IsoTherming® Hydroprocessing Technology: Case Studies for Achieving Low Sulfur Diesel Specifications

Ravi Alla

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**DuPont Clean Technologies**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
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<tbody>
<tr>
<td>IsoTherming® Hydrotreating Technology</td>
<td>Leading technology for the production of low-sulfur, high octane gasoline blend stock</td>
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<tr>
<td>STRATCO® Alkylation Technology</td>
<td>Leading technology for the production of sulfuric acid and related high performance products</td>
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<tr>
<td>MECS® Sulfuric Acid Technology</td>
<td>Leading technologies for air emissions reduction in FCCs &amp; SRUs for SOx, NOx, and particulates</td>
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<tr>
<td>BELCO® &amp; DynaWave® Scrubbing Technologies</td>
<td>Unique technology for removal of sulfur to ultra-low levels from diesel and intermediate petroleum products</td>
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</tbody>
</table>

**Downstream Oil & Gas**
Introduction to IsoTherming® Hydroprocessing Technology
# IsoTherming® Hydroprocessing Technology

## 25 Licenses

- Grassroots: 21
- Revamps: 4
- Operating: 11
- 2017 Startups: 4

## Applications

- Diesel Hydrotreating
- FCC Pretreat Hydrotreating / Mild Hydrocracking
- Kerosene Hydrotreating
- Transmix Hydrotreating
- VGO & LCO Mild Hydrocracking
- Dewaxing
- Gas-To-Liquid (GTL) Upgrading
- Heavy Oil Upgrading
Conventional Trickle Bed Flow Scheme

- Two-Phase Reactor
- Once Through Liquid
- Gas Recycle
- Hydrogen diffuses into liquid as it is consumed in the catalyst bed
- Distribution critical
IsoTherming® Hydroprocessing Technology

- Liquid Phase Reactor
- Liquid Recycle
- All Hydrogen in liquid phase within the catalyst bed
- Distribution less critical
- No Hot/Cold Separators
IsoTherming® Hydroprocessing Technology

Technology Advantages

**Lower Capital Costs**
- Fewer pieces of high pressure equipment
- Elimination of gas recycle loop equipment
- Smaller foot print

**Lower Operating Expense**
- 30 to 60% reduction in fuel gas usage, as heat of reaction is absorbed by liquid recycle and used to heat the feed
- 30 to 40% reduction in power consumption by using a reactor recycle pump vs. recycle gas compressor

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

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

Conventional Technology

- Incomplete wetting
- Complete wetting

IsoTherming® Technology

- Vapor-Liquid Flow
- Catalyst particles with liquid film

Liquid Flow
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
• Smaller Feed/Effluent Exchanger
• Smaller Reactor Charge Heater
Grassroots Unit in China – Startup in 2014

Throughput: 3.75 MMTPA

Product Target: $ < 10 \text{ wppm}$

Design Feed Composition: 60% SRD, 40% cracked stock

Three-year catalyst cycle length

Reactor #2 operates without recycle (no recycle pump)

Project successfully completed as scheduled
Grassroots Unit in China – Startup in 2014

- Unit consistently produces diesel product with sulfur between 7 to 10 ppmw
- Ease of operation
Several Factors Drive Revamps

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Capacity increases</td>
<td>• Equipment and hydraulic limitations</td>
</tr>
<tr>
<td>• Product quality requirements</td>
<td>• New equipment and/or extensive modifications</td>
</tr>
<tr>
<td>• Process more difficult feedstock</td>
<td>• Extended schedule</td>
</tr>
<tr>
<td>• Increase catalyst cycle length</td>
<td></td>
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</tbody>
</table>
Unit History (Pre-Revamp)
• Operating at 1.65 MMTPA
• Diesel product sulfur of 50 ppmw

Revamp Feed Design Basis
• 73 wt% Straight Run Diesel
• 27 wt% Light Cycle Oil

Revamp Project Goals
• Maximize throughput increase
• Decrease product quality to <10 ppmw

Revamp Project Challenges
• Low reactor pressure of 51 kg/cm²(g)
• Feed stock variations
• Plot space constraints
• Minimize capital cost and maximize reuse of existing equipment

Specification | Units | Combined Feed
--- | --- | ---
Flow Rate | MMTPA | 2.28
Specific Gravity @ 15.6°C | 0.859
Sulfur | ppmw | 13,300
Nitrogen | ppmw | 294
Bromine Number | g/100g | 5.8
Aromatics
• Mono | wt% | 21.7
• Di | wt% | 15.1
• Tri+ | wt% | 0.5
ASTM D-86 Distillation
• IBP | °C | 150
• 50 vol% | °C | 272
• 90 vol% | °C | 326
• EP | °C | 357
Revamp in India – Startup in July, 2015

**Reactor R-01 Conversion:**
- Utilized existing nozzles (no new nozzles needed)
- All internal parts prefabricated and were installed through existing the manway
- Reused support rings
- No PWHT needed for conversion to an IsoTherming® Reactor
Revamp in India – Startup in July, 2015

• Single *unspared* pump

• Vertically hung in piping (reduces pipe stress requirements)

• Commercially proven in Ebullated Bed applications (over 40 years)
Revamp in India – Startup in July, 2015

Actual data taken eight months after startup

<table>
<thead>
<tr>
<th>Parameter</th>
<th>UOM</th>
<th>Pre-Revamp</th>
<th>Revamp Design</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>T/D</td>
<td>4950</td>
<td>6825</td>
<td>6800</td>
</tr>
<tr>
<td>Pressure</td>
<td>kg/cm²-g</td>
<td>47.3</td>
<td>51.8</td>
<td>51.8</td>
</tr>
<tr>
<td>LCO</td>
<td>wt%</td>
<td>20%</td>
<td>27%</td>
<td>27%</td>
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<tr>
<td>Specific Gravity</td>
<td></td>
<td>0.86</td>
<td>0.859</td>
<td>0.86</td>
</tr>
<tr>
<td>Feed Sulphur</td>
<td>wt%</td>
<td>1</td>
<td>1.33</td>
<td>1.1</td>
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<tr>
<td>Product Sulphur</td>
<td>ppmw</td>
<td>50</td>
<td>10</td>
<td>10</td>
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<tr>
<td>H2 consumption</td>
<td>T/D</td>
<td>26.0</td>
<td>56.2</td>
<td>48</td>
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<tr>
<td>Charge heater Duty</td>
<td>MMkcal/hr</td>
<td>5.82</td>
<td>3.61</td>
<td>3.6</td>
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<tr>
<td>H2 consumption</td>
<td>kg/Ton of Feed</td>
<td>5.3</td>
<td>8.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>kg/Ton of Feed</td>
<td>3.8</td>
<td>1.5</td>
<td>1.5</td>
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Summary

• IsoTherming® is a reliable & robust process for grassroots or revamp HDT Units, allowing refiners to efficiently achieve Euro 5 diesel specifications

• Lower Capital Costs (CAPEX)

• Lower Operating Expenses (OPEX)

• Better Energy Recovery

• Reliable and Safe