SPWLA SAUDI ARABIA CHAPTER (SAC)
9th Topical Workshop

CORING AND CORE ANALYSIS: CHALLENGES AND BEST PRACTICES
Virtual Workshop Series (Feb, Mar & Apr 2021)

Downhole Fluid Sampling, Contamination Estimation

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Schlumberger

Agenda

- Basic Theory of Optical Density
- DFA (Down Hole Fluid Analysis); Main Measurements
- OCM (Oil Contamination Monitoring) Theory
- WCM (Water Contamination Monitoring) Theory
- Cases
- Q&A

Objective

"To Understand the Down Hole Fluid Analysis Physics of Measurements & Fundamentals of Optical Contamination Monitoring & Water Contamination Monitoring to enable assessment of the Sample Quality & the Hydrocarbon / Water Characteristics InSitu Conditions"

TM

Wireline Formation Tester

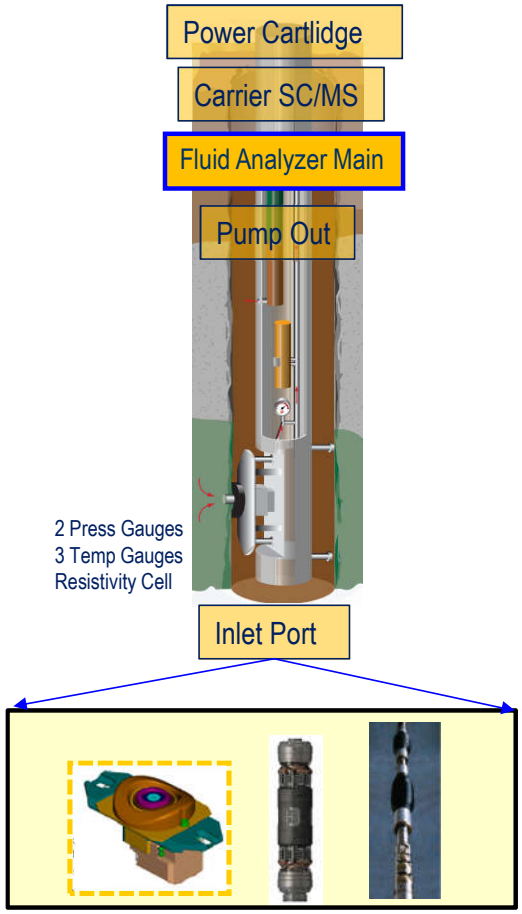
Down Hole Fluid Analysis is an Application within the Formation Tester

Sampling / Downhole Fluid Analysis (DFA):

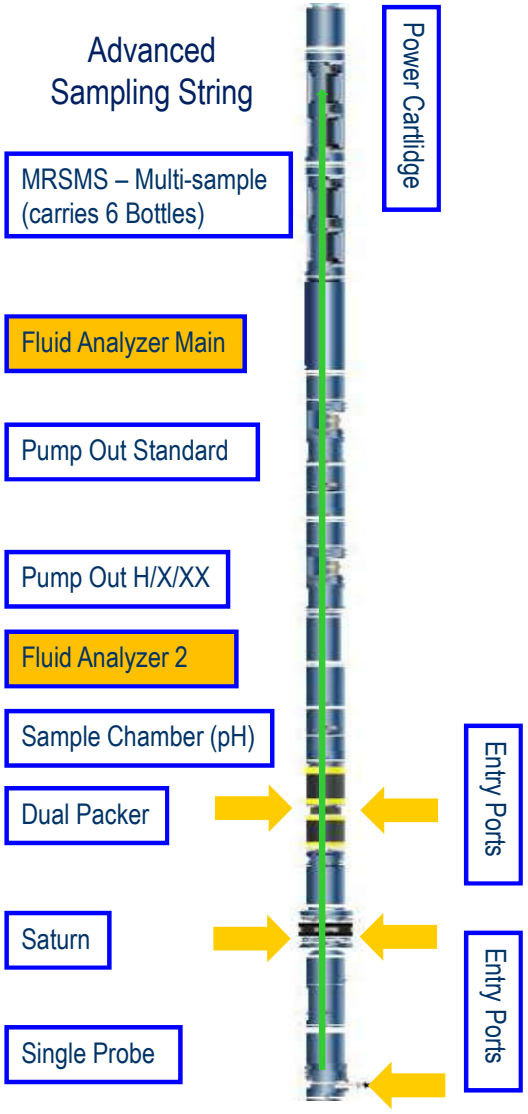
- To confirm the presence of Hydrocarbon / Water bearing zones (clear any OH logs & Gradients uncertainties)
- PVT Studies (Reservoir Simulations, SARA, FDP, Facilities, Flow Assurance etc..)
- Determine Hydrocarbon / Water Type and Characteristics
- Determine Fractions of Fluid
- Assess Vertical & Lateral Communication (Composition, GOR, RFG)
- Estimate Contamination to Determine Sample Quality & Accurate Fluid Characteristics InSitu Conditions

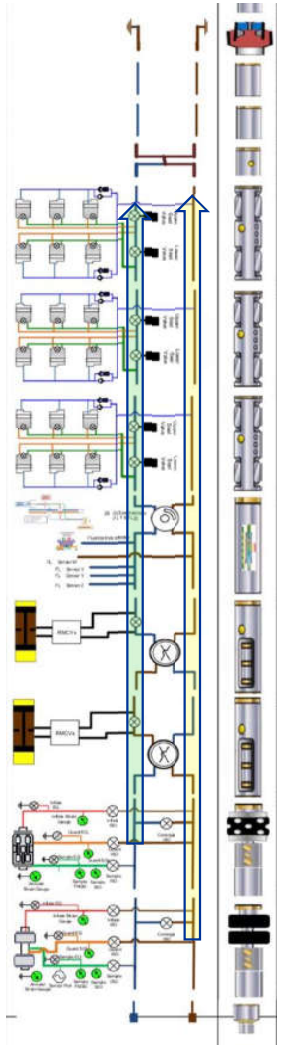
Formation Tester Modules

Basic DFA/Sampling String



Advanced Sampling String





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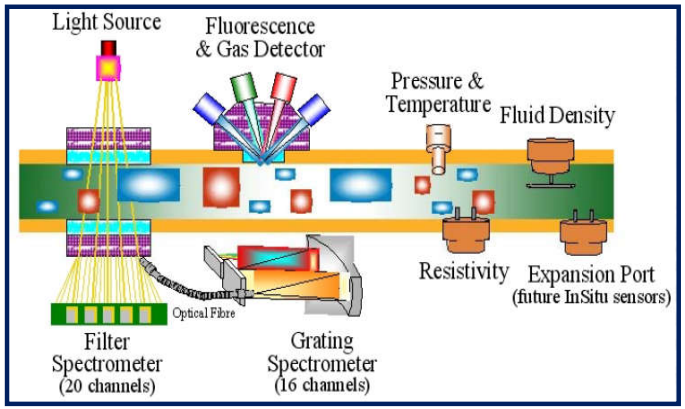
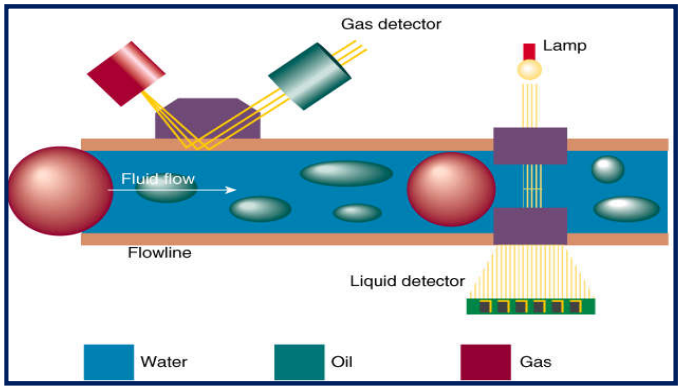
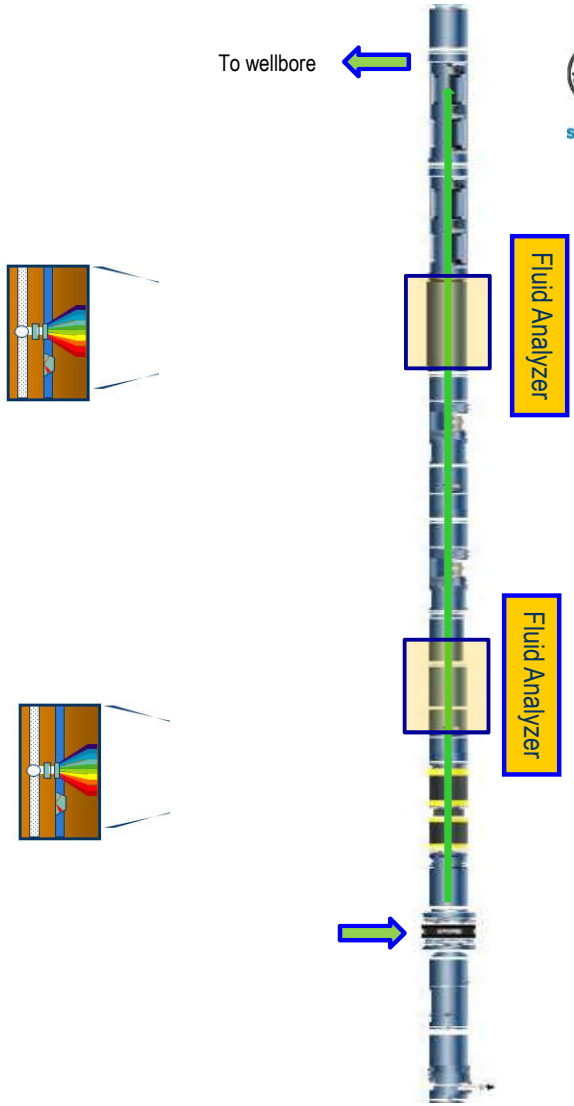
Formation Testing Modules

Fluid Analyzer; EYES Downhole

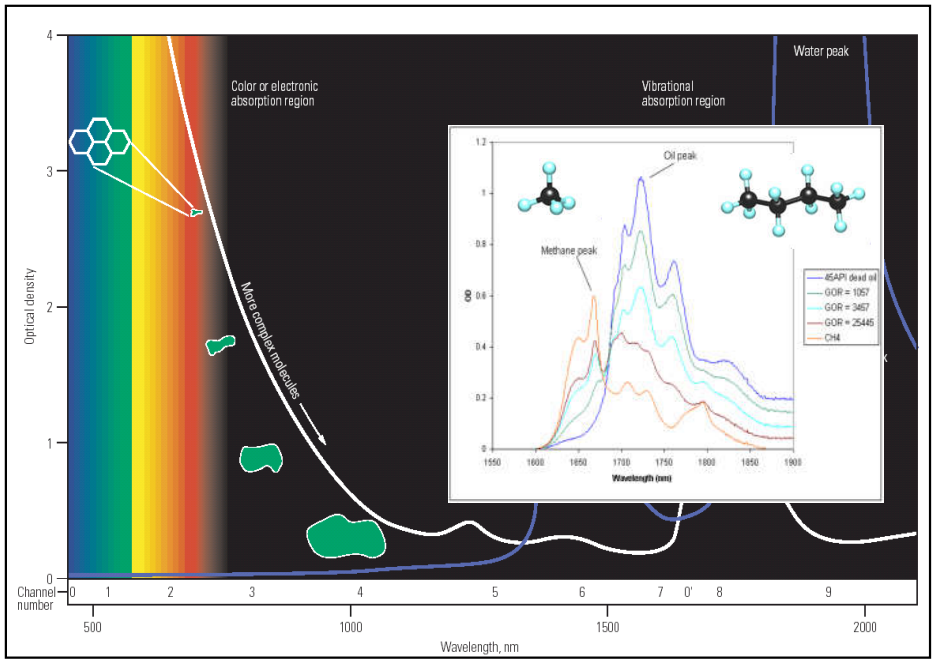


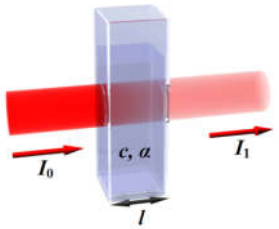




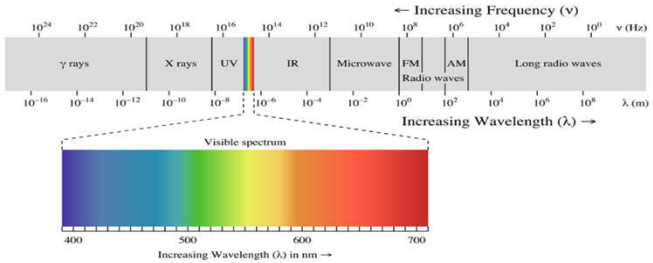
Formation Testing Modules

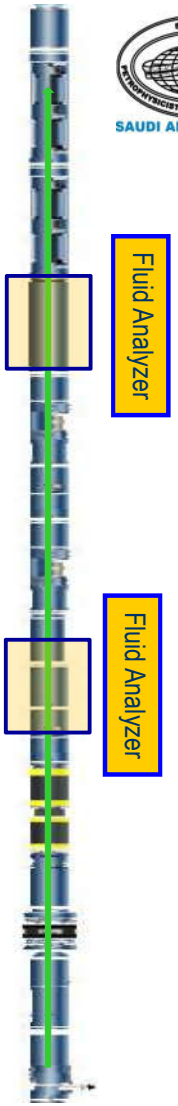
Fluid Analyzer; Optical Density Spectrometry





$$OD \equiv -\log_{10} \frac{I}{I_0}$$





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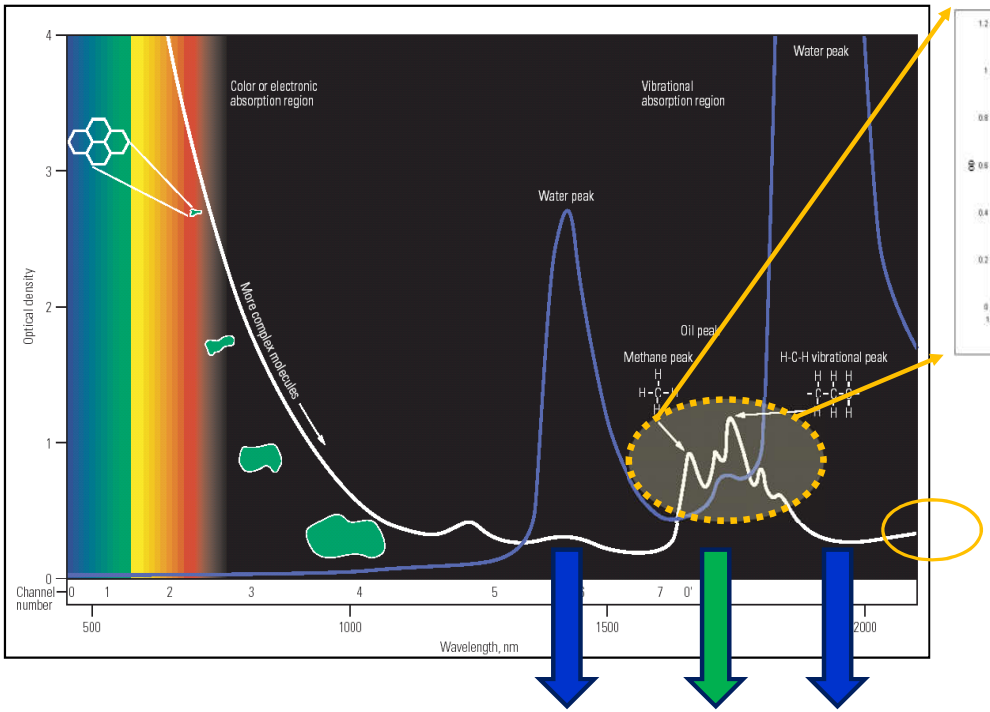
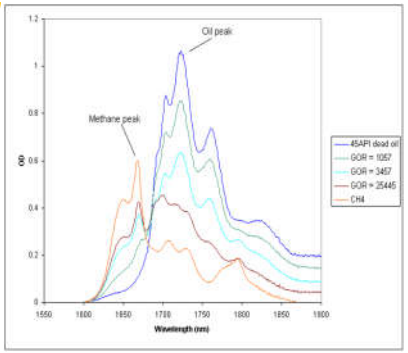
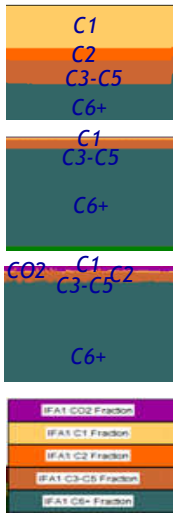
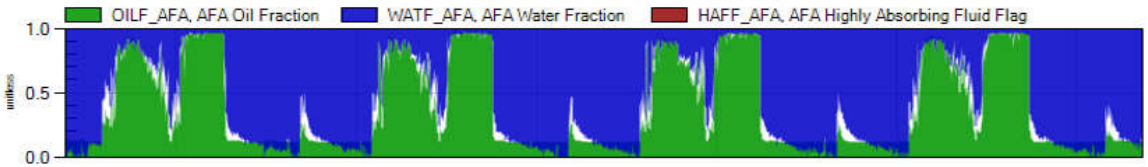
Formation Tester Modules

Fluid Analyzer; Optical Density Spectrometry









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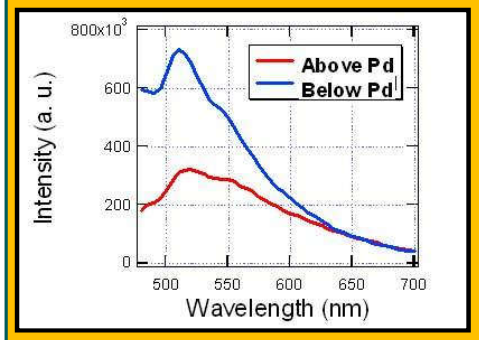
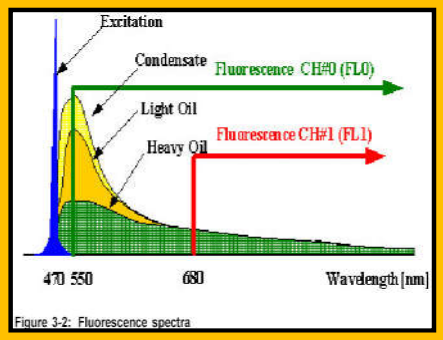
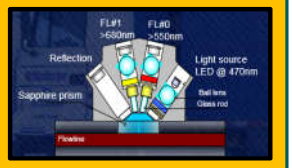
Formation Tester Modules

Fluid Analyzer; Fluorescence, Resistivity, Gas Detection, H2S & DV

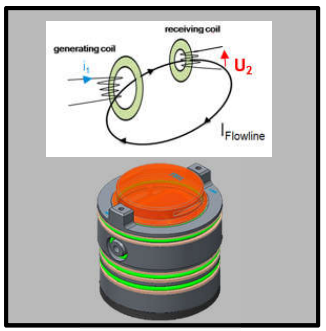
Fluorescence



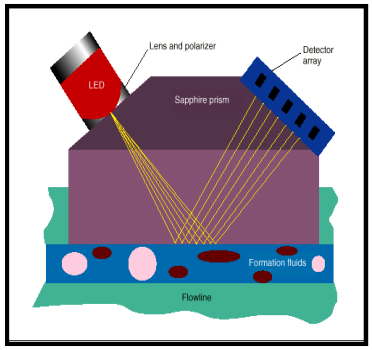




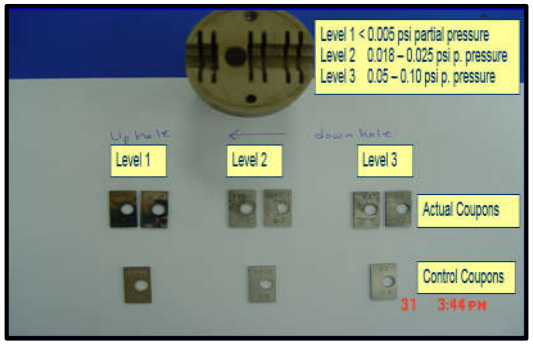
Resistivity



Gas Detection



H2S Coupons



Density-Viscosity Rod

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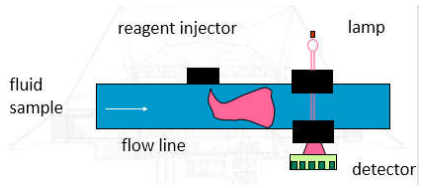
Formation Tester Modules

Spectroscopic pH Determination

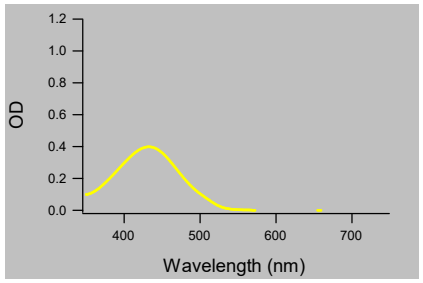


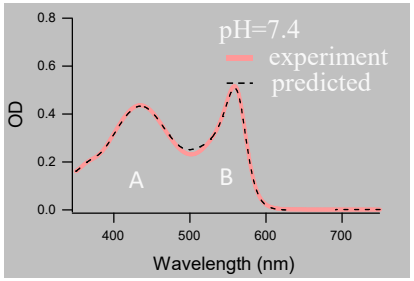
pH < 6
acid only

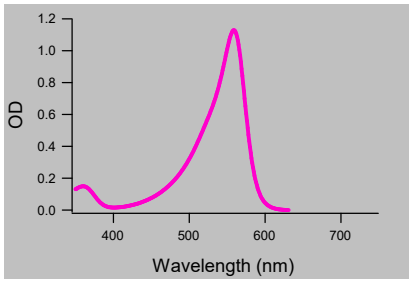
pH Sensitive Dye

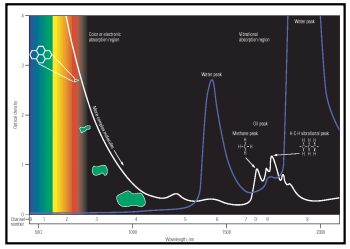
6 <pH < 9
acid-base mixture

pH > 9
base only

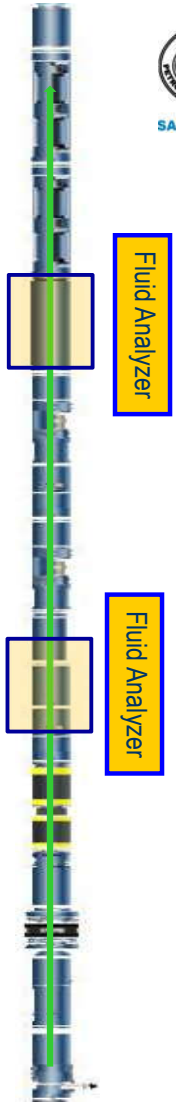








Accuracy ~ 0.1 unit
Range extended by using dye mixtures
pKa' is function of T, P and IS



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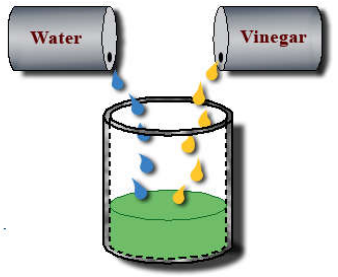
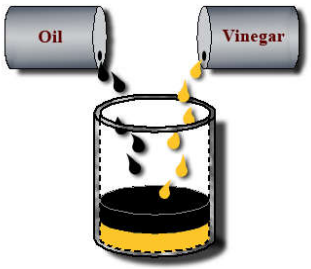
Optical Contamination Monitoring OCM

Fluid Miscibility; Fluid Fractions Vs Contamination

Miscibility is the property of liquids to mix in all proportions, forming a homogeneous solution

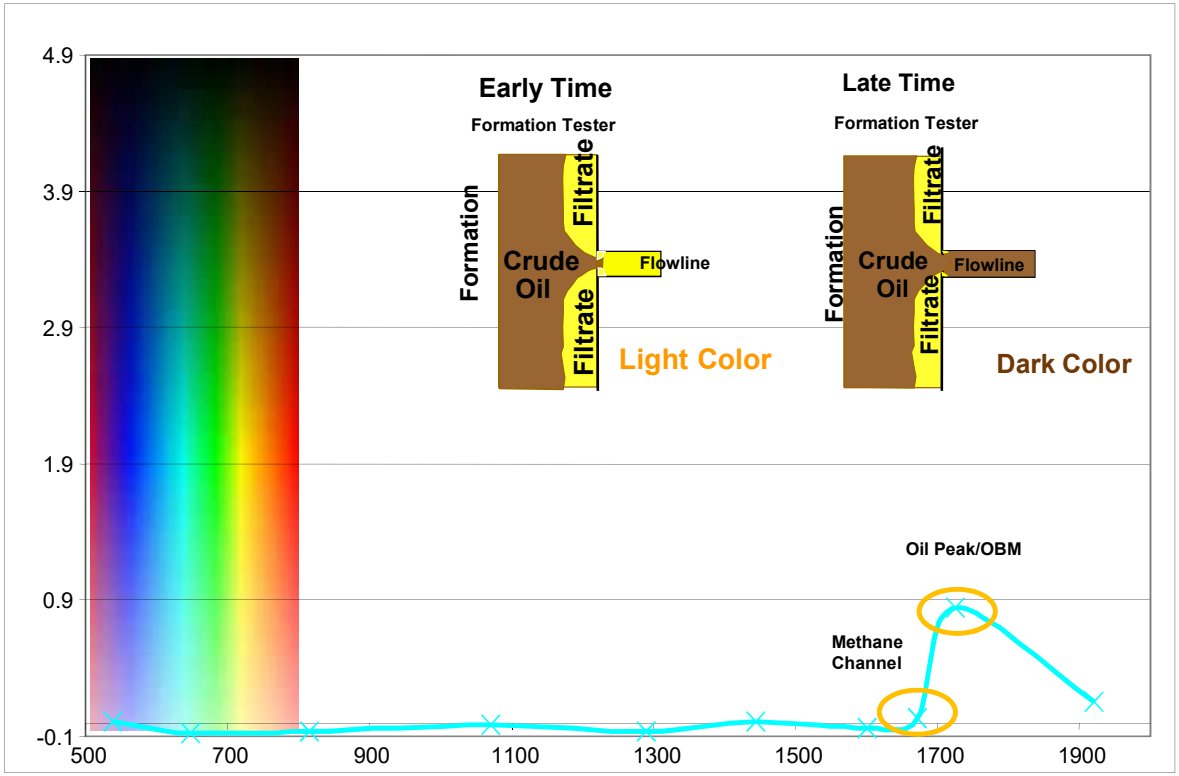
- Miscible fluids
  - OBM filtrate & oil
  - OBM filtrate & gas Condensate
  - WBM filtrate & formation water
- Immiscible fluids
  - OBM filtrate & water
  - WBM filtrate & oil
  - WBM filtrate & gas condensate
  - WBM filtrate & dry gas
- OCM is not applicable to immiscible fluids
- Fluid fraction or fluid cut is more applicable when sampling/DFA immiscible fluids



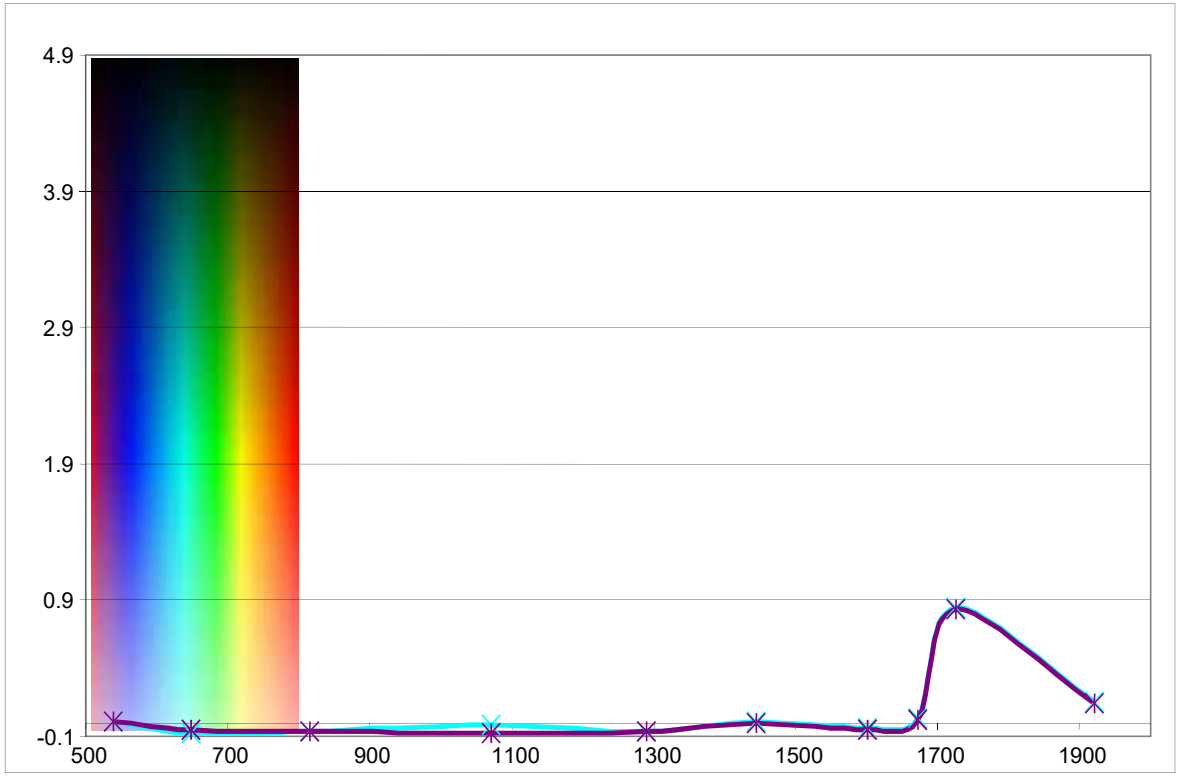


Clean up monitoring: 15 mins (after Mud)

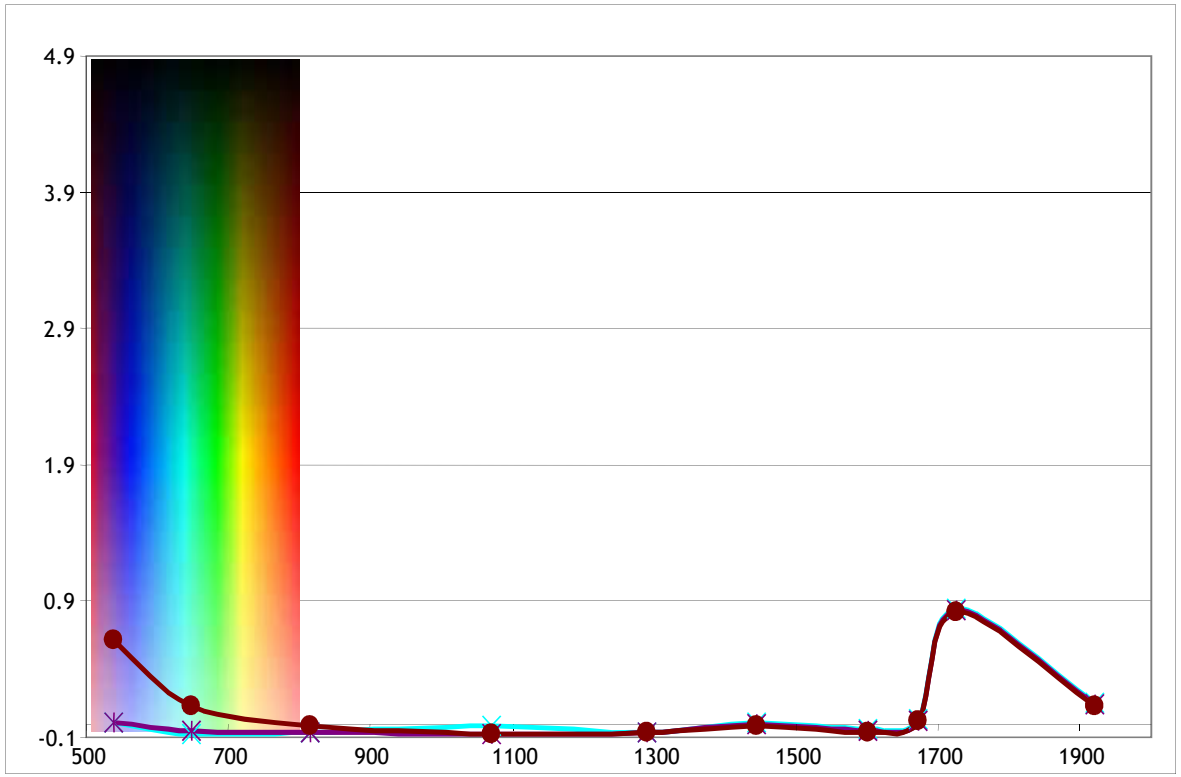
OBM & Oil



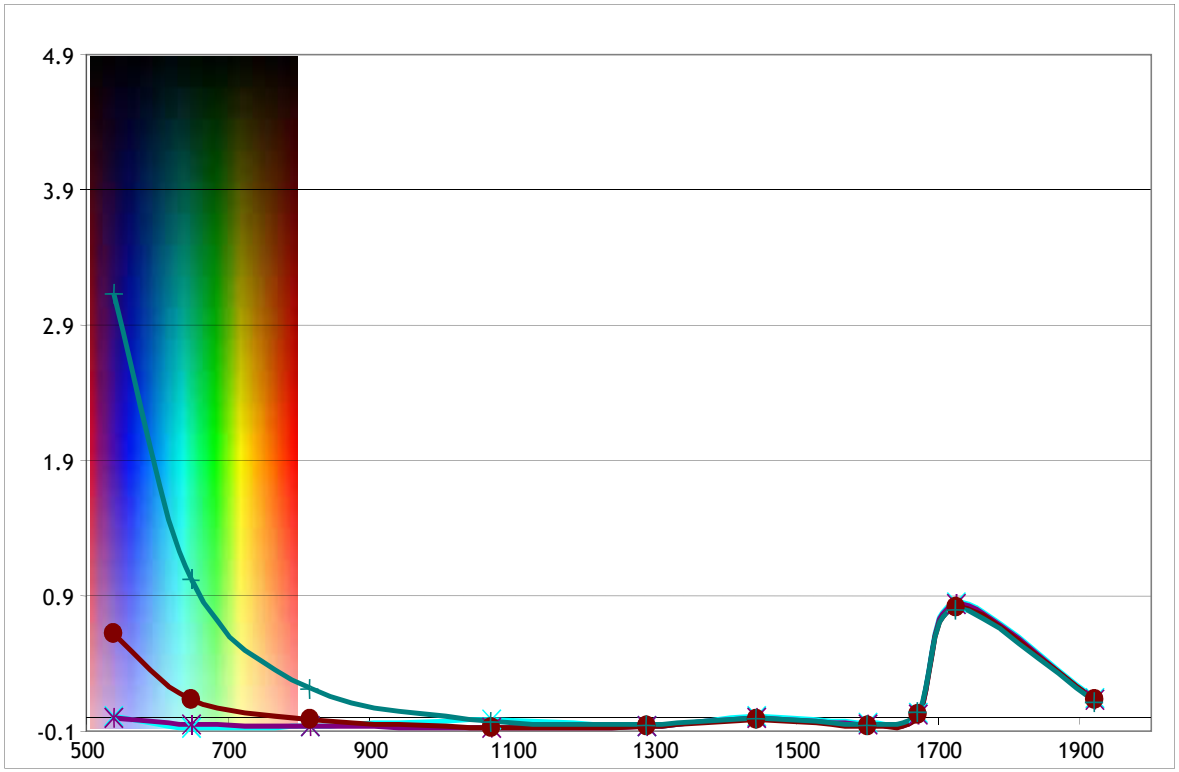
Clean up monitoring: 1 hr



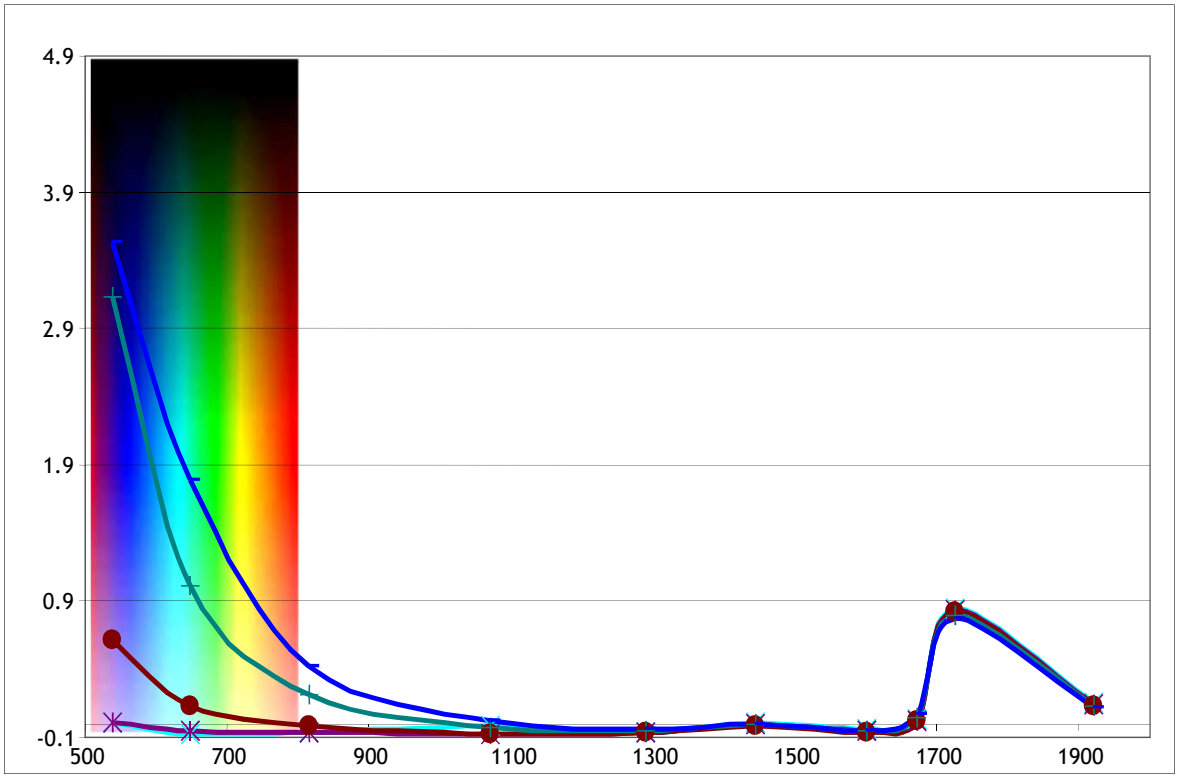
Clean up monitoring: 2 hrs



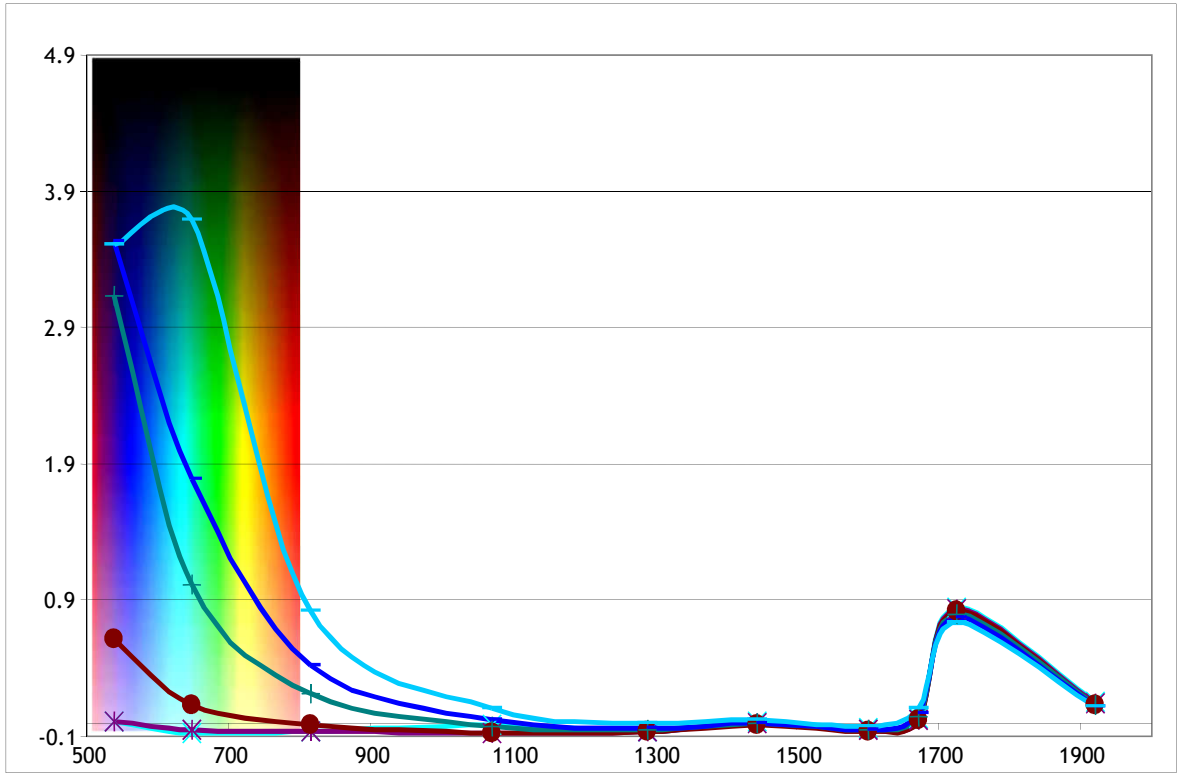
Clean up monitoring: 3 hrs



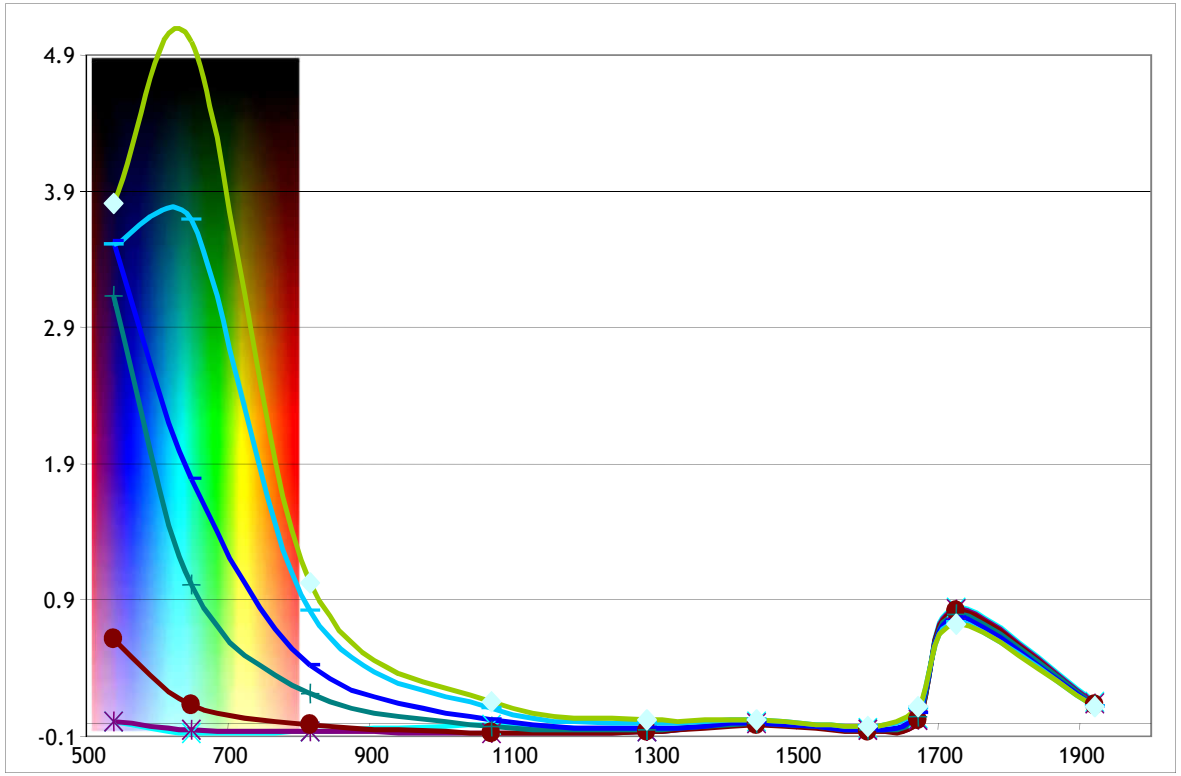
Clean up monitoring: 3.5 hrs



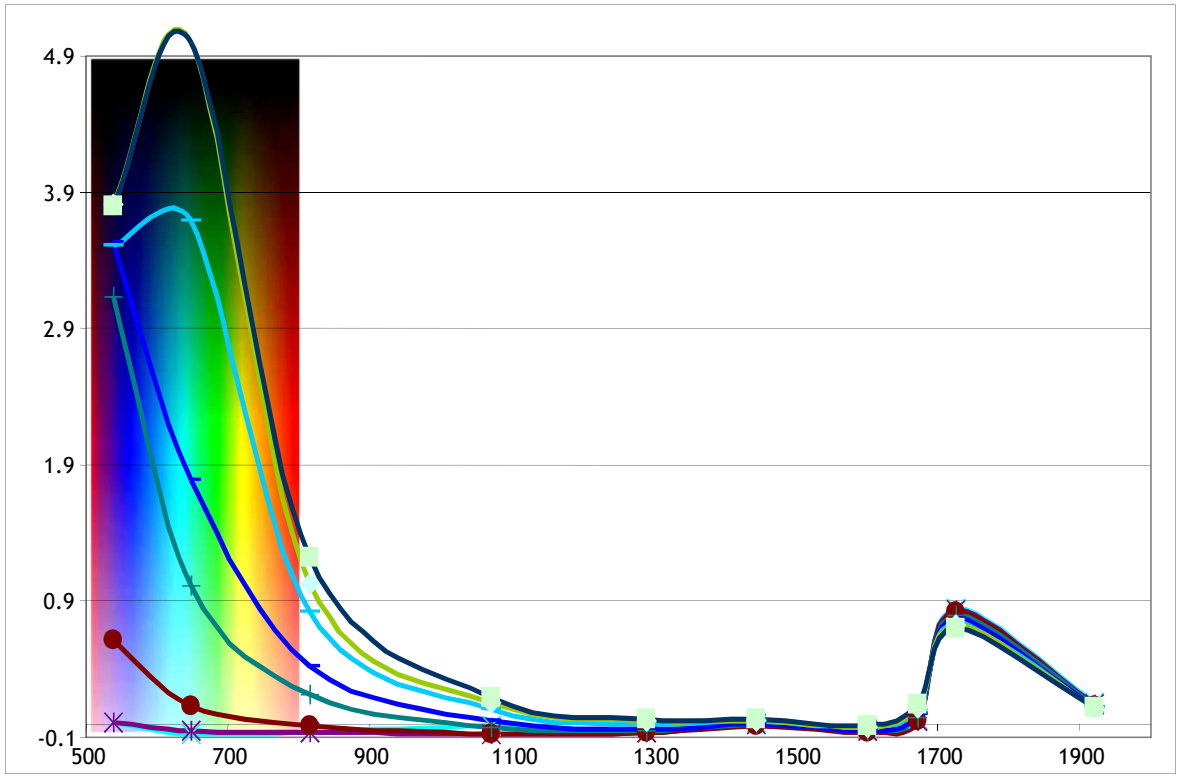
Clean up monitoring: 4.5 hrs



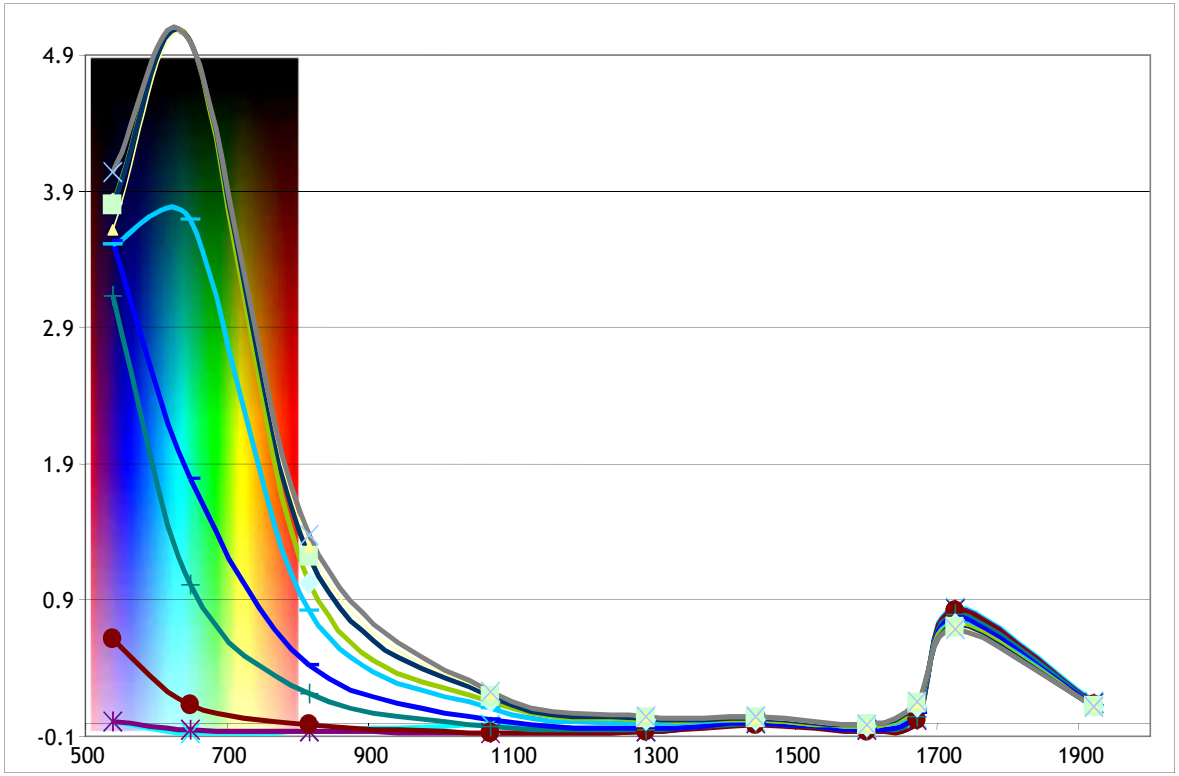
Clean up monitoring: 5.5 hrs



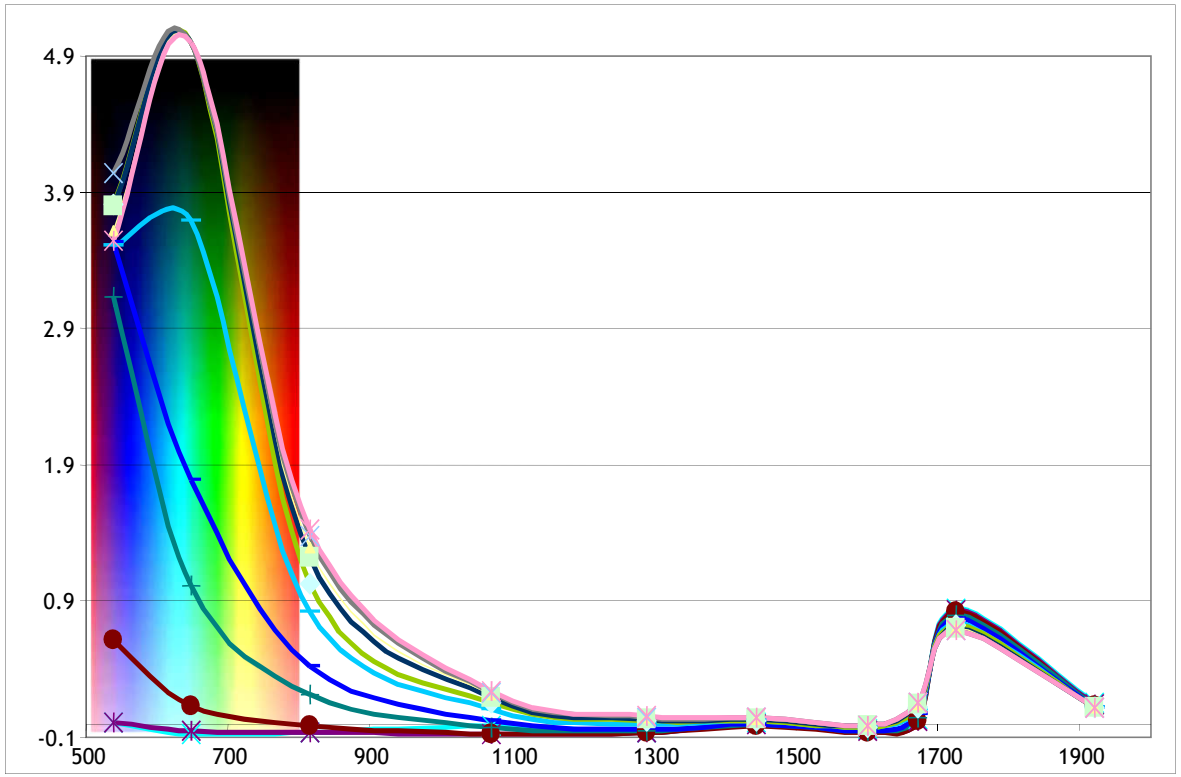
Clean up monitoring: 6.5 hrs



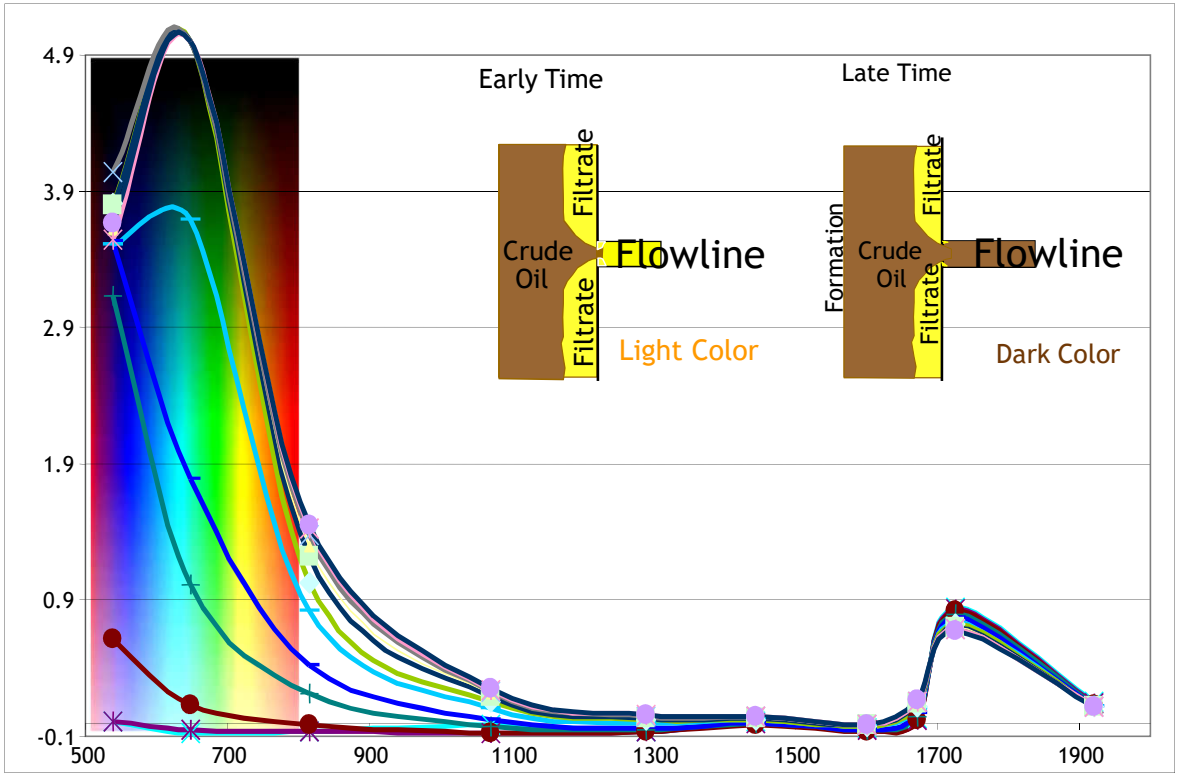
Clean up monitoring: 7 hrs



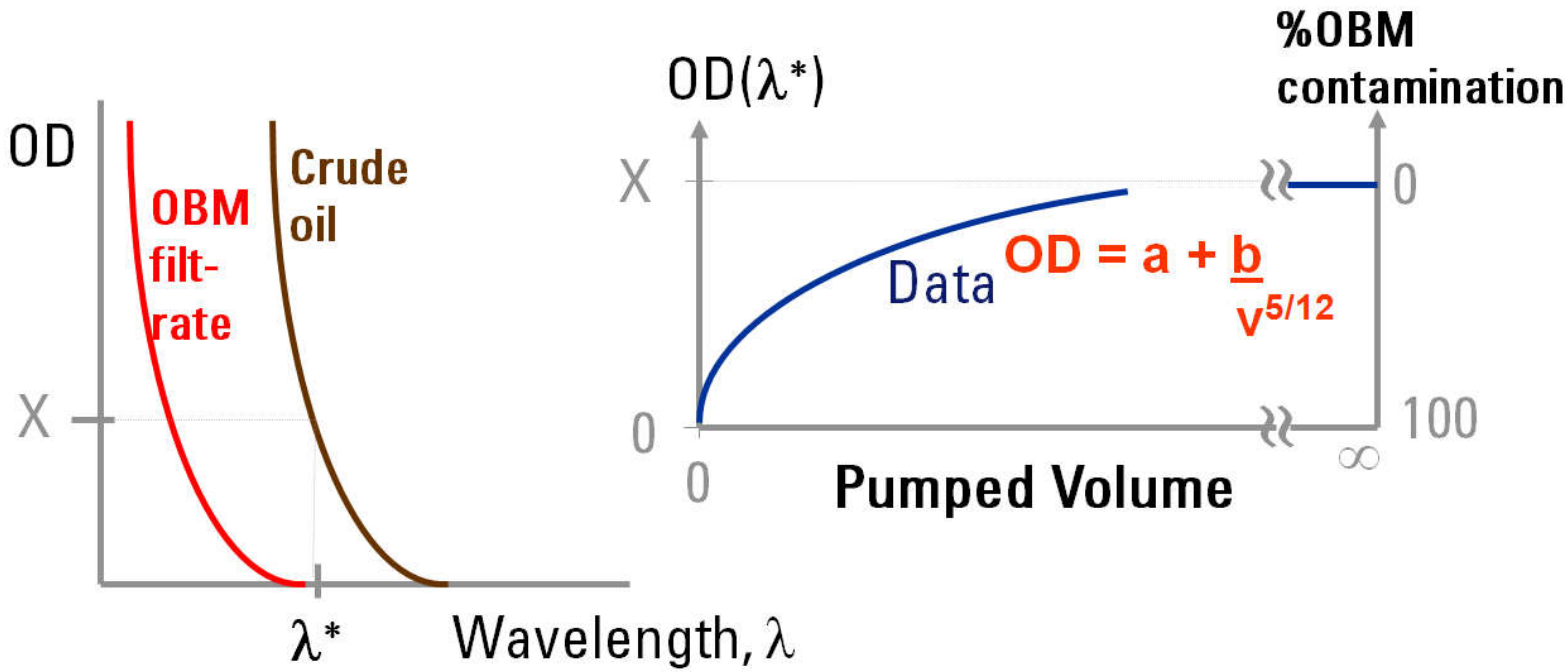
Clean up monitoring: 8 hrs



Clean up monitoring: 9 hrs



Beer – Lambert Law of Mixing Fluids



Beer – Lambert Law of Mixing Fluids

Linear relationship between absorbance and concentration of species

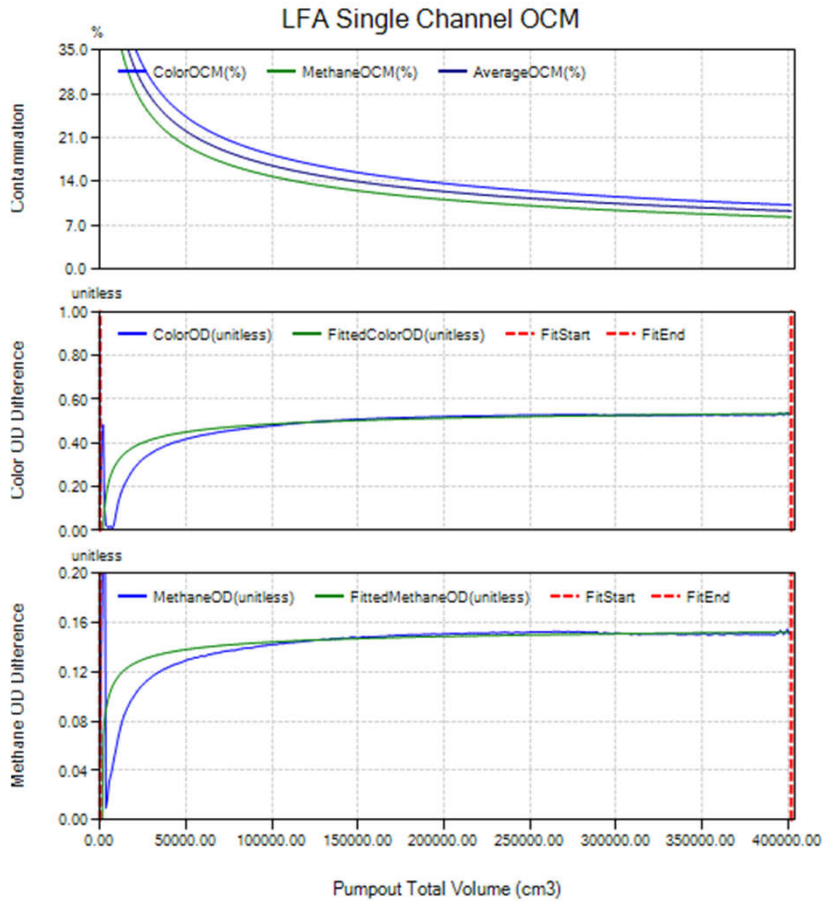
$$OD_\lambda = \eta\ OD_{\lambda,fil} + (1-\eta)\ OD_{\lambda,oil}$$

$$\eta = \frac{OD_\lambda - OD_{\lambda,oil}}{OD_{\lambda,fil} - OD_{\lambda,oil}} \qquad \eta = 1 - \frac{OD_\lambda}{OD_{\lambda,oil}} \quad , OD_{\lambda,fil} = 0$$

$\eta -$ *contamination*

In the color region the OD of filtrate is normally zero

Single Channel OCM



$$\eta = \frac{OD_{\lambda} - OD_{\lambda,oil}}{OD_{\lambda,fil} - OD_{\lambda,oil}}$$

$$OD_{\lambda,fil} = 0$$

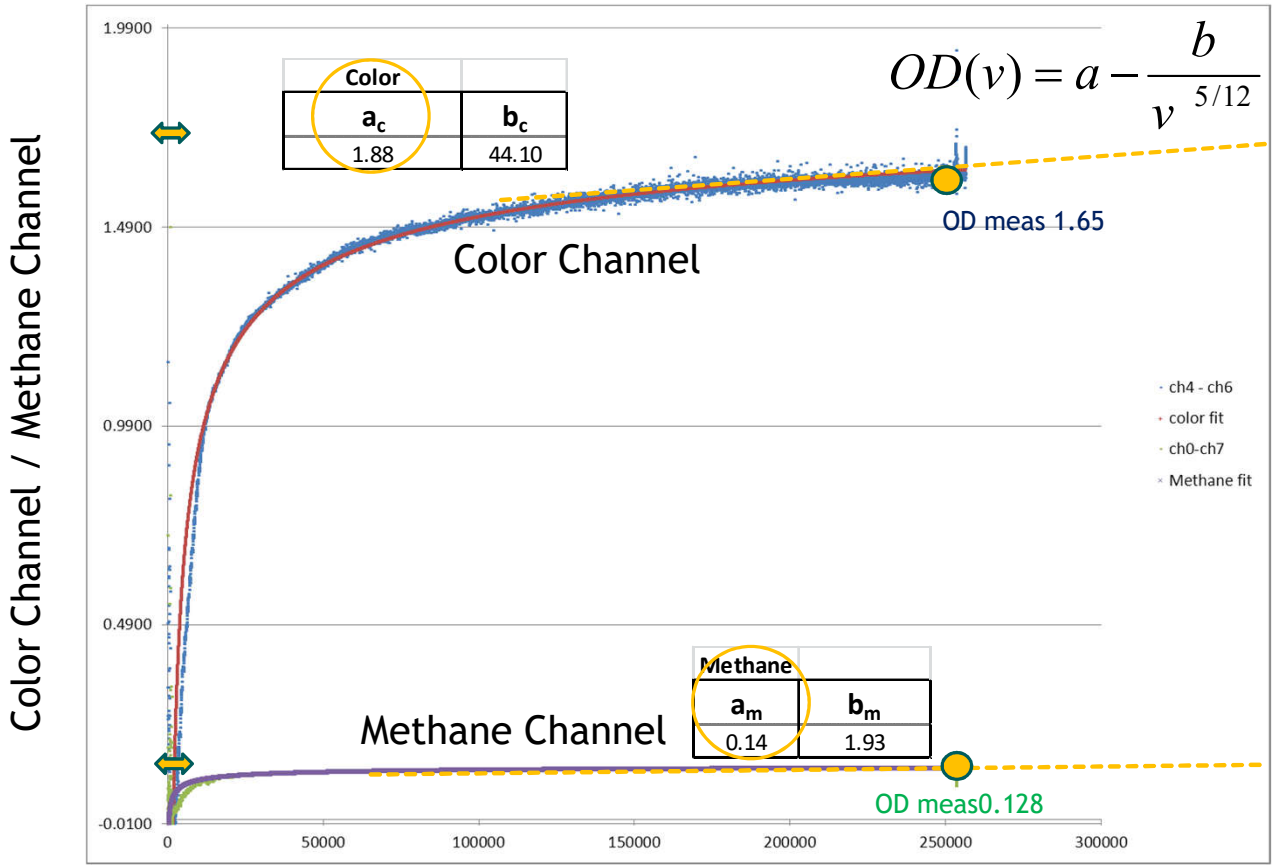
$$\eta = 1 - \frac{OD_{\lambda}}{OD_{\lambda,oil}}$$

$$OD(v) = a - \frac{b}{v^{5/12}}$$

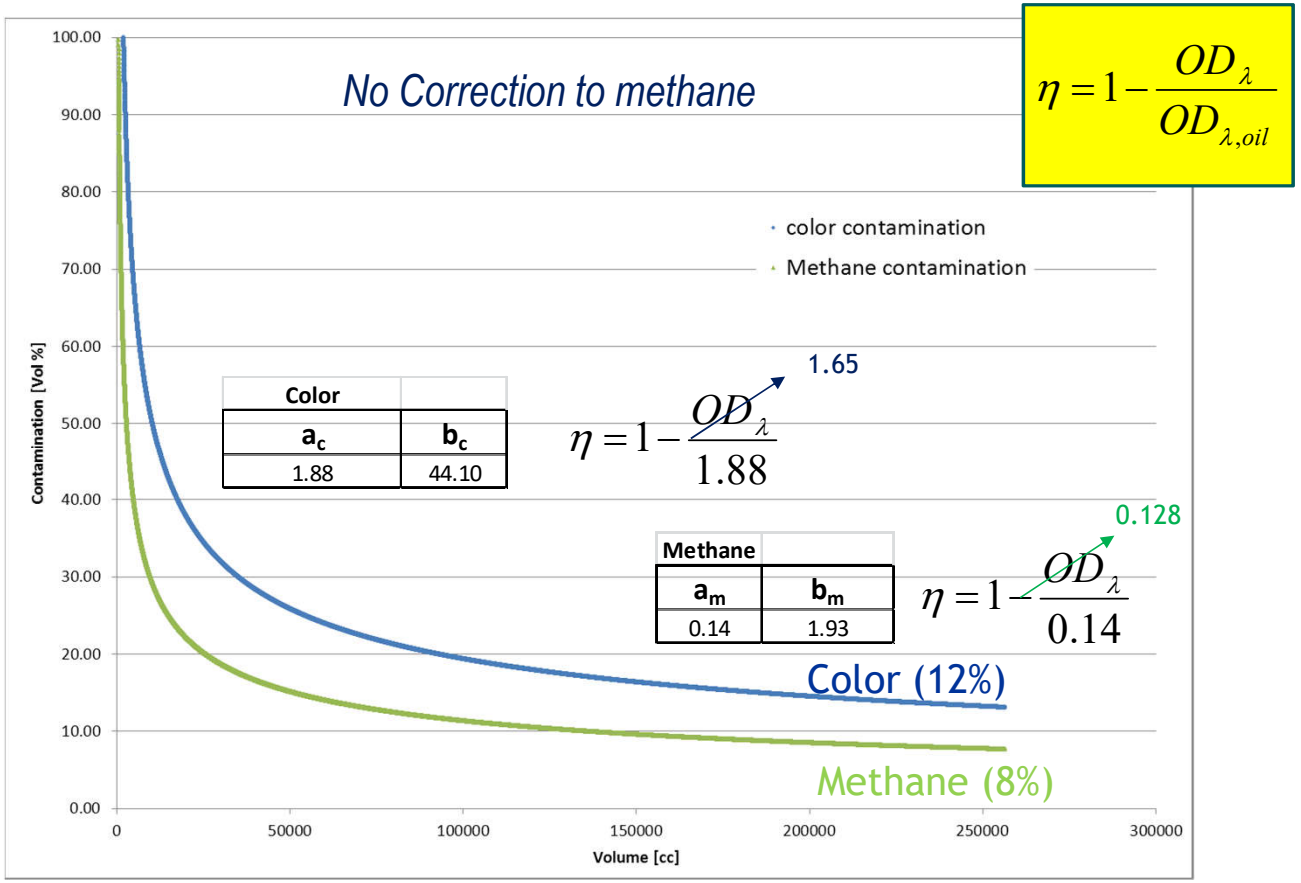
$$OD_{\lambda,oil} = a$$

2/3

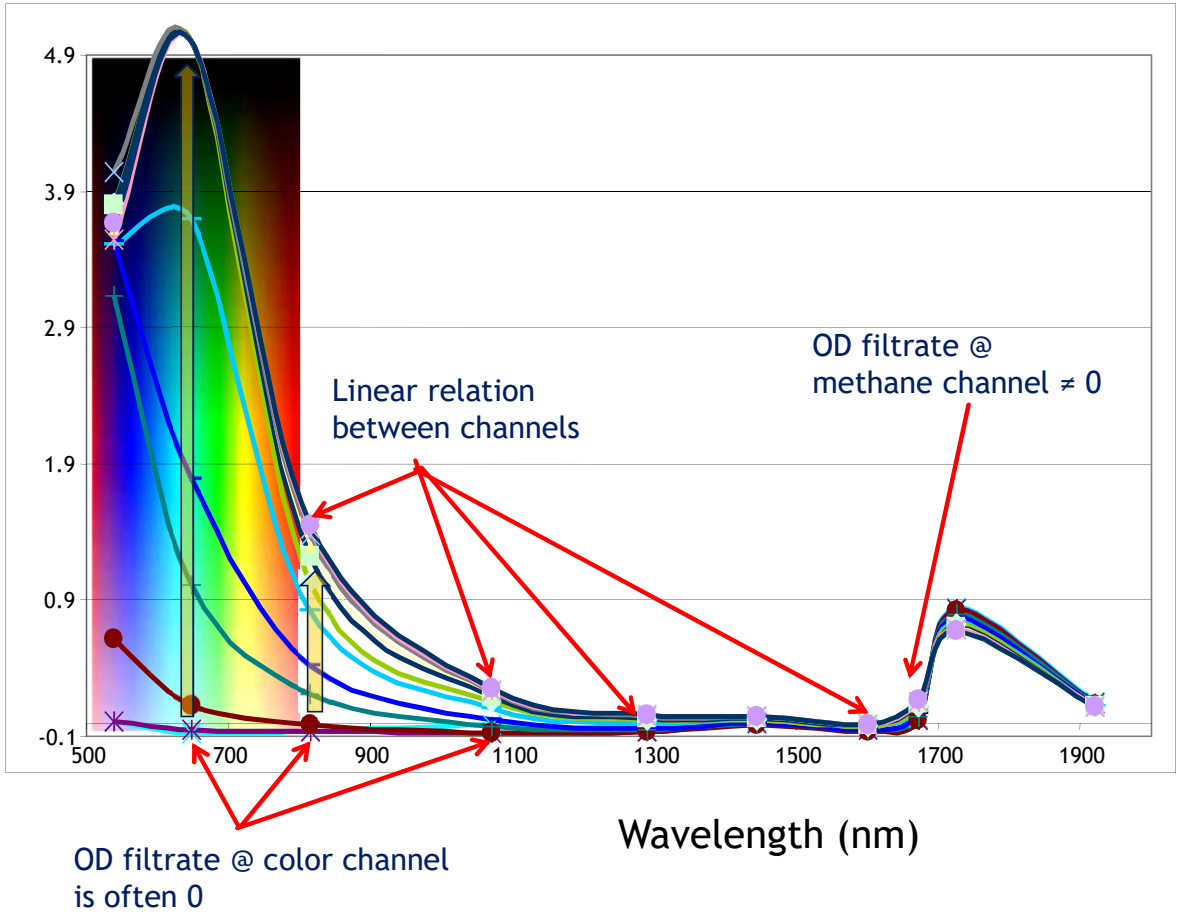
Fitting Methane & Color Channels



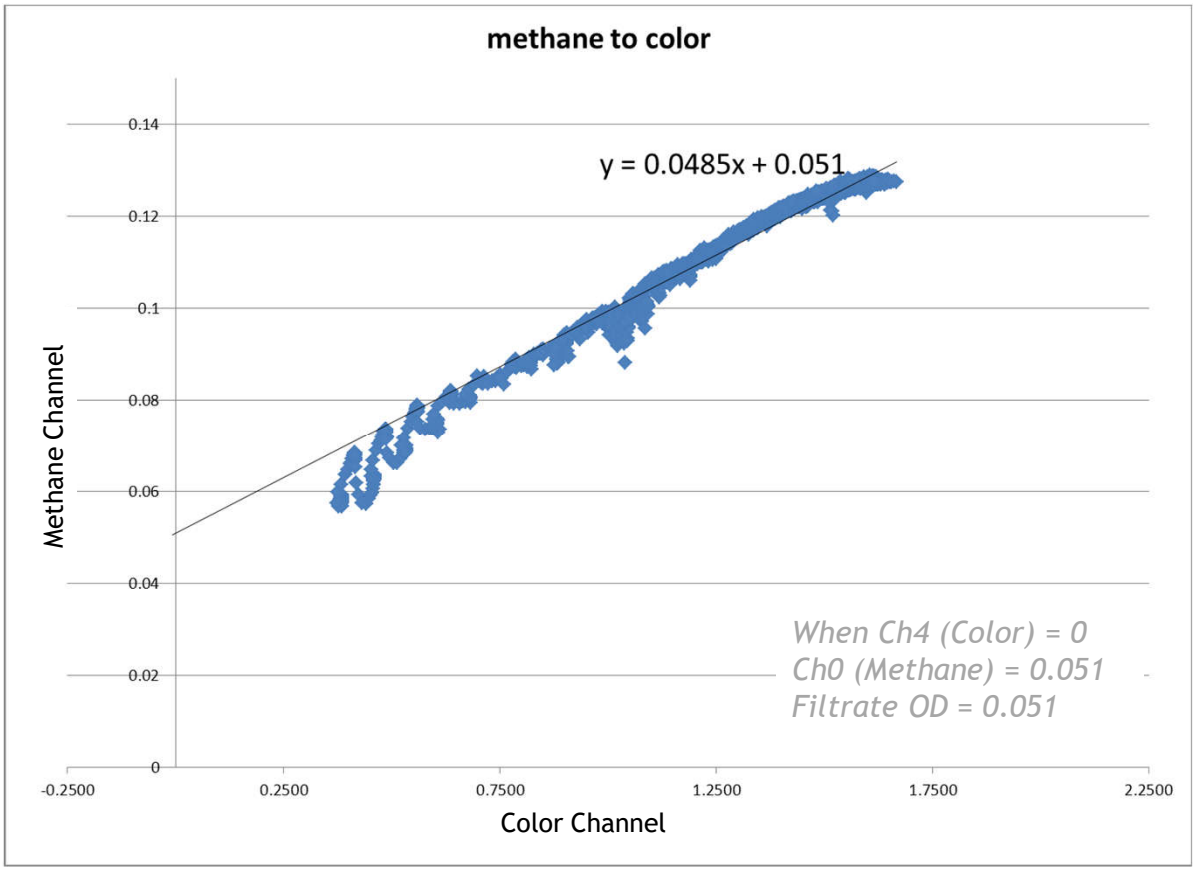
Contamination plotting

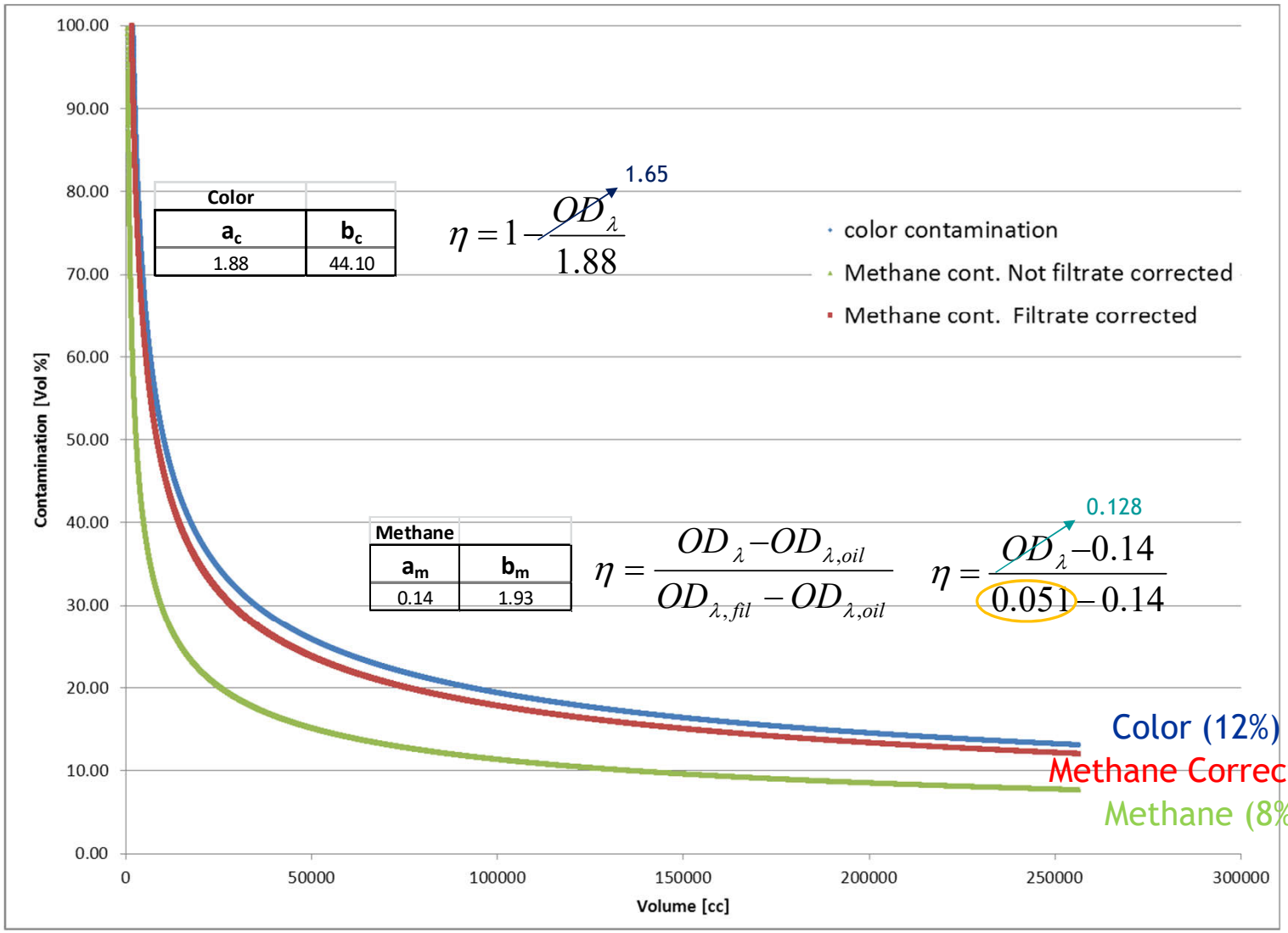


Methane Channel offset: 15 mins



Cross Plot between Methane & Color



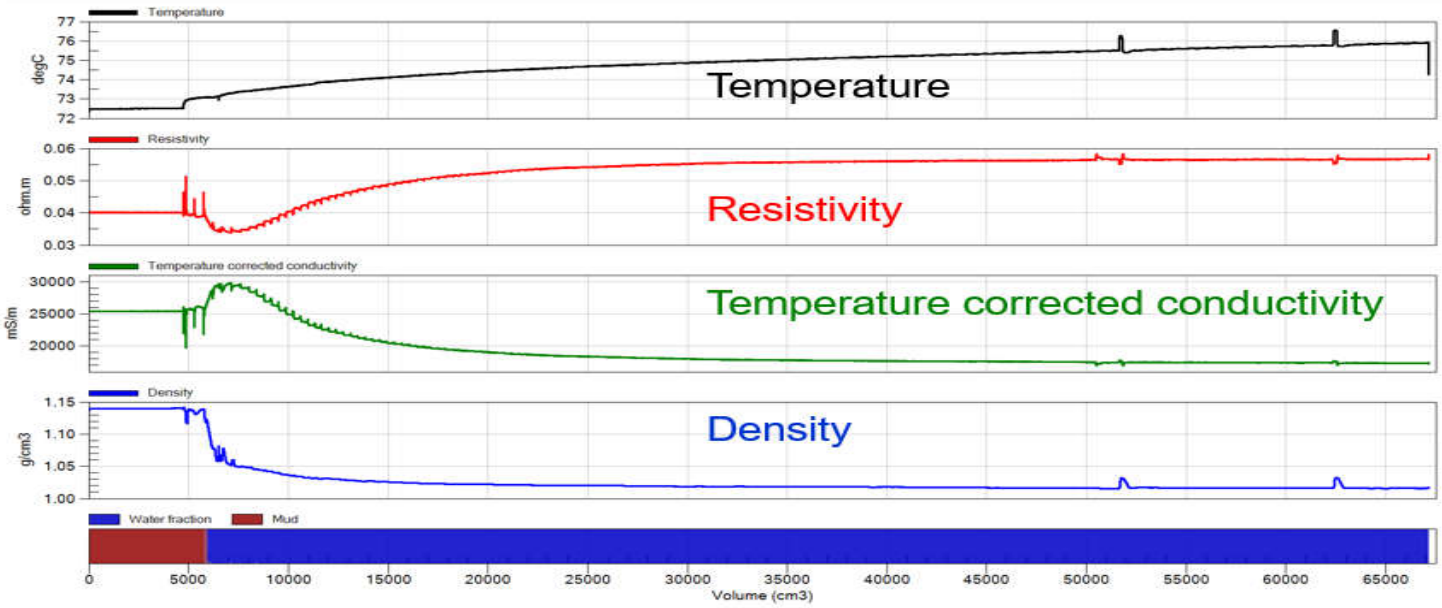

100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Contamination [Vol %]
0
50000
100000
150000
200000
250000
300000
Volume [cc]
Color
ac
bc
1.88
44.10
1.65
$\eta = 1 - \frac{OD_\lambda}{1.88}$
color contamination
Methane cont. Not filtrate corrected
Methane cont. Filtrate corrected
Methane
am
bm
0.14
1.93
$\eta = \frac{OD_\lambda - OD_{\lambda,oil}}{OD_{\lambda,fil} - OD_{\lambda,oil}}$
0.128
$\eta = \frac{OD_\lambda - 0.14}{0.051 - 0.14}$
Color (12%)
Methane Corrected (11%)
Methane (8%)

Water Contamination Monitoring WCM

Mixing rules for Downhole WCM

Density (ρ) and Conductivity (C) change linearly with contamination (η)

- $\eta = \frac{\rho_{fw} - \rho}{\rho_{fw} - \rho_{wbm}}$, density mixing rule at constant P & ~T
- $\eta = \frac{C_{T,fw} - C_T}{C_{T,fw} - C_{T,wbm}}$, Conductivity mixing rule



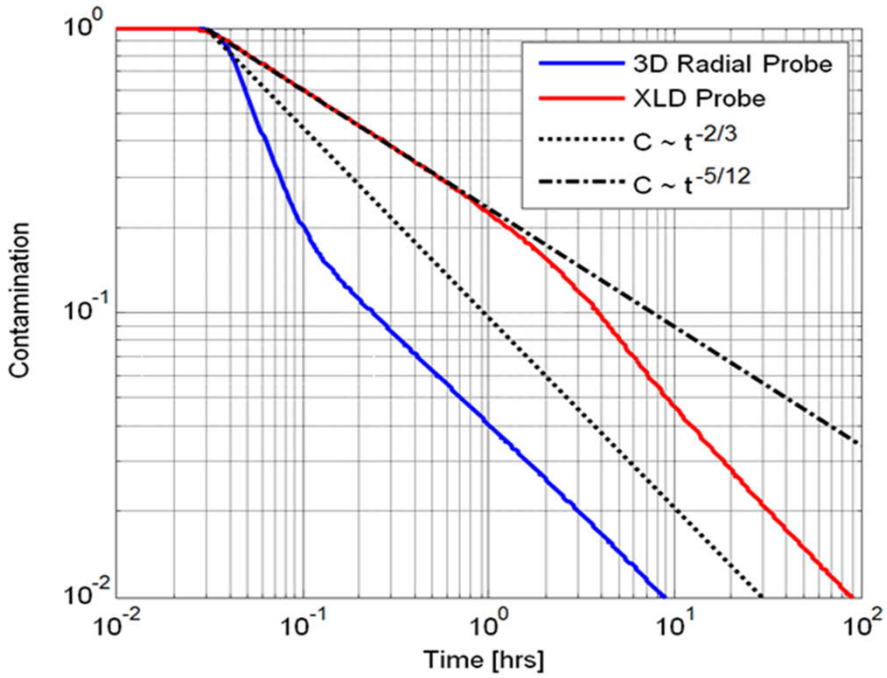
Formation fluid property determination

Fluid property changes with cleanup can be modeled with a power law:

$$\rho = \rho_{fw} + \beta_1 V^{-\gamma}$$

$$C_T = C_{T,fw} + \beta_2 V^{-\gamma}$$

$$V \rightarrow \infty$$



Exponent selection:

- Single probe : γ = 5/12th
- Radial probe : γ = 2/3rd

Flow regime identification

From regression:

$$\rho_{model} = \rho_{fw} + \beta_1 V^{-\gamma}$$

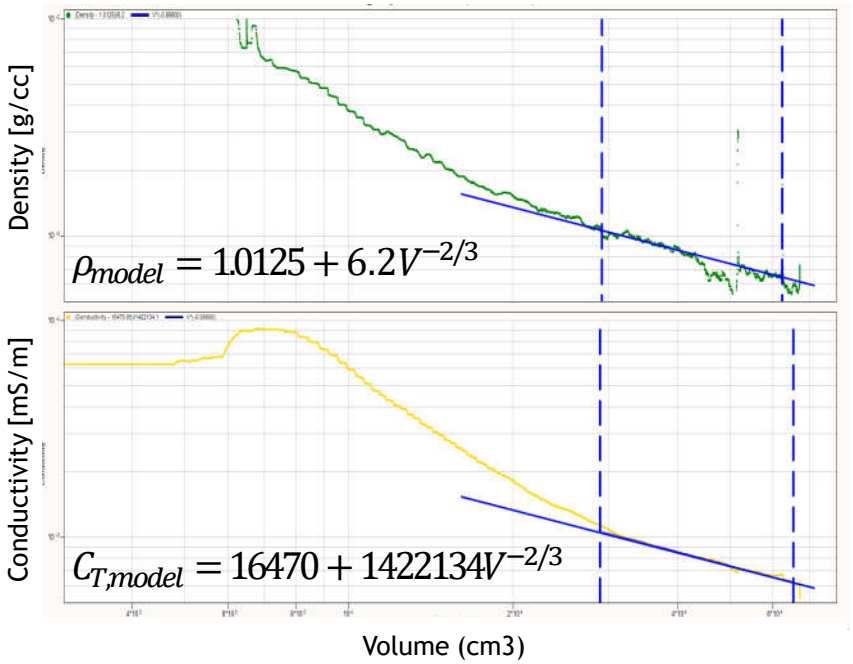
Assume:

$$\rho_{measured} = \rho_{modeled}$$

$$\rho_{measured} = \rho_{fw} + \beta_1 V^{-\gamma}$$

$$\log \left| \frac{\rho_{measured} - \rho_{fw}}{\beta_1} \right| = -\gamma \log V$$

Example 2



End point plotting & QC

Filtrate end point can be achieved from:

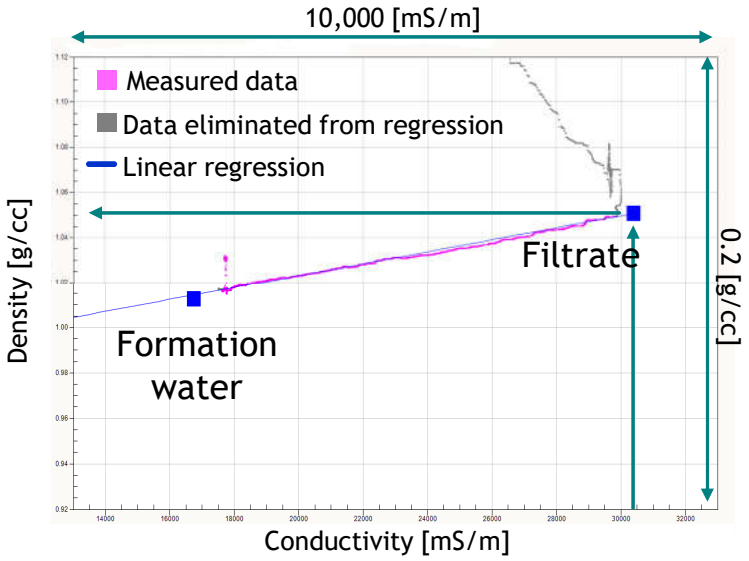
- Surface measurement
- Conductivity Vs Density Cross plot

Measured fluid properties all:

- Vary linearly with contamination
- Vary linearly together

Any properties cross-plotted

- Should generate a straight line
- Linear function can be fitted
- End point should fall on the linear fit



$$\eta = \frac{C_{T,fw} - C_T}{C_{T,fw} - C_{T,wbm}} \quad \eta = \frac{\rho_{fw} - \rho}{\rho_{fw} - \rho_{wbm}}$$

Summary

- Accurate Contamination Estimation is crucial for Sampling Quality which affects PVT studies, FDP, Facilities Design etc..
- Determining Contamination in Real time saves unnecessary Pumping hours & rig time
- Using all sensors available & accurate modeling will minimize the contamination uncertainty

Thank You

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SAUDI ARABIA CHAPTER

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