



Multiflash: Wax Modelling

Introduction

With the on-going trend to deep water developments, flow assurance has become a major technical and economic issue. The avoidance or remediation of wax deposition is a key aspect of flow assurance. While modeling wax deposition depends on a number of factors a major element is the ability to predict the conditions under which wax will precipitate and how much wax will be formed. Improved thermodynamic modeling of wax formation in turn allows better prediction of wax deposition rates.

Wax Appearance Temperature (WAT)

Wax is a solid phase formed from the components of the oil that have the highest melting points. For temperatures of operational interest, i.e. above $\sim 0^{\circ}\text{C}$, wax consists predominantly of the C20+ n-paraffins. In practice WAT is the most difficult point on the precipitation curve to measure as it is theoretically the point where the first infinitesimally small amount of wax is formed. It is only possible to detect a finite amount of wax and experimental methods differ in their ability to detect small amounts of wax. A survey for DeepStar suggested that uncertainties in WAT for good modern measurements may be $\pm 5^{\circ}\text{F}$. For older measurements the uncertainties can be considerably higher.

The plot below shows the results from three different types of measurement for the same oil. Differential Scanning Calorimetry (DSC) has been used to measure the amount of wax precipitated as a function of temperature and a value for WAT of 40°C . NMR produces values for the amount of wax precipitated as a

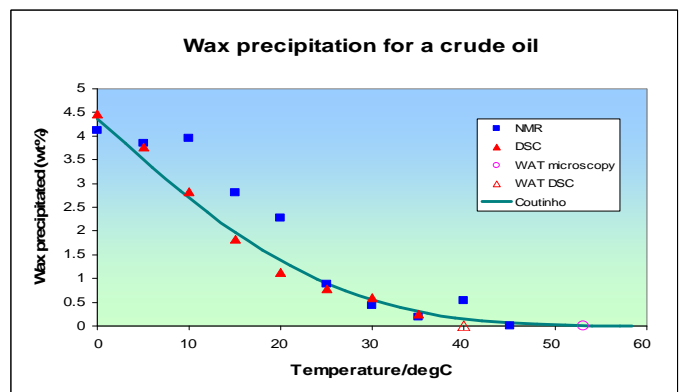
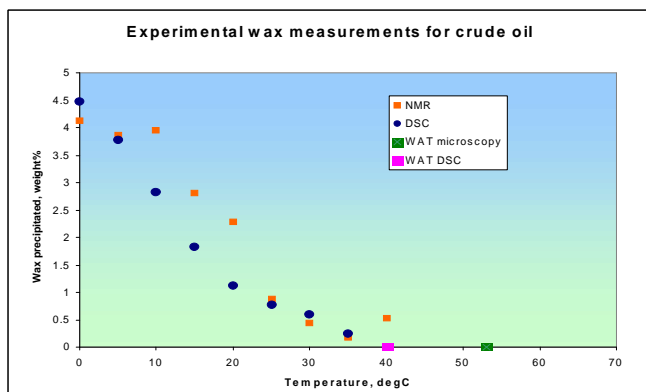
function of temperature but the scatter is too great to yield a reasonable WAT. Microscopy is used to measure the WAT directly and is thought to be the most sensitive technique. The reported WAT is 53°C . Larger discrepancies have been reported in the literature for other oils.

Coutinho Wax Model

In Multiflash we have implemented a wax model developed by Coutinho and colleagues, successfully integrating it with a conventional cubic equation of state for the fluid phases. Coutinho's model is a solid solution model, although it also correctly predicts that the solid solution will separate into a number of distinct crystalline phases. The advantages of the model are:

- It is based on high quality thermodynamic data for wax and oil phases. It has been validated against data for a wide variety of diesel fuels, jet fuels and crude oils.
- It uses the measured n-paraffin distribution when available but has estimation methods if it is not.
- It is designed to predict not only the WAT but also the amount of wax precipitated as a function of temperature.
- It is predictive.

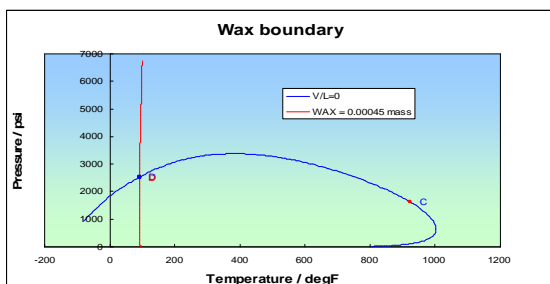
Predicted results are shown below compared to the data shown previously. The amount of wax precipitated is accurately predicted. The experimental WAT is difficult to predict because it corresponds to a finite amount of wax precipitated and also because the calculations are sensitive to traces on heaviest n-paraffins present in the oil.



Wax calculations in Multiflash

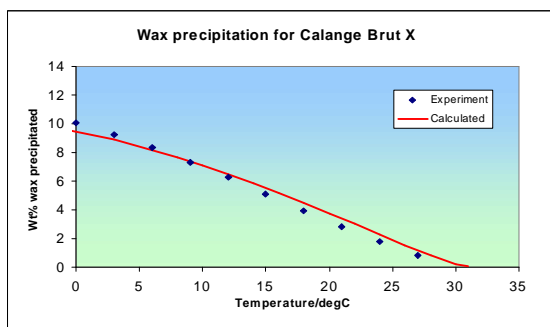
Owing to the difficulties of measuring a WAT for zero amount of wax deposited we recommend that positive amounts of deposited wax are used in Multiflash to identify the WAT, rather than the strict thermodynamic interpretation of zero percent. The suggested default values are 0.045 wt% for reproducing CPM measurements and 0.3wt% for DSC relative to the oil and wax phases, although zero percent may be used if you wish.

The wax boundary can be plotted



as can the amount of wax precipitated

Where n-paraffin distributions are available excellent results may be obtained for wax precipitation.



Tuning the Model

If measurements of WAT or the amount of wax precipitated as a function of temperature and pressure are available, the properties of the wax forming components can be adjusted to reproduce them.

The figure shows a dialog box titled "Match Wax Data". It has two radio buttons: "Wax as % of oil + wax phases" (selected) and "Wax as % of total material". Below is a table for experimental data:

Point	Temperature degF	Pressure psi	Wax Mass %
1			
2			
3			
4			
5			
6			
7			
8			
9			

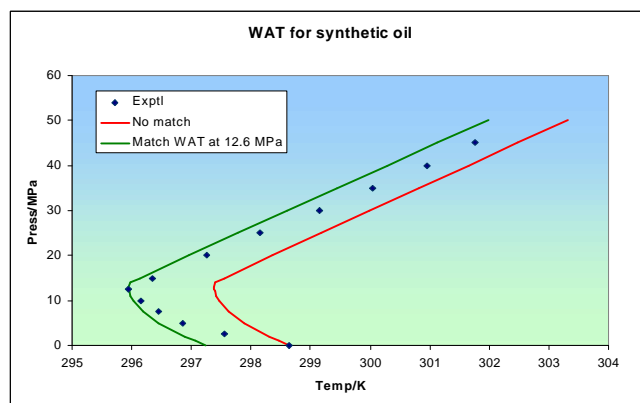
At the bottom of the dialog box are buttons for "Clear", "Match", "Units", and "Close".

Live oils

Earlier comparisons shown are for dead oils. The Coutinho model is based on an equation of state describing the fluid phases and can, therefore, be used to calculate oil-wax equilibria at elevated pressures.

Above the bubble point, there is a two phase equilibrium between live oil and wax. As the pressure increases, the WAT also increases slightly. This is a simple thermodynamic effect that an increase in pressure always shifts the equilibrium in favor of the denser phase, here the wax phase. Below the bubble point, a three phase gas-oil-wax equilibrium exists. The phase behavior is now far more complex. Besides the effect of pressure, the n-paraffin solubility in the oil is altered by the changing concentrations of light hydrocarbons in the oil phase.

If there is a paucity of reliable data for WAT in dead oils then the WAT for live oils presents even greater difficulties. The best verifiable data sets are for a synthetic oil made up of methane, decane and n-alkanes from C18 to C30. Agreement with the Coutinho model is good and even better if a single WAT is matched.



Wax deposition: FloWax

When the temperature of a waxy crude drops below the WAT, the waxes will start to crystallise and deposit on the pipe walls if a radial heat flux to the surrounding exists. This wax deposition phenomenon can result in significant operational and remedial costs, reduced or delayed production, well shut-ins, and pipeline replacement or abandonment. A major recent development has been the implementation of a wax deposition model in our new program, FloWax. This is described in detail in our Wax Deposition leaflet. Infochem's implementation of the Coutinho wax model has provided an excellent contribution to the thermodynamics of wax deposition, and combined with models for fluid flow and heat and mass transfer gives us a true compositional model for wax deposition in pipelines.

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