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Drilling Mud Particle Size Analysis System

Offshore Field Trial

1. Background

JM Canty manufacture and supply vision based process instrumentation, which includes vessel sight glasses & lighting, process and high temperature cameras along with vision based particle sizing systems. This product line has helped Canty to diversify across a wide variety of industries, in which our vision based particle sizing systems are utilised within the pharmaceutical, food and beverage, chemical, mining and oil & gas industries. This wide variety of industries affords Canty the luxury of drawing from their experiences in one industry and implementing the advantages into another industry.

Dynamic imaging through the use of Canty's vision based monitors provides an at-line, near real time particle size analysis of the drilling mud. In industries where size and shape are critical, vision technology offers another dimension in analysis that not only assesses a particle shape, but also delivers direct particle size information. Analysis of drilling mud has several associated challenges such as sampling & solids dropout. Sampling and processing a sample are often difficult due to the weight of the particles in slurry. Stratification and dropout can prevent representative sampling and analysis. Vison capabilities and handling methods enable the mud to be properly sampled at-line in order for a representative sample to be obtained from the line and run in its entirety without further sample division. The instrument can be utilised in near real time on an automated drilling rig to provide critical data to evaluate the drilling muds composition throughout the drilling process.

The benefits of the Canty system over other particle sizing instruments currently on the market are:

1. Distinguish between particles and bubbles/droplets; without this correction, PSD data can be misleading, particularly with OBM.
2. Real time analysis allows frequent monitoring of mud conditions.
3. Distinguish between solids of different shapes (e.g. fibres from cuttings).
4. Representative sample from pipeline analysed without further sample division.
5. Vision technology is a non-contact methodology and therefore no drift in calibration over time.
6. System includes Canty spray ring technology for cleaning of the camera and light lenses should they require it. Fused glass-to-metal lenses are rugged and durable and ideally suited for harsh environments.
7. Viewing into the process is invaluable for data confirmation, troubleshooting (remotely) and continual process improvement.
8. Images can be post-analysed, and utilised to give equivalent sieve readings.

1.1 Objectives

The main targeted applications are for reservoir drill-in fluids (RDF), drilling fluids containing wellbore strengthening material and shaker screen breakthrough. In addition to the above, the system can be utilised for monitoring real time % TSS (Total Suspended Solids)of the completion brine.

This field trial focused on the reliability of Canty's vision-based instrument in measuring and displaying real time Particle Size Distribution (PSD) data of water-based reservoir drill-in fluids (RDF) used for drilling the reservoir section of an injection well. Total Suspended Solids (TSS) of the completion brine was measured using Canty's vision based instrument during casing displacement to achieve the specification of <0.05% of TSS.

The Canty unit was set-up and run on bench top in the mud lab on the rig during the trial. For this initial field trial, the lab system was utilised as proof of concept, with plans for a real-time field trial at a later date.

Mud samples were collected from the returns flowline post-shaker and from the active suction pit approximately every two hours for PSD measurement. TSS samples were collected matching the frequency of the sample collection from the filtration team during casing displacements in order to compare Canty's % TSS results with results from the existing manual method (electric centrifuge).

The field trial was a passive trial and was not used for rig-site decision making.

2. Principle of Operation: Lab Drilling Mud Particle Sizing and Auto- Dilution System

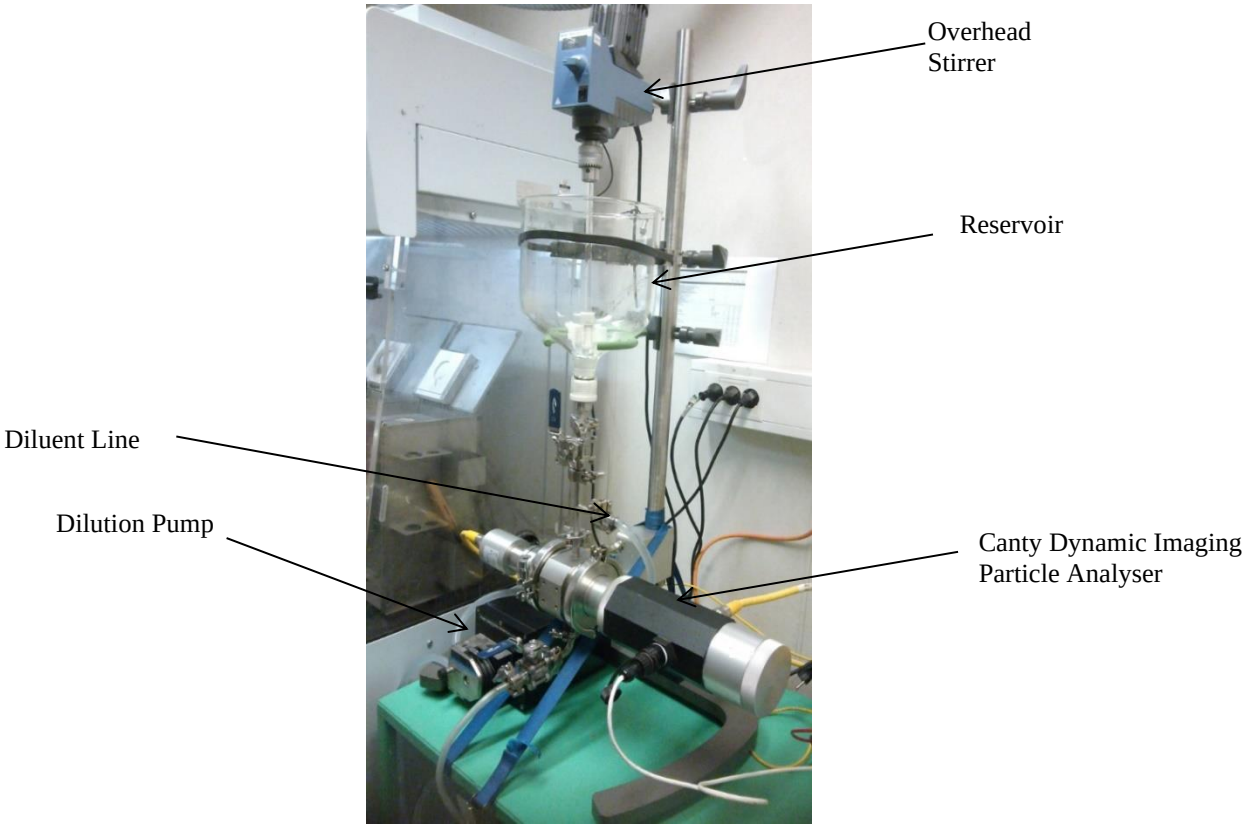


Figure 1 Lab Drilling Mud Particle Sizing and Auto-Dilution System

Due to the high solids concentration of the mud, dilution is critical in order to obtain good particle separation when analysed using the Canty vision based particle analysis system.

The system contains a reservoir, overhead stirrer, auto- dilution pump and the Canty dynamic imaging particle analyser. Prior to adding the drilling mud sample collected from the flow line or active suction pit to the reservoir, the reservoir is pre-filled with diluent (water for water based mud, base oil for oil based mud). The mud sample is then added to the reservoir and mixed with the diluent using the overhead stirrer. The sample is then gravity fed to the analyser. During this operation, the auto dilution pump automatically increases or decreases the flow rate of the diluent based on the number of particle the CantyVision software is detecting on the live image. The 2D image of the particles captured by the high speed microscopic camera are analysed by the Cantyvision software, which measures the true length and width of the particles. This allows for size and shape information to be reported. Particle size information such as DV10, Dv50, Dv90 is outputted in addition to the software having the ability to report Canty equivalent sieve data, allowing for comparison with manual wet sieve data. The system has the ability to analyse in real time or post analyse a recorded video to obtain particle size and shape information. Additionally,

the imaging analysis software has the ability to differentiate between gas bubbles, solids and droplets based on shape information.

Typical dilution ratios would vary between 150:1 to 250:1 based on a 30ml mud sample. This would equate to a dilution volumes between 4.5 to 7 liters for the lab based system with the at-line system dilution volume being greater (9 litres) due to an additional dilution flush pump

The disposal of the sampled diluted mud was reviewed with the wellsite leader as part of the risk assessment and based on the volumes being so low, permission was granted to dispose via the rigs drainage system. For future trials, the option of capturing the diluted sample and returning to the flowline can be explored, which will result in minimal dilution of the active system.

Although this trial was run with Canty's laboratory dilution system in manual mode as proof of concept, the end-goal is seen to be a real-time and at/in-line application; the plan is to run a second trial at a later date under real-time conditions using Canty at-line auto sampling and dilution system. Below details an overview of the system.

Figure 2 At-Line Drilling Mud Auto Sampling and Dilution System

The system contains 1" inlet and outlet flanges, which allows for the system to plumb into the mud line and contains a bypass loop for the when the main line is being sampled. The system consists of two automated actuator valves, Valve 1 for collecting the sample and Valve 2 for opening and closing the bypass line. During the sample collection sequence, Valve 2 is activated to open the bypass line allowing for the mud to flow through the bypass line, Valve 1 is then activated to collect an entire section of the mud within the main line. The volume of mud collected in the ball valve is 30ml.

Two peristaltic dilution pumps (flush pump and dilution pump) are automatically operated to deliver a controlled dilution volume flow rate. The flush pump is utilised to flush the mud sample into the feed line connected to the particle analysis system. The dilution pump also provides diluent to the feed line from a side stream to dilute the mud sample before flowing through the

Canty particle analysis system for subsequent analysis. The sampled diluted mud can be captured and returned to the main flow line.

2.1 Test Methods

Test Method 1. PSD of WBM – Canty Lab system with Auto Dilution

During drilling of the reservoir section, WBM samples were collected from the flowline downstream of the shakers approximately every 2 hours for subsequent PSD analysis with the Canty system.

- System was set-up as per Figure 1.
- Reservoir was pre-filled to 1 litre of water using the automated peristaltic dilution pump.
- The WBM sample bottle was shaken and a 30ml sample was poured into a graduated cylinder. The 30ml sample was then added to the reservoir under agitation.
- Valves were opened to allow the sample to be gravity fed down the feed line to the imaging analysis system.
- Diluent (water in a 10 litre container) was provided (auto dilution peristaltic pump) to the feed line from a side stream to dilute the mud sample prior to analysis.
- The diluent flow rate was varied automatically based on the number of particles counted in the image by the software during analysis.
- The sampled diluted mud was collected in a separate 10 litre container and disposed via the rig's drainage system.
- Between sample preparation and analysis of sample, total time was less than 10minutes for each sample measurement. Note that <10 mins was for the lab system, for the at-line system each measurement can be performed in <5 mins.
- Dilution volume required for each sample was between 5-7 litres.

Test Method 2. % TSS Measurement of Completion Brines during Displacement

After completion of the reservoir section, the system was set-up for TSS measurement of the completion brines during displacement. During brine displacement, 1 litre brine samples were collected matching similar frequency of sample collection as the filtration personnel during the casing displacements. Samples were collected and analysed until the %TSS of the brine was within specification of <0.05% TSS.

- Due to the low percentage solids concentration (<1%) of the completion brines, the reservoir and auto dilution assembly was removed from the Canty lab system.
- System was set-up as per Figure 3, which consisted of the imaging particle analysis system and pump for recirculating the sample through the flow cell for subsequent analysis
- The 1 litre brine samples collected were shaken and 500ml of brine sample was added to a beaker. The sample was then recirculated through the flow cell via a peristaltic pump in order to measure % solids and particle size.
- The sample measurement was performed in less than 2 minutes.

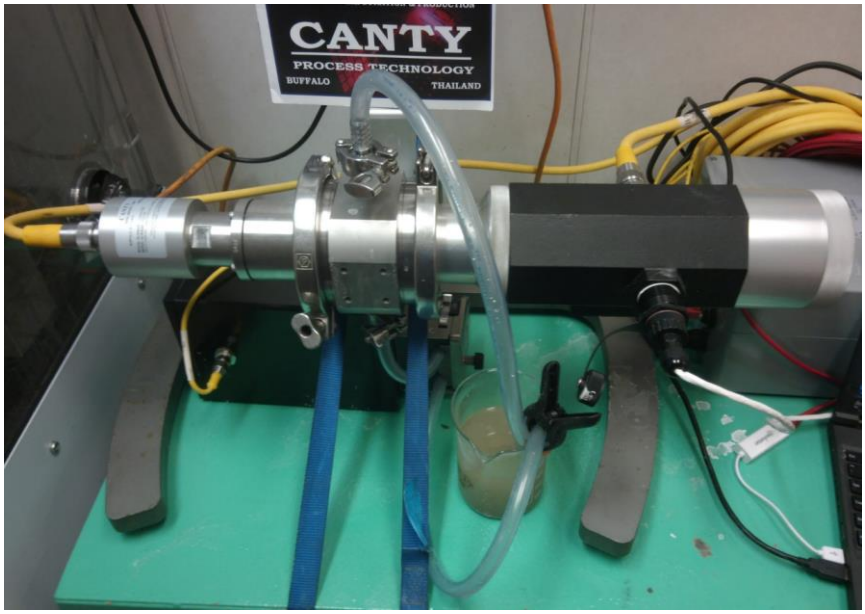


Figure 3 Canty particle analysis system with recirculating loop

3. Results/Discussion

3.1 PSD of WBM

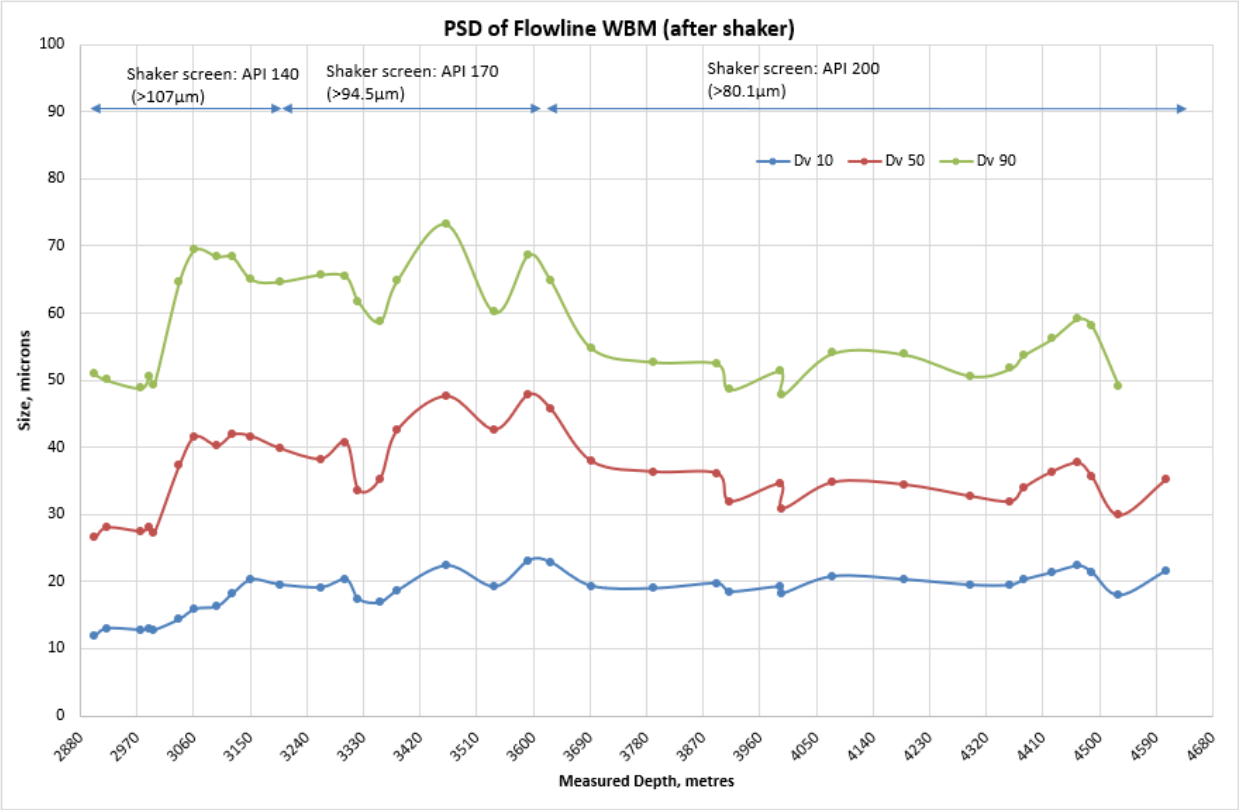


Figure 4 Canty Dv10, Dv50 and Dv90 particle size data during drilling of the reservoir section

Figure 4 displays the Canty particle size data of the samples collected from the flowline downstream of the shaker at various depths during drilling of the reservoir section.

The line bars and text detailed on the graph indicates when the screens on the shakers were changed out to finer mesh sizes.

After baseline conditions of the WBM PSD were establish during commencement of drilling the reservoir section, graph from Figure 3 (PSD of the flowline downstream of the shaker at various drilling depths of the reservoir section) displays an increase in solids particle size after a depth of 3000m. This can be associated with the drill solids being introduced into the WBM from the well. It was also observed that some of these drill solids were oil coated resulting in particle agglomeration (Figure 5). The agglomerated particles were filtered out by Canty's imaging analysis software in order not to affect the overall particle size distribution. Removing these oil coated solids still allowed for a statistically representative number of particles to be reported for each sample measured. A reduction in particle size can also be observed after a well depth of 3600m, which coincided with replacement of the shaker screens to a finer mesh size

(API170 , 94.5µm - API 200 , 80.1 µm). This can also be observed from the Canty equivalent sieve data (Figure 6), which details a reduction in percentage of particles measured in the larger size bin (75 µm - 106µm) at well depths greater than 3600m.

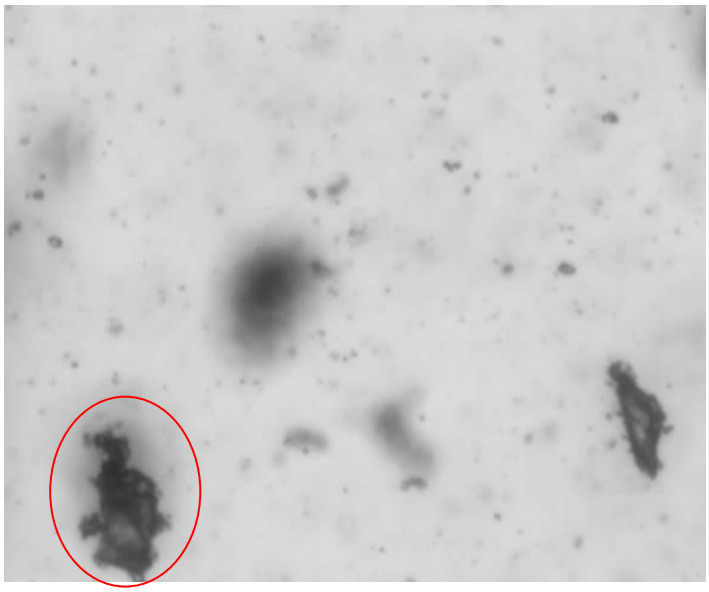


Figure 5 image of particle agglomeration circled in red

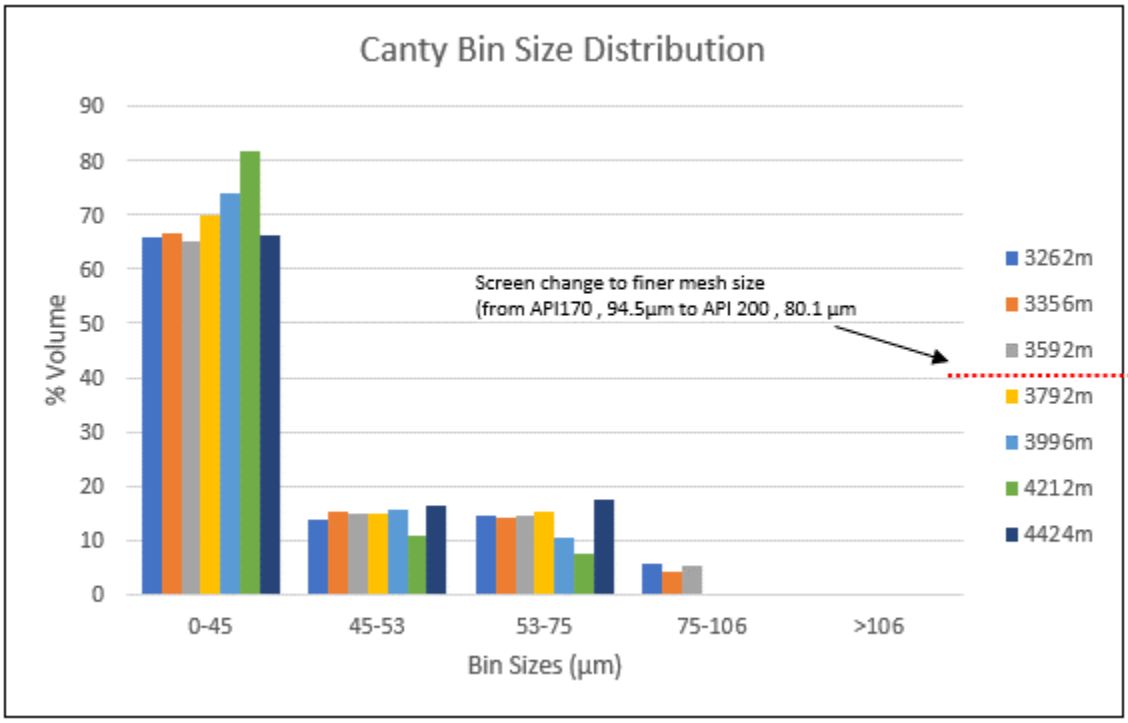


Figure 6 Canty Equivalent Sieve Data during drilling of the reservoir section

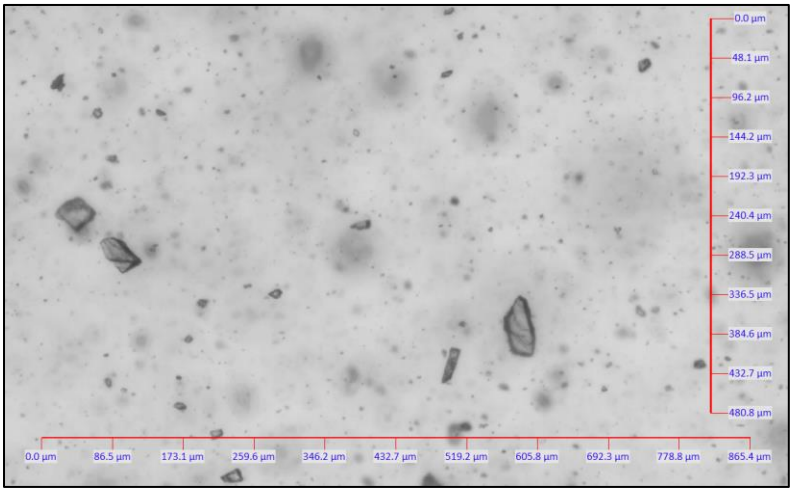


Figure 7 Typical live image of WBM obtained from the Canty imaging system

3.2 % TSS Measurements of Brine during Displacements

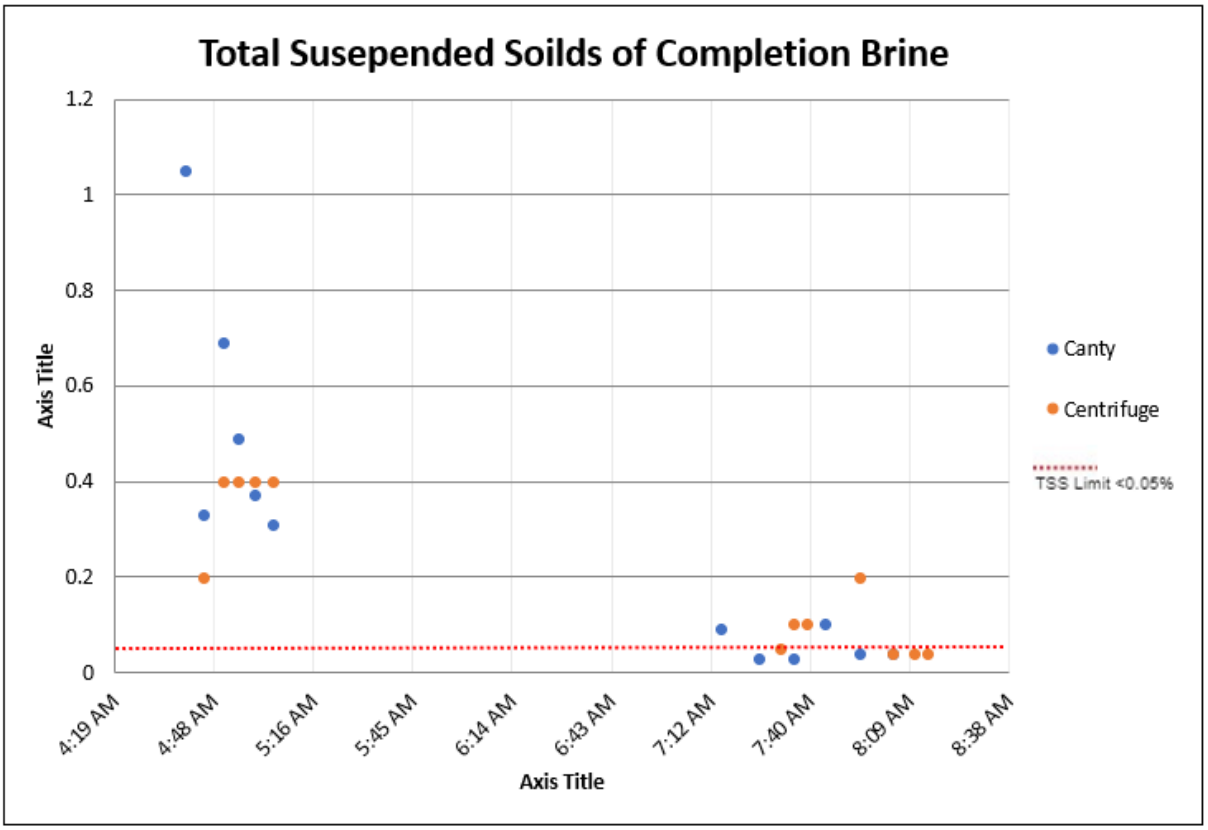
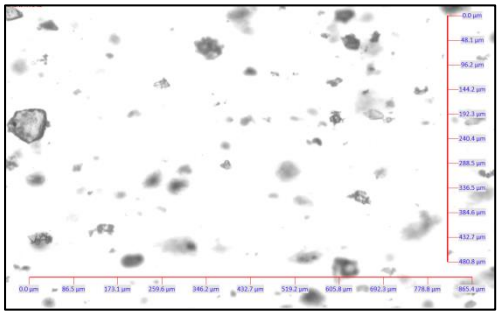
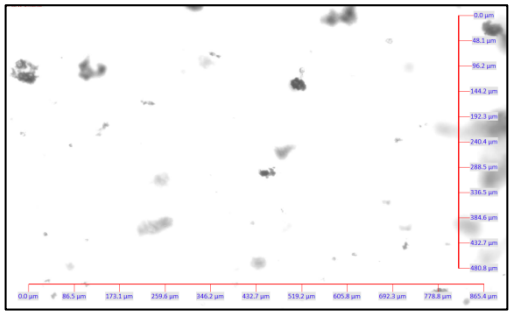


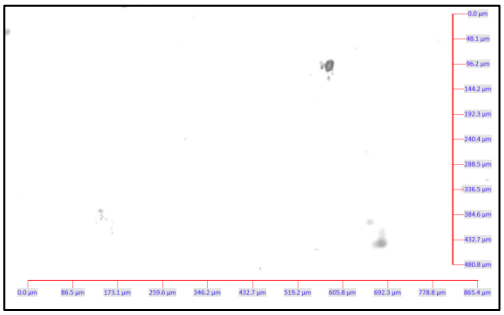
Figure 8 % TSS of brine during displacement. Canty Vs Centrifuge



1.06% TSS



0.32% TSS



0.03% TSS

Figure 9 Visual Comparison of brine samples with different %TSS concentrations.

Figure 8 displays the comparison between the % TSS measurement performed by the Canty imaging analysis system and the electric centrifuge method. The preferred sampling point was the flowline at the back of the shakers. Decisions on brine displacement operation were made based on %TSS from flowline samples.

The Canty system has greater % solids measurement sensitivity (measurements down to 1ppm/0.0001% solids) than the current electric centrifuge method, which measures down to 0.05% only. Below 0.05%, the reading is classified as a trace as the amount of solids cannot be quantified. It was observed from the samples collected between 4:55am and 5:05am, that the Canty system measured a reduction in % solids concentration during displacements compared to the centrifuge measurement, which reported a stable reading of 0.4% for the three samples collected and measured between 4:58am and 5:12am. As this field trial was a passive trial and therefore, operational decisions were only made on the current measurement techniques, the decision was made to suspend operations due to low volume supply of brine in the pits and to re-filter the brine before commencing the displacements at a later time in order to reach the specification of <0.05% TSS. However, having a more sensitive system to changes in solid concentration as the Canty system delivered, would give operations evidence that the % solids trend was in fact reducing. This would allow operations to make the decision to continue with the displacements for a longer period in order to potentially reach the 0.05% TSS specification resulting in not having to suspend operations to re-filter the brine. From the graph, it can also be observed that the Canty system detected the % TSS below 0.05% before the electric centrifuge method. In addition to concentration, the Canty system has the ability to also reports the PSD of the TSS.

4. Conclusion

Although this trial was run in manual mode, the end-goal is seen to be real-time and at/in-line application; the plan is to run a second trial under real-time conditions at a later stage. The opportunities given below are with regards to use of an online system.

4.1 Canty Drilling Mud PSD

Canty Online System	Manual Sieves
Automated at-line system does not require any intervention from an operator. System is set-up to periodically collect samples at specified time during set-up.	Sieves are labour intensive. Measurement takes up to one hour.
No Extra mud engineer required onsite	Extra mud engineer was sent offshore during drilling of the reservoir section to assist with performing lab tests such as manual sieving.
Frequency of PSD measurements can be performed every 10minutes (if required) allowing mud engineers to react quickly to changes in mud PSD.	Four samples in a 24 hour period are collected for manual sieve analysis. Sieve particle size information only available every 6 hours.
System particle size range is from 1µm to 250µm, allowing to identify small changes in solid particle size.	Difficult to measure particles <100 µm with wet sieves.
Ability to report Canty equivalent sieve analysis data to compare with wet sieve analysis data	Manual sieving is a subjective method (human error) and difficult to sieve particles less than 100 µm.
Ability to post process video recorded during live analysis for further investigation of variations in PSD	Non-Applicable

Table 1 PSD Analysis - Canty System Vs Manual Sieve Method

4.2 Canty %TSS Measurement in Brine during Displacements

Canty Online System	Centrifuge
Measure percent solids down to 0.0001%	Measure percent solids down to 0.05%.
No sampling /dilution system required to measure the %TSS of the brine as solids concentration during displacement is below 1%. System can be set-up online by bypassing the auto sampling system, delivering real time %TSS measurements of the brine. The concentration refresh rate is user defined and can be outputted every second in order to identify when the %TSS is below specification.	Offline measurement. Time between sample collection and analysis can take up to 8 minutes. In order to determine if the % TSS of the brine is below specification, three consecutive samples need to have a reading below 0.05% in order for displacements to stop.
The online real time information and increased measurement sensitivity of the %TSS provides operations a further insight into the process allowing them to make timely decisions to avoid downtime.	Response time to determining the %TSS of the brine is within specification will be at least 15 minutes.
The system has greater concentration measurement resolution, which allows tracking trends in TSS concentration to determine if the TSS concentration is reducing or not. This allows operations to make more informed decisions on whether to continue with the brine displacements or suspend and re-filter the brine.	Insufficient concentration measurement resolution. It is difficult for operations to track the trend of the TSS concentration of the brine. This reduces operations ability to make an informed decision to continue with the brine displacement or suspend and re-filter.

Table 2 Brine %TSS Measurement - Canty System Vs Electric Centrifuge Method