THERMO-HYDRAULIC ANALYSIS OF A GAS CONDENSATE PIPELINE FOR HYDRATE PREVENTION DURING STEADY STATE PRODUCTION

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Abstract - This work involves the application of HYSYS software as modeling tool to determine flow assurance of Gas condensate flow through pipeline (from offshore facility to onshore processing facility). Gas hydrates formation which serve as flow assurance problem has been considered. The results obtained have shown that 0.25ft (3in) of urethane foam was the optimum insulation thickness required to keep the fluid above the hydrate formation temperature. The safe margin was considered as 5 ^{O}F and the onshore pipeline does not require insulation. These results obtained have shown that both Pipe Segment Model and Aspen Hydraulics offer simulations for flow through pipelines, with variables including pressure drop, flow, pipe materials, heat transfer, flow correlations, altitude change, and many more.

Index Terms - heat transfer, process optimization, pipeline segment model, Aspen Hydraulics, fluid compositions, mass transfer.

1 INTRODUCTION

Natural-gas hydrates are ice-like solids that form when free water and natural gas combine at high pressure and low temperature. This can occur in gas and gas/condensate wells, as well as in oil wells. Location and intensity of hydrate accumulations in a well vary and depend on: Operating regime, Design, Geothermal gradient in the well, Fluid composition, and other factors [1]. The configurations are found in fig. 1. Details can be obtained from the literature cited.

X-ray diffraction analysis shows the gas hydrate crystal structure to be a derivative of the pentagonal dodecahedron, a twelve sided structure whose faces have five edges. Since the bonding angle is 108^{o} and that of ice is 109.5^{o}, the structure was long thought to be the probable basic hydrate building structure; yet, no orderly packing arrangement can be made with the regular pentagonal dodecahedron. Claussen [3] proposed two separate crystal lattices of modified dodecahedron configurations designed as Structures I and II. Studies on natural gas hydrate have shown that formation is strongly dependent on pressure, temperature, phase composition and interfacial contact area. The effect of third surfaces on the formation variables suggested that the large areas of interactive and possible surface ordering have an effect on the thermodynamic and kinetic characteristics of natural gas hydrate formation [4].

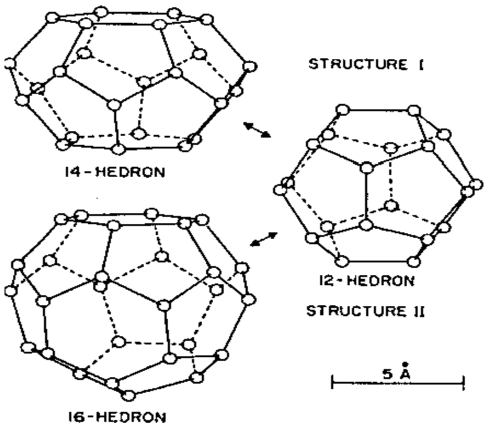

Fig.1: Schematic of Natural Gas Hydrate lattice [2].

These assertions call for the application of mass transfer phenomena in the thermo-hydraulic considerations. The benefits of simulation package application as demonstrated by the author's work [5] are: Accurate design information; Software-produced mass and energy balances and process flow diagrams; Multiple design cases at a fraction of the cost; Process optimization, finding the process' maximum performance point; Sensitivity analyses, determining the process' key control variables and degree of operating stability. The thermo-hydraulic analysis of hydrate formation with software package will result in these benefits. It was also established [6] that data obtained from hydraulic analysis should be able to address the following pertinent issues: Surge pressure during shut down of a liquid line; turn down limitations and inhibition or insulation requirements to prevent wax or hydrate formation (deposition); effect of flow conditions on the efficiency of corrosion inhibitors; and liquid catching and slug control requirements at the downstream of the phase lines.

Gas hydrates is a key flow assurance problem. Hydrates could plug the pipeline, choke the flow, cause large pressure drops, and affect production safety. Downstream processing facilities could be affected. Hydrate plug remediation has an associated cost. Design considerations during FEED/conceptual design phase is imperative in hydrate mitigation. The positive manner to prevent hydrates (and corrosion) is to keep the lines and equipment ''dry'' of liquid water. There are occasions (rightly or wrongly) when the decision is made to operate a line containing liquid water. If this decision is made, and minimum line temperature is below the hydrate point, inhibition of this water is necessary [2].

In vapour-solid equilibrium constant studies of hydrates Carson and Katz [7] have developed k values for hydrate predictions. Besides, Poettmann [8] had developed K value charts which can predict hydrate formations in pipelines depending on process conditions. Several works have been done to analyze the critical nature of hydrate formations and their mitigations. The Katz method possesses pressure limitations and fails to address the hydrate depression effects of molecules too large to fit into the cavities. Too many of these in one location makes it difficult for a stable lattice to form around them [9].

Fundamental understanding of gas hydrate formation and decomposition processes is critical in many energy and environmental areas and has special importance in flow assurance for the oil and gas industry. These areas represent the core of gas hydrate applications, which, albeit widely studied, are still developing as growing fields of research [10], [11].

In all these there has never been any that considered the thermo-hydraulic analysis to ascertain a reliable and efficient method of mitigations of gas hydrates. It is therefore the intention of the author to consider the thermo-hydraulic behavior of gas flow through pipeline systems from offshore to processing facilities on land to ascertain hydrate formation and possible mitigation.

Process Description

- Gas condensate is to be transported via pipeline from an offshore producing well to an onshore processing facility as shown in Fig. 2.
- The design objective is to ensure process operability above hydrate formation temperature during steady state operation
- Insulation was considered as primary mitigation strategy.

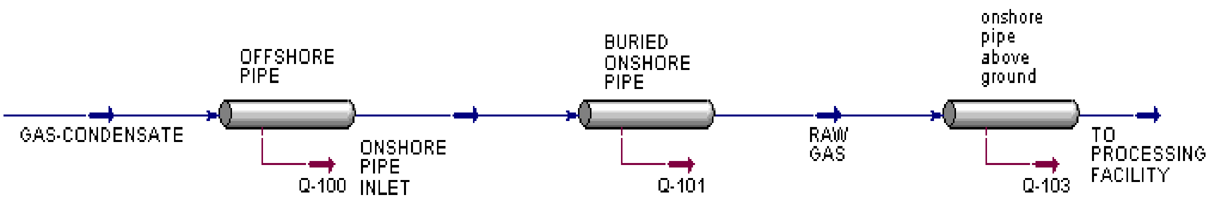

Fig. 2: Gas condensate flow through pipeline (from offshore facility to onshore processing facility)

Methodology

1. HYSYS software was used as flow assurance modeling tool and Fig 2 is a configuration of an HYSYS print out.
2. The Fluid Characterization adopted were:
   - Flash Calculation – Equation of State Model
   - Determination of hydrate formation temperature for the given fluid compositions
   - Generating phase diagram, and envelope and applying them to obtain hydraulic and thermal profile of the process systems.
3. Pipeline Profile Modeling
   - Assuming rough elevation profile for offshore pipe and 0 elevation for onshore pipe
   - Increased segmentation for high precision in results
4. Pipeline Hydraulic Modeling
   - We selected appropriate Flow Correlations
   - Determination of Pressure & Temperature Profiles
5. Parametric Study/Sensitivity Analysis
   - Determination of minimum insulation requirement

Assumptions: The following assumptions were considered

- Steady state
- Negligible effect of fittings
- Constant inlet Pressure and Temperature
- Facility was located in a tropical country with yearly average temperature of 22 ^oC (72 ^oF)
- Pipeline was already sized for maximum flow rates. Turn down production rate was used to determine minimum insulation requirement

Table 1: Fluid Characterization

Formation Temperature [F]	**61.3**
Hydrate Type formed	Type II
Calculation Mode	Assume Free water
Equilibrium Phases	V-Aq-L-H

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Inhibitor Calculation	Not Included

RESULTS AND DISCUSSION

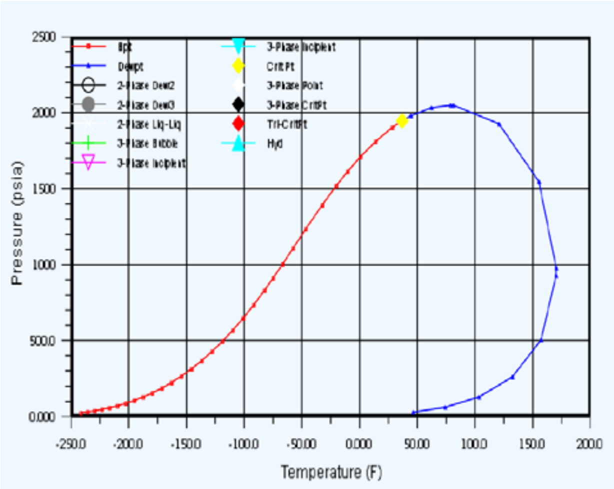

Fig 3: Phase envelope

Hydrate forming temperatures can be observed from Fig. 3. The safe region (no hydrate zone) and the unsafe region (hydrate zone) could be clearly seen from figure 3 as shown by colour of the curves, blue and red for safe and unsafe zones respectively. The flow of condensate gas can form hydrates with high pressure drops, even with a high initial temperature, if the pressure drop is very large [12].

Offshore Pipeline Profile

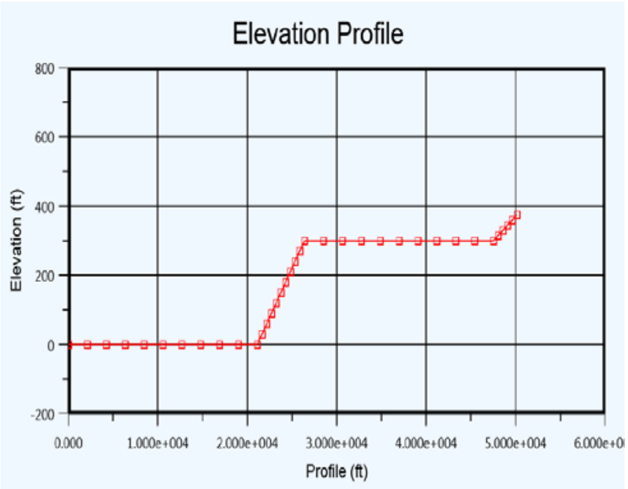

Fig. 4: Pipeline profile

Pipeline Hydraulic Modeling

Multiphase Flow Correlations

Horizontal Pipe flow Correlation : Beggs and Brill (1973)

Vertical Pipe flow Correlation : Beggs and Brill (1979)

Inclined Pipe flow Correlation : Beggs and Brill (1979)

Hydrate Model : Peng and Robinson

This Beggs and Brill empirical correlation was developed from air/water two-phase flow experiments. It applies to pipes of all inclination angles. The procedure to calculate the liquid holdup can be obtained from [13].

Heat Transfer

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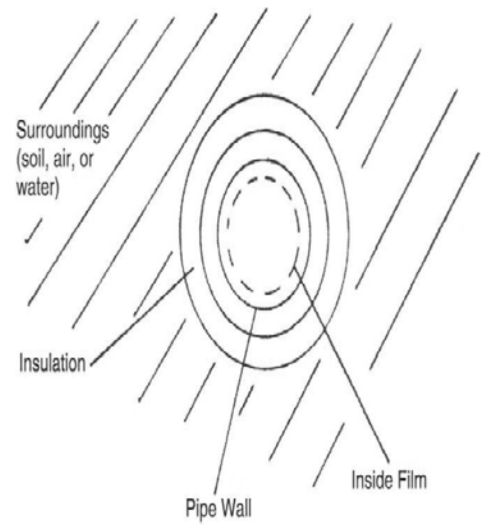

Fig.5 (a) Heat transfer through pipeline section

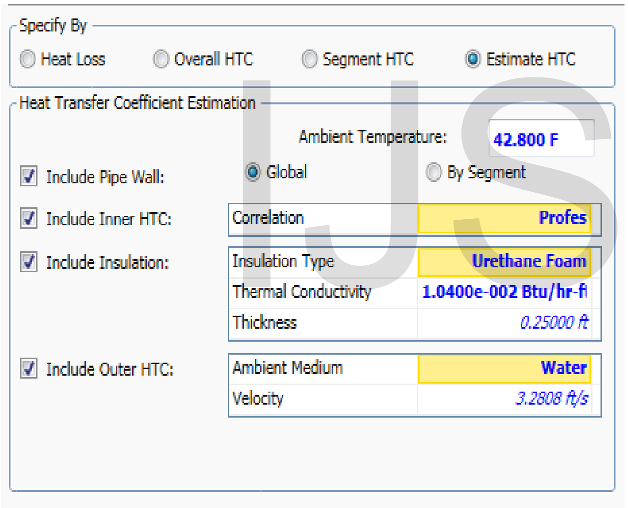

Fig. 5 (b): Heat transfer data applied

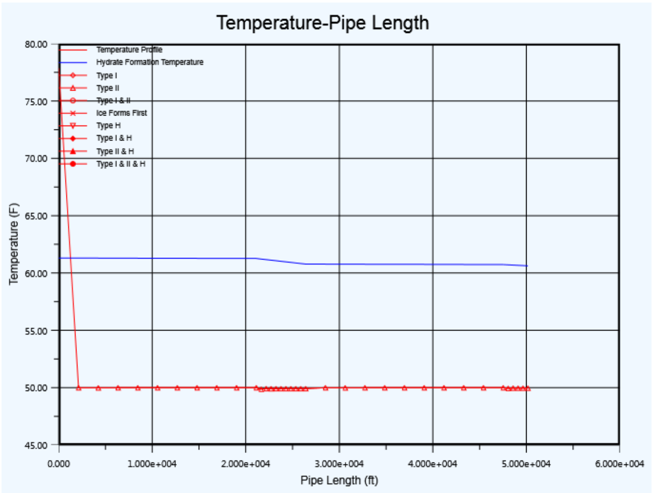

Fig. 6: Offshore Pipeline Temperature Profile (without insulation)

Parametric Study

Investigating the sensitivity of the pipeline's outlet temperature to variation in insulation thickness

From Table 2 one could see that case 2 has shown the point when flow would not form hydrate. Here insulation of pipeline becomes necessary for offshore operations. Fig. 7 shows the configuration and pipe length profile. For buried onshore pipeline, the temperature profile is shown in Fig. 8.

Table 2: Variation in insulation thickness with respect to pipeline outlet temperature

	Offshore pipe insulation thickness (ft)	Outlet Temp (°F)	T_{hyd}	dT_{hyd}
Case 1	0.00	50.0	61.3	-11.3
Case 2	0.25	68.0	61.3	6.7
Case 3	0.5	70.8	61.3	9.5
Case 4	0.75	71.8	61.3	10.5
Case 5	1.00	72.3	61.3	11

Offshore Pipeline Temperature Profile

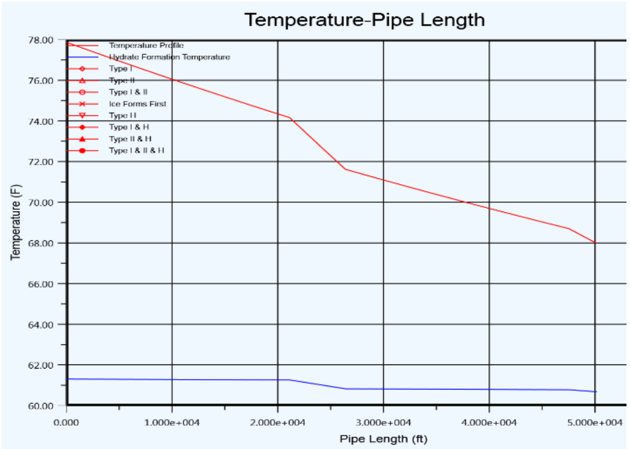

Fig. 8: Offshore Pipeline Temperature Profile

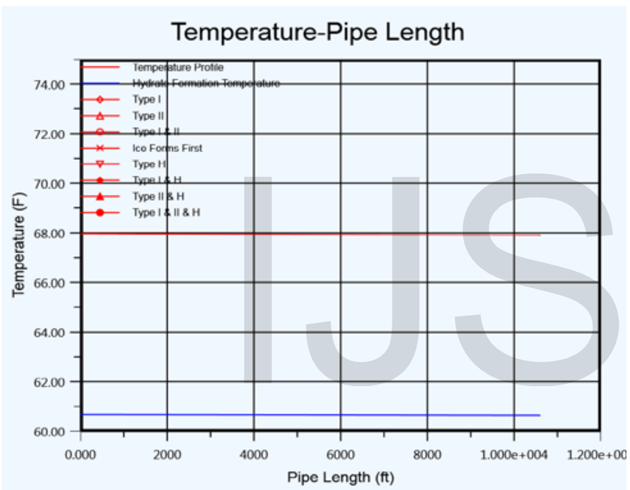

Fig. 9: Buried onshore pipeline temperature profile

The results obtained have shown that 0.25ft (3in) of urethane foam was the optimum insulation thickness required to keep the fluid above the hydrate formation temperature. The safe margin was considered as 5 ^{O}F and the onshore pipeline does not require insulation. However, it is recommended to insulate the shore crossing section as shown in Fig. 10. These results obtained have shown that both Pipe Segment Model and Aspen Hydraulics offer simulations for flow through pipelines, with variables including pressure drop, flow, pipe materials, heat transfer, flow correlations, altitude change, and many more.

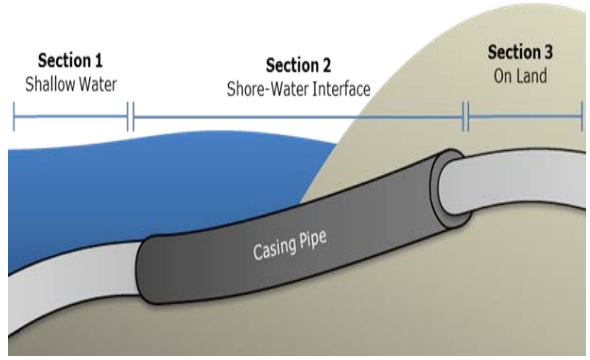

Fig 10: Configuration of Pipeline (from shallow water to land)

CONCLUSIONS

This work has shown that accurate and comprehensive modeling capabilities for pipeline hydraulics for Oil and Gas Industries is achievable. Both Pipe Segment Model and Aspen Hydraulics offer simulations for flow through pipelines, with variables including pressure drop, flow rate, pipe materials, heat transfer, flow correlations, altitude change, and many more. Aspen Hydraulics provides more rigorous modeling in a sub-flowsheet format with additional variables, while Pipe Segment Model can be added as a unit to any Aspen HYSYS flowsheet for quick pipeline calculations. Both support dynamic modeling to account for transient flow conditions such as startup and shutdown, and also to support critical flow assurance calculations.
By utilizing these capabilities, customers in the oil and gas industry can simulate pipelines easily and accurately from within their Aspen HYSYS models, not only in steady-state operations but also as the field and pipeline age. With the information provided by their Aspen HYSYS models, these companies minimize not only operation cost but also maintenance and production expenses. This makes Aspen HYSYS solutions for pipeline hydraulics modeling crucial for the modern oil and gas industry. The process shows high level performance and reliability in pipeline hydraulic operations.

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