A New Coring Technology to Quantify Hydrocarbon Content and Saturation

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ABSTRACT
The industry is challenged to accurately determine the total hydrocarbon composition and saturations in both conventional and unconventional reservoirs. Several attempts in coring technology advances have been employed in the past with limited success. These attempts include methods to collect expelled pore space fluids and gases for further analysis. The attempts have resulted in technologies that provide limited core in terms of length and diameter, low recovery percentages, poor success ratios and complicated core processing. Pressure coring itself has been viewed as a solution but introduces inherent safety concerns by bringing high-pressure systems to the surface. The combination of poor reliability and safety risks has resulted in infrequent use of the various technologies and methods to analyze pore fluids and gases. A new tool has been developed to overcome the safety concerns, simplify core processing and provide the means for quantitative answers.

INTRODUCTION
As most laboratory measurements depend on freshly cut core to accurately assess oil in place, gas in place, gas and oil geochemistry, permeability, porosity and saturations along with several other analyses it is critical to collect pristine core samples. These pristine samples are crucial when attempting to assess the risks, economics, and potential successes of a targeted resource play. Utilizing traditional coring techniques it is impossible to recover all of the fluids and gasses associated with a core sample that is cut as these components can escape the core barrel during the cores trip to surface. The consequence of these lost gases and fluids results in a data gap that a laboratory must then apply a calculated model to in order to provide deliverable results.

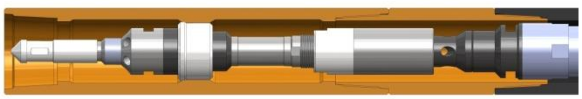
The new technology is a pseudo pressure core application where core and associated pore space fluids are cut at reservoir conditions and brought to surface in a closed, variable volume system. The primary objective is to provide quality core while retaining all pore space gasses and fluids for analysis. This paper describes the design and functionality of this technology including operating and core handling procedures. The technology is currently being used in various sediments across multiple geographies.

TOOL DESIGN
The variable volume characteristic of the tool which is shown in Figure 1 allows gas and fluids to expand while coming out of the hole without creating pressure build up resulting in unnecessary safety risks. The tool is designed to run on both a conventional or wireline coring platform which is specified in Table 1. In both of these applications the core is cut and prior to

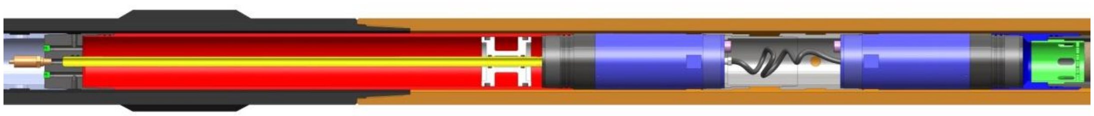
tripping out of the hole, the core barrel is closed and sealed to retain all the gases and fluids. A single or set of storage canisters are positioned in the bottom hole assembly directly above the core barrel to capture any expelled gases and liquids that are released from the core during the trip out of the hole. The tool is configured such that overpressure is maintained on the core to prevent complete escape of the pore space fluids until bleeding can be accomplished in a controlled manner on surface.

Figure 1. Coring System Components

Inner Barrel Retrieval Head



Storage Canister Crack Valve and P&T Recording Modules



Inner Barrel Core Catcher, Valve & Bit Latch

Table 1. Specifications of Coring System

Core Diameter:	3-4”
Standard Core Length:	10’
Max Temperature	250°F (125°C)
Max Pressure (operating)	1000 psi

Over the last three or four decades traditional pressure coring has circulated throughout the industry while facing a series of limitations and reliability issues. Traditional pressure coring systems were designed to be extremely robust meant to handle pressures over 10,000psi that required the tool to be brought to surface under extreme pressures. Eventually the tool would have to be bled down to atmospheric pressure or undergo a high-pressure transfer while on surface. Considering these high-pressures engineering groups have historically only been able to design a tool that produced small diameter cores, which limited the laboratory core analysis package. Given the traditional limitations the newest design was engineered to allow the core to depressurize while tripping out of the hole which drastically reduced the maximum working pressure requirements allowing for a larger core diameter. In addition to reducing the working pressure a proprietary sealing system that is fitted in the bottom of the core barrel was developed to increase efficiency and repeatability in sealing the core and associated gases and fluids in the tool. On top of the core barrel a single, or series, of canisters is placed designed to collect gases and liquids that may be released from the core during the trip out of the hole. Pressure and temperature recording transducers are placed throughout the barrel and the canisters in order to record the coring operations and the pressure communication between the barrel and canisters.

Operating Procedures

A well is conventionally drilled until core point is reached, the drill string is then pulled and the coring tools are tripped into place. The tool can be run both on a conventional and wireline platform with pressure core runs being strategically placed throughout the coring program. When a pressure core interval is identified a standard length core is cut and the assembly is hoisted off the bottom of the hole to break the core at the bit. A wireline is then run down the hole and latched onto the coring assembly. An initial pull strokes the tool allowing the core to pass the valve assembly and seal the tool. A secondary pull disengages the tool that is then tripped to surface.

On top of the pressure core barrel is a crack valve that allows pressure to communicate with the canister once a desired pressure is met. Inside the canister is a floating piston that is open to hydrostatic fluid column pressure that monitors the pressure happening inside the system. As the fluid column above the tool is getting shallower during the trip out of the hole there is less pressure on the backside of the tool, making it easier for the piston to move. At some given point the core will want to release some of its gases or liquids. When that happens the volume inside the barrel expands which creates a pressure differential inside the barrel; the pressure inside the barrel continues to grow, the pressure on the other side of the barrel continues to decrease because the tool is decreasing in hydrostatic pressure. When the internal barrel pressure over comes the crack valve pressure the valve at the top of the barrel opens allowing gases and liquids to communicate between the core barrel and the adjacent canister or between consecutive canisters. This event continues to repeat as the tool is tripped out of the hole. As another safety precaution the tool is fitted with pressure relief valves in case of any failures in the tool due to plugging or a malfunction where gases or liquids will release into the well bore until the pressure falls below the pressure relief valve setting.

BARREL AND CANISTER RECOVERY

It is very important that the surface handling kit is fit for purpose depending on the reservoir application. Strict handling procedures must be implemented to ensure that all required data is accurately documented and measured. Common mistakes in the field such as: poor sample quality, inaccurate data, or missing data, often cannot be overcome due to the time dependent nature of the operations.

As soon as the tool reaches the surface it is laid down and the barrel and canister recovery process begins. The transducers are first download with the pressure and temperature curves being evaluated to ensure the coring and trip out of the hole were a success. If a successful test is observed the storage canisters are removed and the handling of the core barrel begins. The barrel continues to be monitored, as the core may still be creating pressure. The barrel is continually monitored until it is safe to transport to the onsite laboratory.

There are several different methods being practiced on how to recover the gases and liquids from the core depending on the application. In all cases the pressure is released from the barrel with the associated gases and liquids being measure and collected for further laboratory analysis.

Once all of the pressure is relieved from the tool the core is extruded from the barrel and transferred to a shipping canister and sent to the laboratory.

DRY GAS TARGET TECHNICAL EXAMPLE

Shale gas is stored within a reservoir system by three primary mechanisms; 1) gas-filled porosity by compression, 2) adsorbed to organic material present in the rock, and 3) dissolved within the reservoir fluids. One of the primary objectives in a dry gas shale exploration program is to supply the core analysis laboratories with pristine core samples in order to provide sufficient data to enable characterization of bulk rock properties (mineralogy, organic content, porosity and water saturations), and total (sum of adsorbed, absorbed, and free) gas in place volumes over a cored interval.

The upcoming example focuses on helping to determine an accurate gas in place in an unconventional shale reservoir target that is often hard to analyze due to the combination of small grain sizes and micro-porosity. To accurately determine the amount of gas in place without using a lost gas model to estimate the amount of gas that was lost during a cores trip to surface. Traditionally canister gas content measurements are utilized to estimate sample gas content and then confirmed by a combination of porosity, fluid saturation and adsorbed gas storage capacity data used to quantify total gas storage capacity at reservoir temperature and pressure conditions.

Traditional gas content analysis collects a series of core samples to be placed in canisters for volumetric and compositional analysis. Gas volumes released from the canisters are measured over time until the samples are pulled out of the canisters and crushed to measure any residual gas that is left on the rock. The rate at which the gas expelled from the core plus the total volume of gas that is measured from the canister including the residual gas analysis are used to calculate the amount of gas that was lost (“lost gas”) during the trip out of the hole. The total volume for the samples are then calculated as the sum of the lost gas, measured gas and crushed gas contents. These estimations can have large error margins as significant volumes of gas are expelled before the core reaches surface.

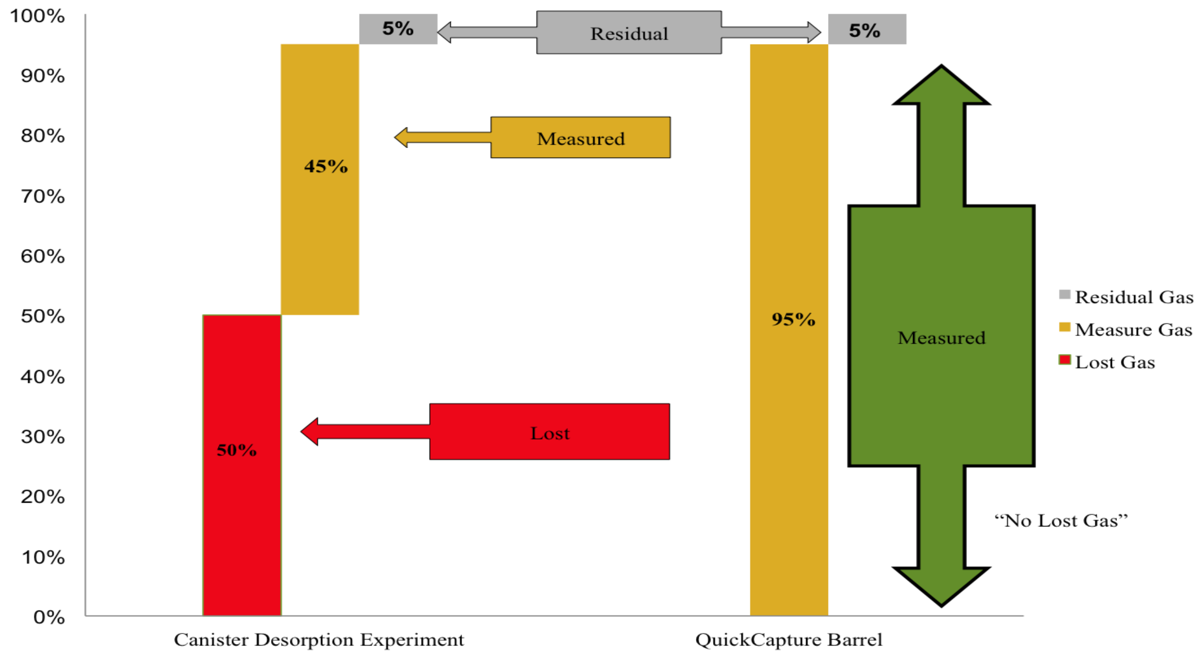
A recent coring program was executed in a dry, shale gas reservoir where no hydrocarbon liquids were present. The objective was to quantify the total amount of gas in place and compare the data results from conventional core versus adjacent pressure core runs. An upper and lower zone were identified with an extensive gas content program performed on each zone followed by a pressure core directly below the samples that were collected for gas content analysis.

Prior to running each pressure core, a wireline retrieved conventional core was obtained and multiple one-foot samples were placed in canisters to determine volumes by using the traditional gas content measurement of combining measured, residual and lost gas.

The new pressure coring tool was deployed directly below the conventional core runs. Once the core reached surface it was transferred from the rig floor to a heated isothermal water bath where total volumes of gas released from the core were measured. Total volumes were measured from the tool on location until negligible volumes were recorded at which point the tool was allowed to cool before the core was transferred to a core transport canister and sent to the laboratory for further analysis. Once the core transport barrel was received at the laboratory it was put back on test for additional gas content volumetric readings. In the laboratory the volume measurements were plotted versus time with all data being fit to a curve to monitor the behavior of the samples. The rate at which the gas evolved from the core was calculated until it was deemed that minimal gas would be lost when processing the core to be analyzed for residual gas analysis. The total gas contents for the pressure core samples were then calculated as the sum of the measured gas from the pressure core barrel, the core transport barrel and residual gas analysis.

The as-received gas content numbers for the canister samples versus the pressure core samples were then plotted against each other.

Figure 2. Graphical Relationship of Canister Data to Adjacent Pressure Core Samples



Note: The above example depicts a recent case history and with regards to client confidentiality all values have been removed however the graph does depict an accurate comparative ratio of gas content volumes.

A distinct difference exists between gas volumes obtained via traditional methods and the pressure coring assembly. Based on actual data, the "lost gas" estimation calculated in the traditional method reflects more than 50% of the gas in place downhole. The information shows a significant portion of gas is lost while pulling out of the hole using conventional coring methods.

Based on the results of this project, it is concluded that the pressure coring application provides accurate volumetric measurements of gas in place. Currently, additional laboratory measurements are taking place to further this study. By combining porosity, fluid saturation, and adsorbed gas, gas storage capacity is being quantified at reservoir temperature and pressure conditions. Pressure coring takes the guesswork out of gas content analysis and is suitable for both conventional and unconventional reservoirs.

CONCLUSIONS

Pressure coring has gone through many different design approaches over the last several decades. This new technology which involves a pseudo pressure core system where core is cut at reservoir conditions and the associated pore space fluids and gases are brought to surface in a closed, variable volume system is rapidly developing it's own place in the market. The applications and associated deliverables are continuing to be defined throughout the industry as there is an evoloving need for accurate resevoir propertie assesments. Combining this new techonoly with traditional coring and evaluation methods will continue to aide in the formation evaluation process.

Research and development continue to take place with engineering on the mechanical properties of the tools as the applications for the tool across the golobe are vastly different. This paper has defined the first phase of a tool that currently already has design modifications taking place to meet the evergrowing needs of the industry.