Texas refiner expands aromatics capacity 20% with staged revamp

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In today's competitive environment, processors no longer have the luxury of making large capital investments to implement "brute-force" solutions to unit limitations.

Phibro Energy Inc., Houston, instituted a step-by-step revamp approach to increase the capacity of the Udex aromatics unit at its Houston refinery. This scheme achieved a more than 20% capacity expansion with minimal investment.

Background

Udex is a solvent-extraction process that uses polyethylene glycol to extract aromatic products from hydrocarbon streams.

The "C" Udex unit at Phibro Energy Inc.'s Houston refinery produces nitration-grade benzene and toluene from catalytic reformer product. Fig. 1 shows the basic flow plan of the process.

The C Udex unit was constructed in 1957 in partnership with licensor UOP. The unit originally was used to produce three xylene products.

In 1965, the unit was converted to use tetraethylene glycol solvent, with a charge capacity of 5,400 b/sd. In 1984, operation was changed to produce benzene, toluene, and xylenes (BTX) products. Unit charge in the BTX operation averaged 4,900 b/sd of feed in 1991.

Changes in the reformulated gasoline and petrochemicals markets enhanced the attractiveness of aromatics production. These changes prompted Phibro to increase the capacity of the C Udex unit and enhance its product quality.

Initially, the proposed revamp project included switching solvents to meet the new production targets. This project was canceled because of the licensing fees and solvent costs involved.

After a detailed study, a low-capital, staged investment approach was chosen to meet project objectives. This approach has already increased capacity from 4,900 to 5,900 b/sd, with minimal investment. Future work items that will allow an additional capacity have been identified.

Project objectives

Phibro defined four major objectives for the revamp project:

- Increase unit capacity from 4,900 b/sd of feed to 6,500 b/sd, at constant feed aromatics concentration.
- Increase benzene product quality to less than 0.01% toluene in the benzene. (Concurrently, modifications were to be included to reduce fugitive emissions of benzene.)
- Reduce total fugitive emissions from the unit.
- Examine the unit carefully and revise piping and instrumentation diagrams in preparation for process safety management reviews.

Operating experience

Maximizing investment return requires a careful approach to unit modifications. Understanding the existing unit, its limitations and potentials, and how it integrates with the entire refinery is the basis of a successful minimum-investment project.

If the operation of the existing unit is not understood, it is difficult to change its operation predictably. Gathering accurate operating data, therefore, is key to mastering the revamp process.

With accurate data in hand, a combined approach—gathering all the experience of operating personnel, unit engineers, and design engineers—allows for a complete understanding of current operation and possible future changes. The final result is a maximum return for the investment.

Key to the approach is the systematic and paced execution of a step-by-step procedure to assure full consideration of the revamp. A systematic, team approach is critical in revamping Udex units because this solvent-based extraction unit is little understood by most refinery personnel.

The interaction of the extraction, solvent stripping, and solvent-recovery (water wash) steps is complex. Operating problems arise from the need to simultaneously manage unit performance and water balance in the glycol-water system.

A step-by-step approach ensures proper understanding of the existing unit while building a consensus regarding the modifications required in the various plant departments.

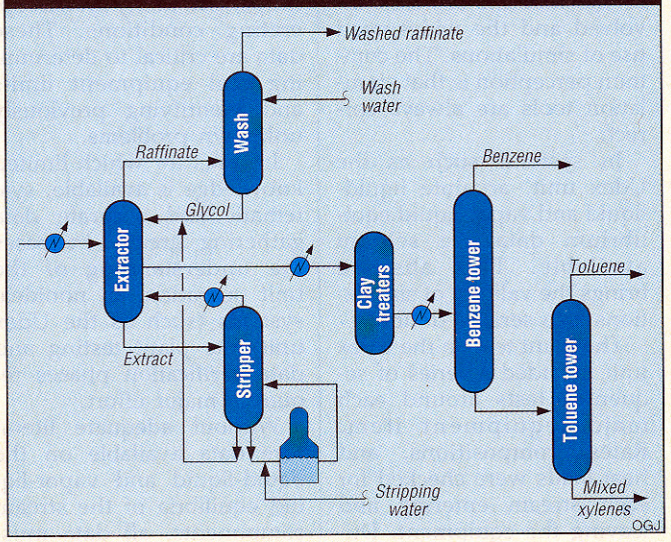
Project execution

The revamp project was executed using the steps shown in Fig. 2.

The results of these steps was preparation of an expanded design package. Major elements included: Test

Fig. 1

PROCESS FLOW SCHEMATIC



run analysis, thermodynamic data development, piping and instrumentation diagrams, equipment-modification specifications, heat and material balances, utility balances, and cost estimates.

Team involvement

If a company does not understand the operation or capabilities of an existing unit, revamping becomes a "hit-and-miss" affair. Therefore, all personnel with knowledge of the process must be involved in the revamp, including:

- Unit operators with knowledge of conditions during normal and upset operations
- Senior engineers who understand the process
- Process engineers who understand the influence units have on one another in an integrated refinery
- Equipment designers who can sort out the interactions of the various pieces of equipment.

With these people involved, the project team can begin to evaluate unit operations and testing requirements.

Revamps based on theory, using only equipment specifications and piping and instrumentation diagrams, usually result in wasted investment. This failure is caused by a lack of knowledge about many "real plant" limitations.

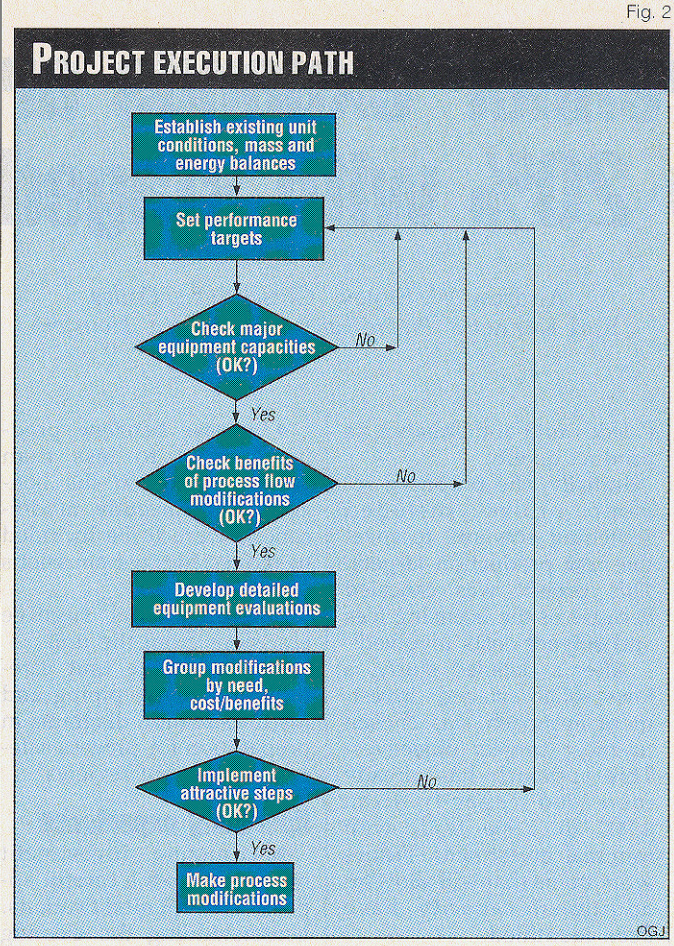
Pressures to cut project costs often result in revamps conducted in an "office-style" fashion using simulation tools. This is a false economy. Effective project execution involves coordination and sustained involvement of all project team members.

Plant testing

Critical to determining required changes is understanding current operation. Available operating data are usually a collection of incomplete material of varying quality from log sheets and process-control computers.

These data serve their purpose adequately. The purpose for which the data are gathered, however, is not project analysis.

Fig. 2



Revamp projects require, as a basis, a set of data for the existing unit—fully balanced for heat and materials. To this end, the project team must execute a plant test.

Accurate plant tests are seldom performed because of the amount of work involved and the widespread use of simulations. The common perception is that simulation tools are always correct.

In systems such as the Udex unit, accurate liquid-liquid and vapor-liquid equilibrium data are seldom available. This absence brings the validity of simulations into serious doubt.

The plant test on the Udex unit included a series of sequential tests around each major equipment item. Rates, compositions, and heat loads were checked for each stream entering and leaving the equipment. Duties were cross-checked, where possible, on both the process and utility sides of all exchangers and heaters.

Executing an accurate plant test requires considerable commitment of personnel. Items to be checked include: Local flow rates, temperatures, pressures, pump amps, control valve positions, exchanger pressure drops, and utility system operating conditions. These data are critical to determining real equipment limits and identifying previously unknown problems.

In units for which limited knowledge is available, systematic and accurate data gathering greatly increases the understanding of the unit operation. In nonideal systems (such as the Udex unit) the plant testing and data verification phases require a major effort.

Without adequate literature data available on the liquid-liquid and vapor-liquid equilibria of the stream components, all data must be rigorously verified. Verified data make possible the determination of correct thermodynamic methods and coefficients for use in modeling unit operations.

Without an accurate thermodynamic basis, the scale-up of unit capacities and stream purities is reduced to an empirical exercise of limited reliability.

Udex unit tests

Testing continued until a verified set of data, balanced for heat and material, was available for each part of the unit. In a Udex unit this includes both a hydrocarbon balance (on feeds and products) and a water and glycol balance (on extraction solvent) around each piece of equipment.

Obtaining this basic data was the most important step of the revamp project. Udex units are notoriously difficult to understand; without the effort invested at this stage, a successful revamp would not have been possible. Even when dealing with an off-the-shelf unit design, minor modifications over time have a cumulative effect.

Personnel experienced with similar units are a critical resource. But be wary of a project team with the attitude that a particular unit is "just like" another one they have worked on. Every unit has something new to teach.

And, at the same time, be prepared to pay the costs, in both time and expense, of understanding a unit. This requires getting every key revamp team leader into the plant.

The availability of experienced personnel reduces but does not eliminate the need to thoroughly acquaint the project team leaders with the operating unit. In the end, this time and expense is repayed by a unit that works both at start-up and during its entire operating life.

Equipment check

The major equipment items in the Phibro C Udex unit are the main towers and

reboiler heaters. The main towers include: The extractor, stripper, raffinate wash tower, benzene tower, and toluene tower. The main fired heaters include the stripper reboiler, benzene reboiler, and toluene reboiler.

Liquid-liquid and vapor-liquid equilibrium coefficients were developed for the components in the system, and each tower was rigorously modeled for the plant test data.

After fine-tuning the models to match plant performance, the final models formed the basis for evaluating revamp alternatives. Heater evaluation required calculating heat release vs. demonstrated capacity for the unit. Results were confirmed by comparison with operating experience for alternate situations during the evaluation period.

Preliminary evaluation

The result of the first evaluation step was confirmation that a capacity increase of as much as 30% could be achieved within the limits of the existing major equipment. The new product specifications could be achieved simultaneously.

At this stage, necessary modifications to other units (feed and solvent units) were identified.

Heat/material balance

After evaluating the major equipment, Phibro decided to continue with the project and identify required equipment and piping changes.

The most important part of accurate equipment evaluation is knowing the capabilities of the current equipment and its future requirements. An accurate heat and material balance provides this information.

The plant-test heat and material balance provides a definition of current performance. The final heat and material balance shows the required capability.

Modifications

During generation of the heat and material balance, process modifications are checked for the impacts and benefits they effect. This requires coordinated analysis of equipment, process changes, and the impact on other units.

The major internal modification to the Udex unit was changing the water balance to simplify the overall process scheme and reduce water treatment requirements. Concurrently, recycle stream integration between the upstream reformer was changed to debottleneck critical sections of the Udex unit. Finally, modifications were made to a separate solvent unit to allow equipment to be switched between the solvent and Udex unit.

The final heat and material balance included all the effects of the major changes proposed in the process flows.

Table 1

REVAMP RESULTS

Date Revamp status	July 1991 Before	August 1991 Before	July 1993 After	August 1993 After
Unit charge, b/d	4,928	4,805	5,834	5,635
Raffinate, b/d	2,868	3,033	3,379	3,113
Benzene, b/d	266	191	343	347
Toluene, b/d	792	750	1,051	1,060
Mixed xylenes, b/d	835	725	782	824
Aromatics in charge, %	43.50	38.55	43.36	46.01
Aromatics recovery, %	95.89	95.62	96.99	97.42
Aromatics in raffinate, %	3.07	2.67	2.23	2.14
Benzene purity, %	99.77	99.81	99.96	99.87
Benzene recovery, %	99.59	99.46	99.63	99.72
Toluene purity, %	99.92	99.95	99.96	99.92
Toluene recovery, %	97.90	98.57	99.16	99.29

Equipment evaluation

Equipment and piping evaluation started with reviews of current equipment performance with the unit operators. Questions asked included:

- "Which control valves and bypasses are fully open?"
- "Which breakers in the substation and which motors require frequent maintenance?"

The answers to these and similar questions convey all the operators' experience to the revamp team. To separate perception from fact, data are always field-verified and checked.

Additionally, with minor modifications, unit service factor can be maintained at higher capacities.

Many revamps fail because the equipment is pushed too hard.

While the revamped equipment can meet its design capacity for a test, it cannot meet overall stream processing requirements because of excessive maintenance requirements. Keeping long-term maintenance and service requirements in mind ensures that revamp modifications gain the expected benefits.

For example, after another unit revamp, the solvent-stripper bottoms pump was experiencing severe recirculation-eye cavitation. This resulted in extremely high maintenance costs. Although the equipment operated acceptably for short periods, it was chronically out of service because of impeller and casing damage. These types of problems must be identified and fixed for a successful revamp.

During detailed equipment evaluation, "mini-tests" were run to check specific equipment items. These included point-to-point pressure drop checks to determine the hydraulic capacities of complete systems of equipment and piping.

Hydraulic calculations are useful. But backing up critical, borderline decisions with real testing gives the best results for the entire project.

Staged implementation

With the final engineering package in hand, cost estimates of modifications were made. Based on the total

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erected costs of various groups of modifications, parts of the project have been implemented in stages.

Implemented items have improved operation of the unit in all areas: Product quality, capacity, environmental performance, and safety.

The first major modification was the switching of two towers to improve overall product quality. A tower from a separate solvent unit was switched with the benzene tower. This allowed the product purity to be increased to a toluene specification of 0.01% or less in the benzene product.

The tower switch replaced a 4.5-ft diameter tower with a 6-ft diameter tower. The increased diameter permitted higher reflux rates and allowed operation at the improved purity specification.

After the benzene tower was replaced, the Udex stripping tower was identified as a major constraint. The stripping tower was revamped by replacing its existing conventional internals with high-capacity internals.

The high-capacity trays were designed to be installed with minimum modifications to the tower shell and attachments. The effective capacity gain was an increase in vapor loadings of more than 30% in the stripper.

During evaluation of the verified piping and instrumentation diagrams, a pressure-drop limitation was located in the stripper-tower overhead circuit. Piping modifications allowed the two overhead condensers in this circuit to operate in parallel instead of in series.

Additional flow limitations were relieved by installing larger nozzles on the towers at the same time new trays were installed. Minor modifications included changing the type of clay used in the clay treaters, replacing exchangers, and modifying piping.

The clay treaters remove color bodies and olefins from the aromatics products. The clay is acid-treated before use, which causes the olefins to be polymerized during operation. This keeps the benzene and toluene products on specification for both visible and acid-wash color.[1]

The exchangers' replacements also included the partial implementation of a new heat-integration scheme developed to improve the unit energy efficiency and operability.

The heat-integration modification included relocating the exchangers to improve overall heat recovery with minimum capital expenditure. The new heat-exchanger network increased the clay treater operating temperature, improving clay treater operations.

Additional exchanger replacements and piping modifications reduced the number of flanges in benzene service. This reduction decreased overall fugitive emissions from the unit. In addition, recycle-stream modifications required the construction of short lengths of small-diameter piping between the Udex unit and the reformer.

Capacity increase

As a result of the modifications, Udex unit capacity was increased by more than 20% (Table 1). Before the revamp effort, unit charge averaged 4,900 b/d of feed. Currently, processing capacity is an average feed rate of 5,900 b/d, and is limited by feed availability instead of by Udex unit constraints.

The upstream reformer capacity currently limits unit production rates. Because of insufficient feed, the upper limit of the Udex unit capacity has not been established.

Reference

1. Novak, L.T., and Petraitis, K.F., "Laboratory Evaluation of Clays in the Treatment of Benzene-Toluene-Xylene Feedstocks," Industrial Engineering Chemistry Research, Vol. 28, No. 10, 1989, pp. 1567-70.