drain port to the test manifold with a suitable needle valve.
7. Make best efforts to reduce the pressure inside the test assembly in stages of 30 to 50 psi per stage in increments, not to exceed 150 psi per minute.

Caution: make sure pressure inside the autoclave assembly is less than 10 psi before attempting open it for core extraction.

Core Extraction (Service Van)

Caution: make sure the autoclave assembly is equalized with atmospheric pressure before attempting open it for core extraction

1. Once pressure has been bled from the system, remove the pressure control section. The inner tube plug with liner and core are ready to be transferred.

2. Open the ball valve using the ball opening tool. Insert a piece of core liner through the open ball and against the core catcher to hold the inner tube plug in the seal sub.

3. Place the core transfer tube on jack stands and line it up with the autoclave. . The core transfer tube, SUPPLIED BY CORE LABS is fabricated from a larger bore inner core sleeve and has carrying handles attached.

4. Push the core extraction assembly though the transfer tube with the core extraction tool facing the seal sub and inner tube plug.

5. Push the core extraction tool consisting of the pawl release sleeve and pulling collet over the end of the inner tube plug and into the end of the seal sub. This will simultaneously engage the collet on the pulling tool with the buttress thread on the end of the inner tube plug and also force the pawls up into the cavity on the seal sub to releases the inner tube plug from the seal sub.

6. Pull on the core extraction assembly to extract the core tube from the inner barrel. And directly into the transfer tube for further observation analysis and preparation for transportation

<u>Preparation for Shipping and Handling Procedures</u>

Handling and preparation of the core for transportation would normally be done using the work table in the heavy lift van. For this test the van will not be available. A work area has been prepared in the CTF workshop, where the core may be inspected and cut in to shipping sized pieces. All work will be performed by representatives of Core Labs, under the direction of Catoosa Test Facility. Visitors may view work being done but only to the extent approved by either Core Labs or CTF.

If any job steps need to be altered or cannot be accomplished safely the “Stop-Work Authority” shall be exercised. “Stop-Work” can be exercised by every worker, observer, or visitor as the situation warrants. Work will not resume until alterations have been agreed upon or the unsafe condition has been remedied

Procedure

1. Core will be moved from the service unit to the core preparation area utilizing the core transfer tube.

2. Core Lab and CTF personnel will extract the core from the transfer tube onto the work table. Take care not to bend or torque the core during the transfer operation.

3. Make observations and inspections of the core, taking note of voids or breaks in the core. Photograph as necessary.

4. Mark core for cutting. Nominally core will be cut twice to obtain three equal length pieces for shipping. Exact cut points will be requested by Georgia Tech representative

5. Prior to cutting ensure that core is properly marked for orientation and position of each piece with clear indications of top and bottom. These should be photographed prior to cutting.

6. Make necessary cuts.

7. For each cut, photograph the ends, using an index card showing the cut and position to differentiate it for later review.

8. Place spacers in the ends of core tube to prevent lateral movement of core in the tube if necessary.

9. Place end caps on the cut pieces and secure them as necessary.

10. Label each core piece with the core number and cut number.

11. Place final cut cores into the core transfer carrier supplied by Georgia Tech for transport once the job has been completed.

12. Final report will be required outlining work performed, and an indexed annotated version of the photographs and measurements taken.

Directional Drilling Requirements

Proposed wellbore for this work will be slot 4 on the Lucy well pad.

Lucy slot 4
13-3/8" 48 ppf nominal ID 12.714 in
Shoe Depth: 748 ft.
Latitude: 36 deg 13'07.89962;
Longitude: 96 deg 34'38.44416"
Elevation 990.8 ft

To date there have been two other wells drilled from that particular slot

Lucy 4-1:
Drilled from 748 to 1050 feet with 12-1/4" bit and 14.5 inch UR
Well subsequently plugged 8/8/12
Lucy 4-2:
Drilled 12- 1/4" from 748 to 3092 feet
Well Not plugged as yet

The well does not require directional control, other than not intersecting with an existing well. Well will be nudged while drilling below the conductor to provide a clean sand face prior to entering the Tonkawa formation.

Required Surveys:

- Pre Coring: None required for drilling
- Post Coring: CTF will provide data from a multi-shot survey of the well.
  Cost of survey is paid for the JIP per the contract.

Nudging the Well:

There is no need for detailed control of either angle or direction in the well as long as it is below 5 degrees from vertical. The intent is to gain enough departure from existing wellbores to avoid any interference, and to be sure that all coring operations are conducted in formation and not cement.

The following is a suggestion to CTF on a nudging procedure. Once the well has been effectively sidetracked away from the existing wells, the nudging assembly should be tripped and replaced with a straight hole drilling assembly to assure no doglegs nor severe deviation tendencies.

Nudging BHA:

A typical BHA will have an undergauge near bit stabilizer, and a limber collar and drilling assembly.

- 12-1/4" Bit
- Directional motor with bent sub or bent housing
- Scribe orienting sub
- drill collars as required for weight
- drill pipe to surface

Orient scribe line to the toolface and run in hole being careful not to rotate the pipe

Nudging Procedure:

1. Once bit double so that a connection will not have to be made for 60 ft. Orient toolface with lead to account for reactive torque so that sidetrack direction is away from existing wells
2. Begin to sidetrack by maintaining constant torque at the bit by adjusting WOB.
3. Monitor cuttings and continue to nudge until 100% cuttings are seen across the shakers.
4. POOH with minimal circulation to avoid washing the hole.

Post Nudge Procedure:

1. Once well has been sidetracked, POOH without circulating on bottom
2. Lay down nudging assembly and pick up a moderate build assembly:
    - Bit,
    - 12" Near Bit Stab
    - 8" DC,
    - Full gauge String Stabilizer
    - 8" DC
    - Additional DC as needed for bit weight
3. RIH with drilling assembly and wash to bottom.
4. Begin drilling on a full double so that a connection does not have to be made in the immediate vicinity of the sidetrack.
5. For the first single drill with reduced RPM and pump to take advantage of any residual build tendency. With this assembly heavy weights will tend to make it build, but for moderate weights it will have a neutral trend.
6. Continue drilling with moderate weight, full pump and higher RPM to encourage the hole to lock into a hold tendency.

Drilling Fluids Program Requirements

For all core operations it is important that a good quality clean mud is used at all times. We plan to use an un-weighted low solids high yield fluid, with a water loss that while not formally controlled, is kept within a range where the standard API fluid loss test will yield a measureable result. Control will come from the gel in the system.

- Mud Wt. 8.4-8.8 (no barite)
- PV: as low as practical
- YP: 10-15
- Gels 0/5
- Water loss: no control

Solids Control & Mud Properties

Primary solids control method will be to use the finest mesh screens the shaker can handle. De-silters, mud cleaners and centrifuges should not be utilized.

- Plastic Viscosity: Monitor the PV of the mud and maintain it as close as reasonable to the value seen when the mud was first mixed. As the PV rises dump and dilute as necessary to keep the fines out of the system.
- Filtration Loss: Adequate pre-hydrated gel should be maintained in the system to provide nominal viscosity and sufficient low gravity solids to maintain a good filter cake.
- Filtration Loss**:** A low end polymer should be utilize to maintain carrying capacity of the mud for adequate hole cleaning. The low shear rate value of the mud (2*6 rpm-3 rpm) should be maintained between 10 and 12.

Mud Checks

For all operations in the program a full API Mud check should be performed twice daily. All additions (product and quantity) to the mud system are to be noted on the report.

Mud Inventory& Record

Chevron will only pay for material that is actually consumed. A daily record is to be kept and approved by the Chevron on site representative on a daily basis.

Operational Results

The final operational and test results are provided in Appendix-1. Below is a general summary.

Summary

Equipment was mobilized and rigged up at the Catoosa Test Facility, as outlined in the mobilization section of the program. Operations started by entering the well bore and nudging the well utilizing a motor assembly. This was done per plan and the hole was drilled to the top of the Tonkawa sand group at 1,102'. At that point, the plan called for various surface and downhole tests to be undertaken. By mid mooring of the third day of operations serious problems were seen with the coring tools, which caused deviation from the pre job time plan. The planed vs actual operation is summarized in the following tables.

After the fourth day of operations it was apparent that the program was going take significantly longer than planned and may or may not produce anticipated results. The decision was made to move from 16 hour operations to a 24 hour operation for the final three days.

Daily Activities

November 4, 2013 – Day 1

Drilled the hole to the core point at 1,106 ft (MD). The hole was advanced with a downhole motor to directionally drill the hole, which drilled quickly and got ahead of schedule by almost a full day. The AAI crew inspected and checked out the ProLog service unit, unpacked and stored hand tools and service tools in the service van and inspected the BHA shipment. Everything was found to be in good order.

November 5, 2013 – Day 2

The service van was positioned near the end of the catwalk for easy transfer of tools from the service van to the catwalk using the extendable crane on the service van. Water, power and compressed air were connected to the service van. The AAI crew mounted and plumbed the test pump and nitrogen booster pump in the service van. The AAI crew continued to assemble and dress Hybrid PCS and related wireline tools and provided rig floor training and guidance in assembly and running Hybrid PCS tools and related equipment as needed throughout the field test program.

The AAI crew prepared the BHA subassemblies and assembled the Face Bit Upper and Lower Assemblies for the rig floor fit up test.

Assembly of the BHA went well and the Hybrid PCS Inner Barrel Asssembly was moved to the rig floor for a surface fit test in the BHA by 9:00pm. However, a problem with a cross threaded and galled thread at the bit sub, which had to be repaired by careful cleaning and filing, prevented the completion of the surface fit test before the 11:00pm shut-down. Continuous hard rain from about 7:00pm on also slowed the work.

November 6, 2013 – Day 3

Weatherford wireline and Core Lab crews arrived on site and set up. Core lab set up in the available Catoosa shop because it had been decided not to ship the heavy van to CTF.

Proceeded to conduct the surface FIT test of the Face Bit Assembly. The length adjuster in the Face Bit Inner Barrel Assembly was adjusted for an optimum 1/8" core shoe to bit clearance. This took several attempts which is not unusual. The tool landed and released properly after the length adjustments were made. However, when it was retrieved, it was discovered that the ball was stuck open. Further investigation revealed that a spring in the Hybrid PCS ball-valve jumped off of its mating surface, which resulted in the liner not retracting all the way into the autoclave. The stuck liner jammed the ball valve open. It was determined that this could be prevented in subsequent runs by adding a spring function check to the assembly procedure.

Next, the Face Bit Center Bit Assembly surface FIT test was carried out. The center bit assembly landed properly and released the running tool on the first attempt. It released properly when pulled by the wireline pulling tool.

Following the surface FIT tests, the marine DP was triped to the bottom of the hole. This took more time than expected. It was determined that the scheduled four in-pipe function tests could not begin until about 10:00PM. It was decided to release the AAI crew early (after three days of 16 hr shift plus a 1-hour commute each day).

Note: While assembling the second Face Bit Upper Inner Barrel Assembly the AAI crew found that the ID of the outer bearing had not been machined correctly and could not be assembled. It was taken to a machine ship in Oklahoma City by one of the AAI crew for rework.

November 7, 2014 – Day 4

The required boring of the outer bearing shaft was completed and returned to the CTF site. During final assembly of the Face Bit Lower Assemblies, it was discovered that two of the three outer shoes for the Face Bit Autoclave had oversized threads that could not be assembled to the Housing Extensions. These two parts had been made manufactured the previous year as part of the attempted Japanese Face Bit field test. These parts had been overlooked during the FAT and had never been assembled on the JIP Hybrid PCS. This left only one functioning outer shoe for the Face Bit Assembly. The two outer shoes with the oversized threads were sent off to have the threads chased and were returned after a few hours.

9:00AM – Proceeded to conduct Dimensional Test 1 of the Face Bit Assembly. The Inner Barrel Assembly landed and locked and correctly released the wireline running tool. Pulled the wireline to the surface, reset top drive and setup for the flow test. Circulated and simulated taking a core for 30 min. Standpipe pressure during the earlier part of the test spiked for about one minute from about 200 to 600 psi for no apparent reason. The pumps were shut down.

11:00AM – Ran the wireline pulling tool which latched, released and wire-lined to surface with no problem. Upon inspection, it was discovered that the ball valve was not totally closed (about 90% turned). Ball valve appeared to be blocked by the rabbit in the core liner, some mud caked on the core rabbit. Note that no screens were used in the mud system. Closer inspection revealed that both the plastic liner and inner aluminum barrel had collapsed (see photo). It was decided to POOH to inspect the BHA.

Collapsed inner tube from face bit Dimensional Test #1.

2:00-7:00PM – Conducted two near-surface pressure tests to identify possible flow restrictions: (1) the first with no liner or steel inner tube – no pressure anomalies were observed. (2) Second test included both a liner and steel inner tube – again no pressure anomalies were observed. No clear reason was discovered for the cause of the differential pressure in the tool that collapsed the plastic liner and inner steel barrel. AAI reviewed the design and decided the Face Bit Upper Assembly did have a restricted flow path in the area of the outer bearing and recommended drilling holes in the extension tubes in the upper assembly to reduce pressure. However, this still did not explain the excessively high pressure spike observed in the first test. A collective decision was made to switch around the testing program and move ahead with the planned test of the Cutting Shoe version and move the Face Bit tool test to the following week. This would provide time to examine the AAI proposal over the weekend and make the modifications if warranteed and continue to study the problem.

10:00PM – Changed out the drill from the Face Bit to the Cutting Shoe version and conducted the surface fit test of the Cutting Shoe Inner Barrel Assembly and Cutting Shoe Center Bit Assembly. The tools set and released properly. However, the cutting shoe center bit unexpectedly extended out ahead of the main bit by about 3/4” (See photo.). This was not considered to be a serious problem.

Face bit center bit extended ahead of the main bit by about 3/4”.

Tripped the BHA into the hole to a depth of several stands and ran the Cutting Shoe version of the inner barrel into the BHA for a flow test.

NOTE: AAI shipped a replacement steel inner tube from stock in Salt Lake City by airfreight. It was expected to arrive the following day.

November 8, 2014 – Day 5

9:20AM – Completed shallow pump test and function test with with cutting shoe inner barrel assembly. All operated normally with no problems incuding proper ball valve closure and no apparent damage of any kind to the tool.

NOTE: The airfreighted replacement inner tube arrived.

11:25AM – Completed dimensional test on Cutting Shoe Inner Barrel Assembly. Back pressure was less than 35 psi. – Normal Test.

3:20PM - Dimensional Test 2: Test of the Cutting Shoe Inner Barrel Assembly. Pumped for five minutes, standpipe pressure averaged 35 psi, which is considerably less than the 600psi observed during the November 7th dimensional test of the Face Bit system. Core barrel was pulled and returned to surface, ball valve was closed, and the pressure in the autoclave was 176 psi which is about 100 psi below hydrostatic. Also note that the pressure regulator was set at 1,000 psi and the the autoclave should have been returned at a pressure near 1,000 psi if the pressure section functioned correctly.

6:45PM - Dimensional Test 3: Test of the Cutting Shoe Inner Barrel Assembly in the casing. Pumped for five minutes, standpipe pressure averaged 35 psi. Core barrel was returned to surface, valve was closed, and the pressure in the autoclave was at 196 psi which was again below hydrostatic. The pressure regulator had again been set at 1,000 psi. It was later determined that the a valve in the pressure regulator section was set incorrectly during assembly and the N2 supply was not connected to the autoclave. (Note: Without assistance from the pressure section, the autoclave pressure will drop below hydrostatic because of an increase in the autoclave volume during ball valve closure.)

The two above test were treated as actual core runs with the autoclave being rapidly returned to the service unit and processed by the AAI crew as if they contained cores, the procedures were witnessed by all of the JIP members and Georgia Tech staff on site.

At that point it was generally believed that the inner barrel failure associated with Dimensional Test 1 (on November 7th) was like caused by some type of debris that had blocked the flow path through the tool or a flow serge, this is based on the observation that the backflow pressure that reached more than 600 psi during the Dimensional Test 1, was about 13x times more than seen in any other test or configuration. There is also the possiblity that the wrong pump was used and generated a higher flow rate than reported. Note that only pump strokes are counted to obtain a calculated flow and there is no actual flow meter in the CTF system.

10:15PM – Tripped to bottom of hole, deployed center bit, to advanced the hole by about 50 ft. ROP was extremely slow and the drilling was stopped because of the 23:00h end of operations. Returned center bit the rig and tripped the BHA back into the casing above 800 ft. The center bit assembly functioned well regarding automatic release while running and normal release when being pulled. The reason for the slow ROP is unknown.

November 11, 2014 – Day 6 (Switch to 24hr operation)

7:00AM - POOH the Face Bit coring BHA and RIH drill bit on marine drill pipe but with conventional drill bit because of the slow ROP using the Face Bit and Center Bit.

Note: The slow drilling with the core tool and center bit on the evening November 9, may have been caused by bit and formation problems. Upon recovery of the Cutting Shoe Bit significant clay balling on the bit was observed with most of the bit ports plugged. May need more care on balancing bit weight with and/or higher circulation rate to work around this problem.

1:30PM - Tagged bottom at 1,088’ and began to drill to core point.

4:30PM - Reached core point at 1,148’ with a good ROP break, definitely indicating reaching the core point sand. POOH of hole to change from the conventional drill bit back to the coring BHA with the Face Bit.

8:45PM - RIH Face Bit coring BHA

11:15PM - Reached bottom hole with Face Bit coring BHA. Did not run in with center bit installed and had to work bottom of hole most likely because of fill. Rotated and pumped to bottom with wiper trips.

November 12, 2014 – Day 7

12:01AM - Filled the accumulator nitrogen reservoir with 3,000 psi and set the regulator to 1,500 psi. just before running in the hole. Core lab and Georgia Tech staff on site. Picked up and RIH the B-2 Face Bit Inner Barrel Assembly.

12:45AM - B-2 Face Bit inner barrel latched into the BHA and released the running tool (normal operation). Did not pump down the barrel. CTF personnel attempted to calibrate the pump stroke counter.

1:25AM - Begin coring (bit at 1,148.45'), 180-240 gpm, torque 3,000-3,500 ftlb, weight on bit 16,000 lbs (half of 33,000lb string weight). Slow start, possibly not in formation, after first 1.5 ft ROP upto 20-25 ft/her. Uniform ROP with almost constant torque (3,000-3,500 ftlb). Good looking core run after slow start. Noted a pressure spike when the pumps first turned on at the beginning of the core run. (Note: This is likely due to the pump engine/transmission system that tends to overspeed when first starting up.) Completed core at 2:22AM at 1,158.28'. Inner core barrel pulled to the rig floor by 4:30am. Upon inspection at the rig floor it was discovered that the matrix and cutters had been stripped from the cutting shoe. The ball valve had closed but pressure had been lost. We recovered a short 8 inch piece for core, which was properly retracted into the autoclave. Small core section included the upper shale to sandstone contact at the top of the formation. Note that the sand was highly friable and should be relatively easily drilled and could washout during coring. May need to back off on the pump rate on future cores. There was also a small amount of core (1-inch long piece) below the ball valve, not a likely operational problem. Two primary failures included the stripping of the cutting shoe face and the loss of autoclave pressure.

Note: It has been concluded that the cutting shoes may not be properly constructed; the matrix may be easily damaged when screwed onto the inner barrel or in handling moving them up and down the v-door to the rig floor. It has been determined for now not to attempt any more coring with this Cutting Shoe version which are the only ones on site.

7:19AM - POOH Cutting Shoe bit and BHA, reached rig floor at 9:12AM

Note: A weird chatter pattern was visible on the ID of the Cutting Shoe Bit that was not there previous to the failed core run. It has been speculated that this may be due to the matrix and PDC cutters grinding on the bit ID as it was disintegrating after the cutting shoe head separated from the cutting shoe shank. (See photos.)

Cutting Shoe with missing crown

Chatter pattern in ID of Cutting Shoe Main Bit.

10:00AM - Pickup Face Bit and BHA and RIH, reached bottom of hole at 11:34AM

1:00-2:00PM - Assembled what was thought to be the Face Bit Upper and Lower Assemblies on the rig floor and RIH. The Inner Barrel Assembly would not latch into the BHA. POOH and laid down same. The center bit upper assembly had been incorrectly used and assembled to the Face Bit Lower Assembly. The resulting assembly was too long and would not latch in the BHA. Both types of Upper and Lower assemblies had been placed on the catwalk and the rig crew inadvertently picked up the wrong one.

2:00PM - Assembled the correct combination of the Upper and Lower Face Bit Inner Barrel Assembly and RIH.

4:30PM - Face Bit inner core barrel (Combination A3, Accumulator reservoir set at 3,000 psi and regulator set at 1,500 psi) landed, latched in BHA and released running tool. POOH running tool and wireline. Begin coring (bit at 1,158.00'), 240-250 gpm throughout core run (tried to keep pump rate low to avoid washing of the core), torque highly variable throughout the core run ranging from 1,100 to 1,500 ftlb on the low end to as high as 2,200-3,700 ftlb, weight on bit 8,000 to 16,000 lbs (string weight 40,000 lbs). Inconsistent core run, variable penetration rates, slow start, increased bit RPM 30 to 70 helped, later in the core run required a significant increase in weight on bit to almost half of the tool string to push ahead. For the last one foot of hole backed off and went back on bottom heavy to finish the core run. Theories ranged for problems with debris form the cutting shoe on Core-1 to sand running down the hole. Most likely just highly variable formation with soft and sticky to hard sections. Reached end of core run at

1164.00’ at 5:41PM. Ran pulling tool and POOH Face Bit Inner Barrel Assembly, reached the rig floor at 7:20PM.

Upon first inspection on the rig floor it was observed that the ball-valve did not close and core was protruding from the end of the core shoe. (Note: Only 6 inches of core were recovered, some chucks of hard sand and shards of shale that had packed off in the shoe and the rabbit ports.) Observations from the service van during disassembly revealed that the PVC core liner and steel inner tube had collapsed again much like during Dimensional Test 1 on November 7th. A re-examination of the standpipe pressures (back pressure in the tool from mud pumping during drilling) reached pressures from 240 to 440 psi. The measured pressures during the Dimensional Test 1 ranged from 200 to 600 psi. Between the Dimensional Test 1 and Core Test 2, the AAI crew drilled additional pressure relief holes in the extension barrels to provide more flow area and relieve pressure drop above the autoclave, but it appears the flow restriction in the bit or some other obstruction still creates too much pressure on the outside of the inner tube and core liner.

9:00PM - Decided to conduct a dimensional (pump) test on a second Face Bit inner core barrel with low flow rates. The maximum standpipe pressure observed was 200 psi. Ran pulling tool and POOH. Ball valve was closed. Pressure in the recoverded autoclave was 250 psi (below hydrostatic pressure of about 500 psi) Pressure regulator had been set to 1,000 psi and should have recovered pressure near 1,000 psi.

10:30PM - Face Bit inner core barrel center bit drill test. Assembled the Face Bit Center Bit Assembly and RIH. Drilled with this assembly to TD. ROP was very low to begin with but increased with pump rate linearly. ROP was reasonable by the end with high flow rates. The center bit was retrieved successfully by wireline and the BHA/DP POOH.

Overall Test Results

The overall test results are summarized below. Following the Catoosa Test a Technology Management Team (TMT) was formed to investigate the results in detail and to develop an action plan for future operational improvements and modifications to the equipment. The TMT final report is included as Section-6 in this Phase IIIB Topical Report.

Successes

1. Inner and outer latch systems worked extremely well with no failures or wear observed.
2. All the tools assembled correctly into the BHA. This was verified during the space out tests at the surface.
3. The low end drive system was verified to function correctly during the Face Bit space out tests at the surface and also during operations. There was no wear on the drive dogs or drive sub.
4. The wireline tools functioned as designed with no failures or wear of any kind.
5. The core transfer tool was effective during the two attempts when we had the opportunity to use it. There was no jamming as experienced in the Japanese operations.
6. Pre-run and post-run pressure tests verified that the autoclave sealing systems were effective. Note: We applied pressure using the pressure test pump to several of the tools that returned with little or no pressure. There was no leakage anywhere and the pressure remained stable.
7. The upper autoclave seals, ball valve and sleeve valve all appeared to function correctly (mechanically) on most dimensional test and coring runs except on a surface test where the inner tube and liner imploded or in one run when the ball return spring jumped coils and jammed.
8. Core liners held up well and also the other sensitive parts of the inner barrel assembly even with apparent substantial core jamming such as when the liner imploded.

Failures and Problems

1. Bit Design Issues

    - It was observed in the space out test that the cutting shoe center bit extended farther ahead of the main bit than expected (about 1 inch instead of 15/32 inch as measured on the CAD drawing).

- The cutting shoe crown apparently came off and disintegrated during the first and only coring test of the cutting shoe inner barrel assembly. (Note that chattering marks were found inside the 3.800 ID of the cutting shoe bit.) This the likely cause of the slow drilling observed during the first few feet of coring with this bit combination.

- The cutting shoe bit / center bit combination also resulted in very slow drilling.

- High standpipe pressure was observed while circulating with the Face Bit Inner Barrel Assembly. The high pressure is believed to be the primary cause of the collapse of the inner tubes and core liners.

2. Pressure Retention

- Bottom hole static 0.45 psi @ 11600 ft or about 500 psi pressure was not retained during the dimensional tests or coring runs even thought the ball valve was closed on most runs. Still did not recover hydrostatic pressure even when ball valve was closed.

- The pressure boost from the pressure control section also did not occur and this was verified by the fish pill recorder. (Note that this would result if the ball valve closure was delayed and did not close immediately. It does not mean the pressure section did not function.)

- There was evidence that the separator piston moved down prematurely on some of the tools while waiting to be run. This is possibly due to nitrogen seepage under or through one of the seals.

- The return spring jumped coils and jammed on during at least one dimensional test preventing the ball from fully closing.

- Add wireline weight issue pushing in on the inner tube plug releasing pressure with the new inner tube plug check valve design.

3. Inner Tube and Core Liner

- The inner tube and core liner imploded during two face bit runs. Much lower TFA in cutting shoe assembly. Could increase TFA of face bit. Don’t clean by jetting. Improve inner tube strength. Note: A premature comment by one of the crew that the pawls had locked under the seal sub was incorrect and later correctly identified the failure of the inner tube plug to move all the way into the seal sub was the result of the imploded inner tube.

4. Human Error

- One fish pill recorder was set up incorrectly and failed to record the pressure history properly when AAI personnel took over this responsibility without adequate training and practice.

- Two types of parts were discovered to have been manufactured incorrectly. The defective parts included two outer shoes that were manufactured for the Japan bit test and the one outer bearing shaft. These were parts for the face bit inner barrel assemblies that were overlooked during the initial FAT assembly process. The two outer shoes had to have the threads chased and one outer bearing shaft had a small upset left in the ID that had to be bored out.

- A face bit inner barrel assembly failed to latch into the BHA. This was discovered to be due to an assembly error on the rig floor. The cutting shoe upper assembly was installed on the face bit lower assembly by mistake. This cause about a 1-1/2 hour loss in rig time to diagnose the problem, install the correct upper assembly and re-run on the wireline.

5. Service Van

- The service van was supposed to have included a heat pump for heating and cooling the unit. Instead it only contained an airconditioner and not a heat pump. This was temporarily solved by purchasing small electric floor heaters. Before the end of the field test, representatives from Prolog traveled to CTF and installed a ceiling mounted heating system to overcome the deficiency.

- There is a problem with the crane power design. Prolog incorporated a very heavy cable to provide power from the floor mounted battery to the crane trolley. This heavy power cord hung down and often got caught on the vise or tools or racks on the wall. This should be redesigned to eliminate this possible safety hazard. (See photos)

Possibly unsafe overhead crane power supply hookup.

- The Service Van was damaged during the CTF tests. It appears to have been stabbed with a forklift truck on the rear of the unit. There is a puncture in the skin and several dents with paint missing. The damage was repaired.

Damage from apparent forklift stab during the CTF field test.

Recommendations

1. We developed a method to verify that the return spring was assembled correctly and that the coils had not jumped over one another during assembly. This problem may be eliminated completely in the future by purchasing springs wound counter-clockwise instead of clockwise direction. Purchase springs wound in a counter-clockwise direction and test them.

2. Review the main bit designs, cutting shoe design and center bit designs with the manufacturers to determine if there are incompatibilities that might cause slow penetration rates.

3. Review the apparent cutting shoe failure with the supplier. Test the remaining three cutting shoes to try to determine if the matrix to steel bond is good.

4. Run tests on the pressure control section to determine if seal seepage and premature piston movement is chronic. If it is, specify better surface finishes or different seal compounds and test to verify the elimination of the problem.

5. Run full function pressure tests on the inner barrel assemblies using the field test pressures to try to reproduce the field test results (little or no recovered pressure and no pressure boost from the pressure control section).

6. The inner tube was redesigned as part of the contract requirements to provide certain improvements including the elimination of the jamming problem experienced by Geotek during liner extraction during the Japanese operations. The design selected utilizes a thin stainless steel tube that provided the necessary ID to provide clearance for the liner and core catchers. This same tube design was used without any problems in the recent China operations that incorporated a cutting shoe. The design apparently needs to be redesigned for use with the face bit option with a thicker wall and/or higher strength material to prevent the implosion under higher coring/drilling pressures. Any new design should be modeled for collapse using conventional mathematical calculations and/or FEA and should also be tested in the lab for resistance to implosion. A hydraulic model of the inner barrel assembly should also be made to predict and possibly improve flow and reduce pressure drop. Bit design might also be modified to require lower flow and resulting pressure drop and still effectively clean the bit and improve penetration rate.

7. The individual responsible for the fish pill recorders must be thoroughly trained and certified for the fish pill operation. This will not be a problem if Geotek is on site as they are normally responsible for and thoroughly trained in their setup and operation.

8. The defective parts were corrected by AAI at two Oklahoma machine shops. These parts need to be re-inspected by the original manufacturers when they are returned to AAI for post test dressing.

APPENDIX 1: OPERATIONAL PLAN AND RESULTS

DAY	OPERATION PLAN	TIME (hr)	Start	Stop	OPERATION ACTUAL	TIME (hr)	Start	Stop
DAY 1 (Mon Nov 4)	Morning Rig up Safety meeting	0.5	7:00 AM	7:30 AM	Morning Rig up Safety meeting	0.5	7:00 AM	7:30 AM
	Pick up bit, motor and orienting BHA	1.5	7:30 AM	9:00 AM	Unload trucks set up job	2	7:30 AM	9:30 AM
	Rig up circulating system	1	9:00 AM	10:00 AM	pick up Motor set scribe line test tool	0.5	9:30 AM	10:00 AM
	RIH drill cement to Conductor shoe @ 748 ft	2	10:00 AM	12:00 PM	Pick up DP RIH to Shoe @ 748 ft	3	10:00 AM	1:00 PM
	Displace hole to mud	1	12:00 PM	1:00 PM	Slide and drill to 922	1.5	1:00 PM	2:30 PM
	POOH set Scribe line RIH and orient motor	2	1:00 PM	3:00 PM	Slide 922 50% cmt	1	2:30 PM	3:30 PM
	Sidetrack well to get 100% formation returns	8	3:00 PM	11:00 PM	Slide to 962 100 % formation from 955	2	3:30 PM	5:30 PM
	Circ btms up and POOH	1.5	11:00 PM	12:30 AM	Circ to confirm cuttings	1	5:30 PM	6:30 PM
	Rig Maint and Shutdown	0.5	12:30 AM	1:00 AM	Rotate to 1106 to core point	2.5	6:30 PM	9:00 PM
			1:00 AM	1:00 AM	circ and cond mud to core	1.5	9:00 PM	10:30 PM
			1:00 AM	1:00 AM	POOH to shoe @700 ft	0.5	10:30 PM	11:00 PM
	Shut down rig for the night	6	1:00 AM	7:00 AM	Shut down rig for the night	8	11:00 PM	7:00 AM
DAY 2 (Tues 5 Nov)	Morning Rigup/ safety mtg	0.5	7:00 AM	7:30 AM	Morning Rigup/ safety mtg	0.5	7:00 AM	7:30 AM
	Make up Drilling assy and RIH	2	7:30 AM	9:30 AM	SpotService Van	0.5	7:30 AM	8:00 AM
	Make up Drilling assy and RIH	2	9:30 AM	11:30 AM	Lay down DP	4	8:00 AM	12:00 PM
	Drill 12.25 hole	7	11:30 AM	6:30 PM	Rig for Marine pipe	1	12:00 PM	1:00 PM
	POOH Lay down 4-1/2 dp Collars and BHA	2	6:30 PM	8:30 PM	Pick up 12 stands 5-1/2 dp	5	1:00 PM	6:00 PM
	Rig for Marine pipe	1	8:30 PM	9:30 PM	Pick up core bbl with Face bit	5	6:00 PM	11:00 PM
	Pick up 12 stands 5-1/2 dp	3	9:30 PM	12:30 AM				
	Rig Maint and Shutdown	6.5	12:30 AM	7:00 AM	Shut down rig for the night	8	11:00 PM	7:00 AM

DAY	OPERATION PLAN	TIME			OPERATION ACTUAL	TIME		
		(hr)	Start	Stop		(hr)	Start	Stop
DAY 3 (Wed 6 nov)	Morning Rigup/ safety mtg	0.5	7:00 AM	7:30 AM	Morning Rigup/ safety mtg	0.5	7:00 AM	7:30 AM
	Pick up core bbl with Face bit	3	7:30 AM	10:30 AM	Surface fit tests	7	7:30 AM	2:30 PM
	RIH W/R to Btm Tag Btm check tally	2	10:30 AM	12:30 PM	RIH W/R to Btm Tag Btm @1102 check tally	3	2:30 PM	5:30 PM
	Circ & Cond hole rotate & Work Core bbl	1	12:30 PM	1:30 PM	Circ & Cond hole rotate & Work Core bbl	0.5	5:30 PM	6:00 PM
	POOH to conductor shoe rig run fit tests	1	1:30 PM	2:30 PM	POOH to conductor shoe @700 ft rig run fit tests	1	6:00 PM	7:00 PM
	Rig up wireline	2	2:30 PM	4:30 PM	Rig up wireline	2	7:00 PM	9:00 PM
	Run Primary inner bbl	0.5	4:30 PM	5:00 PM	Run Wireline Dummy	1	9:00 PM	10:00 PM
	Circ at full coring pressure 30 min	0.5	5:00 PM	5:30 PM				
	Rig up and pull inner bbl	0.5	5:30 PM	6:00 PM				
	Repeat for Configuration 2	1.5	6:00 PM	7:30 PM				
	Repeat for Configuration 3	1.5	7:30 PM	9:00 PM				
	Repeat for Configuration 4	1.5	9:00 PM	10:30 PM				
	Rig Maint and Shutdown	8.5	10:30 PM	7:00 AM	Shut down rig for the night	9	10:00 PM	7:00 AM
DAY 4 (Thurs 7 Nov)	Morning Rigup/ safety mtg	0.5	7:00 AM	7:30 AM	Morning Rigup/ safety mtg	1.5	7:00 AM	8:30 AM
	Test 2 autoclaves with pressure in Acumulator section measure pressures @ surf on each	3	7:30 AM	10:30 AM	Run Inner Barrel Assemby A-1	1.5	8:30 AM	10:00 AM
	Rigup and Run center plug	1	10:30 AM	11:30 AM	Circ at full coring pressure 20 min	0.5	10:00 AM	10:30 AM
	Ream and wash to bottom	2	11:30 AM	1:30 PM	Rig up and pull Inner Barrel A-1	1	10:30 AM	11:30 AM
	Drill 1100 to first core point	2	1:30 PM	3:30 PM	Troubleshoot inner bbl problems	2	11:30 AM	1:30 PM
	Circ to Core	1	3:30 PM	4:30 PM	Pull Outer bbl from Well for inspection	2	1:30 PM	3:30 PM
	Rig up and pull inner plug	0.5	4:30 PM	5:00 PM	Break and laydown outer bbl	2	3:30 PM	5:30 PM
	Pick up inner bbl with charged accumulator RIH	1	5:00 PM	6:00 PM	Troubleshoot problems & perform cir test	2.5	5:30 PM	8:00 PM
	circ 30 min Cut core #1 10 ft core	0.5	6:00 PM	6:30 PM	Redressed outer barrel to accept a cutting shoe	1.5	8:00 PM	9:30 PM
	POOH Core #1	1	6:30 PM	7:30 PM	Pick up A-2 assemby and perform a space out test	2	9:30 PM	11:30 PM
	Cut Core #2 10 ft	3	7:30 PM	10:30 PM				
	Rig Maint and Shutdown	8.5	10:30 PM	7:00 AM	Shut down rig for the night	7.5	11:30 PM	7:00 AM

DAY	OPERATION PLAN	TIME			OPERATION ACTUAL	TIME		
		(hr)	Start	Stop		(hr)	Start	Stop
DAY 5 (Fri 8 nov)	Morning Rigup/ safety mtg	0.5	7:00 AM	7:30 AM	Morning Rig-up & Safety Meeting	1	7:00 AM	8:00 AM
	Cut Core #3 10 ft	3	7:30 AM	10:30 AM	Perform circ test on A-2 Assy with cutting shoe @ floor	1	8:00 AM	9:00 AM
	POOH with outer bbl inspect for damage and washouts	2.5	10:30 AM	1:00 PM	Perform circ test on C-5 Assy with center bit	1.5	9:00 AM	10:30 AM
	Pick up core bbl with Insert bit	2.5	1:00 PM	3:30 PM	TIH to shoe with bit at 745'	3	10:30 AM	1:30 PM
	Pick up Dc and RIH to 700 ft	1	3:30 PM	4:30 PM	Circ and condition mud	1	1:30 PM	2:30 PM
	Rig up wireline	0.5	4:30 PM	5:00 PM	Install A-4 assy. Perform circ test. Retrieve A-4	2.5	2:30 PM	5:00 PM
	Test 2 inner bbl sections for fit	2	5:00 PM	7:00 PM	Install B-3 assy. Perform circ test. Retrieve B-3	2	5:00 PM	7:00 PM
	RIH with core bbl to TD	0.5	7:00 PM	7:30 PM	TIH to 1064' and circ.	1	7:00 PM	8:00 PM
	circ 30 min Cut core #4 10 ft core	1	7:30 PM	8:30 PM	Install center bit assy C-5	1	8:00 PM	9:00 PM
	POOH Core #4	0.5	8:30 PM	9:00 PM	Drill to first core point	2	9:00 PM	11:00 PM
	Run drill- ahead plug	0.5	9:00 PM	9:30 PM	Circ hole clean	0.5	11:00 PM	11:30 PM
	POOH to shoe and Shut down rig	1	9:30 PM	10:30 PM	Retrieve C-5 assy	1	11:30 PM	12:30 AM
			10:30 PM	10:30 PM	POOH to shoe @ 745 and shut down rig for weekend	2	12:30 AM	2:30 AM
	Rig Maint and Shutdown	8.5	10:30 PM	7:00 AM	Shut down rig for the weekend	52.5	2:30 AM	7:00 AM
DAY 6 Mon 11 Nov	Morning Rigup/ safety mtg	0.5	7:00 AM	7:30 AM	Morning Rig-up & Safety Meeting	0.5	7:00 AM	7:30 AM
	RIH	2	7:30 AM	9:30 AM	POOH & LD Core Barrel	3	7:30 AM	10:30 AM
	Drill	3	9:30 AM	12:30 PM	PU drilling BHA & TIH to 1110'	2.5	10:30 AM	1:00 PM
	Run and pull drill- ahead plug	0.5	12:30 PM	1:00 PM	Drill 50' & POOH to BHA	6	1:00 PM	7:00 PM
	Pick up inner bbl with charged accumulator RIH	1	1:00 PM	2:00 PM	Lay down drilling BHA & PU Core Barrel	2.5	7:00 PM	9:30 PM
		1				0.5	9:30 PM	10:00 PM
	Cut core #5 10 ft core		2:00 PM	3:00 PM	TIH to core point @ 1033'			
	Break core circ rig WL and pull core	1	3:00 PM	4:00 PM				
	Circ Btms up and POOH laying down	3	4:00 PM	7:00 PM				
	Rigout equipment	3.5	7:00 PM	10:30 PM				
	Release Rig	0.5	10:30 PM	11:00 PM	Wash to bottom & cut and recover core #1 from 1148' - 58'	2	10:00 PM	12:00 AM

DAY	OPERATION PLAN	TIME			OPERATION ACTUAL	TIME		
		(hr)	Start	Stop		(hr)	Start	Stop
DAY 7 Tues 12 Nov					Wash to bottom & cut and recover core #1 from 1148' - 58'	4	12:00 AM	4:00 AM
					Processed core and discussed plan forward	2	4:00 AM	6:00 AM
					Attempt to make up second cutting shoe inner barrel	1.5	6:00 AM	7:30 AM
					POOH to change out to Face bit assembly	1.5	7:30 AM	9:00 AM
					Change BHA to Face bit configuration	1.5	9:00 AM	10:30 AM
					TIH to 1130'	0.5	10:30 AM	11:00 AM
					Cut & recover core #3 from 1158' to 1164' with A-3 assy	8.5	11:00 AM	7:30 PM
					Rig up to run A-4 assy. Found A-3 collasped. Discuss situation	1	7:30 PM	8:30 PM
					Perform pressure test with B-3 Face assy-no pumping or coring	1	8:30 PM	9:30 PM
					Install center bit assy for Face bit core barrel	1	9:30 PM	10:30 PM
					Drill from 1164' to 1170' , 310 GPM, 13K WOB	1.5	10:30 PM	12:00 AM
DAY 8 Wed 13 Nov					Drill from 1170' to 1186' at 22'/hr, 310 GPM, 13K WOB	2.5	12:00 AM	2:30 AM
					R/D Weatherford WL and clear catwalk of AAI tools	0.5	2:30 AM	3:00 AM
					Rig up and POOH laying down drill pipe & outer barrel	9	3:00 AM	12:00 PM
					Demob and load out equipment	6	12:00 PM	6:00 PM
					Operations Terminated 1800 hrs on Wed 13 Nov	6	6:00 PM	12:00 AM

The following is a summary of the tests planned and the results for each. Because we deviated from plan so early, there were many unplanned tests and tests that were modified from the original plan. These have also been summarized by date and test with the conditions and comments/ observations made at the time.

CORE BBL TEST RESULTS FACE BIT

	UPPER BBL USED	LOWER BBL USED	Accumulator Set point (psi)	Test Name	Results	COMMENTS
Face Dimensional test 1	A	1	0	1-A-1	100% FAIL	W/o tool circ pressure <50psi @ 100 gpm with tool Circ pressure seen to be 600+ psi. Pull tool w/ slight overpull. Ball valve did not close (jammed open by inner tube). Inner Core Tube Failed in collapse
Face Dimensional test 2	B	4	0	2-B-4	NOT DONE	
Face Dimensional test 3	A	2	0	3-A-2	25% ok	Perform fit test W/BBL@ ROTARY OK. CIRC THROUGH TOOL WITHOUT AND WITH INNER BBL ASSY . NEGLIGABLE PRESSURE DROP AT SURFACE. Circ Rates 1/3 of coring rates were too low to evaluate bbl
Face Dimensional test 4	B	3	0	4-B-3	NOT DONE	Test Abandoned due to tool design flaws
Face Accumulator Test 1	A	4	1000	5-A-4	NOT DONE	Test Abandoned due to tool design flaws
Face Accumulator Test 2	B	1	1000	6-B-1	NOT DONE	Test Abandoned due to tool design flaws
Core Run #1 face Bit	A	3	1000	8-C1-A3	100% FAIL	Core 1158-1168. 150 gpm 400 psi Inner bbl collapsed. 0% recovery ball valve did not function
Face Fit Test 1 (NEW TEST)	A	4			100% FAIL	Ran Ass'y in well and latch. Pull assy w/o circ or rotation Ball Closed 71 I chamber.. Valve Leaks
Core Run #2 face Bit	B	2	1000	9-2C-B2	NOT DONE	Test Abandoned due to tool design flaws
Core Run #3 face Bit	A	1	1000	10-C3-A1	NOT DONE	Test Abandoned due to tool design flaws

CORE BBL TEST RESULTS INSERT BIT

	UPPER BBL USED	LOWER BBL USED	Accumulator Set point (psi)	Test Name	Results	COMMENTS
Insert Dimensional test 1 (NEW TEST)	A	2	0	11-A2	OK	Additional test. Install insert bit on assy A-2 @ surface Circ @ 108 gpm @ 60psi unlatch tool ball closed
Insert Dimensional test 1	A	4	0	11-A4	100% FAIL	Passed performance test Used pressure on system. Ball closed 0 psi in inner chamber
Insert Dimensional test 2	B	3	0	12-B3	100% fAIL	Passed performance test Used pressure on system. Ball closed 0 psi in inner chamber
Core Run #1 Insert Bit	A	3	1000	13-C4-A2	100% FAIL	Core 1148-1158. RECOVER 0.9FT (7%) Insert shoe failed. Ball valve leaked No pressure inside
Core Run #2 Insert Bit	B	1	1000	15-C5-B1	100% FAIL	Upper and lower bbl ass'y not make up Dimensional miss-match. Coring abandoned

CORE BBL TEST RESULTS CORE HEAD PERFORMANCE

	UPPER BBL USED	LOWER BBL USED	Accumulator Set point (psi)	Test Name	Results	COMMENTS
Face Bit Plug Drill Record				7-D-I	100% OK	Drill 1168 to 1186 Avg 22 ft /hr (consistent with drill bit)
Face Bit Plug IADC Grading				BIT-1	GOOD	No apparent wear
FACE BIT IADC GRADING				BIT-2	GOOD	Core 1158-68, drill from 1168-1,186 No appreciable wear to cutting structure
Insert plug and drill Report	A			14-D-2	100% FAIL	DRILL 6 FT IN 2 HRS. POOR BIT DESIGN
Insert Bit Plug IADC Grading				BIT-3	GOOD	Bit Cutting Structure Destroyed. Bad Design
Outer Insert Bit IADC Grading				BIT-4	GOOD	Bit not worn
Inner Insert bit IADC Grading				BIT-5	100% Fail	Lost 100% of structure...Bad Design

CORE BBL TEST RESULTS OUTER BBL ASSEMBLY

	UPPER BBL USED	LOWER BBL USED	Accumulator Set point (psi)	Test Name	Results	COMMENTS
FACE BIT BHA Inspection				BHA-1	OK	NO APPARENT WEAR ON OUTER BBL OR BHA
FACE BIT BHA Inspection				BHA-2	OK	No Apparent wear
Insert BIT BHA Inspection				BHA-3	OK	No apparent wear

Chevron CTF Field Test Run Summary				Shoe= 745							
Date	Time	Test Description	Tool # Upper-Lower	Depth from (ft)	Depth to (ft)	Depth Interval (ft)	Core Recovered (ft)	Bottom Hole Pressure (psi)	Pump rate-GPM	Pump press	Remarks
11/6/2013	17:30	circ test- no inner bbl		1064.0				550	310	?????	?????? Check rig data for 6th.
11/7/2013	10:00	Face Bit Dimension Test #1	A-4- A-1?	741.0	741.0	0.0	NA	375	112	660	Pressure spikes at pump startup to 860psi. Ball valve not closed. Core liner and inner tube collapsed and jammed ball.
								375	112	807	
								375	112	650	**Higher press than when coring- deeper**
11/7/2013	18:30	Face Bit Near Surface Flow Test 1		124.0	Surface	0.0	NA	75	120	28	**No Line**r: pumped 120gpm at 20psi.
11/7/2013	19;30	Face Bit Near Surface Flow Test 2		124.0	Surface	0.0	NA	75	120	77	**With liner**: pumped 120gpm at 70gpm. No excessive pressure.
11/7/2013	9:30 PM	Cutting Shoe Spaceout	B-3	Surface	Surface	0.0	NA	NA	NA	NA	Cutting shoe 1/4 inch inside main bit. Catcher 3/16 inside cutting shoe.
11/8/2013	8:00	Cutting Shoe Surface Flow Test	A-2	122.0	Surface	0.0	NA	74	110	56	Flow test - 108 gpm @ 60psi. Ball valve closed properly. Surface test with no N2 pressure.
11/8/2013	9:00	Cutting Shoe center bitSurface Flow Test	C-5	122.0	Surface	NA	NA	74	160	0	Center Bit Spaceout test Center bit protrudes 1" past main bit. Flow test - 160gpm = 0 psi
11/8/2013	14:30	Cutting Shoe Dimension Test 1 and flow test	A-4	855.0	855.0	0.0	NA	425	110	35	Pump Test 110gpm, 35psi Ball valve closed properly.
11/8/2013	17:00	Cutting Shoe Dimension Test 2 and flow test	B-3	745.0	745.0	0.0	NA	375	110	35	Pump Test 110gpm, 35psi. Ball valve closed properly. Supply Valve was clossed - human error. Pressure control section turned off.
11/8/2013	21:00	Cutting Shoe Center Bit Test-drill	C-5	1064.0	1070.0	NA	NA	550	425	160	Tag bottom 360gpm. Drill with 380gpm - 425gpm. Slow ROP. Drilled 6 ft in 2 hours. No penetration the last half hour. POOH. Bit balled up severely. Three nozzles plugged. Cutting shoe had 1 nozzle plugged.
								550	380	115	
11/11/2013	13:00	Conventional Drill to Core Point	NA	1070.0	1148.0	NA	NA	NA	NA	NA	Drilled very slowly at about 20 ft/hr
11/11/2013	23:00	Cutting Shoe Core #1	B-2	1148.0	1158.0	10.0	0.90	570	180	190	Crown came off cutting shoe.Slow ROB at first than okay. 0.9 ft core recovered.Autoclave held pressure after the run.
								570	240	280	***60% of face bit pressure***
11/12/2013	16:30	Face Bit Core #2	A-3	1158.0	1164.0	6.0	0.00	570	247	484	Holes added to extension tube to reduce pump pressure. Wrong upper assembly picked up and would not release in BHA. Picked up correct upper assembly and landed and released normally. Pump 240gpm SPP to 500psi, torque variable 1200-3700, WOB 8-16K, variable penetration. Liner collapsed and jammed ball open.
								570	241	501	
								570	241	486	***200 psi above cutting shoe press***
								570	184	220	***Not linear- about same as cutting shoe***
								570	245	414	
11/12/2013	20:00	Face bit dimension test #2	B-3	1164.0	1164.0	0.0	NA	570	NA	NA	Locked sinker bar using pipe wrench to prevent SB weight on inner barrel assembly during disassembly. Ball valve closed properly.
11/12/2013	23:30	Face bit center bit drilling test	C-5	1164.0	1188.0	NA	NA	580	310	177	Drilled okay at 22ft/hr. Pumped 310gpm at 175psi, 70RPM, 10-15K WOB.
11/13/2013	0:03	Finished drilling w/face bit							NA	NA	

Final Cost and Schedule:

The overall program was estimated to take 7 days. As a precaution however, recognizing that the tool was a prototype, where unforeseen problems could arise, a 9 day time slot was secured at Catoosa. Although the preliminary work getting the well ready for coring and picking up equipment was completed 28% faster than the plan, the actual testing took significantly longer. The entire program was over budget in terms of time and cost.

The table below summarizes the planned and actual schedule.

Catoosa Test November 2013

OPERATION	Plan	Actual	Variance
Rig Up, Drill to Core Point, Rig To Test Core Bbl	37.5 hr	27.0 hr	-28%
Test Core Bbl System	62.0 hr	115.0 hr	85%

The table below summarizes the planned budget.

Drill hole to 1150, Stackup Tools, Cut 5 Cores, Abandon Hole from 1260 ft	
RIG DAYWORK CHARGES	$184,800
FUEL SURCHARGE	$12,200
MUD AND MUD ENGINEERING	$20,000
WIRELINE UNIT RENTAL	$40,000
DP RENTALS (inc tranport, insp & Repair)	$75,000
CORE LABS	$20,000
AAI CORING	$75,000
DRILL BITS	$6,500
WELL ABANDONMENT	$11,000
MISC AND OTHER	$35,500
ESTIMATED PROJECT L COST	**$480,000**

The final overall cost was approximately $496,000 (3.3% over budget), largely due to additional costs associated with service providers (+$15,000), repairs and additional transport for the drill pipe (+$11,000), and the necessity of a motor rental for kickoff (+$25,000). These additional costs were partially offset by not requiring a fuel surcharge (-$12,200) and lower than planned rental rates (-$18,000).

In spite of the poor performance of the coring tool, there were no HES incidents, nor any environmental nor safety issues.

APPENDIX 2: FIELD OBSERVATIONS OF CORE RETRIEVED

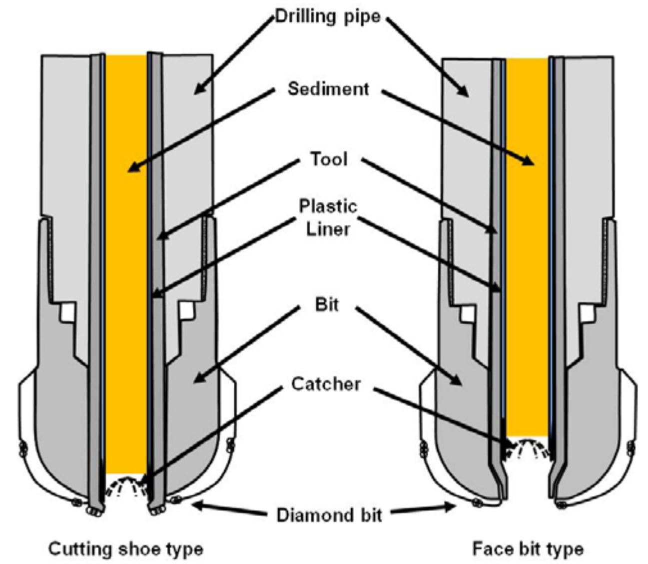
<u>Coring Procedure</u>

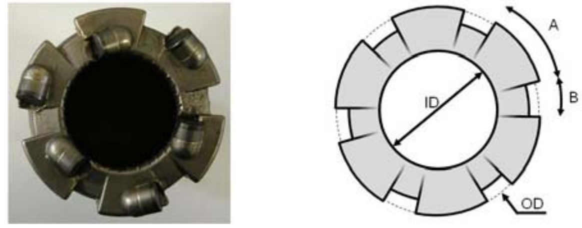
The selected horizon for core retrieval was the Tonkawa sand at 1102' depth. The plan was to drill to the marker at 1,102' and then take 4 cores. Then, drill to the next marker depth at 1240' and take a 5th core.

Two types of coring tool cutting structures were used, the cutting shoe and face bit type. The figure below illustrates the bits. The maximum diameter of these bits was 10-5/8 inches.

	 Cutting shoe type	 Face bit type
Drill bit	Bits for coring operations	

In the cutting shoe type, the core is cut by an inner bit called a cutting shoe while the main bit opens the hole. The face bit type is more like a conventional coring system where the main bit both cuts the core and drills the hole and there is no inner bit. The figure below illustrates the general scheme of the tools in working operations.





Cutting Shoe

Cutting shoe and face bit type

The drill pipe and bit applies torque and weight to the formation in order to advance the perforation. Drilling mud is pumped in the inner pipe and the flow removes the small parts and conduct them in an annular flow to the surface. Inside the drill bit, the coring tool has a maximum external diameter of 95.2 mm which houses the internal 60.15mm diameter plastic liner. As the drilling operation takes place, the plastic liner is static and allows for the sediment to be extracted without rotation. A catcher is placed in the tip of the plastic liner.

Cutting shoe and face bit general dimensions (dimensions in mm.)

Cutting Shoe	
OD	95.25
ID	50.80
A	33.33
B	13.50

Main Bit	
OD	269.88
ID	96.52

Face Bit	
OD	269.88
ID	50.80

Core Retrieved

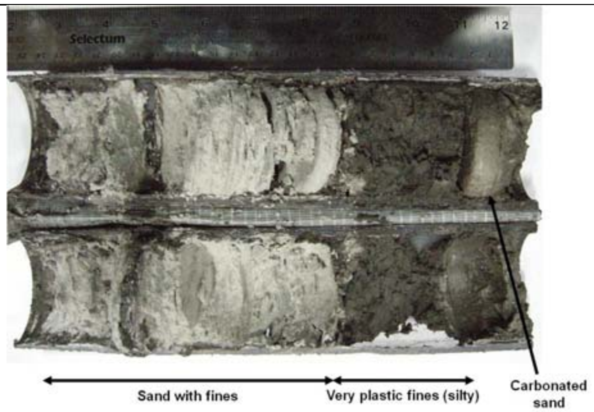
Once the core is trapped in the plastic liner and the drilling operations are over, the system is retrieved by wireline.

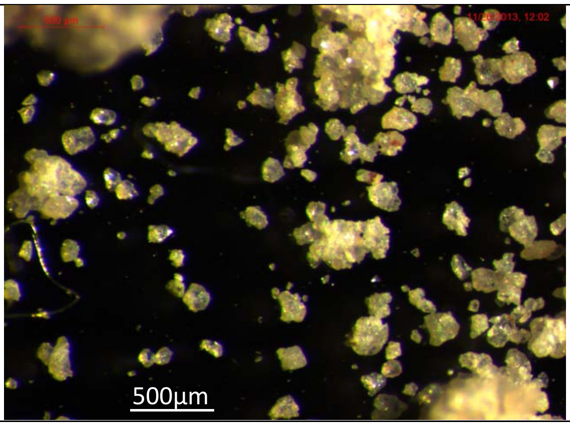
At the surface, the liner is removed from the tool and transferred to the transfer pipe. Then the liner is transported to the workshop where by the help of stands, it is placed ready to cutting procedures. The figure below illustrates this typical procedure.

Core removed from tool	Preparing to cut	Cutting

Coring manipulation

At the marker 1148’ the drill bit advanced 10’, recovering 24 cm of material. From the 24 cm, 9 cm corresponds to a very plastic silt and 15cm is the sandy material of the Tonkawa formation. The figure below shows the material retrieved.

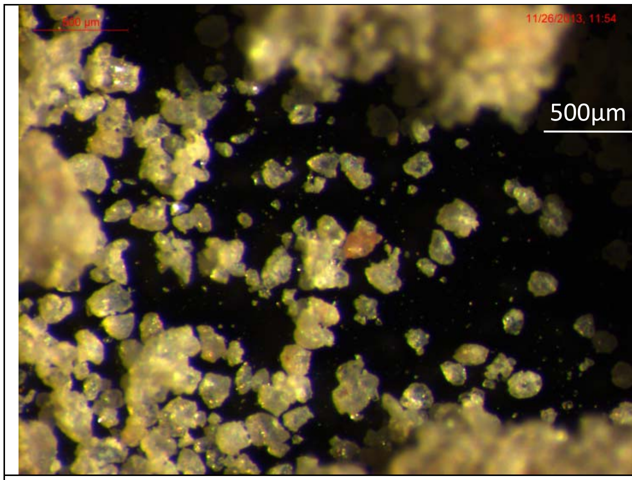


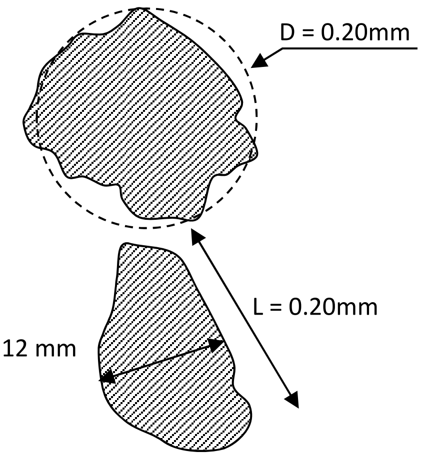


Core retrieved	Sand under microscope

Core retrieved

The figure below shows typical particle size, sphericity and roundness. Particles sizes ranges from 0.05 mm to 0.2 mm classifying it as sand. Defining sphericity as the ratio between the area of the particle projection and the area of the circle with diameter equal to the longest length of the projection; and roundness as the ratio between the average of radius of curvature of surface features and the radius of maximum sphere that can be inscribed, it was found that sphericity ranges from 0.5 to 0.85 and roundness from 0.4 to 0.9.





Microscope photography	Typical particle size

Typical particle

SECTION 6
PHASE IIIB TOPICAL REPORT #41330R27

Technical Review Team Final Report Following Onshore Testing at Catoosa Test Facility

3 November – 13 November 2013

DOE/Chevron Pressure Coring Tool with Ball Valve
Contract CW1094939

Technical Review Team Members

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18 June 2014

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Executive Summary

Note that heretofore the Pressure Coring Tool w/Ball Valve (PCTB) has been referred to as the Hybrid Pressure Coring System or Hybrid PCS or simply H-PCS or HPCS. To minimize confusion between this tool and similar tools, e.g., the Japanese Hybrid Pressure Coring System or Hydraulic Piston Coring System (HPCS), the name Pressure Coring Tool w/Ball Valve or PCTB will be used.

Following the onshore testing of the Pressure Coring Tool w/Ball Valve (PCTB) at the Catoosa Test Facility (CTF) 3 November – 13 November 2013, a Technical Review Team (TRT) was formed to review the PCTB performance and to make recommendations for improvement. Four major areas of concern were identified, 1) bit design issues, 2) pressure retention issues, 3) inner tube and core liner failure issues, and 4) lessons learned.

The TRT reviewed the PCTB initial onshore test results and Aumann and Associates, Inc. (AAI) observations, the overall design, the overall manufacturing processes and procedures, the factory acceptance testing procedures, and overall servicing and operational procedures as well as participants notes, photographs, drilling data record and verbal accounts. The TRT then made a summary of recommended changes to the PCTB for improving overall performance. A description of the work processes the TRT used to evaluate the onshore test performance results is included in the Interim Report (reference Appendix I). The TRT also reviewed the lessons learned and made recommendations to prevent repeating such mishaps in the future.

The TRT attempted to identify the root cause of each individual failure by reviewing participants notes, drilling data record, photographs, and verbal accounts. Where failure root causes were identified, the TRT recommended potential solutions along with an estimated cost and time to complete. Where failure root causes could not be identified, the TRT recommended a laboratory testing scheme that may help identify those failure root causes. AAI has been conducted numerous laboratory tests to confirm identified root causes and in some cases has modified parts and retested to confirm the recommended solutions worked.

This final report details the work carried out by AAI in solving all issues related to the PCTB performance prior to conclusion of the JIP. Therefore, it is recommended that the TRT Interim Report (Appendix I) be reviewed prior to reviewing the final report.

Introduction

As a replacement for the ODP Pressure Core Sampler (PCS) and in preparation for proposed pressure coring during IODP Expedition 337 in 2011, Japan Agency for Marine-Earth Science and Technology (JAMSTEC) contracted with Aumann & Associates to develop a new pressure coring system, the Hybrid – Pressure Coring System (Hybrid-PCS or H-PCS). In the end the Hybrid-PCS was not deployed on IODP Expedition 337 but was adopted by Japan Oil, Gas and Metals National Corporation (JOGMEC) as the replacement pressure core system for the Pressure-Temperature Coring System (PTCS). The Hybrid-PCS is compatible with the standard IODP 4-1/8" ID drill pipe and coring bottom hole drilling assembly (BHA) used on the D/V *Chikyu*. The maximum length of a Hybrid-PCS core is 3.5 m, and the diameter is 5.1 cm. After cutting a core, a ball valve at the bottom of the autoclave is closed to seal the core during wireline retrieval.

JOGMEC recently used the new Hybrid-PCS (cutting shoe version only) to conduct pressure coring operations from the *D/V Chikyu* during the 2012 phase of the MH-21 Nankai Trough Pre-Production Expedition. During this expedition, 21 pressure cores were recovered from a 60 m interval section in one hole. Sampled lithologies range from clay-rich sediments in the overburden formation to sandy layers with high concentrations of methane hydrate in the targeted interval. Geotek's Pressure Core Analysis and Transfer System (PCATS) was used to transfer, analyze, and subsample 35 m of core recovered under pressure. After X-ray CT imaging and non-destructive analysis under in situ pressures, over 60 samples between 10 cm and 120 cm long were cut and stored for further detailed on-shore analysis by scientists.

Since the completion of the 2012 Hybrid-PCS pressure core operations in the Nankai Trough, the Gulf of Mexico Joint Industry Proposal (GOM JIP) has been working with the JOGMEC (who is also a member of the GOM JIP) and Aumann & Associates to develop a replacement system for the HPTC. It has been decided that the GOM JIP and Aumann & Associates, along with the support of JOGMEC, will work together to modify the existing Hybrid-PCS system with engineering learning's from the 2012 Nankai Trough coring program and conduct an onshore test of the modified Hybrid-PCS, now referred to as the Pressure Coring Tool w/Ball valve or PCTB, in Catoosa, Oklahoma in November of 2013.

The test of PCTB in Catoosa began 3 November 2013 and ended 13 November 2013. A total of 16 tests of the PCTB were carried out with mixed results of success. Problems from low penetration rate to failure of a cutting shoe to inability to retain hydrostatic pressure to collapse of the inner tube to failure of the pressure control section, etc., plagued the PCTB operation throughout the tests.

A Technical Review Team (TRT) was formed to review the PCTB onshore test results and make recommendations for improvements to the tool and associated procedures, in hopes of improving the PCTB overall performance and reliability.

This report addresses the work carried out in resolving all identified PCTB operational issues from the issuance of the interim report to the end of the GOM JIP on 31 March 2014. Therefore, it is recommended that the reader familiarize himself with the Hybrid Pressure Coring System Technical Review Team Interim Report (Appendix I.) for the initial TRT comments and recommendations as well as a review of preliminary work carried out by AAI prior to reviewing this report.

Technical Review Team Final Report
Pressure Coring Tool with Ball Valve (PCTB)

TRT Summary List of Issues Resulting from Onshore Testing of the PCTB at CTF

1. <u>Bit design issues</u>:

- Cutting shoe center bit extended further ahead of main bit than expected (1” actual vs. 15/32” design).
- Cutting shoe crown disintegrated during first and only attempt with cutting shoe and inner barrel assembly.
- Cutting shoe bit/center bit combination resulted in very slow drilling with ROP of 1 foot/hour for four hours.
- A high differential pressure created during pumping operations with the face bit could be a result of inadequate total flow area of the face bit; however, further investigation is required to draw this conclusion.

2. <u>Pressure Retention issues</u>:

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

3. <u>Inner tube and core liner failure</u>:

- The inner tube and core liner collapsed during two face bit runs.

- The inner tube was redesigned with a low strength thin wall stainless steel tube to accomplish the objective (increase clearance between inner diameter (ID) of inner tube and outer diameter (OD) of core liner and core catchers to eliminate during core transfer to PCATS, of one of the 15 modifications from the tool in Japan.

- A review of the reason for high differential pressure between the OD of the inner sleeve and ID of the core liner may be the root cause of failure; however, some changes may have to also be made to the inner sleeve material and/or thickness to be compatible with differential pressures of either a redesigned tool or face bit.

4. Lessons Learned:

- One fish pill recorder was set up incorrectly and failed to record the pressure properly due to inadequate training and practice.

- Two types of parts were discovered to have been manufactured incorrectly due to improper quality assurance (QA) and inadequate Factory Acceptance Test (FAT) assembly and checking.

- A face bit inner barrel assembly failed to latch due to an assembly error on the rig floor.

- AAI service personnel assembled tools incorrectly on three runs.

- A premature comment that the pawls had locked under the seal hub was incorrect information which was later correctly identified as directly related to the collapsed inner sleeve/core liner.

1. Bit Design Issues

1a. Cutting Shoe Center Bit Apparent Excessive Extension

<u>Description</u>

During the space out test at Catoosa, it was observed that the cutting shoe center bit extended farther ahead of the main bit than anticipated (about 1 inch rather than 15/32 inch as designed and measured on the CAD drawing).

Figure 1. Face bit center bit extension.

<u>TRT Recommendations</u>

The TRT reviewed participants' notes and photographs pertaining to the cutting shoe center bit apparent excessive extension. The extension was determined to be ~1 inch ahead of the main bit face. The apparent excessive center bit extension could be a result of one of three issues, 1) mismade parts, 2) machine drawings dimensioned incorrectly, or 3) tolerance stack-up through the assemblies involved.

The nominal assembly drawing results in a center bit extension of 0.437 inch. AAI checked the length of the center bits and determined that they were designed and manufactured 0.290 inch longer than the nominal dimensions on the drawing, but within the tolerances allowed.

However, this would result in a center bit extension of 0.727 inch without considering the fairly large tolerances in the BHA components.

As for the tolerance stack-up issue, this could be a reoccurring problem and needs to be confirmed.

The TRT Recommended;

- Verify that the center bit space out is as designed and that all parts were correctly manufactured. This approach will resolve issues 1 and 2.

- Investigate incorporating an adjustment mechanism into the PCTB that will allow the center bit to be properly spaced out with each new BHA used.

Remedial Action

- AAI initiated a tolerance study which revealed the tolerances in the BHA components are as follows:

Landing Saver Sub	0.150
Top Sub	0.125
Head Sub	0.031
Seal Bore Outer Core Barrel	0.750
Bit Sub	0.150
Total	1.206

- Therefore the allowed variation due to specified tolerances in the BHA assembly is +/- 0.603 inch, which could allow for the observed center bit extension.

- AAI designed a center bit length adjuster (reference Appendix II. Center Bit Length Adjuster Drawings) which has been manufactured. The adjuster allows for changing the overall length of the center bit so that the proper extension beyond the face bit can be achieved with any given BHA assembly.

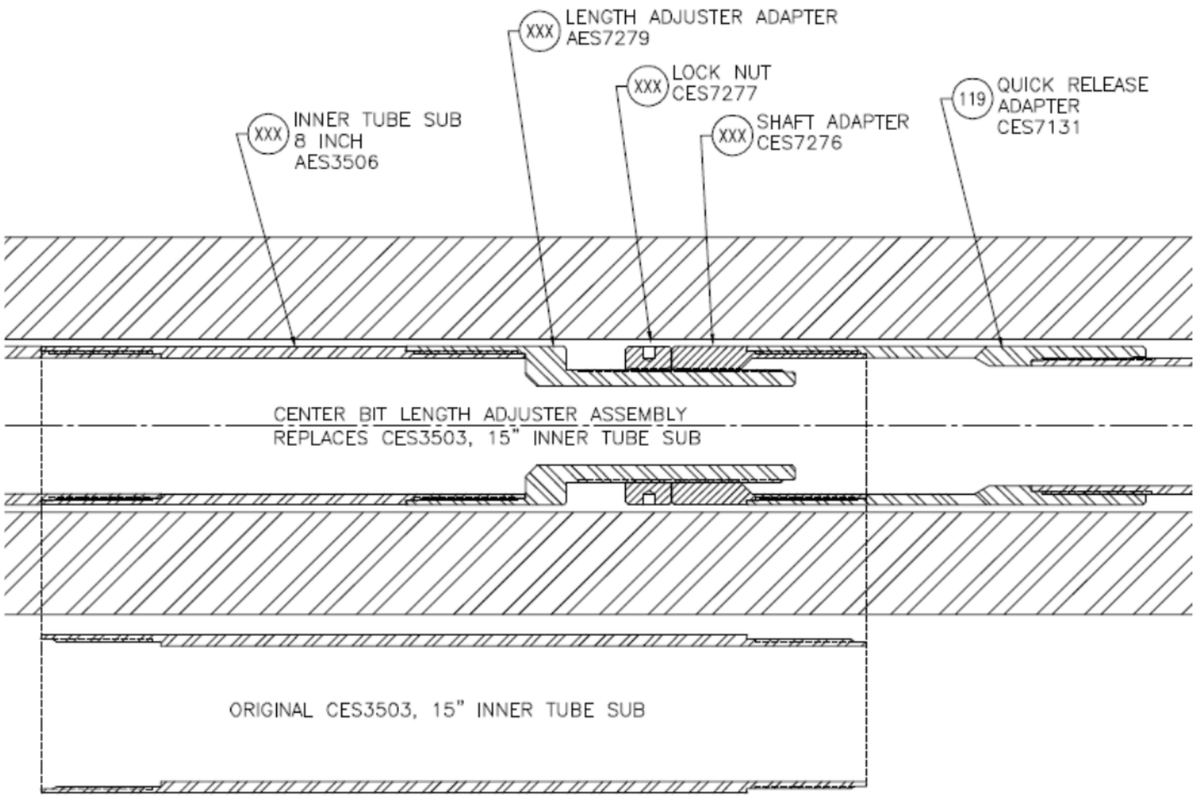

Figure 2. Center bit length adjuster replaces the 15" Inner Tube Sub.
(reference Appendix II. Center Bit Length Adjuster Drawings)

Current Status

A center bit length adjuster has been incorporated into the PCTB assembly and delivered with the tool.

1b. Cutting Shoe Crown Disintegration

Description

During Run 12: Cutting Shoe Core #1, at Catoosa, the bit was positioned on bottom at 1148 ft. The PCTB landed and latched into the BHA properly. Coring commenced with flow rates ranging from 180 – 240 gpm, torque ranged from 3,000 – 3,500 lb-ft, and weight on bit was 16,000 lb. Penetration was slow for the first 1-1/2 ft then increased to 20 – 25 ft/hr to a depth of 1158 ft. The PCTB was then recovered. Upon inspection of the recovered PCTB, the cutting shoe bit matrix crown was found to be missing. About 0.9 ft of core was recovered and was jammed in the core liner.

The cutting shoe crown apparently came off and disintegrated during the first and only coring test of the cutting shoe inner barrel assembly. This is a likely cause of the slow drilling observed during the first few feet of coring with this bit combination. Closer inspection of the cutting shoe also revealed that the shank did not have the agreed upon design which would provide a steel stop for both the cutting shoe insert and the core catcher, resulting in those items stopping against the matrix, which is relatively weak in tension.

Figure 3. Disintegrated cutting shoe crown.

The BHA was then pulled out of the hole for reconfiguration into the face bit configuration. The cutting shoe main bit was found to have a chatter pattern on the ID which may have been created by the disintegrating cutting shoe head.

Figure 4. Chatter pattern observed on main bit.

TRT Recommendations

The TRT reviewed participants' notes and photographs pertaining to the cutting shoe crown disintegration, as well as, examined the actual failed cutting shoe. The failed cutting shoe was inspected by the manufacturer, who determined by visual inspection and review of manufacturing records that the cutting shoe had been manufactured correctly, and the crown material and its bond to the steel body were without defect. The cutting shoe crown was observed to be intact when deployed. Exactly what caused the failure cannot be determined. The crown may have been cracked due to mishandling on the rig and then failed down hole, or may have simply self-destructed during the core cutting process. Note that failure of a cutting shoe matrix crown occurred once before. This was attributed to an incorrect furnacing procedure by the manufacturer.

The TRT recommended;

- Investigate the crown to shank bond quality.

- AAI explore manufacturing all-steel body Polycrystalline Diamond Compact (PDC) cutting shoes, thus eliminating the matrix crown.

- A simple protective sleeve should be supplied to protect the cutting shoes and/or center bits as they are being moved to and handled on the rig floor. These protectors should not be removed until they are being placed in the drill pipe.

- A similar protector should be provided to protect the relatively weak bearing shaft that extends out of the bottom of the upper assembly.

Remedial Action

- AAI hired Royce Anthon, a metallurgical consultant with extensive experience in diamond bit metallurgy, to evaluate the bond between the matrix and steel bit blank of the cutting shoe. He provided a preliminary report stating that in his opinion the matrix material used by the manufacturer is not compatible with the 17-4 PH stainless steel bit shank because of a significant difference in the coefficient of thermal expansion between the two materials. The difference in the expansion rates can cause the matrix to separate from the shank as the bit cools after it is fired in the furnace. He feels this is not a good combination for a reliable bond. Normally the manufacturer uses mild steel such as 1018 which he stated is a better match. However, the coefficient charts available do not seem to support his theory and a request for additional review and explanation was made.

- AAI requested a metallurgical section of the bond area in a new cutting shoe be prepared to confirm the metallurgist’s hypothesis. A void can be seen between the crown and shank in the section, indicating an apparent imperfect bond.

Figure 5. Sectioned new cutting shoe crown. Figure 6. Cutting shoe crown section.

- AAI met with representatives of Atlas Copco, manufacturers of steel bodied bits. They agreed to provide a quotation for manufacturing all-steel body PDC cutting shoes. No matrix is to be used in the manufacture of the all-steel body PDC cutting shoes and, since the all-steel body PDC cutting shoe will not be furnaced, standard heat treated alloy steel can be used for the shank. The PDC cutters will be brazed directly into the steel body which avoids the problems associated with a matrix construction altogether. It should be noted that matrix is traditionally used in diamond bit construction partially to provide a high erosion and abrasion resistant surface. This is not needed in bits and cutting shoes used for coring relatively soft sediments encountered in methane hydrate formations.

- New steel body cutting shoes were manufactured to replace the four allocated to the autoclaves and also to replace the cutting shoes provided as spare parts. The new design is shown in Figure 7. The new design provides large round nozzles that may reduce plugging and also includes larger waterways in front of each PDC cutter that may provide better cleaning.

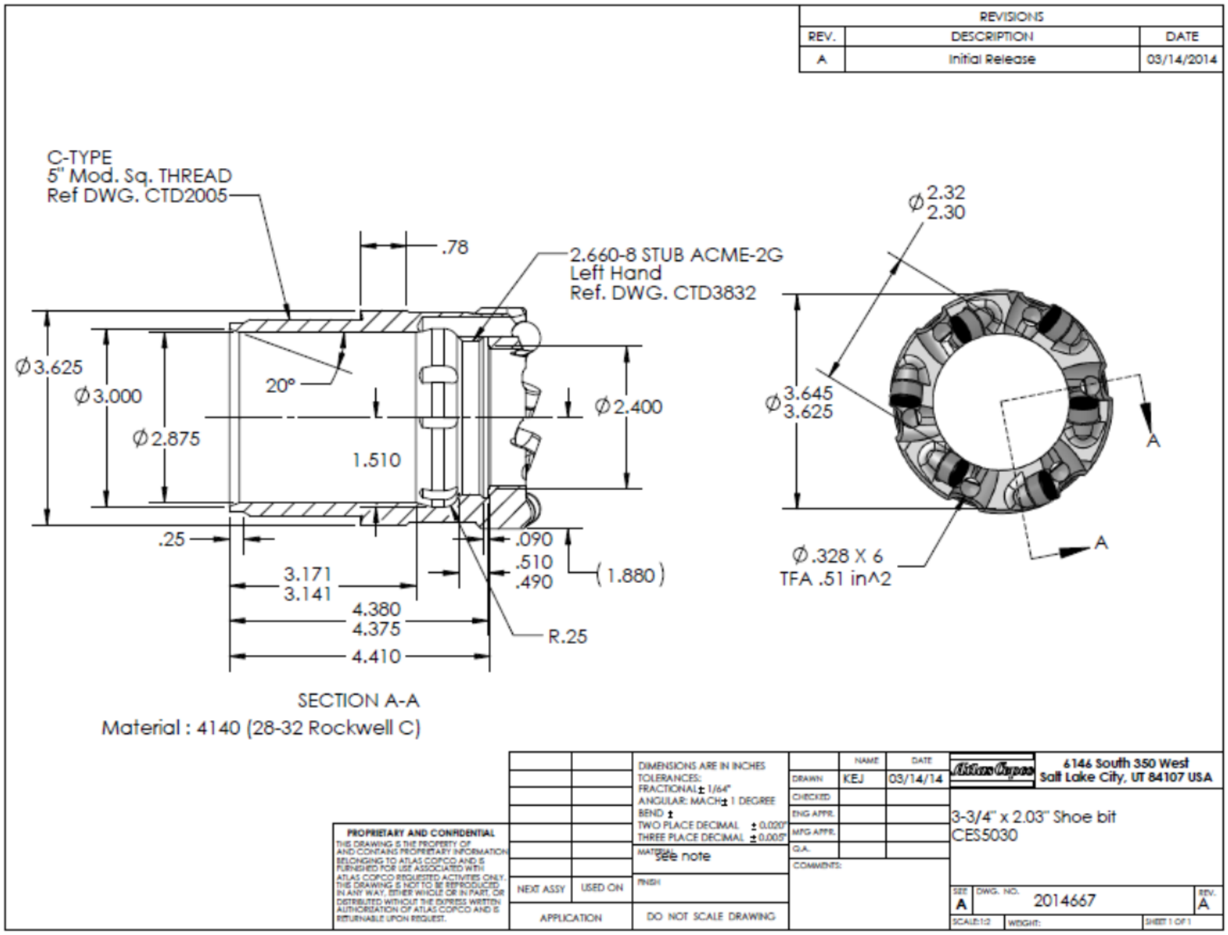

Figure 7. All-steel body PDC cutting shoe design

Current Status

Four all all-steel body PDC cutting shoes have been designed, manufactured, and delivered with the PCTB.

1c. Cutting Shoe Center Bit Low Penetration Rate

Description

During Run 10: Cutting Shoe Center Bit Test at Catoosa, the PCTB cutting shoe center bit was assembled and lowered to the BHA on wireline. The BHA was lowered to TD at 1064 ft where test drilling occurred. The hole was drilled with 380 – 425 gpm flow rate. Only 6 ft of hole was made in the first 2 hours. No penetration was made in the last half hour and the decision was made to pull the BHA and reconfigure it for conventional drilling. When the bit reached the rig floor, it was found to be severely balled up and three nozzles were plugged. One cutting shoe center bit nozzle was found plugged as well.

Run 11: Conventional Drilling to Core Point was then carried out. With the bit back on bottom, the hole was drilled to 1,148 ft for the next coring test. The drilling BHA was then recovered and reconfigured for the PCTB cutting shoe configuration.

During Run 12: Cutting Shoe Core #1, with the bit on bottom at 1148 ft, the PCTB landed and latched into the BHA properly. Coring commenced with flow rates ranging from 180 – 240 gpm, torque ranged from 3,000 – 3,500 lb-ft and weight on bit was 16,000 lb. Penetration was slow for the first 1-1/2 ft then increased to 20 – 25 ft/hr to a depth of 1158 ft. The PCTB was then recovered. Upon inspection of the recovered PCTB, the cutting shoe bit matrix crown was found to be missing. About 0.9 ft of core was recovered and was jammed in the core liner.

Note that subsequent drilling with a worn button rock bit drilled the same formation at a rate of 20 ft per hour. It was speculated that the excessive extension of the cutting shoe in front of the bit may have contributed to the slow penetration rate as well.

<u>TRT Recommendations</u>

The TRT reviewed participants' notes and the drilling record regarding the variable penetration rate observed when coring with the cutting shoe and drilling ahead with the cutting shoe center bit. Note that center bit penetration rates are often variable due to formation changes and the relative slow rotation of the cutters at the center bit. Also, adequate cleaning by circulation of the cutting shoe and center bit faces is difficult to achieve due to the restricted flow paths through the assemblies.

The TRT recommended;

- A bit design expert should be engaged to review the overall cutting shoe and center bit cutting structures, in conjunction with the main bit design, to optimize the overall cutting efficiency.

- There is no simple solution to this issue due to the wide variations in formations.

Remedial Action

The bit designs were reviewed by the manufacturer and deemed appropriate for the task. Also, the total flow area through the bit has been increased which should aid in keeping the bit clean and thus improve the penetration rate (see Item 1d for further information regarding the total flow area increase).

Current Status

Both the face bit and cutting shoe bits have had their total flow areas increased by either adding more ports or increasing the diameter of the port. The bits were modified prior to delivery of the PCTB.

1d. High Pressure Drop in Face Bit Inner Barrel Assemblies

Description

During Run 2: Face Bit Dimensional Test #1, at Catoosa, the PCTB was lowered on wireline to the BHA at 741 ft. The PCTB landed and latched in the BHA and then released properly. When the mud pump was engaged to initiate circulation, a pressure spike of 860 psi was observed. Circulation was established for 30 min. Note that the dimensional tests were intended to be circulation and function tests in the casing with no coring attempted. The PCTB was then recovered on wireline without incident. Upon inspection of the PCTB, it was discovered that the liner and inner tube had collapsed, preventing the ball valve from closing.

Figure 8. Collapsed inner tube from face bit Dimensional Test #1.

The PCTB was redressed without a core liner and inner tube for Run 3: Face Bit Near Surface Flow Test #1. During the test the pump pressure was observed to be ~20 psi at a flow rate of 120 gpm.

The inner tube and liner were installed in the PCTB for Run 4: Face Bit Near Surface Flow Test #2. During the test the pump pressure was observed to be ~70 psi at a flow rate of 120 gpm.

The decision was made to change the testing program and begin testing the PCTB cutting shoe configuration because of the problem with the collapsed inner tube and core liner and the desire to test a configuration that had been successful on previous operations.
Later in the testing program, the PCTB face bit configuration was picked up and run in the hole for Run 13: Face Bit Core #2. Coring began at a depth of 1,158 ft with 8,000 – 16,000 lb weight on bit, 240 – 250 gpm flow rate, and highly variable torque ranging from 1,100 – 3,700 lb-ft, resulting in a variable penetration rate. The coring run was stopped at a depth of 1164 ft and the PCTB recovered. Upon inspection of the PCTB, it was discovered that the liner and inner tube had again collapsed. A review of the pump pressure record indicted that the pump pressure had reached as high as 440 psi.

The face bit center bit combination C-5 was deployed for Run 15: Face Bit Center Bit Test, a drill-ahead test. The hole was drilled from 1,164 ft to 1,188 ft with the pump pressure at 175 psi, a flow rate of 310 gpm and 10,000 – 15,000 lb weight on bit, producing a penetration rate of up to 22 ft/hr. No problems occurred with the face bit center bit.

TRT Recommendations

The TRT reviewed participants' notes and the drilling record regarding high pump pressures associated with the face bit inner barrel assembly. It was observed that the pump pressure was inconsistent with flow rate. For example, during Run #2 Face Bit Dimensional Test #1, pump pressures greater than 600 psi were observed at a flow rate of 113 gpm. While during Run #4 Face Bit Near Surface Flow Test #1, with the inner tube in place, the pump pressure was ~70 psi at a flow rate of 120 gpm. The exact cause of this phenomenon could not be determined and additional flow tests are required.

The inner tube had been redesigned in order to provide more clearance between the ID of the inner tube and OD of the core liner to eliminate sticking during core transferring the core to PCATS. As part of this redesign a low strength thin wall stainless steel tube was selected because it provided the necessary increased ID for more clearance and also corrosion resistance at a low cost. This change may have contributed to the implosion although the unusually high pressure generated by the face bit was probably the real culprit since the inner tubes did not implode during the cutting shoe bit runs.

High standpipe pressure, in excess of 300 psi, was observed while circulating with the Face Bit Inner Barrel Assembly. The high pressure is believed to be the probable cause of the collapse of the two inner tubes and core liners. It was anticipated that the pressure drop in the face bit configuration assembly would be higher than that for the cutting shoe configuration assembly since the cutting shoe provides about 40% more flow area. However, the pressure drop generated by the face bit was much higher than anticipated.

The TRT recommended;

- Review the circulation flow path around and through the PCTB when latched into the BHA.

- Create a SolidWorks model of the PCTB inside the BHA and run computational fluid dynamics flow simulations to identify large pressure drop areas and make an attempt to eliminate any highly restricted areas.

- Analyze and hydrostatically test the inner tube and core liner to determine their collapse strength at AAI.

- Additional goal should be to provide operational parameters for future users.

- Investigate increasing the total flow area through the inner barrel assembly and through the bit.

- Consider increasing the strength of the inner tube if lab tests confirm a very low collapse pressure.

- This same analysis and modification procedure should be completed for the Cutting Shoe Inner Barrel Assembly to ensure that the maximum flow area exists with it as well.

<u>Remedial Action</u>

- The pressure data was reduced from the digital records provided by CTF and the pressure and flow information was added to the Run Summary.

- A review of the PCTB and BHA assemblies was carried out and no extreme flow resistance points were discovered that could account for the high pressure observed during the CTF field test.

- Computational fluid dynamics simulations was dropped due to cost and time to complete.

- Research revealed significant differences and discrepancies in the total flow area (TFA) between the face bit and cutting shoe bit combination.

  - Cutting shoe bit combination
    Actual TFA of cutting shoe main bit was 0.70 sq. in (5 each 27/64 ports)
    Actual TFA of cutting shoe was 0.66 sq. in (6 each 3/8 diameter ports)
    Actual TFA of cutting shoe bit combination was 1.36 sq. in.

  - Face Bit
    Actual TFA of face bit was 0.98 sq. in. (5 each ½" diameter ports)

  Conclusion – The difference in TFA would account for a doubling of observed standpipe pressure.

- It was reported that total flow areas of 1.8 sq. in are typically used for offshore coring with a 10-5/8 inch bit.

- The coring bits were modified to increase the total flow areas as indicated below.

  - Cutting Shoe Main Bit Modification
    Increase total flow area in cutting shoe main bit to 1.8 sq. in. by enlarging the five existing flow ports for a main bit total flow area of 1.2 sq. in.

Figure 9. Cutting shoe main bit modification

  - Face Bit Main Bit Modification
    It should be noted that there is insufficient room to enlarge the existing flow ports in the face bit main bit. Thus, to increase the total flow area, five

additional flow ports where added to the bit. The added flow ports direct flow towards the center of the main bit, more like cutting shoe flow ports, potentially providing better cleaning than may be obtained by only enlarging the original flow ports.

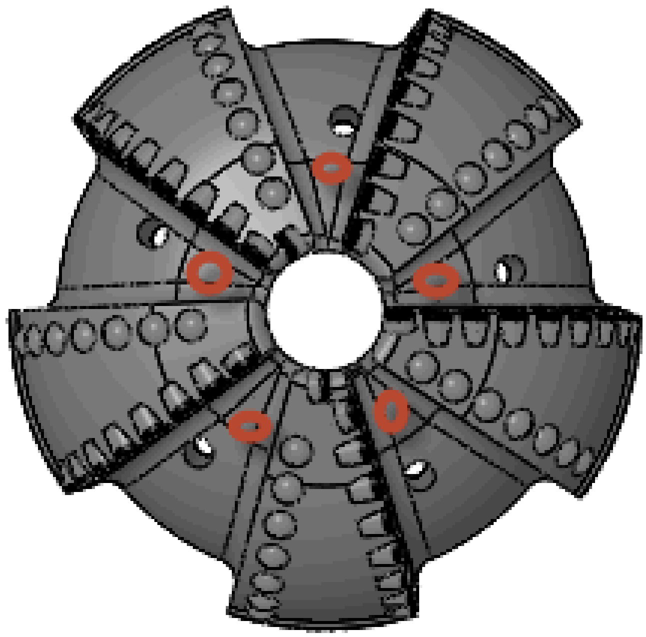

Figure 10. Face bit main bit modification (new ports drawn in red).

2. Pressure Retention Issues

2a. Hydrostatic Pressure Retention Failure

Description

Pressure was not retained during the dimensional tests or coring runs even though the ball valve was closed and appeared to operate properly on several runs. At a minimum, a hydrostatic pressure of from 333 psi (0.45 psi per foot x 740 ft) to 522 psi (0.45 psi per foot x 11600 ft) should have been recovered even with no pressure boost from the pressure control section. Still did not recover hydrostatic pressure even when ball valve was closed. The maximum pressure recovered was around 100 psi.

The pressure boost from the pressure control section also did not occur and this was verified by the fish pill recorder data. (Note that this would result if the ball valve closure was delayed and did not close immediately or if there was a leak somewhere else. It does not mean the pressure section did not function.)

There was evidence that the separator piston moved down prematurely on at least one some of the tools while waiting to be run. This could be due to nitrogen seepage under or through one or more of the seals.

The return spring jumped coils and jammed on at least one dimensional test preventing the ball from fully closing. This return spring was also made assembly difficult at times and also was observed to jam during pre-run testing.

On Run 8: Cutting Shoe Dimension Test #1 and Flow Test, the BHA was run to the casing shoe at 741 ft. Then PCTB cutting shoe configuration A-4 was deployed. Circulation was established resulting in a pump pressure of 35 psi at flow rate of 110 gpm. The PCTB was then recovered and the ball valve was found to be closed. The autoclave was found to have trapped 175 psi. Bottom hole hydrostatic pressure was calculated to be 356 psi. The PCTB regulator was set at 1,000 psi.

On Run 9: Cutting Shoe Dimension Test #2 and Flow Test, the PCTB cutting shoe configuration B-3 was deployed. Circulation was established resulting in a pump pressure of 35 psi at flow rate of 110 gpm. Upon recovery of the PCTB the ball valve was found to be closed. The autoclave was found to have trapped 196 psi. Bottom hole hydrostatic pressure was calculated to be 356 psi. The PCTB regulator was set at 1,000 psi. However, the pressure control section supply valve was found to have been incorrectly closed, thus negating its function.

ON Run 12: Cutting Shoe Core #1, with the bit on bottom at 1148 ft, the PCTB B-2 was deployed. The pressure control section was charged to 3,000 psi with nitrogen and the regulator set at 1,500 psi. Coring commenced with flow rates ranging from 180 – 240 gpm, torque ranged from 3,000 – 3,500 lb-ft, and weight on bit was 16,000 lb. Penetration was slow for the first 1-1/2 ft then increased to 20 – 25 ft/hr to a depth of 1158 ft. The PCTB was then recovered. Upon inspection of the recovered PCTB, the cutting shoe bit matrix crown was found to be missing. The ball valve was closed but no pressure was captured. About 0.9 ft of core was recovered and was jammed in the core liner. The autoclave was repressurized in the service unit after the run using the hydrostatic test pump and it held 1500 psi pressure with no leakage observed.

On Run 14: Face Bit Dimensional Test #2, the PCTB tool combination B-3 was deployed. A circulation pump pressure of 200 psi was applied to the PCTB and then the tool was recovered. During disassembly of the upper assembly from the lower assembly on the rig floor, the sinker bar was locked using a pipe wrench to prevent the sinker bar weight from resting on the inner barrel subassembly and possibly reopening the check valve on the top of the inner tube plug. The ball valve had closed properly, trapping 71 psi. The calculated hydrostatic pressure was 524 psi and the pressure control section had been charged to 3,000 psi with nitrogen and the regulator set at 1,500 psi.

<u>TRT Recommendations</u>

The TRT reviewed participant's notes and the drilling record regarding the PCTB pressure retention failures. Also, several horizontal Full Function Pressure Tests were conducted by AAI at their facilities. The horizontal Full Function Pressure Test configuration encases the autoclave and pressure control section in chambers that can be used to simulate actual bottom hole pressures. Pressures above, below and inside the autoclave can be controlled and monitored while manipulating the position of the inner PCTB components, simulating wireline operations. Fish Pill downhole recorders were also used to record internal and external pressures. The tests showed a pressure draw down of over 180 psi due to the increase in chamber volume as the inner tube plug continues to move up after ball closure. The tests proved that the pressure draw down effect is lessened, but not eliminated, by the addition of the new inner tube check valve. (Note that previous tests showed that without the new check valve, pressure draw down could be up to 600 psi.) This could explain the capture of 170 psi instead of the expected 350 psi in the dimensional tests carried out at the casing shoe.

The TRT recommended;

- Initiate an engineering study reviewing all aspects of the autoclave and pressure control section functions with regard to pressure retention.

- Carry out addition full function hydrostatic lab tests to determine the root cause of the pressure retention failure.

Remedial Action

- AAI reviewed the design of the autoclave and pressure section trying to identify possible causes for the failure to reliably trap pressure in the autoclave.

- The review indicated that two chambers in the autoclave can become pressure traps if operations are done with viscous drilling mud instead of seawater. These pressure trapped chambers can result in very slow ball rotation. The slow rotation would make it easier to jam the ball in a partially open position and could also allow the nitrogen charged fluid from the pressure control section to escape before the ball closed.

- Parts were modified to provide flow slots to provide paths for fluid escape to speed up ball rotation even when used with viscous drilling fluids.

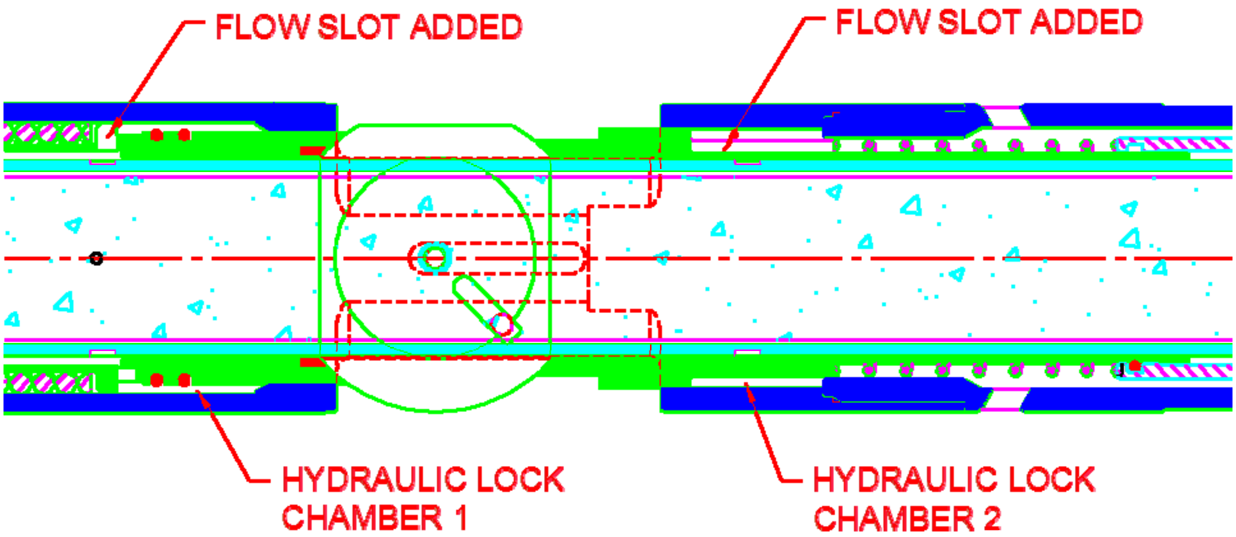

Figure 11. Potential Hydraulic Lock chambers in Ball Valve and flow slot modifications to eliminate them.

Figure 12. Flow slots added to the Ball Valve Release Collet.

Figure 13. Flow grooves added to the Ball Follower.

- Ball valve closure tests were conducted at AAI using thick grease to simulate a viscous drilling mud (reference Appendix III. Ball Valve Closure Test Chart). The grease appears to be more viscous than typical drilling mud. Ball closure was timed with and without grease pumped into the chambers. Assemblies with parts that were modified with flow slots were also tested in the same way. Closure times were measured by counting video frames. The tests showed significant improvement with the added flow slots (reference Appendix Va and Vb. Full Function Pressure Test Chart).

- Full Function Pressure Tests (reference Appendix IV. Post Field Test Full-Function Test Summary) have been conducted since the CTF field test. A Full Function Pressure Test is a pressure test carried out horizontally in the AAI service shop.

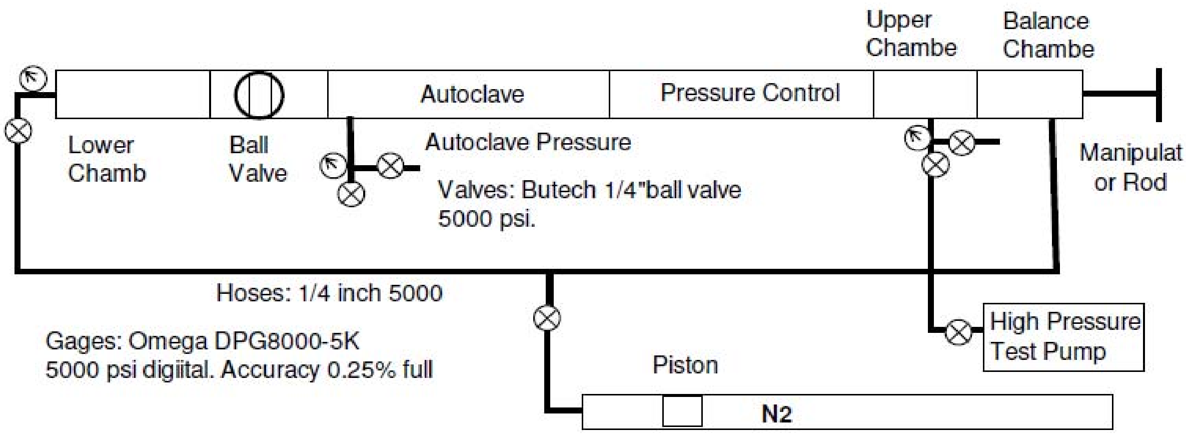

Figure 14. Full Function Pressure Test Setup

The full function pressure test consists of an autoclave and pressure control section assembled together as in a normal coring run. The pressure control section can also be pre-charged with nitrogen and the regulator set as in a normal operation if desired. This assembly is surrounded by chambers simulating drill pipe above and below the inner barrel assembly. At the top of this assembly is a pressure balanced manipulator rod that is used to simulate the pull by the wireline to actuate the coring tool at the conclusion of coring. It does not simulate cutting the core.

The chambers are filled with water and the test chambers and autoclave are pressurized to the desired simulated static bottom hole pressure (500 psi in these tests). Then the manipulator rod is pulled to close the ball and open the sleeve valve just as in an actual coring run or dimensional test. During the tests the position of the manipulator can be measured to ascertain the position of the internal parts of the autoclave and pressure control section. The chamber and autoclave pressures are monitored real time. Fish pill pressure recorders can also be used to make a permanent record of the test pressures.

AAI used this test system to simulate the field conditions during the CTF field test and to also test improvement modifications that were suggested by the engineering study or the results of previous tests.

The full function pressure test indicated that if the pressure control section does not supply additional fluid (and pressure) there is significant pressure drawdown in the autoclave due to volumetric changes while coming out of the hole. The pressure reduction can be up to 350 psi from this effect. That means a surface pressure of 150 psi may be full pressure recovery with a 500 psi bottom hole pressure or little or no pressure when recovering pressures lower than 350 psi. This is not the result of a leak or malfunction of the autoclave but is an unfortunate feature of the design of the tool where axial motion is required after ball valve closure. Note that at higher bottom hole pressures, this pressure drop effect is not necessarily amplified significantly. In other words, with a 2000 psi bottom hole pressure one might expect to see 1650 psi (2000 psi – 350 psi) recovered at the surface which does not appear to be as severe a pressure loss and may not be perceived as a failed run even without a working pressure control section.

Several tests proved the ability of the autoclave to hold pressure reliably when the pressure control section operated properly. Note that these tests were conducted with water and not drilling mud.

- Refer to Section 2b: Nitrogen Pressure Boost Failure, for more test results from the Full Function Pressure Tests.

Current Status

Although lab tests indicated that the problem may have been resolved, additional lab testing is highly recommended before field trials. Full scale testing should be carried out, preferably in the vertical position, with simulated downhole conditions. Refer to section titled "TRT Recommendations for Further PCTB Testing".

2b. Nitrogen Pressure Boost Failure

Description

Pressure was not retained during the dimensional tests or coring runs at the CTF even though the ball valve had closed and appeared to have operated properly. At a minimum, a hydrostatic pressure of from 333 psi to 522 psi should have been recovered even with no pressure boost from the pressure control section. The maximum pressure recovered was around 100 psi.

The pressure boost from the pressure control section also did not occur as verified by the fish pill pressure recorder data. Note that this would result if the ball valve closure was delayed and did not close immediately. It does not mean the pressure section did not function.

On Run 8: Cutting Shoe Dimension Test #1 and Flow Test at the CTF, the BHA was run to the casing shoe at 741 ft. Then PCTB cutting shoe configuration A-4 was deployed. Circulation was established resulting in a pump pressure of 35 psi at flow rate of 110 gpm. The PCTB was then recovered and the ball valve was found to be closed. The autoclave was found to have trapped 175 psi. Bottom hole hydrostatic pressure was calculated to be 356 psi. The PCTB regulator was set at 1,000 psi.

On Run 9: Cutting Shoe Dimension Test #2 and Flow Test at the CTF, PCTB cutting shoe configuration B-3 was deployed. Circulation was established resulting in a pump pressure of 35 psi at flow rate of 110 gpm. Upon recovery of the PCTB the ball valve was found to be closed. The autoclave was found to have trapped 196 psi. Bottom hole hydrostatic pressure was calculated to be 356 psi. The PCTB regulator was set at 1,000 psi. However, the pressure control section supply valve was found to have been incorrectly closed, thus negating its function.

On Run 12: Cutting Shoe Core #1 at the CTF, with the bit on bottom at 1,148 ft, PCTB B-2 was deployed. The pressure control section was charged to 3,000 psi with nitrogen and the regulator set at 1,500 psi. Coring commenced with flow rates ranging from 180 – 240 gpm. When the PCTB was recovered, the cutting shoe bit matrix crown was found to be missing. The ball valve was closed but no pressure was captured. Note: The autoclave was re-pressurized in the service unit after the run using the hydrostatic test pump and it held 1500 psi pressure with no leakage observed.

On Run 14: Face Bit Dimensional Test #2 at the CTF, PCTB B-3 was deployed for a dimensional flow test. A circulation pump pressure of 200 psi was applied to the PCTB and then the tool was recovered. The ball valve closed properly, trapping 71 psi. The calculated hydrostatic pressure was 524 psi and the pressure control section had been charged to 3,000 psi with nitrogen and the regulator set at 1,500 psi.

TRT Recommendations

The TRT reviewed participants' notes, the drilling records, photographs, and subsequent bench test data pertaining to the nitrogen boost failure. This is not a straight forward problem, requiring further extensive bench testing to determine the root cause

The TRT recommended;

- Conduct an engineering analysis of the pressure boost system in conjunction with the overall pressure control section.

- Conduct further full function bench testing to determine the root cause of the nitrogen boost failure.

Remedial Action

An engineering study and analysis was conducted with the following results.

- A slow ball valve closure due to a viscous drilling mud could allow fluid and/or pressure provided by the pressure control section to escape before the ball is fully closed.

- An error was discovered in the timing of the events within the redesigned Hybrid PCS. The new inner tube plug check valve was added and the distances were adjusted to provide the same activation timing for ball closure, inner tube travel and opening of the sleeve valve. However, a new study of the system shows that the sleeve valve begins to open just before the new inner tube plug check valve fully closes which may allow some or all of the fluid from the pressure control section to escape before the check valve is fully closed.

To date several full function pressure tests have been conducted at AAI (reference Appendix IV. Post Field Test Full-Function Test Summary). Three Two possible problems have been identified and corrected.

- Two chambers in the autoclave could become pressure traps if operations are done with viscous drilling mud. These pressure traps can result in very slow ball rotation as verified in lab tests using grease as the trapped fluid. The slow rotation would make it easier to jam the ball in a partially open position and could also allow the nitrogen boost to escape before the ball closed. Parts were modified to provide fluid escape paths to speed up ball rotation even when used with viscous drilling fluids (See Section 2a. Hydrostatic Pressure Retention Failure for modification details). The modified parts were tested and confirmed the improved ball valve operation.

- The ball valve closure occurs too early in the closure cycle as verified during initial full function pressure tests. A study of the drawings will be made to confirm this. Parts will be reworked or new parts supplied to correct the problem if confirmed. This error could result in a higher autoclave volume increase and lower pressure recovered.

- Initial full function pressure tests revealed that the sleeve valve may be opening too early in the closure cycle relative to upper check valve closure. This could dump the regulated pressure through the still open ball valve or through the still open upper check valve, resulting in failure to capture the nitrogen boost pressure. The counterbore in the Lift Sub was bored deeper so that the sleeve valve will opened later in the operational sequence. This modification appears to be effective in horizontal full function lab tests. See Appendix Va and Vb. Full Function Pressure Test Charts of original and modified design results, for graphs of horizontal full function lab test results showing the original vs. the modified performance.

Current Status

Although lab tests indicated that the problem may have been resolved, additional lab testing is highly recommended before field trials. Full scale testing should be carried out, preferably in the vertical position, with simulated downhole conditions. Refer to section titled "TRT Recommendations for Further PCTB Testing".

2c. Premature Movement of Separator Piston

Description

During testing at CTF, there was evidence that the separator piston had moved down prematurely on at least one tool while they were staged for deployment. This could have been due to nitrogen seepage under or through one or more of the seals. This could explain the lack of a pressure boost if the piston moved all the way to the end of its travel, with full nitrogen pressure behind it, before reaching the BHA. At the very least this would reduce the effectiveness of the pressure control section.

TRT Recommendations

The TRT reviewed participants' notes, the drilling records, photographs, and the pressure control section design regarding premature movement of the separator piston.

The TRT recommended;

- Hydrostatically test the pressure control system seals and sealing system at AAI.
- If necessary, change seal compound, seal design, and/or sealing surface finishes and shop test to verify satisfactory performance.
- Provide new seals and/or modify parts as necessary.

Remedial Action

- Several pressure tests were conducted at AAI in December, 2013.
- The leaks that caused premature movement of the separator piston could not be reproduced.
- Lab tests showed no leaking of the reservoir or premature movement of the separator piston even when left over an extended period of time during several different tests.
- The premature movement of the separator piston discovered during the field test at CTF appears to be an isolated case due to a defective seal or small scratch on the seal surface.
- These tests will be repeated on all of the pressure control sections as a new FAT requirement.

Current Status

Although premature movement of the separator piston appears to be an isolated case, it should be closely monitored during future full function testing.

2d. Ball Valve Return Spring Jumping Coils/Jamming Issue

Description

During testing at the CTF, the ball valve return spring jumped coils and jammed on at least one dimensional test, preventing the ball from fully closing. This resulted in a failed run with no pressure. During the CTF field test, methods were developed to insure that the spring was correctly centered on the cutting shoe sleeve and checked to insure the ball valve follower moved easily. This prevented any further problems.

During Run 1: Face Bit Space Out Test #1, PCTB tool combination A-4 was deployed. Actuation of the PCTB resulted in the ball valve not closing due to the ball return spring jumping coils and jamming the mechanism.

TRT Recommendations

The TRT reviewed participants notes, photographs, and the ball valve closure design regarding the ball valve return spring jumping coils issue. This is a straight forward problem to solve.

The TRT recommended;

- Investigate adding a spring guide counter bore to the flow sleeve to trap the spring.
- Investigate the manufacture of a counter- clockwise wound spring and test.
- Revise technical manual to add a step to check for correct spring operation.

Remedial Action

- A spring guide in the form of a counter bore was added to a the end of the cutting shoe sleeve to center the end coil of the spring and prevent it from sliding off during assembly and jamming.
- A cutting shoe sleeve was modified and shop tested as part of the full function tests.
- No more jamming problems were observed during many tests.
- Assembly was much easier.
- The investigation into a counter clockwise wound spring was subsequently dropped.

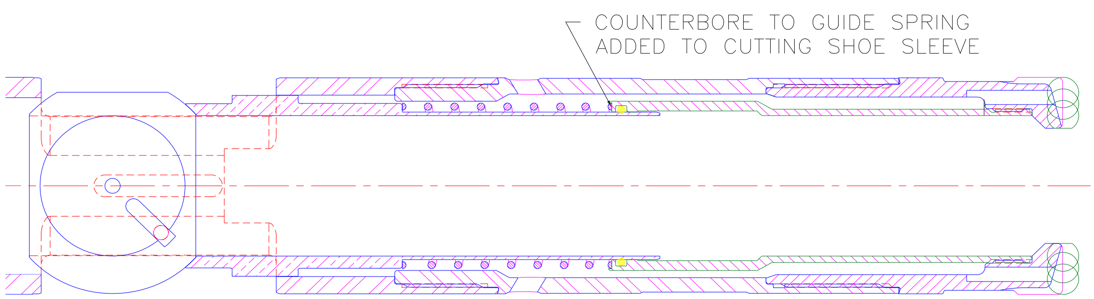

Figure 15. Counter bore added to Cutting Shoe Sleeve.

Current Status

The counterbore was implemented in all cutting shoe sleeve ball followers and also the outer shoes for all of the face bit assemblies.

2e. Concerns Over Premature Release of Autoclave Pressure Due to Weight of Sinker Bar Assembly

Description

It was hypothesized that the weight of the sinker bar assembly, inner latch, extension rods and pressure control section could push down on the inner tube plug, open the new inner tube plug check valve and release the pressure from the autoclave when the trapped pressure in the autoclave was below 736 psi.

TRT Recommendations

The TRT reviewed the design and discussed the theory of premature release of autoclave pressure due to weight of sinker bar assembly. This is a straight forward problem to solve and will have a high impact on the overall PCTB performance.

The TRT recommended;

- Initiate an engineering study of the problem.
- Investigate adding locking dogs inside the inner barrel assembly to prevent downward movement until disassembly.

Remedial Action

- Further engineering study and calculations indicate that it is not possible to reopen the inner tube check valve with the weight of the wireline tools and inner barrel assembly components unless the autoclave pressure falls below 130 psi.
- The engineering study results were verified by a test conducted during one of the Full Function Pressure Tests. The pressure in the autoclave was bled down to 100 psi. The check valve did not reopen even when sufficient force was applied to move the inner tube plug.

- A tentative design was developed by AAI that would lock the autoclave in the extended position and prevent downward movement of the sinker bar assembly after the tool is stroked to the full open position. However, this was abandoned due to the results of the study.

Current Status

Note that movement of the inner tube plug may be observed on the rig floor due to the weight of the sinker bar assembly, upper inner barrel assembly, extension rods, and pressure control section, but this will not reopen the check valve unless there is less than 35 psi inside the autoclave.

A tentative design to lock the autoclave in the extended position and thus prevent downward movement of the sinker bar assembly after the PCTB is stroked to the full open position was developed by AAI. However, this is no longer considered necessary in light of the results of the engineering study and subsequent testing.

3. Inner Tube and Core Liner Failure

3a. Collapse of Inner Tube and Core Liner

<u>Description</u>

The inner tube and core liner imploded during two face bit runs.

During Run 2: Face Bit Dimensional Test #1 at the CTF, when the mud pump was engaged to initiate circulation, a pressure spike of 860 psi was observed. Circulation was established for 30 min. The PCTB was then recovered and upon inspection, it was discovered that the core liner and inner tube had collapsed, preventing the ball valve from closing.

Figure 16. Collapsed inner tube from face bit Dimensional Test #1.

During Run 13: Face Bit Core #2, at the CHEVRON CTF, coring began at a depth of 1,158 ft with 8,000 – 16,000 lb weight on bit, 240 – 250 gpm flow rate, highly variable torque ranging from 1,100 – 3,700 lb-ft, resulting in a variable penetration rate. The coring run was stopped at a depth of 1,164 ft and the PCTB recovered. Upon inspection of the PCTB, the ball valve was found not to have closed and the core liner and inner tube had again collapsed. Note that a review of the pump pressure record indicted that the pump pressure had reached as high as 440 psi.

The inner tube had been redesigned in order to provide more clearance between the ID of the inner tube and OD of the core liner and core catchers to eliminate sticking during core transfer. The redesign utilizes a thin stainless steel tube that provides the necessary ID to provide clearance for the core liner and core catchers. Note, this same inner tube design was used without incident during recent operations that incorporated a cutting shoe.

The inner tube redesign may have contributed to the implosion although the unusually high pressure generated by the face bit may have been the real culprit since the core liner and inner tube did not implode during any of the cutting shoe bit runs.

TRT Recommendations

The TRT reviewed participants' notes, the drilling records, and photographs pertaining to the collapse of the core liner and inner tube in the PCTB face bit configuration. Solving this problem will have a high impact on the overall performance of the PCTB. Solutions may include increasing the total flow area through the inner barrel assembly and main bit.

The TRT recommended;

- Review the flow path and associated restrictions in the BHA for possible flow restrictions.

- Create a SolidWorks model of the inner barrel in a BHA and perform computational fluid dynamics flow simulations to identify large pressure drop areas and make an attempt to eliminate any highly restricted areas.

- Analyze and hydrostatically test the inner tube and core liner to determine their collapse strengths.

- Consider increasing the strength of the inner tube.

- Investigate increasing the total flow area through the main bit.

- An additional goal should be to provide operational parameters for future users.

Remedial Action

- AAI met with the face bit manufacturer and requested them to study the lower end of the PCTB coring system and evaluate the assembled face bit and outer shoe to determine if any areas of high pressure drop at low flow rates exist.

- A reviewed of the design did not discover any areas of excessive high pressure drops at low flow rates.

- AAI performed preliminary calculations to determine the collapse pressure of the thin wall stainless steel inner tube. The calculations indicate that the thin (2.50 OD x 0.49

wall) stainless steel inner tube could collapse when subjected to as little as 370 psi collapse pressure. The calculations also indicated that by using a thicker wall (2.625 OD x 0.109 wall) 303 stainless steel inner tube, the collapse resistance could be increased to over 3,000 psi. (reference Appendix VI. Core Liner Implosion Calculations).

- The computational fluid dynamics modeling was dropped due to time and budget constraints.

- A design for a thicker wall inner tube was created, however, time constraints did not allow for fabrication and testing of new parts.

- General operational parameters have been written into the PCTB Technical Manual for reference by future users.

Current Status

The original thin walled inner tubes were delivered with the PCTB. Although a design for a thicker wall inner tube was created, time constraints did not allow for fabrication and testing of new parts.

The face bit has been modified to increase the total flow area which will alleviate some of the high pressure drop in the lower end of the PCTB, thus reducing the collapse pressure applied to the inner tube.

4. Lessons Learned

4a. Fish Pill Pressure Recorder Set Up Incorrectly

Description

Chevron personnel were originally given the responsibility for operation of the fish pill pressure/temperature recorders but, requested that AAI take over this function at the last minute. A fish pill pressure recorder was set up incorrectly and failed to record the pressure history properly when AAI personnel took over this responsibility without adequate training and practice. This occurred due to a lack of training. Setting up the fish pill recorders is not intuitive.

TRT Recommendation

To prevent this problem from reoccurring, the TRT recommended;

- Specific personnel, who will be on site, should be identified and properly trained in programming and downloading the fish pill pressure recorders.

- Enough personnel, trained on the fish pill pressure recorders, should be made available to cover all hours of coring operations.

Remedial Action

A note regarding this issue has been placed in the PCTB Technical Manual.

Current Status

After using the fish pill recorders during all laboratory testing, AAI personnel have become proficient at deploying them.

4b. Incorrect Parts Manufacture

Description

During Run 1: Face Bit Space-out Test #1 at the CTF, during assembly of the second face bit inner barrel assembly, two problems were discovered. First, one of the outer bearing shafts had not been fully machined. A small upset had been left in the ID of the bearing shaft which prevented the extension rod from passing through it. Second, two of the outer shoes had threads that could not be assembled onto the extension sub.

The defective parts had been ordered at the last minute due to an oversight in ordering by AAI management. The late parts delivery prevented the required 100% inspection and factory acceptance test of those parts.

TRT Recommendations

The TRT recommended 100% inspection be considered as part of the overall manufacturing process and parts are not to be delivered until it has been completed.

Remedial Action

To prevent this problem from reoccurring, orders should be double and triple checked prior to being released to the manufacturer. A double check procedure of pending parts purchase orders has been instituted at AAI. Also, a 100% inspection requirement is considered part of the manufacturing process by AAI and thus parts will no longer be delivered until it is complete.

Current Status

The parts in question were re-machined and inspected prior to delivery with the PCTB.

Procedures for double checking parts purchase orders and 100% inspection have been put in place at AAI.

4c. Face Bit Inner Barrel Assembly Failed to Latch into BHA

Description

A face bit inner barrel assembly failed to latch into the BHA. This was discovered to be due to an assembly error on the rig floor. The cutting shoe upper assembly was installed on the face bit lower assembly by mistake.

During Run 13: Face Bit Core #2 at the CTF, The PCTB was deployed and failed to latch into the BHA and was recovered for visual examination. It was determined that the upper assembly for the PCTB cutting shoe configuration had been assembled with a cutting shoe lower assembly by mistake.

TRT Recommendation

This is a straight forward problem to solve. The TRT recommended that the various subassemblies be color coded so as the correct subassemblies will be made up.

Remedial Action

This problem occurred due to incorrect subassemblies being made up. To prevent this problem from reoccurring, the subassemblies were color coded for easier identification.

Current Status

The various PCTB subassemblies were color coded prior to delivery.

Figure 17. Color coded subs for easier identification.

4d. AAI Personnel Assembled Tools Incorrectly on Three Runs

Description

AAI personnel assembled tools incorrectly on three PCTB deployments. One inner barrel assembly was assembled with the supply bullet valve closed which prevented the pressure control section from applying pressure to the autoclave on the first dimension test. A second inner barrel assembly was assembled with only the basket catcher when it had been expressed to run both a basket and slip catcher. A third tool was assembled without a lockout washer when the desire to use the lockout washer had been expressed.

TRT Recommendation

This is a straight forward problem to solve. The TRT recommended that a run request form be established which states specifically what configuration PCTB or center bit is to be deployed, requiring the signature of all concerned prior to assembly and deployment of the PCTB.

Remedial Action

This problem occurred due to miscommunication and fatigue. To prevent this problem from reoccurring, a run request form (reference Appendix VII. AAI Run Request Form) has been instituted. The run request form specifically states what configuration PCTB is to be deployed and must be signed off by all concerned prior to assembling and deploying the PCTB.

Current Status

A Run Request form has been instituted (reference Appendix VII. AAI Run Request Form). The Run Request form specifically states what configuration PCTB is to be deployed and must be signed off by all concerned prior to assembling and deploying the PCTB. A note regarding use of the run request form has been added to the PCTB Service Manual

4e. Premature Comment by AAI Crew Regarding Pawls Mis-Operation

Description

During the review of the failed PCTB deployment, a premature, incorrect comment by one of the AAI crew regarding that the pawls may have not locked under the seal sub was disseminated prior to completion of the review. The failure was later correctly identified to be due to the inner tube plug moving all the way into the seal sub.

TRT Recommendation

The TRT recommended;

- Only the coring service technicians, and invited personnel, should be in the service unit at any time, especially during the review of failed tools.

- Information regarding any given failure should not be considered valid until an official report is distributed.

Remedial Action

The comment in question was made during the review of the PCTB after a failed coring run. During all such reviews, all ideas, right or wrong, regarding the cause of failure should be expressed and discussed. Only after the true cause of a failure has been discovered should an official report be submitted for distribution. Until the official report is distributed, all comments regarding failures should be considered as speculation. Also, only those personnel actively servicing the coring tools should be given admittance to the service unit.

Current Status

Not applicable.

4f. Insufficient Staff to Adhere to Protocol and Verify Correct Documentation

Description

Insufficient staff was on hand for the PCTB testing at the CTF. The staff became fatigued resulting in incomplete record keeping and PCTB configurations assembled incorrectly.

TRT Recommendation

This is not a straight forward problem to solve since it relies on the willingness of the client to support the PCTB to the level required. It will also be difficult to maintain a full complement of trained coring technicians and have them available for only periodic deployments. Solving this problem will have a high impact on the PCTB overall performance.

The TRT recommended that at a minimum, three coring service technicians, one records technician, and one rig floor coring engineer per 12 hour shift, plus one overall coring supervisor be available to fully support PCTB deployments.

Remedial Action

Sufficient trained personnel should be on site to cover all hours/shifts during coring operations. A minimum of three coring service technicians, one records technician, and one rig floor coring engineer are required per 12 hour shift, plus one overall coring supervisor for continuous pressure coring operations. The rational for this is as follows. It takes two service technicians to dress and prepare an autoclave, and one service technician to dress, recharge and prepare a pressure control section. The records technician would insure that the proper documents were prepared and completed and could also provide a quality assurance function by carrying out the necessary independent double checks for critical settings and tests. The records technicians would also serve as a liaison with the coring supervisor to be sure that tools were being set up and equipped as requested by management. The records technician could also be responsible for maintaining the fish pill pressure recorders. Having sufficient manpower in the service unit and a separate coring supervisor to interface with the client would free up the rig floor coring engineers to devote themselves to ensure that tools were being assembled, serviced and run properly without the distraction of additional responsibilities.

Current Status

Ensuring sufficient staff are on hand to properly support PCTB deployments relies on the willingness of the client to support the PCTB to the level required.

Remedial Action

The TRT recommends a minimum of eleven coring technicians or supervisors to be on hand for any future 24 hour field test or operation. A minimum of three coring service technicians, one records technician, and one rig floor coring engineer are required per 12 hour shift, plus one overall coring supervisor for continuous pressure coring operations.

Appendix I. TRT Interim Report

HYBRID PRESSURE CORING SYSTEM

Technical Review Team Interim Report

Following Onshore Testing at Catoosa Test Facility

3 November – 13 November 2013

DOE/Chevron Hybrid Pressure Coring System Contract CW1094939

23 December 2013

Technical Review Team Members

Tom Pettigrew (Team Leader), Principal, Pettigrew Engineering
Jim Aumann, Principal, Aumann and Associates
Tim Collett, Co Chief Scientist, United States Geological Survey
Tom Fate, Coring Subject Matter Expert, Chevron Energy Technology Company
John Roberts, (Ad hoc member) Technical Director, Geotek

Executive Summary

Following the onshore testing of the Hybrid Pressure Coring System (H-PCS) at the Catoosa Test Facility 3 November – 13 November 2013, a Technical Review Team (TRT) was formed to review the H-PCS performance and to make recommendations for improvement. Four major areas of concern were identified, 1) bit design issues, 2) pressure retention issues, 3) inner tube and core liner failure issues, and 4) lessons learned.

The TRT reviewed the H-PCS initial onshore test results and AAI's observations, the overall design, the overall manufacturing processes and procedures, the factory acceptance testing procedures, and overall servicing and operational procedures as well as participants notes, photographs, drilling data record and verbal accounts. The TRT then made a summary of recommended changes to the H-PCS for improving overall performance. A description of the work processes the TRT used to evaluate the onshore test performance results is included. The TRT also reviewed the lessons learned and made recommendations to prevent repeating such mishaps in the future.

The TRT attempted to identify the root cause of each individual failure by reviewing participants notes, drilling data record, photographs, and verbal accounts. Where failure root causes were identified, the TRT recommended potential solutions along with an estimated cost and time to complete. Where failure root causes could not be identified, the TRT recommended a laboratory testing scheme that may help identify those failure root causes.

Given the short time frame between completion of the onshore testing and submission of this interim report a complete analysis of all issues was not possible. However, many of the issues identified have already been addressed by Aumann & Associates, Inc. (AAI). Also, during the preparation of this report, AAI has been conducting numerous laboratory tests to confirm identified root causes and in some cases has modified parts and retested to confirm the recommended solutions worked. This ongoing work by AAI will be detailed in the final report.

In preparing the final report, to be submitted at a later date, the TRT recommends a review of passed deployment performance of the H-PCS in conjunction with a review of any design changes made between then and the present design along with what drilling fluids were used. Such a review will aid the TRT in better understanding the overall H-PCS performance history and possibly determining other root causes of the failures during the onshore testing. Additional laboratory testing will also need to be carried out to identified the remaining "still to be determined" root causes of failure before recommended solutions can be put forth.

Introduction

As a replacement for the ODP Pressure Core Sampler (PCS) and in preparation for proposed pressure coring during IODP Expedition 337 in 2011, JAMSTEC contracted with Aumann & Associates to develop a new pressure core system – the Hybrid Pressure-Coring System (Hybrid-PCS or H-PCS). In the end the Hybrid-PCS was not deployed on IODP Expedition 337 but was adopted by JOGMEC as the replacement pressure core system for the Pressure-Temperature Coring System (PTCS). The Hybrid-PCS is compatible with the standard drill pipe and coring IODP-BHA on the D/V Chikyu. The maximum length of a Hybrid-PCS core is 3.5 m, and the diameter is 5.1 cm. After cutting a core, a ball valve at the bottom of the autoclave is closed to seal the core during wireline retrieval.

JOGMEC recently used the new Hybrid-PCS (cutting shoe version only) to conduct pressure coring operations from the D/V Chikyu during the 2012 phase of the MH□21 Nankai Trough Pre□Production Expedition. During this expedition, 21 pressure cores were recovered from a 60 m interval section in one hole. Sampled lithologies range from clay-rich sediments in the overburden formation to sandy layers with high concentrations of methane hydrate in the targeted interval. Geotek's PCATS was used to transfer, analyze, and subsample 35 m of core recovered under pressure. After X-ray CT imaging and non-destructive analysis under in situ pressures, over 60 samples between 10 cm and 120 cm long were cut and stored for further detailed on-shore analysis by scientists.

Since the completion of the 2012 Hybrid-PCS pressure core operations in the Nankai Trough, the GOM JIP has been working with JOGMEC (who is also a member of the GOM JIP) and Aumann & Associates to develop a replacement system for the HPTC. It has been decided that the GOM JIP and Aumann & Associates, along with the support of JOGMEC, will work together to modify the existing Hybrid-PCS system with engineering learning's from the 2012 Nankai Trough coring program and conduct an onshore test of the modified Hybrid-PCS in Catoosa, Oklahoma in November of 2013.

The test of Hybrid-PCS in Catoosa began 3 November 2013 and ended 13 November 2013. A total of 16 tests of the Hybrid PCS were carried out with mixed results of success. Problems from low penetration rate to failure of a cutting shoe to inability to retain hydrostatic pressure to collapse of the inner tube to failure of the pressure control section, etc., plagued the Hybrid-PCS operation throughout the tests.

A Technical Review Team (TRT) was formed to review the Hybrid-PCS onshore test results and make recommendations for improvements to the tool and associated procedures, in hopes of improving the Hybrid-PCS overall performance and reliability.

Following is the TRT interim report, to be followed at a later date by a final report.

TRT Comments on the H-PCS Onshore Testing and the Results (reference Appendix A: Chevron CTF Field Test Run Summary and Appendix B: Hybrid Pressure Coring System Configurations)

Run 1: Face Bit Space Out Test #1

A Hybrid Pressure Coring System (H-PCS) face bit configuration space out test was conducted using tool combination A-4. After adjustments were made in the inner barrel assembly, the core catchers were observed to be spaced out at 1/8". Actuation of the H-PCS resulted in the ball valve not closing due to the ball return spring jumping coils and jamming the mechanism. During assembly of the second face bit inner barrel assembly two problems were discovered. First, one of the outer bearing shafts had not been fully machined. A small upset had been left in the ID of the bearing shaft which prevented the extension rod from passing through it. Second, two of the outer shoes had threads that could not be assembled onto the extension sub. Subsequently these parts were taken to local machine shops and the problems corrected by boring out the bearing shaft to the correct ID and chasing the threads on the outer shoes. Following the space out test, the BHA was run in the hole to 741 ft.

Run 2: Face Bit Dimensional Test #1

After redressing the H-PCS, it was lowered on wireline to the BHA at 741 ft for Dimension Test #1. The H-PCS landed and latched in the BHA and then released properly. When the mud pump was engaged to initiate circulation, a pressure spike of 860 psi was observed. Circulation was established for 30 min. Note that the Dimensional Tests were intended to be circulation and function tests in the casing with no coring attempted. The H-PCS was then recovered on wireline

Figure 2. Collapsed inner tube from face bit Dimensional Test #1.

without incident. Upon inspection of the H-PCS, it was discovered that the liner and inner tube had collapsed, preventing the ball valve from closing.

Run 3: Face Bit Near Surface Flow Test #1

With the tool redressed, a near surface flow test #1 was conducted. With no core liner or inner tube installed in the tool, the pump pressure was observed to be ~20 psi at a flow rate of 120 gpm.

Run 4: Face Bit Near Surface Flow Test #2

The inner tube and liner were installed in the tool and near surface flow test #2 was carried out. The pump pressure was observed to be ~70 psi at a flow rate of 120 gpm.

The decision was made to change the testing program and begin testing the H-PCS cutting shoe configuration because of the problem with the collapsed inner tube and core liner and the desire to test a configuration that had been successful on previous operations. The BHA was recovered and reconfigured for the H-PCS cutting shoe operation by replacing the face bit with the cutting shoe bit.

Run 5: Cutting Shoe Space Out Test

The H-PCS cutting shoe configuration, using tool combination B-3, was assembled and place inside the BHA at the surface. The cutting shoe was observed to be positioned 1/4" inside the main bit face and the core catcher was observed to be 3/16" inside the cutting shoe.

Run 6: Cutting Shoe Surface Flow Test

A cutting shoe surface flow test was then conducted using tool combination A-2. The pump pressure was observed to be 60 psi at a flow rate of 108 gpm. Upon recovery of the tool the ball valve was observed to have closed properly. Note, in accordance with the test plan, no nitrogen charge was used for this test.

Run 7: Center Bit Space Out Test

Upon inserting the cutting shoe center bit C-5 in the BHA, it was observed that the center bit protruded 1" beyond the face of the main bit. It was expected that the center bit would only protrude about 7/16" ahead of the main bit. There was some concern that the extra exposure might be a weak point or cause a problem.


Figure 2. Center bit cutting shoe extension

When circulation was established no significant pump pressure was observed at a flow rate of 160 gpm. Note that the recorded pump pressure data appears to be inconsistent at times and therefore possibly suspect. The center bit was removed from the BHA and the BHA was tripped to 741 ft.

Run 8: Cutting Shoe Dimension Test #1 and Flow Test

The BHA was run to the casing shoe at 741 ft. Then H-PCS cutting shoe configuration A-4 was lowered to the BHA on wireline where it landed and latched into the BHA properly. The wireline was released without incident and recovered. Circulation was established resulting in a pump pressure of 35 psi at flow rate of 110 gpm. The H-PCS was then recovered and the ball valve was found to be closed. The autoclave was found to have trapped 175 psi. Bottom hole hydrostatic pressure was calculated to be 356 psi. The H-PCS regulator was set at 1,000 psi.

Run 9: Cutting Shoe Dimension Test #2 and Flow Test

The H-PCS cutting shoe configuration B-3 was lowered to the BHA on wireline where it landed and latched into the BHA properly. The wireline was released without incident and recovered. Circulation was established resulting in a pump pressure of 35 psi at flow rate of 110 gpm. Upon recovery of the H-PCS the ball valve was found to be closed. The autoclave was found to have trapped 196 psi. Bottom hole hydrostatic pressure was calculated to be 356 psi. The H-PCS regulator was set at 1,000 psi. However, the pressure control section supply valve was found to have been incorrectly closed, thus negating its function.

Run 10: Cutting Shoe Center Bit Test

The H-PCS cutting shoe center bit was assembled and lowered to the BHA on wireline. The BHA was lowered to TD at 1064 ft where test drilling occurred. The hole was drilled with 380 – 425 gpm flow rate. Only 6 ft of hole was made in the first 2 hours. No penetration was made in the last half hour and the decision was made to pull the BHA and reconfigure it for conventional drilling. When the bit reached the rig floor, it was found to severely balled up and three nozzles were plugged. One cutting shoe center bit nozzle was found plugged as well.

Run 11: Conventional Drilling to Core Point

With the bit back on bottom, the hole was drilled to 1,148 ft for the next coring test. The drilling BHA was then recovered and reconfigured for the H-PCS cutting shoe configuration.

Run 12: Cutting shoe core #1

With the bit on bottom at 1148 ft, the H-PCS B-2 was lowered in the hole on wireline. The H-PCS landed and latched into the BHA properly. The wireline was released without incident and recovered. The pressure control section was charged to 3,000 psi with nitrogen and the regulator set at 1,500 psi. Coring commenced with flow rates ranging from 180 – 240 gpm, torque ranged from 3,000 – 3,500 lb-ft, and weight on bit was 16,000 lb. Penetration was slow for the first 1-1/2 ft then increased to 20 – 25 ft/hr to a depth of 1158 ft. The H-PCS was then recovered. Upon inspection of the recovered H-PCS, the cutting shoe bit matrix crown was found to be missing. The ball valve was closed but no pressure was captured. About 0.9 ft of core was recovered and was jammed in the core liner. The autoclave was repressurized in the service unit after the run using the hydrostatic test pump and it held 1500 psi pressure with no leakage observed.

The BHA was then pulled out of the hole for reconfiguration into the face bit configuration. The cutting shoe main bit was found to have a chatter pattern on the ID which may have been created by the disintegrating cutting shoe head.


Figure 3. Chatter pattern observed on main bit

Run 13: Face Bit Core #2

The H-PCS was picked up and run in the hole. Upon failure of the H-PCS to latch into the BHA, it was recovered for visual examination. It was determined that the upper assembly for the H-PCS cutting shoe configuration had been picked up and assembled by mistake. The correct H-PCS A-3 configuration was assembled and run in the hole. The H-PCS landed, latched and released properly, and the wireline was recovered. Coring began at a depth of 1158 ft with 8,000 – 16,000 lb weight on bit, 240 – 250 gpm flow rate, highly variable torque ranging from 1,100 – 3,700 lb-ft, resulting in variable penetration rate. The coring run was stopped at a depth of 1164 ft and the H-PCS recovered. Upon inspection of the H-PCS, the ball valve was found not to have closed. It was discovered that the liner and inner tube had again collapsed. A review of the pump pressure record indicted that the pump pressure had reached as high as 440 psi.

Run 14: Face Bit Dimensional Test #2

The H-PCS tool combination B-3 was deployed for a dimensional flow test. A circulation pump pressure of 200 psi was applied to the H-PCS and then the tool was recovered. During disassembly of the upper assembly from the lower assembly on the rig floor, the sinker bar was locked using a pipe wrench to prevent the sinker bar weight from resting on the inner barrel subassembly and possibly reopening the check valve on the top of the inner tube plug. The ball valve closed properly, trapping 71 psi. The calculated hydrostatic pressure was 524 psi and the pressure control section had been charged to 3,000 psi with nitrogen and the regulator set at 1,500 psi.

Run 15: Face Bit Center Bit Test

The face bit center bit combination C-5 was deployed for a drill ahead test. The hole was drilled from 1164 ft to 1188 ft with a penetration rate of up to 22 ft/hr with the pump pressure at 175 psi at a flow rate of 310 gpm and 10,000 – 15,000 lb weight on bit. No problems occurred with the face bit center bit.

Summary List of Issues Resulting from Onshore Testing of the H-PCS

– Bit design issues

- Cutting shoe center bit extended further ahead of main bit than expected (1” actual vs. 15/32” design).
- Cutting shoe crown disintegrated during first and only attempt with cutting shoe and inner barrel assembly.
- Cutting shoe bit/center bit combination resulted in very slow drilling with ROP of 1 foot/hour for four hours.
- A high differential pressure created during pumping operations with the face bit could be a result of inadequate total flow area of the face bit; however, further investigation is required to draw this conclusion.

– Pressure Retention issues

- Autoclave pressure was not retained during either the dimensional tests or the coring runs even though the ball valve closed and appeared to operate properly. The maximum pressure recorded was around 100 psi.
- The pressure boost from the pressure control section did not occur which was verified by the fish pill recorder data.
- There was evidence that the separator piston moved down prematurely on some tools while they were waiting to be run.

- The return spring jumped coils and jammed on at least one dimensional test which prevented the ball valve from closing.
- The weight of the sinker bar assembly, inner latch, extension rods and pressure control section could push down on the inner tube plug which would release pressure from the autoclave at trapped pressures below 130 psi.

– Inner tube and core liner failure

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

– Lessons Learned

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

Hybrid Pressure Coring System Overall Design and Areas of Improvement

The H-PCS design is rather complex. A review of the design by experienced downhole tool designers should be undertaken to determine if the design can be simplified. Any reduction in the number and complexity of parts may help reduce the number of malfunctions, as well as, make the tool more user friendly. For the interim report, the TRT focused on the H-PCS overall operation. A full review of the overall design will be addressed in the final report.

Hybrid Pressure Coring System Overall Manufacturing Processes and Procedures and Areas of Improvement

There are two levels of factory acceptance requirements used by AAI in the manufacture of the H-PCS. First, AAI requires a 100% measured and documented inspection of each part. Second, AAI conducts final acceptance tests (FAT) on each assembly. See the next section for an explanation of the problems and solutions.

Hybrid Pressure Coring System Factory Acceptance Testing Procedures and Area of Improvement

The Factory Acceptance Test (FAT) consists of hydrostatic proof testing to 1.5 times the rated working pressure, additional hydrostatic function tests and horizontal "bench" tests verifying the correct operation of the assembled tools. These procedures are fully documented, followed and verified by Chevron personnel on all of the cutting shoe assembly components. However, very late in the process AAI personnel discovered that the special conversion parts required for the face bit assemblies had been omitted from the ordering process. As soon as this was discovered, AAI placed the orders. AAI's suppliers indicated that they would still be able to complete the parts in time for the field test program. Unfortunately, the completion dates were optimistic and in an attempt to meet the deadline, the inspection procedures were not followed rigorously and parts were delivered too late to assemble them and conduct the FAT's before shipping them for the field test program. In fact some of the parts arrived after the main shipment was made to CTF and there were no assemblies to test them with. A special shipment of those parts was made separately to CTF. These last minute parts were the parts that were found to have the defects that had to be corrected by local machine shops in Oklahoma.

In the future AAI needs to add a QA function to the ordering process to check the AAI purchase orders against the customer order list and this needs to be done early in the ordering process. AAI also recently developed a method and pressure test parts that provides a way to hydraulically function test complete lower assemblies. This "Full Function Pressure Test" simulates bottom hole conditions horizontally in the shop. This new Full Function Pressure Test should be added to the list of required FAT's and, at a minimum, used as a qualification test for any design changes and probably as one of the FAT's required for each assembly.

Hybrid Pressure Coring System Overall Servicing and Operational Procedures and Areas of Improvement

This issue will be addressed after further review by the TRT in the final report.

Summary of Recommended Short Term (prior to 1 March 2013) Changes for Improving Overall Performance (reference Appendix C: Summary of Hybrid Pressure Coring System Improvements)

<u>Cutting Shoe Crown Disintegration</u>
Fabricating all-steel cutting shoes will be explored.

<u>Cutting Shoe Center Bit Low Penetration Rate</u>
Representatives from bit manufacturers will be brought in to analyze the existing cutting shoe center bit design in relation to the main bit design. The cutting shoe center bit design will then be changed based on their input.

<u>Premature Movement of Separator Piston</u>
Hydrostatically test the pressure control system seals and sealing system at AAI. Change seal compound, seal design, and/or sealing surface finishes and shop test to verify satisfactory performance. Provide new seals and/or modify parts as necessary.

<u>Ball Valve Return Spring Jumping Coils</u>
Investigate adding a counter bore to flow sleeve to trap the spring. Manufacture and test counter clockwise wound springs. Revise technical manual to add step to check for correct spring operation.

Collapse of Inner Tube and Core Liner

Review circulation flow path around and through the H-PCS when latched into the BHA. Create a SolidWorks model of the H-PCS inside the BHA and run flow simulations to identify large pressure drop areas and make an attempt to eliminate any highly restricted areas. Analyze and hydrostatically test the inner tube and core liner to determine their collapse strength at AAI. Additional goal should be to provide operational parameters for future users. Note, this work will be completed during 1Q2014.

Solutions include increasing the total flow area through the inner barrel assembly and through the bit. Investigate adding changeable nozzles to provide an easy way to reduce the high BHA differential pressure experienced with the face bit configuration. Also consider increasing the strength of the inner tube if it increases resistance to core liner collapse or, if lab tests confirm a very low collapse pressure and if increasing the inner tube strength increases core liner collapse strength.

Face Bit Inner Barrel Assembly Failure to Latch into BHA

Color coding will be painted on the upper subassemblies (outer bearing and inner barrel sub) to help prevent incorrect assembly in the future.

Summary of Recommended Long Term Changes for Improving Overall Performance

(reference Appendix C: Summary of Hybrid Pressure Coring System Improvements)

Cutting Shoe Center Bit Apparent Excessive Extension

Design and manufacture length adjuster system for spacing out the center bit assembly inside the BHA.

Concerns Over Premature Release of Autoclave Pressure Due to Weight of Sinker Bar Assembly

Add locking dogs inside the inner barrel assembly to prevent downward movement until disassembly.

Overall Performance Issues Still to be Determined

High Pump Pressures Associated with the Face Bit Inner Barrel Assembly

Analyze the flow through the assembly and modify to increase flow areas in restricted areas. Analyze the collapse strength of the PVC core liner in a best case while supported by the original full strength inner tube. Note, the current inner tube is the best that could be achieved without redesigning the tool with a full length steel inner tube which would necessitate a significantly reduced core size.

This same analysis and modification procedure should be completed for the Cutting Shoe Inner Barrel Assembly, to ensure that the maximum flow area exists with it as well.

Hydrostatic Pressure Retention Failure

Full function hydrostatic lab tests and engineering study required.

Nitrogen Pressure Boost Failure

Most likely a failure of ball valve closure or leaky seals in the pressure control section. Full function hydrostatic lab tests and engineering study.

Work Process the TRT Used to Evaluate Onshore Test Performance - Bit and Overall High Pump Pressure Issues

Cutting Shoe Center Bit and Apparent Excessive Extension

The TRT reviewed participants notes and photographs pertaining to the cutting shoe center bit apparent excessive extension. The extension was determined to be ~1 inch ahead of the main bit face. The apparent excessive center bit extension could be a result of one of three issues, 1) mismade parts, 2) machine drawings dimensioned incorrectly, or 3) tolerance stack up through the assemblies involved. The nominal assembly drawing results in a center bit extension of 0.437in. AAI checked the length of the center bits and learned that they were designed and manufactured 0.290" longer than the nominal dimension on the drawing. The drawing does allow for this. However, this would result in a center bit extension of 0.727" without considering the fairly large tolerances in the BHA components. The TRT determined that the center bit space out should be verified as designed, as well as, verify all parts were correctly manufactured. This approach will resolve issues 1 and 2. As for the tolerance stack up issue, this could be a reoccurring problem. The allowed variation due to specified tolerances is 0.12" on the landing saver sub, 0.75" on the seal bore outer core barrel and 0.15" on the stabilized modified bit sub. Therefore, specified tolerances alone could allow for the observed center bit extension. To resolve this issue the TRT determined that an adjustment mechanism be designed that will allow the center bit to be properly spaced out with each new BHA used.

Cutting Shoe Crown Disintegration

The TRT reviewed participants notes and photographs pertaining to the cutting shoe crown disintegration, as well as, examined the actual failed cutting shoe. The failed cutting shoe was inspected by the manufacturer, who determined by visual inspection that the crown material and it's bond to the steel body were without defect. AAI is having an independent study carried out by a metallurgical lab technician who is a matrix expert with many years of experience at Christensen Diamond Products. He is now a consultant. he will review the failed cutting shoe shank and also section and inspect the matrix to steel bond area of another cutting shoe under a microscope. That study will not be completed until 1Q2014. The cutting shoe crown was observed to be intact when deployed. Exactly what caused the failure cannot be determined. The crown may have be cracked due to mishandling on the rig and then failed down hole, or may have simply self destructed during the core cutting process. Note that failure of a cutting shoe matrix crown occurred once before. This was attributed to an incorrect furnacing procedure by the manufacturer. To prevent any future failure of the cutting shoes, the TRT recommended AAI explore manufacturing all steel cutting shoes, thus eliminating the matrix crown . In addition, a simple protective sleeve should be supplied to protect the cutting shoes and/or center bits as they are being moved to and handled on the rig floor. These protectors should not be removed until they are being placed in the drill pipe. Note that a similar protector should be provided to protect the relatively weak bearing shaft that extends out of the bottom of the upper assembly.

Cutting Shoe/Center Bit Penetration Rate

The TRT reviewed participant's notes and the drilling record regarding the variable penetration rate observed when coring with the cutting shoe and drilling ahead with the cutting shoe center bit. Note that center bit penetration rates are often variable due to formation changes and the relative slow rotation of the cutters at the center bit. Also, adequate cleaning by circulation of the cutting shoe and center bit faces is difficult to achieve due to the restricted flow paths through the assemblies. The TRT recommended that a bit design expert be engaged to review the overall cutting shoe and center bit cutting structures in conjunction with the main bit to optimize the overall cutting efficiency.

High Pump Pressure Associated with the Face Bit Inner Barrel Assembly

The TRT reviewed participant's notes and the drilling record regarding high pump pressures associated with the face bit inner barrel assembly. It was observed that the pump pressure was inconsistent with flow rate. For example, during Run #2 Face Bit Dimensional Test #1, pump pressures greater than 600 psi were observed at a flow rate of 113 gpm. While during Run #4 Face Bit Near Surface Flow Test #1, with the inner tube in place, the pump pressure was ~70 psi at a flow rate of 120 gpm. The exact cause of this phenomenon could not be determined and additional flow tests are required.

Work Process the TRT Used to Evaluate Onshore Test Performance – Pressure Retention Issues

Hydrostatic Pressure Retention

Several horizontal pressure tests were conducted by AAI at their facilities. A so called Full Function Pressure Test configuration was used for these tests. This test configuration virtually encases the autoclave and pressure control section in chambers that can be used to simulate actual bottom hole conditions. Pressures above, below and inside the autoclave can be controlled and/or monitored while manipulating the position of the position of the inner components simulating wireline operations. The Fish Pill downhole recorders were also used to record the internal and external pressures.

The tests showed a pressure draw down of over 180 psi due to the increase in chamber volume as the inner tube plug continues to move up after ball closure. The tests proved that the pressure draw down effect is lessened but not eliminated by the addition of the new inner tube check valve. (Note that previous tests showed that without the new check valve, pressure draw down could be up to 600 psi.) This could explain the capture of 170psi instead of the expected 350 psi in the dimensional tests carried out at the casing shoe

Nitrogen Pressure Boost Failure

To date several full function pressure tests were conducted at AAI. Three possible problems have been identified.

1. Two chambers in the autoclave could become pressure traps if operations are done with viscous drilling mud instead of seawater. These pressure traps can result in very slow ball rotation as verified in lab tests using grease as the trapped fluid. The slow rotation would make it easier to jam the ball in a partially open position and could also allow the N2 supplied to escape before the ball closed. Parts were modified to provide fluid escape paths to speed up ball rotation even when used with viscous drilling fluids. The modified parts were tested and confirmed the improved ball valve operation.


Figure 4. Flow slots added to Collet


Figure 5. Flow grooves added to Ball Valve Follower

2. The ball valve closure occurs too early in the closure cycle as verified during initial full function pressure tests. As study of the drawings will be made to confirm this. Parts will be reworked or new parts supplied to correct this during 1Q2014 if this problem is confirmed. This error could result in a higher autoclave volume increase and lower pressure recovered.

3. Initial full function pressure tests revealed that the sleeve valve may be opening too early in the closure cycle. This could dump the regulated pressure out the still open ball valve or out the still open upper check valve. This error could result in the failure to capture the boost pressure. This does not explain the failure to capture hydrostatic pressure.

4. More tests need to be done to absolutely confirm the above.

Premature Movement of Separator Piston

Several pressure tests were conducted at AAI in December, 2013. The leaks that caused premature movement of the separator piston could not be reproduced. Tests showed no leaking of the reservoir or premature movement of the separator piston even when left over an extended period of time during several different tests. Apparently the premature movement of the separator piston discovered during the field test at CTF was an isolated case due to a defective seal or small scratch on the seal surface. These tests prove the design or selection of the seal material is not flawed. These tests will be repeated on all of the pressure control sections as a new FAT requirement.

Spring Jumping Coils/Jamming Issue

During December, a small counter bore was added to the upper end of the cutting shoe sleeve to provide a way to center the end of the return spring correctly on the ball follower during assembly and in operation. Tests with the modified part showed that it not only made assembly easy, it also completely eliminated the problem experienced during the field test of the spring coils jumping and sometimes jamming the ball follower preventing the ball from closing. The addition of the counter bore appears to have eliminated these problems completely. AAI will also adding a step to the Assembly Manual to pull back the ball follower against the spring after assembly to verify that it is not jamming.

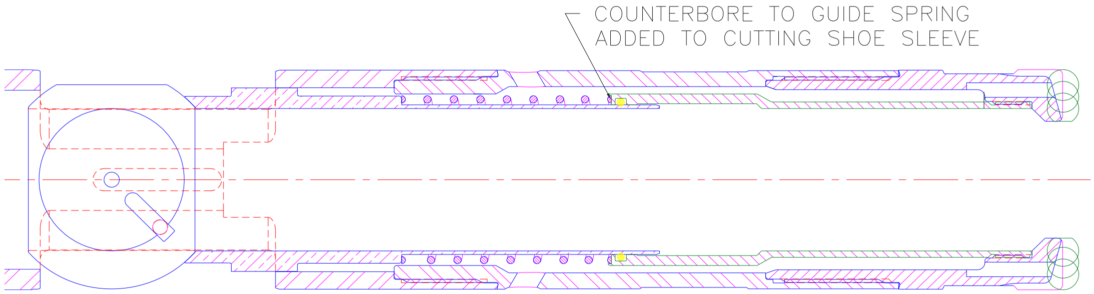

Figure 3. Counter bore added to Cutting Shoe Sleeve

Concerns Over Premature Release of Autoclave Pressure Due to Weight of Sinker Bar Assembly

Further engineering study and calculations confirmed that it is not possible to reopen the inner tube check valve with the weight of the wireline tools and inner barrel assembly components unless the autoclave pressure falls below 130psi. This will be confirmed in a full function pressure test in the near future. A tentative design was also developed by AAI that would lock the autoclave in the extended position and prevent downward movement after the tool was stroked to the fully open position. However, this is no longer considered necessary in light of the results of the above study.

Work Process the TRT Used to Evaluate Onshore Test Performance – Collapse of Inner Tube and Core Liner

Collapse of Inner tube and Core Liner

A layout was made for a possible simple inner tube and core liner hydrostatic pressure test by the addition of a few parts to the autoclave and using the autoclave as a pressure test chamber. With these tests, collapse values for the original inner tube, new thin wall SS inner tube or any new designs could be positively established without the need for an expensive flow test. Parts could be manufactured and collapse tests conducted during 1Q2014.

Lessons Learned (reference Appendix B: Summary of Recommended Hybrid PCS Improvements)

Fish Pill recorder Set Up Incorrectly

This occurred due to a lack of training. Setting up the fish pill recorders is not intuitive. To prevent this problem from reoccurring, specific personnel, who will be on site, should be identified and properly trained. Enough trained personnel should be made available to cover all hours of coring operations.

Incorrect Part Manufacture

The defective parts were parts that were ordered at the last minute because of an oversight in ordering by AAI management. The late parts delivery prevented the required 100% inspection and factory acceptance test of those parts. To prevent this problem from reoccurring, orders should be double and triple checked prior to being released to the manufacturer. Also, the 100% inspection requirement should be considered part of the manufacturing process and thus the parts not delivered until it is complete.

Face Bit Inner Barrel Assembly Failed to Latch into BHA

This problem occurred due to incorrect subassemblies being made up. To prevent this problem from reoccurring, the subassemblies will be color coded painted for easier identification.

AAI Personnel Assembled Tools Incorrectly on Three Runs

This problem occurred due to miscommunication and fatigue. To prevent this problem from reoccurring, a run request form will be instituted. The run request form will specifically state what configuration H-PCS is to be deployed and signed off by all concerned prior to assembling and deploying the tool.

Premature Comment by AAI Personnel Regarding Pawls Mis-Operation

The comment in question was made during an autopsy of an H-PCS after a failed coring run. During all such autopsies, all ideas, right or wrong, regarding the cause of failure should be expressed and discussed. Only after the true cause of a failure has been discovered should an official report be submitted for distribution. Until the official report is distributed, all comments regarding failures should be considered as speculation. Also, only those personnel actively servicing the coring tools should be given admittance to the service unit.

Insufficient Staff to Adhere to Protocol and Verify Correct Documentation

Sufficient trained personnel should be on site to cover all hours/shifts during coring operations. A minimum of three coring service technicians, one records technician, and one rig floor coring engineer are required per 12 hour shift, plus one overall coring supervisor for continuous pressure coring operations. The rational for this is as follows. It takes two service technicians to dress and prepare an autoclave, and one service technician to dress, recharge and prepare a pressure control section. The records technician would insure that the proper documents were prepared and completed and could also provide a quality assurance function by carrying out the necessary independent double checks for critical settings and tests. The records technicians would also serve as a liaison with the coring supervisor to be sure that tools were being set up and equipped as determined by management. The records technician could also be responsible for maintaining the fish pill recorders in the case where Geotek personnel did not have that responsibility. Having sufficient manpower in the service unit and a separate coring supervisor to interface with the client would free up the rig floor coring engineers to devote themselves to ensure that tools were being assembled, serviced and run properly without the distraction of additional responsibilities.

Discussion on Implementation of Recommendations for Performance Improvement

(reference Appendix B: Summary of Recommended Hybrid PCS Improvements)

Cutting Shoe Center Bit and Apparent Excessive Extension

This is a straight forward problem to solve. Solving this problem will have a low impact on the overall performance and is low in complexity in carrying out. It is recommended that a length adjustment mechanism be designed and manufactured for properly spacing out the inner center bit assembly. The cost to complete is estimated to be low, less than $5,000. The task is estimated to be completed in the first quarter of 2014.

Cutting Shoe Crown Disintegration

This is a straight forward problem to solve. Solving this problem will have a high impact on the overall performance and is low in complexity in carrying out. It is recommended that an all steel body cutting shoe be designed and manufactured. The cost to complete is estimated to be medium, between $5,000 and $10,000. The task is estimated to be completed in the fourth quarter of 2013.

Cutting Shoe/Center Bit Penetration Rate

This is not a straight forward problem to solve. Solving this problem will have a low impact on the overall performance and is low in complexity in carrying out. Penetration rates are very depended on many factors, some of which are out of the drillers control. However, it is recommended that a bit design expert be engaged to review the cutting shoe and center bit designs, in conjunction with the main bit design, and make recommendations for design changes. The cost to complete is estimated to be low, less than $5,000. The task is estimated to be completed in the fourth quarter of 2013.

High Pump Pressures Associated with the Face Bit Inner Barrel Assembly

This is a straight forward problem to determine the cause. However, it may be a difficult problem to solve due to the geometry of the inner barrel and BHA components. Solving this problem will have a high impact on the overall performance. The complexity of the solution remains to be determined. It is recommended that the flow through the assembly be analyzed. Based on the analysis, modifications should be made to the system and then tested to determine actual pressure drops at various flow rates. The cost to complete is estimated to be low, less than $5,000. Completion of the task cannot be determined until after the analysis is completed.

Hydrostatic Pressure Retention Failure

This is not a straight forward problem to determine, requiring further extensive bench testing to determine the cause. Solving this problem will have a high impact on the overall performance. The complexity of the solution remains to be determined. It is recommended that further full function bench testing take place to determine the cause. The cost to complete is estimated to be medium, between $5,000 and $10,000. Completion of the task cannot be determined until after the cause and solution are determined.

Nitrogen Pressure Boost Failure

This is not a straight forward problem to determine, requiring further extensive bench testing to determine the cause. Solving this problem will have a high impact on the overall performance. The complexity of the solution remains to be determined. It is recommended that further full function bench testing take place to determine the cause. The cost to complete is estimated to be low, less than $5,000. Completion of the task cannot be determined until after the cause is determined and solution are determined.

Premature Movement of Separator Piston

This is a straight forward problem to solve. Solving this problem will have a high impact on the overall performance and is low in complexity in carrying out. It is recommended that further hydrostatic testing of the pressure control system seals and sealing systems be carried out. If required, change seal compounds, seal design, and/or sealing surface finish. The cost to complete is estimated to be low, less than $5,000. The task is estimated to be completed in the fourth quarter of 2013.

Spring Jumping Coils/Jamming Issue

This is a straight forward problem to solve. Solving this problem will have a high impact on the overall performance and is medium in complexity in carrying out. It is recommended that adding a counter bore to the flow sleeve to trap the spring be investigated. Manufacture counter clockwise wound spring and test. Also, revise technical manual to add a step to check for correct spring operation. The cost to complete is estimated to be low, less than $5,000. The task is estimated to be completed in the fourth quarter of 2013.

Concerns Over Premature Release of Autoclave Pressure Due to Weight of the Sinker Bar Assembly

This is a straight forward problem to solve. Solving this problem will have a high impact on the overall performance and is medium in complexity in carrying out. It is recommended that locking dogs be added to the inner barrel assembly to prevent downward movement until disassembly. The cost to complete is estimated to be medium, between $5,000 and $10,000. The task is estimated to be completed in the first quarter of 2014.

<u>Collapse of Inner Tube and Core Liner</u>

This is a straight forward problem to solve. Solving this problem will have a high impact on the overall performance and is high in complexity in carrying out. It is recommended that the flow path and associated restrictions in the BHA be double checked. Create a SolidWorks model of the inner barrel in a BHA and perform flow simulations. Analyze and test the inner tube and core liner to determine their collapse strengths. Consider increasing the strength of the inner tube if it increases resistance to core liner collapse. Increase the total flow area in the bit, if possible, and investigate adding changeable nozzles. The cost to complete is estimated to be medium, between $5,000 and $10,000. The task is estimated to be completed in the fourth quarter of 2013.

<u>Fish Pill Recorder Set Up Incorrectly</u>

This is a straight forward problem to solve. Solving this problem will have a low impact on the overall performance and is low in complexity in carrying out. It is recommended that specific personnel, who will be on site during the coring operations, be properly trained in how to set up the fish pill. The cost to complete is estimated to be zero. The task will be complete for each deployment.

<u>Incorrect Parts Manufacture</u>

This is a straight forward problem to solve. Solving this problem will have a low impact on the overall performance and is low in complexity in carrying out. It is recommended that 100% inspection be considered as part of the overall manufacturing process and parts are not to be delivered until it has been completed. The cost to complete is estimated to be zero. The task will be complete for each deployment.

<u>Face Bit Inner Barrel Assembly Failed to Latch into BHA</u>

This is a straight forward problem to solve. Solving this problem will have a medium impact on the overall performance and is low in complexity in carrying out. It is recommended that the various subassemblies be color coded painted so as the correct assemblies will be made up. The cost to complete is estimated to be low, less than $5,000. The task is estimated to be completed in the fourth quarter of 2013.

<u>AAI Personnel Assembled Tools Incorrectly on Three Runs</u>

This is a straight forward problem to solve. Solving this problem will have a medium impact on the overall performance and is low in complexity in carrying out. It is recommended that a run request form be established which states specifically what configuration H-PCS or center bit is to be deployed. The form will require the signature of all concerned prior to assembly and deployment. The cost to complete is estimated to be zero. The task is estimated to be completed for all future deployments.

<u>Premature Comment by AAI Personnel Regarding Pawls Mis-Operation</u>

This is a straight forward problem to solve. Solving this problem will have a low impact on the overall performance and is low in complexity in carrying out. It is recommended that only the coring service technicians, and invited personnel, be in the service unit at any time, especially during autopsy of failed tools. Information on any given failure should not be considered valid until an official report is distributed. The cost to complete is estimated to be zero. The task is estimated to be completed for all future deployments.

<u>Insufficient Staff to Adhere to Protocol and Verify Correct Documentation</u>

This is not a straight forward problem to solve since it relies on the willingness of the client to support the H-PCS to the level required. It will also be difficult to maintain a full complement of trained coring technicians and have them available for only periodic deployments. Solving this problem will have a high impact on the overall performance and is medium in complexity in carrying out. It is recommended that that a minimum of three coring service technicians, one records technician, and one rig floor coring engineer per 12 hour shift, plus one overall coring supervisor be available to fully support the H-PCS deployment. The cost to complete is estimated to be high, greater than $10,000, to the client. The task is estimated to be completed for all future deployments.

Closing Comments

1) Further study of the drilling records, participants notes, fish pill data, etc., will be required before a final report can be completed.

2) Additional bench testing is required to determine the cause of some of the failures. Some bench tests have already been completed but the short time frame for delivery of this interim report has not allowed for a full review of those results by the entire TRT. The bench test results need to be reviewed by the entire TRT and discussed at length prior to completing a final report.

3) In addition to the additional bench test results, the data/results from any previous deployments of the H-PCS (Japan, China, India) should be review by the TRT before a final report can be completed.

4) Once all the documentation referred to in 2) and 3) is made available, a follow up TRT meeting should be convened to review and discuss that documentation and make recommendations. This would be a good opportunity to pull in other down hole tool experts to review the overall H-PCS design as well as any other client representatives who have relevant experience with the H-PCS.

5) Prior to any further land or offshore testing of the H-PCS, sufficient bench/lab tests should be conducted to gain 100% confidence in the H-PCS operation. This should include flow tests with the inner barrel placed in a BHA to determine the pump pressures at various flow rates using various weight and viscosity fluids

Appendix A. Chevron CTF Field Test Summary

Chevron CTF Field Test Run Summary

Run	Date	Test Description	Tool # Upper-Lower	Depth from (ft)	Depth to (ft)	Core Interval (ft)	Core Recovered (ft)	Bottom Hole Pressure (psi)	Regulator set pressure (psi)	Capture Pressure (psi)	Pressure Recovered (psi)	Post Run Reservoir Pressure (psi)	Pressure Bump	Pressure Good	Pressure Chart #	Remarks
1	11/6/2013	Face Bit Spaceout	A-4	0.0	0.0	0.0	NA	0	0	0	0		NA	NA	NA	Spaced core catchers to 1/8 inch. Ball Valve did not close because return spring jumped coils and jammed. Discovered one outer bearing shaft had not been bored through. Also, 2 of three outer shoes had bad theads.
2	11/7/2013	Face Bit Dimension Test #1	A-4	741.0	741.0	0.0	NA	322	1,000	0	0	Unknown	No	No	Fish Pill not programmed properly	Pressure spikes at pump startup to 860psi. Ball valve not closed. Core liner and inner tube collapsed and jammed ball.
3	11/7/2013	Face Bit Near Surface Flow Test 1		Surface	Surface	0.0	NA	NA	NA	NA	NA	NA	NA	NA	None	No Liner pumped 120gpm at 20psi.
4	11/7/2013	Face Bit Near Surface Flow Test 2		Surface	Surface	0.0	NA	NA	NA	NA	NA	NA	NA	NA	None	With liner pumped 120gpm at 70gpm. No excessive pressure.
5	11/7/2013	Cutting Shoe Spaceout	B-3	Surface	Surface	0.0	NA	NA	NA	NA	NA	NA	NA	NA	None	Cutting shoe 1/4 inch inside main bit. Catcher 3/16 inside cutting shoe.
6	11/8/2013	Cutting Shoe Surface Flow Test	A-2	Surface	Surface	0.0	NA	NA	NA	NA	NA	NA	NA	NA	None	Flow test - 108 gpm @ 60psi. Ball valve closed properly. Surface test with no N2 pressure.
7	11/8/2013	Center bit spaceout	C-5	Surface	Surface	NA	NA	NA	NA	NA	NA	NA	NA	NA	None	Center Bit Spaceout test Center bit protrudes 1" past main bit. Flow test - 160gpm = 0 psi
8	11/8/2013	Cutting Shoe Dimension Test 1 and flow test	A-4	741.0	741.0	0.0	NA	356	1,000		175		No	No		Pump Test 110gpm, 35psi Ball valve closed properly.
9	11/8/2013	Cutting Shoe Dimension Test 2 and flow test	B-3	741.0	741.0	0.0	NA	356	1,000		196		No	No		Pump Test 110gpm, 35psi. Ball valve closed properly. Supply Valve was clossed - human error. Pressure control section turned off.

Chevron CTF Field Test Run Summary

Run	Date	Test Description	Tool # Upper-Lower	Depth from (ft)	Depth to (ft)	Core Interval (ft)	Core Recovered (ft)	Bottom Hole Pressure (psi)	Regulator set pressure (psi)	Capture Pressure (psi)	Pressure Recovered (psi)	Post Run Reservoir Pressure (psi)	Pressure Bump	Pressure Good	Pressure Chart #	Remarks
10	11/8/2013	Cutting Shoe Center Bit Test	C-5	1064.0	1070.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Tag bottom 360gpm. Drill with 380gpm - 425gpm. Slow ROP. Drilled 6 ft in 2 hours. No penetration the last half hour. POOH. Bit balled up severely. Three nozzles plugged. Cutting shoe had 1 nozzle plugged.
11	11/11/2013	Conventional Drill to Core Point	NA	1070.0	1148.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Drilled very slowly at about 20 ft/hr
12	11/11/2013	Cutting Shoe Core #1	B-2	1148.0	1158.0	10.0	0.90	533	1,500	0	0		No	No		Crown came off cutting shoe.Slow ROB at first than okay. 0.9 ft core recovered.Autoclave held pressure after the run.
13	11/12/2013	Face Bit Core #2	A-3	1158.0	1164.0	6.0	0.00	0	1,500	0	0		No	No		Holes added to extension tube to reduce pump pressure. Wrong upper assembly picked up and would not release in BHA. Picked up correct upper assembly and landed and released normally. Pump 240gpm SPP to 500psi, torque variable 1200-3700, WOB 8-16K, variable penetration. Liner collapsed and jammed ball open.
14	11/12/2013	Face bit dimension test #2	B-3	1164.0	1164.0	0.0	NA	524	1,500		71		No	No		Pumped with SPP of 200psi (TC info) Locked sinker bar using pipe wrench to prevent SB weight on inner barrel assembly during disassembly. Ball valve closed properly.
15	11/12/2013	Face bit center bit test	C-5	1164.0	1188.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Drilled okay at 22ft/hr. Pumped 310gpm at 175psi, 70RPM, 10-15K WOB.

Appendix B. Hybrid Pressure Coring System Configurations

Summary of Recommended Hybrid PCS Improvements for Existing Hybrid PCS

Problem Area	Suggested Next Steps and/or Fix	Preliminary Workshop Esimtate of Impact on Overall Performance (High, Medium, Low)	TRT Esimtate of Impact on Overall Performance (High, Medium, Low)	Complexity of Evaluation and/or Fix	Who will perform the fix?	Preliminary Cost Estimate Low <$5K Med <10K High >10K	Estimated Completion Date
1-a) Cutting she center bit and apparent excessive extension	Design and manufacture length adjuster for the center bit assembly.		Low	Low	AAI	Low	1Q 2014
1-b) Cutting shoe crown disintegration	Design and manufacture steel body cutting shoes (no matrix).		High	Low	AAI and Bit Manufacturer	Medium or 0	4Q 2013
1-c) Cutting shoe/center bit penetration rate	Have representative from bit company analyze cutting shoe center bit to main bit assembly. May be fixed by Item 6.		Low	Low	AAI and Bit Manufacturer	Lown or 0	4Q 2013
1-d) high pressure drop in face bit inner barrel assembly	Analyze flow through assembly and modify to increase flow areas in tight spots.		High	Still being determined	AAI and DCI	Low	Still being determined
2-a) Hydrostatic pressure retention failure	Full function hydrostatic lab tests and engineering study at AAI.		High	Still being determined	AAI	Medium	Still being determined
2-b) Nitrogen pressure boost failure	Most likely a failure of ball valve closure(See 2-a) or leaky seals (See Item 2-c.) in the pressure control section.		High	Still being determined	AAI	Low	Still being determined
2-c) Premature movement of separator piston	Hydrostatically test the pressure control system seals and sealing systems at AAI. Change compounds, seal design and/or surface finishes and shop test to verify satisfactory performance. Provide new seals, modify parts if necessary.		High	Low	AAI	Low	4Q 2013
2-d) Spring jumping coils/jamming issue	Investigate adding a counter bore in the flow sleeve to trap the spring. Manufacture and test counter clockwise springs. Revise manual to add a step to check for correct spring operation.		High	Medium	AAI and Spring Mfg	Low	4Q 2013
2-e) Concerns over premature release of autoclave pressure due to weight of the sinker bar assembly, etc.	Add locking dogs inside the inner barrel assembly to prevent downward movement until disassembly.		High	Medium	AAI	Medium	1Q 2014

Summary of Recommended Hybrid PCS Improvements for Existing Hybrid PCS

Problem Area	Suggested Next Steps and/or Fix	Preliminary Workshop Esimtate of Impact on Overall Performance (High, Medium, Low)	TRT Esimtate of Impact on Overall Performance (High, Medium, Low)	Complexity of Evaluation and/or Fix	Who will perform the fix?	Preliminary Cost Estimate Low <$5K Med <10K High >10K	Estimated Completion Date
3-a) Collapse of Inner Tube and Core Liner	Double check flow path and restrictions in the BHA. Create a Solid Works model and run a flow simulation. Analyze and hydrostatically test the inner tube and core liner at AAI for collapse strength. Consider increasing the strength of the inner tube if it increases resistance to core liner collapse. Increase the TFA in the bit and investigate adding changeable nozzles.		High	High	AAI and DCI	Medium	4Q 2013
4-a) Fish pill recorder set up incorrectly	Assign responsibility and require proper training ahead of the operation. This problem is eliminated if Geotek is part of the operation.		Low	Low	Client (future operation)	$0.00	NA
4-b) incorrect part manufacture	The defective parts were parts that were ordered at the last minute because of an oversight in ordering by AAI management. The late parts delivery prevented the required 100% inspection and FAT of those parts. Add a QC function to the ordering process.		High	Low	AAI	$0.00	NA
4-c) Face bit inner barrel assembly failed to latch into the BHA	Paint color coding on upper assemblies (outer bearing and inner barrel sub).		Medium	Low	AAI	Low	4Q 2013
4-d) AAI personnel assembled tools incorrectly on three runs	Require the use and sign off on run request form.		Medium	Low	Client	$0.00	NA
4-e) Premature comment by AAI crew regarding pawls mis operation	All personnel except AAI personnel should stay out of the Service Unit. Client should wait for official report before documenting failures.		Low	Low	Client	$0.00	NA
4-f) Insufficient Staff to adhere to protocol and verify correct documentation.	A minimum of 3 Coring Service Technicians per and a records technician in the service unit per 12 hr shift and 1 rig floor Coring Engineer is required per shift plus one overall Coring Supervisor is required for pressure coring operations.		High	Medium	Client	0	NA

Appendix C. AAI Executive Summary of CTF Test Results

Aumann & Associates

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(801) 631-2874 • FAX (801)886-9040
Email: Jim@AumannInc.com

DOE/Chevron Hybrid PCS Contract CW1094939
Field Test at the Catoosa Test Facility

November 3 through November 13, 2013

Executive Summary

Successes

1. Inner and outer latch systems worked extremely well with no failures or wear observed.
2. All the tools assembled correctly into the BHA. This was verified during the space out tests at the surface.
3. The low end drive system was verified to function correctly during the Face Bit space out tests at the surface and also during operations. There was no wear on the drive dogs or drive sub.
4. The wireline tools functioned as designed with no failures or wear of any kind.
5. The core transfer tool was effective during the two attempts when we had the opportunity to use it. There was no jamming as experienced in the Japanese operations. It is believed that the increased clearance between the OD of the core liner and ID of the inner tube improved this function.
6. Pre-run and post-run pressure tests verified that the autoclave sealing systems were effective. (Note: We applied pressure using the pressure test pump to several of the tools that returned with little or no pressure. There was no leakage anywhere and the pressure remained stable.

7. The upper autoclave seals, ball valve and sleeve valve all appeared to function correctly (mechanically) on many surface tests, dimensional tests and coring runs. Exceptions were on two tests where the inner tube and liner imploded or in one run when the ball return spring jumped coils and jammed.

8. Core liners held up well and also the other sensitive parts of the inner barrel assembly even with apparent substantial core jamming such as when the liner imploded. We are aware of no damage or wear on any parts except for the two imploded inner tubes and liners.

<u>Failures and Problems</u>

1, 2 and 3 are bit design

4 and 5 is pressure retention

7 is inner tube and core liner

Paragraph 6, 8 and 9 are human error

1. Bit Design
   a. It was observed in the space out test that the cutting shoe center bit extended farther ahead of the main bit than expected (about 1 inch instead of 15/32 inch as designed and measured on the CAD drawing). There is some speculation that this could have resulted in the slow penetration rate with this bit combination.
   b. The cutting shoe crown apparently came off and disintegrated during the first and only coring test of the cutting shoe inner barrel assembly. (Note that chattering marks were found inside the 3.800 ID of the cutting shoe bit.) This is a likely cause of the slow drilling observed during the first few feet of coring with this bit combination. About a foot of core was still cut and recovered even with the missing cutting shoe crown. Closer inspection of the cutting shoe also revealed that the shank did not have the agreed upon design which would provide a steel stop for both the cutting shoe insert and the core catcher. Instead those items stop against the matrix which is relatively weak in tension.
   c. The cutting shoe bit / center bit combination also resulted in very slow drilling. Only four feet was drilled in four hours with this bit combination. Subsequent

drilling with a worn button rock bit drilled the same formation at a 20 ft per hour rate.

d. High standpipe pressure, in excess of 300 psi, was observed while circulating with the Face Bit Inner Barrel Assembly. The high pressure is believed to be the probable cause of the collapse of the two inner tubes and core liners. It was expected that the pressure drop in this assembly would be higher for the face bit than for the cutting shoe assembly because the cutting shoe provides about 40% more flow area. However, the pressure generated by the face bit was much higher than predicted by flow calculations.

2. Pressure Retention

a. Pressure was not retained during the dimensional tests or coring runs even though the ball valve was closed and appeared to operate properly on several runs. At a minimum, a hydrostatic pressure of from 333 psi (0.45 psi per foot x 740 ft) to 522 psi (0.45 psi per foot x 11600 ft) should have been recovered even with no pressure boost from the pressure control section. Still did not recover hydrostatic pressure even when ball valve was closed. The maximum pressure recovered was around 100 psi.

b. The pressure boost from the pressure control section also did not occur and this was verified by the fish pill recorder data. (Note that this would result if the ball valve closure was delayed and did not close immediately. It does not mean the pressure section did not function.)

c. There was evidence that the separator piston moved down prematurely on some of the tools while waiting to be run. This could be due to nitrogen seepage under or through one or more of the seals. This could explain the lack of a pressure boost if the piston moved all the way to the end of its travel with full nitrogen pressure behind it before reaching the BHA. At the very least this would reduce the effectiveness of the pressure control section.

d. The return spring jumped coils and jammed on at least one dimensional test preventing the ball from fully closing.

e. We learned that the weight of the sinker bar assembly, inner latch, extension rods and pressure control section could push down on the inner tube plug, open the new inner tube plug check valve and release the pressure from the autoclave when the trapped pressure in the autoclave was below 736 psi. This theory could explain the loss of hydrostatic pressure if the pressure boost from the pressure control section did not occur. However, the fish pill recordings do not show the autoclave holding pressure until reaching the surface.

3. Inner Tube and Core Liner

    a. The inner tube and core liner imploded during two face bit runs. The inner tube had been redesigned in order to provide more clearance between the ID of the inner tube and OD of the core liner and core catchers to eliminate sticking during core transfer to PCATS. As part of this redesign a low strength thin wall stainless steel tube was selected because it provided the necessary ID at a low cost. This change may have contributed to the implosion although the unusually high pressure generated by the face bit was probably the real culprit since the inner tubes did not implode during the cutting shoe bit runs

4. Human Error

    a. One fish pill recorder was set up incorrectly and failed to record the pressure history properly when AAI personnel took over this responsibility without adequate training and practice.

    b. Two types of parts were discovered to have been manufactured incorrectly. The defective parts included two outer shoes that were manufactured for the face bit option and the one outer bearing shaft. These were parts for the face bit inner barrel assemblies that were overlooked during the initial FAT assembly process. The two outer shoes had to have the threads chased and one outer bearing shaft had a small upset left in the ID that had to be bored out.

    c. A face bit inner barrel assembly failed to latch into the BHA. This was discovered to be due to an assembly error on the rig floor. The cutting shoe upper assembly was installed on the face bit lower assembly by mistake. This cause about a 1-1/2 hour loss in rig time to diagnose the problem, install the correct upper assembly and re-run on the wireline.

    d. AAI personnel assembled tools incorrectly on three runs. One inner barrel assembly was assembled with the supply bullet valve closed which prevented the pressure control section from applying pressure to the autoclave on the first dimension test. A second inner barrel assembly was assembled with only the basket catcher when it had been expressed to run both a basket and slip catcher. A third tool was assembled without a lockout washer when the desire to use of the lockout washer had been expressed. This was intended to effectively eliminate the new check valve and test the original inner tube plug design.

e. A premature comment by one of the AAI crew that the pawls had locked under the seal sub was incorrect and later correctly identified the failure of the inner tube plug to move all the way into the seal sub was the result of an imploded inner tube.

Recommendations

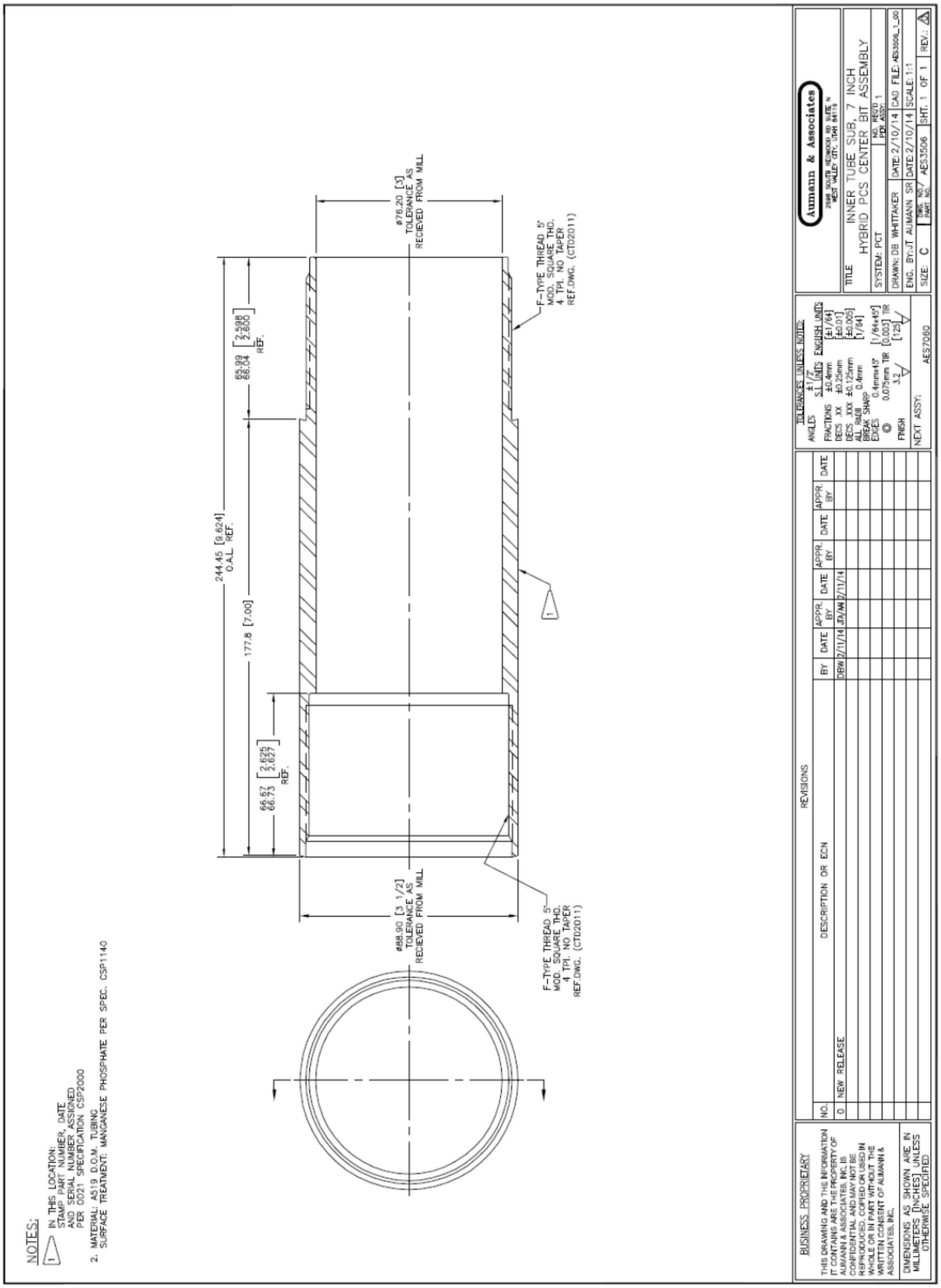
1. We developed a method to verify that the return spring was assembled correctly and that the coils had not jumped over one another during assembly. This problem may be eliminated completely in the future by purchasing springs wound counter-clockwise instead of clockwise direction. We recommend purchasing springs wound in a counter-clockwise direction and shop testing them.
2. Review the main bit designs, cutting shoe design and center bit designs with the manufacturers to determine if there are incompatibilities that might cause slow penetration rates and/or abnormally high pressures.
3. Increase the TFA of the face bit to reduce the pressure and prevent inner tube and/or liner collapse.
4. Review the apparent cutting shoe failure with the supplier. Test the remaining three cutting shoes to try to determine if the matrix to steel bond is good. Remanufacture the cutting shoes using the correct shank design to prevent bottoming out of the cutting shoe insert and core catcher on the matrix. Consider manufacturing a steel body cutting shoe without matrix.
5. Run tests on the pressure control section to determine if seal seepage and premature piston movement is chronic. If it is, specify better surface finishes or different seal

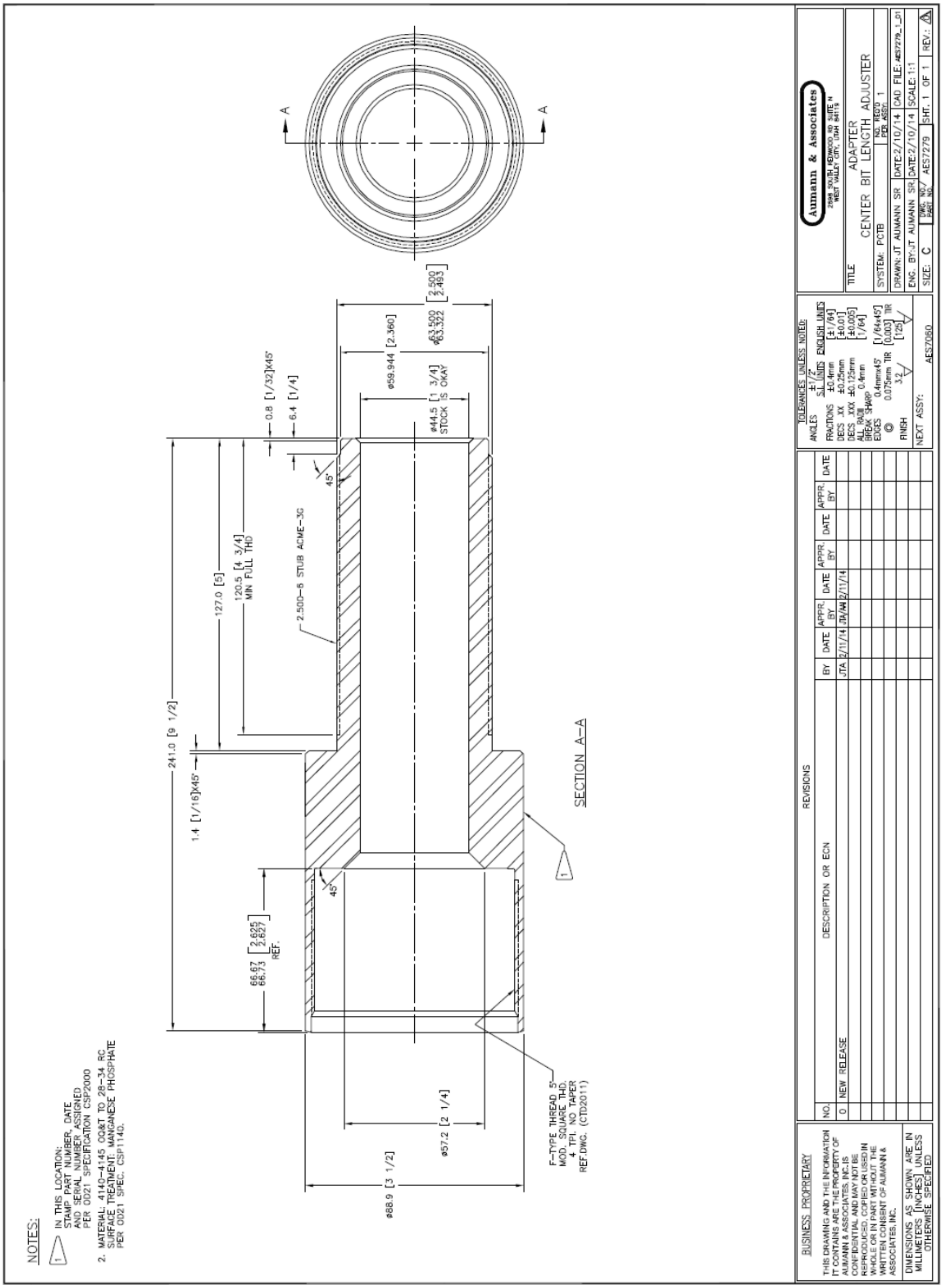
compounds and test and verify the elimination of the problem after changes such as seal compounds, surface finishes and seal design are implemented..

6. Run full function pressure tests on the inner barrel assemblies using the field test pressures to try to reproduce the field test results (little or no recovered pressure and no pressure boost from the pressure control section). Rerun the full function pressure tests after fixes are implemented to verify success of any improvements.
7. The inner tube was redesigned as part of the contract requirements to provide certain improvements including the elimination of the jamming problem experienced by Geotek during liner extraction during the Japanese operations. The design selected utilizes a thin stainless steel tube that provided the necessary ID to provide clearance for the liner and core catchers. This same tube design was used without any problems in the recent China operations that incorporated a cutting shoe. Test the inner tube and liner to determine the collapse pressure of each and both together. The inner tube may need to be redesigned for use with the face bit option with a thicker wall and/or higher strength material to prevent the implosion under higher coring/drilling pressures. Any new design should be modeled for collapse using conventional mathematical calculations and/or FEA and should also be tested in the lab for resistance to implosion. A hydraulic model of the inner barrel assembly should also be made to predict and possibly improve flow and reduce pressure drop. Bit design might also be modified to require lower flow and resulting pressure drop and still effectively clean the bit and improve penetration rate. Note that increasing the collapse strength of the inner tube may not prevent collapse of the core liner.
8. The individual responsible for the fish pill recorders must be thoroughly trained and certified for the fish pill operation. This will not be a problem if Geotek is on site as they are normally responsible for and thoroughly trained in their setup and operation.
9. The defective parts were corrected by AAI at two Oklahoma machine shops. These parts need to be re-inspected by the original manufacturers when they are returned to AAI for post-test dressing.
10. A formal system for passing inner barrel assembly configuration to the AAI crew needs to be utilized.

11. A check list for verifying the settings in the inner barrel assemblies is available and needs to be used by the AAI crew. Also, a double check procedure for all critical settings needs to be documented in the manuals and on the check list and utilized.

Appendix II. Center Bit Length Adjuster Drawings




NOTES:
1 IN THIS LOCATION: STAMP PART NUMBER, DATE AND SERIAL NUMBER ASSIGNED PER OD21 SPECIFICATION CSP2000
2. MATERIAL: 4140-4145 OQ&T TO 28-34 RC SURFACE TREATMENT: MANGANESE PHOSPHATE PER OD21 SPEC. CSP1140.
SECTION A-A
241.0 [9 1/2]
127.0 [5]
120.5 [4 3/4] MIN FULL THD
2.500-6 STUB ACME-3G
0.8 [1/32]X45°
6.4 [1/4]
1.4 [1/16]X45°
66.67 66.73 [2.625 2.627] REF.
45°
ø44.5 [1 3/4] STOCK IS OKAY
ø59.944 [2.360]
ø63.500 ø63.322 [2.500 2.493]
ø57.2 [2 1/4]
ø88.9 [3 1/2]
F-TYPE THREAD 5° MOD. SQUARE THD. 4 TPI. NO TAPER REF.DWG. (CTD2011)
BUSINESS PROPRIETARY
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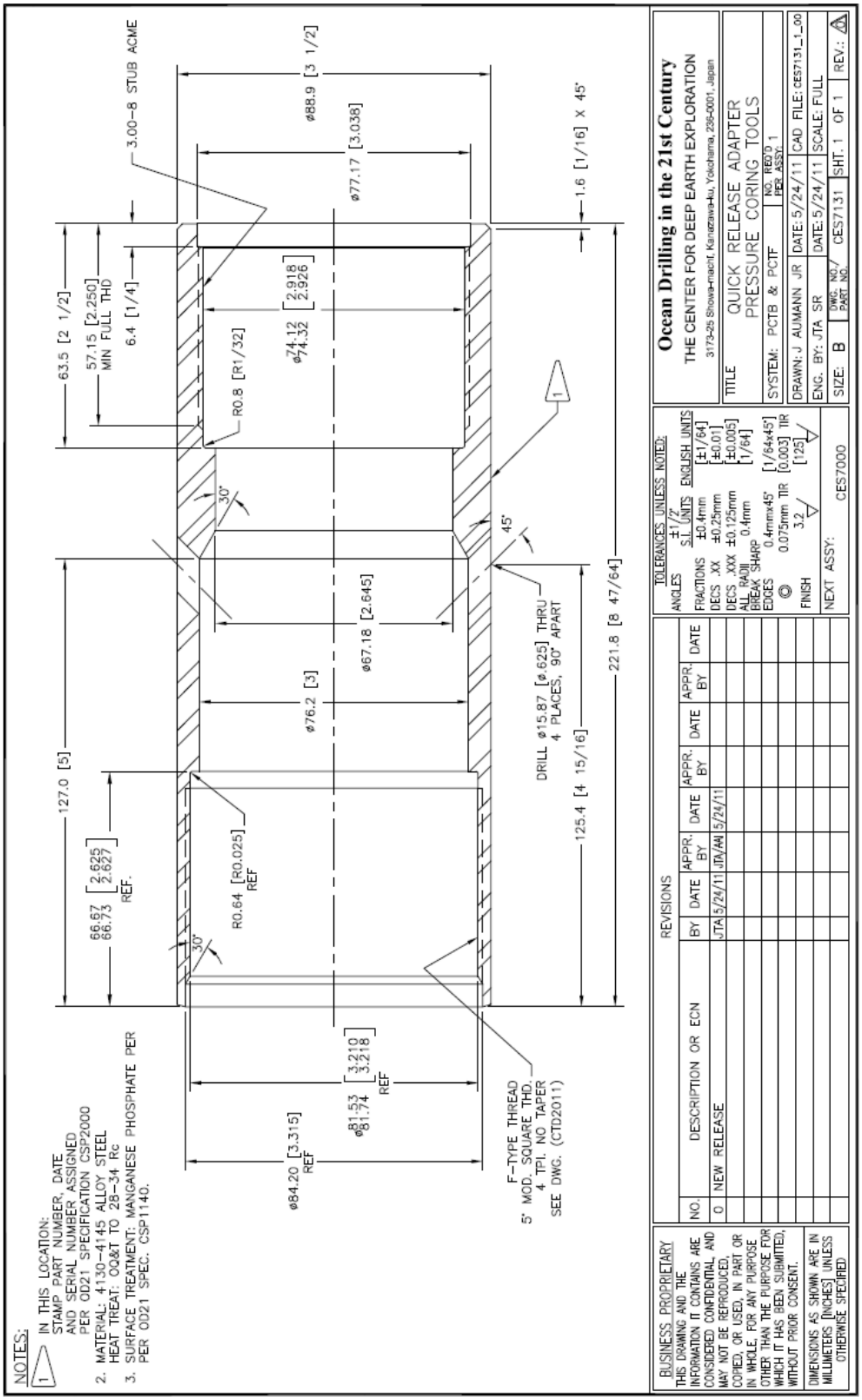
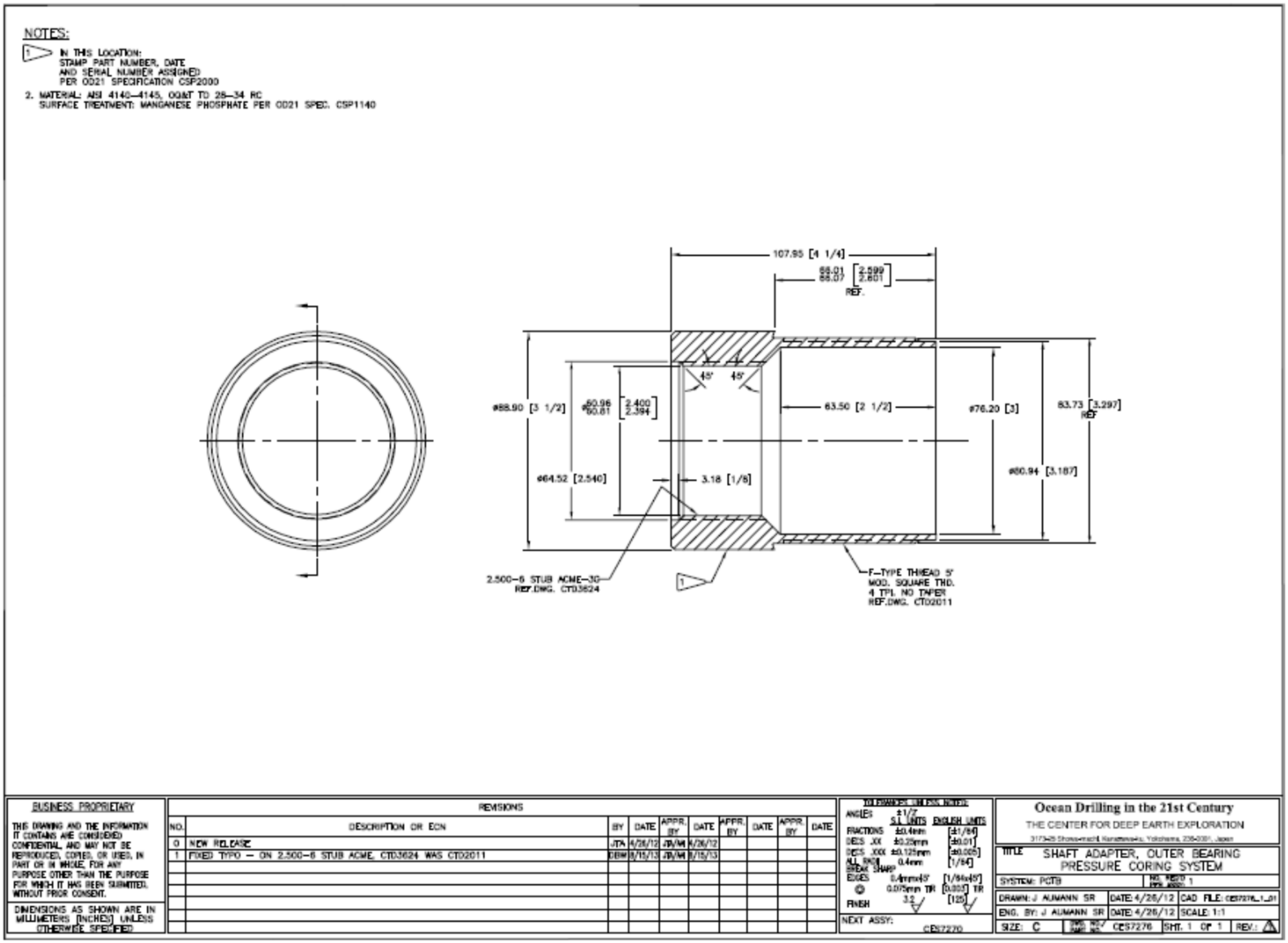
DIMENSIONS AS SHOWN ARE IN MILLIMETERS [INCHES] UNLESS OTHERWISE SPECIFIED
REVISIONS
NO. DESCRIPTION OR ECN BY DATE APPR. BY DATE
0 NEW RELEASE JTA 2/11/14 JTA/AM 2/11/14
TOLERANCES UNLESS NOTED:
ANGLES ±1/2°
S.I. UNITS ENGLISH UNITS
FRACTIONS ±0.4mm [±1/64]
DECS .XX ±0.25mm [±0.01]
DECS .XXX ±0.125mm [±0.005]
ALL RADII 0.4mm [1/64]
BREAK SHARP EDGES 0.4mmx45° [1/64x45°]
0.075mm TIR [0.003] TIR
FINISH 3.2 [125]
NEXT ASSY: AES7060
Aumann & Associates
TITLE ADAPTER CENTER BIT LENGTH ADJUSTER
SYSTEM: PCTB
DRAWN: JT AUMANN SR DATE: 2/10/14
ENG. BY: JT AUMANN SR. DATE: 2/10/14
CAD FILE: AES7279_1_01
SCALE: 1:1
SIZE: C DWG. NO./PART NO. AES7279 SHT. 1 OF 1 REV.: A


NOTES:
1 IN THIS LOCATION: STAMP PART NUMBER, DATE AND SERIAL NUMBER ASSIGNED PER OD21 SPECIFICATION CSP2000
2. MATERIAL: 4130-4145 ALLOY STEEL HEAT TREAT: OQ&T TO 28-34 Rc
3. SURFACE TREATMENT: MANGANESE PHOSPHATE PER PER OD21 SPEC. CSP1140.
63.5 [2 1/2]
57.15 [2.250] MIN FULL THD
6.4 [1/4]
3.00-8 STUB ACME
ø88.9 [3 1/2]
ø77.17 [3.038]
1.6 [1/16] X 45°
R0.8 [R1/32]
ø74.12 ø74.32 [2.918 2.926]
30°
45°
127.0 [5]
66.67 66.73 [2.625 2.627] REF.
ø76.2 [3]
ø67.18 [2.645]
DRILL ø15.87 [ø.625] THRU 4 PLACES, 90° APART
125.4 [4 15/16]
221.8 [8 47/64]
R0.64 [R0.025] REF
ø84.20 [3.315] REF
ø81.53 ø81.74 [3.210 3.218] REF
F-TYPE THREAD 5° MOD. SQUARE THD. 4 TPI. NO TAPER SEE DWG. (CTD2011)
BUSINESS PROPRIETARY
THIS DRAWING AND THE INFORMATION IT CONTAINS ARE CONSIDERED CONFIDENTIAL, AND MAY NOT BE REPRODUCED, COPIED, OR USED, IN WHOLE, OR IN PART OR FOR ANY PURPOSE OTHER THAN THE PURPOSE FOR WHICH IT HAS BEEN SUBMITTED, WITHOUT PRIOR CONSENT.
DIMENSIONS AS SHOWN ARE IN MILLIMETERS [INCHES] UNLESS OTHERWISE SPECIFIED
REVISIONS
NO. DESCRIPTION OR ECN BY DATE APPR. BY DATE APPR. BY DATE APPR. BY DATE
0 NEW RELEASE JTA 5/24/11 JTA/AAI 5/24/11
TOLERANCES UNLESS NOTED:
ANGLES ±1/2°
S.I. UNITS ENGLISH UNITS
FRACTIONS ±0.4mm [±1/64]
DECS .XX ±0.25mm [±0.01]
DECS .XXX ±0.125mm [±0.005]
ALL RADII 0.4mm [1/64]
BREAK SHARP EDGES 0.4mm×45° [1/64×45°]
0.075mm TIR [0.003] TIR
FINISH 3.2 [125]
NEXT ASSY: CE57000
Ocean Drilling in the 21st Century
THE CENTER FOR DEEP EARTH EXPLORATION
3173-25 Showa-machi, Kanazawa-ku, Yokohama, 236-0001, Japan
TITLE QUICK RELEASE ADAPTER PRESSURE CORING TOOLS
SYSTEM: PCTB & PCTF NO. REQ'D 1 PER ASSY: 1
DRAWN: J AUMANN JR DATE: 5/24/11 CAD FILE: CE57131_1_00
ENG. BY: JTA SR DATE: 5/24/11 SCALE: FULL
SIZE: B DWG. NO./PART NO. CE57131 SHT. 1 OF 1 REV.: 0


NOTES:
1 IN THIS LOCATION: STAMP PART NUMBER, DATE AND SERIAL NUMBER ASSIGNED PER OD21 SPECIFICATION CSP2000
2. MATERIAL: AISI 4140–4145, OQ&T TO 28–34 RC
SURFACE TREATMENT: MANGANESE PHOSPHATE PER OD21 SPEC. CSP1140
107.95 [4 1/4]
REF.
45°
45°
ø88.90 [3 1/2]
63.50 [2 1/2]
ø76.20 [3]
83.73 [3.297] REF
ø64.52 [2.540]
3.18 [1/8]
ø80.94 [3.187]
2.500–6 STUB ACME–3G
REF.DWG. CT03624
F–TYPE THREAD 5° MOD. SQUARE THD. 4 TPI, NO TAPER
REF.DWG. CT02011
BUSINESS PROPRIETARY
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DIMENSIONS AS SHOWN ARE IN MILLIMETERS [INCHES] UNLESS OTHERWISE SPECIFIED
REVISIONS
NO. | DESCRIPTION OR ECN | BY | DATE | APPR. BY | DATE | APPR. BY | DATE | APPR. BY | DATE
0 | NEW RELEASE | JTA | 4/26/12 | 4/26/12
1 | FIXED TYPO – ON 2.500–6 STUB ACME, CT03624 WAS CT02011 | 8/15/13 | 8/15/13
TOLERANCES UNLESS NOTED:
ANGLES ±1/2
S.I. UNITS ENGLISH UNITS
FRACTIONS ±0.4mm [±1/64]
DECS .XX ±0.25mm [±0.01]
DECS .XXX ±0.125mm [±0.005]
0.4mm [1/64]
FINISH
NEXT ASSY: CES7270
Ocean Drilling in the 21st Century
THE CENTER FOR DEEP EARTH EXPLORATION
TITLE SHAFT ADAPTER, OUTER BEARING PRESSURE CORING SYSTEM
SYSTEM: PCTB
DRAWN: J AUMANN SR | DATE: 4/26/12 | CAD FILE:
ENG. BY: J AUMANN SR | DATE: 4/26/12 | SCALE: 1:1
SIZE: C | CES7276 | SHT. 1 OF 1 | REV.: 1

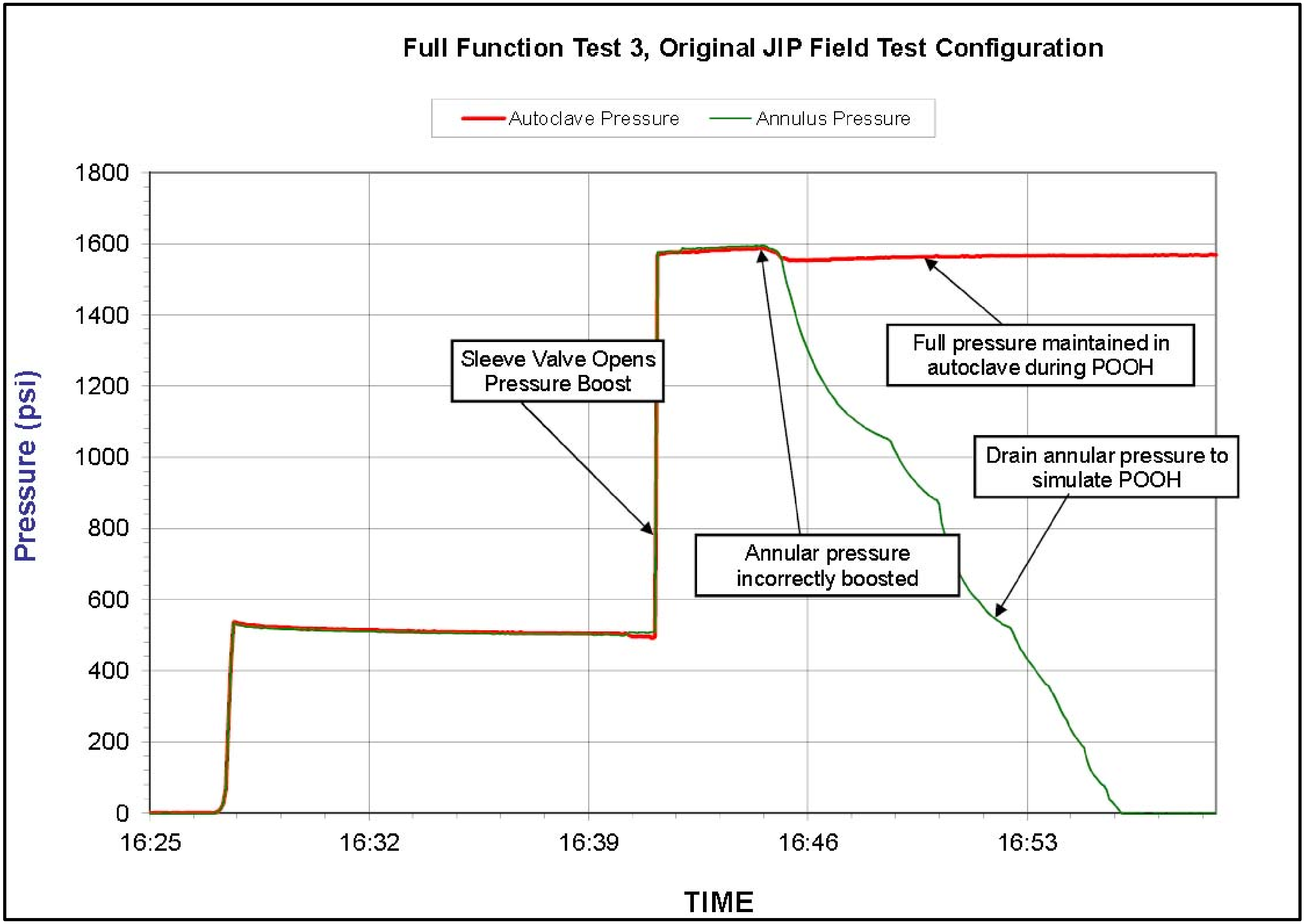
Appendix III: Ball Valve Closure Test Chart

Test	Date and Time of Test	Tool #	BV Spring Collet Rev.	Collet Grease Filled	Ball Follower Rev.	Follower Grease Filled	BV Closure Time (sec)	Notes	Analysis
1	12/02/13 - 15:42	1	CES7506_3	Yes	CES7609_2	No	3.98	Grease applied only to the chamber above the ball. Slow closure. Slowing when Seal Carrier's o-rings entered the BV Housing seal surface. Grease built up rings around Seal Carrier. Lower ambient temperature than the other tests.	First test prooved the theory that a partial hydraulic lock in the chamber above the seal carrier could dramatically slow ball closure when a viscous fluid is used.
2	12/18/13 - 14:17	1	CES7506_4	Yes	CES7609_2	No	0.24	Much faster closure with grooved BV Spring Collet. Most grease was pushed into the center of the Collet.	Flow grooves added to the BV Spring Collet speeded up BV closure by more than 16 times.
3	12/18/13 - 14:57	1	CES7506_4	Yes	CES7609_2	Yes	0.63	Repeat Test 2 but with grease also placed in the 2nd chamber above the ball follower. Slower Ball closure than Test 2 as expected.	Slower due to the addition of the a grease filled Ball Follower (lower) chamber.
4	12/18/13 - 15:32	1	CES7506_4	Yes	CES7609_3 DBW mod	Yes	0.23	Fastest Ball Valve closure of all grease tests. Flow grooves on lower end of Ball follower and on BV Spring Collet with grease in both chambers.	Tests 4 & 5 confirmed that flow grooves added to the BV Spring Collet and Ball Follower greatly reduce the hydraulic lock when operating with a viscous fluid such as grease or viscous drilling mud.
5	12/20/13 - 13:20	1	CES7506_4	Yes	CES7609_3 JTA mod	Yes	0.30	Flow grooves on the upper end of the Ball Follower. Minimally slower BV closure than Test 4. Grease exited the top of the Ball Follower through the new grooves.	
6	12/20/13 - 13:55	1	CES7506_3	Yes	CES7609_2	Yes	2.68	Control Test, using original PCTB configuration but with grease in both chambers. Lots of grease exited the original flow ports of the Housing Extension during closure.	BV Closure time is slow, due to usage of grease creating a partial hydraulic lock in chambers above and below the Ball. Somewhat faster than Test 1 possibly because higher ambient temperature made grease thinner.

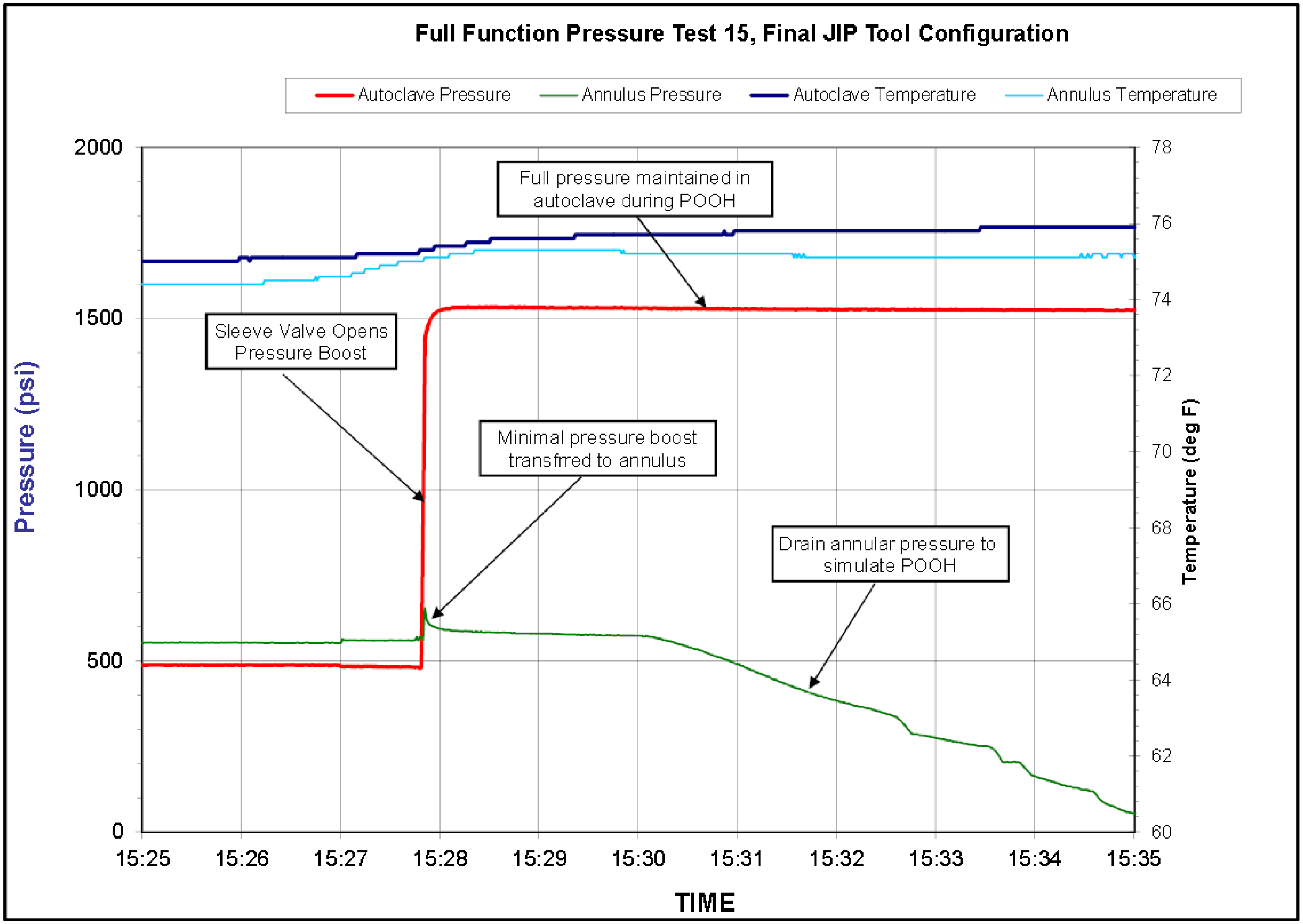
Appendix IV: Post Field Test Full-Function Testing Summary

Test No.	BHP Before Closure	BHP After Closure /Boost	BHP Change	Autoclave Pressure After Closure/ Boost	Autoclave Pressure after POOH	Autoclave Pressure Change (Boost or reduction)	Accumulator Used?	Lockout Washer Installed?	Pressure Control Section Nominal Settings	Notes	Results
Group 1, Test to check original design (No IT check valve) and no active pressure control section.											
10	513	515	2	515	0	-513	Yes 250psi	Yes	No Charge	Test objective was to verify that current test is congruent with the pre-2013 PCTB. Lockout washer installed. Intended zero N2 boost.	Typical reduction of autoclave pressure during simulated POOH due to autoclave chamber expansion. Repeat of original PCTB test results.
11	1009	1015	6	997	404	-605	Yes 250psi	Yes	No Charge	Test repeated with higher simulated hydrostatic pressure. Intended zero N2 boost.	Expected slightly higher pressure reduction due to autoclave chamber expansion.
Group 2, Test to check new design with IT check valve and no active pressure control section.											
2	541	533	-8	506	326	-215	No	No	No Charge	Test for lower pressure reduction with the new IT check valve design. Intended zero N2 boost.	Improved performance. Pressure reduction is only 215psi. Compare to 500-600psi above.
6	503	502	-1	481	145	-358	Yes 250psi	No	No Charge	Test repeated. Intended zero N2 boost.	Slightly more pressure reduction than the first test but still better than with no IT check valve.
Group 3, Test new design with IT check valve but with lockout washer that prevents check valve operation and with active pressure control section											
9	505	534	29	1520	1519	1014	Yes 250psi	Yes	Reservoir: 3000 Set: 1500	Lockout washer installed. No extra spacing to Lift Sub.	Tool performed as it did in the pre-2013 configuration as expected.
13	507	519	12	1506	1501	994	Yes 500psi	Yes	Reservoir: 3000 Set: 1500	Test repeated. Used modified Lift Sub, BV Collet, Ball Follower.	Almost identical results. Tool performed as it did in the pre-2013 configuration.
Group 4, Test to check new design with IT check valve with N2 boost. (JIP Field test configuration.) Boost pressure transferred to annulus.											
3	495	1545	1050	1529	1525	1030	No	No	Reservoir: 3000 Set: 1500	Test same configuration as JIP Catoosa field test.	Boost pressure transferred to annulus Test setup may hide loss of autoclave pressure into the annulus.
4	501	1454	953	1515	1565	1064	Yes 250psi	No	Reservoir: 3000 Set: 1500	Test repeated with accumulator added to annulus in attempt to more accurately simulate large annulus in actual operations.	Boost pressure again transferred to annulus.
Group 5, Test to check new design with IT check valve and increased travel (+0.288 in travel) with active pressure control section. Length change by adjusting part spacing.											
5	509	522	13	1471	1493	984	Yes 250psi	No	Reservoir: 3000 Set: 1500	Lengthened the distance from the Seal Sub to the Lift Sub by 0.287" by adjusting part spacing.	Negligable annular pressure increase. Correct autoclave pressure boost. No leakage during simulated POOH.
8	504	520	16	1517	1514	1010	Yes 250psi	No	Reservoir: 3000 Set: 1500	Repeat of previous test.	Same results as previous test.
Group 6, Test to check new design with IT check valve and modified Lift Sub (+0.288 in travel) with active pressure control section. This is the final configuration shipped to DOE.											
14	495	505	10	1506	1501	1006	Yes 400psi	No	Reservoir: 3000 Set: 1500	Used modified Lift Sub, BV Collet, Ball Follower. Pulled using a forklift to simulate real wireline pull speed.	Satisfactory results with minimal annular pressure increase and full autoclave pressure boost and retention during simulated POOH.
15	503	527	24	1539	1539	1036	Used relief valve set at 500psi instead of accumulator	No	Reservoir: 3000 Set: 1500	Repeat of previous test with relief valve added to annulus to more accurately simulate real operations. Used modified Lift Sub, BV Collet, Ball Follower.	Good results with little annular pressure increase and full autoclave pressure boost and retension during simulated POOH.

Appendix Va: Full Function Pressure Test Chart



Appendix Vb: Full Function Pressure Test Chart



Appendix VIa. Core Liner Implosion Calculations – Thin Wall Design

Hybrid PCS
Thin Wall Stainless Steel Inner Tube

$E := 28 \cdot 10^{6} \cdot psi$ Modulus of Elasticity for Stainless Steel

Poison's Ratio

Outer Diameter $Do := 2.497 \cdot in$

Inner Diameter $Di := 2.406 \cdot in$

Wall Thickness $t := \frac{Do - Di}{2}$ $t = 0.045 \cdot in$

Collapse equation assuming infinitely long tube

$$P_c := \frac{2 \cdot E}{\left(1 - \mu^2\right) \cdot \left(\frac{Do}{t}\right)^3}$$

$P_c = 372 psi$

Appendix VIb. Core Liner Implosion Calculations – Thick Wall Design

Hybrid PCS
Proposed Improved Heavy Wall Inner Tube

Given :

Material : Alloy Steel, AISI 4140, 4142 or 4145 oil quenched and tempered to Rc 32-36

Material Yield Strength $\sigma y := 105000 psi$

Outer Diameter $Do := 2.625 in$

Inner Diameter $Di := 2.406 in$

Thickness $t := \frac{Do - Di}{2}$ $t = 0.109 in$

Diameter to Thickness $r := \frac{Do}{t}$ $r = 23.973$

Using API RP 7G Equation for Pipe Collapse
Transition Zone between Elastic and Plastic Range
For 105 ksi Minimum Material with
D/t Ratio between 20.70 to 26.89

$A := 2.05$ $B := 0.051$

$P_c := \sigma y \cdot \left[\left(\frac{A}{\frac{Do}{t}}\right) - B\right]$ $P_c = 3585 psi$

Appendix VII. AAI Run Request Form

Aumann & Associates

2698 South Redwood Rd. Suite N, West Valley City, Utah 84119

RUN REQUEST

TOOL NO.	**EXPECTED RUN NO.**	**Date:**

NO.	**ITEM**	**REQUIREMENTS**	**REMARKS**	**VERIFIED BY**
1	Core Catcher Type(s)	Type: **B**asket **S**lip **F**lapper		
2	Install Rabbit	Yes No		
3	IT Plug Seals	Lip Seal ____, O-ring ____		
4	System Type	Cutting Shoe Face Bit Punch		
5	Desired Core Shoe Spacing	1/16" 1/8" 3/16"		
6	Check Valve Lockout Spacer	Yes No		
7	Kempner Check Valve	Yes No		
8	Recorder in Rabbit	Yes No		
9	Recorder in IT Plug	Yes No		
10	Reservoir Pressure	psi		
11	Regulator Set Pressure	psi		
SPECIAL INSTRUCTIONS				**VERIFIED BY**

Approved by:	**Signature**	**Date:**

SECTION 7
PHASE IIIB TOPICAL REPORT #41330R27

Planning & Design of an Offshore Hydrate Pressure Coring Operation

Prepared by: Jim Mounteer (Argon Energy)
Tom Fate (Chevron)
Contributions from Chevron Deepwater GOM Drilling Team

2011 - 2012

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1. INTRODUCTION

In 2009, the Gulf of Mexico Hydrate Joint Industry Project (JIP) conducted an offshore drilling and logging operation (called Leg II) into hydrate formations at various offshore locations in GOM's Green Canyon, Atwater Valley and Walker Ridge areas. High quality log information with good stratigraphic and hydrate properties were obtained from these wells. The wells are listed in the Table below.

2009 DRILLING PROGRAM						
WELL	**API No.**	**Latitude (N)**	**Longitude (W)**	**Water Depth (ft)**	**Well Depth (fbrf)**	**Well Depth (fbsf)**
AC21A	608054007000	26 55 23.8503	94 54 00.0702	4889	6700	1760
AC21B	608054007100	26 56 39.1900	94 53 35.6216	4883	6050	1116
GC955H	**608114053700**	**27 00 02.0707**	**90 25 35.1142**	**6670**	**8654**	**1933**
GC955 I	608114054400	27 00 59.5305	90 25 16.8928	6770	9027	2205
GC955Q	608114054300	27 00 07.3484	90 26 11.7156	6516	8078	1511
WR313G	**608124003900**	**26 39 47.4841**	**91 41 01.9404**	**6562**	**10200**	**3586**
WR313H	**608124004000**	**26 39 44.8482**	**91 40 33.7467**	**6450**	**9770**	**3269**

Leg II demonstrated the occurrence of gas hydrates at medium to high saturations in reservoir-quality sands. The hydrate deposits were found in close accordance with pre-drill predictions, demonstrating the validity of the hydrate exploration and appraisal tools and techniques used in finding, delineating, and characterizing targeted accumulations.

Encouraged with the Leg II results, the JIP initiated plans to expand the program in a follow-up phase that was designed to obtain cores and characterize hydrates at as close to in situ conditions as possible. The plan for Phase IIIB would include a Leg III offshore operation to twin the Walker Ridge 313 wells G & H and Green Canyon 955 well H to obtain extensive continuous pressure cores, wireline logs, wireline pressure profiles and fluid samples (MDT) from gas hydrate bearing sand horizons at these locations. These pressure cores would be cut with a customized core barrel to retain in-situ pressure during the acquisition, retrieval to the surface, transfer and transportation operation.

The planning for this drilling and coring program was initiated in 2011 and concluded in 2012. The study included extensive examinations of design alternatives for the pressure coring device, development of scoping-level operational plans for the offshore drilling and coring program, and the development of a system to analyze the pressure cores under in situ pressure conditions.

The purpose of this report is to document the results of the operational scoping study for the offshore drilling and pressure coring operation. An important element of the scoping study was the assessment of the safety and compliance requirements that were needed to meet the new drilling regulations put in place following the Macondo well incident in the Gulf of Mexico in 2010. The conclusion of the drilling safety review is that the use of 6th generation deepwater drill ship is required in order to ensure adequate safety margins in conducting the complex operations planned for Leg III. The cost of the Leg III program with a 6^{th} generation drill ship would be extremely high, approximately $40 MM.

This report is divided into several sections that include the following topics:

- Development of an offshore drilling and hydrate pressure coring operation plan.
- Safety review of an offshore drilling and hydrate pressure coring program.
- Cost and schedule estimate of the drilling and hydrate pressure coring program.
- Summary and conclusions of the study.

2. DEVELOPMENT STUDY FOR OFFSHORE DRILLING AND PRESSURE CORING OPERATION PLAN

2.1 SCOPING STUDY

By the end the first quarter of 2011, the initial scoping work on a pressure coring system was completed. A proposal for the development of High Pressure Temperature Corer (HPTC) was submitted by Aumann and Associates Incorporated (AAI). The plan was to initiate the work on the design and fabrication of a pressure core barrel for the use in the Walker Ridge and Green Canyon deepwater locations. The water depths at this location were in the 6,500-6,800 feet range. Concurrently, a front end drilling engineering design (FEED) work for the anticipated offshore coring operations will also be initiated.

WIRELINE CORE BARREL SPECIFICATIONS:

The basis of design for fabrication included:

- Allow for 11.5 foot cores to be cut
- Allow for in situ pressures of 5,500 psi
- Allow conventional wire-line tools to be run through the barrel, allowing open hole logging operations to take place
- Cut at least a 3-1/2 inch OD core
- Insulate the autoclave to prevent heat transfer to and from the external environment
- Provide a pressure source to maintain the core at in-situ pressure such that core would always stay above the dissociation point.

OUTER CORE BARREL:

No provision for design and construction of an outer barrel system was made during the screening phase. It was assumed that an outer barrel would be fabricated by a third party vendor, and that a suitable landing profile top and bottom would be provided to be compatible with the AAI design. Feasibility work was undertaken with Baker-Hughes to use a modified 8-1/8” OD marine barrel for this work. A barrel was proposed for fabrication once the HPTC system had been completed and the drill string finalized

DRILL PIPE:

No design work had been performed prior to April of 2011 related to the drill string to be used. The scoping level plan was to drill using casing rather than conventional drill pipe. This would allow the large cores to be cut and retrieved. The contract estimate was based on an assumption that a suitable casing drill string could be found.

DRILL RIG:

There was no work performed prior to 2011 to define the suitable rig for this Leg III program. It was assumed that a Multi-Purpose Service Vessel (MPSV) like the Mr John or Q4000 which had been used in the past would be feasible, but it was recognized that new options needed to be considered.

SCHEDULE:

The base plan was to begin field operations in 2012. To accomplish the base plan, the following milestones were required.

1. A contract for the HPTC coring device would be awarded in Q1-2011 and the core barrel design and construction was initiated.
2. The basis of design for the coring program would be documented and agreed by all key parties by the end of Q2-2011.
3. All long lead items would either be on order or clearly defined by the end of Q3-2011.
4. Concept engineering would be completed and a budget number would be prepared for the 2012 program by 3Q-2011.
5. Project authorization would be ready by year end 2011 to allow contracting and detailed engineering to proceed in advance of coring operation.

The detailed design for the core barrel was subsequently completed and the contract was awarded for its construction on the premise that the core barrel was the longest lead item. At that time, there were no identified high risk areas that would preclude the project ability to core. The project proceeded to the field engineering phase.

2.2 FRONT END ENGINEERING DESIGN (FEED) PHASE

This part of the report documents the front end drilling engineering design work that was completed. This section documents the plan for an anticipated offshore coring project. It also outlines field engineering concerns and risks which had to be accounted for in the final core barrel design.

At the time that detailed drilling engineering design work was commenced, the HPTC core barrel developed by Aumann and Associates Inc. (AAI) was more than 80% complete. During the design and fabrication phases for the barrel construction, several design changes were made to the original specifications. The greatest of these was the decision to increase the Outer Diameter (OD) of the inner wireline retrievable barrel to require a 6.50 inches Inner Diameter ID (6.25" drift) outer tube. This was driven by the ID requirement through the bit to allow wireline access, while preserving the ability to utilize a bearing section at the bit. All other feed level design work predicated the ID and OD requirements to accommodate the core barrel. This decision had many ramifications on the overall cost to the operation.

DRILL PIPE:

A wire-line retrievable core barrel is of course constrained in outside diameter by the ID of the pipe through which it is run. At the time fabrication of the HPTC barrel commenced, it was assumed that a suitable drill-string could be sourced and rented. It was known that conventional API drill pipe would not be applicable, but casing as a drill string was thought to be a viable option.

As a part of this work, technical load and conditional requirements for the tube were defined, based upon the basis of design work scope developed for the project. A request for quotation was prepared and sent to VAM and Grant Prideco. Based on their feedback and costs, an analysis was undertaken to determine the solution which maximized safety reduced operational risk, while offering the best commercial alternative.

Based on the analysis of the project team, the use of casing as a drill string in open water is not a viable solution. The vendor offering casing did not feel comfortable with rotating, handling torque nor in conducting multiple trips with the pipe. The other vendor elected not to quote a casing option. In spite of being the cheapest price ($81/ft), it was rejected on technical and safety considerations.

Grant Prideco offered a new design of 7-5/8 drill pipe having either a 10" OD x 6-3/8" ID API tool-joint or a proprietary 9-1/2" OD by 6-1/2" drifeetID. Although a new design, the technical workup was complete and the pipe was ready for manufacture. It met or exceeded all technical requirements, but had a cost of $325/ft. The pipe was subsequently rejected based on cost and handling inefficiencies.

After re-evaluation of the HPTC barrel, it was determined that the ID restriction could be reduced from 6.25 to 5.9 inches, by redesigning the lower bearing section. VAM and later Grant Prideco offered a 6-5/8" 25.2 # G-105 drill pipe with an API coupling offering a 5.906" inside diameter. This pipe is not a common rental size as it offers no significant benefit over the much more robust 27# S-135 in normal use, but did provide a large bore in a standard size, at a more affordable price ($142/ft). This pipe would have had to be purchased for the program, which was subsequently determined to be not economically viable.

Using the data provided, the overall cost for the 6.5" HPTC barrel using 7-5/8" DP was $5.2MM, with all necessary tools and spares. No attempt was made to account for inefficiencies in derrick management for the larger pipe. As an option the cost of scrapping the existing 6.5" barrel and redesigning for a 5.906" ID was investigated. Although some options offered by the larger barrel would have to be amended or eliminated, it was felt this could be done, and the slimmed barrel could be manufactured in time for the proposed 2012 drill date.

The comparable "all in" cost to scrap the existing equipment, redesign and manufacture as smaller version and procure the necessary 6-5/8" drill string and spares was estimated to be $3.3MM. This option potentially saved approximately $2MM, while preserving the option for further cost reduction if the drill string could be rented, or sold to a third party after our limited use. The option also allowed:

- Use of standard fishing tools/ jars etc.
- Use of standard rig handling equipment
- Faster and safer handling as using existing automated racking systems
- Smaller overall hole size resulting in less mud use, cheaper core heads, faster ROP, better hydraulics, etc.
- Allowed probable re-inclusion of a flapper float for increased safety
- Allowed an increase to outer core barrel wall thickness to reduce BHA and buckling tendency

Based on approval for this recommendation, the project work was re-scoped to revise the core barrel design to a smaller size. Ultimately the barrel was downsized to the point that it could be run in existing drill pipe having a 4.25 drift. Work on the HPTC system was halted and the project refocused on a different design called Hybrid Pressure Coring System (HPCS) which would be more compatible with existing drilling pipe.

2.3 OFFSHORE DRILLING PLAN

The stratigraphic wells drilled in 2009 were drilled with the Q-4000 rig. For that operation, the rig was moved on location using surface GPS for location reference, and an LWD/ drilling BHA was run from the rig to the seafloor. Drilling was undertaken and the well logged as it was drilled. The exact seafloor location and re-entry were not a prime concern. Typically each well took 12-18 hours after which the BHA was pulled and the rig moved to another location. Standard drill string handling tools and components were utilized, making an affordable and economic program.

Pressure coring operation is far more complex than drilling and logging operation in offshore deepwater environment. For safe and efficient operations a number of key considerations needed to be taken into account in the planning of the pressure coring operation.

In selecting the wells to core, care was taken to avoid wells that that had previously exhibited evidence of shallow water flows or other problems. In spite of the selection, precautions were still needed to be taken to negate any possibility of seeps and flows from happening. This would require the use of a weighted kill mud while operational, and having sufficient positional control to be able to “twin” the existing stratigraphic wells drilled in 2009 so that we could have some certainty as to the geology and stratigraphy of the well.

To place a rig at a given position relative to the ocean’s surface is relatively simple. Typically differential GPS will provide a very accurate surface location reference. However, seafloor positioning especially in 6000 to 8,000 feet of water is much more complex operation. Current technology would use an array of intelligent pingers, which are dropped to the seafloor over a large grid. They interrogate each other and can quickly derive where each of them are in relation to each other. The rig in turn interrogates the pingers and can establish where it is in relation to the pingers, and because we know where the rig is from DGPS, we can accurately calculate the position of anything in the seafloor grid.

Operationally, a rig operator would have to first determine if they could visually locate evidence of the previously drilled stratigraphic well using ROV sweeps. Once the well position has been located, a pinger array would be dropped around the site, and in 12-18 hours the actual stratigraphic well site and location of a possible core well to twin it could be mapped. In this manner if the rig had a drive off or drift off event or was forced to move because of weather or schedule, the exact location would be known to continue with operation. In addition, the new well must be drilled close enough to the original stratigraphic well to allow core points and tops to be picked from the existing logs. Without careful and precise seafloor positioning, the coring operation would either be done “blind” (potentially leading to poor recoveries) or at significant additional cost in order to drill a correlation well prior to drilling the core hole.

As hole conditions (especially in the well's deeper sections) was less than perfect, a weighted mud would have to be used to improve stability. To avoid having to completely remove the drill string from the well in the case of less than perfect wellbore conditions, a short jet string was planned for each well. This ensured that the well could be visually located in the future and the operation could provide a "safe haven" for the core barrel to be 'parked" while conducting wireline and other work. Because we had only one prototype core barrel, this consideration was paramount in the design plan to safeguard its safety.

For riserless operations, it has become routine to utilize a weighted mud for drilling. The weighted mud keeps the wellbore stable and prevents any shallow flows from happening. Based on analysis over the years, it has been determined that a drilling weight of 10.5 -11 ppg is required for drilling, with 12ppg as a barrier for static columns. To accomplish this, the operation normally blends treated and viscosified seawater with a 16 ppg low solids parent fluid. Each barrel of the heavy material will provide 3 barrel of 11 ppg fluid when mixed in this fashion. For a coring operation, many thousand barrels of the heavy 16 ppg fluid would be needed for each location to be drilled. This would require a rig with substantial fluid storage or a large workboat full of the liquid mud needed.

The coring program was broken into three major organizational "blocks". Each is based on a handover of responsibility and control as the major focus changes. These categories are designed to be independent of the work procedures and tools of the other. Wherever possible one phase of the work will not use equipment from another phase as such practice could affect the critical paths of the tasks in both phases. The work scope and design basis for each is a separate work activity. The basic work blocks are as follows, and detailed in the subsequent sections.

Block-A: Well bore & Rotary Table Operations

> This work involves the permitting of the wells, contracting services and equipment necessary to Drill, Log, Cut and recover core from the three planned wells. This aspect is detailed in this report.

Block-B: Handling core on Surface

> When the core reaches surface, it will be transferred under controlled conditions from the core barrel autoclave to a pressurized transfer/storage device which will be stored on the rig in a climate controlled container. The cores will be shipped to the onshore core analysis location. This work was outlined but never detailed for this project

Block-C: Core analysis and Disposition

When the core samples reach the desired location, the core will be moved to the longer term storage facility and analysis will be undertaken. Once core has been fully processed, the now empty core transfer devices will be returned for servicing and reuse. Preliminary locations and layout of a suitable processing facility was under taken.

For each phase of the work the intent was to treat each block independently, where the output of one is the principal input for the next. The intent was to keep the number and type of interface issues at a minimum to prevent project and risk creep from one to the other.

2.4 PRELIMINARY OFFSHORE OPERATIONAL PLANS

After review of the previous wells drilled in Leg II the election was made to cut continuous core on the GC 955-H, WR 313-G and WR 313-H locations (Fig. 1). Cost estimation for this work was undertaken, utilizing the design basis discussed in the previous section.

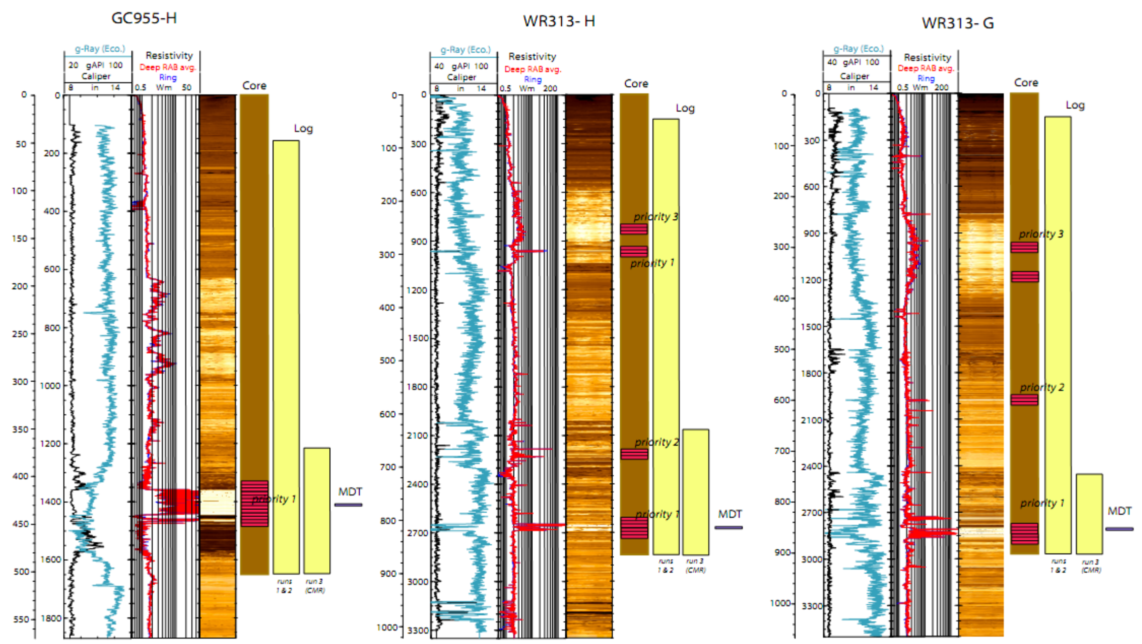


Figure 1

The plan was to move onto location, find the existing wellbore and undertake coring operations close enough to that location so that we could depend on consistent tops from one wellbore to the other. Historically we have had problems with continuity of sand bodies in deeper wells, to the point that the accepted best practice has become the bypass core, where the interval is drilled and logged, then the well is sidetracked to allow coring to commence on depth using the offset log. We do not have that luxury, so the intent was to drill the core well as close as practically possible to the original wellbore drilled and logged during Leg ll. The proximity from one well to the other will be defined by the project geologists based on evaluation of the logs and seismic. The resulting requirements and restrictions were incorporated into the final operational plan. As a contingency, a 30 foot non-pressured core was planned immediately before the first pressure core interval to allow correlation to the offset Leg II well log.

PROPOSED CORING INTERVALS				
LOCATION	**FROM (bml)**	**TO (bml**	**# CORES**	**PRIORITY**
GC 955-H	1,290	1,320	1 (30FEETCONV)	Correlation
	1,320	1,476	15 (156FEETHPTC)	1
WR 313-G	920	950	1 (30FEETCONV)	Correlation
	950	986	3 (36 FEETHPTC)	3
	1,150	1,186	3 (36 FEETHPTC)	3
	1,950	1,986	3 (36 FEETHPTC)	2
	2,170	2,206	3 (36 FEETHPTC)	2
	2,810	2,872	6 (62 FEETHPTC)	1
WR 313-H	845	875	1 (30FEETCONV)	Correlation
	875	901	3 (36 FEETHPTC)	3
	950	986	3 (36 FEETHPTC)	1
	2,220	2,286	3 (36 FEETHPTC)	2
	2,630	2,692	3 (36 FEETHPTC)	1

As can be seen from the operational requirement the designs had to accommodate up to 3000 feet of wellbore, and up to 19 cores.

2.4.1 LOGGING AND EVALUATION PLAN

Preliminary planning assumed a full logging suite at TD in each core hole, after drilling 300 feet of rat hole below the final core. From a drilling perspective a contingency log had been added to allow the new core hole to be correlated to the existing offset location.

Although it was recognized that our current plan was to locate the core hole adjacent to the previously drilled well, we had no guarantee that we could physically find the original wellbore or that the geology was consistent from one location to another. At this point a contingency log run had been added to the log suite to allow for better correlation. In addition the operational plan was to cut a 30 foot non-pressured core immediately before the pressure core interval. It was felt that the log and the core provided enough assurance to be on depth for the rest of the coring program.

The logging evaluation plan is shown in the Table below:

LOCATION	Interval (bml)	Run	Logs
GC 955-H	SF-1320	1	Contingency correlation log
	SF-1775	2	Triple combo
		3	FMI Sonic
		4	NMR
		5	MDT set up for samples
WR 313-G	SF-950	1	Contingency correlation log
	SF-3238	2	Triple combo
		3	FMI Sonic
		4	NMR
		5	MDT set up for samples
WR 313-H	SF-825	1	Contingency correlation log
	SF-2990	2	Triple combo
		3	FMI Sonic
		4	NMR
		5	MDT set up for samples

2.4.2 WELLBORE AND ROTARY TABLE OPERATIONS

The intent was to make the coring operation standalone with the smallest possible footprint offshore. As planned the necessary equipment and services could be mobilized efficiently to any rig of convenience, and coring could be undertaken with minimal time and cost delays. Wherever possible, standard oilfield equipment was to be utilized on a rental basis to minimize cost and risk.

The offshore coring work required that we either contract a rig specifically for the operation or that we wait for a rig of opportunity, where we may be able to tag onto the end of a program at some potential savings in day rate cost. This was a key consideration as the rig spread cost will drive for 60-70% of the entire cost. Because of this it was judged that we would be better spending more up front to make a coring system that is as transparent to the rig as possible and is well integrated to minimize non-productive time. This required that we have easily rigged modules requiring little or no specialized rig support, and that we minimize the number of people and processes that are required to complete a successful operation. At a minimum we required.

- Core barrel and spares plus core repair rebuild equipment and crew
- Inner non-pressured wireline core equipment, service container and crew
- Inner pressure core equipment service container and crew

- Slickline for running retrieving plus overshots, service tools and crew
- Wireline logging tools and crew
- Drill string and drilling speciality tools
- Well control, fishing and backoff Tools (Driling plus wireine)
- Core heads and coring hand

Once the cores reach surface, we planned to transfer the core to a pressure container, and store it for shipment to onshore. In keeping with a minimal footprint concept we looked at either a simplified transfer protocol from the coring autoclave to a shipping autoclave, or increasing the number of autoclaves and not doing any field transfers.

2.4.3 BASIC WELL PLAN

The operational plan proposed as the basis for design was devised to provide minimal risk of failure while maximizing success. The concerns and solutions derived at a high level were categorized as follows

1. **Coring on Depth and getting proper samples:** It was assumed that we would spend some time on location locating the previously drilled stratigraphic wells, and intentionally positioning ourselves as close as feasible to that location for our core hole.
    a. From a permitting perspective it placed us within the bounds of the previous permit and shallow hazard survey.
    b. The core hole twined an existing logged hole significantly reducing any well control risk
    c. The geological tops picked for the core hole would hopefully be horizontally continuous to the core location

    As a safeguard, the program at this point assumed a 30 foot non-pressured core would be cut and a log on top of the first zone would be run to double check the correlation.

2. **Heating the core while cutting causing dissociation**: It was planned to attempt to cut the core with minimal disruption. Heat would be generated from two sources neither of which could be avoided entirely. Firstly the heat generated by the cutting head cutting the core must be accounted for. Directionally we planned to work with the core bit company to design a bit that maximized heat transfer away from the cutters to the mud system. Additionally we planned to tailor the mud flow rate to provide maximize bit cooling, while minimizing flow.

    The second source of heat came from the mud carrying heat from surface to the bit as it moves through the drill string. Coolers and chillers for the surface mud were considered, but rejected as they are ineffective in long water columns where the sea temperatures tend to predominate. It was felt that we could only impact this by adjusting our operational parameters to minimize the effect.

3. **Well Control Wellbore Stability:** Offset wells during Leg II demonstrated the need for mud weights greater than seawater to maintain the wellbore. It seems logical for the base case to assume the use of a weighted mud system, utilizing the pump and dump methodology. Normally this involves large volumes, but preliminary calculation showed that with the smaller hole size used in the program that volumes required would be manageable by most rigs working in those water depths. The type and weights of fluids to be used as well as the point where P-n-D is initiated was to be defined in a later portion of the program.

The offset wells (within 50-100 ft), have been drilled and logged, and the sites chosen show no tendency for shallow flow or gas encroachment. Well control was not felt to be a major issue for this program. Any gas we are likely to see, would probably come from heat transfer from the mud to the formation causing hydrate dissociation. To mitigate this and preserve the formations as much as possible, the basis of design assumed the following general procedure

- Run the internal corer and cut the first pressure core.
- Once cut, pull above the core interval and trip back to the seafloor area. This kept both the formation and the core cooler
- Retrieve the core via wireline
- RIH with next core barrel to cut the next core
- Repeat the process as needed

To further enhance our ability to re-enter the well-bore, it was decided to jet in 2-4 joints of casing (13-3/8" notionally) with an indexing pad. This allowed the coring string to be pulled into casing, and stopped where it could not get stuck while wire-line work was performed. By using the same index point each time it was felt to be simple to optimize this repetitive procedure. Because each mini trip was more or less the same, fingerprinting the trip signature from a well control perspective would be simpler.

On surface, the rig up would be much simpler. The drill string is out of the open hole, and the drill string landed in the rotary slips. Before the core barrel is removed, the pipe would have a side entry sub, a single pack-off ram and stripper rigged up at the rotary. We would not need lubricators, or exotic hook-ups to handle things at surface.

As a contingency, we planned to maintain a cementer and cementing unit on standby in the event we had a flow that could not be controlled. As a part of this contingency we planned to develop procedures and designs for cement slurries and placement techniques which could be used during various phases of the operation.

3. SAFETY REVIEW OF DRILLING AND PRESSURE CORING OF HYDRATE PROGRAM

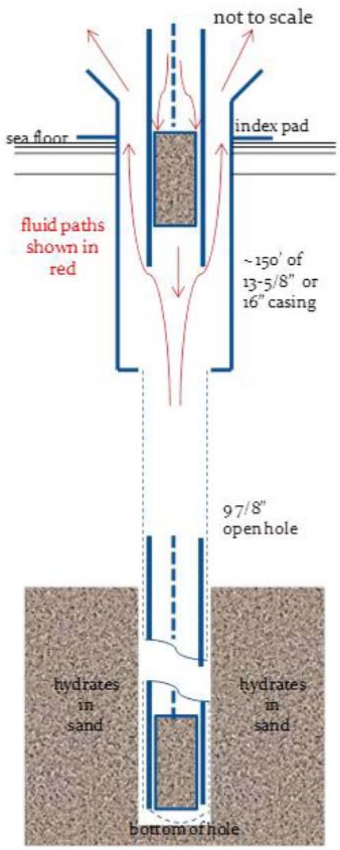
Post the Macondo well incident in 2010, drilling operations in the GOM have become quite different from those normally undertaken in other areas in the world. The greatest impact is that all drilling activities within US territorial limits must comply with all of the new US Codes, Practices and Regulations (as a result of the incident). Additionally, all equipment and personnel coming into the US to work in offshore drilling must:

- Meet applicable electrical, structural, and pressure vessel codes in the US. These may or may not be equivalent to European or international codes.
- Must have valid US certificates and licenses for things like nuclear materials, and other hazardous goods.
- Have valid US work visas for the program.
- Have certificates and training as required for work on a drilling rig.

Drilling rigs have a dual compliance system in that they must meet both shipping/marine regulations as managed by the Coast Guard, and drilling regulations as managed by the newly created BSEE &BOEM. These regulations are complex and they often overlap. Because hydrate accumulations are considered drilling hazards in deepwater GOM drilling operations, the pressure coring operation of hydrates poses serious technical and safety challenges. Chevron as operator of the JIP requested the assistance of Chevron's Drilling Department to review the operation and safety of a hydrate pressure coring program. This section provides a brief summary of the results of that review.

Early on in the design of the Leg III coring program, it was recognized that conventional hydrate coring techniques could present safety and operational issues with maintaining deep, long-duration open holes in soft sediments and minimizing damage to the native hydrate formations being cored at the bottom of the hole. In a conventional wireline program, the core is cut, the drill string and core barrel are lifted slightly off bottom to break the core and wireline is then rigged and run to retrieve the core barrel and then run again to place the next core barrel. If a hydrate formation is cored under this conventional practice, while the wireline is being run in and out of the well, the drill pipe and bottom hole assembly are moving up and down with the rig, potentially placing surge/swab forces on the wellbore in the immediate vicinity of the native hydrate formation. In addition, to keep the pipe from potentially sticking, cleaning circulation is also maintained on the wellbore, exiting the BHA in the vicinity of the native hydrate formation. Both circumstances may lead to washout, hydrate dissociation and other deleterious effects.

As such, the dissociation and consequent gas generation implication inherent in prior practices has safety implications that have to be mitigated. If the BHA is kept near the hydrate formation at the bottom of the hole, well control risk would be high. This would require a flapper float valve on the BHA, and the wireline on the rig must be either run through the top drive or in the extreme case on a grease pack-off system.



A safe pressure coring practice has been developed for the Leg III operation. The drill pipe, BHA and core barrel are tripped up to the same position inside a seafloor conductor casing near the seafloor each time that pressure core wireline operation is run (refer to the illustration).

The well first has a large diameter conductor string jetted in place. This allows the drill pipe to be tripped up inside the large diameter conductor for wire-line operations. Being close to the mudline in a large Internal Diameter (ID) conductor with a drill string filled with a weighed mud ensures any flow from the drill pipe will be out the bottom and outflow from the BHA will continue out to the large diameter annulus and then to the seafloor while tripping or not circulating, even in the event of a gas or water flow event from the well. Operationally, minimal mud flow is maintained on the drill string to assure that any gas migrating out of the wellbore will preferentially take the path up the annulus to the sea as a path of least resistance. This allows a very simple surface hook-up on the drill pipe as was outlined earlier.

This practice places the top of the drill pipe in a safe and consistent position on the rig floor where it could be set in the slips and allowed to move with the heave of the rig without surge swab problems occurring at the bottom near the native hydrate formation or in the open hole. This also allows the use of a very simple surface hook-up. A side entry sub which will allow the hole/pipe to be filled with mud and will also allow mud to be swabbed from the drill pipe during core retrieval is used in conjunction with an air stripper hydraulic pack-off sub and manual TIW (Texas Iron Works) shutoff valve on top for well integrity. During cutting of core the intent is to circulate at the minimum flow rate that will provide a positive cleaning efficiency. This minimizes heat conveyed to the native hydrate formation from the warm mud, while still cooling the bit face and moving cuttings up the wellbore. Once a core has been cut, the pipe is pulled out of the open hole to the conductor, while pumping mud at the lowest feasible mud rate. While the BHA is in the conductor and the core is being retrieved by wireline the hole is filled with mud at a rate showing resulting in a consistent flow from the wellbore as viewed by the Remote Operated Vehicle (ROV). Variations in flow plume could be indicative of a migrating gas bubble. Given that the hole is always full of kill weight fluid and the drill string is pumped out of the hole while tripping to maintain a hole filled with mud, a gas or water flow is a very remote possibility. Once the inner core barrel has been retrieved and a new barrel rerun, the pipe is washed to bottom at enough mud flow rate to circulate cuttings from the wellbore prior to the next core being cut. This pumping schedule, while somewhat counterintuitive from a drilling perspective, makes sense if the goal is to minimize hydrate dissociation and washout of the native formation and maximizing core quality.

Due to the ease of dissociation of the hydrate, the unconsolidated sediments in the coring operations and possibility of shallow water flow, hydrates have been traditionally considered drilling hazards. The discussions in the above section show that the drilling operations to collect pressure cores are very complex. In addition, the risk factor is increased because the pressure coring tool will be a prototype tool that will be custom built for use in a research project. The functionality of an experimental prototype tool might not be reliable and its operation interface with a deep water drilling rig is complex. Given the gravity of an offshore incident in Deepwater GOM, the new regulations and the hazard of a pressure coring operation in hydrates, the drilling review concluded that the only acceptably safe option for Leg III would be a 6th generation drillship that is operated by an experienced GOM operator. Only a 6^{th} generation drillship under the operatorship of an experienced deep water operator would have sufficient safety capability to handle various drilling contingencies, and met all safety and environmental requirements.

4. COST ESTIMATION FOR OFFSHORE LEG III HYDRATE DRILLING AND PRESSURE CORING PROGRAM

4.1 WORK BREAKDOWN ESTIMATE

Time estimates for the proposed, complex deep water open hole pressure coring, wireline logging and wireline MDT involving long expected times in-hole as proposed are unprecedented and therefore had wide ranges of uncertainty. As a consequence, the Leg III time estimates were established using a Work Breakdown Structure (WBS) that considered the time to conduct unit operations based on past industry and scientific rig experience. For each WBS estimate a tolerance has been applied to account for potential best and worst cases, again based on experience.

4.1.1 PENETRATION RATES

For purposes of illustration, below is one example of an estimated WBS to run and retrieve a wireline plug from the bit:

Run Retrieve Plug	
Rig up Wireline	5
Stab and install stripper	3
RIH @ 20k/hr	20
handle Plug	10
POOH A 20K per hr	20
Remove Stripper, Rig out wl	6
Clean floor	6
Avg Time (min / plug)	**70 mins**
Avg Time (hr / plug)	**1.2 hr**

The assumptions for the WBS time estimate above are program and operation specific. In the Basis of Design it was assumed that the core barrel would be tripped to the same position inside a seafloor conductor casing each time that wireline was run. This practice places the top of the drill pipe in a safe and consistent position on the rig floor where it could be set in the slips and allowed to move with the heave of the rig without surge swab problems occurring below in the open hole. This also allowed the use of a very simple surface hook-up. A side entry sub to allow the hole to be filled with mud was planned in conjunction with an air stripper and manual rattegan on top for well integrity. Times shown were in minutes for each major operation. The side entry sub design provided a 5.901 min ID and a fast knock off top sub to allow the stripper, rattgan and top cap to be lifted as a unit once the tool was at surface.

Wireline speeds planned were the maximum allowed by the vendor for tripping the tools and all other times were estimates based on experience in similar operations. The resulting total of 1.2 hr per trip was then utilized in building up the overall time line with a minimum and maximum variance added.

Similar timelines were formulated for all key operations, such as jetting and cementing casing, drilling, running or retrieving wireline, core barrel, retrieving wireline, logs and wireline MDT operations

4.1.2 PENETRATION RATES

Average Drilling Rate		
Instantaneous ROP	600.0	Min
Rotation time on stand		9.4
Circ		3
Slips		5
Circ		2
Avg Time per stand		0.32
Avg ROP		290.72

It had been assumed that the hole can be adequately cleaned at instantaneous penetration rates of 600 feet/hr if a rig with high pressure high volume pumping systems was available. Counting circulation times and connection times the effective average ROP used was approximately 290 feet/hr. However, analysis of Leg II indicated a substantial amount of time was spent on flat time events stemming in large part from poor hole cleaning and wellbore stability caused by salt water slug drilling techniques. For the significantly more complex and lengthy Leg III operations a high quality mud was specified because the wellbore must be held open for an order of magnitude more time than Leg II. A weighted (10-11 ppg) mud system was planned for most of each Leg III hole. The use of mud allows high penetration rates with increased wellbore stability. Similar to Leg I and Leg II and numerous other hydrate expeditions a riserless pump and dump configuration was planned (i.e. no BOP and riser system).

4.1.3 RUNNING AND RETRIEVING WIRELINE

Running internal bblbbl	
WD: 6670	Min
Move Core handler to catwalk(offline)	
put Core handler in mouse hole	5
Pick up Inner BBl with wireline	2
Set latches and put inner bbl in dp	5
Install striper	5
rih @ 10k/hr to reference mark	40.02
latch tool	5
pooh wireline @ 20k/hr	20.01
rig out stripper	5
Wash to btm @ 4 min/stand	
Core @ reduced pump	10
Break core Backream out	
Set pipe in slips and rig wireline	5
Stab and Install stripper	5
RIH wireline@ 20 k /hr	20.01
Latch core	5
pooh w/ core @ 20k/hr	20.01
Remove Stripper &Install Clamp	5
Put Core into handler shuck	3
Pick up shuck and lay down same	5
Clean up floor	5
Avg Time (hr/core)	**2.83**
Trip in (min/Stand)	**4.00**
Trip out (min/stand)	**3.00**

4.1.4 CONVENTIONAL CORING PRACTICE

Early on in the design of the coring program it was recognized that conventional techniques used in other hydrate coring operations could have a deleterious effect on maintaining deep, long duration open holes and on minimizing damage to the bottom hole native hydrate formations. In a conventional wireline program the core would be cut, the drill string and core barrel would be lifted slightly off bottom to break the core and wireline would be rigged and run to retrieve the core barrel and run again to place the next core barrel. Under this conventional practice while the wireline is being run in and out of the well the pipe is moving up and down with the rig, placing surge/swab forces on the wellbore in the immediate vicinity of the native hydrate formation. To keep the pipe from potentially sticking cleaning circulation is also maintained on the wellbore, again in the vicinity of the native hydrate formation. With the bottom hole assembly near the hydrate formation bottom hole mitigation of well control risk requires a flapper valve on the bottom hole assembly and the wireline on the rig must be either run through the top drive or in the extreme on a grease packoff system.

4.1.5 LEG III CORING PRACTICE

The design basis and timeline proposed in this program was based on tripping drill pipe and raising the bottom hole assembly to a safe position in a near-seafloor conductor prior to wirelining so that well control, pipe sticking and open hole surge and swab were not a concern. To do this the well had plans to jet a large diameter conductor string in place. This allows the drill pipe to be tripped up inside the conductor for wire-line operations. Being close to the mudline in a large ID conductor with a drill string filled with a weighed mud ensured any flow out from the core barrel would be to the annulus and seafloor while tripping or not circulating even in the event of a gas or water flow event from the well. Operationally a minimal mud flow was to be maintained on the drill string to assure that any gas migrating out of the wellbore would preferentially take the path up the annulus to the sea as a path of least resistance. This allows a very simple surface hook-up on the drill pipe as was outlined earlier.

While coring, the intent is to circulate at the minimum flow rate that will provide a positive cleaning efficiency. The intent was to minimize heat conveyed to the native hydrate formation from the warm mud, while still cooling the bit face and moving cuttings up the wellbore. Once a core had been cut, the pipe would be lubricated out of the open hole to the conductor, again at the lowest feasible mud rate. In the conductor while the core was being retrieved by wireline the hole was filled at a rate showing a consistent flow from the wellbore as viewed by the ROV. Variations in flow plume would be indicative of a migrating gas bubbles. Given that the hole is always full of kill weight fluid and the drill string was pumped out of the hole to maintain a hole filled with mud a gas or water flow was thought to be a very remote possibility.

Once the inner core barrel had been retrieved, and a new barrel rerun, the pipe was to be washed to bottom at a high enough rate to circulate cuttings from the wellbore prior to the next core being cut. This pumping schedule while somewhat counter intuitive from a drilling perspective makes sense if the goal is to minimize hydrate dissociation and washout of the native formation and maximizing core quality.

The timeline shown assumes a great deal of rig floor optimization has taken place regarding core retrieval. The Project Team aimed at having the core moved from the rig floor to a cold environment in 5-10 minutes. Historically during hydrate coring operations there cases where more than 45 min to an hour were being spent on measuring pressures, temperatures and making rotary breaks on a core. Our intent is to quickly move the core barrel to an offline handling location and then to storage, so that a new barrel can be run as soon as possible in the core hole and the quality of the sample in the autoclave from the previous coring run is preserved with minimal disturbance.

Little work was undertaken in optimizing time spent at the rotary other than the conceptual ideas presented here. The barrel needs to be moved as quickly as possible either to a mouse-hole transfer shuck, or to a horizontal cradle. In either case it is important that they have cooling capabilities, and enough support to prevent bending and possible core breakage. During the design phase for any new program it is a strong recommendation that the team look at the handling requirements for the barrel and if necessary make changes in the design to promote rapid handling of the barrel.

4.1.6 WIRELINE ELECTRICAL LOGGING

Run Retrieve PEX log				
	PEX	FMI	CMR	MDT
		Min	Min	Min
Rig up Wireline	180	120	120	120
Stab and install stripper	30	30	30	30
RIH @ 20k/hr to mudline	20.01	20.01	20.01	20.01
Log in @ 7/3.6/18 kft/hr	15.34	29.833	76.714	15.3429
Log out@ 3.6/1/8/.7 kft/hr	29.83	59.667	153.43	200
POOH @ 20k/hr	20.01	20.01	20.01	20.01
Remove Stripper Rig out wl	5	5	5	5
Clean floor	45	45	45	45
Avg Time (hr/log)	5.75	5.49	7.84	7.59

The basis of design, required a full suite of logs on the wellbore following the final core. The time for each run was calculated using times provided by Schlumberger for anticipated run speeds and handling times. The final MDT run was still very undefined at the time of the estimates so a block of 20 x 10 min pressure tests was assumed for the timeline.

The previous basis of design assumed that a log-through-the-bit-system would be utilized. This ultimately meant a requirement for a 6.5 inch ID drill pipe to accommodate both the core barrel and a 5-7/8" thru bit wireline log clearance. The Chevron Leg III safety assessment determined that commercially available drilling casing would not have high enough safety factors for deployment of the system in deep water and no conventional drill pipe existed as a replacement. The large diameter HPTC development program was therefore discontinued and will be replaced by a slim hole design that can be run in conventional drill pipe. Wireline logging operations would need to be done in open water using the ROV to guide the log into the well via the casing at the seafloor.

4.2 TIME ESTIMATE FOR DRILLING AND PRESSURE CORING EXPEDITION ON A 6TH GENERATION DRILL SHIP

The notional case for time estimate is based on the unit times provided. The operation was broken down into steps, each of which was either estimated or calculated. The planned time shown reflects unit times taken from the tables discussed earlier. To these a minimum or target time of 90% of the plan was calculated and a maximum of 120% of plan. At the end a 25% Non-Productive Time allowance has been added. Similar levels of detail were applied.

In all cases the base timeline assumed that an operational drill ship with full dual and offline capability would be utilized. Additionally modern drill ships have the capabilities to handle a high capacity, high rate mud system and afford a much more efficient derrick management system than smaller, older rigs. The next page shows the results.

An available short window could be utilized for single stack rigs whilst the BOP's for the prior contract are being recertified pursuant to the new BSEE regulations. It is expected that a 20 day to 30 day period would be required for this servicing every 3-4 months, during which a single well coring program could nicely fit.

Each well was treated as a separate mobilization, and it was assumed that the coring package and fluid systems could be moved to the rig and set up while the rig was finalizing abandonment/suspension operations of the current drilling hole. Similarly at the end of the well, demobilization of the coring package is treated as an offline activity. This results in a significant time and cost savings over a rig of opportunity. Because the rig is operational, it was further assumed that it would move to and from our location with the necessary drill pipe racked in the derrick. The jet string and 13-3/8" conductor would be picked up and racked in the derrick, again offline. While the rig is positioning, the entire pump and dump system would be transferred to the rigs storage and active mud system, and the jet/ conductor string would be run, allowing spud as soon as position is confirmed.

Gulf of Mexico Joint Industry Project Leg III Coring time Estimate

Well Name	GC 955H
Rig Name	TBA 6 Gen Drillship
Latitude	27 00 02.0707
Longitude	90 25 35.1142
API	608114053700
WD	6670

COMMENTS: Single Well Jet 200 ft Conductor to 6870, Drill & Core 1790 bsl (8460) log and Abandon.

Interval	FROM (bml)	TO (bml	Core Length	Core Runs
1	1,315	1,491	11	16

Sea Floor Depth (ftbrf)	Sea Floor Depth (ftbml)	Operations Description	Plan Time (hr)	90% Time (hr)	120% Time (hr)	Cum. Plan Days	Jetting (ft)	Drilling (ft)	Coring (ft)	Circ Low hr	Circ hi hr
6670	1790	Offload Core Tools , Service Trailer Transfer unit (offline)					200	1414	176	60	28
6670		Offload Drill pipe & handling tools , mud system (offline)									
6670		Pick up Coring DP & workstring rack in derrick (offline)									
6670		Mix Mud and rig tp spud (Transit)									
6670		Transit to GC 955H (moccasin to GC955 133 mi@ 8)	16.6	15.0	20.0	0.7					
6670		Locate Pinger and set beacons on seafloor	12.0	10.8	14.4	1.2					
6670		Pick up Conductor & index pad (offline)				1.2					
6670		Run jet string (offline)				1.2					
6670		Make up DP and RIH (Offline)	6.0	5.4	7.2	1.4					
6870	200	Jet in conductor	4.0	3.6	4.8	1.6	200				2
6870	200	POOH lay down Jetting BHA	7.0	6.3	8.4	1.9					
6870	200	Make up Core BHA & rih	10.0	9.0	12.0	2.3					
7985	1315	Control Drill to 1350 BSL W/center plug in place	3.8	3.5	4.6	2.5		1115			3.8
7985	1315	Circ hole to clean mud	3.0	2.7	3.6	2.6					3.0
7985	1315	POOH to Shoe	0.7	0.6	0.9	2.6				0.7	
7985	1315	Rig wireline and pull Centerplug	1.2	1.1	1.4	2.7					
7996	1326	Pressure Core #1	4.5	4.1	5.4	2.9			11	3.67493	0.84076
8007	1337	Pressure Core #2	4.5	4.1	5.4	3.1			11	3.6819	0.84774
8018	1348	Pressure Core #3	4.5	4.1	5.5	3.2			11	3.68888	0.85471
8029	1359	Pressure Core #4	4.6	4.1	5.5	3.4			11	3.69585	0.86168
8040	1370	Pressure Core #5	4.6	4.1	5.5	3.6			11	3.70283	0.86866
8051	1381	Pressure Core #6	4.6	4.1	5.5	3.8			11	3.7098	0.87563
8062	1392	Pressure Core #7	4.6	4.1	5.5	4.0			11	3.71678	0.88261
8073	1403	Pressure Core #8	4.6	4.2	5.5	4.2			11	3.72375	0.88958
8084	1414	Pressure Core #9	4.6	4.2	5.6	4.4			11	3.73072	0.89656
8095	1425	Pressure Core #10	4.6	4.2	5.6	4.6			11	3.7377	0.90353
8106	1436	Pressure Core #11	4.7	4.2	5.6	4.8			11	3.74467	0.91051
8117	1447	Pressure Core #12	4.7	4.2	5.6	5.0			11	3.75165	0.91748
8128	1458	Pressure Core #13	4.7	4.2	5.6	5.2			11	3.75862	0.92446
8139	1469	Pressure Core #14	4.7	4.2	5.6	5.4			11	3.7656	0.93143
8150	1480	Pressure Core #15	4.7	4.2	5.7	5.6			11	3.77257	0.93841
8161	1491	Pressure Core #16	4.7	4.3	5.7	5.6			11	3.77955	0.94538
8161	1491	Run center plug	1.2	1.1	1.4	5.6					
8161	1491	RIH	1.1	1.0	1.3	5.7					1.1
8460	1790	Drill Rathole	1.0	0.9	1.2	5.7		299			1.0
8460	1790	Circ and POOH TO shoe	8.0	7.2	9.6	6.0					2.66667
8460	1790	PEX RT Scanner	5.8	5.2	6.9	6.3					
8460	1790	FMI Sonic Scaner	5.5	4.9	6.6	6.5					
8460	1790	CMR HNGS	7.8	7.1	9.4	6.8					
8460	1790	MDT Pressure Sampling (10 points)	7.6	6.8	9.1	7.1					
8460	1790	MDT Sample testing (1 sample test)	2.0	1.8	2.4	7.2					
8460	1790	POOH lay down tools				7.2					
8460	1790	Rig for Transit offline	3.0	2.7	3.6	7.4					
25%		Contingent time	45.3	40.8	54.4	1.9					
		HOURS	181.2	163.1	217.5		200.0	1414.0	176.0	60.4	27.9
		DAYS	7.55	6.80	9.06						

4.3 DRILLING COSTS FOR DRILLING AND HYDRATE PRESSURE CORING PROGRAM

Based on the time estimates, cost quotations were obtained for the necessary logistical support and operational items such as bits, mud, rental pipe, wireline crews, etc. Basic rig rates were based on informal quotes for a typical 6^{th} generation deepwater rig currently in operation in the 6000-8000 feet water depth range. Costs were developed for three coring operations back to back or three separate operations with three separate mobilizations

6'th Gen @ Notional $800000 per day Spread Cost: Three Independent Wells						
		Days + NPT	Dayrate items	Non Dayrate	Tangibles	Well total
Green Canyon 955H	P10	8.5	$6,800,000	$1,869,750	$455,350	$9,125,100
	P50	**9.9**	$7,920,000	$2,078,000	$455,350	**$10,453,350**
	P90	11.3	$9,040,000	$2,285,250	$455,350	$11,780,600
Walker Ridge 313 H	P10	10	$8,000,000	$2,199,150	$455,350	$10,654,500
	P50	**11.7**	$9,360,000	$2,443,500	$455,350	**$12,258,850**
	P90	13.4	$10,720,000	$2,687,850	$455,350	$13,863,200
Walker Ridge 313G	P10	9.6	$7,680,000	$2,083,050	$455,350	$10,218,400
	P50	**11.2**	$8,960,000	$2,314,500	$455,350	**$11,729,850**
	P90	12.8	$10,240,000	$2,545,950	$455,350	$13,241,300
Total For Program	P10	28.1	$22,480,000	$6,151,950	$1,366,050	$29,998,000
	P50	32.8	$26,240,000	$6,836,000	$1,366,050	**$34,442,050**
	P90	37.5	$30,000,000	$7,519,050	$1,366,050	$38,885,100
6'th Gen @ Notional $ 800000 per day Spread Cost: Three Sequential Wells						
Total For Sequential Program	P10	28	$22,320,000	$6,151,950	$1,366,050	$29,838,000
	P50	**32.6**	$26,080,000	$6,836,000	$1,366,050	**$34,282,050**
	P90	37.2	$29,760,000	$7,519,050	$1,366,050	$38,645,100

4.4 TOTAL COST ESTIMATE FOR A DRILLING AND HYDRATE PRESSURE CORING PROGRAM

The cost of operating a 6th generation rig varies with time, depending on supply and demand and on inflation. In 2001, the rate for a 6th generation rig exceeds well over $1,000,000 /day not including mobilization and demobilization cost. The rig cost alone for a three wells coring program would be well over $32,000,000. This would not include other JIP personnel cost, pressure coring equipment and post-expedition core analysis. The latter would be no less than $6,000,000 to $10,000,000. The total cost would be well over $40MM, which is prohibitively expensive. Even if the program is reduced to one well, the cost would come close to $17,000,000 to $20,000,000. It should be recognized that the risk of failure for a one well program would be very high due to operation risks. There would be no time to debug the pressure coring operation and prototype pressure coring equipment and as well to assess and make operation adjustment to geological risks and unexpected hazards.

5. SUMMARY

The planning and design of a Leg III drilling and pressure coring operation for hydrates in the offshore Gulf of Mexico has been carefully conducted in detail. The study included a scoping study, a front end engineering study (FEED), a drilling and coring safety review, and a detailed time and cost estimate of an offshore operation to obtain hydrate pressure cores. The main conclusions of the study are:

1) Offshore drilling and pressure coring of hydrates carry inherent considerable safety risks as hydrate accumulations are considered drilling hazards. The analysis within this study showed that there are many risk factors in a pressure coring operation with an experimental prototype pressure coring tool. To provide adequate safeguard, a 6th generation drill ship should be deployed for Leg III pressure coring operation.
2) Time and cost estimate of Leg III pressure coring operation using a 6th generation drill ship would be prohibitively expensive as the rental cost would exceed $1MM / day. The total cost of a nominal three well program would exceed $40MM.