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Wax Flow Assurance Issues in Gas Condensate Multiphase Flowlines

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Abstract

Gas condensate multiphase flowlines undergo wax deposition and build-up in ways much different than crude oils, either live or dead. One of the main reasons is that the liquid hold-up in gas condensate flow lines tends to accumulate wax crystals. If the concentration of wax crystals becomes high, the liquid hold-up becomes a viscous "wax slush" that increasingly cannot be pushed out of the pipeline either via natural or induced slugging. Pigging in that case is not a solution because of the high likelihood that the pig will get stuck. As a result, more innovative ways are required to deal with this emerging major flow assurance problem in gas condensate flowlines of long tieback satellite wells. This paper presents the following:

- Wax Deposition in Liquid-full Conduits
- Wax Deposition in Gas Condensate-carrying Conduits
- Mechanism of Wax Build-up
- Importance of Wax Content and Solubility
- Soak and Cough Operations
- The benefits of Slugging
- Dispersants vs. Crystal Modifiers
- Wax Slush Viscosity and the Risks of Pigging

Wax Deposition in Liquid-full Conduits

The general wax deposition case is depicted in Fig. 1. Typically, the two most dominant factors of wax deposition are[1]:

- Wax molecules move toward via diffusion and adhere at the wall. The rate of adhesion is largely governed by the temperature difference between wall and fluid.
- Erosion and shearing of the wax crystals occurs due to the hydrodynamic drag of the flowing boundary layer of fluid. The rate of wax deposit shearing and shear force depends largely on the flow rate, viscosity, and other system parameters.

Fig. 2 shows a typical liquid-full horizontal flowline undergoing wax deposition.[1] As the fluid is being cooled down, at some point in the pipe, its temperature arrives at its onset of wax crystallization and wax crystals begin to form. This occurs in the figure at segment 2. At this point the temperature difference between the fluid and the wall is at its highest. As a result, the attraction of the wax crystals toward the wall is at its highest. As the wax crystal and molecule concentration of the fluid near the wall is depleted, more wax crystals and molecules diffuse through the boundary layer to replenish the concentration. The concentration of wax molecules and crystals in the bulk fluid becomes uniform or smooth primarily through convective mass transfer. As the fluid moves on downstream its temperature drops further and more wax crystals are formed. This causes the adhesion rate of wax crystals at the wall to increase that in turn causes diffusion toward the wall to increase and thus a higher level of deposit forms. As the deposit thickness increases so is the shear rate due to the decrease in the flow area and increase in flow velocity. This increase in shear rate acts against wax deposition because it results in an increase in the rate of wax crystals being carried away. Deposition decreases further down the pipe because the temperature of the fluid begins to approach that of the wall and, as a result, the attraction of the wax crystals diminishes. If the ΔT becomes zero then there is no deposition, except at extremely low flow rates at which there is non-trivial deposition due to gravity. At some time, the rate of diffusion of wax molecules and crystals toward and adhesion at the wall becomes equal to the rate of shearing wax molecules and crystals away from the wall all along the pipe length. At this time the system is said to have achieved a steady state condition.

Fig. 3 depicts graphically the above description of wax deposition in a typical liquid-full horizontal flowline. The general equation governing wax deposition under the above conditions is[1]:

$$\nabla \bullet N_{Wax} + \frac{\partial c_{Wax}}{\partial t} + R_{Wax} = 0 \qquad \text{Eq. 1}$$

Where: N_{Wax}, molar flux of wax into the boundary layer
c_{Wax}, concentration of wax
R_{Wax}, rate of adhesion of wax

Analytical solutions to Eq. 1 can be obtained if several simplified assumptions are made.[1] A solution to the above