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HYDROCARBON PROCESSING®
February 2004 issue, pgs 39-41
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Review fundamentals when retrofitting for ULSD

The success of revamps is driven by accurate front-end process design. Performing feasibility studies controls cost estimates and ensures meeting goals for upgrades

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In mid-2006, the US EPA rules mandate a maximum sulfur content of 15 wppm for onroad diesel—ultra-low-sulfur diesel (ULSD). Coinciding with the new EPA regulations, the industry is also driven to improve profitability and limit capital expenditures by maximizing usage of existing assets. Consequently, most refiners are considering revamps to existing hydrotreating (HDS) units to meet these new regulations. According to various industry sources, 75–80% of all ULSD compliance-driven US refinery projects will be hydrotreating facility revamps.

Preparation is key. Most refiners implement major capital projects within the framework of a front-end loaded (FEL) or staged-and-gated-project management process—generically known as the stage gate. This process involves several phases in which each consecutive stage involves more in-depth analysis and preparation of increased engineering deliverables as shown in Fig. 1.

One key step of this process is the options phase. This is the second step of the FEL and involves a feasibility study to evaluate all options to meet the overall project objectives. One of the deliverables is a cost estimate with an accuracy of 25–35%. The feasibility stage is a critical step that can determine the success or failure for revamp projects.

Accurate front-end process design is an essential element for ULSD revamp projects. This stage includes benchmarking pre-revamp operating conditions with a process simulation and reactor-loop hydraulic model. Equally important is applying sufficient process and detailed engineering efforts at earlier stages of the projects to provide improved scope definition, and thus, supplement the technology and catalyst selection. Specific aspects of an effective revamp feasibility study and key process design and project execution issues will also be addressed.

Revamp feasibility study for ULSD. During the options evaluation stage, the engineering effort will focus on significant process design issues. At this stage, an engineering company can provide necessary process and detailed-design capability to arrive at an accurate project scope and cost estimate.

Front-end process design will include benchmarking pre-revamp operating conditions with a process simulation and reactor-loop hydraulic model. An abbreviated detailed engineering effort is also needed to obtain the required cost estimate for the options phase, which is usually within the 25–35% range.

Meeting ULSD requirements with existing revamped HDS facilities will involve a combination of several process modifications that affect key process variables. Table 1 lists various modifications that can be required for an HDS unit revamp to meet ULSD specs.

To attain the required options-phase cost estimate accuracy, a field survey by the appropriate discipline engineers and designers is required. This includes:

- Verifying plot space for new equipment
- Routing of major new piping
- Analyzing existing structures for new/modified equipment
- Reviewing existing electrical systems
- Reviewing the presence of underground obstructions where new equipment is to be located
- Constructability review including transportation of new equipment to the site (outside and inside the refinery).

During the options phase, proposed equipment modifications should be checked in detail by equipment specialists. Often equipment modifications identified by a "process only" approach can miss key mechanical design issues that significantly impact the project scope and cost.

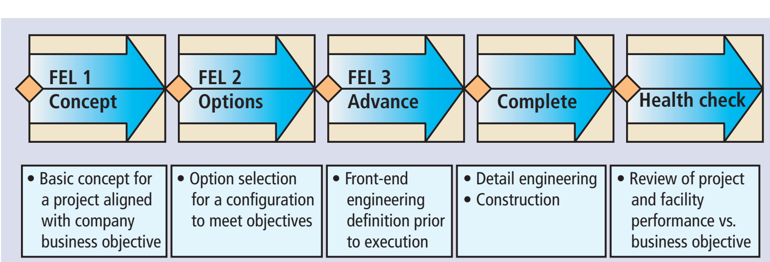

FIG. 1. Block diagram of the stage-gate process.

TABLE 1. Typical revamp scope for ULSD

• New reactor(s)
• High-performance distributors in existing reactors
• Recycle gas amine contactor
• Heat exchanger/charge heater modifications
• Increased makeup hydrogen compression
• Purification of makeup hydrogen

As noted, the capital cost estimates prepared during the options phase will have an accuracy range of 25–35%. For new installations, factored estimates based on sized equipment lists are suitable. However, revamp projects require more detailed engineering definition.

The feasibility study is the key to early validation of process capability and capital requirements. It is one of the most critical phases for any revamp project and should accomplish these objectives:

- ▶ Provide a reasonable basis for an accurate cost estimate to validate project financial performance
- ▶ Identify serious health, safety and environmental risks that must be addressed
- ▶ Identify cost of the next project phase to prepare a cost estimate with a 10% accuracy level
- ▶ Finalize process flowsheet configuration, and heat and material balance. Most optimization alternatives are addressed during the study.

Revamp feasibility study fundamentals. Revamp feasibility studies require a number of special considerations and activities not usually included in the scope for a grass-roots project. These include:

- Obtaining accurate design information for the existing facility
- Collecting sufficient operating data to benchmark the current performance
- Identifying chronic operational issues that could impact project success
- Giving sufficient consideration to design engineering definition (piping, civil, structural, electrical)
- Addressing the constructability issues unique to revamp projects
- Coordinating engineering and construction activities with the facility turnaround schedule.

Study basis. A complete design basis is developed and updated during the study, so that the final design basis document is available should the project be sanctioned for further development. A good design basis will ensure recovery of a major portion of the engineering effort expended during the study. Major components of the study basis include:

- ▶ Feedrate and physical properties
- ▶ Product quality specifications
- ▶ Battery limits temperature and pressure for all feeds and products
- ▶ Utility characteristics, quantity limits and value
- ▶ Meteorological conditions
- ▶ Third-party information such as reactor yields and reaction process conditions.

Information collection. To determine an accurate project scope, detailed information regarding the existing facility design and operation are required. This information includes:

- Up-to-date process flow diagrams
- Piping and instrument diagrams that are field checked in the plant areas where there is revamp scope
- Reactor loop piping layout for early hydraulic evaluation
- Equipment data sheets and design drawings
- Reasonably accurate and consistent operating data including a reactor-loop pressure profile. This data is needed to prepare a benchmark process simulation and to evaluate existing equipment performance
- Inspection reports and maintenance records to reflect equipment changes from original design
- Results of previous studies and test runs
- Onsite interviews with operational and technical personnel to identify current issues or operational problems.

Benchmarking current operation. This activity develops a process-simulation model based on operating data and is adjusted to obtain a reasonable match with plant conditions. After the heat and material balance is complete, calculated equipment performance parameters are compared to original design information. Adjustments can be made for the revamp design. Typical examples are shell and tube exchanger fouling rates that are higher than the original design and under-performing air coolers with low observed heat-transfer coefficients.

Especially important is establishing an accurate benchmark for the reactor-loop pressure drop. Rarely is it possible to obtain a complete pressure profile to identify the individual equipment and piping pressure drops in the reactor loop. Estimates based on actual equipment design characteristics and approximations of piping equivalent length must be completed and reconciled with plant measurements to develop the hydraulic model

Process design. The model prepared for the benchmarking effort is adjusted to the revamp conditions for each design case. Heat and material balance(s) are defined. This information is then used to determine required modifications to existing equipment and performance requirements for new items. Usually equipment data sheets are not needed for the 25–35% accuracy level of estimate. A sized-equipment list with sufficient design details for obtaining phone/fax quotes from vendors will suffice.

Typically economic evaluations are made for various options being considered based on the capital and estimated operating costs. These evaluations become the basis for the refiner decision-gate analysis. If the project proceeds to the next stage, most of the process design work is recoverable as long as the design basis does not change significantly. This underscores the need to emphasize the design basis early in the study.

Following equipment scope determination, process flow diagrams and P&IDs are revised to show new and modified equipment and control systems. The existing unit P&IDs are hand marked by the contractor process engineers, becoming the basis for early estimating and design. These P&IDs are later finalized.

Engineering design. Factored cost estimates are not suitable for revamp projects unless the refiner is only interested in order-of-magnitude accuracy. For a 25–35% accuracy estimate, additional engineering details are needed. These are prepared by various contractor discipline engineers based on the process engineering definition provided:

▶ Plot availability for new equipment is field verified and incorporated into constructability planning. New reactor placement becomes a major consideration.

▶ Piping designers use the marked-up P&IDs and go onsite to prepare preliminary isometric sketches of major new lines. Piperack availability is verified for proposed new lines and major demolition scope is defined.

▶ Civil engineers estimate quantities for new foundations and prepare preliminary sketches for new structures. Potential major structural interferences are identified. Checks are made for potential underground obstructions which could impact foundation design and underground piping or electrical additions.

▶ Instrument engineers prepare an instrument index showing all new components and obtain costs for each item. Limitations in existing DCS systems are identified.

▶ An electrical engineer works with the owner's counterpart to identify significant electrical infrastructure deficiencies and define the electrical scope of work.

▶ A construction specialist inspects the site to identify any constructability concerns including transportation of new equipment in the plant.

This level of detailed engineering effort actually yields a cost estimate with an accuracy in the range of 20–25%. The engineering scope can be reduced by using a cost estimator to execute some design-engineer tasks. The impact on cost to prepare the feasibility study, however, is not significant.

Based on the engineering design, specialist determinations and sized equipment list, an estimate of field labor man hours is prepared. Labor costs are estimated based on plant wage rates and productivities. Other cost items that will be considered are indirect labor costs, engineering, owner's cost, contingency and escalation.

A reasonably accurate revamp project cost estimate can now be prepared for a modest cost. If project benefits do not support the owner's financial performance requirements, the project can be canceled or delayed without significant penalty. If the project proceeds, most of the process design work will be recovered unless the design basis changes.

Other project-related activities including early checks on potential long-lead equipment deliveries are pursued and preliminary scheduling activities are prepared. A key step is integrating the refinery turnaround scheduling into the overall project definition to ensure process configuration compatibility with the turnaround restraints.

Completing the revamp feasibility study enables a thorough evaluation of the various options for meeting ULSD standards. During the feasibility study a preliminary project execution plan can be prepared along with a project schedule. The cost to execute the next project phase can also be prepared.

Options for success. To meet ULSD requirements, many US refiners will consider revamping their existing distillate HDS units. Success for these projects is driven by accurate front-end process design and catalyst technology selection as well as project development and execution planning. Executing revamp projects under a staged-project management process requires a disciplined approach that involves more detailed engineering development as compared to grass-roots projects. The options phase, undertaken by an experienced process design group, is paramount for developing an accurate cost estimate and is key to successful project execution.

As a ULSD project is developed, the refiner has several choices for sourcing the engineering deliverables at various phases of development. Individually, this information can be obtained from a catalyst supplier/technology licensor, process design consultant and engineering company. Alternatively, an engineering company, with an experienced process design group, can provide many engineering functions and effectively integrate the catalyst technology with the required equipment revamp. This includes interaction with the catalyst suppliers/licensors to match the reaction process condition, with the design characteristics of the existing HDS reactor-loop equipment and piping. **HP**

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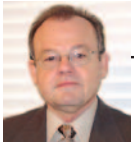

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On the Cover: 3D view of National Cooperative Refinery Association (NCRA) grassroots FCC-feed mild hydrocracker at the McPherson, Kansas refinery. Construction is expected to be completed by late 2005. Mustang provided the FEED, procurement and detail design for this major project.

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