Equilibrium Catalyst Inc
FCC Catalyst & Logistical Management

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State of the Art Facility

» Houston Pine Vista – Fully operable 6/1/2011

» Facility Specifics
  ◦ 11.5 Acres
  ◦ 55,000 SF of warehouse
    ◦ Can store approximately 3500 tons of fresh catalyst
  ◦ 50,000 SF of covered concrete
  ◦ 8 additional acres of concrete space
  ◦ 800 feet of rail – capable of handling 10 rail slots
  ◦ 37 additional storage vessels – capable to maintain 3500 tons of inventory
  ◦ Facility will maintain full bagging operation including bag-house

» Classification Capability
  ◦ Capability to classify approx 25 tpd of catalyst
  ◦ ECI can create a high fine ecat to load through additive loaders to allow you to reduce
    0–40 in your fresh catalyst
  ◦ Reduce fresh 0–40 from 12–14 to 8–10 (Every 12 tons purchase = $1mm/yr)
Catalyst Selection Process

How do you select the right catalyst?

- FCC Optimization is 80% Feed / 15% Unit Hardware / 5% Catalyst
  - The key is to understand the probability distribution of your feed (light – heavy)
  - Clearly understand how each feed historically operated in the unit (Unit limitations)
  - Design a catalyst strategy that provides you the best means to operate your feed spectrum given your unit limitations

- Keys to Catalyst Selection
  - Need to understand the effective activity needed in your circulating ecat (delta coke optimization)
  - Need to clearly decide on the target selectivities (gasoline / LCO / LPG)
  - Need to clearly understand budget restrictions (you all have one)
  - Design a catalyst strategy to meet the target circulating ecat activity
    - Function of catalyst architecture
    - Effective catalyst activity
    - Daily addition rate
    - Metals tolerance
    - Unit deactivation
    - Unit feed rate

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Economics of Change in Coke

<table>
<thead>
<tr>
<th>Case Number</th>
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<tbody>
<tr>
<td>Case Title</td>
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<tr>
<td>Total Net Profit</td>
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<tr>
<td>Unit Net Profit</td>
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<tr>
<td>Combined Fresh Feed</td>
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<tr>
<td>- Combined Feed Rate</td>
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<tr>
<td>- API Gravity</td>
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<td>Riser Reactor Conditions</td>
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<tr>
<td>- Feed Temperature</td>
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<tr>
<td>- Riser Outlet Temperature</td>
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<tr>
<td>- Cat/Oil Ratio</td>
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<tr>
<td>- Catalyst Circulation Rate</td>
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<td>- Regen Bed Temperature</td>
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<td>Fresh Catalyst</td>
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<tr>
<td>- Total Make-up Rate</td>
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<tr>
<td>- Surface Area</td>
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<td>Equilibrium Catalyst</td>
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<tr>
<td>Conversion</td>
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<td>- Fresh Feed Conversion (as Produced)</td>
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<tr>
<td>- Fresh Feed Conversion Cut Point</td>
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<td>Product Yields</td>
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<td>Weight Percent Basis</td>
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<tr>
<td>- H2+C1+C2+C3</td>
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<td></td>
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<tr>
<td>- Coke</td>
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<tr>
<td>- Total C3 + C4</td>
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<tr>
<td>- Light Cycle Oil (430 F to 650 F)</td>
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<tr>
<td>- Decant (650 F +)</td>
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<tr>
<td>- C3+ Liquid</td>
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- Resid units need to make every attempt to always lower unit delta coke
- All metals increase unit delta coke
- A modest shift in catalyst coke can cost the refinery > $0.25 / bbl
**How do you design a fresh cat / ecat system for varying feed quality?**

- **Circulation**
- **Wet Gas Limit**
- **Fractionator (Upper)**

Higher % of Fresh Catalyst to Drive Activity

ECAT added for control of metals, manage delta coke and minimize costs

**Feed 'Heaviness'** (% Resid in Feed)

**Effect of Catalyst Addition Rate on Unit Change Out Rate**

- **P=1−e(−sft)**
- 2% Turnover Rate Completes 36% Change out in 30 days.
- 5% Turnover Rate Completes 50% Change out in 19 days.
- 10% Turnover Rate Allows 50% Unit Change out in 9 days.

- **Basis:** f=0.75
\[ Y = \frac{Y_0 \cdot s}{s + k} \]

Catalyst Activity Calculation

Unit Inventory = 360 tons

<table>
<thead>
<tr>
<th>Unit MAT</th>
<th>Yo Fresh Catalyst MAT</th>
<th>k - Turnover Rate</th>
<th>k - Deactivation Coefficient</th>
<th>Catalyst Additions, TPD</th>
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<tbody>
<tr>
<td>70</td>
<td>81.25</td>
<td>0.0556</td>
<td>.047</td>
<td>20</td>
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<tr>
<td>70</td>
<td>79</td>
<td>.077</td>
<td>.047</td>
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> Unit Activity can be Maintained by Varying Fresh Catalyst Activity and Addition Rate.

Effect of Catalyst Age on Unit Activity

- Very Important for Resid Unit to always attempt to decrease the age distribution of circulating catalyst
- Older Catalyst
  - Decrease Yield of Gasoline, C3=
  - Increase Yield of Slurry, Coke
- Must attempt to find optimal way of maximizing catalyst addition rate
Catalyst Addition Rate
What is the optimal addition rate?

- **Benefits of Higher Catalyst Addition Rate**
  - Higher Catalyst Addition Rate will lower Unit Metals Levels
    - Lower Metals on Circulating ECAT will always provide higher valued yields
  - Higher Catalyst Addition Rate will decrease the average age of the catalyst in the circulating inventory
    - Lower Catalyst Age will always provide higher valued yields

- **Harm from Higher Catalyst Addition Rate**
  - Increase in fresh additions from current baseline will increase catalyst budget
  - Sometimes excessive addition rate of base fresh catalyst can increase delta coke and force regenerator bed temp above design limitation

ECAT Opportunity
ECI

- **ECI Can Provide Customized ECAT Solution**
  - ECI will provide ECAT with consistent target properties (TSA/MSA/ReO/Ni+V)
  - Establish the key targets to compliment current fresh catalyst properties
  - Remove 1 TPD of fresh catalyst and replace with 2 TPD of ecat
  - Ecat utilized must be designed with the following key features:
    - ZSA of ecat must be higher than ZSA of current circulating catalyst inventory
    - MAT activity should be 2–3 numbers higher than MAT of current circulating catalyst inventory
    - Total FCAT / ECAT additions must reduce metals on the circulating catalyst inventory compared to current baseline operation
Successful design and implementation of purchased ecat will provide a FCC unit the following opportunity:

- Design a catalyst addition strategy to increase total additions
- New strategy will achieve decrease in circulating metals
- New strategy will lower catalyst inventory age
- New strategy will lower slurry
- New strategy will increase LCO, Gasoline, LPG yields
- New strategy will lower total catalyst costs

As refinery economics have deteriorated, some organizations have embraced alternative procurement strategies to maintain desired yields and reduce total operating costs:

- More frequent bids with domestic suppliers to increase competition
- Consider blending multiple supplier catalysts together
  - Potential for best in class yield selectivity benefits
  - Increase catalyst flexibility to meet changing selectivity preferences
    - Change from Max Gasoline to Max LCO to increase in LPG
  - Potential for cost reduction as you attempt to work with supplier to open competition at low cost opportunities
Our Goal is to get customers to think differently about how to purchase FCC catalyst:
- Design a formulation to be 50-70 % primary technology and 30-50 % cost capability
- More effective use of purchased ecat if suitable
- Leverage testing 2nd choice / new technology
- Entice suppliers to provide short term low cost opportunities to prove technology

ECI has multiple facilities strategically placed to blend all key components together.
These catalysts are presently available in these quantities, either from storage, or from the refinery generating them. No guarantee can be made as to their continued availability, nor quantity. The analysis given below is a "weighted average" based on the actual equilibrium analysis sheets and input from the supply refinery as to the composition of their inventory. Since operating conditions may vary and since we do not control such conditions, we must DISCLAIM ANY WARRANTY EXPRESSED OR IMPLIED, with regard to results obtained from the use of these products.

**E-Cat Target Values**

<table>
<thead>
<tr>
<th>ECI ID #7</th>
<th>High Z-Ecat #1</th>
<th>M</th>
<th>Ni</th>
<th>V</th>
<th>S</th>
<th>A</th>
<th>Na</th>
<th>Re</th>
<th>F</th>
<th>P</th>
<th>A</th>
<th>B</th>
<th>D</th>
<th>E</th>
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<tr>
<td>B</td>
<td>77</td>
<td>300</td>
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<th>Ni</th>
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Incorporation

The use of Ecat will decrease

Summary

- ECI provides multiple ways to help provide you lowest cost options for FCC catalyst optimization
  - Fresh Catalyst Blending
  - Incorporation of Purchased ECAT

- The use of Ecats have sound technical fundamentals for use in a unit attempting to maintain unit yields at the lowest $/day cost

- Addition Rate is critical for success in implementing an ecat/fcat strategy
  - Remove 1 TPD of Fresh Catalyst and replace with 2 TPD of Ecats
  - Ultimate Ratio of FCAT / ECAT is unit specific

- The use of Ecats will increase unit conversion via:
  - Lower Circulating Ecat Metals
  - Decrease in the unit age fundamental

- The use of Ecats will decrease $/day catalyst costs

- ECAT key targets properties must be supplied consistently to best optimize the FCC unit

- Ecat has successfully been utilized in various units that process gas oil, mild and heavy resid