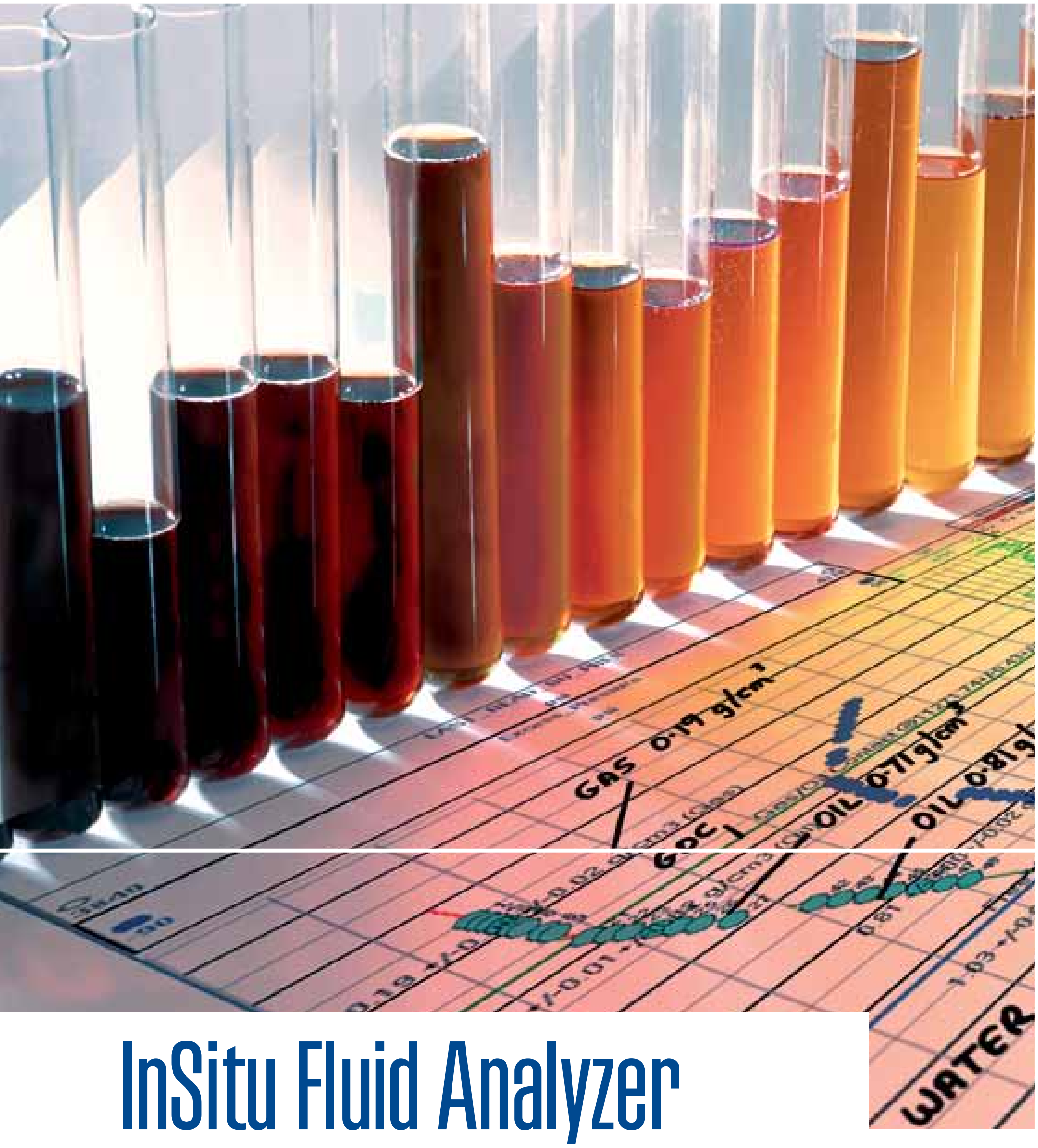
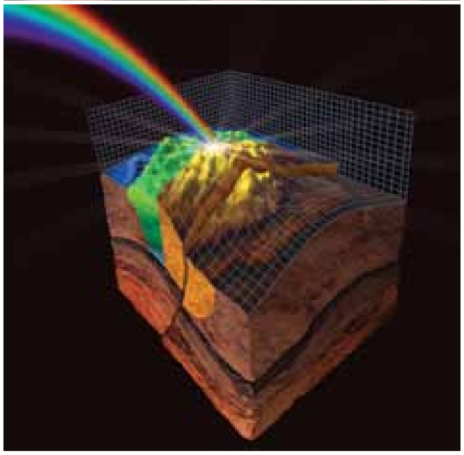
Schlumberger





InSitu Fluid Analyzer

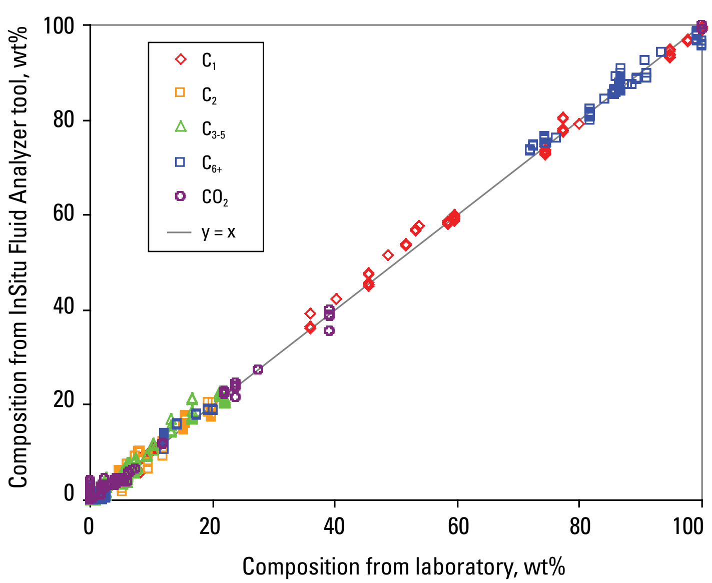
Quantitative fluid measurements at reservoir conditions, in real time

APPLICATIONS

- Reservoir fluid characterization
- Identification of compartments and lateral sealing boundaries
- Quantification of compositional grading
- Strategy development for corrosion and scale
- Sample assurance: single phase and purity
- Reservoir simulation (EOS modeling)
- Improved-accuracy determination of pretest gradients and fluid contacts
- Asphaltene gradient determination
- Differentiation of biogenic and thermogenic dry gas
- Identification of volatile oil and gas condensate
- Determination of gas/oil ratio (GOR) and condensate/gas ratio (CGR)

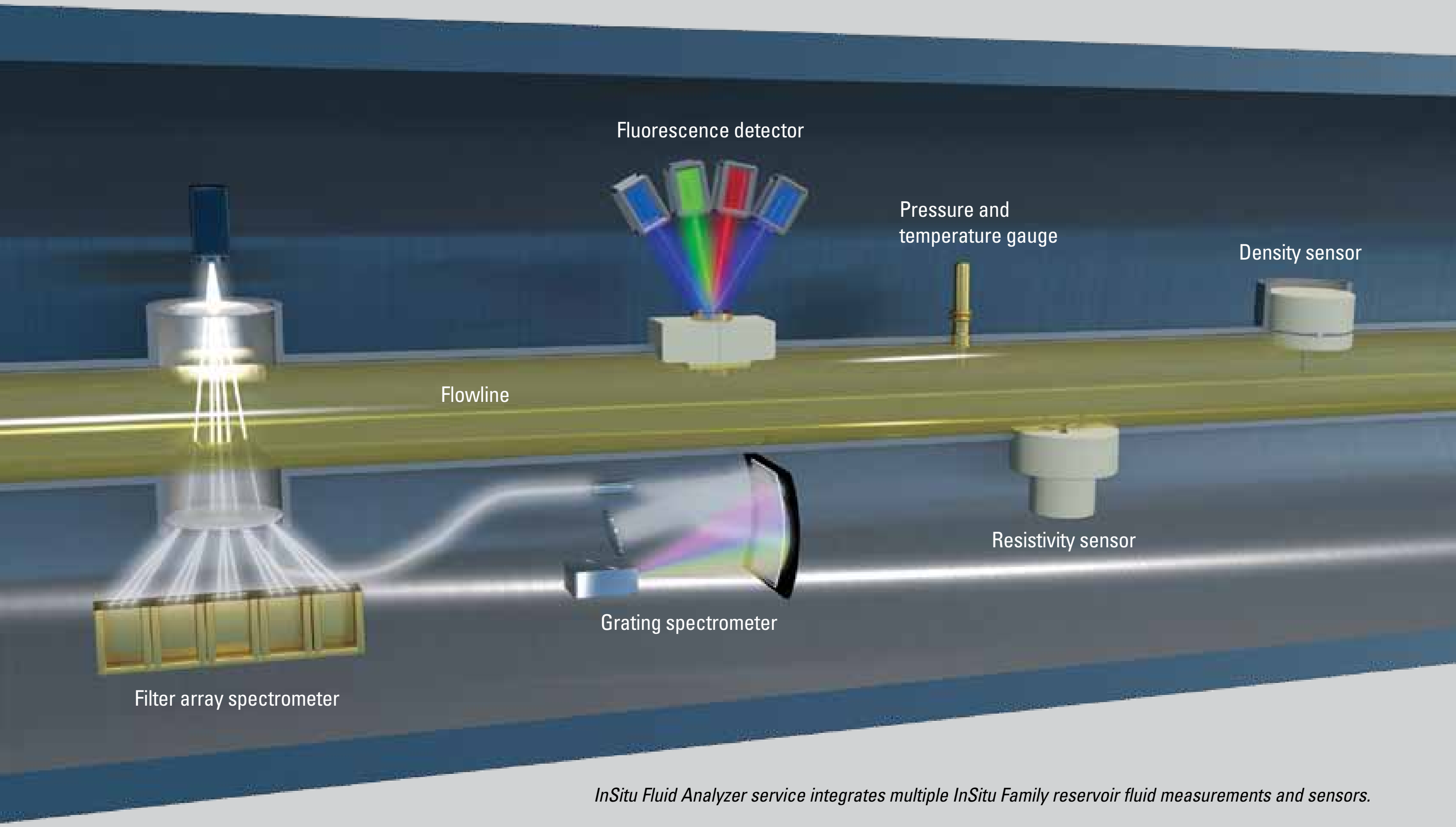
Quantified fluid measurements that were previously unachievable from wireline logs or laboratory analysis are now possible downhole and in real time. By investigating fluids at their source, you gain a deeper insight to fluid composition and distribution, to improve your understanding of the reservoir.

InSitu Family* reservoir fluid measurements acquired with the InSitu Fluid Analyzer* system deliver the next generation of measurements for real-time downhole fluid analysis (DFA):



This graph demonstrates excellent agreement between InSitu Fluid Analyzer and laboratory composition measurement data.

- hydrocarbon composition (C_1, C_2, C_3–C_5, and C_{6+})
- gas/oil ratio (GOR)
- live-oil density
- CO_2
- pH of water (aquifer, connate, injection, or water-base mud [WBM] filtrate)
- reservoir fluid color
- free-gas detection
- downhole fluorescence (dew precipitation in retrograde gas condensates)
- flowline pressure and temperature (regime of sample chamber, not the probe)
- resistivity of reservoir water
- oil-base mud (OBM) filtrate contamination.



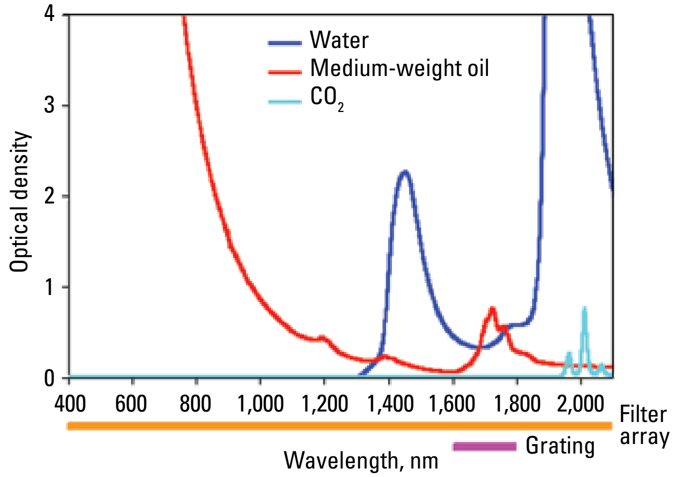
InSitu Fluid Analyzer service integrates multiple InSitu Family reservoir fluid measurements and sensors.

Fluid Profiling* analysis of InSitu Family DFA measurements gives further insight to reservoir fluid distribution and variation. Characterization of the fluid system is extended from a single well to multiple-well (field-based) applications, such as quantifying compositional gradients and identifying zonal connectivity.

DUAL SPECTROMETERS FOR ENHANCED ACCURACY

The foundation of DFA is optical absorption spectroscopy. The InSitu Composition* hydrocarbon fluid composition measurement introduces the first downhole deployment of a laboratory-grade "grating spectrometer" in addition to the conventional filter array spectrometer. This technical innovation expands the accuracy and detail of the compositional information, resulting in quantifiable fluid data. The filter array spectrometer measures wavelengths in the visible to near-infrared (Vis-NIR) range from 400 to 2,100 nm across 20 channels that indicate the color and molecular vibration absorptions of the reservoir fluid and also show the main absorption peaks of water and CO_2. The grating spectrometer has 16 channels focused on the 1,600- to 1,800-nm range, where reservoir fluid has characteristic absorptions that reflect molecular structure.

The dual-spectrometer measurements together with real-time calibration (performed downhole every 1 second) and improved compositional algorithms significantly improve the accuracy and repeatability of quantitative reservoir fluid analysis. It is this improved accuracy that enables Fluid Profiling comparison of fluid properties between wells, making field-wide DFA characterization a new critical tool for reservoir studies.



The wavelength ranges of the filter array and grating optical spectrometers are optimized for the detection and analysis of hydrocarbon and CO_2 components in crude oil and natural gas, as well as for the determination of water content and pH. The measurement of optical density (OD) is simply the base-10 logarithm of the ratio of incident light to the transmitted light through a cross-section of reservoir fluid in the flowline. OD is presented as a dimensionless unit, whereby one OD absorbance unit implies a 10-fold reduction in light intensity. For example, OD = 0 means 100% of light is transmitted, OD = 1 indicates 10% light is transmitted, and OD = 2 means 1% light is transmitted. The measurements are conducted across the entire frequency spectrum of light in the Vis-NIR range.

InSitu COMPOSITION MEASUREMENT

The Vis-NIR spectrum measured by the two InSitu Composition spectrometers is used for the analysis of fluid hydrocarbon composition, GOR, CO_2, water content, and mud filtrate contamination. In addition to the improved measurement capabilities of the dual spectrometers, the compositional analysis is refined with an algorithm developed from Beer-Lambert's law, which indicates that the optical absorption of a component is proportional to its concentration. Thus the spectrum of a live oil is a weighted sum of the absorptions of its individual components.

The significant variation of the C_{6+} group in live oil is also accounted for in the algorithm. The C_{6+} group is the main component of stock-tank oil, and the detailed spectrum of the grating spectrometer in the 1,600- to 1,800-nm range was used to characterize stock-tank oil on the basis of wax and branched-alkane content. From this data, the fluid composition analysis corrects for spectrum variation. An independent determination of ethane (C_2) is now possible for the first time owing to the increased resolution of the grating spectrometer together with advanced deconvolution. This extra detail in analyzing light-end hydrocarbon components is critical for productivity analysis and economic assessment. The ratio of C_1/C_2 can also help determine whether the hydrocarbon source is biogenic or thermogenic.

From the composition, the gas/oil ratio (GOR) and condensate/gas ratio (CGR) are determined from the vaporizations of the hydrocarbon and CO_2 components at standard conditions for flashing a live fluid.

InSitu GOR

From the enhanced composition measurement, the gas/oil ratio (GOR) and condensate/gas ratio (CGR) are determined from the vaporizations of the hydrocarbon and CO_2 components at standard conditions for flashing a live fluid. This new implementation provides greater range and increased accuracy over the measurement offered in previous generation tools (LFA* live fluid analyzer and CFA* compositional fluid analyzer). Results can now be entered into reservoir simulation models with confidence.

InSitu CO_2 MEASUREMENT

Carbon dioxide is present in the fluids of many reservoirs and must be accurately accounted for when developing hydrocarbon reserves. However, reliable quantification of CO_2 from reservoir fluid samples can be difficult, especially if there is water in the collected samples, because CO_2 easily reacts with water, whether from mud filtrate contamination or formation water.

The measurement of CO_2 content by the InSitu Fluid Analyzer system is performed with the filter array spectrometer. A dedicated channel to the CO_2 absorption peak is complemented with dual baseline channels above and below that subtract out the overlapping spectrum of hydrocarbon and small amounts of water. The new channels and enhanced algorithm make it possible to plot the CO_2 content in real time, together with upper and lower accuracy tolerances on the measurement. This gives increased confidence in the measurement accuracy under different environments.

InSitu COLOR MEASUREMENT

With optical filters improved for high-temperature performance, the InSitu Color* reservoir fluid color measurement uses the extended measurement range of the 20-channel filter array spectrometer to determine fluid color. The reliability of the measurement is supported by continuous real-time autocalibration, application of a contamination algorithm that uses all the spectrometer channels, and a coated-window detection flag for enhanced QC. The color measurement supports fluid identification, determination of asphaltene gradients, and pH measurement.

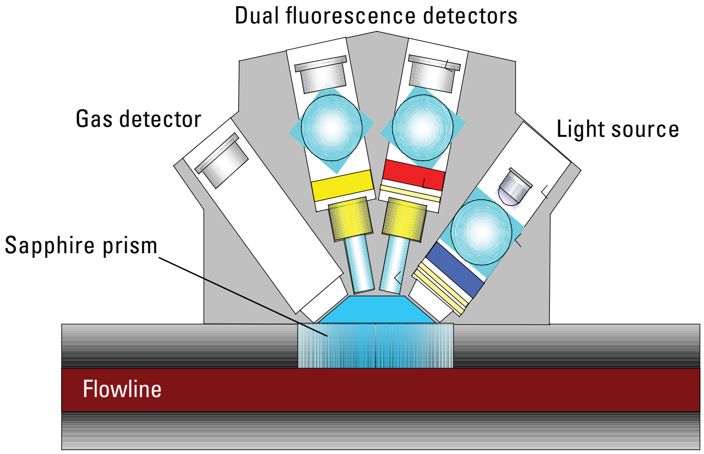
InSitu DENSITY MEASUREMENT

Measuring density downhole at reservoir conditions provides numerous advantages over surface measurements, especially for determining pressure gradients in thin beds or carbonate transition zones. This real-time measurement directly yields the slope of the pressure gradient for the identification of fluid contacts.

The InSitu Density* reservoir fluid density measurement is based on the resonance characteristics of a vibrating sensor that oscillates in two perpendicular modes within the fluid. Simple physical models describe the resonance frequency and quality factor of the sensor in relation to the fluid density. Dual-mode oscillation is superior to other resonant techniques because it minimizes the effects of pressure and temperature on the sensor through common mode rejection, which further improves the accuracy of the measurement. The InSitu Density measurement is made under flowing conditions, and the resonator is resistive to corrosive fluids.

InSitu FLUORESCENCE MEASUREMENT

The InSitu Fluorescence* reservoir fluid fluorescence measurement detects free gas bubbles and retrograde condensate liquid dropout for single-phase assurance while conducting DFA and sampling. Fluid type is also identified. The resulting fluid phase information is especially useful for defining the difference between retrograde condensates and volatile oils, which can have similar GORs and live-oil densities. Because the fluorescence measurement is also sensitive to liquid precipitation in a condensate gas when the flowing pressure falls below the dewpoint, it can be used to monitor phase separation in real time to ensure the collection of representative single-phase samples.



Downhole reflection and dual fluorescence measurements provide assurance that the reservoir fluid is in single phase before DFA and sampling.

InSitu pH MEASUREMENT

The formation water pH is a key parameter in water chemistry, used for calculating the corrosion and scaling potential of the water, understanding reservoir connectivity and transition zones, determining the compatibility of injection water and formation water, and designating optimal salinity and pH windows for polymer and gel injections. Obtaining high-quality DFA and samples of formation water relies on tracking mud filtrate contamination by distinguishing between formation water and mud filtrate in real time.

Water pH is measured with the InSitu pH* reservoir fluid pH measurement by injecting dye into the formation fluid being pumped through the InSitu Fluid Analyzer flowline. The pH is calculated with 0.1-unit accuracy from the relevant visible wavelengths of the dye signal measured by an optical fluid analyzer. Making the measurement at reservoir conditions avoids the irreversible pH changes that occur when samples are brought to the surface, as acid gases and salts come out of solution with reduced temperature and pressure and routine laboratory flashing of the sample.

InSitu pH sensor measures fluids across the entire flowline cross section, which makes it more robust than potentiometric methods of measurement, which are compromised when oil and mud foul electrode surfaces. Direct pH measurements with dye also avoid the limitations of resistivity measurement in monitoring contamination, which requires a sufficient resistivity contrast between the filtrate and formation water.

FLOWLINE RESISTIVITY MEASUREMENT

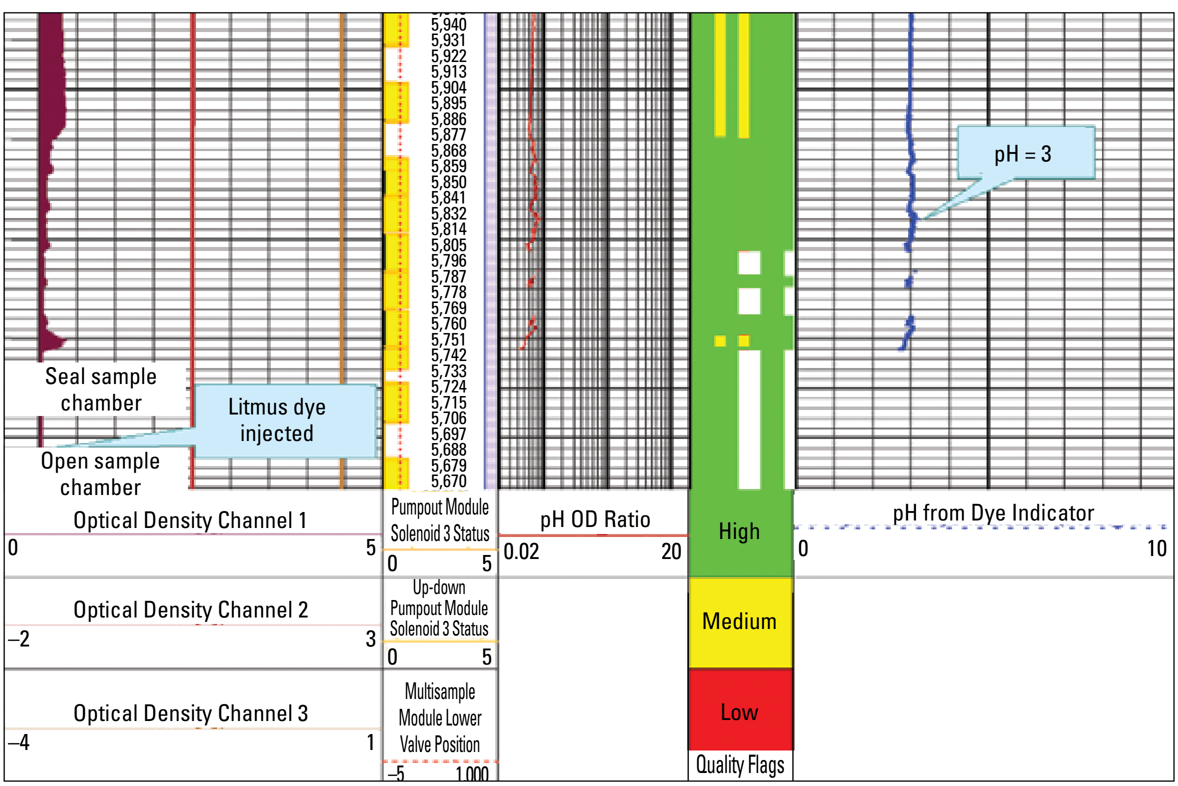
The flowline resistivity sensor uses the same proven technology employed in Schlumberger formation testing tools. With the resistivity sensor included in the DFA assembly, it is possible to monitor resistivity during dual-packer sampling operations in WBM.

FLOWLINE PRESSURE AND TEMPERATURE MEASUREMENTS

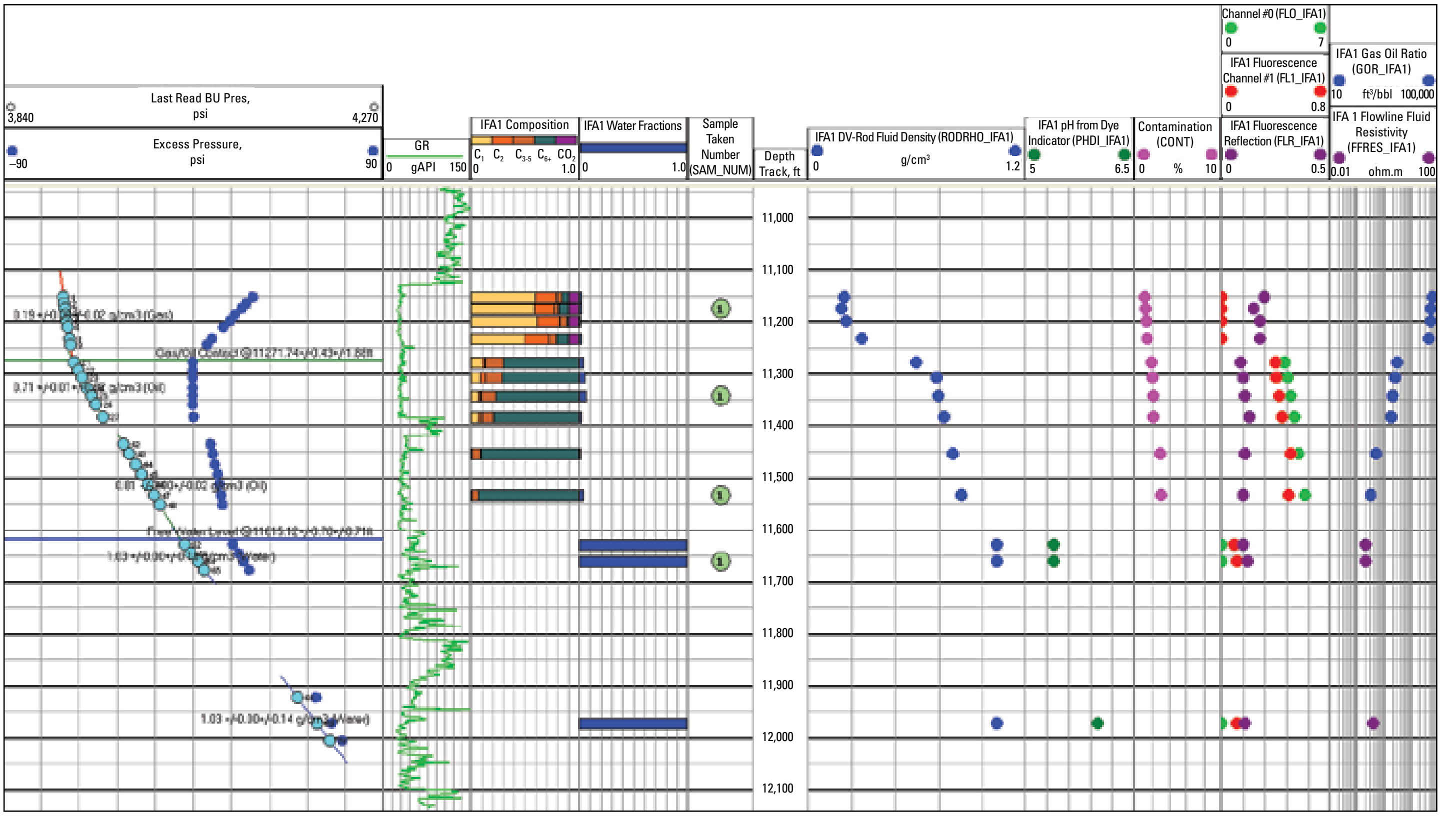
The high-resolution pressure and temperature sensors used in Schlumberger formation testing tools are also incorporated in the InSitu Fluid Analyzer service. Direct measurement of pressure and temperature is essential to identify the position in the PVT envelope where the other fluid properties, such as density, are measured, especially when the sensors are placed downstream of the flowline pump. The DFA measurements within the flowline can then be accurately translated back to virginal reservoir conditions by employing well-known equation-of-state (EOS) algorithms.

SAMPLING QUALITY CONTROL

With InSitu Family measurements, the reservoir fluid is analyzed before samples are collected, which substantially improves the quality of the fluid samples. The sampling process is optimized in terms of where and when to sample and how many samples to collect. In addition, the pressure sensor provides an accurate record of overpressuring the sample contents before the sampling chamber is closed.



InSitu pH measurement of pH = 3 indicated high CO_2 that was missed in laboratory analysis conducted after the sample was flashed. With knowledge of the actual CO_2 content, the operator could minimize subsequent corrosion and scaling problems.



The comprehensive InSitu Pro real-time quality control and interpretation software depth view combines the results of pressure and fluids analysis from multiple data sources.*

DFA also provides a convenient technique for establishing a chain of custody for fluid samples. Differences between analytical data acquired downhole and that from corresponding samples in the laboratory are a strong indication that the laboratory sample may have been compromised.

FLUID PROFILING

Fluid Profiling characterization provides the distribution of fluid properties across the reservoir, beyond what a traditional sampling program can achieve. The quantified accuracy of the InSitu Family measurements expands DFA application from a single well to multiple-well analysis, defining reservoir architecture across the entire field. Quantification of the variation of fluid properties at higher resolution than conventional sampling and analysis is key to identifying and differentiating compositional grading, fluid contacts, and reservoir compartments.

InSitu Fluid Analyzer Mechanical Specifications	
Temperature rating, degF [degC]	350 [175]
Pressure rating, psi [MPa]	25,000 [170]
Diameter, in [cm]	5 [12.7]
Length, ft [m]	10.43 [3.18]
Weight, lbm [kg]	368 [167]

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