Honeywell

White Paper

Simulation for Flow Assurance

Executive Summary

Since their development in the early 1990s flow assurance studies have become critical in the oil and gas industry, and no where more so than in off-shore, deep water developments,

It is a vast subject, and the studies must include a wide range of steady-state and dynamic analyses covering a multitude of areas. Two are key, however: Thermodynamics, focusing on fluid phase changes in the system and the risk of deposition of solid phases in the pipelines; and hydrodynamics, ensuring a sufficient pressure gradient in the system for continuous flow.

Engineers in the oil and gas industry are naturally keen to extract maximum benefit from their simulation software investment for flow assurance studies. To ensure this, simulation software must have appropriate tools to deal with and enhance studies in both these areas.

Honeywell's UniSim® Design has these. It interfaces with commonly used thermodynamic behavior prediction products and includes features such as its Hydrates Utility and Fluid Optimizer; and it has a range of tools for analyses of the multi-phase flow regime and pressure profile evolution over time. An OPC client interface, meanwhile, allows links with multi-phase pipeline simulators to significantly simplify the execution of dynamic analyses. Finally, workflow tools ensure efficient and timely delivery of analyses results.

In choosing the right tools for flow assurance studies, no one tool will satisfy every requirement. In making their decisions, engineers must consider the scope, skills and budget requirements. This will enable them to decide on the right balance between best-in-class but narrowly focused specific applications, and more versatile generic tools that can cover and deliver value across a great range of applications.

Section Header Style

What is Flow assurance?

Flow assurance is a concept initially introduced by Petrobras in the early 1990s (in Portuguese as *garantia do escoamento* , literally "guarantee of flow"), and was driven by the deep water investments kicked-off by the company at that time. Today, this topic encompasses many discrete and specialized subjects, bridging a wide range of engineering disciplines.

Flow assurance is important for all oil and gas assets, but it is critical for off-shore, deep water developments, due to the high pressures and low temperature (~4 degree Celsius at the seabed) involved. The financial implications associated with a loss of production or asset damage can be measured in billions of dollars, without counting the time and effort required to address the operational issues caused by an erroneous design.

The main goal of flow assurance studies is simple: To determine whether the fluids coming from the wells can arrive at the surface facilities under all the possible operational conditions. To have a firm answer this question, a significant number of complex calculations are required, including both steady-state and dynamic analysis and covering two main areas:

- **Thermodynamics,** focusing on fluid phase changes in the system, as the generation and deposition of a solid phase in the pipelines can compromise production, safety and asset reliability

Hydrodynamics, focusing on the pressure gradient in the system, as this will drive production all along the field life-cycle.

Other areas are also considered in flow assurance studies, including corrosion, erosion and sand handling, but these are outside the scope of this paper.

Flow Hindrances: the Role of Thermodynamics

The production gathering system involves a network of pipelines connecting the different wells to the surface facilities. These pipelines usually transport a mixture of oil, gas and water at varying pressures and temperatures, driven by the pressure drop and heat transfer along the pipelines walls.

Based on the characteristics of the fluids coming from the reservoir, engineers can predict the conditions leading to the formation of hindrances reducing or preventing flow, and then developing strategies to mitigate them. These hindrances are mainly solid deposits generated in the pipelines, including gas hydrates, asphaltenes, and waxes.

These solid deposits originate from multiple sources, and they can be driven by several factors, including the gas/oil/water ratio, the geographical location of the field, and physical and chemical properties, but especially by the pressure and temperature. Due to the long distances involved, the pressure drop and the heat loss through the pipeline wall from the reservoir to the slug catcher/surface facilities can be significant, cooling the fluids and resulting in precipitation of solids in the pipeline. Figure 1 (below) shows a typical oil-phase diagram, with a representation of such behavior.

These deposits not only reduce the overall efficiency of the oil production by reducing the flowing area in the pipeline; they can also completely and irreversibly block it, stopping production, damaging the asset and compromising the safety of the facility.

Predicting the thermodynamic behavior of such systems requires specialized know-how and experience to identify the operational window that would prevent the formation of such solids. Many products in the market are used to predict these systems, but Calsep's PVTSim and KBC's Multiflash are among the most often deployed. Honeywell's UniSim Design has developed interfaces to both, allowing engineers to smoothly integrate these software tools as thermodynamic engines within the simulations.

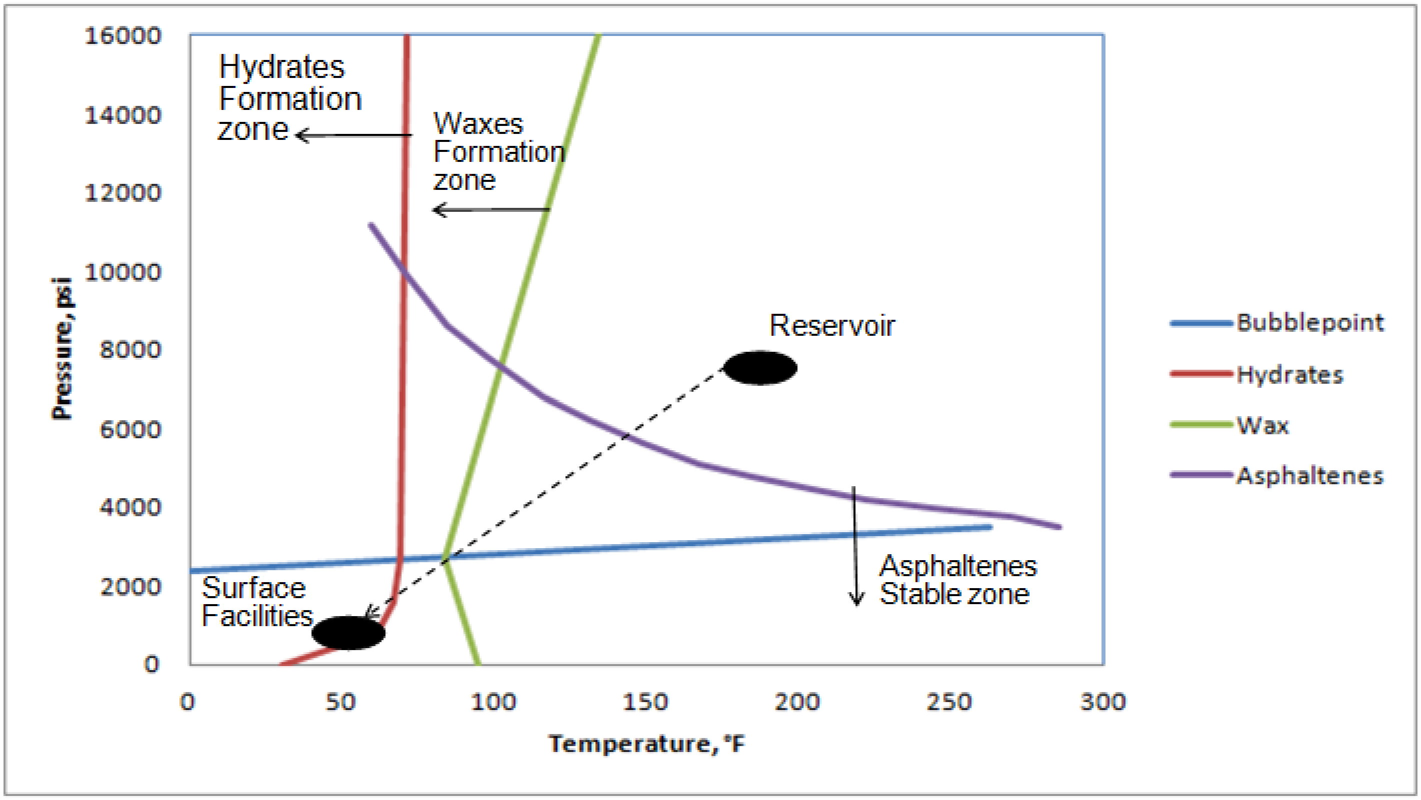

Figure 1. Typical oil-phase envelope, highlighting the hydrates and waxes equilibrium curves, and the asphaltenes precipitation locus[1].

Some other native features in UniSim Design can also be of value to flow assurance engineers in their tasks.

- **The Hydrates Utility** quickly predicts the likelihood presence of hydrates in a given stream. This is add-on utility's basic functionality needs to be used in combination with other tools to support a complete flow assurance study, but it can prove useful in quickly screening different design options
- **The Fluid Optimizer** – When lab data is available, the fluid optimizer provides a framework for tuning binary interaction parameters (BIP) used in thermodynamic models (such as the Peng-Robinson model) to meet the required process conditions. Users can choose to either view the legacy BIP treatment by default, or represent BIPs as constants or functions of temperature.

Pressure Profile and Multi-phase Flow

In addition to the flow hindrance issues discussed above, the other main question a flow assurance engineer must address concerns the pressure profile along the gathering network. Is the pressure gradient enough to allow these fluids (oil, gas and water) to flow from the reservoir to the surface facilities, along the life-cycle of the reservoir?

To answer this question, engineers generally perform steady state and dynamic analysis to predict the following:

- The multi-phase flow regime under a given operating window (see Figure 2)
- The pressure profile evolution over time, setting up the basis for the design of the production facilities and definition of the future production strategies to maintain productivity.

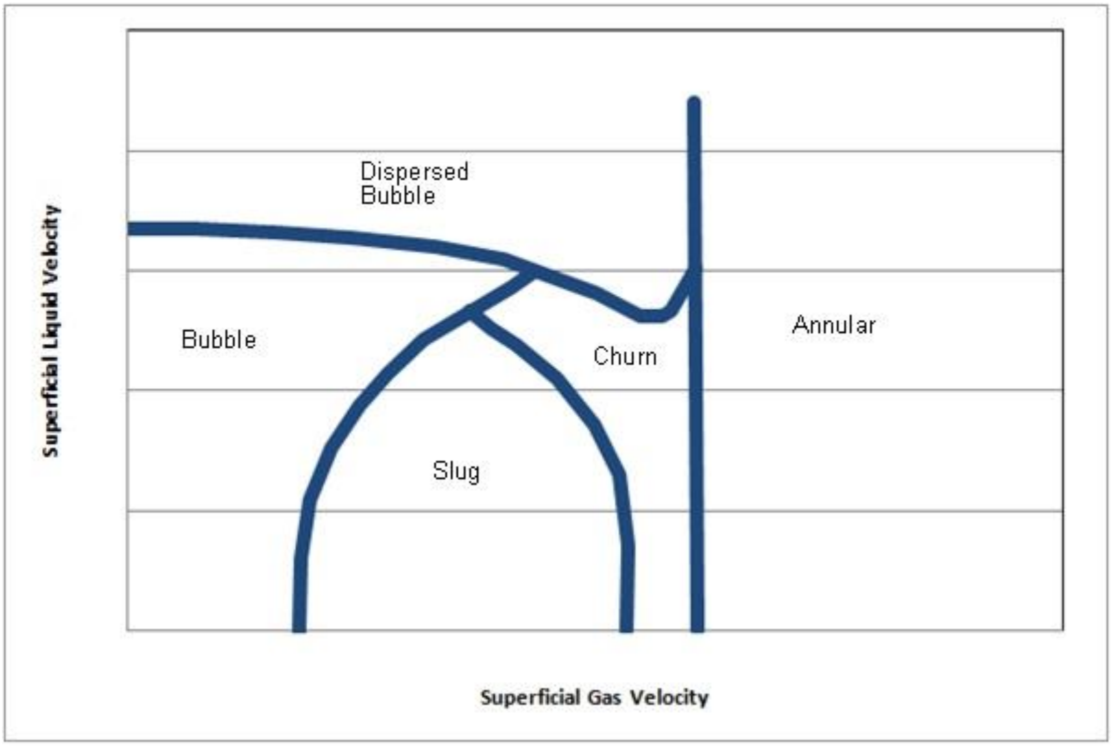

Figure 2. Generic flow regime map[2].

A number of tools are available to support engineers on these tasks, and they can be used standalone or integrated together, depending on the considered scope.

Steady State

In steady state, engineers will probably investigate three areas before selecting the right tool to perform such studies:

- User interface or GUI to define topology
- Pressure drop correlations

Solver.

Owing to the amount of pipe lengths, elevations, and diameters involved in a gathering system, using the right GUI can have a big impact on the time spent and efficiency in defining the topology of the gathering network. UniSim Design's pipe unit operation tool has a variety of features to support engineers in such topology definition but alternative tools, such as Schlumberger's PIPESYS can also be integrated within UniSim Design to support this activity.

The right user interface does not guarantee having the right results, however, and there are a variety of available pressure drop correlations that can be used to predict the pressure profiles. The relevance of a given correlation in a specific case will depend on the correlation applicability window, the associated research and experimental data supporting it, and the company's best practices and experience. UniSim Design includes most of the available open-literature correlations, including Beggs and Brill, Aziz, Govier and Fogarasi, and others, but it can also interface with proprietary correlations such as Schlumberger's OLGA/S.

Finally, engineers can have the right user interface and correlations, but still be unable to get results, due to issues with the robustness of the solver.

Indeed, the traditional sequential modular solver, available in most of the popular simulation engines, proves useful in convergent or divergent gathering networks. However, if the complexity of the gathering network increases (i.e. different paths can be used to move fluids from one point to another), the sequential modular solver can havelimitations, and other techniques, such as the equation oriented solver might be required.

UniSim Design has long supported engineers on convergent/divergent networks in steady state anlyses, and the newly equation oriented features introduced in version R430 provides additional flexibility to users solving more complex hydraulic problems. Depending on customer preferences, other gathering network simulation software such as Schlumberger's PIPESIM can also be smoothly integrated with UniSim Design.

Dynamic Analysis

In dynamics, simulating the complexity of multi-phase flow would require specialized tools such as Schlumberger's OLGA or Kongsberg's Ledaflow. These products can predict the dynamic behavior of the gathering network under different operating conditions, supporting engineers in dentification of the flow regimes that provide the basis for design choices. As an example, a prediction of the slug size in a given facility will drive the size of the slug catchers in the surface facilities.

Linking these multi-phase pipeline simulators to UniSim Design can significantly simplify the execution of those studies where the combined performance of the gathering network and surface facilities must be assessed. UniSim Design offers an OPC client interface that allows direct link to both these technologies. In particular, the link between UniSim Design and Schlumberger's OLGA has been deployed in several design studies and operator training applications.

Handling Workflows

The right tools will provide the right results, but getting them efficiently and on time depends on the workflow supporting these analyses.

UniSim Design provides a number of features supporting engineers in their study workflows. From simple tasks such as naming the simulation case files, through to validation of the heat and material balance or performing sensitivity analysis, a number of features and tools can be used to improve workflow efficiency. A few examples follow:

- **Case Scenario Management** is an engineering tool facilitating efficient workflows, especially for large projects involving staged deliverables and a team of process engineers. It is most commonly used for comparing separately developed, but similar simulation models in a single workspace, and for propagating changes of user-modifiable variables from one simulation model to others. This tool is particularly useful for operating and engineering companies where large projects for process design and engineering studies are executed
- **Revision Control** allows users to keep track of design and simulation cases for projects. It saves the revision related information with the case file, automatically generates meaningful or user-specified file names, and helps improve project management
- **USE-IT (UniSim Design - Excel Interface)** allows UniSim Design users to configure process modeling based case studies within a Microsoft Excel worksheet. Once configured, USE-IT can be used to run sensitivity analyses and/or simulation reports

The Simulation Balance tool offers users a central location where the flowsheet balance on material and energy is tracked and reported. It identifies the sources for mass/energy imbalance and prompts users to review and address potentially damaging issues in their production facilities and/or simulation models.

Getting Started

There is no single tool supporting all flow assurance study requirements, and engineers face a wide variety of choices. To arrive at the best solution the engineer needs to consider the following:

- Scope – Different scopes can drive different tool selections, even on the same project or asset.
- Skills - Although some products can provide similar solutions for the same scope, the engineer's choice will be driven by his own experience and skills on a given product.
- Generic vs Specific – Some products can be best-in-class for a specific area, while others can be sufficient for a wider number of subjects.
- Budget – There is a trade-off between the cost of licenses and training for all required applications compared to the strategy of using generic tools or subcontracting some of the work to 3rd party specialists.

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[1] Adapted from "Closing the flow assurance Loop", Amin, Amin and Kunal Dutta-Roy, E&P Magazine, September 2005

2 "Quantitative flow Visualization System for Gas-Liquid Two Phase Flows", Hiscock, John, Faculty of Engineering and applied Science, Memorial University of Newfoundland, Canada, July 2000

For More Information

Learn more about how Honeywell's UniSim Design can improve your process performance, visit our website www.honeywellprocess.com/software or contact your Honeywell account manager.

Honeywell Process Solutions

Honeywell
1250 West Sam Houston Parkway South
Houston, TX 77042

Honeywell House, Arlington Business Park
Bracknell, Berkshire, England RG12 1EB

Shanghai City Centre, 100 Junyi Road
Shanghai, China 20051

www.honeywellprocess.com

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