

**EFFECTIVE FCC REVAMP MANAGEMENT LEADS  
TO SUBSTANTIAL BENEFITS**

by

Bill Miller, Jeff Warmann, and Alan Copeland  
Williams Refining, LLC.  
Memphis, Tennessee

and

Terry Stewart  
International Alliance Group  
Houston, Texas

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## **Abstract**

Williams Refining, LLC has successfully implemented a major revamp to increase the capacity and yield performance of its fluid catalytic cracking (FCC) unit located in Memphis, Tennessee. The entire project was accomplished in less than one calendar year, from start of engineering to completion of the turnaround. Project management, procurement, engineering and construction was provided by International Alliance Group (IAG) of Houston, Texas as general contractor. The FCC revamp design utilized the latest technology from UOP LLC. The success of this project was a direct result of the effective team approach between Williams, IAG and UOP.

## Introduction

Williams Refining, LLC (Williams) is a petroleum/petrochemical division of Williams Energy Services. The refinery is located in Memphis, Tennessee and processes 150,000 BPSD of crude oil.

The refinery has been involved in a continuous growth pattern since the late 80's with the greatest progress and focus occurring since 1993. The philosophy of constant improvement and growth has allowed the refinery to go from a 40,000 BPD 1980's design to the 150,000 plus barrels that it processes today. Figure 1 and Figure 2 represent the crude capacity and FCCU throughput, respectively, over the past seven years.

The FCC unit at Memphis, TN was originally owned and operated by Delta Refining, and was designed by UOP in 1978 to replace the existing 13,000 BPD TCC unit. The original design was for 29,300 BPD of paraffinic gas oil feed operating at 80% conversion. The unit consisted of a riser reactor with a tee disengager and a high efficiency combustor style regenerator with external catalyst mixing. The start-up of the unit was in July 1980.

In 1981 Delta Refining became Mapco Petroleum when purchased by the Mid America Pipeline Company (MAPCO). From 1981 to 1986 the unit was typically operated on a blend of VGO and resid feed.

In 1986, the reactor riser's feed distribution system was revamped to an elevated style employing premix type distributors along with lift gas and steam to aid with uniform catalyst distribution prior to feed injection. The operating philosophy of the refinery led to

increased feed rates while decreasing conversion of the feedstock to meet the limit of the air blower.

In May 1991, the Mapco FCC Unit was revamped to a UOP Vented Riser termination device along with an Exxon Wet Gas Scrubber. These changes allowed the refinery throughput to continue increasing while improving the yield structure of the unit. The FCC increased to 35,000 B/D while processing 100% atmospheric bottoms material. Over the next several years, Mapco ran this unit with high main column BS&W. Several attempts were made without success to identify the root cause of the reactor catalyst loss. Yields from the unit were much improved over the previous operation even though the main column bottoms typically contained 1% catalyst.

In September 1995, Mapco revamped the unit to include the Ramshorn riser termination device and increase the unit capacity to 45,000 B/D. The spent catalyst stripper and the elevated feed nozzles were replaced. A supplemental air blower was installed. The initial operation after startup was successful with improved yield selectivity and throughput that reached 48,000 B/D; however the catalyst losses from the reactor were not eliminated. The Ramshorn was modified to the LD<sup>2</sup> style and the main air blower was replaced in March 1997 with a higher capacity machine. These modifications resulted in a throughput of approximately 62,000 B/D.

During the same time frame, upgrades and improvements to other parts of the plant were occurring that complimented the FCC as plant capacity grew. The sats gas plant installed in 1996 unloaded the FCC Gas Plant, Alky and Poly units. Installation of a C3/C4 splitter and an Alky revamp in 1997 along with crude unit revisions in 1997 and 1998 allowed for increased crude throughput with improved economics and additional flexibility in FCC operations. The final stages of the East Crude Unit revamp scheduled for completion during the FCC outage in 1999 would result in increased Jet fuel and distillate production leading to heavier FCC feed.

## Recent Operation

In early 1998 the refinery became Williams Refining LLC.

In early 1998 permitting and planning were begun to include the vision for the refinery through 2001. This involved plans for crude expansion, a continuous catalytic reformer, FCC and alky unit capacity increases, etc. This plan required a Prevention of Significant Deterioration (PSD) review and permit that was finalized in July 1999. Our FCC flue gas scrubber significantly reduced environmental permitting issues.

By mid 1998 the timing for the 1999 turnaround had been established but the FCC project had not been defined. Operation of the FCC at rates of 40% over the 1995 design were pushing the limits. Cyclone inlet velocities in the regenerator were at 110-120 feet per second, standpipe fluxes had reached 1.25 million lbs./hr./sq. ft., the regenerator combustor was approaching 8 feet per second superficial velocity, and 0.15 wt. % carbon was left on regenerated catalyst.

The next turnaround on the FCC would need to address these issues and be able to better handle the heavier feed that would result from increased and improved crude unit operations.

The major issues facing Williams included:

- Excessive reactor side catalyst losses, approximately 4 to 6 tons/day
- Regenerator cyclone inlet velocities
- Catalyst standpipe flux rates
- Combustor operation and coke burning capabilities
- Future heavier and higher con carbon residue feed
- Reduced reactor riser contact time with increased feed rates

## Refinery Goals and Objectives

The refinery now wanted to increase the feed rate capability to a target of 69,000 BPD. In addition, the quality of the feedstock would decline with density dropping 2 to 4 degrees API and a Conradson carbon residue increase from 1.8 to 2.2 wt. %. The future operation of the existing unit offered little process flexibility which would ultimately result in lower conversions. The refinery was ready to look for the next technology upgrade that could address these issues and give enough improved operation to payout the upgrade. For this reason, Williams decided to entertain ideas for revamping the FCC.

Time was tight, it was September of 1998 and the refinery turnaround was scheduled to begin in 14 months. It would not be possible to change the timing of the turnaround as other refinery projects were already firmly scheduled and any alterations would have a strong negative impact regarding cost, downtime and the lost opportunity due to market demands. The targeted goals for the revamp of the FCC were to complete the turnaround in a 21 to 25 day window, to meet market supply requirements, maintain refinery economics, and remain within the refinery's intermediate and product storage capabilities.

It was clear that the opportunities were plentiful. Resolving all of the mechanical and operational issues and the associated logistical hurdles would require a well prepared and executed turnaround plan.

The foundation of any successful plan includes a clear understanding of the goals and objectives. As far as the FCC was concerned, the objectives for the upcoming revamp were clear.

## Feasibility Study

A revamped feasibility study had to be completed to analyze the best technical options and weigh their benefits versus cost and implementation / constructability. Williams contacted two FCC technology licensors that had first-hand experience with the operation of this unit.

The licensors started their feasibility studies in the middle of September 1998. These independent studies were driven by brainstorming sessions to understand the latest technology and the potential solutions it could provide.

As the studies progressed, the revamped unit started to take on the look of a new unit. The thought of completely replacing the conversion / catalyst section of the FCCU was entertained. However, from this analysis it became obvious that a new unit had three major negatives against it: the costs were prohibitive, the plot space was non-existent, and the project could not be completed in the designated turnaround window. The revamp option became the only realistic alternative to upgrade technology and address the opportunities.

## The Key that Unlocked the Revamp

The outcome of these revamp studies was encouraging and Williams ultimately selected UOP to provide the FCC technology for this revamp. The decision was based on innovative solutions proposed by UOP that addressed all the opportunities. The key that allowed Williams to revamp, was the use of UOP's Vortex Separation System (VSS<sup>TM</sup>) inside the regenerator. UOP's VSS is well proven as a reactor riser termination device, however it had only been proposed for use in the regenerator once before. This would be the first regenerator VSS installation to be put into service.

The solution using the VSS fits well with UOP's high efficiency regenerator design. The VSS essentially replaces the first stage cyclones, thereby creating room for larger single stage cyclones. These cyclones were larger in diameter and inlet area to allow proper handling of the expected flue gas rates at the increased raw oil throughput and operating severity. The VSS in the reactor accomplished the same feat and with a higher containment. This meant that both the 15ft reactor and 24ft regenerator diameters could be kept, thereby minimizing the structure revisions required to hold them. This solution reduced the plot space requirements, turnaround duration, and was more cost effective than the other options reviewed.

In addition to the upper regenerator VSS, UOP also proposed a larger diameter combustor section to efficiently carry out the carbon burn of the spent catalyst. The larger diameter combustor could be fit into the structure. On the reactor, UOP proposed additional revisions including elevated Optimix™ feed distributors, increased residence time riser, reactor cyclones, and a spent catalyst stripper employing UOP's latest high-efficiency tray design. The revamp would also include larger catalyst standpipes, expansion joints, and slide valves. In essence, the entire catalyst section of the plant would be replaced tying into the existing reactor vapor line and flue gas ducting. A sectional elevation of this proposed layout is presented as Figure 3.

In addition to these changes the FCC main fractionator and gas con system would require modifications to handle the increased throughput and provide for improved fractionation and recovery.

### **Economic Analysis, Project Justification and Implementation**

As the feasibility studies and planning sessions progressed, Williams recognized the need for outside support to assist in the crucial steps of project justification and implementation. This partner should also be able to provide overall management of the

project through the engineering, procurement, construction, and commissioning. Due to all of the other projects currently in progress Williams no longer had the resources available in-house.

Williams invited International Alliance Group (IAG) of Houston, Texas and others to submit a proposal and execution plan to implement the proposed FCC revamp project. Williams selected IAG based on their previous experience in turnaround and project management and their proven track record. IAG was formed in 1995 to deliver leading edge technology for refinery revamps, define and establish real economic opportunities, provide single-point responsibility with turnkey pricing for technology, and execute projects supplying project management, engineering, procurement, and construction.

IAG had already completed 11 turnkey FCC Revamp projects implementing FCC technology improvements including elevated feed systems, riser/standpipe change outs, reactor replacement, flue gas systems and regenerator modifications. IAG has a complete staff of highly experienced individuals averaging over 26 years of refinery experience.

IAG's involvement began by assisting with final technology selection and economic justification analysis. This analysis was a very dynamic one that required the cost, constructability, downtime and payout to be included. IAG analyzed the numerous revamp options being proposed by both licensors and assessed the economics, constructability and schedule of each option within Williams prescribed constraints. These constraints included: cost effective retention of existing structure, turnaround start date, turnaround completion date, and capital limitations.

## Project Team Approach

A “project team approach” was promoted by Williams based on past project experience. Together, Williams and IAG were able to combine their collective experiences regarding selection of the detailed engineering firm, primary contractor and all of the equipment vendors and field sub-contractors. This allowed Williams definitive input to assemble a project team with quality members who have exhibited not only the ability to deliver a high quality end product, but the critical ability of being willing and able to work as a member of a large team. Essentially, Williams and IAG were able to create a “Dream Team,” comprised of many members with long track records in FCC turnaround specialties and familiarity with performing work at the Memphis refinery.

This collection of high quality Dream Team members also allowed for Williams and IAG to simultaneously manage the capital and maintenance activities of this revamp project seamlessly. This ensured that all team members were fully aware of the schedule, scopes of work, and the status of the project including maintenance activities. This excellent communication would result in a well-coordinated work effort where selected contractors adjusted to varied work requirements within the scope of work to meet schedule and project goals.

Figure 4 lists the contractors, licensors and management firms that made up the core of this Dream Team. In addition to this group of 23 contractors, there were another 6 equipment fabricators and 50 equipment suppliers who played significant roles in the revamp project. Williams relied on IAG to manage these relationships releasing themselves to concentrate on the overall effort and to focus on areas that needed special emphasis.

## Project Goals

The ongoing feasibility study and economic analyses provided the ability to clearly identify realistic goals for the revamp of the FCC. Specifically, the goals for the revamp included:

- Increase capacity of the unit to 69,000 BPSD, with future capability of 75,000 BPSD.
- Reduce reactor catalyst losses from 4-6 tons/day to less than 1.5 tons /day.
- Improve conversion and gasoline yield by 3.5 liquid volume percent.
- Provide the capability for future heavier feed operation.
- Reduce the regenerator cyclone inlet velocity.
- Improve catalyst circulation and regeneration capability.
- Expand the capacity and recovery in the Main Column & Gas Concentration Unit.
- Meet the scheduled turnaround start date and duration.

## Project Justification

Williams recognized that meeting the scheduled turnaround date would require a solid project scope that would not change significantly. This was necessary to allow the start of basic engineering, to define long lead items, and to secure pre-funding for the basic and detailed engineering and purchasing of the long lead-time equipment. Final funding approval was not completed until late February. Williams issued Purchase Orders to IAG with cancellation charges through the end of February 1999 for the licensor, engineers and contractor to assist in project justification and scope development in the event the project was not fully funded. The initial project team members included UOP (Basic Engineering & Licensor), Stewart & Bottomley, Inc. (Detailed Engineering), MPEC (Process Engineering Main Column/Gas Con) and Altair Strickland, Inc. (FCC Structure Construction).

Based on UOP's final design basis and yields, Williams and IAG prepared a detailed project justification for approval. This justification required estimating the downstream unit effects, expected revenues, equipment costs, implementation time, and the erected cost. Key inputs from the licensor, construction contractor and engineering contractor were required to accomplish these tasks. This effort consumed two months, ending in January, 1999.

Long lead fabricated equipment identified during project justification was pre-funded with purchase orders containing cancellation charges. The list included the following:

- Reactor/Stripper with VSS and UOP's new high efficiency stripper tray design
- Regenerator/Combustor with VSS
- Cyclones for the Reactor and Regenerator
- Wet Gas Compressor Components
- Slide Valves
- Expansion Joints
- Riser/StandPipe and UOP Optimix Feed Distributors

All of this equipment became critical path at some point in the schedule, however, it was the reactor and regenerator vessels with associated internals that governed the implementation schedule. For this reason Williams and IAG had to give these vessels the highest priority with regards to design engineering.

### Project Scope

The extensive economic analysis and project justification phase allowed Williams and IAG to define a complete scope of work for the revamp project. UOP's yield analysis

was utilized by MPEC for preliminary process design of the Main Column and Gas Concentration Sections followed by preliminary mechanical design by Stewart & Bottomley, Inc. for the downstream requirements. Altair Strickland, Inc. assisted in constructability reviews and provided detailed construction pricing. The project scope was now presented as being “final” and it was understood that it could not be altered significantly if the turnaround schedule was to be met. The “final” scope for the revamp included the long lead fabricated equipment already identified plus the following:

- New catalyst standpipes including a second catalyst recirculation line
- Orifice Chamber modifications
- New Power Cabling for the Main Air Blower
- Main Column internal upgrades
- Sultzer/UOP VGMD Trays™ in the Primary Absorber, Stripper, and Debutanizer columns
- New feed piping system, exchangers and controls
- Slurry and Light Cycle Oil heat integration system upgrades
- Various exchanger, pump, piping and instrument control system enhancements.

The final capital project scope, economically justified and submitted for approval was approximately \$35MM.

### Project Implementation

Even before the scope of work was finalized it was clear in December of 1998 that this revamp project was to be conducted in a manner like no other before it. With the feasibility study completed and the economic analysis starting to focus in on the ultimate solution, it was now possible to start thinking about project implementation. The scheduled turnaround start date was only 11 months away and it was obvious that this project would be accomplished in a very unconventional way.

As mentioned earlier, pre-funding for the basic engineering, detail engineering, and long lead-time equipment items was started well before receiving final approval. Only in this way could Williams hope to meet the aggressive turnaround schedule. Essentially, the scope of this project had to be “solid” and any change in scope had to be thoroughly scrutinized and approved. A firm revamp scope would allow a detailed schedule to be established along with reporting and cost accounting procedures for tracking the project.

Basic Engineering by UOP was started during the economic analysis and project justification phase of the project. This was approximately ten weeks before Williams would eventually provide official approval for this project. It was the feasibility study and initial feedback from the economic analysis phase that allowed Williams to identify major design items.

The “Justification” phase of the project defined that the reactor and the regenerator combustor and head be replaced. This option was more cost effective than retrofitting and reusing pieces. It was also known that the diameter of these vessels would have to be the same as the existing vessels in order to retain the existing structure. This allowed UOP to start the basic engineering even though the rest of the scope and processing objectives had not been finalized. It was understood that adjusting the typical flow of design work would result in “recycle” and could possibly result in a slightly higher cost to complete than a normal design project. However, the design of the “long-lead” items was needed as soon as possible and the schedule and economic benefits of this approach far outweighed the costs.

UOP’s preliminary basic design was forwarded to Stewart and Bottomley, Inc. for preliminary detailed engineering for these vessels. Stewart and Bottomley’s preliminary detailed design was sufficient for IAG to prepare bid packages and select fabricators. It also allowed IAG to place firm orders for the Reactor and Regenerator on January 13,

1999 and January 28, 1999 respectively, to ensure procurement of the raw material and reservation of shop space. This overlap of basic and detailed engineering was the only way to meet the scheduled turnaround date and the concept was extended to remaining equipment for engineering, procurement and construction.

Final approval for the project initiated overlapping efforts similar to that for the Reactor and Regenerator for all capital and maintenance work in order to meet an established turnaround date of October 18, 1999. A detailed project schedule, including allocation for maintenance work, was prepared along with specific reporting and cost accounting procedures to track the project.

By the time the raw material arrived at the fabricator's shop, the scope and processing objectives had been finalized. UOP and Stewart and Bottomley began to finalize the engineering specifications and design for this equipment based on the final project scope that was agreed upon. This method of engineering is not the most efficient by standard views but certainly was most effective in meeting the schedule.

Under IAG's direction and supervision, all equipment fabrication and delivery including inspection was rigorously staffed and expedited. There was very little, and in some instances, no float time for the major equipment due to the interwoven requirements of engineering and procurement. These tight and highly dependent deadlines meant sometimes revising designs and fabrication to meet the schedule.

Williams defined maintenance work scopes for the turnaround and with IAG integrated the schedule and contractor requirements with the capital work activities. Maintenance work scopes were budgeted at approximately \$10MM and included work outside of the FCCU. The intent was to have a seamless schedule and construction effort by all team members to meet total project goals. Only through the project team approach and the unique working relationship between the contractors could design, procurement and

construction adjustments be made without jeopardizing schedule or overall project costs. In numerous instances the contractors adjusted work activities and sequences to keep the project on or ahead of schedule with little or no cost impact. The capital work was executed primarily on a lump sum basis with the remainder on a guaranteed maximum. There were change orders, but all were within the contingencies established during the project justification phase. Over the 10 month implementation phase, weekly meetings were held via video conferencing. These meetings served as an open channel of communication, updating all parties on schedules, costs, upcoming week's requirements, and milestones. Scope changes were held to a minimum and in every case the scope adjustments were justified by reason of economic payout, operability, reliability and safety. The emphasis by all team members was on maintaining schedule and overall project cost.

In mid-April 1999, UOP completed their basic engineering specifications (Schedule A). Sub-contractor pre-qualifications were issued in May followed by a final qualified sub-contractor bid list being established in June. At this time replacement of the regenerator shell had been reviewed and found to be cost effective to replace due to refractory replacement that was discovered during a short outage in early June. Even at this stage of the project, flexibility in accomplishing the goals overrode earlier decisions. Sub-Contractor bid packages were prepared based on preliminary designs and issued in June followed by final selection and award of contracts through August. Stewart and Bottomley, Inc continued on with detailed design engineering into September 1999. Procurement of long lead-time equipment and specialty items and valves continued through August. Expediting, inspections, and quality control were ongoing until the shipment of the last long lead-time item.

A detailed pre-turnaround and turnaround construction schedule was developed based on six 10-hour days for pre-turnaround work and two 12-hour shifts working seven days per week for the turnaround. The shortest turnaround duration possible was needed

due to refinery infrastructure, interdependence of other units, storage limitations, crude supplies, marketing commitments and refinery economics. The pre-turnaround work was initiated in July and completed on October 17, 1999 when the FCCU was shutdown. The actual turnaround mechanical work started October 18, 1999 and was completed November 11, 1999. Oil was introduced to the FCCU late that evening, culminating a 25 day “oil out to oil in” turnaround. Capital construction work associated with insulation, instrumentation, miscellaneous structural and clean-up continued on, ultimately being completed on December 15, 1999. A complete presentation of the FCC Project Implementation Schedule is included as Figure 5.

In the end, the revamp project scope was held essentially constant with the exception of the new regenerator shell and replacement of an existing catalyst slide valve. Both affected the critical path and were cost effective scope revisions.

### Revamp Results

The start up of the revamped unit began with oil introduction on November 11, 1999, meeting the project goal. The start up of the unit was smooth and absent of any catalyst carry over that plagued this unit over the past several years. Within two days of oil introduction the unit was processing 68,000 BPSD, essentially the proposed design capacity. Subsequent power failures and external induced upsets to the FCC have resulted in no catalyst losses and easy unit re-start. After working through an inventory of heavier than design feedstock contaminated with high sodium, calcium and iron concentrations, the unit was performing well but data for the higher charge rates and conditions was unavailable for inclusion in this report.

The following tables summarize the major goals of the revamp alongside of the actual performance.

Table 1. Project Results

	Proposed	Actual
Turnaround start date	Oct. 18, 1999	Oct. 18, 1999
Turnaround Duration, Oil out to Oil in, days	21 to 25	25
Total Capital and Maintenance Cost, \$MM	45.0	45.0

Table 2. Process Results

	Proposed	Actual
Feed API gravity / Conradson Carbon, wt.-%	24.4 / 2.20	24 / 2.7
Conversion, Liquid Volume%	>70.5	72.5
Capacity, BPSD	69,000	55,000
Reactor Side Catalyst Losses, tons/day	1.3	1.25

From the above table, it is clear that the major goals have been met. As these goals formed the basis of the economic justification, the meeting and exceeding of these goals ensures the profitability of the revamp.

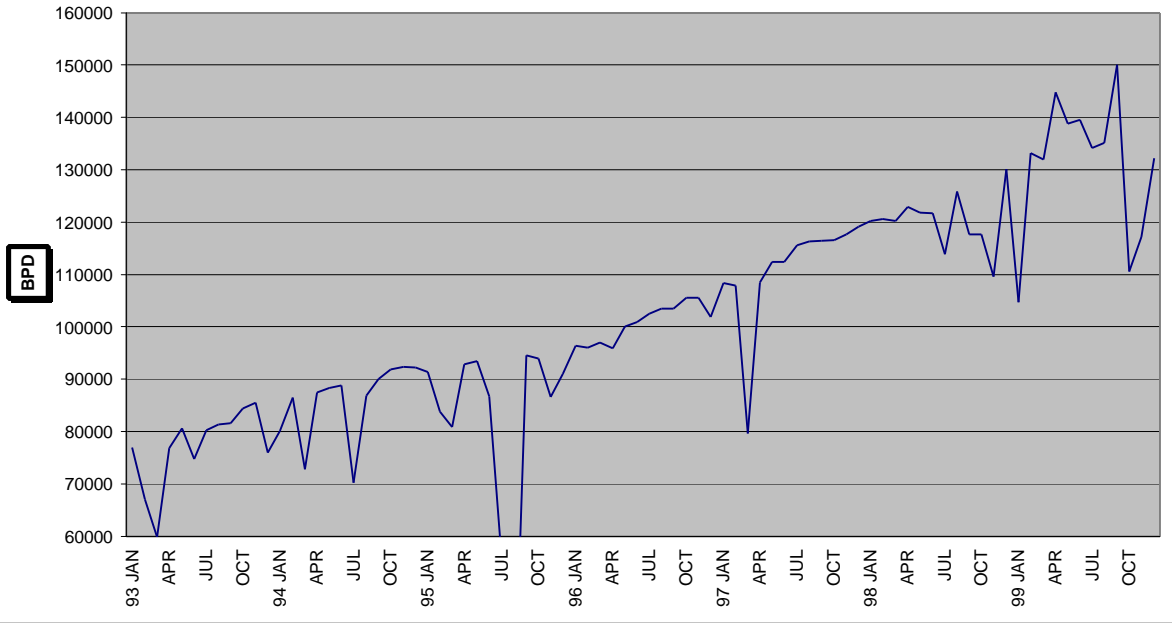
### Conclusions

The revamp of Williams FCCU was completed on time, on budget, and performed according to guarantees due to the close working relationship that the Williams “Team” approach to project management provides. This project clearly illustrates that:

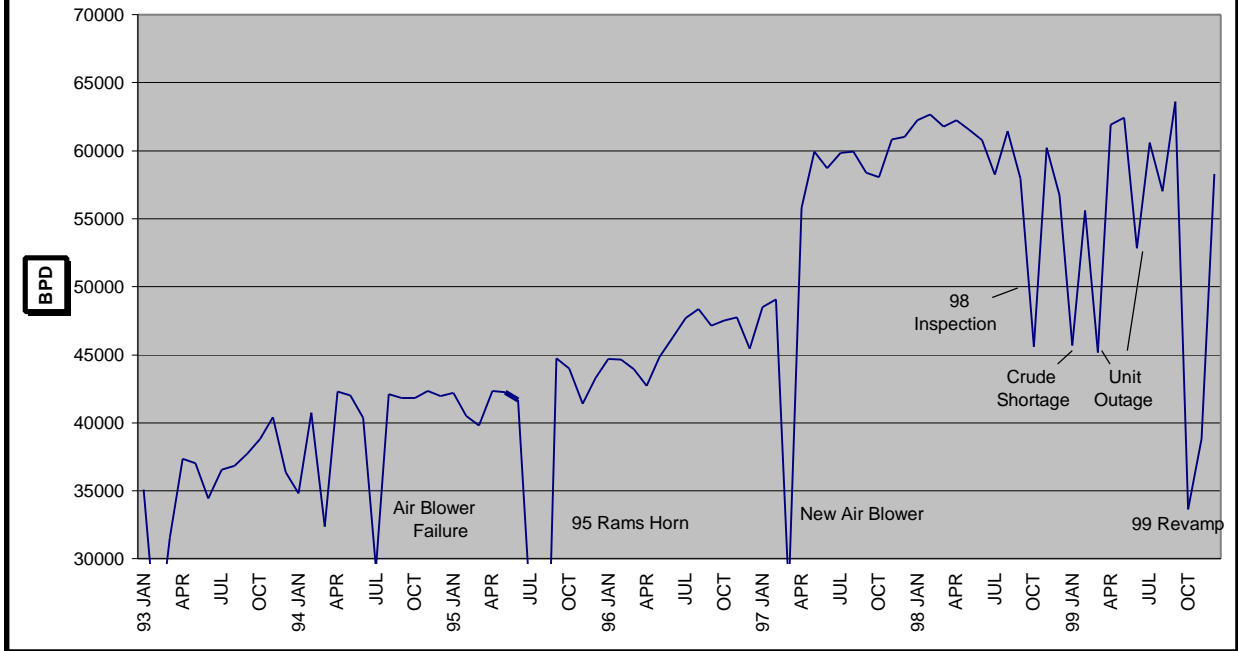
- Extensive revamps of an FCCU can be implemented very quickly
- Technology upgrades should always be evaluated to improve operations and increase bottom line profits
- Experience, expertise and a novel approach to executing projects with a “can do” attitude is essential to perform “fast track” projects while attaining defined goals.
- You don’t have to sacrifice quality or price to achieve performance.



**FIGURE 1  
MEMPHIS REFINING  
JAN 93 - DEC99  
CRUDE CHARGE**

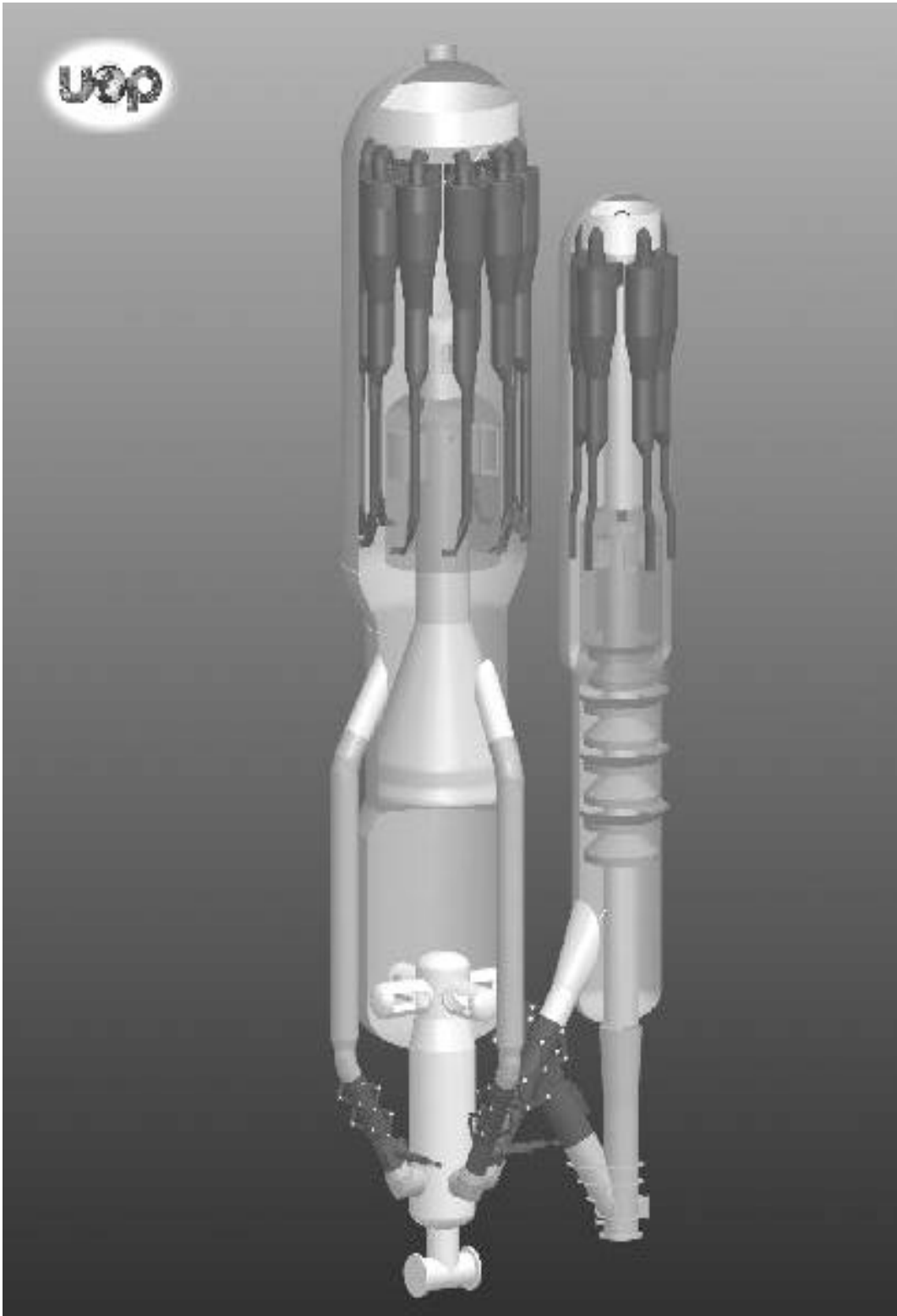


**FIGURE 2  
MEMPHIS REFINING  
JAN93 - DEC 99  
FCCU RAW OIL CHARGE**



**Figure 3**

**Reactor / Regenerator Sectional Elevation**



**Figure 4**  
**The Dream Team**

<b>Contractor</b>	<b>Work Scope/ Function</b>
All-Tech Inspection	Inspections
Altair Strickland	FCC Structure
American Instruments	Instrument / Electrical
Atlantic Scaffolding	Scaffolding
Barnhart Crane & Rigging	Cranes/ Transportation
BP Mechanical Insulation	Insulation / Fireproofing
Cust-O-Fab Field Services	Mechanical Work - Gas Con / FCCU Piping
Deep South Crane	Heavy Lift Crane
Delta Services	Air Fan Cleaning / Acidization / Burner Cleaning
Diamond Refractory	Refractory
Hydrochem	Water Cutting
IAG	Project Management
JL Manta Corp	Acidization
MPEC	Process Engineering
Phillip Services (Incat)	Catalyst Removal
Senior-Flexonics / Pathway	Expansion Joints
Stewart & Bottomley	Engineering
Tapco	Slide Valve
Udelhoven	Instrumentation
United Industries	Mech Work - Turnaround / Bundle Extraction
UOP	Process Technology Licensor
Wallace Electric	Electrical Work
Williams Refining	Everything



FIGURE 5

