

Application of Simulation Models in Operations – A Success Story

David Schumann and Gregory Davis, Valero Energy Company,
and Piyush Shah, Aspen Technology, Inc.

Abstract

Process simulation models can offer significant capabilities for operating personnel to analyze and troubleshoot current performance and to develop optimum responses in a proactive manner. This can increase agility in decision making, improve reliability and lower operating cost. Historically, only engineers have had the knowledge of how to utilize these process models. Limited engineering resources and lack of off-shift availability can limit a model's effectiveness. To more fully realize these benefits, operating personnel need an easy-to-use interface driven by robust and reliable simulation models. This paper discusses the best practices of using simulation models in operations, and demonstrates how new developments in modeling technologies can help.

The Valero Paulsboro Refinery has applied its crude unit simulation model for operational troubleshooting, analysis and optimization. This paper outlines the challenges and opportunities of using this model. It also illustrates the use of Aspen Simulation Workbook (ASW) to develop a Microsoft Excel based user-friendly interface to link high fidelity simulation models with the data historian tags, and to automate the complex workflow. In addition, it demonstrates how the Aspen HYSYS model was upgraded to an advanced model using Aspen RefSYS to provide a robust model that has been used to evaluate over 10 different crude assays and track petroleum properties (e.g. Sulfur, Conradson Carbon, API, etc) of the products. Aspen RefSYS simplifies the use of pseudo components in crude assay characterization and improves the convergence of atmospheric and vacuum columns.

This tool can empower operators to test moves on the model prior to making them on the unit, and respond quickly to crude changes. It will also enable planners to validate and fine tune operating plans and account for the unit's hardware constraints more effectively.

Introduction

A number of trends are impacting today's refining industry worldwide driven by supply and demand fluctuations, global competition, and increasing market volatility. One such trend is the variety of crudes refiners have to evaluate and process in order to drive down their cost of crude acquisition, within constraints of their desired product mix, specifications, and environmental requirements. This has put a squeeze on refiners who now often have to consider heavier, sour crudes, while simultaneously having to respond to tighter environmental regulations and product specifications.

Crudes can be purchased and blended for economic incentive and due to inventory constraints. Traditionally, previous experience and typical cut ranges are often used to estimate operating conditions. Process models can offer valuable analysis and insight for these situations, but may not be used due to perceived complexity and long convergence times of many models. The complexity often stems from multiple recycle streams, which along with large numbers of pseudo-components can increase model convergence times. Recent experience at Valero has shown that with improvements in crude model simulators and reduction in model complexity, process simulators can provide fast and valuable operating information and can become robust enough to analyze multiple crudes in one model file.

Process Simulation of Crude Units

The initial scope of work between AspenTech and Valero was to develop a robust model that could evaluate multiple crudes and be used by people inexperienced with process simulators. During the initial phase of model work, an original Aspen HYSYS model was used that included a preheat train and approximately 20 recycle

loops. This original model was slow and had convergence issues when input data deviated from the design case. Multiple crudes were added to the HYSYS model, which slowed the model down and hindered convergence even more. A relatively simple shift in crude blend percentage could take an engineer experienced in HYSYS modeling several days to obtain a meaningful convergence.

After discussion of the desired key unit operating parameters for the model (i.e. overhead temperature, side stream distillation specifications, etc.), a new condensed model was developed that essentially decoupled the preheat train from the distillation model, while still providing for connectivity between the two sections in terms of heat integration. The number of recycle loops was reduced by 50% which slightly improved model performance and convergence times. However, the nearly 1000 pseudo-components being used in every thermodynamic calculation continued to limit the robustness of the model.

HYSYS is a valuable crude process simulator because it has the ability to take crude assay data and create a set of hypothetical pseudo-components that represent the crude. The drawback is that with every additional crude, HYSYS, like most other commercial simulators in the market, creates a new set of pseudo-components. The more crudes, the more pseudo-components, the slower the model convergence. To address this multiple crude problem, AspenTech has recently introduced an upgrade to their Aspen RefSYS product, an advanced simulator for refining, including conversion units. The advantage is that RefSYS is a layered option for HYSYS with the same user environment for a familiar look and feel. This allows for easy upgrading of models from HYSYS to more advanced applications in RefSYS.

The concept of RefSYS is not complicated. Essentially RefSYS performs the same conversion of input crude assay data to hypothetical components, but instead of creating a complete new set of pseudo-components for each crude RefSYS uses the same default pseudo-components for every crude. In the case of the Valero crude model the number of pseudo-components was cut from approximately 1000 to 100. This reduced convergence time to seconds. These improvements to the model allow the user to achieve fast analysis of crude blending and comparison of unit limitations of

multiple crudes. It also enables to track and monitor petroleum properties such as sulfur, freeze point, and API gravity for all the feed and product streams. A screenshot of the Aspen RefSYS model is presented in Figure 1.

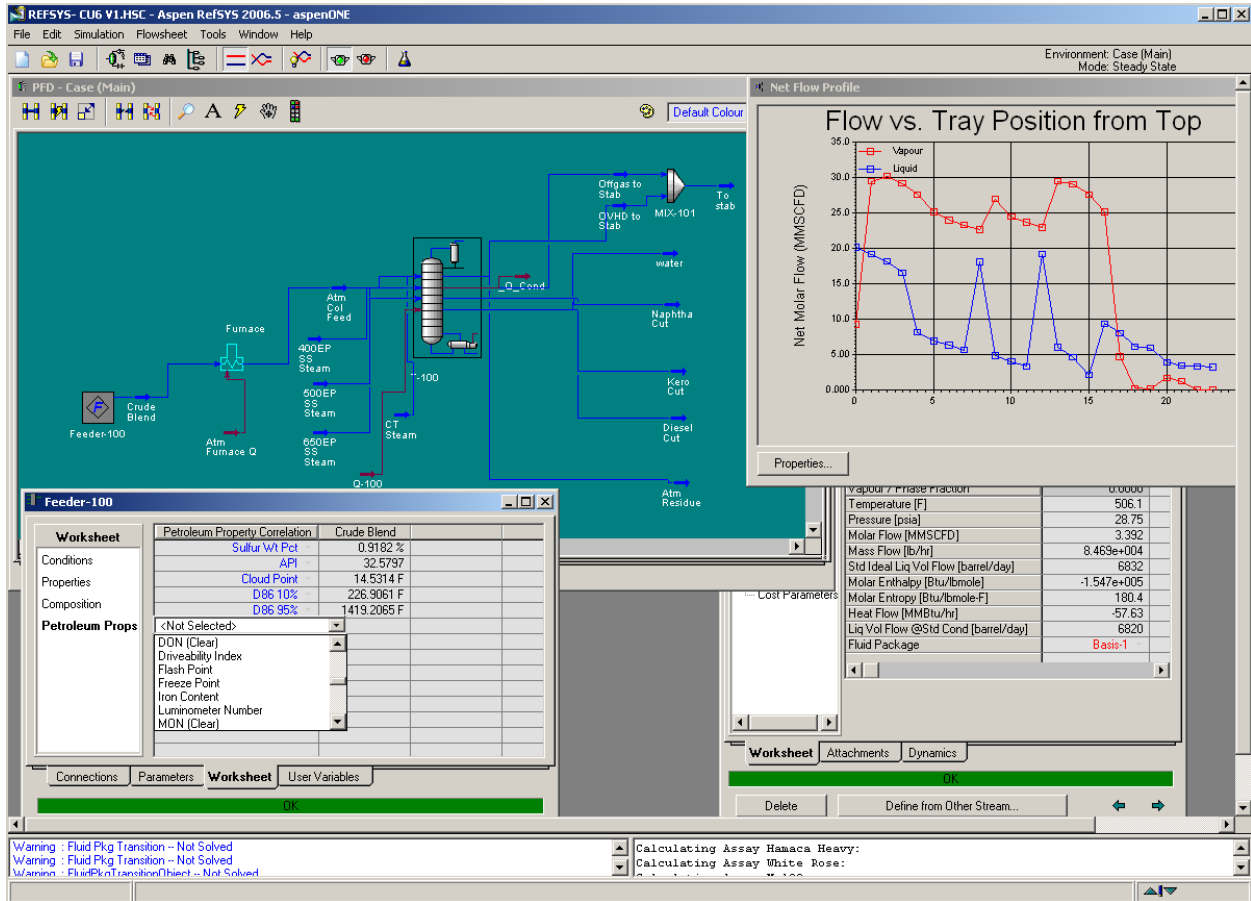


Figure 1: Screenshot of Aspen RefSYS model of the Crude Unit

However, the relative complexity of the simulator itself limits the use to process engineers and other experienced model users.

Model Deployment to Operations and Planning

Another one of the original project goals was to develop a tool that could be easily used by others involved with crude unit operation and planning, but do not have the modeling experience required to navigate process simulators. The solution to help develop this tool was Aspen Simulation Workbook (ASW). ASW enables the process

simulation model developer to easily create (without any Visual Basic programming) a Microsoft Excel based user-friendly interface to HYSYS or RefSYS models. It allows for process flow displays, tables for simulator input and output data, and links to process data historian tags. The ASW interface still allows all normal Excel functions.

ASW was used in the development of the Valero crude model to display a simplistic process flow. The flow diagram included blended raw crude feed, heaters, atmospheric and vacuum towers with all relevant pumparounds and product streams. Stream specifications available for manipulation in ASW were chosen based on relevance to actual crude operating specifications, and the selected output stream information was also displayed in the ASW interface. Deciphering between the two was made simple by color coding input and output variables. Also by displaying only the relevant input variables in the ASW interface, it reduces user confusion and eliminates the chance of any unwarranted simulator basis changes (i.e., number of column stages, side stream draw tray, etc.) A sample screenshot of the ASW interface of the atmospheric crude column is presented in Figure 2.

One advantage of this approach is the user is now working in the Excel environment and all the basic functionality is maintained. Paulsboro uses an Excel based interface to their historian system. With real time process data in an adjacent Excel sheet and simple reference formulas, the ASW inputs can now be made to be real time. Using advanced excel functionalities user can iterate an ASW input to achieve an output within a desired range.

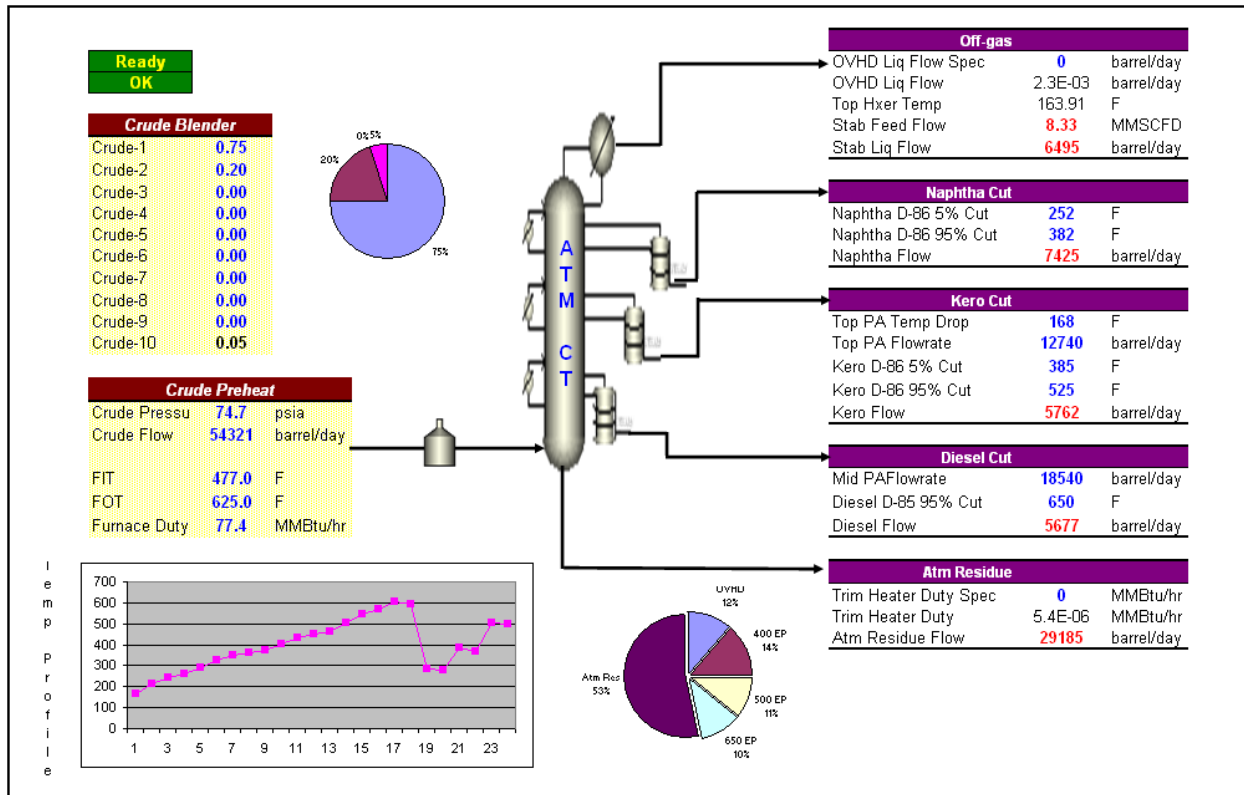


Figure-2: Sample screenshot of the ASW Excel Interface of the Crude Column

Application to Crude Blend Analysis

The basic set-up of the ASW interface has ten crudes available for blending and/or comparison defined by a user such as unit operator or planning engineer. The user is then able to specify the atmospheric heater outlet temperature, atmospheric tower input specifications such as side stream product quality, overhead temperature, pumparound rates, and pumparound heat removal. Simple correlations are developed to predict pumparound temperature drop as a function of crude rate and pumparound flowrate.

This easy to use ASW interface is used to:

- Validate model using current plant data to establish a base line performance

- Perform “what-if” scenarios to test moves before making them on the unit and develop confidence in the outcome of the moves.
- Fine-tune the operating conditions and plan by evaluating hardware constraints such as liquid loading capacity of the tray or pump flow capacity and economics

This analysis helps unit operators to understand the impact of various trade-offs quickly and develop an action plan to optimize the unit performance with confidence without the help from simulation expert. This allows unit operators to capture potential benefits in real time in a proactive manner.

. Future Direction

It is possible to extend similar ideas and develop ASW interface driven by high fidelity simulation models for other process units of the refinery. Valero Paulsboro is planning build similar interfaces for their gas plants and other refinery units in near future.

Conclusions

Advances in process modeling technology enable refiners to expand the use of high fidelity process models in operations and planning. Aspen RefSYS and ASW help in providing faster response to operational problems and increases agility in decision making.

References

1. Kaes, Gerald L., “Refinery Process Modeling Modeling”, Kaes Enterprise Inc, March 2000.
2. Aspen RefSYS Users Guide, 2007.