BENEFITS OF INTEGRATING PROCESS MODELS WITH PLANNING AND SCHEDULING IN REFINING OPERATIONS

The refining industry is experiencing increased volatility on a global basis. The volatility is felt in areas such as crude supply and demand fluctuations, product availability and pricing, and therefore refining margins. These factors have a direct impact on business operations. This volatility requires refiners to make complex business decisions with the agility to adapt to changing market conditions. These decisions determine the choice of crudes and their supply sources, playing a key role in determining the profitability of operations. Tools that help enable the optimization of these decisions provide significant value and contribute to the success of refining operations.

Different decision-support tools have been developed for specific business functions, such as process modeling, design, simulation and optimization, production planning and scheduling, performance monitoring, energy management and more. These solutions improve accuracy and reduce decision making time. There has been integration within solutions in each function, but little integration between the functions. Solutions are now available for integration between these functions for new best practices that improve operating efficiencies and profitability.

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Introduction
A best practice among leading refiners is to take advantage of a wide variety of crudes that are available today while meeting product demand. In addition, many refiners have revamped their assets to process a wider range of crude types including today's heavy sour crudes. These two trends have significantly increased optionality for many refineries, helping them maximize and sustain margins in a competitive global environment. To take advantage of these options, agility in crude selection and accuracy in planning and scheduling to process these crudes is necessary.

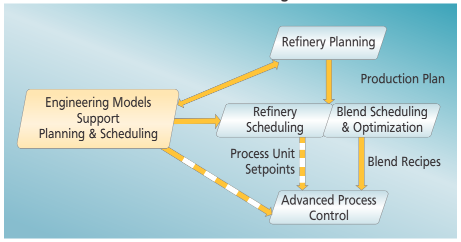
Agility and accuracy in crude selection, planning and scheduling requires easier and faster assay analysis and LP model updates and their associated workflows. This paper describes a best-in-class solution available today to achieve these objectives using rigorous process models integrated with crude oil assay management and LP models.

Need for Integrating Process Engineering with Planning & Scheduling
The world is experiencing severe economic uncertainty. In addition, refiners are facing business trends that further impact the refining industry's outlook, presenting new challenges and driving important changes and best practices. These trends include:

- Demand fluctuations that impact operations planning and drive capacity and sourcing decisions.
- Crude supply variations impacted by factors such as price, quality and availability, which combined drive the crude selection decisions that then determine operations and ultimately profitability.
- Government regulations mandating product specifications and controlling carbon emission levels are tightening but vary geographically, and have a direct impact on operating costs.
- Recognizing the complexity of the challenges facing the industry, companies are increasingly relying on software solutions to maximize the success of meeting these challenges.

Once the crude feed and monthly plan are established, the potential refining margin is more or less defined, assuming no unforeseen operating issues. To maximize this potential refining margin, it is important to have visibility and collaboration between various stakeholders. This includes an integration of the workflow between the headquarters trading and planning group and the refinery operations group (Fig. 1). It is essential that these organizations communicate and that they have common business processes, preferably supported by a common IT system. As Figure 1 illustrates, this integration ranges from planning (including crude selection), scheduling, blending, control, and process engineering.

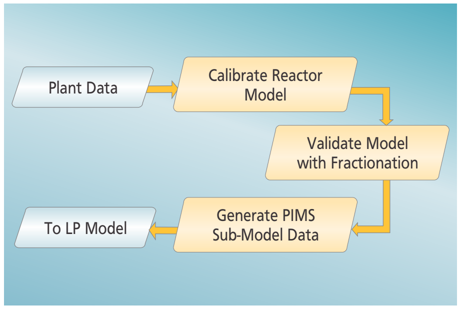
Figure 1 Engineering models support key refinery business processes for greater accuracy and consistency in decision making



The integration and use of rigorous engineering models in Planning and Scheduling facilitates greater accuracy, consistency and range of prediction. The traditional workflow to update planning models is often manual, the integration with engineering tools, if attempted, is complex, and traditional solutions require the use of multiple products and could take weeks. This length of time, along with the associated costs, is a significant barrier to using engineering models to update planning models. This means that planning models are infrequently updated to match current refinery and unit performance, thereby losing the opportunity to develop realistic and optimal plans and successfully achieve planned targets.

In response to this industry challenge and need, AspenTech has focused development efforts on optimizing the workflow and breaking those barriers. The release of aspenONE® Engineering V7.3, including Aspen HYSYS® and Aspen HYSYS Petroleum Refining, delivers the functionality that optimizes the workflow and delivers the benefits to improve operatingefficiencies and profitability for refining customers through engineering support for planning and scheduling (Fig. 2).

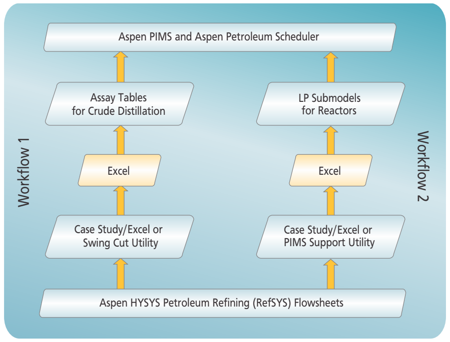
Figure 2 aspenONE simplifies the workflow, integrating engineering models with planning models for updates



Overview of Engineering Support for Planning and Scheduling
The use of process models to support operations decisions can contribute to sustaining and improving refinery margins. It supports faster, more frequent and accurate updating of planning models that can support faster and better feedstock selection. It also increases agility in responding to operational opportunities that can directly impact refining costs and profits.

The aspenONE solution which supports refinery planning and scheduling with process models enables two critical workflows. Each path uses Microsoft® Excel to transfer data from the engineering model to the planning and scheduling applications (Fig. 3).

Figure 3 There are two workflows supporting crude distillation and reactor models respectively that can be used in updating planning andscheduling models

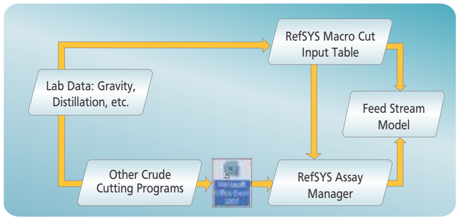


The following sections discuss how Aspen HYSYS and Aspen HYSYS Petroleum Refining (RefSYS) and its suite of reactormodels are deployed in an integrated workflow to support updates to the Aspen PIMS™ LP planning and Aspen Petroleum Scheduler™ models.

Workflow 1: Updating Assay Tables for Crude Distillation
Characterizing crude properties and composition is time consuming, and errors can have significant impact on simulation results. Crude oil lab data is converted into detailed compositions using Aspen HYSYS/RefSYS pure and hypo components. Bulk lab data is "cut" into pure and hypo components which form an "Assay."

Assay data helps refiners to determine whether a crude oil feedstock is compatible for use in a particular petroleum refinery or if the crude oil could cause yield, quality, production, equipment, environmental or other problems. The petroleum assay is a vector that stores physical properties and assay properties for a specific component list. The assay properties are usually imported from an assay management system for crude characterization (Fig. 4).

Figure 4 Assay properties are usually imported from an assay management system for crude characterization



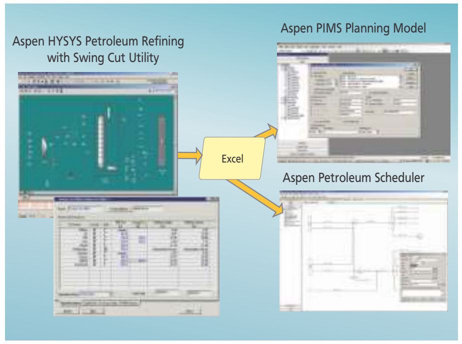
Crude oil characterization data is used in three key ways by engineers, planners, and schedulers. Engineering models confirm whether crude distillation units can successfully process purchased crude oils. Planning models select optimal crude oils for refining within operational constraints. Scheduling models assure smooth and predictable delivery of products. The planning group in a refinery uses this characterized crude in their LP planning model to optimize crudes for the refinery (Fig. 5).

LP crude assays consist of yields and properties of heart cuts and swing cuts. Heart cuts refer to material that must always be allocated to a given refinery stream. For example, the kerosene heart cut is material that will always be taken from the crude column kerosene draw. Swing cuts represent material that can be allocated to two adjacent crude column draws. The Swing Cut Utility (Fig. 5) allows the generation and export of assay tables with user-specified swing cuts and provides tighter integration between Aspen HYSYS Petroleum Refining and Aspen PIMS to achieve a wider refinery modeling solution.

Workflow 2: Updating Reactor Sub-Models for Conversion Units

Reactor models are based on rigorous kinetics and improve overall planning and scheduling accuracy by improving the plan vs. actual performance of refining operations (Fig. 3). Cooperation between the process engineering, planning and scheduling groups is required for maintaining accurate planning models. In examining a typical problem a refinery may face, such as when a new catalyst has been added to the FCC unit, the planning model must be updated to reflect this change. Today aspenONE solutions enable this workflow to be quickly and easily executed through a seamless integration between Aspen

Figure 5 The Aspen HYSYS Petroleum Refining model was calibrated and applies the Swing Cut Utility. The results are transferred into Microsoft® Excel and can be fed into both the Aspen PIMSplanning model and the Aspen Petroleum Scheduler model



HYSYS Petroleum Refining, its rigorous first-principles reactor models, and Aspen PIMS and Aspen Petroleum Scheduler. Each step of the workflow can be examined in evaluating how an efficient integrated approach can be achieved using the FCC example:

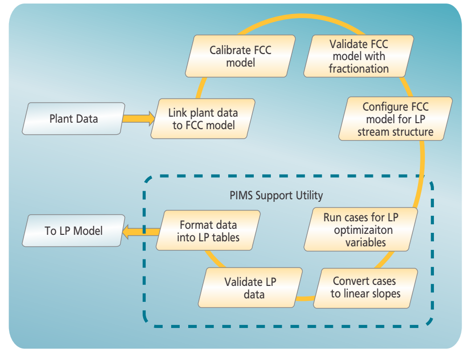
- **Link Plant Data to FCC Model.** Aspen Simulation Workbook™ links plant data from a real-time database to the FCC model with one powerful spreadsheet linked to one Aspen HYSYS Petroleum Refining flowsheet, not multiple spreadsheets for multiple flowsheets.

- **Calibrate FCC Model.** The calibration is performed starting with the main FCC flowsheet and then drilling down into the reactor model and using views that are based on familiar Aspen HYSYS interfaces to specify feeds, catalyst, operating conditions, and measurements for a calibration run. The calibration can then be run and factors saved for use in the simulation run.

- **Validate FCC Model with Fractionation.** The FCC Fractionator property view enables you to configure and modify the distillation column part of the FCC operation. The reactor model is easily placed in the fractionation flowsheet and the reactor to fractionation stream connections established with easy-to-use transitions.

- **Configure FCC Model for LP Stream Structure.** LP models typically do not use plant stream structure. So the plant fractionation model must be converted into an LP fractionation model configuration. This can be performed in the same overall Aspen HYSYS flowsheet case using a

Figure 6 Workflow steps to update FCC sub-model using the integration between Aspen HYSYS Petroleum Refining and Aspen PIMS.



component splitter, short cut or even rigorous fractionation options.

The next four steps are conveniently encapsulated in the PIMS Support Utility in Aspen HYSYS:

- **Run Cases for LP Optimization Variables.** Generate tables and plots of data for LP using the familiar Aspen HYSYS Databook Utility.

- **Convert Cases to Linear Slopes.** Generate derivatives (slopes) for the LP sub-model using the Aspen HYSYS derivative utilities.

- **Validate LP Data.** Validate the LP sub-model with plots that compare linear to rigorous Aspen HYSYS Petroleum Refining models.

- **Format Data into LP Tables.** Copy/paste table and/or derivatives from Aspen HYSYS utilities to Aspen Simulation Workbook and format to fit LP input.

With this PIMS Support Utility, the user can select the independent and dependent variables, enter base and shift values for the independents, and then with a single click generate the delta shift vectors and derivatives, validation plots, and the LP table values in Excel format. This innovation automates a process that was previously labor-intensive and time consuming.

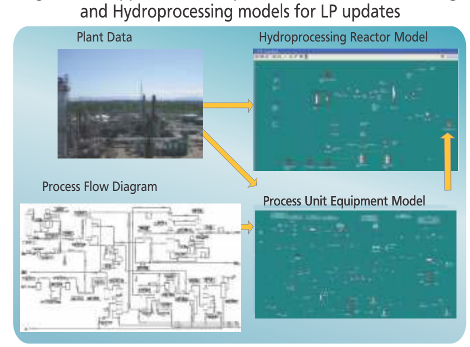
These advances in aspenONE Engineering for Refining coupled with the aspenONE Planning and Scheduling suite enables process engineers, planners, schedulers and crude selection decision makers to collaborate efficiently. This process allows refiners to examine new opportunity crudes quickly and easily and maintain LP models for better refining margins.

In the next section we will examine case studies presented by AspenTech customers highlighting their success in the useof this integrated approach to improve performance.

Customer Case Studies

BP. At OPTIMIZE 2011, AspenTech's Global User Conference, BP presented a project that used rigorous hydrocracker process models as a basis for unit monitoring, what-if analysis and LP updates [1]. The hydrocracking model was used in production and planning support for crude selection at a BP site. Aspen HYSYS Petroleum Refining was first used to model the complex, multiple-unit simulations of the entire complex. Aspen HYSYS Hydrocracker delivered a rigorous hydrocracker model used to simulate multiple reactor units and help confirm Aspen PIMS results.

Figure 7 BP application of Aspen HYSYS Petroleum Refining and Hydroprocessing models for LP updates

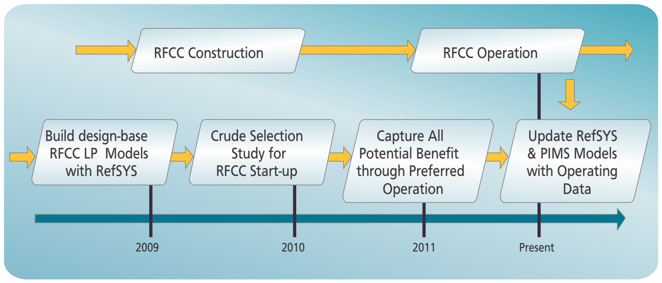


The model was then used to predict the effects of new crudes on the hydrocracker complex. The results gave operations the confidence to run the new crudes in the refinery. The model was applied to study alternative crudes to achieve approximately $20 million of incremental benefit by processing these opportunity crudes. The process model was applied to several other projects to further support operations.

Taiyo Oil (Japan). Taiyo Oil is an independent petroleum company that operates the Shikoku Refinery (120,000 BPD) in Japan. As part of a refinery expansion, Taiyo management required an improvement in the planning and scheduling system and its business processes to improve refinery margins. This was achieved by improving the accuracy of yield predictions for planning and scheduling and understanding RFCC behavior

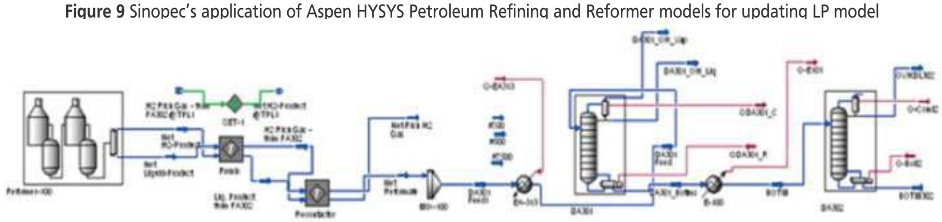
OPTIMISATION

Figure 8 Use of Aspen HYSYS Petroleum Refining (RefSYS) at Taiyo Oil to support FCC unit start-up, LP planning and scheduling model updates



for improving operational constraints [2]. Aspen HYSYS Petroleum Refining (RefSYS) incorporated plant data to calibrate reactor models and was used to model multiple units including crude distillation and reactor units. The Aspen HYSYS Reformer and Aspen HYSYS CatCracker models were used to help plan plant operating strategy for start-up and update and improve LP models for Aspen PIMS and Aspen Petroleum Scheduler. This approach made data available in a timely manner, enabling profitable operation from startup. The continuous review and update of the RefSYS/LP model contributed to meeting the required improvement in planning and scheduling and a 12.7% profit increase reported for the refinery.

Figure 9 Sinopec's application of Aspen HYSYS Petroleum Refining and Reformer models for updating LP model



Sinopec (China). A project to perform optimization studies and LP vector generation for refinery planning for Sinopec Yangzi Petrochemical Corporation, Nanjing, was executed in collaboration between Virginia Polytechnic Institute and State University (Virginia Tech) and Sinopec Center of Excellence in Process System Engineering. The Yangzi refinery processes about 181,000 BPD or 9.0 million MTA of a variety of crudes each year, and primarily produces high-octane gasoline and aromatics: benzene, toluene and xylenes (BTX). In a phased implementation, simulation models for several reactor units were developed and used to support Sinopec's needs. Aspen HYSYS Petroleum Refining was used in conjunction with its rigorous models that are available for FCC (Aspen HYSYS CatCracker), naphtha reforming (Aspen HYSYS Reformer), and hydroprocessing (Aspen HYSYS Hydrocracker), all of which use convenient Aspen HYSYS interfaces for calibration and integration into larger flowsheets.

At OPTIMIZE 2011, AspenTech's Global User Conference, Sinopec and Virginia Tech presented the results of their reformer (CCR) project [3]. The feed is hydrotreated heavy naphtha (sulfur and nitrogen removed). Five months of historical plant data was used to model and one month of data was used to then calibrate the model. The model was then implemented in operations and validated continuously with updated data sets comparing model results against significant changes in feed quality. Reactor temperature profile and key product yields showed good agreement with plant data.

The integrated model was used for LP vector generation for Aspen PIMS planning models to optimize refinery crude feedstock selection, operations planning and scheduling. The benefits of the project were achieved by optimizing reactor inlet temperature and column pressure profiles to meet yield specifications and to achieve a reduction in compressor duty. In addition, other changes resulted in lower production of benzene and improved production of xylenes. The resulting changes in process operations, without any new capital investment, delivered payback of $7 million USD/year.

Summary

AspenTech has recognized the value in providing engineering data that enables process engineers to support planning and scheduling activities for a refinery. The workflows described in Figure 3 are easy to integrate into existing process simulation workflows. Aspen HYSYS Petroleum Refining includes tools to automate the workflow and directly export the updated delta-base vectors to Aspen PIMS (LP software). This automation allows quick updates of the LP model to accurately reflect unit performance with respect to actual capabilities and constraints, thereby reducing plan-versusactual gaps and leading to more predictable performance.

In addition, the rigorous models created can be used in many other refining applications, such as catalyst selection, heat exchanger fouling analysis, optimizing crude selection and improving operating decisions. All of these applications improve accuracy and reduce the time for decision making, improving the margins of refinery operations.

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