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Solvent Deasphalting – Conversion Enabler

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Agenda

- Impact of heavy feeds on hydrocracking unit
- Solvent Deasphalting process reduces contaminants in residue streams
- Case study: Residue upgrading by SDA-HC
Residue Streams are Challenging to Process

- Contaminant levels increase with boiling range in most crudes
- Residue streams typically contain high sulphur, nitrogen, Conradson carbon, organometals and asphaltenes

<table>
<thead>
<tr>
<th>Stream</th>
<th>Atmospheric Residue</th>
<th>Vacuum Residue</th>
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</thead>
<tbody>
<tr>
<td>Sulphur, ppm wt</td>
<td>2.3</td>
<td>3.0</td>
</tr>
<tr>
<td>Nitrogen, ppm wt</td>
<td>2600</td>
<td>4000</td>
</tr>
<tr>
<td>Conradson Carbon, %wt</td>
<td>8</td>
<td>16.3</td>
</tr>
<tr>
<td>Ni + V, ppm wt</td>
<td>83</td>
<td>164</td>
</tr>
<tr>
<td>Asphaltenes, %wt</td>
<td>1.5</td>
<td>3.1</td>
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</table>
Impact of Feed Contaminants on HC Unit Operation

1. **Sulphur**: Converts to hydrogen sulphide over hydrotreating catalyst. Competes for active sites on hydrocracking catalyst, reducing activity.

2. **Nitrogen**: Converts to ammonia over hydrotreating catalyst. Reduces activity of hydrocracking catalyst.

3. **Conradson Carbon**: Increases coke formation and shortens catalyst cycle.

4. **Metals Content**: Vanadium and Nickel are catalyst poisons.

5. **Asphaltenes**: Indicative of heavy polynuclear aromatics (HPNA) precursors in the feed. Moderate levels cause rapid deactivation of catalyst and short cycle length.
Solvent Deasphalting (SDA) Process

• Licensed technology for reduction of contaminants in feedstocks such as AR, VR by physical separation

• Reduces the contaminant (sulfur, nitrogen, Conradson carbon, asphaltene and Ni+V) contents of feedstocks to produce:
  - Deasphalted Oil (DAO) containing lower levels of contaminants
  - Pitch containing most of the feed contaminants

• Light liquid paraffins (typically C3 to C5 range) precipitate asphaltenes and resins from heavy oils

• Separation of DAO and solvent under either subcritical or supercritical conditions

• Combines commercially-proven process technology with proprietary extractor internals
Selectivity in Solvent Deasphalting

Sulfur, Conradson Carbon and Metals Appearing in Deasphalted Oil, %

Deasphalting Oil Yield, Vol-%

Typical Operating Range

Sulfur
CCR
Nickel
Vanadium

Honeywell UOP
SDA Process (Two-Product Configuration)

Vacuum Residue Charge → Extractor → DAO Separator → DAO

Steam → Pitch

Steam
SDA Process (Three-Product Configuration)

Vacuum Residue Charge → Extractor → Resin Settler → DAO Separator

Extractor → Resin → Settler

Steam → Pitch

Steam → Resin

Steam → DAO
Uses for SDA Pitch

- Fuel for steam / power generation
- Fuel for cement manufacturing
- Bitumen manufacturing
SDA Commercial Experience

- Combination of UOP and Foster Wheeler technology
- First unit licensed in 1973
- >45 units licensed with a combined capacity of >650,000 BPSD
- Both 2 product and 3 product configurations in successful operation
SDA Technology is Highly Cost Effective

- Low capital cost
  - Carbon steel equipment
  - Low pressure
  - No compressors

- Potential for very high local content

- Low solvent consumption and cost
  - Solvent typically C4s from refinery LPG system
Case Study: Upgrading by SDA - Hydrocracking

- Two stage hydrocracking unit licensed by a competitor
  - Feed 25% DAO, 75% heavy VGO
  - Full conversion
  - Maximum kerosene and diesel
Initial Operating Cycles Highlighted Challenges with DAO Processing

- First 9 cycles used competitor catalyst
- Average cycle length ~12 months
- Severe fouling of heat exchangers led to heater limiting unit
- Fouling of second stage catalyst top bed caused high pressure drop
- Deactivation of cracking catalysts from HPNAs
- DAO contains high levels of HPNA pre-cursors

- HPNA = Heavy Poly Nuclear Aromatics
  - Compounds with 7+ aromatic rings, e.g. tribenzcoronene
Why are HPNAs Important?

Raw Feedstock Precursors

Condensation  Reactions

HPNAs on Catalyst Surface

Forms Coke  Fouls Downstream Equipment
UOP Catalyst & HPNA Management Technology Installed

• UOP catalyst loaded in Cycle 10
  - Catalysts with proven track record in DAO service
  - Supported with pilot plant work

• UOP HPNA-RM™ module installed on recycle to second stage during cycle 10
  - Carbon bed technology to absorb HPNA
Step Change Improvement in Cycle Length

Improvement achieved by:
- Implementation of HPNA management technology
- Catalyst system improvements
- Continuous development of the unit by the refiner (e.g. filters, exchangers)
Significant Improvement in Unit Performance

• Capacity increased by **42%**
• Cycle length increased by **>300%** - at higher feed capacity
• Refiner chose UOP catalysts for all following cycles
• Operation now limited by factors outside unit
Summary - Benefits of adding SDA – HC Complex to an Existing Refinery

• Scenario:
  - 100,000 bpsd refinery with existing vacuum distillation and recycle hydrocracking unit
  - Add a new SDA unit
  - Revamp the hydrocracker - full conversion at higher capacity

• Project provides significantly higher refinery profitability
  - 40% decrease in fuel oil
  - 12% increase in refinery Euro V diesel production
  - Increase value of refinery products by around 170 million $/year
  - Payback on capital cost <4 years

• Optimisation of SDA – HC complex requires specialist knowledge
  - Balance fuel oil upgrading with impact on hydrocracker
  - Ensure pitch properties meet requirements for proposed use
  - Managing HPNAs is critical to successful operation – UOP has proprietary technology to achieve this

Basis: EuroV diesel 61.9 $/bbl, Fuel Oil 21.6 $/bbl
The information contained in this presentation is provided for general information purposes only and must not be relied on as specific advice in connection with any decisions you may make.