Abstract

In today’s refining industry, process flexibility is a key component in maximizing refinery profit. Changing petroleum markets can provide opportunities to improve net operating margin if the refinery has the capability to capitalize on price-advantaged crude stocks and a market-driven product slate. For most refineries, this type of flexibility starts in the crude unit. Production bottlenecks in the crude unit, particularly in the back-end vacuum distillation section, can limit a refinery’s ability to process many advantaged crudes on the market today. However, crude unit revamps can be cost prohibitive if the engineering design does not fully consider the practical aspects of modifying an existing unit. Revamp execution must also be performed while minimizing shut-down duration, as the added costs of an extended shut-down can compromise overall project economics.

The ConocoPhillips refinery in Ponca City, Oklahoma recently completed a project to improve refinery profitability through increased flexibility of their No. 1 Crude Unit. The revamp, which focused primarily on improvements to the vacuum distillation section of the crude unit, has enabled the refinery to significantly improve their net operating margin by processing a wider variety of advantaged crudes. This complex revamp was performed during a normal turnaround schedule, based on smart engineering design and effective constructability planning.

Background

In late 2001 the ConocoPhillips refinery in Ponca City, Oklahoma initiated a project to increase the processing flexibility of their No. 1 Crude Unit. The project would expand the unit’s capability to process price-advantaged crudes, and would significantly increase the total gas oil production from the unit, taking advantage of spare FCC capacity in the refinery.

In early Front End Loading (FEL) engineering, several alternatives were investigated to meet the project’s objectives. Each alternative required consideration of the practical issues associated with the revamp of an existing unit. The FEL process determined that the project would need to focus primarily on debottlenecking and improving the performance of the vacuum distillation section of the crude unit. The existing crude unit would be incapable of processing significant amounts of advantaged crude, as the vacuum tower, vacuum heater, and associated peripheral equipment were not sufficiently sized for recovering the additional heavy vacuum gas oil (HVGO) that would be produced. Additionally, it was determined that the increased recovery of gas oil would need to be performed while maintaining a current limit on vacuum residuum (resid) to the coker. This limitation would require a significant improvement in vacuum unit performance, and a focus on increasing the HVGO to vacuum resid cutpoint.

The project vision was that an increased percentage of advantaged crude would result in lower refinery feedstock costs, and the production of additional gas oil would allow use of existing spare FCC capacity to significantly improve the overall margin per barrel. Also, as crude pricing and availabilities shift in the future, the refinery would have the process flexibility to change accordingly. However, it was clear that the capital cost of a complex revamp could easily compromise the overall project economics without good engineering design, and a significant focus on realistic revamp limitations and constructability. Challenges for the project included fixed capital cost constraints, work in an existing unit with limited plot space availability, and the objective of implementing all revamp changes in a normal turnaround schedule to protect the overall return on investment.

By the end of FEL engineering, the project scope was defined to include a new vacuum tower, new vacuum furnace, and new overhead vacuum system (Figure 1). The revamp would also require significant modifications to the crude pre-heat train, and the modification or replacement of several pumps in the unit based on the revised operating conditions.
Optimizing the Design for Refinery Flexibility

1.0 Front End Processing for Advantaged Crudes

The focus of this paper is primarily on the design and revamp of the vacuum distillation section of the Ponca City crude unit. However, the project basis for this revamp was an increased proportion of advantaged crude in the unit feed. These crudes are typically heavier, and more difficult to process due to potential factors such as increased salts, sulfur, metals, or higher acid numbers than lower cost feeds. Based on these considerations, several design issues were addressed as part of the crude/vacuum unit revamp.

The first and most obvious limitation to processing heavier advantaged crudes is crude hydraulics. Prior to the revamp, the Ponca City unit was limited by crude hydraulics at the front end of the unit (from the raw feed pumps to the desalters). While most of the preheat train over this section was already separated into two parallel paths, feed piping from tankage to the unit was transferred in a single, undersized line. This section of piping represented a significant bottleneck in the system and was modified to use an existing line in parallel, thereby providing added hydraulic margin to allow the feed of heavier crude charge. Additionally, exchanger and controls modifications were implemented to allow desalter temperature to be increased with
heavier feeds, which was required to allow desalter performance to be maintained. The first stage desalter PRV was also modified to a pilot operated valve, allowing operating pressure to be pushed closer to set pressure without valve chattering and loss of feed.

At the atmospheric (ATM) crude tower, several modifications were made to the bottom stripping section and boot. In the stripping section, the existing trays were replaced with new two-pass trays, and the stripping steam rate was maximized to the limits allowed by the existing overhead system. The existing ATM tower bottoms pumps were limited by NPSH, and therefore tray spacing in the stripping section was reduced to allow the boot operating level to be increased. These modifications maximized AGO recovery, and allowed for the existing pumps to be maintained with minor modification.

At the intermediate flash tower, the bottoms pumps were modified (including a new motor and turbine upgrade) to allow for the increasing vacuum unit charge rate. The operating level in the intermediate tower was also increased to account for increased NPSH requirements at the new pump design rates.

2.0 Vacuum Tower Design

The definition of a “deep cut” design is somewhat relative, based on a specific refinery’s experience, feed stock variation, and downstream product limitations. The design point for “deep cut” can range from anywhere above 1000 °F to as high as 1100-1150 °F.1,2 In any case, the main idea is the same; to cut “deeper” into the vac resid bottoms, with the objective of recovering a high proportion of vacuum gas oils, while minimizing the vacuum tower bottoms rate to downstream units. For the Ponca City revamp, the design cutpoint was based on a target of 1050 °F. This was the basis for process and equipment design, although project economics were considered at a value slightly less than 1050 °F to allow for feed stock uncertainties.

Vacuum tower design was critical in meeting the project objective of a “deep cut.” The sizing basis of the vacuum tower was unique and illustrates the type of design consideration that must often be made in a unit revamp. Capital cost constraints, combined with plot space limitations in the existing vacuum unit, dictated that the new vacuum tower be installed in the same location as the existing tower. Due to constructability issues, and the desire to minimize turnaround duration, the new tower would need to be installed on the existing foundation if at all possible.

The final tower sizing was determined through a coordinated effort between process and structural engineering. The existing foundation set the overall dead weight limit for the new tower, with the structural design limit based on a liquid-full upset condition. Minimum depth beds were employed to keep the tower weight down, and pumparound distributors were arranged to utilize every inch of available height in the tower (including installation of the LVGO collection tray and HVGO spray distributors in the upper transition section). Once the minimum height was established, the tower diameter was maximized to the limits allowed by the foundation capacity. The result of this analysis determined that a 22 ft diameter tower could be safely installed on the same foundation as the existing 15 ft diameter tower. By installing the largest tower possible on the existing foundation, long term return on investment would be maximized, and the tower diameter would allow significant processing flexibility for future requirements. Figure 2 illustrates the vacuum tower layout for the new 22 ft diameter tower.

The vacuum tower was designed as a “wet”, or “damp” unit, utilizing both heater velocity steam and vacuum tower stripping steam.5,6 This arrangement reduces hydrocarbon partial pressure to
increase lift, and the use of velocity steam in the heater helps to ensure tube velocities are sufficient to minimize long-term coking.

The process design of the tower was based on a flash zone pressure of 37 mmHg. This flash zone pressure was determined through an optimization analysis considering several process parameters, interrelated in the operation of a vacuum tower. Parameters that require consideration include target cutpoint, heater outlet temperature, transfer line pressure drop, pumparound duties, and product draw temperatures. Intuitively, the lower the operating pressure, the better. At an equivalent cutpoint, lower pressure results in a reduced heater outlet temperature, which leads to reduced oil film temperatures in the furnace, and reduced coke formation and production of cracked gas. However, these benefits must be balanced against increased transfer line and tower sizing requirements, reduced product draw temperatures (thereby reducing temperature differentials on crude preheat exchangers), and increased vacuum system sizing. After consideration of all variables, the optimum flash zone pressure was selected at 37 mmHg. At this flash zone pressure, a 1050 °F cutpoint could be achieved while maintaining a maximum heater outlet temperature of 780 °F.
The vacuum tower internals were provided by Koch-Glitsch, LP.\(^3\) The internals design was based on a coordinated effort between Koch-Glitsch, ConocoPhillips internal fractionation consultants, and Burns & McDonnell.

The inlet nozzle utilized a Koch-Glitsch “enhanced” radial vapor horn, providing low inlet device pressure drop, combined with effective velocity distribution and vapor/liquid separation. The tower boot was designed with a steam stripping section, using five two-pass fixed valve trays with an upper chimney tray distributor. The amount of stripping steam to the vacuum tower was optimized based on a balance between HVGO recovery and the capital/operating cost for the incremental stripping steam. The design was based on a stripping steam rate of 2,500 lb/hr with a
maximum rate of 4,000 lb/hr (nominally 3.5 to 6 lb/BBL vacuum resid product). Figure 3 illustrates the results of the stripping steam optimization. This optimization analysis does not include consideration for the impact of velocity steam. When used, velocity steam can typically off-set a portion of the stripping steam required at equivalent cutpoint. The relative effectiveness depends on the specific installation, and requires optimization following start-up. For this project, it was estimated that 1 lb/hr of velocity steam would allow stripping steam to be reduced by as much as 0.5 lb/hr at equivalent cut-point. Operating data from the first year confirms that this off-set is nominally correct.

![FIGURE 3 – Effect of Stripping Steam on Vacuum Tower Performance](image)

The wash section of the new tower utilized a “combination” bed consisting of a bottom section of open grid packing, with an upper section of high-efficiency structured packing. This design provides general droplet de-entrainment and fouling resistance in the lower grid section, combined with increased surface area and fractionation performance in the upper structured packing section. Wash zone design is a critical aspect of long term vacuum tower performance. Adequate wash oil rate is important for maintaining HVGO product quality, and to minimize wash bed coking. The wash oil rate at the top of the wash bed was based on maintaining a target minimum wetting rate of 0.15 gpm/ft² at the bottom of the wash bed. This is a typical guideline, which is consistent with most applications in the literature. The wash oil draw (or overflash), which consists of excess liquid from the wash section plus any flash zone entrainment, was designed to either recycle back to the inlet of the heater or bypass directly to the tower boot (introduced just below the tower inlet device). For the Ponca City revamp, a cost-benefit analysis for wash oil recycle indicated the potential recovery of 0.3 to 0.5 bbl of HVGO per bbl of recycle. This provides a significant economic payback versus the bypass of overflash to the vacuum tower boot, as long as sufficient vacuum heater capacity is available to heat the added recycle.
The HVGO and LVGO pumparound sections were designed utilizing multiple layers of high efficiency structured packing for optimal heat transfer performance and fractionation. Both pumparound distributors were installed using a spray type design, with the LVGO collector tray and HVGO spray headers being incorporated into the upper cone transition to minimize tower height.

One of the challenges of any “deep cut” design is in properly characterizing the heavy region of the assay (1000-1300 °F). This data is critical, as it is the basis for the development of hypothetical components to be used in process simulations and yield projections. Several papers have stressed the use of high temperature “simulated distillation” to define the TBP curve percent recoveries for fractions up to 1300 °F.\textsuperscript{2,3,5,7} This is a valuable method for obtaining an accurate characterization for a specific crude sample. However, crude slates change, and the impact of slight variations in feed can create significant variations which may overshadow the apparent “accuracy” of a design basis assay.

Figure 4 compares three of the design crude slate assays considered for this project. These assays on a full 0-100% scale appear “similar”. However, a more focused analysis of the range around the 1050 °F point illustrates that the actual liquid volume percent recovery at 1050 °F could vary by as much as 2-3% (Figure 5), depending upon the “actual” crude slate. This point is not to minimize the importance of good feed characterization, but rather illustrates the fact that differences in actual feed stocks can introduce significant performance variation when making predictions on cutpoint. To design a truly flexible crude vacuum unit, it is critical to define a realistic range of feeds that can be expected after start-up.

![FIGURE 4 – TBP Data for Design Basis Crude Slates](image)
3.0 Vacuum Heater Design

Once the vacuum tower sizing was established, the vacuum heater design was developed with two primary objectives. The first, and most obvious objective, was that the heater would be designed to provide the design duty required to meet the target cutpoint for the project (target design cutpoint of 1050 °F). Second, the heater would be designed based on providing a “matched” heater design for the 22-ft vacuum tower. This criterion was used to maximize total return on investment and future operating flexibility.

The heater design utilized a 4-pass “nested” design with 2 passes on each wall. The 4-pass design was selected to minimize project capital cost while maintaining high mass flux rates, and minimizing heater velocity steam to limit overhead vacuum system sizing. The heater was designed for a maximum peak heat flux of 17,500 Btu/hr-ft² and an average radiant heat flux of less than 10,000 Btu/hr-ft² (actual flux at design was 9,300 Btu/hr-ft²). These values are consistent with typical recommended values in the literature.5,7 The final tube size in each pass was 10 inch diameter with 12 inch outlet connections, pushing the physical limits of heater design. In order to maintain reasonable oil film temperatures, the mass flux rate was kept above 80 lb/sec-ft². Velocity steam at a nominal rate of 300 lb/hr per pass was used to keep mass flux rates up, and minimize long term coking tendency.

The hydraulic design was based on the 37 mmHg flash zone pressure and a maximum transfer line pressure drop (including the tower inlet device) of 3 psid. This pressure drop requirement
was established to allow the heater outlet temperature to be maintained at a maximum of 780 °F, while achieving the target 1050 °F cutpoint for the full range of design crude slates. As with the vacuum tower, plot space constraints required that the new heater would need to be installed in the same location as the existing. The existing foundation was extended pre-turnaround to accommodate the expanded heater footprint.

Transfer line design is a critical and inseparable component to overall vacuum heater design. Without a properly designed transfer line, even the best tower and heater design will not meet the performance objectives of the unit. Design of the transfer line was a particular challenge due to the existing layout, which positioned the heater and tower in relatively close proximity and in direct line with one another such that there were few alternatives for providing for thermal expansion. Numerous transfer line routings were analyzed using a coordinated effort between process, structural, and pipe stress engineering. Figure 6 illustrates the layout of the final transfer line design.

The transfer line hydraulics were designed with a target maximum velocity of 80% of sonic for the vapor phase. Figure 7 illustrates the transfer line velocity profile, and Figure 8 illustrates the calculated pressure profile from the heater outlet to the vacuum tower inlet.
Transfer line transitions from vacuum heater outlet to flash zone.

FIGURE 7 – Transfer Line Velocity Profile

Transfer line transitions from vacuum heater outlet to flash zone.

FIGURE 8 – Transfer Line Pressure Profile
4.0 Overhead Vacuum System Design

The overhead vacuum system was designed to maintain a vacuum tower overhead pressure of 27 mmHg, corresponding to a target flash zone pressure of 37 mmHg. The most difficult aspect of properly sizing a vacuum tower overhead system is in predicting the cracked gas rate. Typically, cracked gas rates can range from 0.3 wt% to greater than 1.0 wt% (wt% cracked gas vs. vacuum heater feed). Cracked gas production is a product of furnace outlet temperature, peak furnace oil film temperatures, furnace residence time, and crude oil stability. The cracked gas design basis for this project was defined based on internal ConocoPhillips empirical data, combined with individual reference points from recent projects. Figure 9 illustrates the impact of cracked gas production versus furnace outlet temperature. As indicated, cracked gas production increases quite rapidly at furnace outlet temperatures above 800 °F. Empirical relationships can be helpful for estimating cracked gas rates, yet actual performance is highly dependent on the unique combination of crude slate and specific unit design parameters. Where possible, test data is always preferred to ensure vacuum system sizing is sufficient for the application.

FIGURE 9 – Cracked Gas Rate vs. Outlet Temperature (Typical)

One unique aspect of the Ponca City crude unit is the presence of an intermediate flash tower, located between the atmospheric and vacuum units (Figure 1). This section of the crude unit takes reduced crude from the atmospheric tower bottoms, reheats this stream using an intermediate heater, and flashes off an additional gas oil product prior to continuing to the vacuum heater. This added step of reheat, and additional residence time at high temperature may
lead to some additional instability in the vacuum unit feed, which can also result in higher than expected cracked gas production.

Final vacuum system sizing was based on a relatively conservative cracked gas rate of nominally 0.7 wt% of feed at a heater outlet temperature of 780°F. This design basis allowed for some of the unique aspects of the Ponca City crude unit, as well as flexibility to handle changing feed characteristics. The vacuum system equipment was designed to allow for operational flexibility and optimization. A three stage system was installed with three parallel ejectors on the 1st stage and two parallel ejectors on the 2nd and 3rd stages. Parallel ejectors provide added flexibility, allowing one or more ejectors to be taken out of service when cracked gas loads dictate to minimize steam requirements for the system. A kickback recycle from the 1st stage discharge to the 1st stage suction allows pressure control with changing vacuum tower overhead rates.

5.0 Crude Preheat Train Modifications

One area where operational flexibility can be critical is in the crude preheat train. Figure 10 shows the crude preheat train prior to the revamp.

![Crude Preheat Train Diagram](image)

**FIGURE 10 – Crude Preheat Train (Before Revamp)**

The Ponca City No.1 crude unit preheat train can be divided into three sections.

- Heat exchange with light products before the desalter.
- Heat exchange with intermediate products from the desalters to the atmospheric tower preflash.
- Heat exchange with heavier products vs. preflash bottoms.
Under the new crude unit operation, significantly more heat would be available at the back end of the unit, where HVGO pumparound duty and vacuum tower boot quench rate would be significantly increased. These increased duties required additional heat transfer area to be installed for HVGO vs. crude service and vacuum resid vs. crude. The crude preheat design also required optimization of overall heat recovery versus vacuum tower flash zone pressure. As discussed previously, lower flash zone pressure is generally preferred, as this allows furnace outlet temperature to be reduced at equivalent flash zone vaporization. However, reduced operating pressure also results in lower gas oil draw temperatures, which can significantly impact the crude preheat design.

Once the optimum vacuum tower flash zone pressure was set, a simplified pinch analysis was performed to optimize the location of new exchangers under a variety of conditions. Rather than designing new exchangers for a single, worst case scenario, the system was designed to provide operational flexibility under a range of current and future crude slates. A rigorous pinch analysis, while ideal for a grassroots installation, is not always realistic for a unit revamp. Revamp design must consider the practical aspects of the existing unit, including overall layout, exchanger network configuration, and revamp constructability.

The heat train analysis identified areas where the flexibility of the system could be improved by providing the capability to shift heat loads from one section of the heat train to another. For example, one piping modification allowed exchangers located downstream of the desalters to be shifted to an upstream position. This swing configuration allows desalter temperature to be increased, as required, to maintain desalter performance when heavier crudes are fed to the unit. Additionally, the piping to an existing resid exchanger was modified to allow swing operation from downstream of the preflash drum to a location upstream. This configuration allows preflash temperature to be adjusted as required for various feeds. Finally, heat train flexibility was implemented for vacuum resid cooling. This was required to allow resid cooling to be maximized during a coker outage scenario when vacuum resid must be sent to storage. Figure 11 shows the crude preheat train following the revamp.
By having the process flexibility to shift heat duties within the preheat train, the refinery is still capable of processing past crude slates, as well as a 100% advantaged crude slate, while maintaining high energy efficiency and optimum desalter and preflash performance. Adding flexibility to the design, rather than just adding more exchanger surface area, will result in improved profitability long term, with minimal added capital investment.

One unique application applied as part of the Ponca City revamp was use of an Alfa Laval Compabloc® heat exchanger in the new HVGO vs. crude service (Figure 12). The available plot space near the existing HVGO exchangers was extremely limited, and significantly more exchanger surface area was required due to the large increase in HVGO product. Compabloc® exchangers are fully-welded cross-flow plate heat exchangers which provide extremely high heat transfer coefficients in a small, compact unit. Since the application was novel, two Compabloc® exchangers were installed in parallel. The second exchanger was designed to normally function as an installed spare, but was also considered for operation in parallel under certain operating modes when HVGO duty would need to be maximized. Even with the installation of a full-sized spare, the two Compabloc® exchangers required less plot space than the multiple large shell and tube exchangers which would have been required to achieve the same duty. The exchangers installed each contain over 2,100 ft² of surface area with a design duty of approximately 27 MMBtu/hr. The overall performance of these exchangers, in what is a first-of-a-kind U.S. application, has been a key point of interest following start-up from the revamp. An overall summary of performance is provided in the results section of this paper.
Construction and Turnaround Execution

A key economic driver in the crude/vacuum unit revamp was to complete construction during a normal scheduled turnaround. Based on layout constraints in the unit, the major pieces of new equipment, including the vacuum tower, vacuum heater, and overhead vacuum system, had to be installed in the same location as the existing equipment, requiring the demolition of old equipment and installation of new to be performed during the turnaround.

Prior to the turnaround, the new vacuum tower and vacuum heater were fully erected on temporary foundations, and completely dressed to the maximum extent possible (Figure 13). Complete installation of all tower internals, insulation, instrumentation, ladders and platforms was performed pre-turnaround. The vacuum heater box was fully assembled, with the heater design allowing the entire unit (less the stack) to be moved from the temporary foundation to its final location in a single lift. Within 10 days of
the start of the turnaround, the old vacuum tower and heater had been removed and the new tower and heater set in place on the existing foundations.

![New Heater and Tower On Temporary Foundations (Pre-Turnaround)](image)

In addition to the new tower and heater, turnaround activities included the installation of three new crude preheat exchangers (one shell-and-tube, and two Compabloc® exchangers (Figure 14)), the relocation of one existing shell-and-tube exchanger, the installation of a new three-stage overhead vacuum system, two new HVGO pumps, and over 5,700 feet of piping modifications. The steam ejector vacuum system was field assembled onto a single skid incorporating the large 1st and 2nd stage ejectors and heat exchangers. This allowed the majority of the new vacuum system to be installed in a single lift (Figure 15).
The revamped crude/vacuum unit started up in November of 2004. The key project objectives were: 1) improve refinery profitability through increased capability to process price-advantaged crudes, and 2) increase vacuum gas oil recovery to take advantage of spare FCC capacity in the refinery. Based on these objectives, the project results are simple – the unit has proven fully capable of running 100% advantaged crude, and the incremental gas oil produced has completely utilized all spare FCC capacity. In a nominal market the project was expected to provide very good earnings with an approximate two-year simple payback. However, with the market conditions of 2005, return on capital well exceeded expectations.

The Ponca City refinery runs a continuously variable crude slate. This reality combined with the myriad other refinery factors that impact day-to-day operation, make it difficult to draw exact apples-to-apples comparisons between pre- and post-project performance. The results presented consider two bases for comparison. The first is a review of data for the two-month period of May/June 2004 (peak gasoline season) versus the same period for 2005. This comparison provides a basis where seasonal drivers for refinery operation would be roughly similar. The second basis is a comparison of the best 7-day average of 2004 to the best 7-day average of 2005 for each performance variable. Figure 16 illustrates some of the overall unit feed and product results, and Figure 17 provides results specific to the increased production of HVGO.
Figure 16 – Project Results – Feeds/Products

In an overall feeds/products comparison, the key performance indicators include overall charge rate, crude API gravity, vacuum tower feed rate, ratio of HVGO recovered versus crude charge, weight percent 1050 °F and lighter in vac resid, and vac resid rate.

Capacity increase was not an objective in the design basis for the project. However, it was acknowledged during FEL that a slight rate increase could be expected due to the inherent flexibility of the revamp design. The May/June comparison data reflects a crude rate increase of nominally 10% following the revamp, with a corresponding reduction in API gravity of 11%. The best-of comparison showed the same directional improvements, though slightly less in magnitude (9% and 7%, respectively). For the May/June data, vacuum tower feed increased by 15% from 2004 to 2005, and this increase was 23% comparing the best of 2005 versus 2004. HVGO versus crude ratio increased by over 70% and 60%, respectively, from 2004 to 2005, for the two comparison bases. For the weight percent of 1050 °F and lighter material in the vacuum resid, the results were independent of the basis with reductions of 54% and 56%, respectively. Finally, the vacuum resid rate in the two comparisons was essentially unchanged at +3% and -4%. This result is consistent with the design objective of increased gas oil recovery while maintaining a fixed limit for vac resid feed to the coker.
For HVGO product and quality, key performance indicators include HVGO rate, cutpoint, API gravity, and metals/concarb content. Both comparisons show an HVGO rate increase of nominally 90% post-revamp. HVGO cutpoint showed a 9% increase in the May/June comparison, with this figure being 7% when comparing the best-of results.

Cutpoint alone does not demonstrate the true performance of a vacuum tower. Gas oil quality is critical, and has a significant economic impact on downstream units. Metals content (nickel plus vanadium) has decreased dramatically post-revamp (85%), with concurrent reduction in Conradson Carbon residue by 40 to 60%. A further illustration of this improvement is the reported change in appearance of the HVGO product; from a black or very dark-green color pre-revamp to a transparent dark-amber color post-revamp.

A final area of interest has been the performance of the new Alfa Laval Compabloc® exchangers, which were installed in HVGO vs. crude preheat service. These exchangers were selected due to limited plot space availability, and lower total installed cost (particularly when higher metallurgies are desired). The key controlling factor for these exchangers has been crude-side pressure drop (HVGO side pressure drop has not noticeably increased). The first exchanger exhibited a run length of approximately 5 months before operations decided to switch to the spare exchanger due to hydraulic limitations. Crude-side pressure drop on the second exchanger appears to be increasing at a slower rate than was observed on the first unit (perhaps indicating some start-up pluggage that may have occurred on the first exchanger). Despite increased pressure drop, heat duty performance for the exchangers has been relatively constant (actually exceeding the design heat duty). Currently, ConocoPhillips operations is experimenting with
on-line cleaning alternatives. An initial attempt in September of 2005 using LCO circulation provided mixed results. However, the manufacturer expects that on-line cleaning will offer acceptable results once a fit-for-purpose cleaning procedure is established. Mechanical cleaning (hydroblast) is also an alternative being considered, as the exchanger side plates are fully removable to allow mechanical cleaning.

Conclusions

The ConocoPhillips refinery in Ponca City, Oklahoma recently completed a project to improve refinery profitability through increased flexibility of their No. 1 Crude/Vacuum Unit. This revamp, which focused primarily on improvements to the vacuum distillation section, has enabled the refinery to significantly improve their net operating margin by increasing the unit’s capability to process a high percentage of price-advantaged crudes.

The design features of this project illustrate some key considerations in developing a robust and flexible crude unit revamp. Unlike a grass-roots design, successful implementation of a revamp requires full consideration of the practical aspects of modifying an existing unit; considerations such as existing equipment limitations, layout constraints, and overall constructability.

The results of the Ponca City revamp have met or exceeded the performance expectations of the project. Gas oil rates have been increased through a combination of crude slate modifications and increased cutpoint. Gas oil quality has been significantly improved versus past operation. Process results from the first year indicate the unit’s capabilities have not been fully challenged, yet the unit should have the flexibility required to reach the next level as downstream limitations are addressed.

Acknowledgements

Any project, regardless of size, comes with a list of critical success factors (CSFs); those elements, without which, the project is scripted for failure rather than success. A few are common to all projects, and some are project-specific. Many are organizational and culture-driven, and others are technical. Corporate and local management invariably hold the master keys to the switches that energize or de-energize the circuits of these CSFs. When a project is successful, it’s an indicator that, from top-to-bottom, you nailed the CSFs. This project has its own list. We wish to acknowledge a specific few.

A significant driver for the success of this project was the great effort put forth during front end process engineering to leverage the experiences of, and lessons learned from, past vacuum tower projects at ConocoPhillips. Without naming them individually, a number of ConocoPhillips personnel played important roles in bringing those lessons to bear, particularly the company’s in-house fractionation consultants, and the personnel that participated in the many peer reviews the project underwent. We would also be remiss not to acknowledge the contributions of the Ponca City West Plant operators and area engineers, who contributed invaluable knowledge and expertise from the earliest stages of project development through design and construction. Finally, as with any successful major project, we acknowledge the many people, far too numerous to name, consisting of the various engineering and administrative disciplines in ConocoPhillips and Burns & McDonnell, whose dedicated efforts and talent helped to make the vision a reality.
References


