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# Consider comprehensive CPD efforts to cut costs

**With performance real-time field data, designers can devise process retrofits at the conceptual stage that control project scope and minimize engineering revisions during FEED and detailed engineering**

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Defining the project scope for grassroots facilities is a straight-forward exercise. Optimum execution procedures for engineering and construction can be developed through office-based conceptual process design (CPD) efforts. No existing equipment or ancillary processing units must be considered during the grassroots CPD stage.

Yet in reality, most project activity within the HPI is focused on revamping existing production plants. Retrofitting existing facilities warrants a more detail-oriented CPD in that the project concentrates on revamping equipment already installed. During the revamp CPD, many project decisions determine changes to the process flow scheme and define the scope of the project

Scope definition has an enormous impact on the project's estimated cost. Total installed cost (installed, direct and indirect field costs, engineering, taxes, etc.) is typically 4–8 times the cost of equipment for refinery process unit revamps. Therefore, failure to identify scope items can quickly lead to large scope growth and cost escalation between CPD and detailed design. CPD efforts that minimize the process design effort solely to reduce up-front engineering costs may seem appropriate. However, these actions almost always lead to higher overall engineering costs, revamp cost escalation, and/or compromised revamp objectives. So what are the options to ensure more precise design strategies for retrofitting an existing facility?

**Poorly defined scope is the number one cause of revamp cost escalation; CPD defines the flow scheme and, therefore, the revamp scope.**

**Foolproof method.** The only foolproof way to do CPD for a revamp is by establishing the performance base-line of the existing unit. A comprehensive test run is conducted to gather actual field data such as process temperatures, pressures and flows. Original equipment drawings, P&ID's, and control room data is not sufficient. With real-time field data, designers can calibrate the simulation model with field information. Designers can:

- Identify all major cost bottlenecks
- Determine alternative process flow schemes
- Evaluate the least-cost option.

With a more precise conceptual design, equipment lists and cost estimates are developed. Admittedly, this effort consumes time and resources. However, unless such work is thoroughly and carefully done at conceptual design stage, the project scope can grow enormously during front-end process design (FEED) and detailed engineering (DE).

In the following case history, the National Petroleum Refiners of South Africa (PTY) Ltd., (NATREF, a joint venture of SASOL and Total South Africa) began a study to determine whether increasing crude capacity at its Sasolburg refinery was a sound investment. A NATREF multidisciplinary team coordinated engineering work with several contractors to conduct a staged process beginning with CPD, continuing through FEED and ending in DE.

**What is CPD?** Conceptual process design (CPD) is the most important activity in a revamp project. Often, the significance of CPD is overlooked. Thus, minimum engineering effort is expended on CPD with the expectations that more detailed process design work can be performed during FEED or the beginning of DE. Consequently, many revamps start with superficial process work and little money assigned for CPD.

CPD determines the revamp costs and whether or not the results will meet yield, run length and reliability objectives.[1–4] Failure to meet even one of the processing objectives can convert an otherwise profitable revamp into one that loses refiners millions of dollars due to poor performance or an unscheduled outage to correct revamp design flaws. When done properly, CPD will identify *all* significant process and equipment modifications, and scope growth will be minimal as engineering progresses.

Currently, revamps are deemed successful if: 1) through-

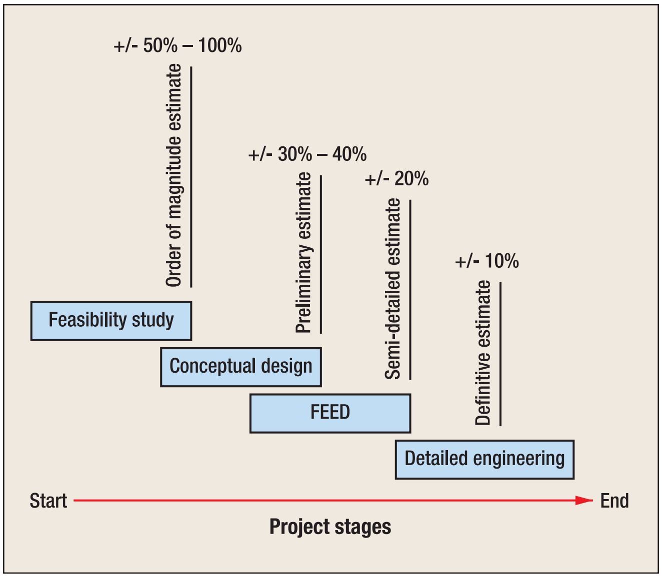


**Fig. 1.** Stages of engineering.

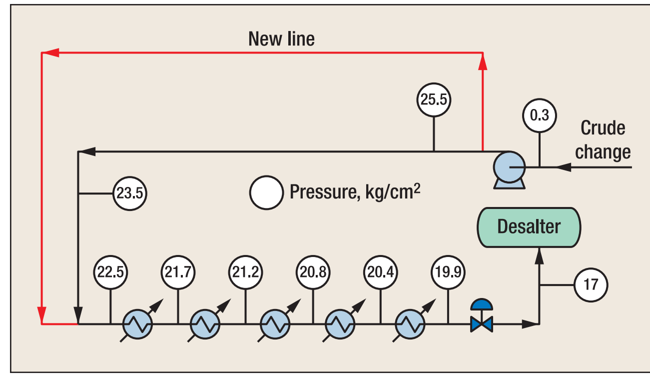


**Fig. 2.** Crude hydraulics—parallel feed line.

put, yield and reliability objectives are achieved, and 2) they are on schedule and under budget. Large overruns can wreck revamp economics. Volumes have been written about cost estimating, cost control, project management and scheduling. All of these are important activities that must be executed well. However, if the CPD is poor quality or insufficient in detail, then no amount of cost estimating, cost control, project management and scheduling activities will prevent scope growth. So what are the guidelines for revamp CPDs? The following example presents the CPD guidelines that NAFTREF used to specify revisions to crude/vacuum units to increase crude capacity at its Sasolburg refinery.

## REVAMP CPD

Project schedules often demand fast-track revamp (typically under $20 million) CPD. Overall revamp durations can be as short as one year from beginning to startup for fast-track projects or longer for larger investments. Whatever the case, CPD must be fast and efficient. There is no time for re-engineering.

CPD costs must also be controlled. At the conceptual design stage, the revamp has not yet received full funding (Fig.1). If engineering costs are excessive and the revamp is not funded, then money is wasted. However, a minimum amount of engineering *must be* done to sensibly direct capital expenditure. Otherwise, all major scope-related items may not be identified and the process flow scheme selected may not yield the least-cost design.[5]

Minimum CPD cost and sufficient engineering are always competing objectives. The trend has been to reduce the cost for CPD by pushing essential process engineering evaluations into FEED and DE. Often, this effort results in either scope growth or scope rationalization, where many pieces of equipment are removed to control costs. At this point it may be well to ask if the equipment can be removed to control costs without impairing the process scheme, why was the equipment specified in the first place? In corollary, if the process scheme will be impaired, how can removal be justified? A more intelligent, efficient and thorough CPD is needed to satisfy competing objectives.

## A DIFFERENT APPROACH

When a conventional office-based approach is applied to revamp design, the major portion of the process engineering design occurs in the FEED stage. Only a superficial amount of design is done during the CPD and a cursory review of the equipment is done. Consequently, the revamp scope of work is poorly defined. Conventional office-based CPD focuses on scheduling and cost estimating, not on process design. Yet if scope is poorly defined, the estimate will not be accurate.

During CPD, all related revamp modifications must be identified so that a cost estimate can be prepared. If the scope of work is well-defined, costs can be accurately estimated. Conversely, if the scope is incomplete, then the estimate will not capture all costs. *Poorly defined scope is the number one cause of revamp cost escalation.* CPD, not cost control or project management activities, defines the flow scheme and, therefore, the revamp scope.

For grassroots design, defining the scope is a straightforward exercise. These projects can follow optimum project execution procedures for engineering and construction. Office-based CPD approach works well because no existing unit with its many challenges and obstacles is present. However, project execution procedures that work well with grassroots design must be altered for revamp design. Revamp CPD demands a more detailed process design because most of the equipment exists. Revamps present unknowns, constraints and problems that are common within an existing operating unit. The conceptual designer must maximize reuse of existing equipment (or minimize new equipment installation). Otherwise, revamp costs can be excessive and jeopardize project approval.

Revamp conceptual designers must thoroughly understand existing unit performance and constraints and know how to circumvent them with practical, cost-effective flow scheme modifications. This requirement does not exist in grassroots CPD. While the conventional office-based approach works well for grassroots projects, rarely does it foster an intimate understanding of all factors affecting revamp success. Without this understanding, it is impossible to make good investment decisions.

Refiners must recognize that CPD is where the process flow diagram (PFD) is set and equipment modifications are identified. *The options for the engineering effort to influence costs are greater in the CPD stage than at any other time in the revamp.* If the PFD that is developed during the CPD is found to have flaws during FEED or DE, then scope growth will almost always result. Once the PFD is set, usually very little time is available to re-engineer the PFD. Scope rationalization, "value" engineering or other similar exercises are commonly used to lower costs due to a flawed process flow scheme and/or incomplete scope definition. But, "value" engineering participants often have little understanding of unit limitations that drive the process flow scheme selection; hence, the focus becomes eliminating equipment. This simply is not

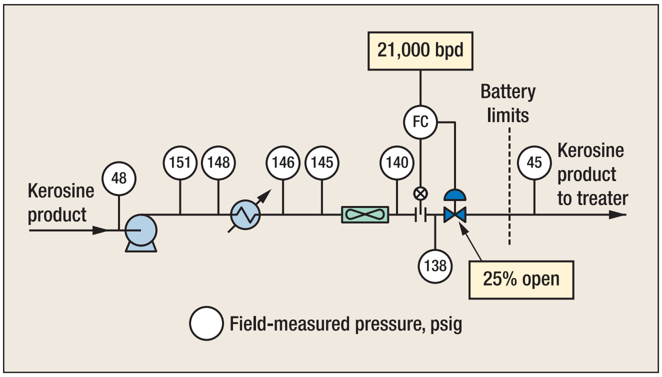


**Fig. 3.** Baseline kerosine product hydraulic profile.

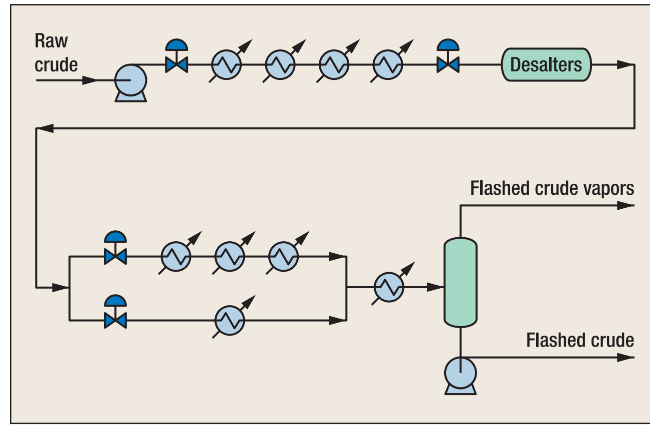


**Fig. 4.** Existing raw crude/desalter crude PFD.

an effective means of meeting reliability and operability requirements.[6,7]

In this revamp, NATREF had done a crude/vacuum unit feasibility study based on a conventional approach using only office calculations. The study recommended making minimum modifications to the PFD; equipment sizes were increased or new parallel equipment such as a new vacuum column and vacuum heater were to be installed. One consequence of maintaining the existing PFD was that a new parallel crude line from the charge pumps in the tank farm to the unit would be needed to meet the higher crude flowrate (Fig. 2). Increasing crude flowrate raises pressure drop if the existing process flow scheme is retained and the desalter operating pressure were fixed. The new parallel charge line would be over 5,000 ft long and the cost high. During CPD, it was essential that alternative process flow schemes are explored.

**A different CPD approach—consider unit performance.** The complexities of revamp design demand a stronger emphasis on understanding the present unit performance and constraints; otherwise, scope growth will be likely. Additionally, conceptual designers must also consider non-idealities like fouling and corrosion.[8,9] These demands are not usually attainable with the office-based approach without excessive CPD cost and schedule impacts. These guidelines, which supplement CPD activities, should curtail revamp scope growth:

- Perform comprehensive unit performance test run
- Evaluate unit hydraulics
- Examine heat integration, fired heaters and column internals.

Following these guidelines requires that the conceptual process designers' experience be matched to the specific unit being revamped.

**Performance test runs.** By definition, a revamp starts with an existing operating unit. Maximum re-use of existing equipment minimizes new equipment and revamp expenses.[10] A conceptual design engineer must have an intimate understanding of the existing unit performance and bottlenecks to maximize the reuse of existing equipment.[11,12] However, the competing objectives of schedule and cost limit the time and money available to become intimately familiar with the existing unit operation during the conceptual stage. A performance test run is an effective method to develop an in-depth understanding of the unit performance and bottlenecks while conserving time and resources. The performance test run enables the conceptual design engineer to:

► Measure unit performance
► Quantify unit bottlenecks
► Quantify hydraulic system limitations
► Identify and quantify non-idealities such as heat exchanger fouling
► Identify damaged or under-performing equipment
► Generate a calibrated process simulation.

The plant performance test run is the only method to measure the *real* unit performance and bottlenecks. Often, a performance test is considered a casual exercise. Samples are drawn for laboratory analysis while the refinery process computer retrieves process data. Maybe a few control valve positions are noted in the field. This information is used to build a simulation model. This is not a comprehensive performance test; the results are usually misleading and contribute to disastrous scope growth later in engineering.

A comprehensive performance test run establishes a full pressure, temperature and composition profile for the unit. In addition to obtaining data from the process computer, pressures are measured locally for all hydraulic systems to establish baseline performance criteria (Fig. 3). Temperatures are measured locally where remote indication does not exist. Control valve and battery limits pressures are measured. Bypasses that are partially open around control valves are noted. The test run does not end with the collection of field-measured and computer system data. The data is then used to generate a heat and material balance, which is the basis for a baseline simulation. The simulation is calibrated with field-measured test run data. The simulation calibration will typically include:

- Distillation tower stage efficiencies
- Heat exchanger fouling factors
- Heat exchanger hydraulics allowances
- Fired heater radiant flux imbalances.

Comprehensive performance test runs are rarely done for refinery revamp CPD because the designers or project management do not see the value added. The conventional wisdom is that a simulation can be generated with information that is extracted from the as-built data sheets and drawings, original equipment specifications and limited plant data (office-based approach). Therefore, test runs are deemed wasteful. *This is a terrible misconception.*

Simulations that are built with the office-based approach rarely represent actual operating unit performance. Conducting a performance test run will be more expensive and time-consuming than an office-based CPD approach. However, planning and executing a comprehensive test run is the most cost-effective method of performing the *minimum* amount of CPD required to fully define the revamp scope at the conceptual stage.

**Hydraulics.** When crude/vacuum units are revamped to increase throughput, crude hydraulics are almost always a unit con-

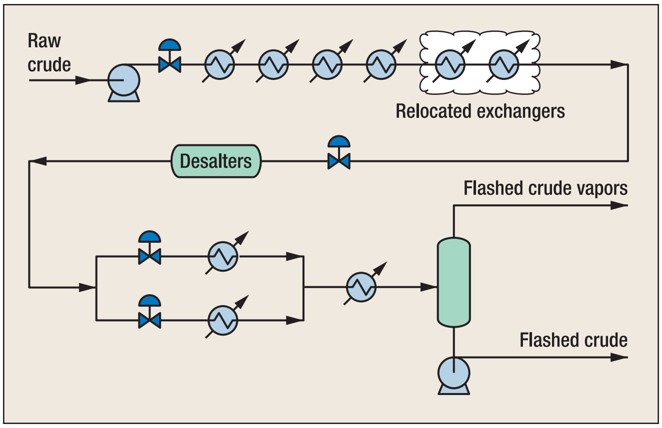


**Fig. 5.** Re-piped raw crude/desalter crude PFD.

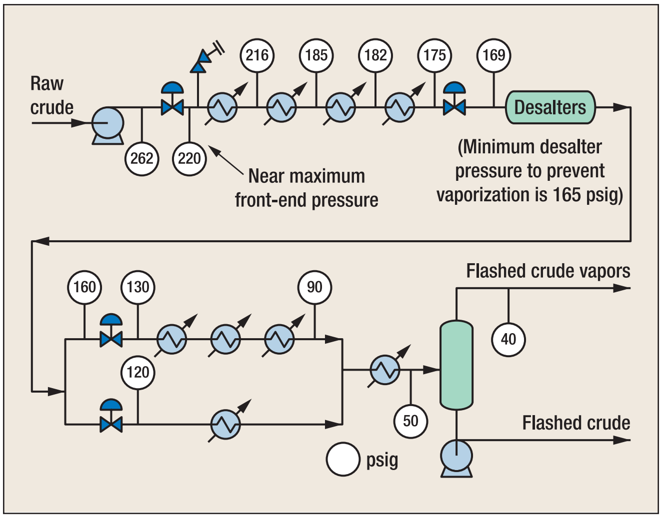


**Fig. 6.** Field-measured raw crude/desalter crude pressures.

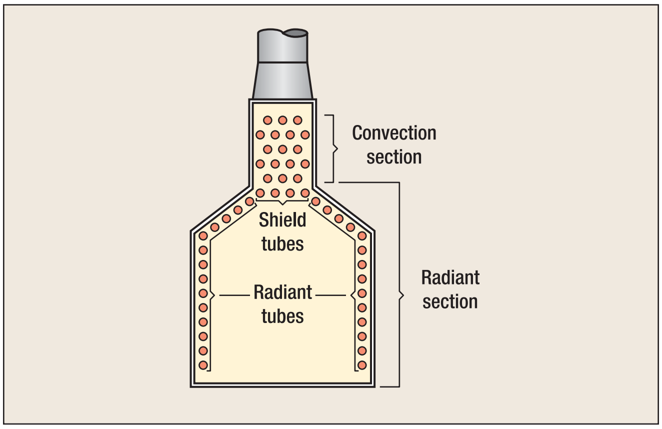


**Fig. 7.** Simplified heater sketch.

straint. Capital expenditure necessary to overcome crude hydraulic constraints can be a significant portion of the total revamp cost. However, crude hydraulics are rarely reviewed during the CPD at the detail level necessary to identify all hydraulic-related scope of work changes. But sensible decisions about the revamp flow scheme cannot be made without understanding the impact of crude hydraulics.

An office-based method of evaluating hydraulics consists of collecting the equipment as-built data sheets and piping isometrics and rigorously calculating the system pressure drop. While this approach is very scientific, it is not practical. It consumes many man-hours, is very expensive, takes too long for the CPD stage, and does not necessarily reflect actual unit hydraulics, which are affected by fouling. These rigorous calculations are more appropriate for the DE stage where a final check of all system design is warranted.

A more efficient method to identify hydraulic constraints during CPD can be accomplished by using field-measured performance test-run data. One of the performance test-run objectives is to develop a complete hydraulic profile of each circuit. Once hydraulic profiles are developed from the performance test run, the conceptual design engineer can scale the baseline hydraulic profile up or down to quickly and accurately evaluate revamp hydraulics.

**Heat integration.** In another completely different crude/vacuum unit revamp, an objective was to increase the crude unit desalter operating temperature. Fig. 4 shows the raw and desalted crude preheat trains. Revamp modifications resulting from an office-based CPD approach are shown in Fig. 5. Two crude heat exchangers were re-piped from downstream of the desalter to upstream of the desalter. The piping costs were estimated and included in the overall revamp cost estimate.

When a detailed hydraulic evaluation was performed during DE, it was discovered that relocating the two desalted heat exchangers upstream of the desalter would increase the front-end operating pressure above the design pressure of the first heat exchanger. At this stage, it was too late for re-engineering. Alloy exchangers would have to be replaced with exchangers designed for higher operating pressure. Not only was the operating pressure at the front end above the design pressure of the first exchanger, it was also above the pressure of the piping flange rating. Flanges and valves would have to be replaced as well. These changes resulted in a significant amount of scope growth.

In this example, scope growth was incurred because the crude hydraulics were not properly evaluated at the CPD stage. The engineering company had chosen to use an office-based approach. When the conceptual designers were asked during the CPD if the crude hydraulics would be a problem when two exchangers were added to the raw crude preheat train, their response was, "No, but we will look at the hydraulics in the next engineering stage." Had the conceptual designers used performance test-run data that was available, they would have quickly seen the design flaw (Fig. 6).

It is especially important to consider crude unit hydraulics during the CPD stage. Crude units use a high level of heat integration between the crude/vacuum column products and pumparounds in the crude preheat train. This level of heat integration tightly links the crude and vacuum columns' heat balance and crude preheat train hydraulics. For example, modifications to one or more of the crude/vacuum pumparound systems may involve installing additional exchangers to satisfy revamp heat balance requirements. The additional preheat train exchangers affected crude hydraulics.

**Fired heaters and distillation column internals.** Fired-heater and distillation column internals modifications can be significant revamp cost items. Major modifications in these areas can extend turnarounds and require special planning. Fired heater and distillation column internals must be evaluated in sufficient detail during CPD to identify modifications and define revamp scope. Unfortunately, fired heaters and column internals are often only reviewed with cursory calculations or rules-of-thumb during CPD. This approach can result in scope growth.

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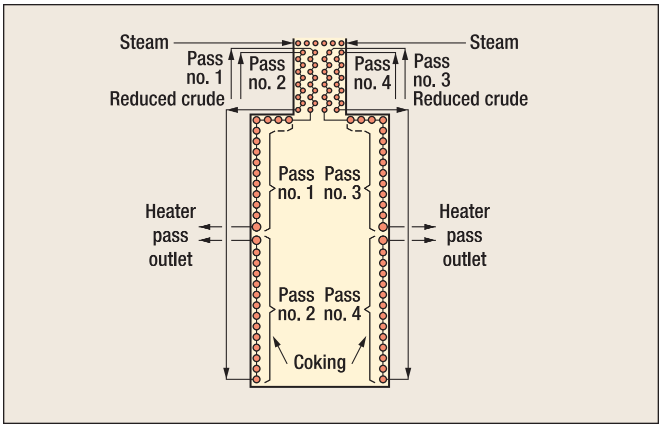


**Fig. 8.** Heater layout sketch.

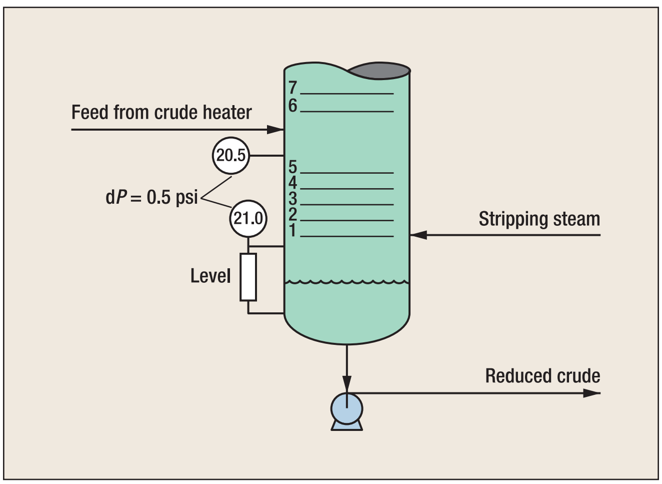


**Fig. 10.** Stripping section pressure survey.

Abbreviated or rule-of-thumb evaluations like use of *average* radiant heat flux or percent of flood, can be very misleading and form incorrect conclusions about fired heater or distillation column performance. Accurate field data and a detailed review of the specific equipment parameters are required to determine maximum heater or distillation column capacity.

Fired heaters and distillation column internals pose a real challenge to the conceptual design engineer. Often, the conceptual design engineer lacks the equipment expertise needed to determine equipment scope even though he or she may be proficient at modeling and developing heat and material balances. Yet, to minimize cost, equipment specialists may not get involved in CPD. Consequently, heater and column internals scope are often poorly defined.

**Average radiant flux rate.** This value is the heat duty absorbed in the radiant section of a heater divided by the surface area of the radiant section tubes (Fig. 7). Average radiant flux rate rules-of-thumb are used in the refining industry to provide only very general guidelines for heater capacity. Sometimes, conceptual designers do use average radiant flux guidelines to determine heater capacity during CPD. But when heaters operate with flux imbalances, using average radiant flux rate alone can lead to grossly incorrect conclusions about heater capacity.

Average radiant flux guidelines assume uniform flux distribution in the radiant section. In reality, many heaters operate with flux imbalances that result in a difference in pass flowrates as high as 50% between radiant passes.[13,14] Flux maldistribution is a function of firebox tube geometry, pass layout, burner operation, number of burners and burner location (Fig. 8). The vacuum heater in Fig. 9 operated with *average* radiant flux rates of 9,000 Btu/hr-ft$^2$, within the guidelines for vacuum heater operation. However, the heater flux imbalances resulted in flux rates of 13,000 Btu/hr-ft$^2$ and 5,000 Btu/hr-ft$^2$ for the lower and upper passes, respectively! The lower passes were coking while the upper passes were not.

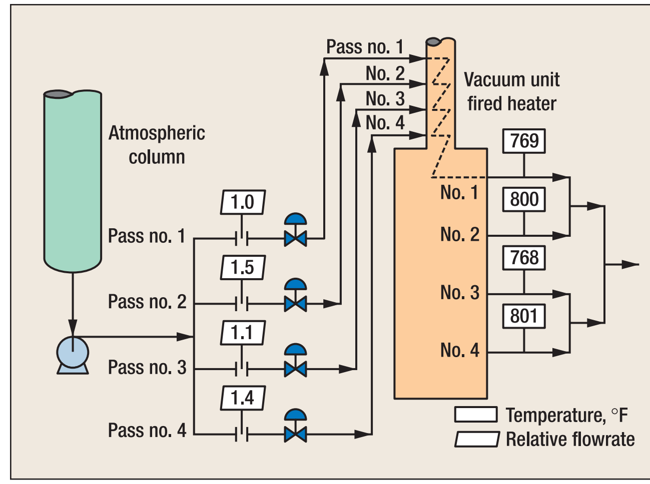


**Fig. 9.** Pass heat-flux maldistribution.

This example demonstrates that average radiant flux rate is not a good indicator of heater coking potential or capacity. Peak-film temperature and oil-residence time, which determine vacuum heater coking and ultimate capacity, are better indicators of heater capacity. Oil mass velocity and flux distribution determine peak oil-film temperature. When heaters operate with large radiant section flux maldistribution, the difference in peak-film temperature can be as high as 75ºF between passes. This is why average radiant flux rate should not be used to make decisions concerning heater capacity. A tube-by-tube heater simulation calibrated with accurate field-measured data is the only way peak oil-film temperatures can be calculated when heaters experience flux maldistribution. Three essential items must occur to accurately calculate peak-film temperature in this situation:

- ▶ The conceptual designer must recognize that the heater has flux maldistribution
- ▶ Accurate field data must be collected
- ▶ A rigorous heater model (tube-by-tube) must be calibrated with the field-measured data to simulate the flux imbalance.

Often, the rigorous nature of the calculations necessary to properly evaluate fired-heater capacity are considered as exercises more appropriate for the FEED and DE stages. This position delays critical scope definition decisions until later stages of engineering, thus escalating project costs.

**Crude column stripping trays.** In most refineries, the performance of crude column stripping trays is critical. Low stripping tray efficiency or damaged trays increase the amount of light material in the crude column bottoms product. Light crude columns bottom product loads the vacuum ejectors, thus raising column-operating pressure and costing refiners millions of dollars. Replacing damaged or poorly designed stripping trays with properly designed trays almost always has an attractive payback, but can be an expensive revamp item.

To maintain the budget, tray replacement must be identified during CPD. Failure to identify low efficiency stripping tray operation or damaged trays, unfortunately, is a common over-

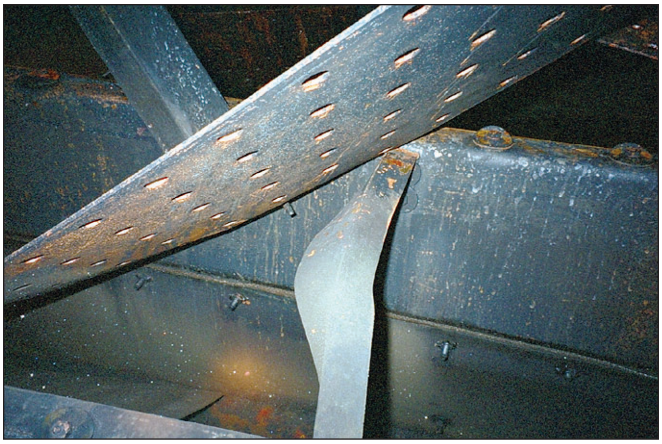

**Fig. 11.** Damaged stripping trays.

sight during CPD. Yet, damaged or dislodged stripping trays can be identified with precise field-measurements using accurate pressure gauges. An experienced CPD engineer will measure stripping tray pressure drop during a performance test (Fig. 10).

Damaged or dislodged stripping trays have little or no pressure drop, while intact stripping trays have a pressure drop of 0.06–0.12 psi per tray. Stripping trays have inherently low efficiencies. A well-designed stripping tray will have an efficiency of 40%, while a poorly designed tray can have an efficiency of only 10–25%. Poorly designed stripping trays result in low strip-out of light material from the crude column bottoms product. Crude column stripping trays operate with high liquid loads and low vapor loads. This combination demands a special design; otherwise, the trays will have low efficiencies. A well-designed stripping tray is *not* an off-the shelf item.

Poorly designed stripping trays operating with low efficiencies often go unnoticed during CPD. Standard calculations of percent flood are sometimes the only calculations that conceptual designers use to determine if a distillation tray is "fit-for-purpose." But standard calculations of tray percent flood will not identify a poorly designed stripping tray. In fact, stripping trays operating with low efficiency will have an acceptable percent flood. Since the problem with poorly designed stripping trays is weeping, not flooding, more rigorous calculations are needed to identify poorly designed stripping trays. If the stripping trays are not evaluated in sufficient detail during CPD, then the need for replacement can go unnoticed until FEED or detailed design stages—an expensive oversight.

**Conceptual designer experience.** Revamp conceptual process design must be fast and efficient. The experience of the conceptual designer specific to the unit being revamped can make the difference between an efficient CPD package that defines all of the revamp scope, and one that results in significant scope growth or even worse, does not achieve revamp objectives.

In revamping a crude/vacuum unit, the conceptual designer must have extensive experience with crude/vacuum units. In revamping an FCC unit, they must have extensive experience with FCCUs. While this is only common sense, it is often overlooked. Conventional approaches to CPD based on project management hierarchy view the CPD as simply another activity. People are assigned based on availability and the projected CPD completion on the Gantt chart, rather than necessary expertise.

When the conceptual designers have extensive experience specific to the unit being revamped, their insight will determine the

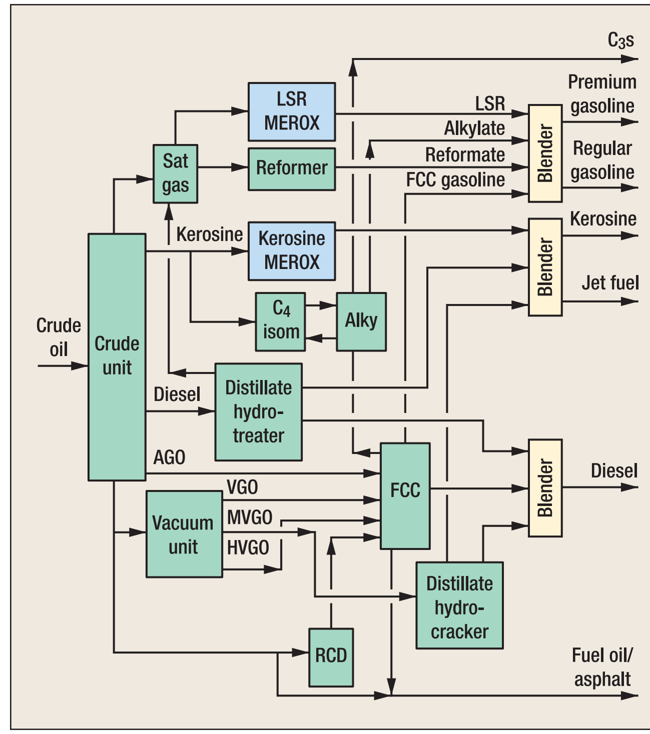


**Fig. 12.** NATREF refinery block diagram.

best revamp options to evaluate and which ones to discard—both efforts save time and money. A minimum cost solution may require altering the process flow scheme to circumvent bottlenecks.[15] This can be complex. Quickly knowing what alternate flow schemes to consider only comes with experience. Furthermore, conceptual designs that are generated by designers who lack experience with the unit being revamped often result in unstable, inoperable or unreliable designs. Most refinery units have qualities or characteristics that are specific to each process. Failure to consider these qualities can result in unproven or untried revamp solutions. Refiners should ask, "where have you successfully done this before and who can I talk to about it?"

**Stripping tray mechanical design.** Distillation column internals are normally designed for steadystate operation. Failure to consider non-steadystate operation, like startup, during CPD can lead to scope growth. Not only must stripping trays be designed properly to achieve good efficiency, but well-designed stripping trays must be able to withstand startup conditions during which they can be easily dislodged (Fig. 11).[16,17] Thus, stripping trays require a more robust mechanical design. Stripping trays should be constructed with shear clips and through bolts and should typically be designed to withstand an uplift force equivalent to 2 psi. The cost of a mechanically robust stripping tray is approximately 3–5 times the cost of a standard stripping tray. If the conceptual designer is not familiar with crude unit start-up procedures, a standard stripping tray may be specified with unfortunate results.

**NATREF'S revamp experience.** NATREF's objective was to increase crude processing capacity by over 22%; consequently, all refinery units required some capital investment. The revamp scope of work and capital investment varied for each unit. However, the crude/vacuum and FCC product recovery units combined capital investment represented about 40% of the total refinery investment. Fig. 12 shows the simplified refinery block diagram.

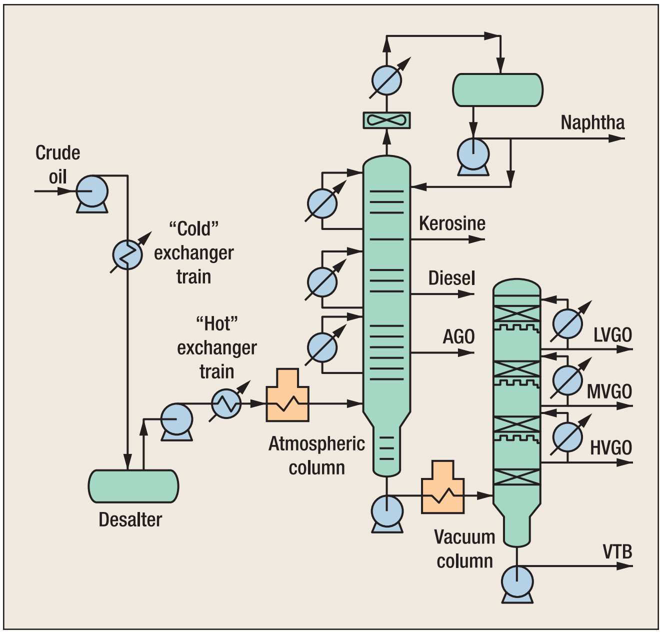


**Fig. 13.** Existing NATREF crude/vacuum unit simplified PFD.

NATREF used a four-staged engineering approach for the refinery expansion; the four stages of engineering were:

- Feasibility Study
- CPD
- FEED
- DE.

NATREF funded the refinery expansion and has already completed construction on several units. The revamped FCCU product recovery unit has started up, while the crude/vacuum unit work will be finished in early 2002. Even though the crude/vacuum and FCC product recovery unit revamps were more complicated than other refinery unit revamps, they experienced significantly less scope growth. The crude/vacuum and FCC product recovery units total equipment costs (corrected for escalation) increased by **5%,** while some of the other units cost estimates escalated by **20%**.

NATREF attributes the difference to the CPD. NATREF and their team used the rigorous CPD approach for the crude/vacuum and FCC product recovery units. The CPD for the other refinery units was done in a traditional manner with thorough process design work conducted during FEED and DE, *not* within the CPD.

In December of 1998, NATREF kicked off the CPD with a comprehensive test run on the crude/vacuum unit and FCCU product recovery unit. NATREF's CPD work scope included:

- ▶ Conducting a comprehensive performance test run
- ▶ Identifying *all* major cost bottlenecks
- ▶ Evaluating process flow scheme alternatives to find the least-cost flow scheme
- ▶ Developing equipment lists and cost estimates.

The performance test run gathered sufficient plant data to evaluate unit performance and identify limitations that would prevent additional crude processing capacity. During and immediately following the test run, it became clear that several major pieces of equipment had limitations that would have to be circumvented to increase crude processing capacity. Maintaining the existing process flow scheme (Fig. 13) simply would not allow raising the crude rate without high investment and poor energy utilization.

As test run data gathering must be comprehensive and should not rely solely on the easy-to-get information such as process control computer data, complete pressure and local temperature surveys were done throughout the unit. Fig. 14 shows some vacuum unit pressure measurements. Vacuum heater outlet pressure, transfer-line pressure and flash-zone pressure were all measured with an accurate absolute-pressure manometer.

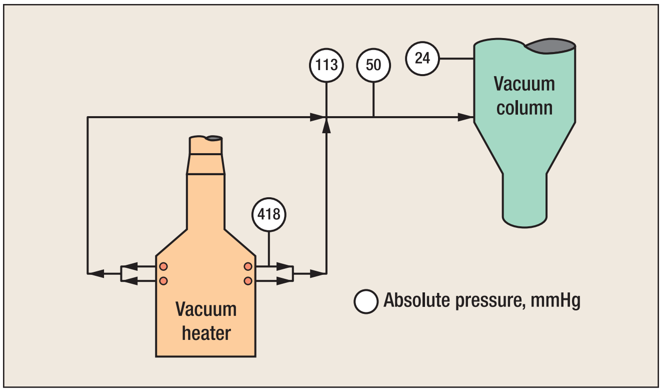


**Fig. 14.** NATREF transfer line pressure survey.

Increasing vacuum unit feedrate would have increased transfer line pressure drop and raised heater outlet pressure, which would reduce the HVGO product yield or require higher heater outlet temperature to maintain cutpoint. NATREF deliberately over-fired the vacuum heater to capture additional margin. This operation required close monitoring, and additional heater firing was not feasible. This emphasizes that identifying limitations *cannot* be done with computer system data alone.

Once all performance test run measurements were completed, a calibrated base-case process flow sheet model was developed. Unit constraints were clearly defined in the model; otherwise, it would not have been possible to efficiently evaluate practical flow scheme alternatives.

Some major crude unit constraints that had to be circumvented to meet NATREF's capacity objectives were:

- Vaporization at the crude heater pass inlet control valves
- Crude hydraulics and preheat train design pressure
- Desalter capacity
- Crude heater duty
- Crude column heat removal and shell capacity
- Vacuum heater duty
- Vacuum column shell capacity
- Product cooling circuits.

A conceptual designer with extensive specific experience can narrow the flow scheme alternatives to a few practical options, but rote solutions are common. As in NATREF's feasibility study, paralleling or replacing equipment with larger pieces of equipment is almost never cost-effective when major unit constraints exits. Finding the least-cost flow scheme requires extensive crude unit revamp experience, which is critical to cost control.

Two major bottlenecks were the atmospheric and crude vacuum column diameters. Both columns had to be paralleled or replaced if the existing process flow scheme were maintained. The engineering company that performed the feasibility study had decided to parallel the vacuum column with an existing idled vacuum column located in another unit. This required a new parallel vacuum heater. Revamps should maximize the use of existing or spare equipment *and* minimize investment for installing new equipment.

Practical flow scheme alternatives were studied, with the selected process flow scheme shown in Fig. 15. The most cost-effective flow scheme used two preflash columns: an atmospheric preflash and a vacuum preflash. The atmospheric preflash column would:

- ▶ Eliminate vaporization at the heater inlet
- ▶ Debottleneck crude hydraulics
- ▶ Reduce crude column overhead condensing duty
- ▶ Lower loads on the crude column
- ▶ Facilitate changes to the preheat train that would increase heat recovery
- ▶ Eliminate the need for new crude heaters.

Similarly, the vacuum preflash column would pre-flash atmospheric residue before the vacuum heater and use an idled vacuum column. Accordingly, crude throughput could be increased without exceeding the capacity of the vacuum heater, transfer line and vacuum column. The vacuum heater would require a retrofit; however, a new parallel heater would not be necessary. Identifying the right process flow scheme ultimately minimizes revamp project costs.

Once the least-cost PFD was identified, equipment lists and cost estimates were completed, which are relatively straightforward activities. However, all significant scope items had to be identified. Otherwise, the most highly skilled cost estimator in the world could not do the job properly. CPD performance tests must identify all bottlenecks and find the least cost process flow scheme if estimators and schedulers are to do their jobs effectively.

**Revamp project options.** The complexities of revamp CPD demand stronger emphasis on understanding the existing unit performance and constraints, and applying more attention to detail than grassroots projects. Consequently, an office-based CPD approach that works well for grassroots design purposes may be ineffective for revamps. Since the CPD sets the project scope and will, therefore, largely determine revamp costs, well-executed CPD effort can minimize capital investment and still achieve yield and run-length objectives, *and deter scope growth* during the revamp design life cycle. Properly executed CPD effort initially incurs more expenses than office-based CPD efforts. However, the conceptual designers' experience can incorporate expertise that will reduce the cost of FEED and DE. ■

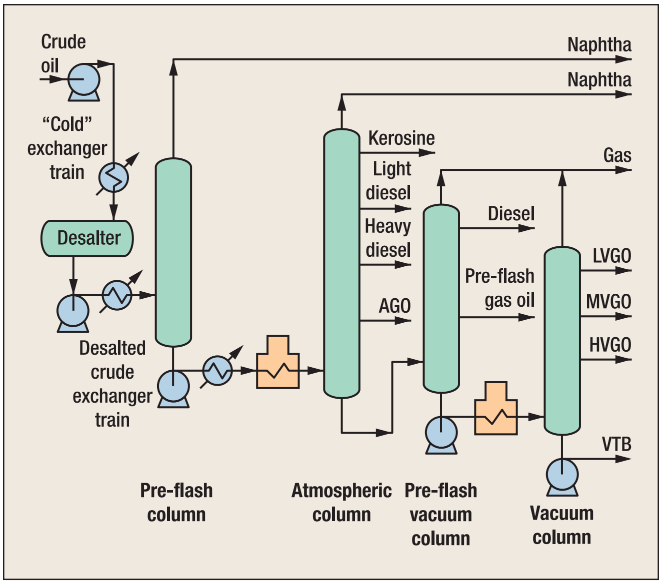


**Fig. 15.** Revamped NATREF crude/vacuum unit simplified PFD.

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