Modernizing a Vintage Cat Cracker

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El Dorado Refinery

- Refinery located in El Dorado, Kansas is one of the largest refineries in the Plain States and Rocky Mountains with a crude oil capacity of 150,000 Barrels per Stream Day (BPSD)
- The El Dorado refinery is a high-complexity Coker refinery with the ability to process significant volumes of heavy and sour crudes.
- The fully integrated refinery principal processing units consist of crude and vacuum distillation; hydrodesulphurization of naphtha, kerosene, diesel, and gasoil streams; isomerization; catalytic reforming; fluid catalytic cracking; alkylation; delayed coking; hydrogen production; and sulfur recovery.
- Refining operations began at the site in 1917.
FCC

- 42,000 BPSD Kellogg Model III design that came on-stream in 1949.
- 60+ years of operation, the unit has undergone several revamps and technology hardware modifications to increase the capacity from the original capacity to 15,400 BPSD to the current capacity.

- Revamp Goals
  - Minimize Dry Gas
  - Increase Liquid Yields
  - Improve Coke Selectivity
Project Scope

Remove Hemispherical Top Head and Install 2:1 Elliptical Head

Replace Inertial Separator with Closed Cyclones Riser Termination

Modify Stripper Section

New Feed Nozzle Technology
Technology Description

KBR Closed Cyclone™ System
- Minimize Post-Riser Cracking
- Minimize Dry Gas
- Increase Gasoline Yield
- Improve Coke Selectivity

ATOMAX-2™ Feed Injection
- Smaller Droplets
- Flat Spray with Optimized Riser Coverage
- Easy to Install and Easy to remove
Construction – Pre-turnaround / Turnaround Work

• Schedule
  – Start of Engineering – 26 months in advance of TA
  – Placing Cyclone order (Long lead) – 18 months before
  – Pre-shutdown construction – 6 months before
  – Oil-out / Oil-in – 28 days

◆ Determination of Construction Sequence

◆ Maximize Pre-shutdown construction work
  ◆ Installation of Jig-stand for Old Reactor
  ◆ Installation of new Cyclones on the Jig stand
  ◆ Crane set-up
## Performance Comparison

### Reactor Yield Comparison

<table>
<thead>
<tr>
<th></th>
<th>Before Revamp</th>
<th>After Revamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Rate, BPD</td>
<td>41,900</td>
<td>41,500</td>
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<tr>
<td>Feed API Gravity</td>
<td>24.2</td>
<td>24.1</td>
</tr>
<tr>
<td>Feed Conradson Carbon</td>
<td>0.33</td>
<td>0.26</td>
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<tr>
<td>Catalyst Activity</td>
<td>73</td>
<td>77</td>
</tr>
<tr>
<td>Zeolite / Matrix Ratio</td>
<td>2.04</td>
<td>1.73</td>
</tr>
<tr>
<td>Riser Outlet Temperature, °F (°C)</td>
<td>980 (527)</td>
<td>980 (527)</td>
</tr>
<tr>
<td>Regenerator Bed Temperature, °F (°C)</td>
<td>1,310 (710)</td>
<td>1,287 (697)</td>
</tr>
<tr>
<td>Catalyst to Oil Ratio</td>
<td>5.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Dry Gas, wt%</td>
<td>3.5</td>
<td>2.4</td>
</tr>
<tr>
<td>C3+C4 LPG, vol%</td>
<td>26.4</td>
<td>26.7</td>
</tr>
<tr>
<td>Gasoline (C5 – 430°F D86), vol%</td>
<td>59.9</td>
<td>61.8</td>
</tr>
<tr>
<td>LCO (430°F – 670°F, D86), vol%</td>
<td>20.3</td>
<td>20.6</td>
</tr>
<tr>
<td>Slurry, vol%</td>
<td>3.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Coke, wt%</td>
<td>5.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Conversion, vol%</td>
<td>76.5</td>
<td>75.6</td>
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<tr>
<td>Delta Coke</td>
<td>0.91</td>
<td>0.70</td>
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</tbody>
</table>
Performance Comparison (Cont...)

- **Dry Gas Yields with Catalyst to Oil Ratio**

- **Gasoline Yields with Catalyst to Oil Ratio**

- **Coke Yield with Catalyst to Oil Ratio**

- **Delta Coke with Catalyst to Oil Ratio**
Project Economics

• Initial Project – Closed Cyclones™ only; Estimated 288 BPD increase in Liquid Products
• Feed Nozzle Upgrade - Estimated additional 222 BPD increase in Liquid Products; no increase in turnaround duration
• Initial Payout Estimate – 1 year
• Actual Payout – 3 months
Conclusion

- Proper planning, scheduling and selection of the right technology are the keys to success in any FCC unit revamp.
- FCC unit at the El Dorado refinery was successfully revamped with KBR Closed Cyclone™ Technology & ATOMAX-2™ Feed Nozzle Technology
- The turnaround and construction were completed on schedule due to proper planning and execution
- Revamped Unit yields exceeded initial estimates resulting in better gasoline and coke selectivity and lower dry gas
- The project was a financial success with a payout of three months