Developments in Catalyst Handling For FCC & RFCC Units

Johnson Matthey Process Technologies

Oct 2014
FCC Catalyst Handling –
At the Core of the FCC

**Catalyst**
1. Receiving into Refinery
2. Maintaining onsite inventory
3. Adding to FCC
4. Receiving into Refinery
5. Maintaining onsite inventory
6. Adding to FCC
7. Withdrawing from FCC
8. Shipping & Disposal

**Additives**

**Images and Diagrams:**
- Catalyst processing equipment
- Additive handling equipment

**Company:**
Johnson Matthey Process Technologies
1. Receiving Catalyst into the Refinery
Receiving Catalyst Into The Refinery

- This is a simple operation for refiners who receive catalyst in PD Trucks or rail cars
  - Trucks/Cars unloaded directly into hopper

- For refiners who receive catalyst in lined Sea Containers, specialised tilting and unloading facilities are required
  - Fixed tilting platforms have been used, but these take up a lot of plot space

- Preferred solution is to use a tractor with built in tilting device
  - Allows use of standard trailer chassis
  - Tractor can be used for regular service, as well as container unloading
Solutions: Sea Container Unloading

- Liner Cutter Manifold (LCM) allows sea container liner to be cut safely, with no catalyst losses

- Catalyst Transfer Manifold (CTM) allows container to be unloaded in 30mins or less

- Using this well designed equipment:
  - Maintains clean environment
  - Minimizes operator catalyst exposure
Solutions: Dual Bag Unloading System

- Some locations still receive catalyst in supersacks
  - Without correct facilities can be hard to manage, with high catalyst wastage
- Dual bag unloading system allows one bag to be unloaded while the other is being replaced
- Maximizes operator efficiency
- Reduces catalyst handling losses
- Unload 10t of catalyst in <1hr
- Maintains clean environment
- Minimizes operator catalyst exposure
Using the Correct Equipment Saves Money

• Basis: 50,000 BPD RFCC, 10 ton/day fresh catalyst, catalyst cost of $3,000/ton ($10.95 million per year)
• What are the catalyst losses with conventional catalyst handling systems?
  • Conventional manual unloading facilities
  • Venting using cyclone on catalyst hopper
• Typical fresh catalyst handling losses
  • Big bags 0.1% - 1kg per bag, 10kg/day
  • Sea containers 0.05% - 10kg per container, 5kg/day
  • Vent losses 0.1-0.25%, 10-25kg/day
  • Plus miscellaneous spillage
• Typical total losses 20-50kg/day, ($22,000 - $55,000 per year)
2. Maintaining Adequate Onsite Catalyst Inventory

1. Receiving Catalyst into the Refinery
2. Maintaining onsite inventory
Onsite Catalyst Storage Capacity

• When revamping an FCC, catalyst addition rates often increase
• Existing catalyst storage hoppers may no longer provide adequate buffer storage
• Especially a concern at remote refineries, or locations with unreliable shipping
Solution:
Extra Storage Capacity – The Pig

The Pig
• Up to 85 Tons Capacity
• Compatible with Tilter Truck
• Pneumatic truck able to fill or empty pig as needed
• Pigs can provide significant strategic onsite storage
3. Adding Catalyst to the FCC or RFCC Unit

1. Receiving Catalyst into the Refinery
2. Maintaining onsite
3. Adding to FCC
Solution: Reliable & Accurate Catalyst Addition Systems

- $\text{INTERCAT}_\text{JM}$ Catalyst Addition Systems well established as “State of the Art”
- Over 300 systems installed worldwide
  - Reliable, accurate, low maintenance
  - Long term support
- System of choice on most new build FCC & RFCC units
Fresh Catalyst Addition System Designs

- Numerous design options are available

Conventional autoreload addition systems typically 5-10 ton capacity

Where extra storage is required, large capacity addition systems can have up to 120 ton capacity
Advanced Design Features

- Sintered Metal filter for zero catalyst losses
- Robust Self Cleaning Design
  - Eliminates the need for unreliable & complex bag house
  - Allows vent stream to go straight to atmosphere
- Everlasting Valve for catalyst flow control
- Extremely reliable in fresh catalyst service
- Maintenance frequency > 5 years (valve cycling every 10 - 20 minutes)
- Now standard equipment on all INTERCAT\textsuperscript{JM} Addition Systems
### Sample of Refinery Ecat Conversions

<table>
<thead>
<tr>
<th>Refinery</th>
<th>Average MAT (Target)</th>
<th>Std Deviation from Mode</th>
<th>% within +/-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinery A</td>
<td>71.6 73</td>
<td>1.83</td>
<td>52%</td>
</tr>
<tr>
<td>Refinery B</td>
<td>67.7 68</td>
<td>2.27</td>
<td>50%</td>
</tr>
<tr>
<td>Refinery C</td>
<td>72.5 73</td>
<td>2.11</td>
<td>52%</td>
</tr>
<tr>
<td>Refinery D</td>
<td>70.5 70</td>
<td>1.18</td>
<td>73%</td>
</tr>
<tr>
<td>Refinery E</td>
<td>70.3 71</td>
<td>1.20</td>
<td>72%</td>
</tr>
<tr>
<td>Refinery F</td>
<td>68.7 69</td>
<td>1.80</td>
<td>61%</td>
</tr>
<tr>
<td>Refinery G</td>
<td>68.8 70</td>
<td>1.92</td>
<td>52%</td>
</tr>
<tr>
<td>Refinery H</td>
<td>65.7 65</td>
<td>2.46</td>
<td>43%</td>
</tr>
<tr>
<td>Refinery I</td>
<td>61.4 60</td>
<td>2.55</td>
<td>53%</td>
</tr>
<tr>
<td>Refinery J</td>
<td>75.7 76</td>
<td>0.99</td>
<td>86%</td>
</tr>
<tr>
<td>Refinery K</td>
<td>64.8 64</td>
<td>3.19</td>
<td>33%</td>
</tr>
<tr>
<td>Refinery L</td>
<td>71.1 71</td>
<td>1.35</td>
<td>73%</td>
</tr>
<tr>
<td>Refinery M</td>
<td>68.3 68</td>
<td>1.25</td>
<td>80%</td>
</tr>
<tr>
<td>Refinery N</td>
<td>71.2 74</td>
<td>2.51</td>
<td>29%</td>
</tr>
<tr>
<td>Refinery O</td>
<td>70.8 74</td>
<td>2.60</td>
<td>30%</td>
</tr>
<tr>
<td>Refinery P</td>
<td>69.7 70</td>
<td>1.85</td>
<td>66%</td>
</tr>
<tr>
<td>Refinery Q</td>
<td>62.1 61</td>
<td>2.98</td>
<td>37%</td>
</tr>
<tr>
<td>Refinery R</td>
<td>70.8 72</td>
<td>2.76</td>
<td>47%</td>
</tr>
<tr>
<td>Refinery S</td>
<td>68.2 67</td>
<td>1.60</td>
<td>64%</td>
</tr>
<tr>
<td>Refinery T</td>
<td>72.0 73</td>
<td>1.59</td>
<td>56%</td>
</tr>
<tr>
<td>Refinery U</td>
<td>71.9 73</td>
<td>1.78</td>
<td>55%</td>
</tr>
<tr>
<td>Refinery W1</td>
<td>76.6 77</td>
<td>0.89</td>
<td>89%</td>
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<tr>
<td>Refinery W2</td>
<td>76.9 77</td>
<td>0.81</td>
<td>96%</td>
</tr>
<tr>
<td>Refinery Y1</td>
<td>69.4 71</td>
<td>3.96</td>
<td>37%</td>
</tr>
<tr>
<td>Refinery Y2</td>
<td>72.4 73</td>
<td>2.11</td>
<td>54%</td>
</tr>
<tr>
<td>Tight control</td>
<td>62.6 62.7</td>
<td>0.90</td>
<td>71%</td>
</tr>
<tr>
<td>Averages Average Control</td>
<td>70.2 70.8</td>
<td>1.71</td>
<td>60%</td>
</tr>
<tr>
<td>Loose Control</td>
<td>68.1 68.6</td>
<td>2.68</td>
<td>42%</td>
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</tbody>
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Loader Precision Economics

Simple model

- 50,000 barrel/day RFCC unit
- Industry average 2% MAT std deviation from target
  - Best in class achieve 1% MAT std deviation from target
- Typical performance improvement of 1% possible
  - Valued as 0.5%wt conversion
  - Worth $1 Million per year
  (Offers increased flexibility which can be used for feed rate or other improvements as economics dictate)

<table>
<thead>
<tr>
<th>Product</th>
<th>Yield Delta wt%</th>
<th>Price assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Gas</td>
<td>0.02</td>
<td>1.2 times Fuel Oil</td>
</tr>
<tr>
<td>LPG</td>
<td>0.06</td>
<td>Propane</td>
</tr>
<tr>
<td>Gasoline</td>
<td>0.37</td>
<td>Regular unleaded gasoline at 0.75sg</td>
</tr>
<tr>
<td>LCO</td>
<td>-0.32</td>
<td>Diesel/Gas Oil at 0.925sg</td>
</tr>
<tr>
<td>CLO</td>
<td>-0.18</td>
<td>Fuel Oil at 1.08sg</td>
</tr>
<tr>
<td>Coke</td>
<td>0.05</td>
<td>0.5 Times Fuel Oil</td>
</tr>
<tr>
<td>Total</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

European Spot Prices

Singapore Spot Prices
4-5. Receiving & Maintaining Additive Inventory

1. Receiving Catalyst into the Refinery
2. Maintaining onsite
3. Adding to FCC

Additives
4. Receiving into Refinery
5. Maintaining onsite inventory
FCC Additives – Receiving into Refinery

• Tote bins commonly used for FCC additives in Europe & USA

• This solution not so practical for large users, or for refiners in remote locations
Solution: Large Additive Users

- Introducing “Herman’s Hoppers” - 15 ton portable transport silos.
- Silo is transported and placed into position by a specially designed truck.
  - Similar to systems used in cement industry
- Safe, practical solution for medium to large additive consumers.
- Also offers solution for catalyst change-out, flushing ECat or fines injection
- Already in use in UK and Germany, and now in North America
Solution: Dual Bag Unloading System

- For overseas additives users receiving additives in supersacks
- Bag unloading systems allow additives to be unloaded with minimum losses

- Single or dual unloaders available
- Dual system maximises operator efficiency
- Reduced catalyst handling losses
- Unload 10t of catalyst in <1hr
- Maintains clean environment
- Minimises operator catalyst exposure
6. Adding Additives to the FCC

1. Receiving Catalyst into the Refinery
2. Maintaining onsite
3. Adding to FCC
4. Receiving into
5. Maintaining onsite
6. Adding to FCC
Solution: Multi-Additive Addition Systems

• It is becoming commonplace for refiners to want to add several additives to the FCC at the same time
• Up until recently, each catalyst needed its own addition system
  – Multiple installation locations required (plot space)
  – Multiple utility requirements & process tie ins
• Some locations have restricted plot place, restricted air availability, or a limited budget for installation
• Johnson Matthey therefore offers two choices for multi-additive use:
  • Multi-Compartment (MC-3) Addition System
  • Multi-Source (MSCAS) Addition System
Multi-Compartment Addition System

Main Vessel Contains Three Compartments - 2 x 1 ton, 1 x 2 ton

IMS-MC Controller

Three Outlet Lines, Each with it’s own Everlasting Valve
Multi-Source (MSCAS) Addition System

- Can add up to four different catalysts or additives at the same time
- Each source independently controlled
- Based on scaled down version of standard addition system design
7. Withdrawing Catalyst from the FCC

1. Receiving Catalyst into the Refinery
2. Maintaining onsite
3. Adding to FCC
4. Receiving into
5. Maintaining onsite
6. Adding to FCC
7. Withdrawing from FCC
Existing Catalyst Withdrawal Systems

• Most existing FCC Catalyst Withdrawal Systems are very basic:
  • Manual control by gate valve, with manual carrier air adjustment
  • High temperature and poor velocity control results in high erosion rates of valves and lines.
  • Frequent maintenance required, risk of hot catalyst spills
• Infrequent withdrawals result in large, sudden changes in regenerator catalyst bed level
  • Can have a significant impact on unit operation and flue gas emissions
• Withdrawals normally done at night – maybe for a reason…?
Solution: INTERCAT\textsubscript{JM} Design Overcomes Drawbacks

- Erosion of throttling valve for controlling withdrawal rate is completely eliminated
  - Pressure balance design allows the use of a simple on/off Everlasting valve
- Eliminates large changes in Regenerator bed level
  - Withdrawal is continuous, so bed level can be kept constant
- Eliminates high velocities in withdrawal piping
  - Line velocity tightly controlled at 10-20 ft/sec for minimal erosion
- Forced air cooling prevents high temperature catalyst from damaging road tankers
  - Withdrawn catalyst is cooled before being transferred to storage
Skid Mounted Design for Simple Installation

- Capacity up to 32 tons/day, first system being installed 2H 2013
8. Shipping & Disposal of Spent Catalyst

1. Receiving Catalyst into the Refinery
2. Maintaining onsite
3. Adding to FCC
4. Receiving into
5. Maintaining onsite
6. Adding to FCC
7. Withdrawing
8. Shipping & Disposal
Solution:
Truck Filling & Dust Control

- Spent catalyst needs to be loaded into trucks or sea containers for disposal
- Johnson Matthey supplies equipment to enable this to be done in a safe, controlled, and environmentally friendly manner
Summary – Where Johnson Matthey Can Help You

Catalyst
- Receiving into Refinery
- Maintaining onsite inventory
- Adding to FCC
- Withdrawing from FCC
- Shipping & Disposal

Additives
- Receiving into Refinery
- Maintaining onsite inventory
- Adding to FCC
And Finally – Dust Control – Sintered Metal Filters

- The same filters that are used on INTERCAT<sub>JM</sub>’s addition systems are now available for use on refinery catalyst hoppers
- The zero emissions solution – low maintenance, and a long life
Summary – Complete Technical Solutions

- The increased catalyst handling that accompanies revamping of FCC and RFCC units can lead to significant operational challenges
- Managing FCC catalyst through its whole lifecycle can improve profitability, safety and environmental performance
- Johnson Matthey’s Catalyst Management expertise is well known in the Industry
  - Fresh catalyst unloading
  - Onsite storage solutions
  - Catalyst and additive addition systems
  - Catalyst withdrawal systems
  - Spent catalyst handling
  - Hopper dust filtration systems
- Refiners can call upon Johnson Matthey wide experience to help solve any FCC catalyst handling problems