Wax Flow Loop

An Instrument for Pipeline Simulation and Research on Wax Inhibitor Chemicals

Wax deposition in crude oil or petroleum product carrying pipelines, reservoirs or well heads can cause a number of severe problems, particularly when transporting waxy crude oil under offshore conditions. Decreased pipe diameters are a major concern to oil production and transportation companies, as they represent a major increase in pumping costs and decrease in production rate, not to mention the loss of quality of the oil. In extreme cases of deposition, routine shut-down has to be scheduled to pig the pipeline, and ultimately, a complete shut-down can be the result.

Lateral cut of a pipeline with extreme paraffin deposition

Diffusion of dissolved wax has long been recognized to be highly causative in deposit formation, very prominently evident at high heat fluxes. However, the contribution of particle transport and the fundamental mechanisms responsible for this transport have not been conclusively drawn. An adequate particle distribution and deposition theory was found to be lacking in the current wax deposition literature.

To prevent deposition inside the reservoir, in the well head and inside the transmission lines, it is necessary to be able to predict the onset and amount of deposition due to various factors. Therefore, besides establishing mathematical models, tests and research on a real test pipeline are required, especially in the field of oilfield chemical development.

Wax Flow Loop by F5 Technologie, Base Model

The wax flow loop by F5 Technologie combines accuracy, ergonomics and wide

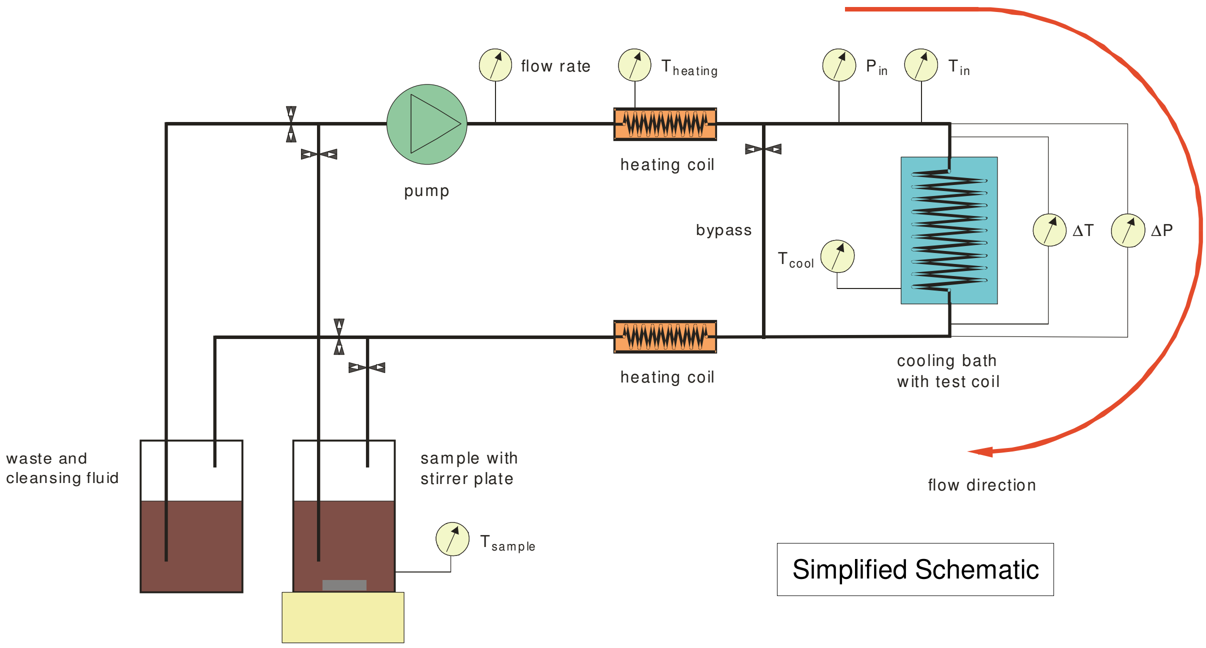
F5 Technologie GmbH
Auhagener Strasse 8b
D-31515 Wunstorf

Tel +49 (5031) 687 93 13
Fax +49 (5031) 687 93 18

E-mail: info@f5-tech.de
http://www.f5-tech.de

flexibility to a maximum benefit to researchers and producers in the field of paraffin deposition inhibition. So, the experimental approach to paraffin deposition effects becomes reliable and reproducible. And this at real lab-scale size: The complete rig fits onto your lab desk.

A simple principle for multi-purpose use



The core of the wax flow loop is a cooled test pipeline. It is equipped with pressure and temperature transducers at its inlet and outlet. The oil which is preheated to a set temperature is pumped through this test pipeline. Paraffins start to deposit on the pipeline's inner wall. The pulsation-free pump provides a constant flow rate. The reduced diameter causes a differential pressure increase, while the paraffin's thermal insulation property can result in a reduction in differential temperature over the test pipeline.

This operating principle is simple, but many conclusions can be drawn from the test results, especially when the test equipment is sophisticated and well-engineered.

Our wax flow loop can be used for:

- Wax deposition and wax inhibitor testing
- Determination of the wax appearance temperature (WAT)
- Pipeline simulation / pipeline restart
- Flow improver testing and rheological tests

Pipeline downscaling means compromise

The real pipeline in the field is simulated by setting wax flow loop conditions as temperature, pressure, pipeline length and diameter and flow rate (which means shear rate). So, the efficiency and chemistry of paraffin deposition inhibitors can be tested as near to real conditions as possible. On the other hand, lab conditions make the tests repeatable. This makes our wax flow loop a useful tool for developing and testing new oilfield chemicals as well as for quality control.

Simulating a real pipeline in a lab scale means downscaling the pipeline. Environmental conditions as temperatures and pressures can be provided in the lab. Two another very important parameters are:

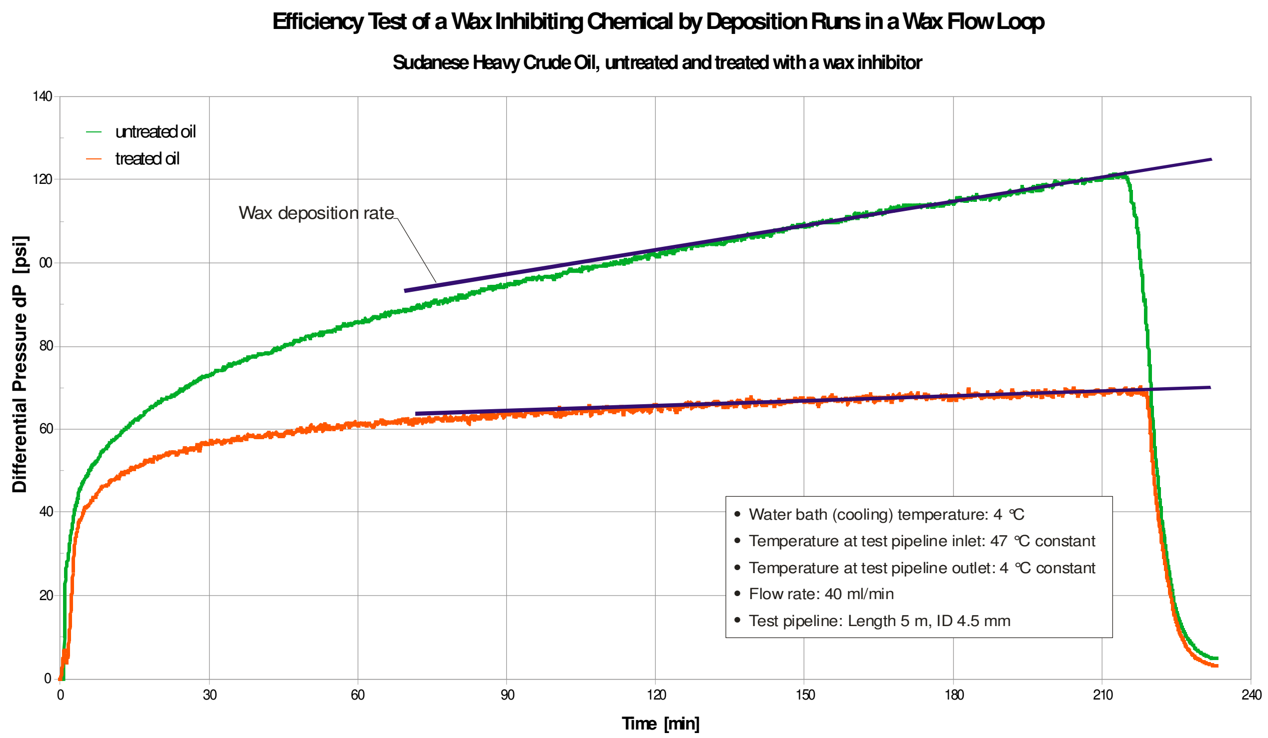
Reynolds Number: $$\mathrm{Re} = \frac{D \cdot v}{\nu}$$ laminar or turbulent flow?

Shear Rate: $$s = 8 \cdot \frac{v}{D}$$ for Newtonian fluids

In each case, downscaling a real pipeline to lab scale means: The Reynolds number and the shear rate diverge. To achieve the same Reynolds number in the test pipeline as in the real pipeline out in the field, we have to set a high flow rate to compensate for the test pipeline's smaller diameter. This results in a much higher shear rate than under field conditions. Vice versa, a test pipeline shear rate near to field conditions leads to a much smaller Reynolds number, in most cases in the laminar area.

Which parameter to simulate exactly to the cost of the other parameter is a question which has to be decided from case to case. Our customers however mostly stick to simulating the shear rate, based on their experience in comparing results from the field to inhibitor efficiency test results gathered with our wax flow loop.

Evaluating the test results



These are two basic test results: Wax deposition of an untreated oil (green) and the same oil treated with a wax deposition inhibiting chemical (orange). Both curves stabilize within the first 10 to 15 minutes. Then, the curves develop differently, which leads to the following conclusions:

1. The treated oil deposits less absolute amount of wax than the untreated sample. This is shown by the lower differential pressure of the orange curve.
2. The curves' slopes indicate the wax deposition rate. Obviously, the treated oil (orange) has a lower deposition rate. The two curve slopes are:

   Untreated oil: R_u = 11.61 psi/h

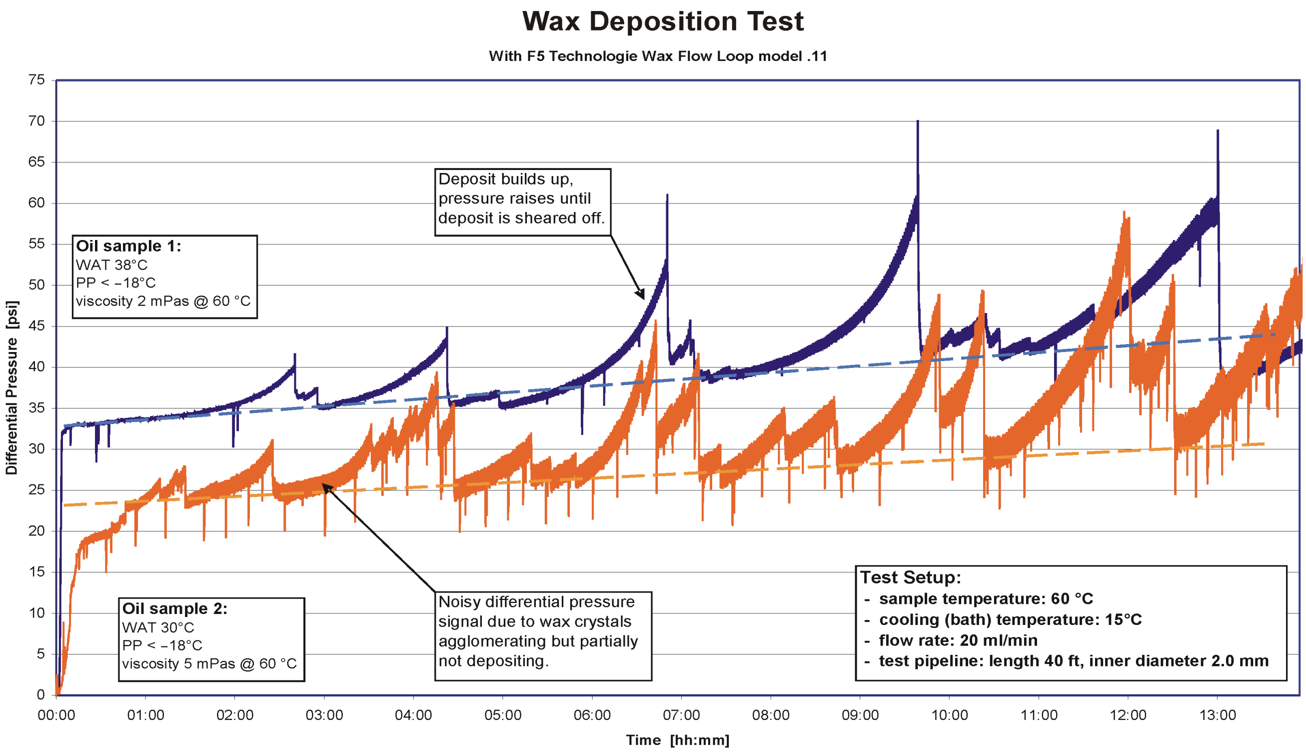
   Treated oil: R_t = 2.58 psi/h

   The efficiency of the used inhibitor (at that concentration and under the set conditions) is calculated with:

$$E = \frac{R_u - R_t}{R_u} \cdot 100$$

   In the example above the inhibitor's efficiency is E = 77.8 %.

Of course there are cases in which the interpretation of the results is more difficult, but our wax flow loop shows results even when other instruments already fail. Here is an example with oils which have a low paraffin content of less than 2%:



Oil sample 1 (blue curve): WAT 38 °C, PP < -18 °C

Oil sample 2 (orange curve): WAT 30 °C, PP < -18 °C

The used pipeline length was 40 ft (approx. 12 m).

The curves show peaks: The differential pressure builds up faster and faster in an exponential curve, then it falls rapidly. This shows that wax deposit builds up on the pipeline walls until the deposit is sheared off suddenly. The shear rate during this test was comparably low, and the results exactly show the behaviour in the real pipeline. After the real pipeline has been simulated successfully and reference results with an untreated sample are available, in the next step the oil samples are treated with inhibitors and tested under the same conditions to determine the optimal inhibiting chemical at its optimal concentration.

Modular design means flexibility and upgradeability

All our instruments are developed according to customer requirements. And so, as our wax flow loop is designed modularly, we now can offer many extensions and options which have been asked for by our customers:

- **Back pressure valve** for pressurizing the test pipeline by the pump to pressures up to **100 bar** (1450 psi)
- System pressurizing with **synthetic natural gas (SNG)** up to **200 bar** (2900 psi). The gas dissolves into the dead crude oil to simulate live crude oil. The sample containers are pressure vessels.
- **Live crude oil injection** ports
- Special test pipeline with several pressure sensors to measure a **pressure profile along the pipeline**
- Test pipeline inside an oven for temperatures up to 220 °C, required for **asphaltene research**
- In-line **viscosity** and **particle measurement**.

So, if you require some specially designed features, please contact us!

High Pressure Wax Flow Loop: 200 bar (3000 psi)