Fast-track design for kinetic hydrate inhibitors without laboratory testing

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Recent research indicates that kinetic hydrate inhibitors (KHI) can provide predictable, long-term hydrate protection under some conditions. A flow assurance design, performed by the authors, was carried out in the Varg field, located in the Norwegian sector (block 15/12) of the North Sea in a water depth of 84 metres (Figure 1). The oilfield is operated by Talisman Energy Norge AS (TENAS) and production is accompanied by a lean gas, which has been re-injected into a dedicated reservoir.

Over time, the re-injected gas volume has accumulated. A new Varg Gas Export pipeline will be installed to transport the excess gas to the nearby Rev field, which is located 6km from the Varg field and is connected to the Armada platform located on the UK side of the North Sea. The Varg gas will be transported using a 6" flexible pipeline to the Rev manifold where the Rev and Varg fluids will be commingled and transported through the existing 12" Rev pipeline to Armada. KHIs are introduced into the field for hydrate protection.

Gas production from Varg will commence within two years from identification of the KHI concept.

Figure 1 – Location of Varg and Rev fields in the North Sea.

KHI selection

In order to meet the arrival pressure conditions at Armada, it is necessary to choke on the Varg topsides, which leads to significant temperature drop downstream of the choke due to Joule-Thomson cooling. As a result, hydrate formation in the Varg to Rev pipeline is likely to occur.

The use of MeOH or MEG is restricted in daily levels (continuous inhibition) to only during specific operations such as re-start. Because of this, KHI has been considered as an alternative to prevent hydrates from forming. The Rev fluids are warmer than the Varg fluids, so after the commingling point, the mixture warms up and the fluids will be outside the hydrate formation region in the Rev to Armada pipeline.

For this development, typical hydrate prevention techniques; thermodynamic inhibitors, insulation, etc., were not possible due to high CAPEX, restricted operability and regulations imposed at the receiving facilities.

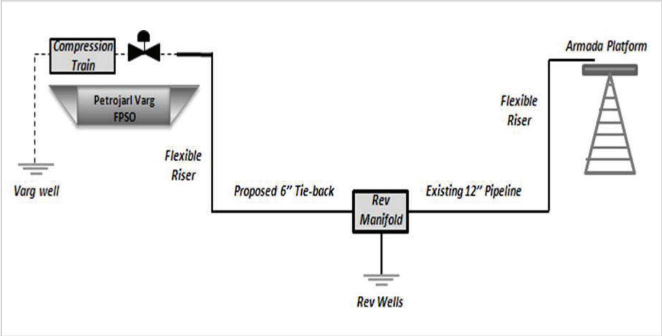

Figure 2 – Simplified schematic of proposed Varg tie-in and existing Rev pipeline to Armada.

The objective of the KHI is to prevent/delay hydrate formation for a certain amount of time. They are being successfully used in many subsea fields around the world, including in the North Sea.

They are normally selected after a laboratory performance testing program in order to determine induction times. This experimental campaign can add months or even a year to the project schedule. This project was fast-tracked in order to reduce project execution time and costs, therefore laboratory testing of the candidate KHI did not take place until after completion of FEED.

Flow assurance

From a flow assurance perspective, hydrate management was considered as the main challenge in this project. Based on the new techniques to evaluate KHIs and understanding of mechanisms of hydrate nucleation/growth, it was concluded that a KHI would perform well in the Varg system, which is rich in propane and butane, even though high sub-coolings are predicted.

The experimental campaign is designed with the aim of ▸

determining the time that the KHI will be protecting the system before hydrates have nucleated. Measuring this time is very difficult and unreliable as the crystallisation process is inherently stochastic so that many repetitions are required. Recent research has shown that KHIs are capable of delaying nucleation and also crystal growth. New techniques for evaluating KHIs have been developed based on non-time dependent inhibition properties that circumvent the stochasticity of the crystallisation. These new methodologies provide a useful decision-making tool in order to manage the uncertainty of the KHI performance during the different phases of the project.

The design was bound by the need for all operating modes to be within the expected constraints of KHI performance. Confirmation of performance took place during a laboratory programme through mid-2012. Results confirmed that the Varg design is within the performance limits of the KHI. Start-up is planned in late 2013.

The design takes advantage of the fact that the ‘as-built’ Rev to Armada pipeline has shown that actual insulation performance, and hence operating no-touch times, are significantly greater than the original design. The intention is to exploit this over-design with the tie-in of the cooler Varg fluids. In addition, the hydrate management strategy consists in the continuous injection of KHI.

Tie-back selection and insulation

The value of insulating the 6" Varg to Rev was also investigated in order to assess possible improvements in no-touch time, turndown rate and operational flexibility that can be gained by improving the heat retention in the system. Such improvement could eventually yield a better KHI performance as the required sub-cooling during normal operation would be reduced.

However, the benchmark analysis showed the effect of applying relatively heavy foam insulation to the Varg gas export pipeline is minimal under all foreseeable operating conditions. Furthermore, settle-out conditions following shutdown were identified as the critical design point for the KHI performance.

Hydrate management philosophy

The two parts of the Varg/Rev to Armada production system are protected against hydrate formation by two different methods. The Varg gas enters the pipeline relatively cold due to Joule-Thomson cooling from the high-pressure FPSO compression train, and has a relatively high hydrate dissociation temperature due to the high content of n-propane and n-butane.

The hydrate prevention strategy for this section during normal operation is continuous injection of KHI delaying crystal nucleation/growth. In the Rev to Armada section, the commingled fluids (cold Varg fluids and warm Rev fluids) are kept outside the hydrate formation region due to insulation and burial of the pipeline; there is no need for any additional actions to avoid hydrate formation. During normal operation, the total residence time of the fluids in the pipeline will be shorter than the induction time provided by the KHI. Finally, the expected water content (including condensed water) in the pipeline is very low; hence in case of failure of the KHI, the risk of forming a full-bore hydrate plug will be unlikely.

In the event of a short-term shutdown, the system will be protected by the KHI (Varg to Rev tie-back) and by retention of heat (Rev to Armada pipeline). After some time, around 36 hours, the system will be depressurised in order to keep the fluids outside the hydrate formation region.

The performance of the KHI will vary depending on the operating conditions and the subsea ambient conditions. However, long induction (hold) times are expected (possibly exceeding the no-touch Rev to Armada section) as the KHI will show a high performance in the hydrate metastable region.

For start-up and re-start, methanol will be used to inhibit hydrate formation. The thermodynamic inhibitor will be continuously dosed for the first few hours of production until normal operation has been reached. At this point, MeOH dosage will be halted and the KHI will be continuously injected at the inlet of the flexible pipeline inhibiting the aqueous phase and the amount of produced and condensed water is very low. As the KHI is a low-dosage hydrate inhibitor, the required concentration dosages are small so there are no significant effects on the hydrate/gas/water thermodynamic equilibrium albeit the carrier solvent typically being MEG and/or EGBE. The required dosage concentration will be confirmed by the KHI qualification program.

KHI performance testing results

The qualification program determined that adequate required dosage of KHI is 3.5% vol/vol. Also, the pre-selected KHI is compatible with the corrosion inhibitor (the effects of corrosion inhibitor on the performance of the KHI are negligible, with some evidence of slight positive effect are low pressures) and offer a good hydrate (complete) inhibition for the Varg gas under flowing (mixing), shut-in and restart conditions. At high subcoolings (>15°C), the performance is more tenuous (hydrate growth observed at moderate rates).

Tests using a specifically developed shut-in/cooldown/restart protocol showed that the KHI can prevent hydrate formation during shut-in (and subsequent cooldown of up to one week) and that it may be possible to restart without problematic hydrate formation as long as the system is warmed to temperatures within the complete inhibition region within a few hours.

Conclusion

The general methodology described is applicable to any greenfield (or even brownfield) development considering the use of KHI for hydrate inhibition. The efficacy of a KHI-based solution can be conservatively assessed without laboratory testing, reliably and rapidly.

Two technological milestones have played an important role in this flow assurance driven design. Firstly, the identification of a suitable KHI has been important when developing the design with the adequate level of conservatism. These new KHIs have been formulated to achieve a high performance even at high sub-coolings. Secondly, the advances in the understanding in KHI inhibition have led to the development of more reliable KHI performance ▸

evaluation techniques providing a useful decision-making tool for managing the uncertainty of the KHI performance during phases of the project.

These milestones remove a significant roadblock on the use of KHI in greenfield projects, which otherwise require a lengthy delay for laboratory assessment. This new methodology enables consideration of KHI in potentially many other projects, where its use will see significant reductions of CAPEX and/or OPEX, as experienced with the Varg gas export project ■

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