

SPE WORKSHOP

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Understanding of Asphaltene Precipitation and Deposition

Asphaltene measurements and modeling:
Do they represent actual field performance and help
fixing the problem?

Doris Gonzalez, BP



Outline

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- Asphaltene Definition
- Precipitation vs. Deposition
- Sampling / Fluid Characterization
- Laboratory Techniques for Precipitation and for Deposition
- Field Observations:
 - Asphaltene Deposition in Reservoir Rock
 - Deposition in tubing, flowline, riser & top sides
- Chemical injection
- Asphaltene Modelling

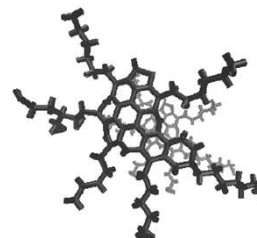
Asphaltene Definition – Uncertainty #1



Solubility class of components of the crude oil that are insoluble in low molecular weight alkanes, specifically n-heptane, and soluble in aromatic solvents like toluene or benzene.

Laboratory tests designed for:

- Atmospheric vs. Pressurized
- Validation



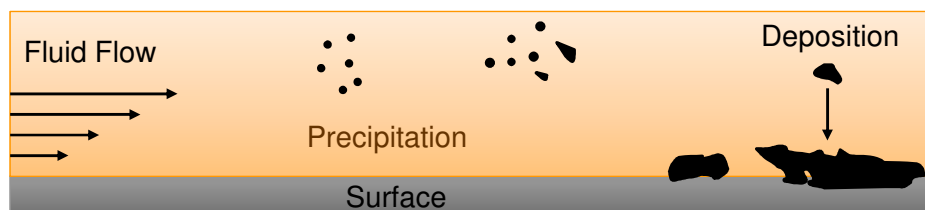
Polar vs. Non-Polar

Insights of asphaltene aggregation mechanism from molecular dynamics simulation. J. De León, B. Hoyos & Wilson Cañas-Marín. Universidad Nacional de Colombia & Ecopetrol, 2014.

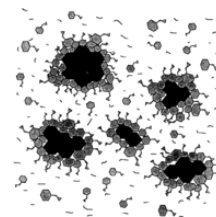
Deposition of the high-molecular-weight components of petroleum fluids as solid precipitates in surface facilities, pipelines, downhole tubulars, and within the reservoir are well-recognized production problems. They are large molecules consisting primarily of hydrogen and carbon, with one to three sulfur, oxygen, or nitrogen atoms per molecule. The basic structure is composed of rings, mainly aromatics, with three to ten or more rings per molecule.

PetroWiki

Precipitation vs. Deposition – Uncertainty #2

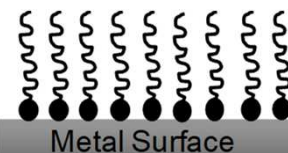


Most asphaltene inhibitors function as dispersants

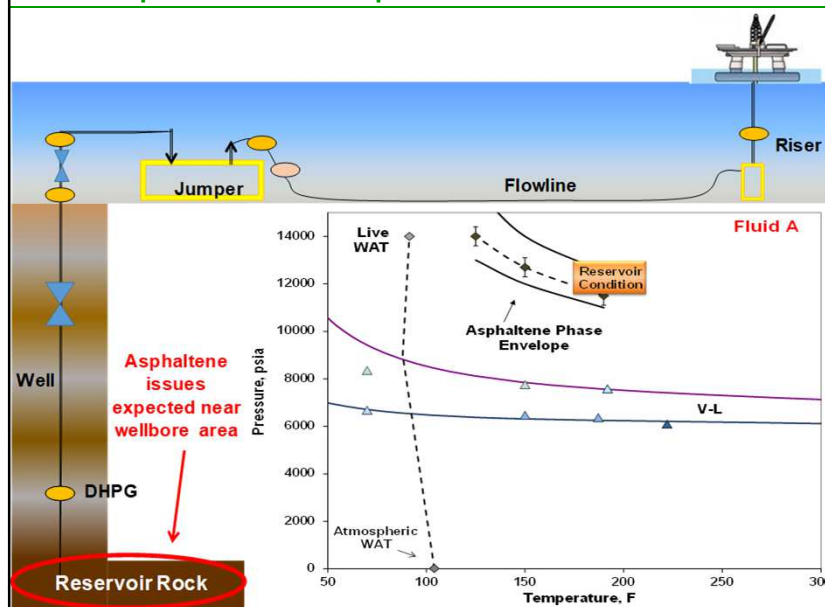


- Industry has focused on precipitation tests: AOP determination
- Understanding of deposition is under development
- Asphaltene inhibitors (AI) are designed based on precipitation rather than deposition
- Most of the AI are dispersants and are evaluated and selected using the asphaltene dispersancy test (ADT)
- Other inhibitors like CI are designed to protect surfaces

Adsorbed inhibitors molecules act as a barrier



Field Observations: Asphaltene Deposition in Reservoir Rock

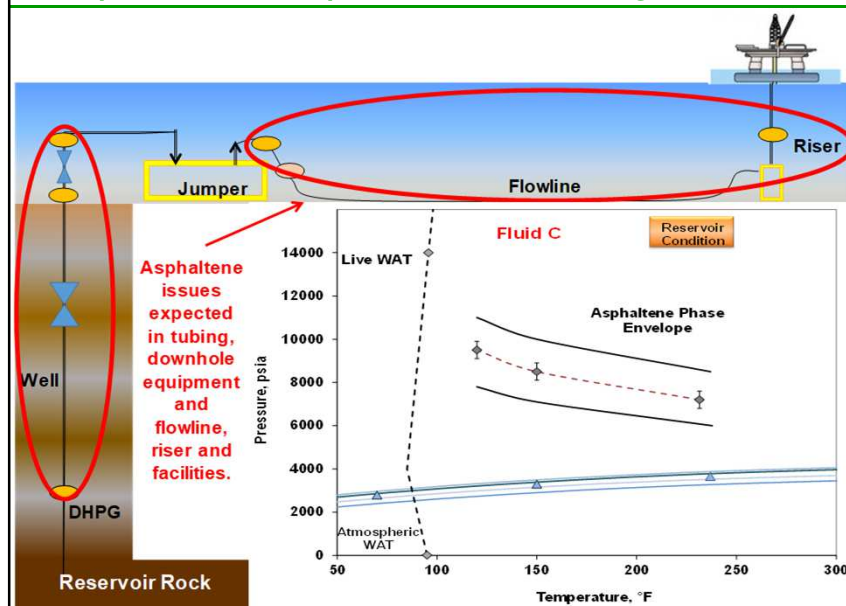


Formation Damage near wellbore area

Surveillance using pressure transient analysis (PTA) and multi-rate test (MRT) to determine Skin increase.

A novel application of standard surveillance techniques to formation damage control by identifying the location of the obstruction and quantifying skin type.
Fabio Gonzalez et al. BP America. SPE-179010-MS, 2016

Field Observations: Asphaltene deposition in tubing, flowline, riser & top sides



- Real time monitoring based on frictional pressure losses.
- Periodic Pigging.
- Deposits at the safety valve could jeopardized its performance.



Strategies to monitor and mitigate asphaltene issues in the production system of a GoM Deepwater subsea development.
Doris Gonzalez et al. BP America. OTC-27123-MS

Sampling / Fluid Characterization



Sampling:

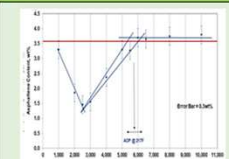
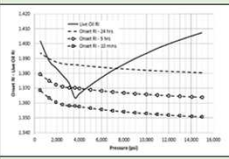
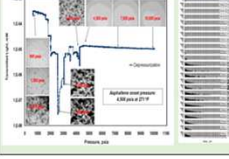
- Downhole sampling using pressure compensated chambers and transferred into pressure compensated cylinders.
- Low OBM contamination level = $f(\text{GOR})$
- Surface samples are not recommended for asphaltene fluid characterization. Surface and recombine samples can be used for comparative studies.

Fluid Characterization:

- Full PVT study: GOR, Pb, viscosities, etc.
- SARA Analysis
- AOP using NIR+HPM+PSA. Interpretation risks associated to individual techniques.
- WAT atmospheric & live: sub-sample handling
- Geochemistry: fingerprint, isotopes
- Optional for STO stability: refractive index & critical percentage heptane (CPH - vol %)

Lab Precipitation Techniques



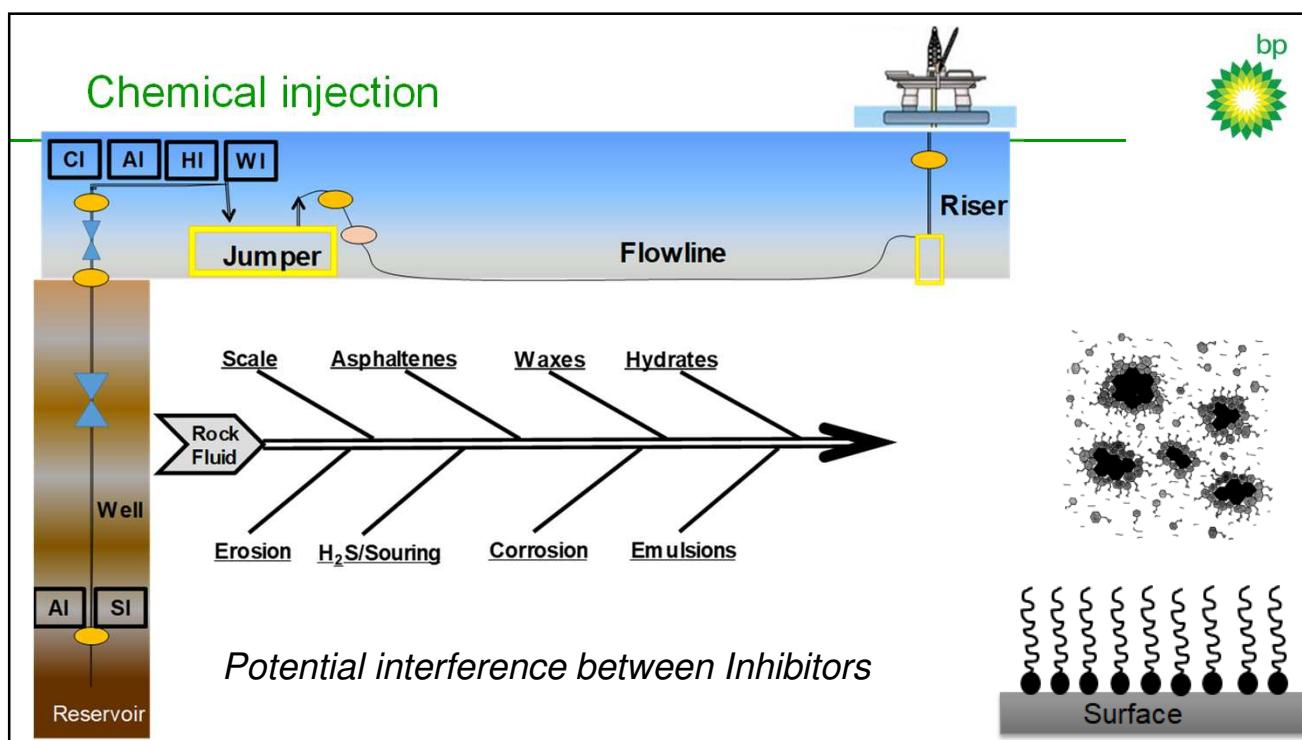
	Technique	Description	Conditions: fluid type / volume / P & T	Uncertainties / Repeatability	Pros / Cons	Results
Precipitation: Asphaltene Onset Pressure (AOP)	Gravimetric Method Journal of Canadian Petroleum Technology, 2002, vol 41. No.7 SPE-153602-MS, 2012	In a PVT cell, ~ 100 mL of live fluid is depressurized in steps. At each pressure, stabilization time (2 hr) for particles to settle down. Small volume of fluid is flashed to atmospheric condition to measure its asphaltene content using n-pentane.	Downhole live Fluid: ~ 200cc Isothermal depressurization from pressure above reservoir condition to pressure below bubble point.	Asphaltene content = +/- 0.2 wt% Asphaltene Onset Pressure = +/- 500 psia	Pro: Test at reservoir conditions using DH fluid. Cons: stabilization time? Did all particles settle down? Uncertainty on asphaltene content measurement	
	Asphaltene Instability-Trend (ASIST) / Asphaltene Stability Method (ASM) ASIST: e&f-300837y, 2012. ASM: OTC-27226, 2016	ASIST: N-alkane titration method based on Refractive Index. ASM: determines Critical Percentage Titrant (CPT). Flocculation points are visually confirmed by the observation of oil-precipitant mixtures under an optical microscope.	Dead oil ~ 400 cc. Measurements at atmospheric pressure and two or three temperatures	Kinetic time: fix AOP sensitivity ~ a change in 0.001 in RI could represent a change of 500psia in the onset.	Pro: Inexpensive Con: kinetic effect in RI meas.	
	Solid Detection System SDS: High Pressure Microscope HPM + Particle Size Analysis PSA + Video SPE-153602-MS, 2012	80 mL of live fluid is isothermally depressurized in steps. During the depressurization, the light transmittance through the sample is recorded. At each pressure, HPM photographs are taken of the fluid. PSA and video are generated after.	Downhole live Fluid: ~ 100cc Isothermal depressurization from pressure above reservoir condition to pressure below bubble point.	Combine techniques to determine AOP value. AOP = +/- 500 psia	Pro: Test at reservoir conditions using DH fluid. Cons: Limited to 1um particle size determination	

Lab Deposition Techniques

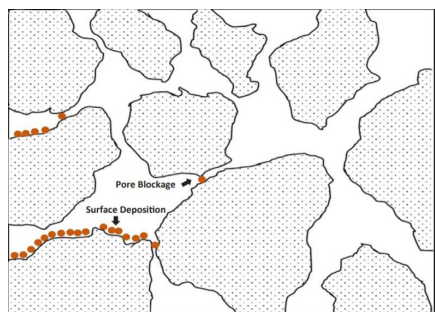


	Technique	Description	Conditions: fluid type / volume / flow regime	Brine / AI Evaluation	Pros / Cons	Results
Asphaltene Deposition	Capillary Tube J. of Dispersion Science and Technology, 2004, vol 25, OTC-23347, 2012	Asphaltene deposition occurs in a long capillary tube (~30m) of 0.03" ID at atmospheric conditions or very low pressure & T> WAT	Dead oil + n-alkane / ~ 1L; Continuous; Laminar	No Brine / No AI eval.	Pros: Determine asphaltene deposition profile. Cons: Laminar flow regime only.	
	Real-View (OSDC) Energy & Fuels, 2006, 2010,	Device based on the flow between rotating concentric cylinders called the Couette-Taylor (CT) system. Analogy between flow in a CT system and a pipe. Test is run at high pressure (15,000 psi) and Tres (up to 300F).	Live oil (DH or recombine) / Flow through ~1L; Batch: 150cc; Continuous; Turbulent	No Brine / No AI eval.	Pros: Deposition at HPHT in continuous & turbulent flow regime. Cons: The amount of deposit is below 20 mg for oils with low asphaltene content.	
	Packed-Bed Column Energy & Fuels, 2016, vol 30 Energy & Fuels, Dec. 2018	Column (glass, PTFE, SS) ~1/2" OD packed with spheres (carbon steel or any metal) ~ 2-4mm. Conditions: from ambient to high pressure (~ 3,000 psi) and 80 C.	Deal oil + n-alkane / ~ 200 cc / Continuous / Laminar to Turbulent flow regime	Yes Brine / Yes AI eval.	Pros: Deposition at HPHT in continuous & turbulent flow regime. This is a new technique in development to include live fluids at higher pressures.	
	Rocking Cell for asphaltene deposition	Batch systems; tubing that slowly rocks with a rolling sphere. The ball falling time is recorded during a depressurization process at HT.	Recombined fluid ~30cc in blind cell at HPHT / Batch flow regime	Yes Brine / Yes AI eval.	Pros: Detects changes at HPHT. Cons: Recombine fluid; batch system; small volume of fluid; blind cell; no deposit confirmation.	
Rock	Coreflooding SPE 121414-Kuwait	Asphaltene deposition in core plugs. Conditions: from ambient to high pressure and high temperature.	Coreflooding test using live fluid or dead+precipitant / Continuous / Laminar to turbulent flow regimes	No Brine / No AI eval.	Pros: Determine changes in permeability using core plugs and reservoir fluids	
	Microfluids J. of Petroleum Science and Engineering, 2016, vol 145, Energy & Fuels, Dec 2018	Asphaltene deposition in micro-channels or porous media microfluidic devices	Model oil: n-C5 asphaltenes+Toluene+n-Alkane precipitant / Laminar flow	No Brine / No AI eval.	Pros: Study of deposit formation and removal. Cons: Non commercial yet	

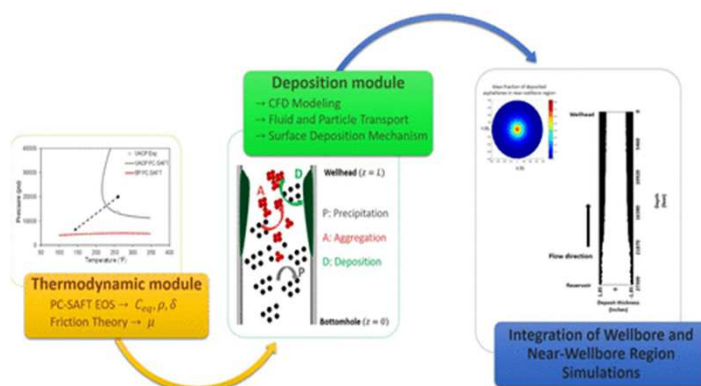
Chemical injection



Modeling Asphaltene Precipitation & Deposition



A new model for permeability impairment due to asphaltene deposition. Davud Davudov, Rouzbeh Ghanbarnezhad Moghanloo. The University of Oklahoma, Fuel 2019



Systematic investigation of asphaltene deposition in the wellbore and near-wellbore region of a deepwater oil reservoir under gas injection. Part 2: Computational fluid dynamics modeling of asphaltene deposition. Narmadha Rajan Babu, Pei-Hsuan Lin, Mohammed Abutaiya, Caleb Sisco, Jianxin Wang, and Francisco Vargas. Rice University & Chevron Energy. Energy & Fuels, Dec 2018

Modeling → Digital data tools



Data analytics of field production system to Prevent & Predict

APEX – digital twin:

Highly-sophisticated simulation system that creates a virtual copy of the production systems. It helps to optimize production by modelling physical constraints and testing different scenarios in minutes.

POA, or Plant Operations Advisor:

Analyses more than 150 million data points in real time across 1,200 mission-critical pieces of equipment. Anomalies in the data can alert operators to take action to prevent potential issues developing further.

Conclusions



- ✓ Integrate: field data → lab studies → modeling work
- ✓ Increase field observations & surveillance work
- ✓ Improve laboratory techniques using representative fluids
- ✓ Validate models against field and lab data

Thank you

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Asphaltene measurements and modeling:
Do they represent actual field performance and help
fixing the problem?

Comments / Questions?