Field validation of laboratory flow assurance testing results in an Indonesian offshore facility

Mohamad Aulia[a], Probjot Singh[b,*], Hyun Su Lee[b], Bill Thomason[c]

[a] *ConocoPhillips Indonesia*
[b] *ConocoPhillips USA (* probjot.singh@ConocoPhillips.com)* [c] *Retiree ConocoPhillips USA*

This paper describes the flow assurance (paraffin deposition / gel restart) laboratory testing program implemented during the appraisal and engineering phases of a new field development in offshore Indonesia where the production crude was found to be waxy (15% wax content) and have a pour point temperature (86°F) higher than the seabed temperature. Transporting high pour point crudes by subsea pipelines is traditionally handled by adding sufficient pour point depressant (PPD) chemical and/or diluent (condensates or low paraffin crudes) to lower the pour point below the seabed temperature. For this crude, even with condensate liquids extracted from the produced gas recombined, no PPD was available that would lower the pour point to the seabed temperature at reasonable treating rates. The laboratory testing program was developed to evaluate the flow assurance risks related to pipeline plugging, gel restart and wax control.

Fluid samples from several appraisal wells were obtained by Drill Stem Testing (DST) and sent to the ConocoPhillips Production Assurance Technology Group in Bartlesville, Oklahoma for flow assurance analysis. The laboratory / analytical program consisted of the following groups of tests:

- *General Properties:* API gravity, sulfur content and total acid number (TAN).
- *Separation Properties:* Emulsion and foaming characteristics and asphaltene deposition tendencies
- *Flow Assurance:* Viscosity, pour point, paraffin content/distribution by HTGC, wax appearance temperature (WAT), wax deposition rate and gel strength measurements.

The flow assurance team assessed gel handling options beyond the traditional approach and found a solution that relied on an advanced technology involving gel breaking with applied pressure. This relied on accurate measurements of the strength of the gel that will occur in the pipeline under normal operating conditions. To evaluate the concept of gel breaking with applied pressure, laboratory tools and methods were developed to enable accurate measurement of gel strengths of the crude blend (crude, dissolved gas, gas liquids added, and PPD added) that will occur in the pipeline. With the gel strength defined at a specific temperature, the applied pressure required to break the gel and restore flow has been computed for a given pipeline diameter and length. Preliminary work indicated that, without PPD, more than 10,000 psi would be required to break a gel formed by the crude in the 23 km 12-inch pipeline; a pipeline with this pressure rating would not be feasible.

A state of the art controlled stress rheometer (Haake RS150) was acquired to enable gel strength measurements at pipeline operating pressures[1]. This system enabled temporal simulation of pipeline temperature, flow stress, and cooling conditions. Laboratory scale pipeline flow loop studies were also performed to verify that the gel strengths measured in the rheometer were the same as occurred in a long pipe. Extensive data were developed for the crude with this laboratory system. These data included the gel strength of the crude as a function of temperature, PPD additions, gas liquid additions, and dissolved gas. It was then possible to compute what additions of PPD, dissolved gas, and condensate (diluent) would be required to enable breaking the gel and restarting a gelled crude oil in the 23 km subsea pipeline with a 1000 psi of applied pressure.

The impact of the program on the facility design will be described and program results will be compared to operating experience. The flow assurance test results had several positive impacts on the facility and infrastructure design. The field restart pressure, wax deposition rate and pigging frequency were found to be very close to the model predictions based on the laboratory results. The laboratory results showed that the pipeline operation can manage paraffin by weekly pigging and continuous injection of PPD. With the help of continuous PPD injection and an effective fluid property monitoring system (enabling pour point estimation), pipeline restarts after extended shutdowns have been smooth. Based on the effectiveness of the selected chemical and pigging operation, no insulation was needed for the pipeline.

Coordination between the Project Team, Operations and the Production Assurance Technology group led to important insights which significantly improved the facility design and operating procedures. This important study / program will be valuable for sharing with other oil and gas professionals to properly manage future fields operations having similar waxy crude properties.

References

1 Singh, P., Thomason, W.H., Lee, H.S., Fogler, H.S., Monitoring Yielding Condition of a Viscoelastic Waxy Oil Gel (2006) AIChE Annual Meeting, San Francisco, CA.