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info@gateinc.com



Figure 1: SARA—Saturates, Aromatics, Resins & Asphaltenes

The asphaltene molecules (A) are at the center surrounded by resins (R). The resins are surrounded by aromatics (a), and the complex is surrounded by the bulk fluid composed mainly of saturates (S).

All oils contain asphaltenes, but asphaltenes do not deposit from all oils. Deposition occurs when the colloidal suspension is disrupted. This can occur as a result several phenomena such as pressure change, mixing incompatible crudes, gas lift, temperature increase, stripping liquids carried over into compressors, acidizing, CO₂ flooding or shear effects.



Asphaltenes: Deposition & Testing

Asphaltenes are large, complex organic components present in the oil phase, along with resins, aromatic hydrocarbons, and alkanes (saturated hydrocarbons). Resins play an important role in stabilizing asphaltenes in crude oil. When the resins get destabilized, (under unfavorable pressure-temperature conditions) asphaltenes can agglomerate and deposit.

Asphaltene deposits cause:

- Reservoir impairment (permeability loss).
- Plugging of wellbores and flowlines.
- Emulsions (asphaltenes are surface active and stabilize emulsions).
- Pump failure.
- Fouling of compressors and other systems in gas service, due to oil carryover in separators.
- Asphaltene particles provide nucleation points that promote wax deposition and hydrate formation.

Introduction to Asphaltenes

Asphaltenes are very high molecular weight aromatic molecules, which can contain carbon, hydrogen, nitrogen, oxygen, and sulfur, as well as trace amounts of vanadium and nickel. They are believed to be oxidation products of organic resins and exist as colloidal suspensions in crude oil stabilized by resins. The chemistry of asphaltenes is not well understood. The working definition of asphaltenes is "the organic fraction of crude that is not soluble in low-boiling point straight chain alkanes such as n-pentane and n-hexane."

Asphaltenes are responsible for adding most of the color to crude oils. Black oils usually contain the highest asphaltene concentrations.

Causes of Deposition

The mere presence of asphaltenes in a crude oil does not cause asphaltene-related production problems. Oils with high asphaltene concentrations frequently experience no deposition. Asphaltenes are destabilized by pressure drop above the bubble point, by composition changes that decrease the resin concentration, and by shear forces. The temperature at which the first sign of asphaltenes are seen is called the Asphaltene Onset Pressure. At this pressure, asphaltenes start precipitation. This is not to be confused with deposition, as AOP does not always mean deposition pressure.

Asphaltenes typically deposit between the reservoir pressure and the bubble point. The explanation for this behavior is that the density of light saturates changes more rapidly as a function of pressure than does the density of resins. As a result, the concentration of resins is effectively reduced as the pressure decreases. Once the bubble point is reached, the light saturates preferentially flash and the concentration of resin in the liquid rises. Hence, below the bubble point pressure, the stability of asphaltene suspensions increases with decreasing pressure.

Composition changes that decrease the resin to asphaltene ratio may cause asphaltene deposition. For example, if a stream rich in asphaltenes, but also containing sufficient resins to keep the asphaltenes in solution, is mixed with a stream very low in resin content, asphaltenes may deposit. Gas lift also decreases the resin concentration and can be associated with aggressive asphaltene deposition in susceptible fluids.

The SARA complexes which hold asphaltenes in suspension are large and bulky and can be disrupted by shear forces. Temperature will usually not have an effect, but a large increase in temperature may cause asphaltene deposition. The stabilizing effect of resins occurs through polar interactions. This mechanism is weakened by heat in the same way that oil/water emulsions are weakened by heating.

Asphaltenes: Deposition & Testing



Asphaltene Testing

- Asphaltene content involves extracting asphaltenes from the oil via use of a solvent such as heptane or pentane.
- Depressurization at constant temperature requires the pressure to be reduced gradually to the bubble point and monitored for solids deposition usually by detecting the scattering of laser light.
- SARA measures the concentrations of saturates, aromatics, resins and asphaltenes (SARA) which are important in predicting the behavior of a crude stream.

Monitoring Suggestions

- Check rag layers (at oil/water interface) for particles.
- Check produced water system for solid particles.
- When entering vessels check for deposits.
- When repairing rotating equipment check for asphaltene fouling.
- Check compressor oil systems, especially if the oil comes into contact with the process.

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Flocculation of Asphaltenes is Not Reversible

The deposition of asphaltenes is typically not reversible. For instance, if pressure drop causes asphaltenes to deposit, re-pressuring the system will not typically result in the asphaltene being re-suspended in the bulk fluid.

Unlike waxes which crystallize out of solution and can usually be melted with heat, asphaltenes have no melting point and typically cannot be remediated via heating.

Asphaltene Testing

Asphaltene testing is complex and involves multiple tests and associated iterations. At a minimum, this testing typically involves:

- Measuring Asphaltene Content
- Depressurization at Constant Temperature (with and without gas lift)
- SARA Analysis

Sampling should be performed upstream of the expected problem area ensuring no contamination effect with other chemicals. Since deposition often occurs above the bubble point, the sampling must often be done at reservoir conditions. The sample must be maintained at or above the reservoir pressure as it is brought to the surface. Improper sampling protocols may result in deposition within the sample container.

Several models have been developed to predict asphaltene precipitation as a result of compositional analysis. None of them are foolproof, but they provide a good first screening of deposition potential.

The SARA tests can provide useful first approximations of the impact of commingling. Where concerns exist, commingling tests should be performed. These include:

- Asphaltene Screening Testing: This involves adding a small volume of oil to a large volume of hexane and noting the concentration at which deposition occurs.
- Asphaltene Inhibitor Testing: This involves using the concentration identified in the screening study to test the impact of inhibitors.
- Asphaltene Dispersant Testing: This involves using the concentration identified in the screening study to test the impact of dispersants.

Asphaltene Prevention & Mitigation

Asphaltene deposition is best mitigated or prevented through design and/or chemical treatment. These techniques include:

- Minimizing agitation and shear forces.
- Maintaining pressure above the AOP and bubble point where possible.
- Avoiding mixing of incompatible crudes or well fluids.
- Avoiding gas lift, acidizing, and CO₂ injection, where practicable.
- Applying inhibitors and dispersants as needed.
- Solvents such as xylene can be used to dissolve deposits. In fields with a frequent need for solvent wash it may be advantageous to test various aromatics or blends of aromatics for solvent power.
- Deposits in the wellbore can be removed via cutting tools.

Conclusion

Asphaltene deposition can cause significant impacts for offshore production. Their mere presence does not indicate deposition. Testing and modeling may be required to ensure that production will not be hindered by asphaltene deposition. When adequately forewarned, the flocculation and deposition of asphaltenes can be controlled and mitigated using various production and chemical treatment techniques that can be built into the field economics and chemical delivery system design from the very beginning of a project.

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