CHANGES TO MAINTAIN FCCU CONVERSION

AM-02-44

by

Jacqueline D. McKinney
Consultant
Six Sigma
Conoco, Inc.
Lake Charles, Louisiana

and

William D. Henning
Consultant
Refining Technology Group
Conoco Inc.
Ponca City, Oklahoma

and

Peter Andrews
FCC & Refinery Consultant
Andrews FCC Consulting
Houston, Texas

and

Bruce Dodds
Senior Project Manager
International Alliance Group
Houston, Texas

Presented at the

2002 NPRA
ANNUAL MEETING
March 17-19, 2002
San Antonio, Texas

Abstract

Conoco Inc. successfully implemented a major and innovative project to address catalyst circulation and improve yields from the Orthoflow F fluid catalytic cracking (FCC) unit located at their Lake Charles, Louisiana refinery. A key component of the project was the addition of an external spent catalyst stripper to reduce the load on the existing internal spent catalyst stripper. The project also replaced the regenerated catalyst plug valve and regenerated catalyst J-bend standpipe with a cold wall wye section and UOP's elevated Optimix feed distribution system. The project improved FCC catalyst circulation, resulted in increased conversion and improved yield selectivity, while also providing the flexibility for processing of heavy aromatic feedstock.

The project's success can be attributed to advanced planning and to the team approach taken by Conoco, International Alliance Group (IAG), Andrews FCC Consulting and UOP. Approximately two and one half years prior to the actual shutdown, Conoco assembled a team of FCC specialists to discuss operational and reliability objectives and apply knowledge learned from previous FCC projects executed at Conoco's Ponca City and Denver refineries. IAG provided single-point responsibility for meeting the goals of the project through turnkey implementation of technology, engineering, procurement and construction. The team approach not only resulted in a successful revamp, it also allowed Conoco to improve FCC operations and improve unit profitability in the period leading up to the turnaround.

Background

The Lake Charles Refinery located in Westlake, Louisiana is Conoco's largest facility, with a crude distillation capacity of 245,000 barrels per day (BPD). The refinery processes both heavy, high-sulfur crude and low-sulfur crude. The refinery produces a full range of fuel products and the feedstock for Excel Paralube, which is Conoco's joint venture facility that produces high quality lubricating hydrocracker base oils.

The FCC converter is a Kellogg Orthoflow F design, *Figure 1*, which was placed in operation in 1979, (replacing an older TCC unit). The original unit capacity was 30,600 BPD gas oil feed. The unit has been debottlenecked over the years, with the last major project being completed in 1993, where the unit feed capacity was increased to 48,000 BPD. The 1993 modifications included a new riser and new feed nozzles, changes to the disengager cyclones, and extensive changes to the fractionator and gas plant.

FCC Unit Recent Operation

The FCC typically processes a gas oil feed that is a mixture of approximately 75% hydrotreated coker and vacuum gas oils, and 25% sweet virgin gas oils.

Existing operating constraints included:

- Air blower capacity
- Wet gas compressor motor amps
- Catalyst circulation instability in the spent catalyst standpipe
- High flue gas afterburn in flue gas line to expander (maldistribution)

Generally, the FCC operates with a fairly high riser outlet temperature. The feed preheat temperature is also set fairly high, to minimize coke yield, and maximize feed rates within the air blower capacity. The regenerator is operated in full-burn.

The Lake Charles FCC converter configuration is typical of the stacked Orthoflow F design. Feed is introduced through eight elevated radial-feed nozzles in an external vertical riser. The riser termination consists of four rough-cut cyclones and five secondary cyclones. The catalyst stripper, which is internal to the disengager vessel, uses two stages of stripping steam distribution and is heavily loaded. The stripper terminates into a long vertical spent catalyst standpipe that connects the stripper, internally through the regenerator vessel, to a plug valve. The spent catalyst is distributed across the top of the regenerator bubbling bed through a riser and set of radial troughs. To burn the coke off the catalyst, air is introduced into the regenerator through pipe grid distributors. The regenerated catalyst exits the bottom of the vessel through a plug valve and is transferred from the plug valve well through a J-bend standpipe to the bottom of the riser.

Assembling the Team

A turnaround was scheduled for February 2001. Approximately two and one half years prior to the turnaround, Conoco assembled a team of FCC specialists as part of the technology improvement process. This team was comprised of representatives from Conoco, International Alliance Group (IAG), Andrews FCC Consulting and UOP. The team evaluated both short-range and long-term operational objectives and established the following primary processing objectives for the 2001 turnaround:

- Preserve the profitability of the FCC unit by maintaining conversion to more valuable products while processing a more aromatic gas oil feedstock.
- Operate within existing main air blower constraints.
- Ensure that modifications would be compatible with any future projects to increase feed rate up to the existing coke burn limit.

The team also considered other objectives, including improving unit reliability and minimizing unit downtime.

The team identified various options to improve operability and profitability, and grouped those options into two categories: short-range (and low-cost) recommendations, which could be implemented either before or during the turnaround, and long-term recommendations to be implemented during the unit shutdown.

Short-Range Optimization Opportunities

The team identified and prioritized minor modification or short-range opportunities, which could immediately impact unit operability and profitability. These items focused on advanced process controls, catalyst activity changes, expander and cyclone reliability. The short term changes implemented before the 2001 project with no capital resulted in immediate improved FCC profitability. This also shifted the unit baseline performance for the 2001 project from the start of run in Spring 1997 to a new test run base case in the Summer of 1999.

Long-Term Optimization Opportunities

The team addressed process constraints and unit reliability issues when identifying long-term opportunities to be implemented during the turnaround. Specifically, the team evaluated the mechanical integrity of the reactor riser, new feed distribution technology, limitations of the main air blower, and catalyst circulation. One of the biggest challenges was to prepare the FCC unit to process a more aromatic feedstock.

During the planning phase, the team identified the following long-term processing and reliability objectives (and associated solutions) for the FCC unit turnaround:

- Maintain conversion and increase profitability
    - Install UOP Optimix feed distributors and replace the J-bend with a wye section and a catalyst acceleration zone.
    - Optimize reactor riser residence time.

    - Address aromatic feedstock effects.
- Provide the flexibility for future projects to increase the unit capacity above the design case by improving catalyst circulation capabilities with a second catalyst stripper (a new external spent catalyst stripper).
- Minimize unit downtime.
- Operate within existing main air blower constraints.
- Improve mechanical reliability:
    - Address reactor riser refractory issues (hot spot in riser).
    - Replace regenerated catalyst plug valve with state-of-the-art slide valve.
- Minimize project costs by giving full consideration to structural and space limitations.
- No increases in FCC stack emissions.

UOP Optimix Feed Distribution Solution

Some of the more successful FCC unit projects in Conoco (including its Ponca City and Denver Refineries) have incorporated UOP's Optimix feed distribution technology. These revamps replaced the J-bend standpipe with a straight standpipe, wye section and vertical reactor riser. The use of a wye section created the vertical riser and the catalyst acceleration zone. The catalyst acceleration zone is important to condition the catalyst to a moderate density and velocity prior to injecting the atomized oil to deliver optimum catalyst / oil contacting. Concurrently, the vertical reactor riser residence time was optimized based on the expected operation of the unit. The Optimix feed distribution system was proposed to help Conoco achieve their processing goals.

Spent Catalyst Stripper and Catalyst Circulation Solution

In addition to the process and reliability improvements that a new riser and feed distribution system provided, the project needed to address catalyst circulation. The original FCC unit design had the spent catalyst stripper and standpipe internal to the reactor and regenerator vessels. The spent catalyst standpipe passed through the center of the regenerator and opened into the middle of the distributor well, forming an annulus. Any modification to the existing design would be difficult, expensive and time consuming due not only to the complexity of the changes to the existing design but also because of other major maintenance activities scheduled inside the vessel. If this project was to minimize downtime, a unique approach was required.

The team of FCC specialists developed an innovative solution. Quite simply, a new external spent catalyst stripper would be installed to unload the existing internal stripper. A spent catalyst stripper incorporating UOP's improved tray technology would be a key element of this revamp and would allow the FCC to circulate more catalyst and take full advantage of the improved feed distribution and stripper technology.

Lift Gas

Late in the project design an opportunity was identified to reduce steam use and sour water make in the FCC, both of which were approaching refinery limitations. Relatively inexpensive piping and instrumentation was installed to recycle gas plant tail gas thereby reducing some of the steam used as riser lift medium. This provided flexibility to decrease unit steam consumption during periods when incremental wet gas compressor capacity is available.

Project Economics

With the technology upgrades clearly identified, the team turned its attention to project economics. UOP provided two separate yield estimates. For the reactor riser, regenerated catalyst standpipe and feed distributor replacement, IAG estimated a total installed cost (TIC) of $5.9 million. Yield improvements from the UOP Optimix feed distribution system technology were forecasted to increase FCC unit profitability significantly from a base case of processing a more aromatic feedstock in an unmodified FCC unit. The feed distributor, standpipe and reactor riser project (if completed as a standalone project) had a good internal rate of return (IRR).

The TIC estimate for the new external spent catalyst stripper project was $1.4 million. Incremental yield improvements from the addition of the UOP spent catalyst stripper technology were also estimated to provide a good return.

Based on these forecasted economics, Conoco obtained approval from refinery management for the technology upgrades.

Project Execution Goals

The foundation of any successful turnaround requires a clear understanding of the project objectives. The team had clearly identified the FCC unit process objectives (listed above). In addition, five project execution goals were established:

- Safety: Zero lost work days, zero recordable cases and zero first aid cases.
- Quality: Material, workmanship and operating performance were all targeted.
- On Time: All material on site prior to unit shutdown and completion of the turnaround on time.
- On Budget: Minimum scope changes.
- Environmentally Safe: No environmental releases for the duration of this project.

Project Scope

The detailed FCC unit scope of work began to take shape once the project execution goals were established. The project included the following:

- A new external (parallel) spent catalyst stripper utilizing UOP's latest spent catalyst stripping technology to increase the stripping capacity and eliminate catalyst circulation limits of the FCC unit. The new stripper design basis was to handle approximately one-fourth of the total catalyst circulation. This would allow the existing stripper to operate in a region where it had been shown to be effective in the past.

- A new external spent catalyst standpipe, slide valve and expansion joint.
- A new spent catalyst distributor, at the entry to the regenerator, compatible with the existing radial flow trough distributor.
- A new regenerated catalyst standpipe, slide valve and expansion joint to replace the J-bend and internal plug valve to handle the higher catalyst circulation.
- A new riser wye section with a vertical catalyst acceleration zone and acceleration distributor.
- UOP's elevated Optimix feed distribution system.
- A new reactor riser with crossover to the existing disengager.

Figure 1 highlights the scope of the project with a "Before and After" approach.

The team identified additional opportunities that initially were beyond the original project scope, including: continuous catalyst withdrawal, regenerator level control improvements, improving the steam quality to many of the converter vessel taps, revising the plug valve pressure taps, and improving the spent catalyst distributor trough aeration design.

Project Implementation

The FCC Riser Modification Project Kick-Off Meeting was held on March 16, 2000. The meeting had all FCC unit turnaround participants in attendance: Conoco, IAG (project management / procurement), UOP (basic engineering / technology licensor), Atkins Benham (detailed engineering), and Construction & Turnaround Services (construction). The capital project team was led by IAG, who was charged with single-point responsibility to ensure that all efforts remained focused and on schedule. In addition to these roles, Conoco and IAG coordinated the integration of the capital and maintenance turnaround schedules. During the planning phase the goals, objectives, and responsibilities of each team member were reviewed in order that the turnaround would take place, as scheduled, in late February 2001. This meeting served as the official start date for UOP's Schedule A Basic Engineering package. UOP would issue Rev. 0 of the Piping and Instrumentation Diagrams (P&ID's) and mechanical drawings within eight weeks from this meeting. The key milestones of this project are listed below:

- March 16, 2000 - Project Kick Off Meeting
- April 3, 2000 - Preliminary UOP Equipment Specifications released
- April 3, 2000 - Field Data collection for Detailed Engineering and Design
- April 24, 2000 - Preliminary P&ID's released
- May 1, 2000 - Equipment engineering began
- May 18, 2000 - Long lead item procurement commenced
- May 22, 2000 - P&ID and Hazard and Operability (HAZOP) review meetings held
- June 5, 2000 - Detailed design engineering of piping, civil and structural
- July 21, 2000 - UOP Schedule A package issued
- December 28, 2000 - Receive approvals from state environmental agency
- January 15, 2001 - Begin Pre-Turnaround activities (equipment citing, online demolition and converter hot work)
- March 2, 2001 - Oil out (de-inventory and equipment prep work)
- March 7, 2001 - Begin Turnaround (unit turned over to mechanical group)
- March 9, 2001 - Converter section vessels open for inspections
- April 11, 2001 - Project and Turnaround work completed, unit turned over to operations

With the pre-turnaround activities essentially completed, the oil was removed from the unit on March 2, 2001. Mechanical activities started five days later due to de-inventory issues. IAG managed the turnaround activities with Construction & Turnaround Services providing all of the required labor. Atkins Benham and UOP provided additional field assistance as necessary. Utilizing a team approach to project execution significantly minimized the demands on Conoco resources.

The duration of mechanical work during the turnaround was initially set at 31 days. Construction & Turnaround Services planned to work six days a week with two 10-hour shifts. This allowed the seventh day to be used for critical path activities and off-peak hours for x-ray.

Prior to this project, start-up of the FCC usually had the wet gas compressor off-line four to six hours with a flare that was very noticeable by neighbors. This was not the case on the start-up immediately following the project. There have been subsequent unit re-starts with similar ease, due primarily to the new slide valve. The Conoco operators are impressed with and are appreciative of the new flexibility designed into the FCC.

Project Results

Table 1 summarizes the improved unit performance following implementation of the short-range opportunities as well as the technology upgrades installed during the turnaround.

The table highlights the significant improvement achieved in gasoline yield and conversion. Gasoline yield has increased 2.8 wt.-% while conversion has increased 4.5 wt.-%. These benefits are essentially delivered by the Optimix feed distribution system (the Optimix distributors and the catalyst acceleration zone) as the operation at the time of these tests indicate constant catalyst circulation with the new stripper in operation. The improved conversion also helped alleviate limitations in the slurry oil product rundown to storage.

With the new spent and regenerated catalyst standpipes and the external spent catalyst stripper, the unit is no longer limited by catalyst circulation constraints. Essentially, the unit is again operating at “new unit” design criteria. Since the time of the test run in Table 1, the operation of the unit has been further adjusted but has not yet reached its maximum potential - optimization continues.

A lower regenerator temperature is an indicator that the severe afterburn that once plagued the operation of this unit has been eliminated, which was part of the original project scope.

Additionally, replacing the plug valve and incorporating slide valve control of the catalyst circulation resulted in improved operability. Conoco is now able to control the reactor temperature within 1 °F versus the previous “control” that allowed the reactor temperature to vary +/- 3 °F. Also, the new slide valve improves reliability, accessibility and makes routine maintenance easier.

Table 1. Process Results

	7/2/99 Base Case	7/18/01 Test Run
Feed Rate, BPSD	47,999	47,450
Feed Gravity, °API	24.4	24.6
Feed Characterization, K	11.75	11.69
Feed Carbon, wt.-%	0.30 (Concarbon)	0.18 (Ramsbottom)
Feed 650 °F -, LV-%	20.0	24.0
Catalyst Activity, MAT	73	73
Reactor Temperature, °F	1,000	1,000
Feed Preheat Temperature, °F	620	622
Feed Atomization Steam, wt.-% FF	2.1	1.3
Regenerator dense bed temperature, °F	1,332	1,322
Catalyst to Oil, lb./lb.	6.1	6.1
Yields, wt.-%		
H_2S & C_2 -	2.9	2.8
Propane and Propylene	5.5	6.3
Butane and Butylenes	9.6	9.9
Gasoline (C_5 - 430 °F TBP)	46.0	48.8
LCO, (430 °F - 650 °F TBP)	17.8	18.3
Clarified Slurry Oil, (650 °F +)	14.7	9.7
Coke	4.4	4.2
Conversion	67.5	72.0

In summary, all FCC unit processing objectives for this revamp were met. The turnaround:

- maintained conversion and improved the value of the FCC yield slate when processing a more aromatic feedstock with improved feed distribution and spent catalyst stripping technology,
- addressed catalyst circulation and stripping efficiency, providing additional unit flexibility, and,
- did not increase stack emissions.

Conoco's overall project goals and objectives were met. Conoco values people and environmentally friendly operations and continues to pursue a "flare-less" FCC start-up.

Conclusions

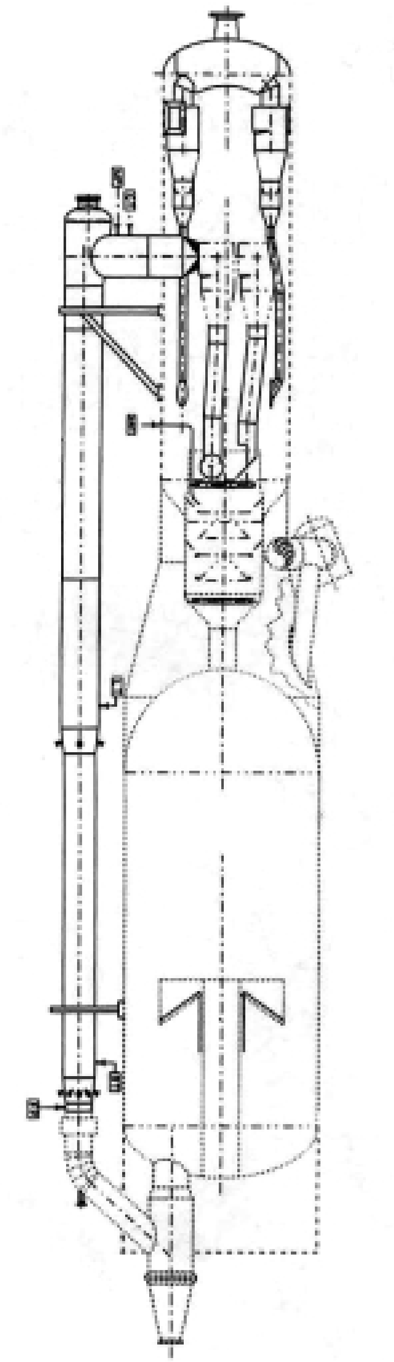
The success of Conoco's Lake Charles FCC Riser Modification Project illustrates the value of assembling a specialized project team early and ensuring that the objectives for the project are well defined. The early planning effort allowed time to evaluate technical solutions and define the project scope to deliver innovative FCC unit revamp solutions. In addition, Conoco was able to apply best practices from the previous Denver and Ponca City refinery FCC projects and to overcome a significant catalyst circulation challenge inherent in Orthoflow-style FCC units.

The team approach resulted in innovative technical solutions. Single point responsibility for turnkey supply of technology, engineering, procurement and construction ensured continual focus on project objectives and the schedule. The final result is increased conversion, improved yield selectivity, flexibility to process heavier feeds and improved mechanical reliability.

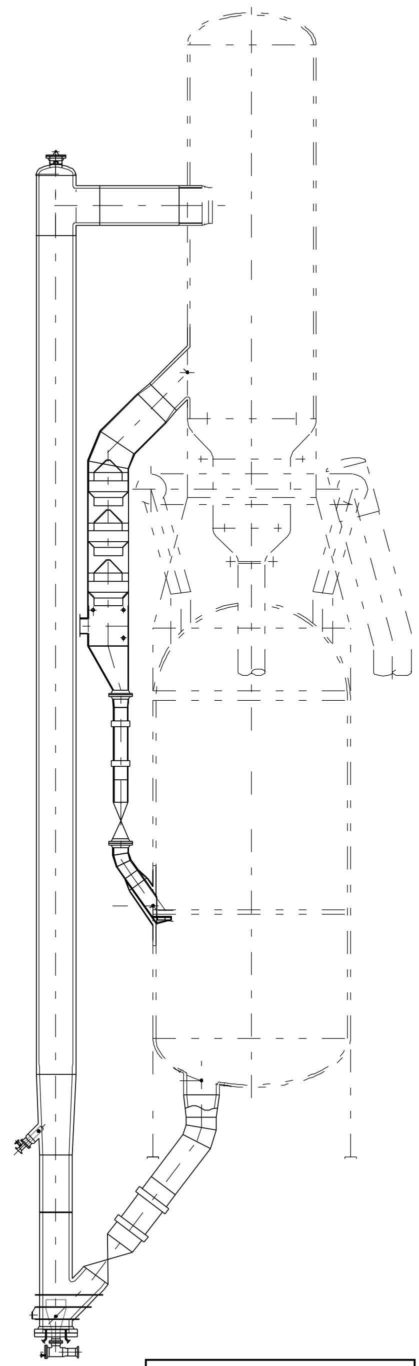
Figure 1

Reactor / Regenerator Sectional Elevation

(Revamp scope items highlighted as solid bold lines in "After" schematic)



BEFORE



AFTER