Keeping down the cost of revamp investment

A comparison of the standard versus practical approach to the revamping of a crude unit. In this article the focus is on optimising the use of existing equipment, changing the process flow scheme to minimise flash zone pressure and thereby maximising the yield

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Revamping integrated atmospheric crude-vacuum units requires an evaluation of the overall unit operation. Increasing charge and improving distillate yield involves a thorough understanding of the existing equipment constraints. To achieve the objectives with a minimum cost solution requires maximising use of existing equipment. New equipment requires capital funds that are scarce in the modern competitive refining industry. Projects must have quick returns and low sensitivity to factors that could compromise economic incentives.

Inaccurate evaluation of unit limits wastes capital (fixing non-problems) and reduces unit reliability (real problems not fixed). The integrated conceptual revamp approach can easily be the difference between an expensive and unjustifiable project and one with excellent return on investment.

The revamp of a 58,000 bpd (384 M^3/hr) crude unit is examined to illustrate how minimum cost solutions can be applied to a crude unit by modifying the process flow scheme and applying changes to best utilise the existing equipment. The objective of the revamp was to increase crude capacity by 20 percent while achieving unit reliability objectives and maintaining or improving product yields (measured as a percentage of crude) and quality.

The project was divided into two phases to manage capital expenditures. Phase I included required modifications to achieve a smaller incremental charge rate increase and meet all reliability and yield objectives. Phase II incorporates the remainder of the modifications to reach the final throughput goal.

Unit operations are set by the real-world performance of the specific equipment in the unit. Back-office calculations based on “typical” units both misidentify and miss unit limitations. For example, back-office calculations make assumptions about residue stripping tray efficiency. Good efficiencies in these services range from 30 percent to 35 percent. Many units suffer from poor reliability and design and have efficiencies of zero to 5 percent. One response by many contractors to their inability to properly design this equipment is to assume a 5 to 10 percent tray efficiency.

Low expectations avoid disappointments, but leave much of the recoverable diesel in the atmospheric tower bottoms. The results of standard project approaches breed low expectations. Integrated practical approaches to revamp design combine the best elements possible from improved equipment operation and process flow sheet changes. This minimises capital investment and maximises profits.

General crude unit limits

Crude unit revamps must balance the product yields in the distillation columns to stay within the major equipment limits. Major equipment includes fired heaters, distillation column vessels, hydraulic systems, and the heat exchanger network. A typical crude unit has an atmospheric and vacuum column. Some have a preflash column or drum located between the desalter and the atmospheric column. A few crude units have a moderate pressure vacuum column between the atmospheric and vacuum column. A crude unit revamp will determine the individual column product yields based on the major unit equipment constraints.

Feed enthalpy, flash zone pressure, stripping section performance, and overflash requirements set potential distillate yield from an atmospheric crude column. Reliable quality control of the lowest product side cut also depends upon the equipment performance. Cutpoint balancing between the atmospheric and vacuum columns provides a means to debottleneck existing equipment, upgrade the temperature levels available for

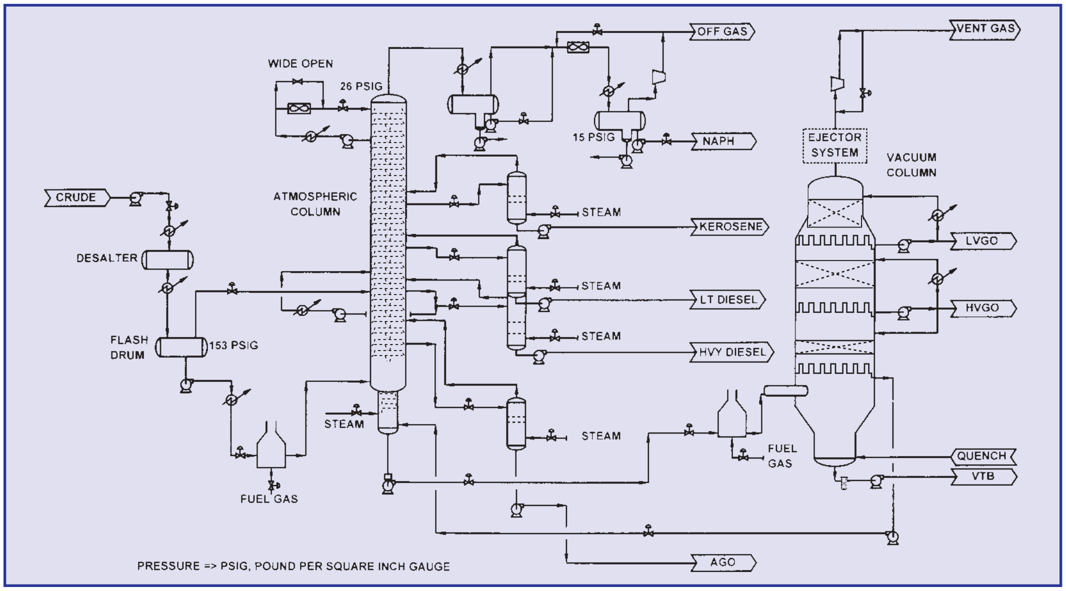

***Figure 1** Before revamp unit configuration*

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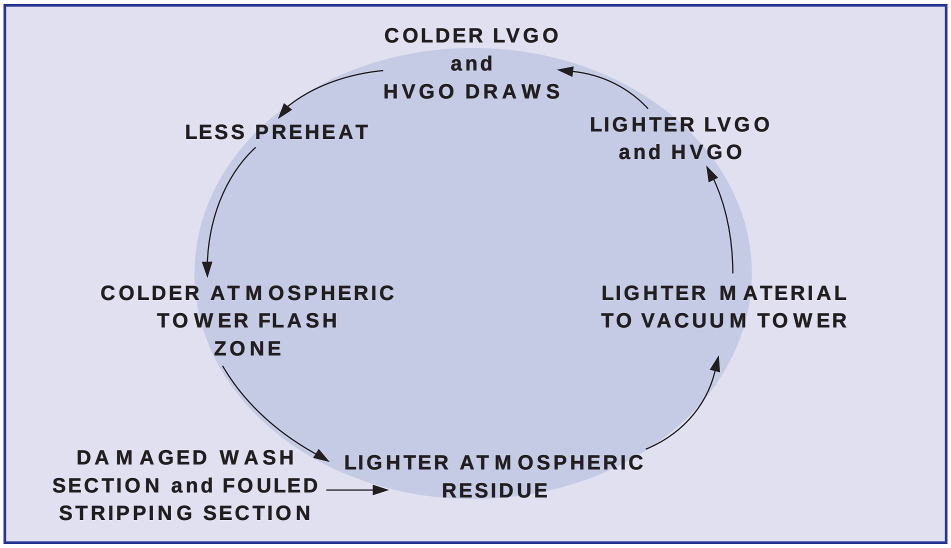

Figure 2 *The way poor equipment performance affects the process*

preheat to increase heat recovery potential, and increase diesel and gas oil yields.

Preflash column cutpoint balancing (if a preflash column exists) adds extra flexibility to circumvent major equipment limits as well. Moderate pressure vacuum columns are installed when both the atmospheric and vacuum column vessel diameters limit crude capacity.

Crude oil heat exchanger network and heater performance set total crude column feed enthalpy. Increasing atmospheric column distillate yield (atmospheric column cutpoint) shifts light vacuum gasoil (LVGO) product into atmospheric gasoil (AGO) and diesel. High AGO cutpoints move diesel boiling range material out of the LVGO product and into atmospheric column diesel by increasing crude column oil vaporisation.

Increasing the atmospheric column cutpoint decreases the LVGO product rate. This reduces heat losses to air/water that occur in the LVGO pumparound. This improves preheat performance.

Increasing the crude preheat exchanger network and heater capabilities to increase feed enthalpy is one way to improve unit performance and yields [Barletta A F; Practical considerations for crude unit revamps; *Petroleum Technology Quarterly*, Autumn 1998].

This article focuses on another way; optimising the use of existing equipment and changing the process flow scheme to minimise flash zone pressure. Minimum flash zone pressure maximises the lift (yield) at any given temperature.

Test run operation

Unit constraint identification and analysis

The first step in any revamp is to properly determine the unit's capabilities and limits. Properly executed, the test run separates the successful revamp from the failed project. Figure 1 (preceding page) shows the before revamp unit configuration. The unit included a crude preflash drum, an atmospheric tower, and a vacuum tower. The atmospheric column performance limited crude throughput and product yields.

Test run analysis showed that the major equipment limitations were:

— Atmospheric crude tower overhead system
— Reliability of atmospheric crude tower internals
— Feed enthalpy to the atmospheric crude tower and vacuum tower
— Crude feed hydraulics.

The capacity of the overhead gas compressor was the major limitation to unit yield and as a result, throughput. The crude tower top pressure had to be raised to 25psig (172 kpa-g) or higher to keep the gas rate under the compressor capacity at 58,000 bpd of crude charge. Higher gas rates forced relieving the cold receiver vent to flare. Some crude columns run as high as 50psig (345 kpa-g) overhead pressure due to wet gas compressor or other overhead problems. Others run as low as 3 or 4 psig (21-28 kpa-g). Low atmospheric column operating pressure increases distillate yield. It also unloads the vacuum column and ejector system.

The measured overhead exchanger pressure drop during the test run was 10.5psi (72 kpa). These exchangers had reached their maximum heat removal capability at 58,000 bpd ($384M^3$/hr) crude charge. Overhead system pressure drop, heat removal limitations and offgas capacity limitations were a significant bottleneck to the crude unit's capacity and product recovery.

The atmospheric crude tower wash and stripping trays did not allow reliable operation for a four to five year run length. In fact, the average historical run length was on the order of one and a half years. Coke formation occurred in the wash and stripping section, leading to several unscheduled shutdowns. As the coke formed in the stripping section it blocked the downcomer and active area of the tray. Blocked trays cause flooding. Flooding entrained atmospheric residue up through the wash bed and into the AGO product.

To keep from flooding, the stripping steam rate was reduced to near zero. The stripping trays no longer function, therefore light material (kerosene/diesel) was fed to the vacuum column. The light material increased the vacuum column load and LVGO pumparound duty, and overloaded the vacuum ejector system, increasing the vacuum column pressure and reducing vacuum gas oil recovery [Golden S W; Troubleshooting vacuum unit revamps; *Petroleum Technology Quarterly*, Summer 1998].

The atmospheric column internals had inherent design problems that prevented reliable operation. Without replacement, equipment reliability would continue to limit the crude unit run length and product recovery.

Decreased vacuum column HVGO product yield reduces heat recovery to the crude oil preheat system. Figure 2 shows the recycle effect of reduced preheat train effectiveness typically encountered. In a unit with heaters at their firing limit, less preheat duty limits the heater outlet temperatures, dropping even more light material into the atmospheric column bottoms and making the problem worse.

Crude preheat limitations reduced crude capacity and product recovery. The atmospheric furnace's inlet (preheat outlet) temperature was relatively low due to product rundown heat losses, integration of the crude unit heat recovery with other process units, low atmospheric column cutpoint, and the inherent difficulty of heat recovery when processing light crudes. Low feed preheat temperature increases the atmospheric heaters' duty, forcing them to operate at maximum firing.

Crude charge system hydraulics is an important revamp consideration. High pressure drop in the atmospheric heater and low preheat temperatures (low heater inlet temperatures) limited crude charge during the test run. Crude charge hydraulic limitations occurred between the flash drum and the crude heater. Many atmospheric units have similar hydraulic limitations. Low heater inlet temperature increases heater firing. Often, instead of a four year run, the heater may require decoking every two to three years. Low crude column heat input reduces the distillate product yields, reduces fractionation, and downgrades diesel to FCC feedstock. High crude column operating pressure, poor stripping tray efficiency, and low stripping steam rate also reduces flash zone oil vaporisation. Low flash zone oil vaporisation results in low internal reflux. The result is low AGO cutpoint and high diesel boiling range material in the AGO product.

Test run laboratory data showed the diesel-AGO split having a D86 overlap (95%:5%) of 51˚F (28˚C). Poor fractionation is typical of many refinery crude unit diesel-AGO products. Better fractionation can drop the overlap to 25˚F to 30˚F (14-17˚C). Improved fractionation requires higher liquid/vapour (L/V) ratios in the atmospheric tower's lowest fractionation section. Liquid/vapour ratio is a measure of fractionation ability.

Diesel/AGO product fractionation is a function of internal reflux rate and the number of fractionation trays. Increasing the number of fractionation trays at low internal reflux does not improve fractionation. Low crude column flash zone vaporisation causes low internal reflux rate between diesel and AGO product.

If the light material does not vaporise in the flash zone, it is unavailable for use as reflux. Therefore, higher flash zone vaporisation increases internal reflux and AGO product yield, and decreases the amount of diesel boiling range material in the AGO and LVGO products.

The test run showed 16 percent diesel boiling range material in the FCC feed; mainly in the AGO and LVGO cuts. This was more than 4 percent loss of diesel on the entire crude.

Increasing flash zone oil vaporisation requires higher crude column pumparound heat removal. The diesel pumparound operates at maximum heat removal at all times. This maximises preheat. The crude column has a naphtha and diesel pumparound. The naphtha pumparound exchanges heat with cold raw crude oil from tankage and then returns through fin-fans to the column.

Column tray capacity and draw nozzle sizes limit naphtha pumparound circulation rate. The pumparound return temperature is maintained above 200˚F (93˚C) to minimise localised water condensation that can occur in the top section of the column. Low temperatures lead to corrosion problems in the top of the column.

The pumparound fin-fan had a bypass to control the return temperature. The bypass operated fully open in an attempt to keep the return temperature above 200˚F (93˚C). Ultimately, heat removal in the naphtha pumparound is reduced by low circulation rates. This limits flash zone oil vaporisation.

During the test run, the naphtha pumparound temperature leaving the crude exchangers was 209˚F (98˚C). The combined temperature after the fin-fans was 203˚F (95˚C). In cold weather operation, the fin-fans have colder air and remove much more heat. During cold weather, the crude versus naphtha pumparound exchangers are bypassed to keep the return temperature to the column between 190˚F and 200˚F (88˚C and 93˚C). This limited crude preheat, complicating the crude column low oil vaporisation problems.

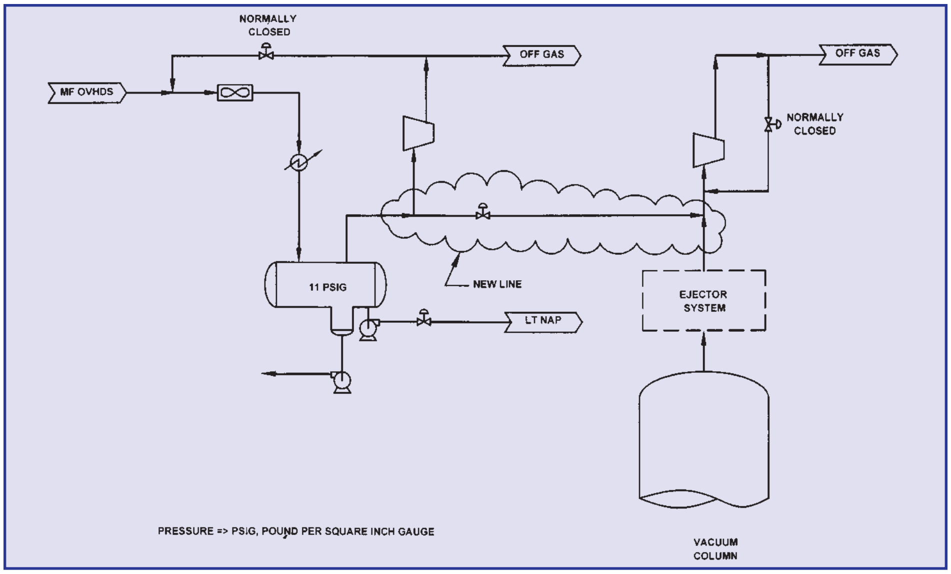

Figure 3 *Compressor debottleneck, Phase I*

Conceptual design

The most important step to control revamp costs is effective conceptual process design. Circumventing major equipment limitations is essential to minimising investment. The major equipment modifications and opportunities to circumvent the limits must be identified as soon as possible. This is not a rote project management function, but a matter of basic chemical engineering and process equipment knowledge.

Conceptual design requires a thorough understanding of the integrated crude unit as well as good engineering skills. Conceptual design is the most important revamp cost factor.

Revamp engineers must understand both conceptual process issues and equipment design details. The performance of the equipment and the process are linked. The best equipment cannot perform in a poor process flow scheme. The best process scheme will fail if the equipment does not work.

While detail equipment design is often considered a minor issue best left to the equipment vendors, there are numerous failed revamps from this approach. Both equipment and process must be understood to minimise capital investment. The initial, conceptual stage sets the capital required for the plant objectives.

Reducing costs by elimination of equipment or changes, at the end of a project (typical method of value engineering) only results in lower reliability, yield losses, and higher maintenance expenses. Value engineering is simply not effective as currently practised.

Conceptual engineering review, early in a revamp, by a qualified group of operators, process engineers, plant management, and revamp engineers is a vital function. However, this is not done with the conventional engineering approach.

Revamp objective

The objective of the revamp is to increase crude capacity by 20 percent while meeting unit reliability objectives, and maintaining or improving product yields (yields as a percentage of crude) and quality.

Conventional project approach

A typical engineering company's approach would be to tightly define the boundaries of the problem, assign specific tasks to different specialist teams, and use traditional project control methods to steward activity. Each team attempts to optimise its own area, often with little regard for the overall revamp investment or reliability.

The "throw the work over the fence to the next group" approach gives higher final revamp investment and lower reliability. The advantage of the traditional approach is ease of control and activity tracking. In a revamp, an operating unit that meets the defined objectives determines the plant's profitability; not project management tracking.

A traditional approach evaluates each piece of equipment and decides if it has sufficient capacity for the proposed operation. Equipment is added in parallel when the existing unit has insufficient capacity. As necessary, an entire extra parallel exchanger network may be added to the heat integration train to realise a crude charge hydraulic limit. Multiple parallel crude flow paths increase process control complexity, destabilise unit operation, and increase exchanger fouling due to low crude oil tube velocity. Unstable units lose money compared to stable units.

Taking the conventional approach, first examine the project consequences. The equipment already limiting at the current throughput includes the offgas compressor, the overhead condensing system, both the atmospheric and vacuum heaters, and the crude hydraulics downstream of the flash drum. Not readily apparent from the test run was the next limit, the shell diameters of the atmospheric and vacuum towers.

The existing AGO and HVGO product cutpoints could not be maintained on both columns with increased crude charge. If the atmospheric column cutpoint dropped, the column bottoms pumps would limit capacity, requiring replacement along with the vacuum column and vacuum heater. Also, lower crude column AGO cutpoints would further reduce diesel yield.

Assume the existing vacuum column and heater will be used. This requires a higher cutpoint in the atmospheric column. Assuming the flash drum operating temperature is maintained, then the atmospheric column will be replaced with a much larger vessel required to get the higher AGO cutpoint. Alternatively, the flash drum pressure could be reduced to increase the flash drum vaporisation, but the atmospheric column diameter would have to be increased anyway. At the higher atmospheric column cutpoint the column was limited by vessel diameter above the inlet of the flash drum vapour. Higher AGO yield can be achieved by lowering column operating pressure and increasing feed enthalpy. Higher feed enthalpy (hotter flash zone temperature) requires a new atmospheric crude heater.

Thus, for the conventional project management design the following list of major equipment items must be replaced, or equipment added in parallel to meet the objectives:

— Offgas compressor
— Additional atmospheric column overhead condensing surface area
— Atmospheric heater
— Atmospheric column
— Flash drum pump.

Not only will this be an expensive revamp, but plot space and unit downtime for installation will also be problems. All the modifications must be installed at the same time.

Failure to put any modification in will eliminate the benefit of the entire project. Value engineering has little application in this situation.

Integrated conceptual (practical) revamp approach

All process engineering steps of the revamp must be integrated and considered as a whole. This is especially true for crude units, but applies nearly everywhere. Crude units have heat integration between the crude preheat exchanger network, towers, and product rundown systems.

Performance of the distillation columns affects each other. Tower performance influences heat recovery capability. Heat recovery changes affect tower performance. Typical process design procedures do not account for the process and equipment interactions. A revamp process design is not a linear operation, but a circular process that accounts for the integrated process and equipment impacts.

An effective conceptual design approach minimises capital investment by identifying under-utilised equipment and changing the operation or process flow scheme to better use this equipment to eliminate bottlenecks. The thought process may also include adding equipment in conjunction with changes to the process flow scheme. The effort focuses on circumventing the major equipment limitations.

Taking this approach, we will now examine the crude unit again and compare it to the previous standard approach. To allow further investment optimisation, we will cut the revamp into two sensibly grouped phases.

Revamp - Phase I

The main objective of the initial revamp was to eliminate the reliability problem with the atmospheric column. Improvements in product yield from low cost external equipment changes and column internal modifications to reduce the crude column operating pressure can be put into one logical investment group.

The overhead compressor limit raised column pressure. The atmospheric column overhead compressor spillback closed off during the heat of the day and the column pressure set point had to be increased to keep from flaring excess gas. The atmospheric column offgas yield was 16.3mscfh (437nm^{3}h). The compressor operated at maximum capacity.

During the test run, the vacuum unit hotwell gas compressor was operating at very low gas loads compared to its capacity. The spillback line on the liquid ring pump of the vacuum column offgas compressor was operating with 4.1mscfh (110nm^{3}h) of recycle. The liquid ring pump had experienced operating problems because there was very little gas load. The spillback did not have a cooler, therefore it caused a high inlet temperature to the vent gas compressor.

The field work identified an existing compressor with spare capacity. The original design of the vacuum unit compressor created an opportunity. The revamp included installing a line (Figure 3) from the atmospheric compressor suction to the suction of the vacuum unit vent gas compressor. The revamp used spare vent gas compressor capacity to reduce the operating pressure of the crude column. The vent gas compressor spillback would operate in the closed position, using atmospheric column offgas instead to load the compressor.

Shifting crude unit gas from the existing crude overhead compressor to the vacuum unit offgas compressor allowed the crude column operating pressure to be reduced. It also reduced the inlet temperature to the vent gas compressor which reduced maintenance costs. This simple and inexpensive change in the process flow scheme has significant benefits.

The crude column wash and stripping sections' design caused severe fouling of the trays. Stripping section tray fouling required the stripping steam rate to be reduced. Poor stripping section performance increased the kerosene-diesel boiling range material in the feed to the vacuum column. Low crude column oil vaporisation from high operating pressure and poor stripping section performance reduced the AGO product yield.

In an attempt to maintain the AGO product yield as high as possible, the operators reduced overflash below the minimum wetting rate for trays. Maximum AGO product rate minimised the light material in the feed to the vacuum column given the stripping section performance. However, most of the light material in the vacuum column feed was caused by the stripping section performance not overflash.

The light feed to the vacuum column raised the ejector gas load, which increased the vacuum column operating pressure. The wash section has valve and bubblecap trays and uses unmetered internal wash to control AGO product quality.

The inherent system design did not allow the operators to constantly run at minimum overflash without fouling the wash section trays. The overflash rate was controlled by changing the AGO product yield. Small crude column material balance or heat balance swings cause big changes in the internal wash oil stream. The result is an overflash rate that is unstable, leading to swings between too much wash reflux and not enough. Wash section trays have high residence time and stagnant areas which, when combined with insufficient overflash, promote tray fouling.

Operating below the minimum wetting rate for trays leads to fouling and black AGO product. The approximate minimum wetting rate for trays is 3-5 vol% overflash as a percentage of crude. Tray modifications, such as picket fence weirs to keep liquid from blowing off the trays, can be used to improve tray performance; but these modifications only improve the situation slightly. Trays still require a certain amount of liquid to avoid fouling. They require a much higher wetting rate than a well designed packed bed. Excessive wash flow rates downgrade diesel boiling range material to FCC feed.

The revamp modifications (Figure 4) changed the AGO product/wash oil system to a total draw with pump back reflux. The wash oil rate (reflux) is flow controlled, therefore, the reflux rate is maintained to keep the bed properly wetted. The wash section uses packing, enabling minimum over-

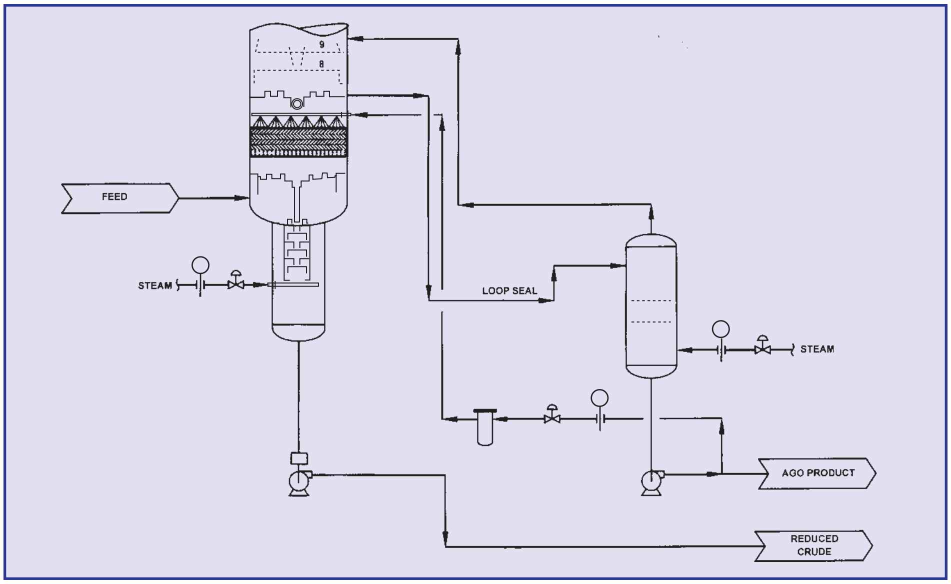

Figure 4 *Atmospheric column modifications, Phase I*

flash without fouling of the column internals. The packed wash zone has less pressure drop than the trayed design, providing a slight improvement in flash zone pressure with a consequential increase in cutpoint.

The stripping section tray design was modified to reduce the fouling tendency and increase tray efficiency. Improved diesel and AGO recovery from the modified stripping section shifts product from the vacuum column LVGO draw to the atmospheric column diesel and AGO products. Heat is upgraded from 270˚F (132˚C) LVGO pumparound to 550˚F (288˚C) diesel pumparound and 630˚F (332˚C) AGO product rundown. This improves preheat train operation and reduces overall investment.

Revamp - Phase I results

The modifications have increased diesel and lighter distillate yield by 2.7 vol% based on whole crude. This value was determined from the best operation prior to the revamp and the post revamp yield was determined from the average of several months of operation.

The vent gas compressor tie-in unloaded the atmospheric column offgas compressor, dropping the overhead receiver pressure by 4psi (28kpa). After the stripping section and wash zone modifications, no signs of coking have occurred after one year of operation. The need to raise column pressure to avoid dumping the overhead receiver to flare, due to the compressor limitation, has been minimised. Crude charge has been consistently increased by five percent over the pre-revamp operation.

Prior to the revamp, the diesel yield was limited by cloud point. After the modifications, this limitation no longer existed. The limit to diesel production has been the balance between FCC feed and diesel yield. Properly functioning units can be optimised, improperly functioning units cannot.

Phase I included minimal capital expenditure by modern standards at just over $1 million. The investment in the first phase of the project was returned approximately four times in the first calendar year of completion. Measured return on that investment included only the incremental throughput and yield above a properly operating unit, one without operational adjustments such as limited stripping steam and reduced throughput just to keep the unit on line.

Revamp - Phase II

The objectives of the second phase of the crude unit revamp were to increase the crude charge rate by 20 percent while maintaining or improving product yields (yields as a percentage of crude) and quality. The cutpoint of the atmospheric column must be increased due to the downstream limitations of the vacuum charge pumps, heater and column; otherwise, product yields and quality would be sacrificed.

To achieve the required cutpoint in the atmospheric column, modifications must be made to significantly reduce the operating pressure of the atmospheric column to increase vaporisation. To achieve this, additional crude column overhead surface area must be added to reduce the heat removal limitation and reduce the pressure drop in the overhead system. Increasing AGO cutpoint further upgrades material from LVGO. It also upgrades heat in the preheat train from 270˚F (132˚C) LVGO draw to 630˚F (332˚C) AGO draw. Secondary heat effects include making the LVGO and HVGO heavier, increasing both of their temperatures. Preheat temperature increases.

The existing naphtha pumparound fin-fan surface is not properly utilised. As noted previously, the fin-fans need to be essentially bypassed to control the return temperature. These fans are located adjacent to the atmospheric column overhead fin-fans. Changing the service of these exchangers to crude column overhead condensing service is an effective use of the surface area to debottleneck the overhead system limitations.

Column internals and draw nozzle sizes limit the top pumparound circulation rate. Removing the fin-fans from naphtha pumparound service requires a higher pumparound circulation rate to achieve the targeted duty with the remaining exchangers. During the test run, the pumparound circulation rate was 46,600 bpd ($309m^3h$).

The naphtha pumparound pumps are capable of 75,000 bpd to 80,000 bpd (497-$530m^3h$) for additional heat recovery to crude by maximising the exchanger log mean temperature difference. Higher pumparound rates also allow higher naphtha return temperatures. This reduces overhead corrosion problems (less water condensation).

However, during the test run the pressure drop across the four naphtha pumparound trays was 2psi (13kpa). These trays are hydraulically flooded. The downcomer backup reached the tray above. When this occurs, the trays flood. The high downcomer backup is caused by the high head loss under the downcomer. These trays must be modified to enable increased pumparound circulation to fully utilise the pumparound exchangers and to increase the pumparound return temperature to reduce the corrosion in the top of the column.

In addition to adding surface area to the atmospheric column overhead system, the overhead receiver pressure must be reduced to about 2psig (14 kpa-g). This reduces the atmospheric column top pressure to about l4psig (40 kpa-g). At lower pressure, the vapour rate from the overhead receiver increases substantially.

The test run compressor inlet volumetric rate was operating at the machine's maximum capacity. The new, low-pressure operation, produces 4.4 times the actual volumetric gas flow; a much larger compressor is required. Not only is a new compressor required, but the existing atmospheric column does not have the cross-section required to handle the increased vapour volume at the lower pressure and higher lift.

In the current operation, the offgas may either be processed in another unit or sent directly to fuel gas. Dropping the tower pressure increases the amount of heavy material in the offgas. The propane and heavier offgas content rises significantly. A new drum and pump are required to combine the compressed gas and naphtha to recover the light ends. This modification would also be necessary in the modifications planned with the conventional project approach.

The more practical conceptual design adds a preflash column, as shown in Figure

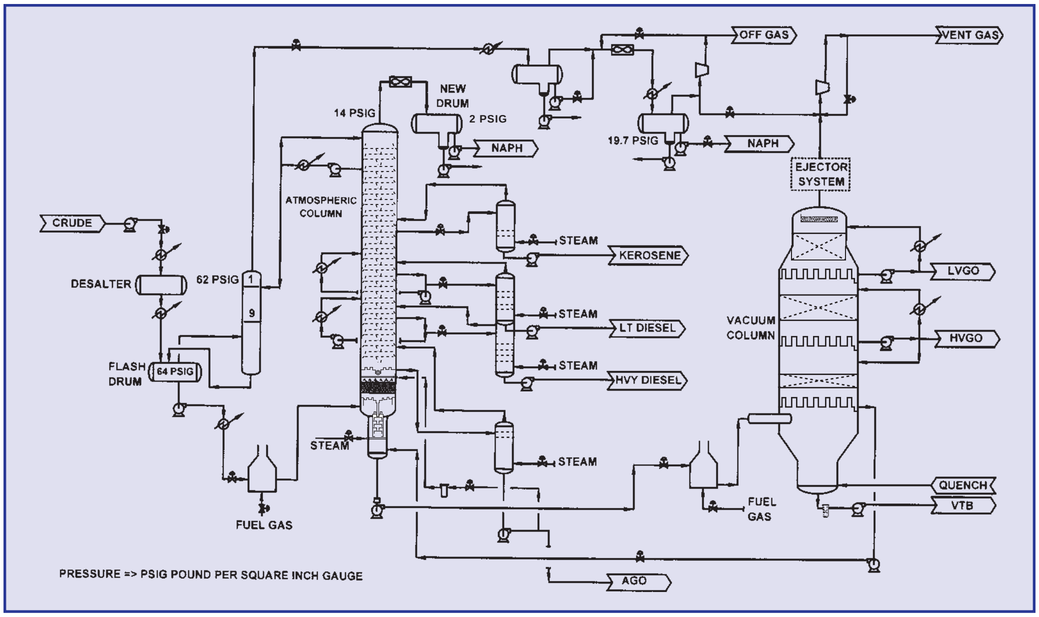

Figure 5 *Revamp process flow scheme, Phase II*

5, with the current atmospheric column overheads system repiped to the preflash column overheads. A pressure control valve is added in the preflash column overhead line. This allows the preflash column to operate at higher pressure to control vaporisation in the preflash column.

Effectively, the compressor vapour load now comes from the preflash column (new) instead of the atmospheric column. The compressor suction volume, now at higher pressure, drops and compressor modifications are avoided. The composition of the preflash overhead vapour is approximately the same as the existing atmospheric overhead vapour, allowing for the current dispositions to continue.

The new preflash column adds the necessary capacity to increase preflash cutpoint, and also unloads the atmospheric heater, atmospheric column and atmospheric column overhead system. The preflash column size is much smaller, both in diameter and height, than a new atmospheric column.

These changes have cumulative effects. Moving the naphtha pumparound fin-fans to the atmospheric column overhead and reducing the overhead gas make at the same time allow the new atmospheric column overhead receiver to be operated at pressures as low as zero psig.

The major equipment investment, for the practical conceptual design, required to meet our objectives is:

— Preflash column
— Atmospheric column overhead drum
— Flash drum pump
— Crude preheat exchangers

The overall benefit is low flash zone pressure for increased cutpoint to debottleneck the major equipment limitations with a much lower capital investment.

Phase II requires more capital outlay in equipment, both in the unit and throughout the rest of the refinery. The return on capital for Phase II is lower but is still acceptable in the long-term objectives of the refinery.

Conclusion

The overall thought process outlined shows the benefit of an integrated (practical) design approach rather than the conventional process design approach. Brute force projects that parallel, or replace, equipment require more capital, longer shutdowns, and are harder to break down into smaller investment units.

In contrast, minimising capital investment is determined by the creativity of the practical conceptual design process. Proper conceptual design used modifications of the process flow scheme for the vent gas compressor tie-in, the new atmospheric preflash column arrangement, and pumparound fin-fan relocation to minimise atmospheric column flash zone pressure. The increase in cutpoint of both the flash drum-preflash column and the atmospheric column debottleneck the other major equipment limitations and minimise capital investment.

The practical conceptual design approach allowed for investment staging, further improvement of plant economics, and investment planning. The Phase I revamp work has been completed and is working as predicted. The Phase II revamp work is now on the plant investment plan.

Many units have unrecognised capacity in existing equipment. At other times, process flow sheet changes can achieve significant benefits. Concentrating on the limits of a unit and neglecting opportunities increases costs. Balancing opportunities to circumvent limits reduces needed investment.

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