Catalyst Management Protocols in Saudi Aramco
Case Study: Fluid Catalytic Cracking Catalyst Selection

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KFUPM-RI, 5-6th Nov., 2006
Outline

- Objective
- Saudi Aramco Overview
- Saudi Aramco Refining Sector
- Importance of Catalyst Selection
- Saudi Aramco Catalyst Protocol (SAES-A-207)
- Case Study: Jiddah Refinery/FCC Catalyst selection
- Catalyst Proposal Evaluation
- Case Study Conclusion
- Q&A
Objectives

• To share with you how Saudi Aramco manages catalyst selection in refineries

• To present a case study for catalyst selection at the Jiddah Refinery Fluid Catalytic Cracking Unit
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Saudi Aramco Overview

- Owned by the Saudi Arabian Government
- A fully-integrated, global petroleum enterprise and a world leader in exploration and producing, refining, distribution, shipping and marketing
- Manages proven reserves of 260 billion barrels of oil (nearly a quarter of the world's total) the largest of any company in the world, and manages the fourth-largest gas reserves in the world
- Owns and operates the world's second largest tanker fleet to help transport its crude oil production, which amounted to 3.3 billion barrels in 2005
- Has affiliates, joint ventures and subsidiary offices in China, Japan, Netherlands, Philippines, Republic of Korea, Singapore, United Arab Emirates, United Kingdom and the United States
Saudi Aramco International Headquarters
Dhahran, Saudi Arabia
Saudi Aramco Refining Sector

- **Total Capacity:** 3 million barrels per day
- **Five domestic refineries**
- **Interest in three domestic joint venture refineries with:**
  - ExxonMobil; Shell; Sumitomo
- **Planned three domestic joint refinery projects with:**
  - Total; ConocoPhillips; Dow
- **Interest in five international joint ventures:**
  - Motiva Enterprises (USA)
  - S-Oil (S. Korea)
  - Petron (Philippines)
  - Showa Shell (Japan)
Refineries Geographical Distribution

Jubail
Yanbu'
Rabigh
Riyadh
Ras Tanura
Jiddah

Local Refineries
J/V Refineries
Why is a Catalyst Selection Protocol Needed?

- Refining Catalyst (RC) is a big “chemical” purchase for a refinery
- RC performance is a key contributor to refinery profitability
- RCs have to be assessed as a high technology products and not as a commodity
- Selecting the wrong catalyst can be very costly and may result in operating problems
- Minimizing catalyst inventories and optimizing the catalyst utilization
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Objective of Saudi Aramco Catalyst Selection & Replacement Standard (SAES-A-207)

To implement a program that results in the cost-effective management of catalysts and desiccants for the company.
SA Standard for Catalyst Selection Protocols

- Generate Technical Package and Performance Guarantee
- Solicit Proposals from Vendors
- Proposal Evaluation
- Pilot Plant Testing
- Users Survey
- Economic Evaluation
- Recommendation
- QA/QC of Pre-delivery sample
- Performance Test
Steps for General Catalyst Selection

Data Gathering:
- Unit Operation Data
- Refinery Objectives
- Unit Limitations

Catalyst Proposals:
- Physical & Chemical Properties
- Vender Projection

Consistency Check

Potential Catalyst Selection

Pilot Plant (P/P) Test

Evaluate Results of P/P

Economical Evaluation on Technically Acceptable Catalyst Systems

Catalyst Selection & Recommendations

No P/P
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FCC Background

- FCC is a process that cracks heavy oil to value-added products using powdered catalyst.
- FCC has been refinery workhorse for gasoline production since 55 years (around 45% of all gasoline comes from FCC).
- Around 400 FCC units worldwide with a capacity of 14.2 million bbl/d (avg. unit is 35,000 bbl/d).
- Leading FCC catalyst producers are Albermarle, Engelhard (BASF), CCIC and Grace.
- Major Process licensors: UOP, Exxon, KBR, Shell, S&W/IFP, ABB.
FCC Typical Process Flow Description

- Raw Oil
- Lifting Steam
- Reactor Vapor Line
- Stripping Steam
- RISER
- REACTOR
- LCO
- Cir. HCO
- Heavy Naphtha
- LPG & Gases
- Orifice Chamber
- Atmosphere
- Air From Air Blower
- Lifting Steam
- Air Heater
- Slide Valves
- Feed Injectors
- Main Column
- CSO
- Cir. HCO
- LCO
- Heavy Naphtha
- L. Naphtha
- LPG & Gases
- Raw Oil
<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Rate, MBPD</td>
<td>20</td>
</tr>
<tr>
<td>Feed Stock</td>
<td>Gas Oil (240 – 630°C)</td>
</tr>
<tr>
<td>API gravity @ 60F</td>
<td>23.25</td>
</tr>
<tr>
<td>Specific gravity @ 60F</td>
<td>0.91</td>
</tr>
<tr>
<td>Sulfur wt %</td>
<td>2.6</td>
</tr>
<tr>
<td>Total Nitrogen ppm</td>
<td>630</td>
</tr>
<tr>
<td>Basic Nitrogen ppm</td>
<td>155</td>
</tr>
<tr>
<td>Conradson Carbon wt %</td>
<td>0.24</td>
</tr>
<tr>
<td>Ni ppm</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>V ppm</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Refractive index</td>
<td>1.52</td>
</tr>
<tr>
<td>Viscosity cSt</td>
<td>26</td>
</tr>
</tbody>
</table>
Operating Conditions

- Combined Feed T, °C 235
- ROT, °C 514
- Flue Gas T, °C 736
- Reg. Dilute Phase, °C 689
- Cat. Circulation, ton/min 16
- Catalyst addition rate, TPD 1.0
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Catalyst Proposal Evaluation

• Four technical proposals received from catalyst vendors
• Selection Criteria For JRD/FCCU Catalyst:
  • Octane Number
  • Gasoline sulfur content
  • Gasoline yield
  • Technical support
  • Consistency of the vendor projection with Laboratory Tests
  • Economical Analysis
## Vendor Projections (Delta Yields)

<table>
<thead>
<tr>
<th>PRODUCT (v.%), TYPE</th>
<th>BASE Catalyst</th>
<th>Catalyst A</th>
<th>Catalyst B</th>
<th>C1</th>
<th>Catalyst C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Gas (C₂) (FOE)</td>
<td>4.33</td>
<td>0</td>
<td>-0.23</td>
<td>-0.07</td>
<td>-0.04</td>
</tr>
<tr>
<td>LPG (C₃ - C₄)</td>
<td>14.0</td>
<td>2.54</td>
<td>0.33</td>
<td>-0.25</td>
<td>1.62</td>
</tr>
<tr>
<td>Gasoline (C₅ - 430 F)</td>
<td>57.80</td>
<td>0.38</td>
<td>2.49</td>
<td>1.03</td>
<td>0.16</td>
</tr>
<tr>
<td>Light Cycle Oil</td>
<td>14.95</td>
<td>-0.74</td>
<td>-0.3</td>
<td>-0.36</td>
<td>-0.73</td>
</tr>
<tr>
<td>Heavy Cycle Oil + Slurry</td>
<td>13.90</td>
<td>-1.05</td>
<td>-1.53</td>
<td>-0.25</td>
<td>-0.30</td>
</tr>
</tbody>
</table>
## Vendor - Product Qualities

<table>
<thead>
<tr>
<th>Product Quality</th>
<th>Base</th>
<th>Catalyst A</th>
<th>Catalyst B</th>
<th>Catalyst C1</th>
<th>Catalyst C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ RONC</td>
<td>90</td>
<td>0.85</td>
<td>0.27</td>
<td>0.07</td>
<td>0.25</td>
</tr>
<tr>
<td>Δ S (wt.%)</td>
<td>0.3</td>
<td>-0.001</td>
<td>-0.031</td>
<td>-0.006</td>
<td>-0.006</td>
</tr>
</tbody>
</table>
Laboratory Catalyst Testing

- Physical Properties
- Stability – Fresh, and two steaming conditions
- Microactivity Test (MAT) – Selectivity
- Octane
# MAT Results

<table>
<thead>
<tr>
<th>Product Quality</th>
<th>Base</th>
<th>Catalyst A</th>
<th>Catalyst B</th>
<th>Catalyst C1</th>
<th>Catalyst C2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Gas (C₂) (FOE)</td>
<td>2.23</td>
<td>2.32</td>
<td>2.48</td>
<td>2.17</td>
<td>2.05</td>
</tr>
<tr>
<td>LPG (C₃ - C₄)</td>
<td>17.85</td>
<td>18.15</td>
<td>19.63</td>
<td>17.65</td>
<td>16.6</td>
</tr>
<tr>
<td>Gasoline (C₅ - 430 F)</td>
<td>54.4</td>
<td>55.52</td>
<td>54.4</td>
<td>55.38</td>
<td>55.65</td>
</tr>
<tr>
<td>LCO</td>
<td>15.2</td>
<td>14.45</td>
<td>12.85</td>
<td>15.45</td>
<td>16.4</td>
</tr>
<tr>
<td>HCO</td>
<td>6.6</td>
<td>5.95</td>
<td>5.67</td>
<td>6.42</td>
<td>6.2</td>
</tr>
<tr>
<td>Coke</td>
<td>3.8</td>
<td>3.73</td>
<td>4.18</td>
<td>3.07</td>
<td>3.2</td>
</tr>
<tr>
<td>RONC</td>
<td>88.8</td>
<td>87.03</td>
<td>89</td>
<td>88.55</td>
<td>86.85</td>
</tr>
<tr>
<td>S (ppm)</td>
<td>615</td>
<td>640</td>
<td>650</td>
<td>560</td>
<td>668</td>
</tr>
</tbody>
</table>
Selection Analysis

Catalyst A
- Large Increase In LPG
- Second Most Expensive
- Projected Increased Gasoline RON Not Supported By MAT

Catalyst B
- Large Increase In Gasoline
- Most Expensive
- Projected Gasoline Volume Increase Not Supported By MAT

Catalyst C1
- Large Increase In Gasoline
- MAT testing supports vendors projection for Gasoline yield and RON.

Catalyst C2
- Large Increase In LPG
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Case Study Conclusion

- Four technical proposals received from catalyst vendors
- Extensive MAT tests were conducted to evaluate and validate the performance of the proposed catalysts
- The catalysts were ranked according to the refinery criteria
- Catalyst C1 was recommended due to its high RON, and high gasoline yield with low sulfur content
- The estimated annual benefit to the Jiddah refinery was over around 1.4 million/year
Catalyst Management Protocols in Saudi Aramco

Case Study: Fluid Catalytic Cracking Catalyst Selection

Thank You

Q/A
Saudi Aramco Jiddah Refinery

Figure 1. Saudi Aramco’s Jeddah Refinery

Figure 2. Map of Saudi Arabia with location of Jeddah Refinery marked