Innovative & Cost-Effective Technology for Producing Low Sulfur Diesel

Matthew Clingerman, DuPont Clean Technologies

EGYPT DOWNSTREAM SUMMIT & EXHIBITION

February 2016
Agenda

1. Introduction to DuPont Clean Technologies
2. Meeting Diesel Specifications
3. IsoTherming® Hydroprocessing Technology
4. Case Studies
5. Summary
Through science and engineering, we solve some of the world’s greatest challenges.

DuPont has been bringing world-class science and engineering to the global marketplace in the form of innovative products, materials, and services since 1802.
DuPont 2015 Segment Sales

DuPont Agriculture ($9.8B)
Core Markets:
Seeds | Agricultural Chemicals

DuPont Nutrition & Health ($3.3B)
Core Markets:
Food & Nutrition Products

DuPont Electronics & Communications ($2.1B)
Core Markets:
Photovoltaics | Consumer Electronics | Advanced Printing | Displays

DuPont Industrial Biosciences ($1.2B)
Core Markets:
Industrial Enzymes | BioBased Materials

DuPont Performance Materials ($5.3B)
Core Markets:
Transportation | Industrial | Packaging | Electrical/Electronics

DuPont Safety & Protection ($3.5B)
Core Markets:
Industrial | Construction | Military & Law Enforcement | Transportation | Consumer

$25B
DuPont Clean Technologies

IsoTherming® Hydroprocessing Technology

Leading technology for the production of low-sulfur, high octane gasoline blend stock

STRATCO® Alkylation Technology

Leading technology for the production of low-sulfur, high octane gasoline blend stock

MECS® Sulfuric Acid Technology

Leading technology for the production of sulfuric acid and related high performance products

BELCO® and DynaWave® Scrubbing Technologies

Leading technologies for air emissions reduction in FCCs & SRUs for SOx, NOx, and particulates
Countries around the world are adopting low-sulfur diesel specifications that emulate Euro-V
Worldwide Fuel Specifications are Evolving

• Three key issues:
  • satisfy global demand
  • meet regional specifications
  • maximize return on investment

• Refiners must ensure that the fuel meets local market specifications plus any specifications for pipelines and ‘at the pump’.

• Increasingly stringent legislation means that diesel sulfur levels will continue to fall.
IsoTherming® Hydroprocessing Technology

Straightforward, Flexible Design
• Versatile reactor design and unit configuration
• Customized revamp applications

Cost Effective
• Reduced OpEx / decreased utilities consumption
• Capital cost savings
• Maximum usage of existing equipment
IsoTherming® Hydroprocessing Technology

Proven Experience

25 Licenses

- Grassroots: 20
- Revamps: 5
- Operating: 12
- 2016 Startups: 5

Applications

- Diesel Hydrotreating
- Kerosene Hydrotreating
- FCC Pretreat / Mild Hydrocracking
- VGO & LCO Mild Hydrocracking
- Dewaxing
- Gas-to-Liquids Upgrading
- Heavy Oil Upgrading
Conventional Hydrotreating Process

Make-up Hydrogen → Blended Feed → Product

Lean Amine → Rich Amine

HHPS → CHPS

Stripper Off Gas → Naphtha Product

STEAM
IsoTherming® Hydroporcessing Technology

- Liquid Phase Reactor
- Liquid Recycle
- Hydrogen in solution within the catalyst bed
- Distribution less critical

Diagram showing the flow of Make-up Hydrogen, Product, Blended Feed, Liquid Phase Reactor, Liquid Recycle, Hydrogen in solution within the catalyst bed, Distribution less critical, HLPS, CLPS, Stripper Off Gas, Naphtha Product, and STEAM.
Major Equipment Comparison

CONVENTIONAL

- Recycle Gas Compressor
  - HP Lube and Seal Systems
  - HP Surge/Recycle Controls
  - HP Suction Knockout Drum
  - Continuous Vibration Monitoring
  - Vibration Control Foundation
- Hot HP Separator
- HP Condenser
- Cold HP Separator
- HP Amine Scrubber
- Lean Amine Pump
- Larger Feed/Effluent Exchanger
- Larger Reactor Charge Heater

ISOTHERMING®

- Reactor Recycle Pump
- Hot LP Separator
- Smaller Feed/Effluent Exchanger
- Smaller Reactor Charge Heater
Advantages of IsoTherming® Technology

**Reduced Fuel Gas Usage**
- 30 to 60% reduction
- Heat of reaction absorbed by liquid recycle and used to heat the feed
- Lower heater firing rates in normal operation

**Better Energy Recovery**
- 30 to 50% increase
- Optimized heat integration/heat recovery allowing for steam or power generation

**Lower Power Consumption**
- 30 to 40% reduction
- Reactor recycle pump vs. recycle gas compressor

**Reliable and Safe**
- Quick recovery from unit upsets
- Minimal HP equipment & reduced hydrogen inventory
- No runaway reaction
- Lower greenhouse gas emissions
Revamping Existing Capacity

• Motivations
  • Capacity Increases
  • Product Quality Requirements
  • Process More Difficult Feedstock
  • Increase Catalyst Cycle Length

• Challenges
  • Hydraulic limitations
  • Existing catalyst volume
  • Extensive modifications

Major modifications require long shut downs to implement and can be very costly
IsoTherming® Revamp Solutions

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>IsoTherming®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactors</td>
<td>New Required</td>
<td>May Retrofit Existing</td>
</tr>
<tr>
<td>Recycle Gas Loop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recycle Gas Compressor</td>
<td>Modify/Replace</td>
<td>No Modification</td>
</tr>
<tr>
<td>Reactor Recycle Pump</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>High Pressure Gas Loop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charge Heater</td>
<td>Modify/Replace</td>
<td>No Modification</td>
</tr>
<tr>
<td>Feed/Effluent Exchangers</td>
<td>New Exchangers</td>
<td>No Modification</td>
</tr>
<tr>
<td>Gas-Liquid Separators</td>
<td>Modify</td>
<td>No Modification</td>
</tr>
<tr>
<td>High Pressure Piping</td>
<td>Modify/Replace</td>
<td>Some Tie-Ins</td>
</tr>
<tr>
<td>Project Timing</td>
<td>Longer</td>
<td>Shorter</td>
</tr>
<tr>
<td>Plot Space Requirements</td>
<td>Greater</td>
<td>Lesser</td>
</tr>
<tr>
<td>Project Cost</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Equipment Investment</td>
<td>Higher</td>
<td>Lower</td>
</tr>
</tbody>
</table>
Revamps with IsoTherming® Technology

• Maximize Unit Throughput
• Improve Diesel Product Quality
• Process More Cracked Feedstock
• Increase Catalyst Cycle Length
• Minimize Capital Investment
• Reduce Operating Expenses
IsoTherming® Technology Case Studies

- Grassroots Diesel Hydrotreater in China
- ULSD Revamp in India
- Full Conversion to IsoTherming® Technology
IsoTherming® for Grassroots DHT Units

Production of China National IV

- **Throughput**: 0.6 MMTPA
- **Product Target**: S < 50 wppm (China IV)
- **Project Execution**: ~ two years
  - From Process Design kickoff to fresh feed introduced into the unit
- Unit successfully achieved < 50 wppm S diesel specifications, per design, while at the following conditions:

<table>
<thead>
<tr>
<th></th>
<th>BPD</th>
<th>0.6 MMTPA (design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor WABT</td>
<td>°C</td>
<td>360 - 368</td>
</tr>
<tr>
<td>Reactor Pressure</td>
<td>kg/cm²</td>
<td>65</td>
</tr>
<tr>
<td>Diesel Product Sulfur</td>
<td>wppm</td>
<td>35 - 50</td>
</tr>
</tbody>
</table>
IsoTherming® Revamp Solutions
Benefits Achieved in a 37,000 BPSD Trickle Bed Unit

- 35% Capacity Increase with Minimal Modifications
- 2% Reduction in Charge Heater Duty
- 10% Reduction in Feed / Effluent Exchanger Duty

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Pre-Revamp Case</th>
<th>Post-Revamp Conventional Technology</th>
<th>Post-Revamp IsoTherming® Technology</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>BPSD</td>
<td>37,000</td>
<td>50,000</td>
<td>50,000</td>
</tr>
<tr>
<td><strong>Power consumption per barrel of feed</strong></td>
<td>KWh/bbl</td>
<td>2.42</td>
<td>2.16</td>
<td>1.72</td>
</tr>
<tr>
<td><strong>Fuel gas consumption per barrel of feed</strong></td>
<td>lb/bbl</td>
<td>1.23</td>
<td>1.40</td>
<td>1.02</td>
</tr>
<tr>
<td><strong>Cooling water consumption per barrel of feed</strong></td>
<td>ft³/bbl</td>
<td>18.0</td>
<td>18.1</td>
<td>17.3</td>
</tr>
</tbody>
</table>
Utilize Existing Nozzles

All internal parts pre-fabricated and were installed through existing manway

Reused supports

No welding to the reactor

40 days from shutdown to beginning of startup
IsoTherming® Revamp Solutions

Full Conversion to IsoTherming®
IsoTherming® Hydroprocessing Technology

Summary

A reliable & robust process for Grassroots or Revamp HDT Units

Simple & Straightforward
• Less equipment required
• Fewer modifications in revamps

Cost Effective
• Lower capital cost
• High energy efficiency
• Shorter project schedules & implementation time
Thank You