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Managing waxy crude production in deep water increases production

The ability to predict with accuracy whether a well will experience flow assurance issues is a valuable asset. Operators that can do it save in two ways.

AUTHORS

Chris Alderson and Sitham Suppiah, Murphy Oil Malaysia, and Abul Jamaluddin, Schlumberger

A number of variables contribute to the possibility that a well or flowline will experience flow assurance problems in its lifetime. Particularly critical in deepwater field development, flow assurance has been addressed using a conservative approach in the past. Millions of dollars have been invested in preventive and mitigation techniques ranging from chemical inhibitors to electrically heated seabed flowlines. Most of these techniques have met with success, and they have become part of the conventional wisdom.

The principle undesirable elements that contribute to flow assurance issues are paraffin (wax), hydrates, scale, and asphaltenes. These can manifest themselves singly or in various combinations. The conditions that lead to their appearance vary. Naturally, the hydrocarbon composition itself is the leading source of these materials, but also one must consider the physical environment – fluid pressure and temperature, which establish the conditions under which the materials make their appearance, and tieback distance and flow rate that establish the time the fluids are exposed to those conditions.

The operators’ dilemma

Should a major investment be made in chemical inhibitors, or should a company gamble that the subsea flowlines will not suffer flow assurance issues? Few companies want to take the gamble. Many who have taken it have paid the price for their temerity. Engineers at Murphy Oil were unwilling to do either. They reckoned that a scientifically supportable way could be found to predict in advance the need, degree, and type of flow assurance prevention or mitigation required using well and operations information from many wells that included log data and reservoir fluid sample properties along with robust computer simulation.

The task was challenging. Heretofore, predictions had been made on fluids in their dynamic state, but Murphy wanted to run a test to see how live oil would behave. The company wanted to develop a simulation that could factor in cool-down effects on static fluid and start-up effects when production was resumed. In particular, Murphy wanted to evaluate whether the subsea flowline carrying waxy fluid would gel up and what restart pressures would be needed if the flowline shutdown became protracted.

Chemical suppliers had proposed a variety of inhibition treatments. One recommended continuous dosing with a pour-point depressant to forestall gelling. Murphy asked Schlumberger to make an independent assessment of the situation to see if a reliable prediction formula could be developed.

The particular deepwater field to be studied lies in water depths averaging more than 4,200 ft (1,300 m) where water temperature is a steady 39°F (4°C). The stock tank oil from the field had a wax content of around 11% and a relatively high pour point of 64°F to 73°F (18°C to 23°C). Tieback distance was approximately 3 miles (5 km).

Systematic approach

Rather than seeking a solution to a specific problem, engineers at the Schlumberger Deepwater Technology Hub, the well testing group at the DBR Research Center Edmonton, Canada, and flow assurance specialists in Perth, Australia, worked to develop a three-step workflow ensures a consistent approach to thermodynamic and transient modeling that takes environmental and dynamic conditions into account. (Images courtesy of Schlumberger)
a consistent workflow process that would work for any flow assurance issue with any hydrocarbon composition in any environment. They would acquire representative samples of the oil and first perform standard pressure/volume/temperature (PVT) analysis on it to define its phase boundaries. The sample analysis also would show the oil’s propensity to deposit any of the undesirable elements – wax, hydrates, scale, or asphaltene. The analysis would dictate the subsequent tests and simulations to be carried out.

In this specific case, the principle threat came from wax deposition during cool-downs associated with shut-ins. Accordingly, the thermodynamic properties and transport characteristics of the wax were determined from the sample. To ensure modeling was realistic, the sample was reconstituted to produce a representative live oil sample by recombining it with separator gas to match the wellhead gas/oil ratio (GOR). A compositional analysis was conducted on the reconstituted sample, and the wax content measured using a high-temperature gas chromatography technique. Consequently, the wax appearance temperature was measured using microscopic technology with crossed polarized lights. The wax appearance temperature was calculated from thermodynamic models and compared with the measured value.

To develop a way to simulate conditions in the subsea flowline after shut-in, the sample was placed in a model pipeline test apparatus and cooled at a representative rate. This was done so the sample’s gel strength could be determined. Subsequent testing was performed to determine the sample’s rheology.

Transient simulation models were constructed using OLGA software. The models allowed simulation of shut-in, cool-down, and restart of the multiphase flowline. Once the simulation was developed, input parameters could be varied to determine the threshold conditions for best- and worst-case scenarios.

In this case, it was determined that although the flowline contents would gel up at a specific elapsed time after shut-in, the pressures required to restart flow were well within the limits of the tubulars, and sufficient reservoir pressure was available to re-energize the system.

No chemical inhibition was required. Potential annual savings were estimated at $1 million per flowline.

Why develop a model?

In building a robust model, the stage was set for systematic periodic flowline tests for the life of the reservoir. As production continues, reservoir parameters change. GOR can increase, as can water cut. Hydrocarbon composition can change over time as well. The model eliminates the need to repeat the groundwork each time a sample is obtained. It can be characterized and fed into the model for analysis.

The workflow was structured so any flow assurance problem could be predicted. Thus the approach would work for any of the undesirable elements or any combination of them and for any given set of environmental conditions.

All that is required to conduct a laboratory test is a representative sample of oil and a set of current environmental measurements. The measured parameters are input into the model while the sample is sent to the laboratory where, after reconstitution to ‘live oil’ status, compositional analysis, material appearance temperature/pressure, gel strength, and rheology are determined. Then the simulation can take place yielding a prediction of the conditions under which the undesirable elements will start to appear and the approximate timing of onset.

Simulation will enable operators to make judicious decisions about whether an inhibition treatment is warranted, as well as the volume, rate, and type of treatment proposed. Conversely, as in the case study, the simulation may provide confidence that no treatment is required under the proposed scenario, saving considerable operating expense.

Models with experimental validations allow the luxury of playing “what if?” games to postulate various scenarios in advance to see what would occur if they were implemented. In many cases, it is possible and practical to maintain flow in conditions above the threshold of appearance of the undesirable elements, thereby forestalling them altogether. The cost of maintaining these environmental conditions can be weighed against the cost of chemical inhibition and the most economically advantageous solution chosen.