Case Studies Confirm Downhole Sensor Measurements and Verify Sample Quality Using New Non-Invasive Sample Testing Method*

Sami Eyuboglu[1], Mickey Pelletier[1], Tony van Zuilekom[1], Marvin Rourke[2], George Saghiyyah[3], Witjaksono M. Mulyo[3], Andre Silva[3], and Richard Palmer[3]

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[1]Halliburton, Houston, TX (sami.eyuboglu@halliburton.com)
[3]Saudi Aramco, Dhahran, Saudi Arabia

Abstract

When samples are obtained using a wireline pump-out formation testers, downhole sensors are used to estimate the sample quality and contamination during the sampling process. However, in many cases the samples can be altered when they are retrieved at the surface or in their transport from the rig site to a PVT lab. Currently the only methods of examining the samples require opening the chambers which risks corrupting the integrity of the sample. Therefore, this research offers an alternative approach to onsite sample analysis where, when the samples are brought to the surface, new non-invasive measurements can be made that do not require opening the sample chamber. These measurements enable the determination of fluid properties which are then used for fluid identification and verification of the sample quality. The fluid property measurements can be compared directly with the downhole sensor measurements to verify that the sample integrity has been maintained. This new method also enables well site decisions to be made regarding which samples are the most representative and documents the condition of the samples just prior to being transported to a PVT lab.

The sample chamber design is an integral element to the new non-invasive measurements in that it enables the precise measurement of the sample volume in the chamber. By knowing the dead weight of the chamber and the weight with the sample and its precise volume, an accurate density measurement can be made. Then by monitoring the sample volume changes while applying pressure to the sample the compressibility can be determined. These measurements can be performed on standard sample chambers, as well as on nitrogen-compensated chambers. To verify that the sample properties have not been altered the surface measurements can be compared with the downhole fluid ID sensor measurements. Estimates of contamination can be made by combining the surface measurements with downhole sensor measurements.

To demonstrate the utility of these new measurements, a range of field examples are presented that include water, oil, and gas samples in the presence of varying oil- and water-based mud contamination. In addition to comparisons with downhole measurements, the new surface

measurements are compared to subsequent laboratory measurements to verify the validity of the new technique. Then conclusions and recommendations made based primarily on the experience of the field examples.

Introduction

One of the basic functions of formation fluid sampling is to confirm the mobile fluid phase in the reservoir. Significant uncertainty about the formation sample quality can affect completion decisions, as well as the reservoir assessment. This situation is further complicated in low permeability reservoirs in which a long oil-water transition zone can exist. The definition of the mobile fluid phase in the transition zone can be achieved by sampling with a pump-out wireline formation tester (PWFT). This tool incorporates downhole sensors to analyze the fluid while pumping, the results of which are used to determine when and how to sample. After the samples are taken to the surface, they are routinely sent to a fluid lab for transfer and analysis. Inevitably, however, there is a delay between retrieving the samples and obtaining the results; in many cases, this can be weeks, rather than days. A quick process is often desirable that can be performed at or near the wellsite without opening the sample bottles to indicate the quality of the sample before the chambers are sent to the lab. This process would provide information about whether or not the sample is still at elevated pressure (i.e., above the bubblepoint), as well as the volume of the sample, and the fluid density and compressibility. This information can be used to verify the downhole sensor analysis and confirm sample integrity, both of which could influence subsequent decisions, such as further sampling or well completion strategy.

This paper presents a new technique for sample quality verification when the samples are retrieved at the surface. This technique identifies the fluids and verifies the sample quality to ensure that the sample integrity has been maintained. It also enables the determination of the most representative samples at the wellsite to be shipped for additional PVT lab testing. Eyuboglu et al. (2009) present detailed information about this technique and case studies for standard chambers. This paper describes four examples that use both standard and nitrogen compensated chambers to validate the applicability of this technique.

Sample Quality Check

Sample quality check (Sample QC) is a novel technique that uses non-invasive measurements of samples to verify the sample quality at the surface. Sample chamber weighing and pressuring procedures are performed to determine the sample density and compressibility. These measurements can be performed on standard and nitrogen compensated chambers, as shown in Figures 1 and 2 respectively. The standard chamber (Figure 1) is filled with buffer fluid and weighed before sending it downhole. When sampling downhole, the sample is filled against hydrostatic pressure and the sample is over-pressurized, as needed. The recovered sample size for a standard chamber is approximately 1000 cc. The use of the nitrogen compensated chamber (Figure 2) is similar to the standard chamber, except it is filled with nitrogen rather than with buffer fluid. Nitrogen chambers are designed to reduce the pressure drop that occurs when retrieving samples primarily because the samples are cooler when they reach the surface. The cooler ambient conditions cause the oils to contract or reduce in volume, which makes it difficult to maintain the pressure above the saturation pressure with standard chambers. Nitrogen is a gas and therefore more compressible than oil. The nitrogen compensated single phase chamber volume typically exceeds 500 cc, which is adequate for a full suite of PVT lab experiments. The field examples presented in this paper were sampled by using both standard and nitrogen-compensated chambers. The Sample QC results can be combined with downhole measurements, such as fluid densities, to estimate the contamination level of the fluid. Measurements of the density of the filtrate, formation water, and oil adjusted for pressure and temperature are used to estimate the contamination level. In many cases, these estimates are better than the contamination estimates made while sampling.

Sample Chamber Weighing and Pressurizing Procedure

The sample chamber consists of a bottle in which the sample is contained in a chamber with a piston that is free to move. The piston is located at the topmost position when the chamber is empty (Figure 1). The void space behind the piston is open to the wellbore hydrostatic column and is normally pre-filled with 1000 cc of water. The first step of the Sample QC method to weigh the empty sample chambers in the pre-run configuration. The multi-chamber section (MCS) in the PWFT carries three chambers with 1000 cc volume capacity. The chambers are retrieved from the MCS after completing a sampling run and secured by placing transport plugs and transport spools onto each chamber. It is critical that the sample integrity be maintained from the time that it is retrieved from the downhole conditions until it reaches the PVT laboratory for testing. When a chamber is filled during downhole sampling, the piston is pushed down to the lowest position and the water is expelled to the wellbore. Post-run chamber is weighed as a second step of the Sample QC method (Figure 3). The chamber serial number, weights, well name, and depth of sample are recorded immediately.

The standard and nitrogen buffered sample chambers have a floating piston, the back of which is exposed to the borehole fluid to maintain hydrostatic pressure. Part of the standard operating procedure includes applying pressure to the hydrostatic port to add pressure to the sample before it is shipped to the laboratory. The pressurizing procedures are the next stage of the Sample QC method. After using a Gauss meter to locate the initial piston position, a mark is placed on the chamber assembly (Figure 3). The distance measurement (in mm) is recorded from the lower end of the chamber housing to the mark. A high-pressure pump is connected to the bottom of the chamber after locating the piston position. The pressure that causes the first movement of the piston indicates the internal pressure of the captured sample. The pressure is increased by 1,000 psi increments and the piston position is recorded after each pressure increment. The pressure increments continue until the desired over-pressure value is reached, which is generally the maximum pressure applied downhole when the chamber was filled. The final piston position is recorded after reaching the maximum pressure. The Sample QC method is completed by weighing the chamber. Figure 3 shows the sample chamber weighing and pressurizing procedure.

A graphical user interface (GUI) computer program was developed to analyze the Sample QC inputs and to display the results to the client. A single display is used in the application to show both input and output information. Figure 4 shows the Sample QC program; detailed information about the software can be found in Eyuboglu et al. (2009).

Case Study

The case study consists of four samples obtained from the same well and demonstrates the practical application of the Sample QC method by using both standard and nitrogen compensated chambers to confirm sample integrity, fluid type, and sample quality shortly after their retrieval from the PWFT tool at the surface (Figures 5, 6, and 7).

The samples used for Example 1 (Figure 6) and Example 2 (Figure 7) were collected at the same depth. First, the standard chamber was filled (Example 1, Figure 6) after pumping 190 liters. After pumping 195 liters, a nitrogen compensated sample chamber (Example 2, Figure 7) was filled. As shown by the sampling time drive log in Figure 5, all downhole sensors confirm that oil was sampled. The flowing density of the oil when sampling was 0.89 g/cc; when the bottles were sealed, over-pressurizing increased the density to 0.92 g/cc. Figure 6 shows Sample QC results for Example 1. These results include a measured density of 0.921 g/cc and an average compressibility of 3.99 ppm/psi, which correlates to an oil sample. For the nitrogen compensated chamber (Example 2), the Sample QC results (Figure 7) indicate an oil sample with a density of 0.917 g/cc and an average compressibility of 3.38 ppm/psi. Both chambers show a very high degree of similarity with one another and with the downhole density sensor.

The samples used for Example 3 and Example 4 (Figures 8, 9, and 10) were also taken from the same depth. After pumping 82 liters, the nitrogen compensated sample chamber was filled (Example 3, Figure 9); a standard chamber bottle was filled (Example 4, Figure 10) after pumping 83 liters. The first oil entry was indicated by the downhole density sensor (Figure 8) after 40 liters, and gradually increased in volume. Slugs of oil were indicated by the density flowing with water, which can be observed by the downward spikes in the density curve shown in Figure 8. The density of oil was observed to be ~0.95 g/cc; however, a significant amount of filtrate water was present (>50%) when filling the bottles. Figure 9 shows the Sample QC results for the nitrogen compensated chamber (Example 3). These results indicate that the sample contains a mixture of oil and filtrate, with a measured density of 1.012 g/cc and an average compressibility of 2.89 ppm/psi. Figure 10 shows the Sample QC results of the standard PVT chamber (Example 4), which also indicate oil and filtrate mixture in the sample, with a measured density of 1.028 g/cc and an average compressibility of 2.87 ppm/psi.

Summary and Conclusions

The Sample QC method is a novel approach used to identify fluid and sample quality by using nitrogen compensated sample chamber thus ensuring the sample integrity has been maintained. The examples have proven the Sample QC method to be a valuable post-sampling tool that makes accurate measurements of both the density and compressibility of the captured samples (standard and nitrogen compensated), as well as the volume and internal pressure. Sample integrity did not change because all measurements were performed without opening the sample.

Acknowledgments

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Reference

Eyuboglu, S., M. Pelletier, M. Rourke, T. van Zuilekom, G. Saghiyyah, W. Mudjionomulyo, A. Silva, and R. Palmer, 2009, New Non-Invasive Sample Chamber Testing Methods Confirm Downhole Sensor Measurements and Verify Sample Quality, Presented at the 50th Annual SPWLA, The Woodlands, Texas, June 21-24.

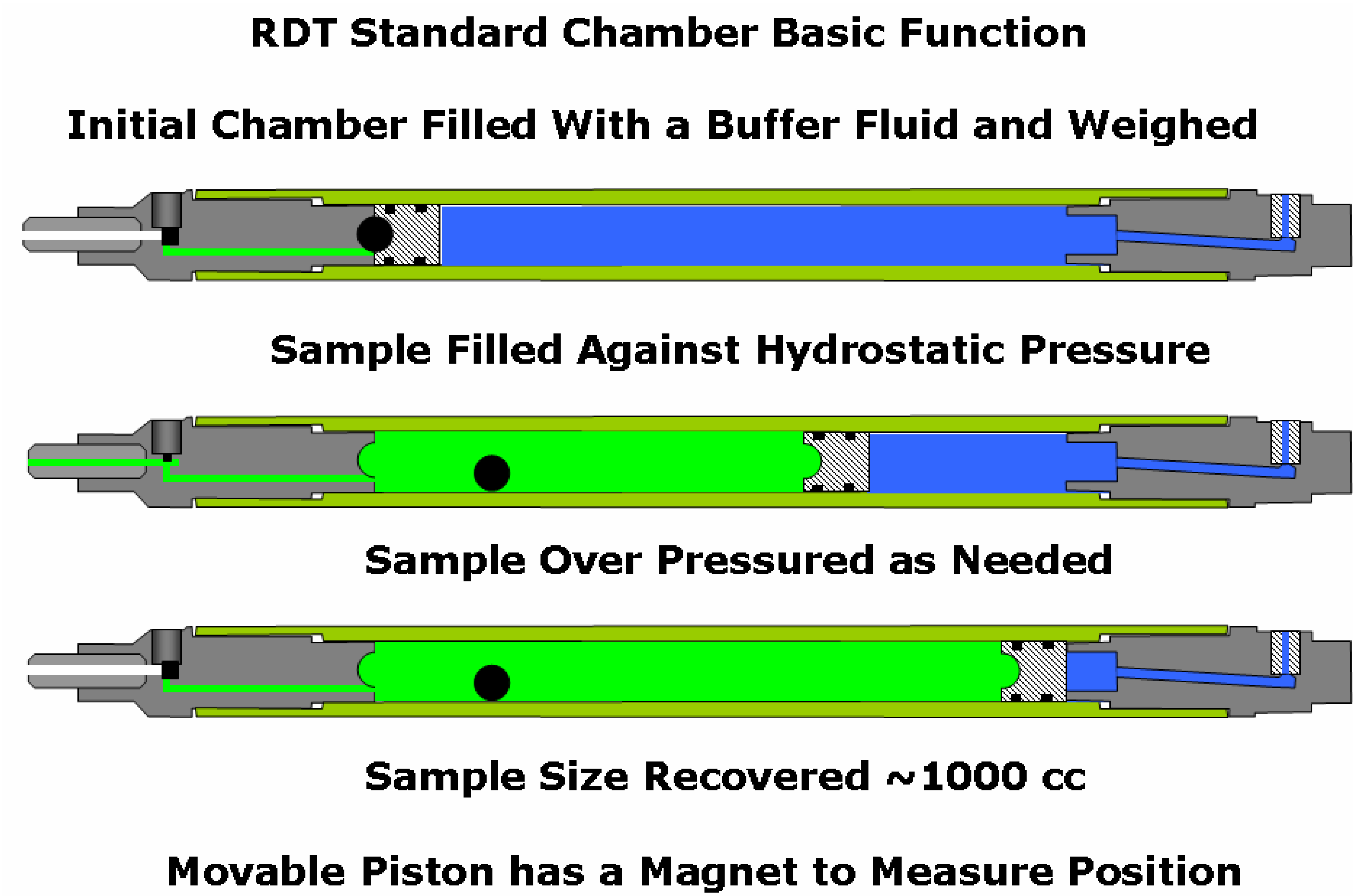

Figure 1. The standard chamber.

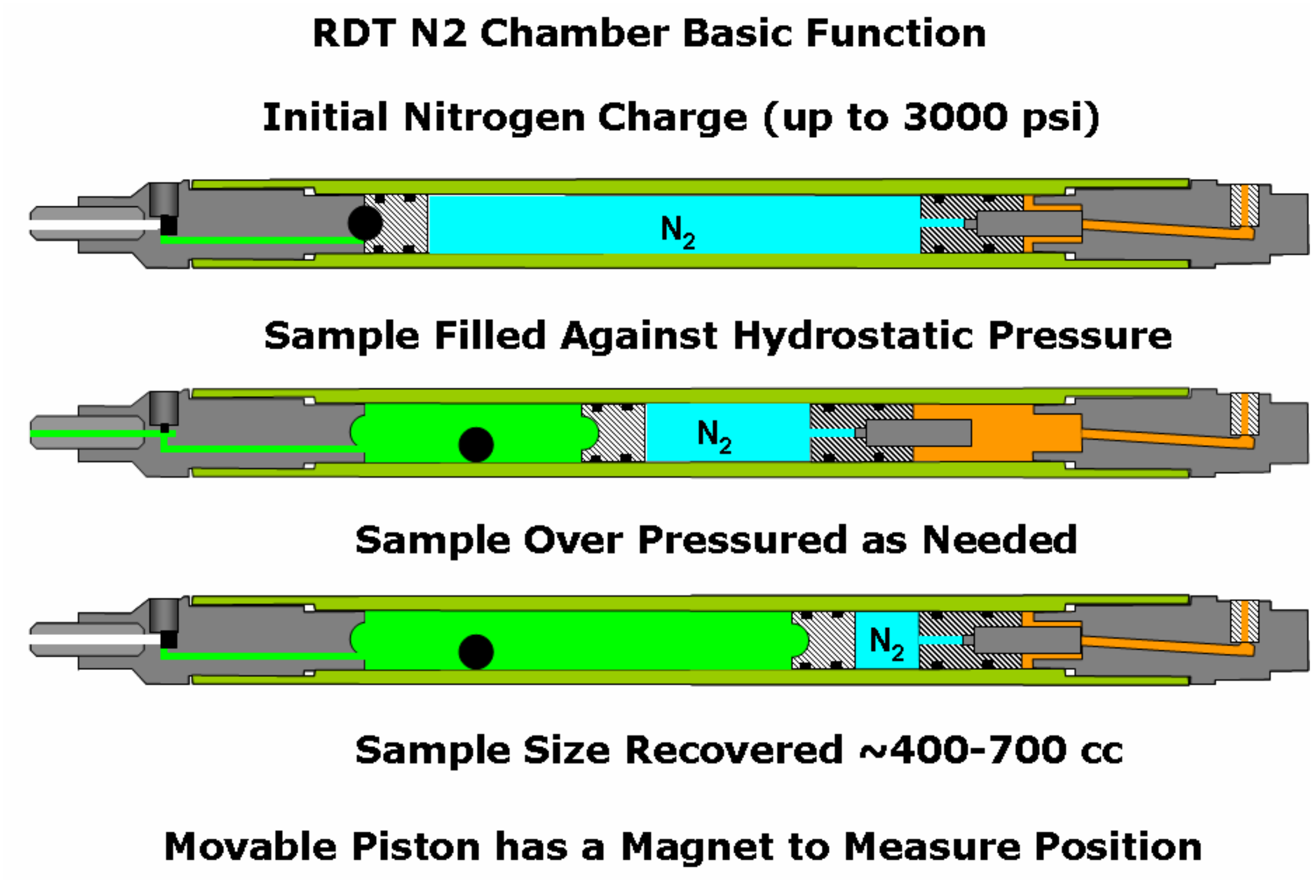

Figure 2. The nitrogen compensated chamber.

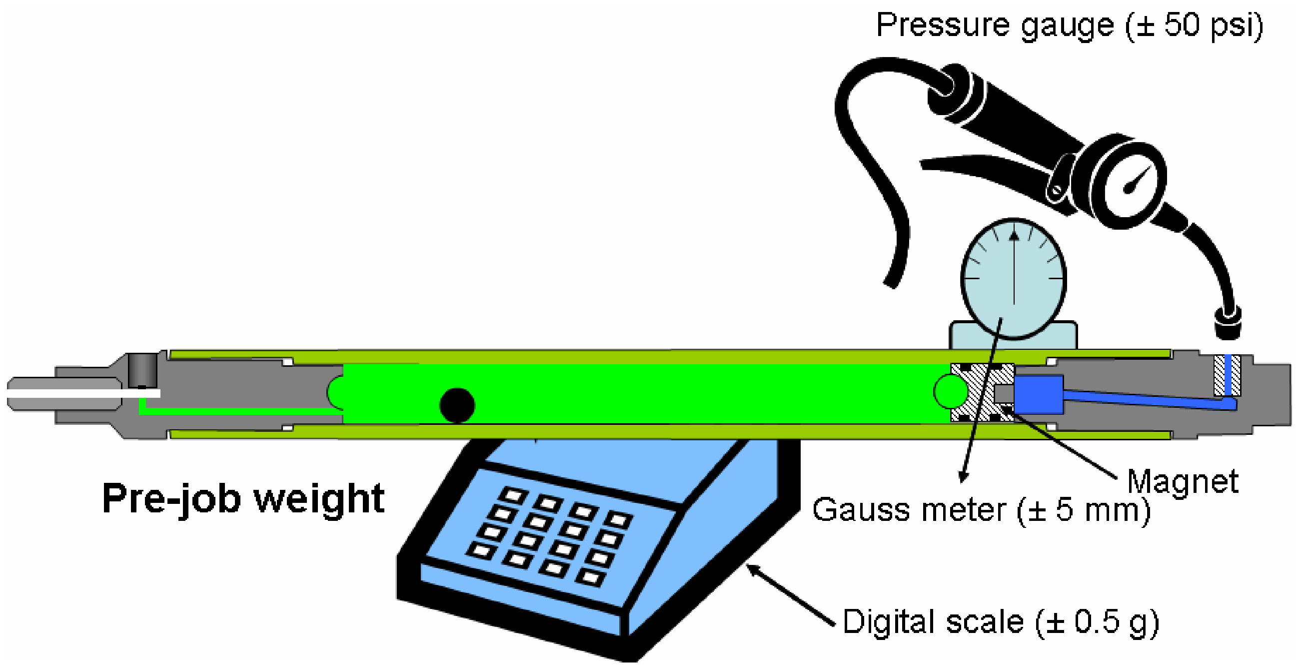

Figure 3. Sample chamber weighing and pressurizing procedure.

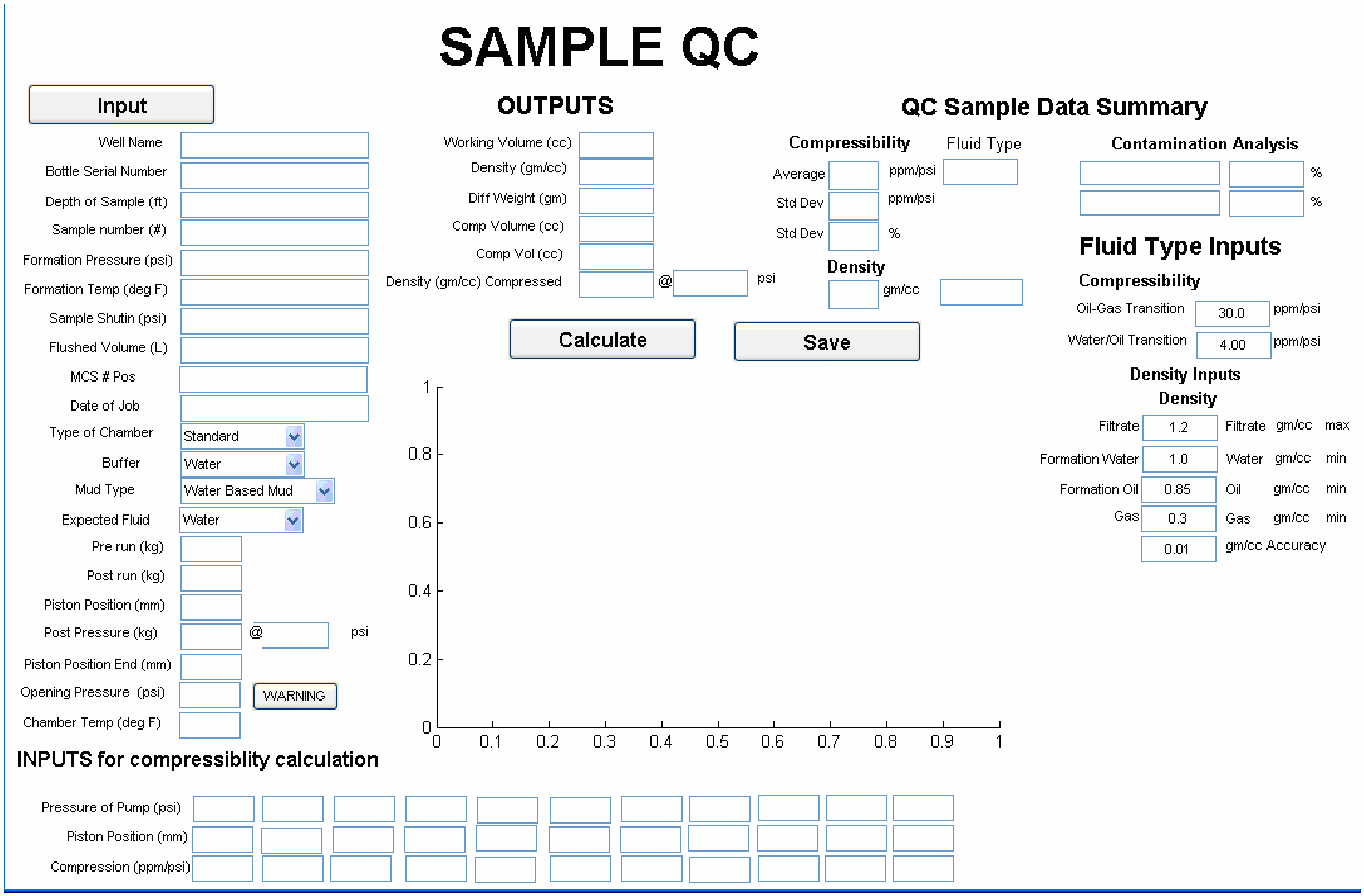

Figure 4. Sample QC program display.

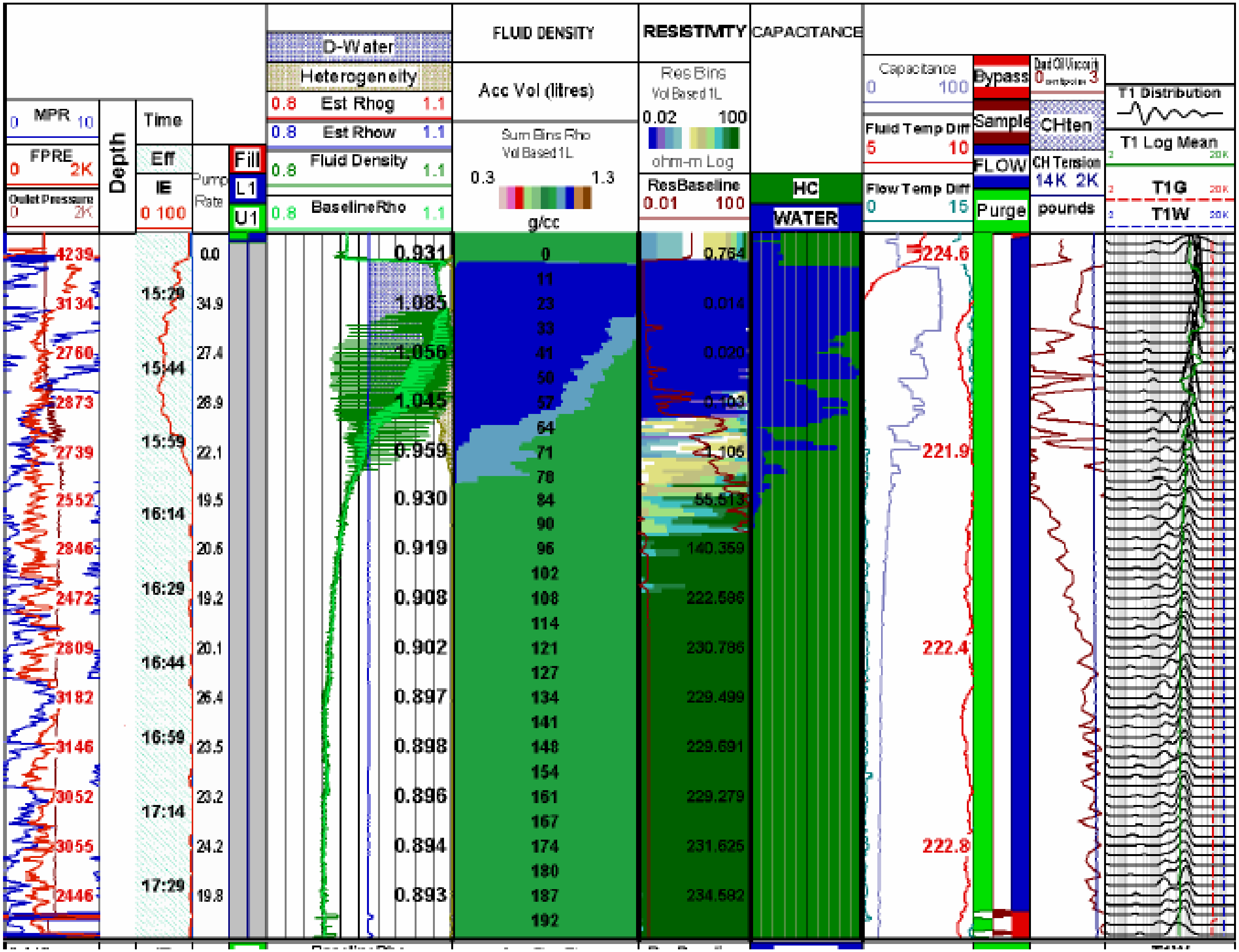

Figure 5. The view of the sample pump-out time based log for Examples 1 and 2.

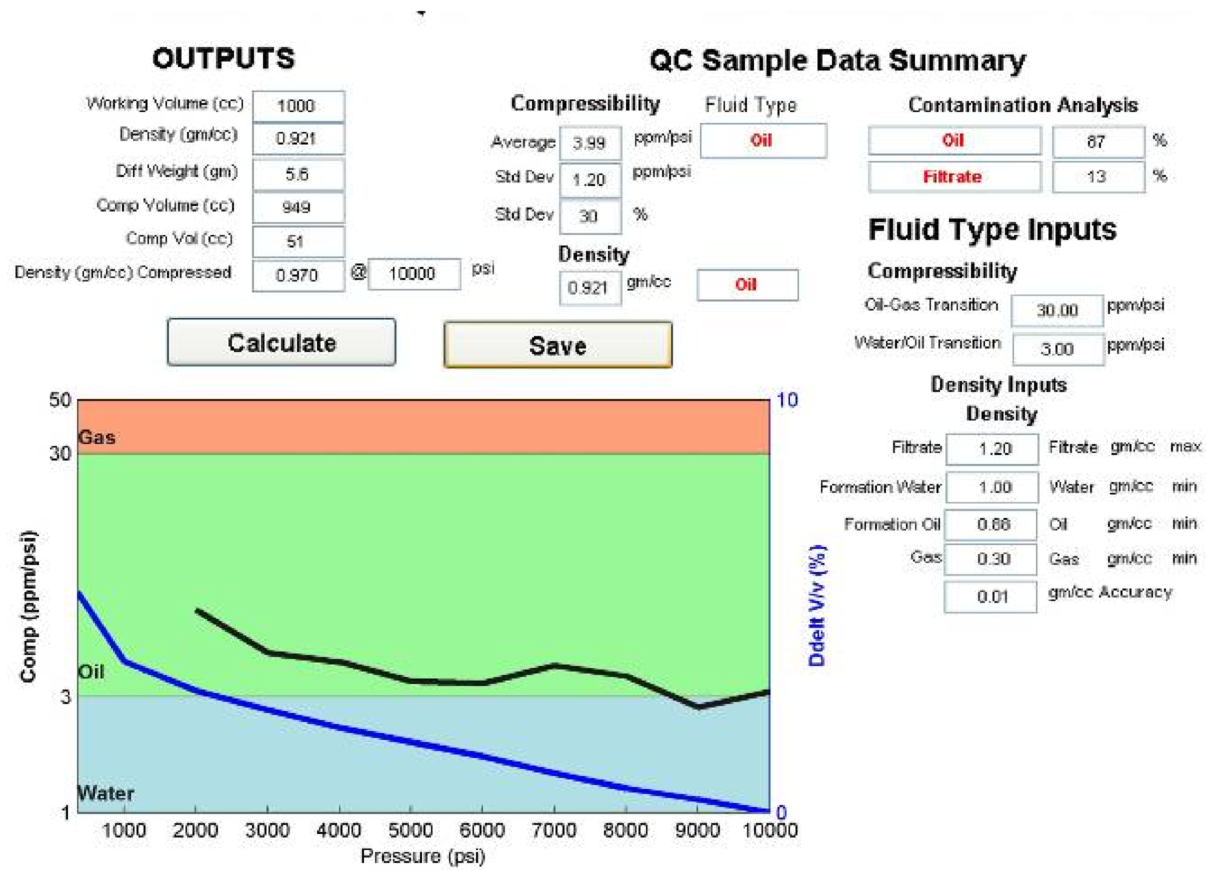

Figure 6. Sample QC display for Example 1 (standard chamber), which has 0.921 g/cc density and 3.99 ppm/psi compressibility value.

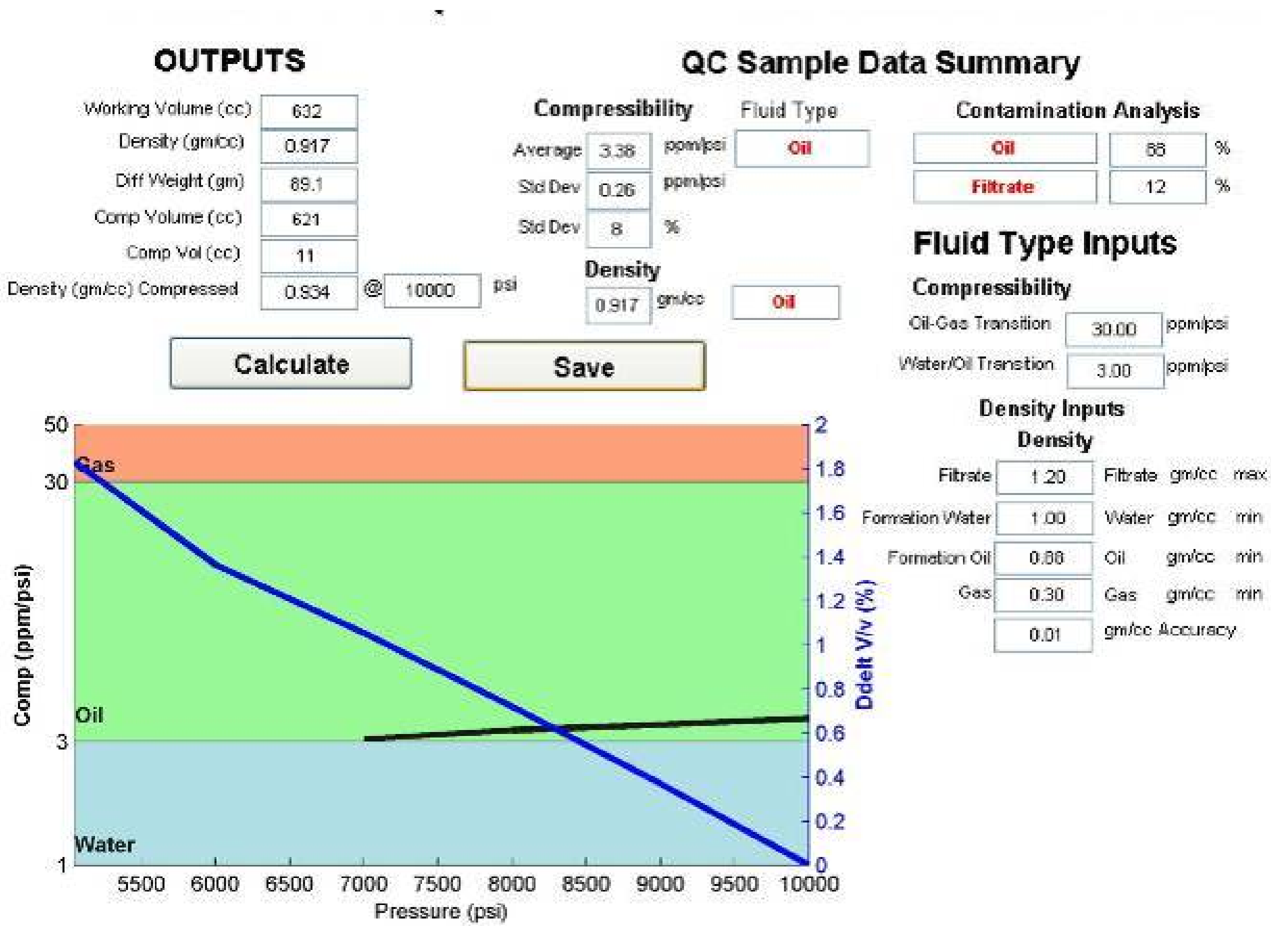

Figure 7. The top panel shows the Sample QC display for the Example 2 sample (nitrogen chamber), which has 0.917 g/cc density and 3.38 ppm/psi compressibility value.

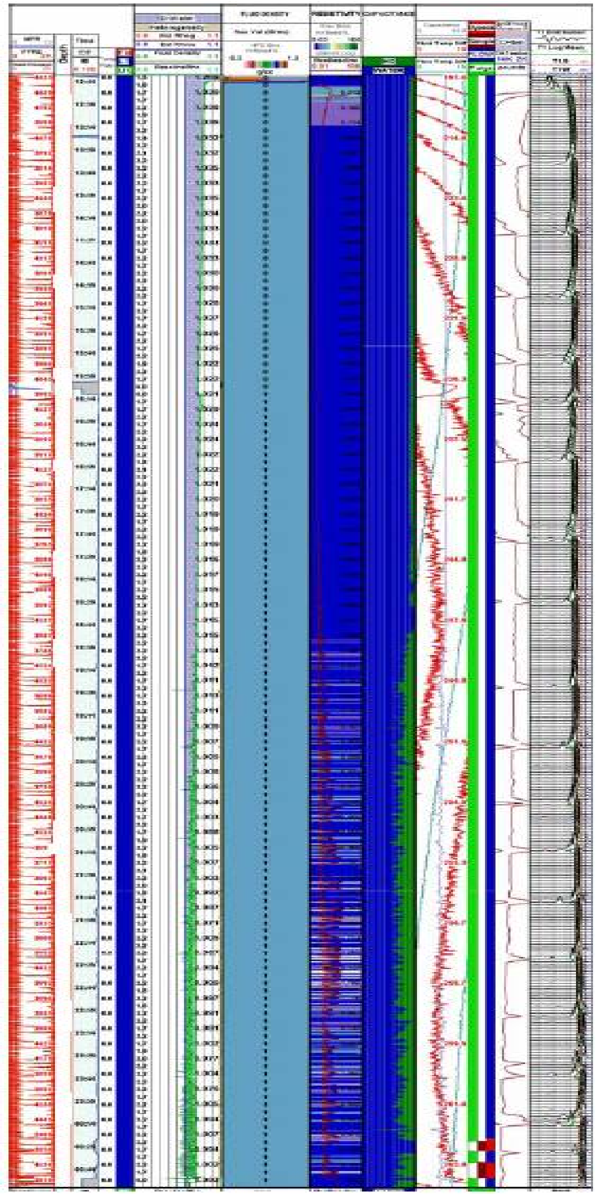

Figure 8. The view of the sample pump-out time based log.

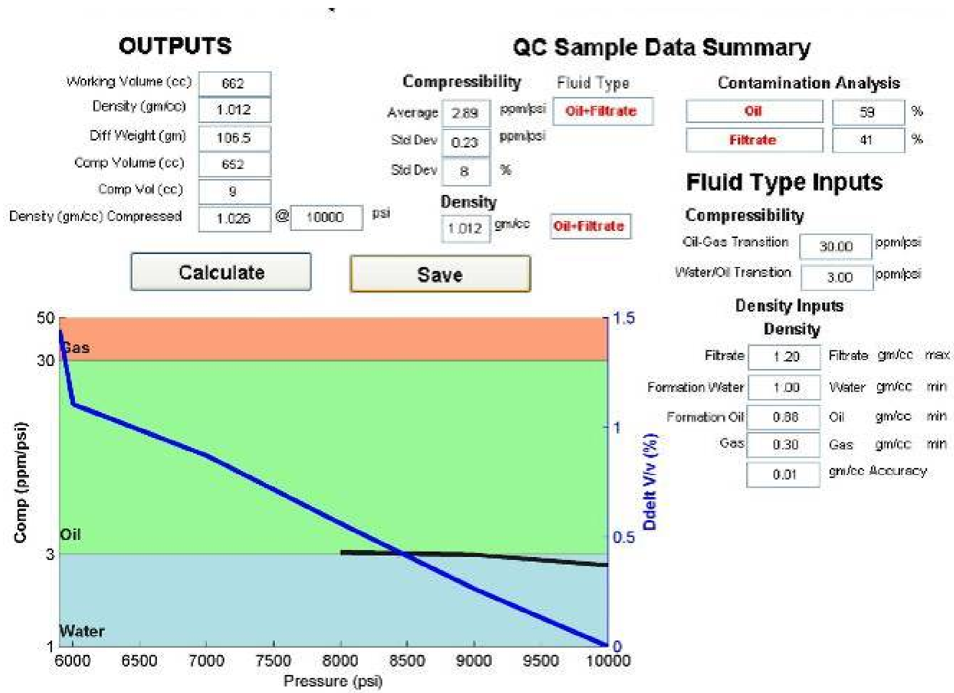

Figure 9. The top panel shows Sample QC display for the Example 3 sample (nitrogen chamber), which has 1.012 g/cc density and 2.89 ppm/psi compressibility value. The table shows the laboratory results.

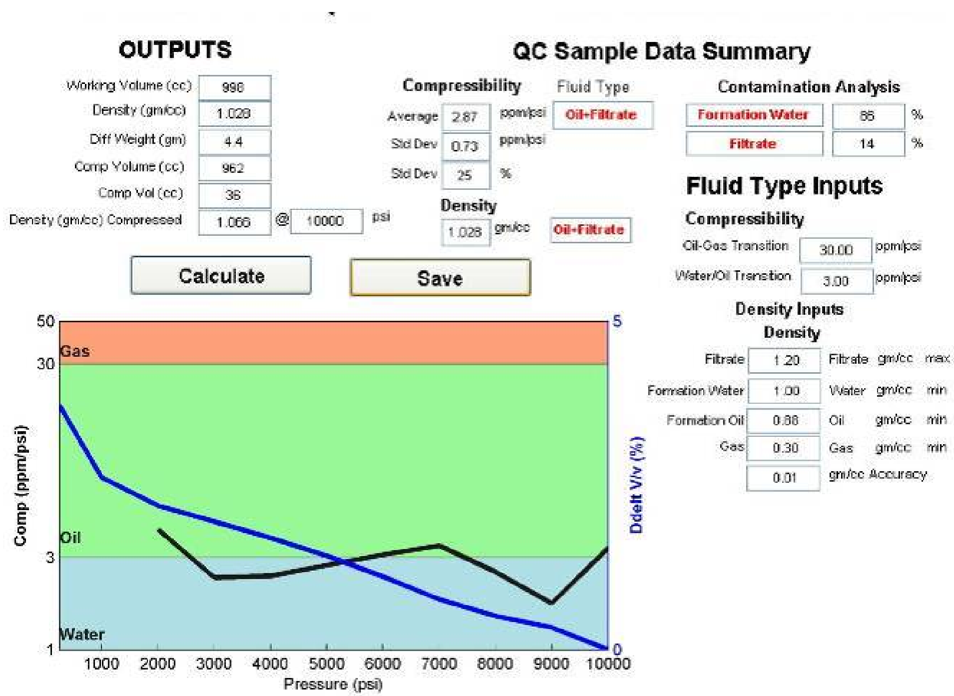

Figure 10. The Sample QC display for Example 4 sample (standard chamber), which has 1.026 g/cc of density and 2.87 ppm/psi of compressibility value.