competition within the Japanese petroleum industry became excessive after deregulation in the 1990s. To counter this increasingly competitive situation and improve margins, Fuji Oil deployed an innovative optimization program for planning and scheduling activities. This case history discusses the two-phase program to stabilize the crude distillation unit (CDU) operation with downstream units.

Background. Thirty refineries operate within Japan with a total crude processing capacity of about 4.8 million bpd. Capacity and total product demand is closely balanced. Almost all refined products are sold to the domestic market, although Japanese refineries occasionally import and export products between other Asian countries. The Japanese petroleum businesses, once protected, faced tough competition after industry deregulation in the mid-1990s. Competition within the Japanese market became excessive, thus dramatically reducing refinery margins. To counter this increasingly competitive situation and to improve margins, Japanese refineries, including Fuji Oil, have deployed a variety of Innovative Production Technology Improvement Programs based on the bottom-up “Kaizen” methodologies. This case history investigates Fuji Oil’s improvement activities in the planning and scheduling activities at the Sodegaura refinery.

Overview of challenges and initiatives. Fuji Oil’s Sodegaura refinery is located near Tokyo Bay, on the opposite shore of Tokyo’s metropolitan district. The refinery has a processing capacity of 192,000 bpd. The Sodegaura facility is a typical refinery with the exception of a unique thermal cracking unit for asphalt production. Almost all vacuum bottoms are fed to the asphalt unit; thus, crude feedstock properties heavily affect operating constraints of this unit. Asphalt pitch is shipped as coke binder to steel manufacturers after controlling the sulfur content to less than 6%.

Similar to other Japanese refineries, Fuji Oil imports most crude oil from outside of Japan. About 80% of crude oils are imported from the Middle East. Fuji Oil determines optimal crude oil purchases two months before receipt using economic planning software. Shipping crude oil from the Middle East to Japan requires approximately 20 days. The imported crude feedstocks have a wide property variance; API of feedstocks can range from 15°API to 60°API. Such variances are problematic for the CDU, which is designed for an average 32.5°API. Issues resulting from these varying crude APIs include reduced crude feedrate to meet the CDU top-section constraints with light-crude operations and bottom section constraints using heavy-crude operations. The refinery also experiences production losses with crude switches and operations instability changing feedstocks and CDU performance.

To improve refinery margins and reduce losses stemming from instability caused by wide variations of crude-charge qualities, Fuji Oil focused on improving the planning and scheduling as part of its ongoing Innovative Production Technology Improvement Project. Part of this initiative involved partnering with software providers to standardize the models and to integrate software for refinery planning and scheduling operations. This initiative consists of two phases:

Phase 1 developed an accurate planning system. These systems incorporated business processes through a combination of software solutions for planning and scheduling, and process-simulation technology. The unit model accuracy is checked and validated through daily reconciliation of plan vs. actual. A business process using Plan, Do, Check and Action (PDCA) was established. It performs root-cause analysis whenever problems occur and updates models as required. Phase 1 began in mid-1999 and was completed in 2001.

Phase 2 implements crude optimization using refinery scheduling software. The main objective is stabilizing CDU operations by reducing feed property fluctuation and further increasing...
CDU throughput without any capacity expansion investment. Phase 2 began in mid-2002.

**Phase 1—Planning initiative.** Phase 1 objectives included:

- Developing an accurate planning system by integrating refinery planning and scheduling software and process simulator
- Performing daily checks on plan vs. actual to maintain accuracy in the unit model and basic data.

Fig. 1 shows the operation cycle of planning and scheduling in Phase 1. It includes monthly and daily model validation to ensure accuracy of the planning model. Each month, the planning tool is used to determine the next three months’ rolling plan with three periods for crude selection and the process units’ operation mode. The planning and scheduling software is fully integrated using the same assay data and process unit models. The scheduling system takes the optimum plan developed by the planning tool and transforms it into the daily schedule. This daily schedule is then sent to the operation section as a work order.

The main process units are controlled by an advanced process control (APC) system. Historical real-time plant data, collected by a data historian system, is used to compare results with the daily plan and to evaluate the model accuracy on a daily basis. On a monthly basis, the accuracy of the unit model is further evaluated with the process simulator and updated when required.

To implement the PDCA cycle smoothly, Fuji Oil also developed supporting systems on data gathering, analyzing, and plan vs. actual comparison. As a result, Fuji Oil has succeeded in establishing a business process for continuous improvement. This process enables the refinery to keep improving system accuracy for the planning and scheduling tools.

For example, Fig. 2 shows the tracking of the daily plan vs. actual, which is disclosed to operators. Fig. 3 shows the plan vs. actual comparison of benzene content in reformate from naphtha composition on a monthly basis. The process unit model is updated when the deviation of prediction from actual is detected. These checks are done for all process units, yields and properties to keep the planning model accurate.

Fig. 4 is an example of how scheduling is executed using a molecular-base, i.e., detailed stream-composition, modeling approach. The detailed stream composition of the reformer feed is tracked and calculated through upstream process units from the crude assay data. On occasion, an imported naphtha stream is required to supplement reformer feed. The composition of the imported naphtha is analyzed on receipt as input to the scheduling system. This system predicts the reformate composition on a detailed basis applying a reformer-reactor model after the desulfurization unit. With this application, operations can accurately predict xylene yields.

Benefits achieved in Phase 1 include:

- Achieving consistent and optimum operation in crude selection and purchase, product sales and purchase, and unit operation
- Detecting unit constraints and problems in the planning stage and adjusting the required crude quality to meet demand
- Providing the operations group better information from the scheduling group to operate the CDU and downstream units at maximum conditions.

**Phase 2—Planning initiative.** Fuji Oil processes 10 to 20 crude oil types from all over the world with APIs ranging from 15°API to 60°API. Crude is stored in tanks and grouped accord-
Optimized vs. not optimized operations.

Comparison of API trend in CDU charge

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Phase 2 objectives were:

- Stabilizing CDU operation, i.e., minimize disturbances caused by crude oil switches
- Increasing throughput without capacity expansion investment.

To achieve these objectives, a crude-optimization approach was adopted that reduced the variability of crude charge.

Fuji Oil developed the crude optimization system in Phase 2 by using a calculator functionality of the scheduling system. This capability incorporates the CDU operating conditions, target API, key yields and sulfur level of the produced asphalt as input variables. The software compares these key operating properties before and after the crude tank switch and optimizes the crude blending ratio from available crude while minimizing changes in key product properties.

After establishing the crude optimization system, Fuji Oil succeeded in stabilizing the CDU top pressure. Thus, the CDU operates at maximum design capacity. Fig. 5 illustrates the improved CDU operations after the crude optimization system was placed in operation.

By balancing the key crude properties, the crude optimization system allows Fuji Oil to increase CDU throughput without expanding capacity and operating the CDU at the maximum performance for unit equipment.

Sulfur content in the asphalt pitch was previously controlled at the CDU bottom tank. Now, it is controlled at the crude optimization stage, which allows Fuji Oil to reduce the CDU bottom-tank volume. The crude optimization system also minimizes fluctuations of API, sulfur and middle distillates, thus further stabilizing operations.

Fig. 6 shows the API trend for the CDU charge before and after implementation of the crude optimization system. Before the crude optimization system, the API fluctuated significantly. But there is little fluctuation after the system implementation. Product loss, accompanied with CDU fluctuation, is also minimized.

Phase 2 benefits include:

- 5% throughput increase in CDU without capacity expansion investment
- Reduced product loss during crude switch by stable CDU operation
- Improved stability of downstream unit operations
- Lower intermediate tank volume.

Lessons learned. Before Fuji Oil embarked on this Innovative Production Technology Improvement Project, there was a lack of communication between the planning and production sections. When there was communication, it tended to be one-way—as a work order.
The Innovative Production Technology Improvement Project is a program for all employees in the refinery, including operators, to promote such bottom-up Kaizen activities as profit improvement. As a result of this project, the planning section actively discloses results from the planning and scheduling software to operators in the production section. Through collaboration, the operations group can now operate the refinery closer to design conditions with a better compliance to the objectives of the planning section. The planning section can avoid unit problems and bottlenecks in the planning stage with an improved understanding of operating conditions. With the technology improvement program using integrated planning and scheduling software, Fuji Oil has achieved optimum, feasible and accurate refinery operations, as well as improved intra-organizational communication. HP

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Osamu Ueki is the deputy manager for the logistics section within the operation management department of Fuji Oil Co.’s Sodegaura refinery. He holds an MS degree in chemical engineering from the Chiba Institute of Technology. He has 10 years of experience in research and laboratory, and five years of experience in scheduling since 2002. Mr. Ueki currently maintains the scheduling system at the refinery.

Umetaro Okamo is a senior business consultant manager of manufacturing and supply chain for AspenTech Japan. He is responsible for the business development and customer support in these areas. Mr. Okamo has more than 25 years of experience in the process industry and has held a variety of roles in the area of plant design and commissioning, various process IT project implementation and supply chain business development. Mr. Okamo has BS and MS degrees in chemical engineering from Tokyo University.