Ultra low Sulfur HSD production - CENTERA\textsuperscript{TM} Catalysts Are Key
To unlock potential of Hydrotreaters

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International Conference on
‘Refining Challenges- Way forward’
April 16-17, 2012
Organised by Petrofed, New Delhi, India
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CENTERA™ Is Key to Unlocking Unit Potential

**Agenda**

- Fundamental Understanding of CENTERA™ Advancements
- Broad application in hydroprocessing units
- Case studies demonstrating CENTERA™ Benefits
- CENTERA™ makes it easier to move “Beyond ULSD”
**CENTERA™ Is Key to Unlocking Unit Potential**

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<table>
<thead>
<tr>
<th>Element of Technology</th>
<th>Description</th>
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<tbody>
<tr>
<td>Strong Legacy</td>
<td>Builds on Innovations from CENTINEL GOLD and ASCENT technologies</td>
</tr>
<tr>
<td>Better Dispersion</td>
<td>Utilizes improved support technology for better dispersion of active metals</td>
</tr>
<tr>
<td>Maximum Sulfidation</td>
<td>Generates highest possible degree of sulfidation to form ideal Type II active phases</td>
</tr>
<tr>
<td>Optimal Assembly of Active Sites (Nanotechnology)</td>
<td>Results in optimal decoration/configuration of promoter metals on MoS$_2$ and higher performance with better metals</td>
</tr>
<tr>
<td><strong>Enhanced Retention of Activity</strong></td>
<td>Allows sites to be locked in place</td>
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</table>
Better Dispersion of MoS$_2$ Particles
Continuous Improvement Using Better Support

Particle Diameter
CENTINEL: 40 – 45 Å
CENTINEL GOLD: 30 – 35 Å
CENTERA: 25 – 35 Å
Maximum Sulfidation
Generates Fully Accessible Type II Active Phase

First shell Mo-S coordination number = 6

Degree of sulfidation as in bulk MoS$_2$
Enhanced Retention of Activity
Keeps Activity Following Activation, Upsets

Difficult (50%) Cracked Stock Blend: ~70 barg Operation
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Broad Application in Hydroprocessing Units
Improved Performance in Many Areas

- Applied across wide range of pressures (20-200 barg)

- Improved HDN
  - Drives higher HDS in ULSD service
  - Enhances aromatic saturation and conversion in higher pressure applications like FCC PT and HCPT

- Improved HDS
  - Important in FCC PT, HC and ULSD applications to maximize production of low sulfur gasoline and diesel across an entire cycle

- Improved stability
  - Enhanced retention of initial activity
  - Significantly lower SOR temperatures lead to lower deactivation rates
CENTERA™ DC-2650 CoMo for FCC PT
Improved HDS Becoming Critical for ULSG/ULSD Production
CENTERA™ DN-3620 NiMo for HCPT
Relieves HDN Constraints and Provides Big HDS Improvement
Outstanding Performance for LCO Hydrocracking

HCPT Testing of 100% LCO Feed
Feed: S = 3.05 wt%; N = 726 ppm
P = 78 bar; LHSV = 1.4; TGR = 1265 Nm3/m3

11 °C or 40% RVA Increase
CENTERA™ DC-2618 CoMo for Low-Medium Pressure ULSD
Advantage Across the Board, Especially at Low Pressure

Activity Advantage vs DC-2531 as $\Delta$Temperature Required, °C

<table>
<thead>
<tr>
<th>A: ME SRGO 20 barg</th>
<th>B: Maya SRGO 30 barg</th>
<th>C: Maya SRGO/LKGO 40 barg</th>
<th>D: Maya SRGO/LCO 40 barg</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-2532</td>
<td>DC-2533</td>
<td>DC-2618</td>
<td>DC-2618</td>
</tr>
</tbody>
</table>

CONFIDENTIAL
CENTERA™ DN-3630 NiMo for Medium-High Pressure ULSD
Significant HDS Advantage Driven By Improved HDN

ULSD Testing of Heavy Arab Med SRGO Feed
Feed: S = 1.67 wt%; N = 185 ppm
P = 60 barg; LHSV = 1.0 hr-1; TGR = 200 Nm3/m3

Temperature for Sp=10 ppm, °C vs. Catalyst Age, hrs

C08-17 DN-3531
C07-03 DN-3330
C08-14 DN-3630
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Case Study #1:
Evaluate CENTERA™ vs CENTINEL GOLD Systems

Opportunity: Evaluate Tradeoffs of Activity and H₂ Consumption
- Both systems provided activity advantage over incumbent DN-3330 system
- Sandwich CoMo/NiMo CENTERA™ system showed H₂ savings
- CENTERA™ DN-3630 system gave big activity benefit with some increase in H₂ Consumption

Conclusion: Benefits of an all NiMo CENTERA™ system allowed more cracked stock processing, which outweighed potential H₂ savings

ULSD Testing of Heavy SR/LCO/LKGO Blend
Feed: S = 1.1 wt%; N = 950 ppm
P = 42 barg; LHSV < 1.0 hr⁻¹; TGR = 400 Nm³/m³
Case Study #2:
Evaluate CENTERA™ vs ASCENT Systems

CENTERA™ Catalysts Provide Significant Performance Benefits

  • Heavy feed and visbroken components add significant nitrogen, which inhibits HDS for high LHSV unit.
  • High SOR WABT puts unit in thermodynamically constrained region immediately.
  • Incorporating CENTERA NiMo significantly improves HDN, HDS. Dramatic reduction in SOR WABT.

Conclusion: Benefits of adding NiMo CENTERA™ opens up operating window, and has potential to double cycle length.

ULSD Testing of Heavy SR/VB Blend
Feed: S = 0.3 wt%; N = 170 ppm
P = 400 barg; LHSV > 1.5 hr⁻¹; TGR ~ 80 Nm³/m³
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Diesel Hydrotreating Units Are Versatile Assets
CENTERA™ Is The Key To Moving Beyond ULSD
Backup Slides
## CENTERA™ DC-2618 and DN-3630
### Features and Benefits

<table>
<thead>
<tr>
<th>ULSD Feature</th>
<th>Customer Benefit</th>
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<tbody>
<tr>
<td><strong>Maximum HDS Performance</strong></td>
<td></td>
</tr>
<tr>
<td>• DC-2618 - Highest Activity CoMo at Low-Med P (5-20°F, 3-12°C) vs DC-2533. Comparable to CENTINEL GOLD DC-2318 at Med-High P.</td>
<td>• Longer runs&lt;br&gt;• Process heavier/harder feeds&lt;br&gt;• Enable diesel upgrading for non-sulfur properties (e.g. cetane, cold flow)&lt;br&gt;• Enables use of more regen catalyst usage.</td>
</tr>
<tr>
<td>• DN-3630 - Highest Activity Conventional NiMo in Market (8-13°F, 5-8°C) more active than DN-3330.</td>
<td></td>
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<tr>
<td><strong>Enhanced Retention of Activity</strong></td>
<td>Higher SOR activity. Less hyperactivity during first month of operations.</td>
</tr>
<tr>
<td><strong>Top Performance CoMo and NiMo for customized application</strong></td>
<td>Provides ability to manage both activity and H₂ consumption. Enables stacking and sandwiching combinations.</td>
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<tr>
<td><strong>Handling and Loading Flexibility</strong></td>
<td>No special packaging required. Loading of reactor easily handled in air environment</td>
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<tr>
<td><strong>Normal sulfiding procedures</strong></td>
<td>No long holds at intermediate temperatures required for some Type II activations</td>
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<tr>
<td><strong>Robust during startup</strong></td>
<td>Extended gas phase heatup (12-hr at 150°C) possible before liquid is introduced. Permits leak testing and reactor wall heating to satisfy temper embrittlement requirements.</td>
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<tr>
<td><strong>Regenerable by ENCORE</strong></td>
<td>Best multi-cycle economics</td>
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Particle Morphology Affects Activity
Interaction with Alumina is Key Determinant

MoS$_2$ - Type I
• mainly single layers
• incomplete sulfidation
• Al-O-Mo bonding still present
• poor accessibility of active sites
• less active than Type II

MoS$_2$ – Type II
• stacked particles
• fully sulfided
• no Al-O-Mo bonding
• high accessibility of active sites
• high hydrogenation activity
• more active than Type I
Comparison of DBT HDS Pathways for CENTERA and ASCENT NiMo Catalysts
CENTERA Shows Improvement in Both Reaction Routes

![Comparison of DBT HDS Pathways](image)
General ULSD Product Placement

CoMo vs NiMo

Potential Stacking Opportunities

Hydrogenation Environment / H₂ Consumption

P = 400 psig  P = 600 psig  P = 800 psig  P = 1300 psig
Catalytic Dewaxing
Commercially Proven Solutions

- Drop-in catalyst for short-term solution
- Revamp implemented later with full ULSD solution
- High activity catalyst plus dewaxing used to increase feed by 12%
- Same dewaxing catalyst used for both cycles (even some regen)