Carbon Utilization and Petrochemical Integration: Capturing value via residue to chemicals projects

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Agenda

- Oil & Petrochemicals Market Dynamics and Challenges
- H-Oil Ebullated Bed Technology
- Crude to Chemicals Solutions
  - Aromatics Case Study: Grassroot Complex Towards Aromatics
  - Olefins Case Study: Integration with Steam Cracker Complex
Oil & Petrochemicals Market Dynamics and Challenges
Strong Petrochemicals Demand Growth

Market Drivers Growth (Base 100: Year 2010)

- Petrochemicals*: +4.0%/y
  (*Ethylene, Propylene, Butadiene, BTX, Methanol)
- GDP: +3.7%/y
- Natural Gas Demand: +1.5%/y
- Population: +1.1%/y
- Fuels Demand: +1.0%/y

Source: Bank, CEH, Axens
In 2035, How Much Oil will be Converted into Petrochemicals? (RTS Scenario, IEA 2018)

In 1990, 5.3 Mbpd were converted into petrochemicals

1. 10.2 Mbpd
2. 12.3 Mbpd
3. 15.6 Mbpd
4. 17.3 Mbpd
In 2035, How Much Oil will be Converted into Petrochemicals? (RTS Scenario, IEA 2018)

Feedstock Oil demand, Mbpd

Share of Total oil demand

Source: The Future of Petrochemicals, IEA, 2018
H-Oil Technology
Ebullated Bed Residue Hydrocracking H-Oil®

- Demonstrated high conversion levels
- No limitation on feed properties
- Mature & reliable technology more than 1.2 MBPSD licensed capacity
- High availability > 96% demonstrated on several units
- 2 new high conversion H-Oil® units starting-up in 2019
- 3 recent awards in 2019
VR High Conversion: Main technology routes

- Vacuum Bottoms Recycle
- Residence Time Path:
  - Low Space Velocity Design
- Coker Integration:
  - Concentration of the CCR in the Coke
- SDA Integration:
  - Concentration of Asphaltenes in pitch
H-Oil Reactor Design: Paths for High Conversion

- Recycle of the Vacuum Bottom – VBR
  - VBR reduces the severity per pass, low conversion per pass and reduced formation of sediment levels
  - Demonstrated Commercially: H-Oil unit started-up in the 80’s had operated at high conversion of VR with VBR, this mode was part of the design.

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>LSFO</th>
<th>High Conversion</th>
<th>Maximum Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>VR Feed Capacity</td>
<td>Base</td>
<td>Base Plus VBR</td>
<td>Base + 25%</td>
</tr>
<tr>
<td>1000 °F+ Conversion,</td>
<td>Base</td>
<td>Above 85%</td>
<td>Base</td>
</tr>
</tbody>
</table>
H-Oil Reactor Design : Paths for High Conversion

- Low LHSV Design – Long residence time
  - **Maximize** catalytic performance for both conversion and hydorefining
  - **Control** the sediment with reactor temperature
  - High quality Effluents due to High HDS and High CCR Removal
  - **Demonstrated** in commercial unit:
  - H-Oil under start-up in 2019 at low LHSV is design for more than 85% of conversion.

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H-Oil® Suite: Low LHSV Commercial Follow-up

- Lower capacity operation industrial demonstration
  - Higher conversion
  - Less sediment production
  - Enhanced refining performance

- LHSV / WABT prove powerful to break conversion ceiling

40% VR availability reduction

Up to 15% of conversion

Significant sediment reduction
Coker Integration

- **Unlock** sediment constraints for H-Oil® UCO
- **Create** value not only with high conversion but also with better coke quality
- **Maximize** the use of existing assets

### Case Study

<table>
<thead>
<tr>
<th>%wt</th>
<th>Overall Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-Oil Unit</td>
<td>75</td>
</tr>
<tr>
<td>H-Oil Unit + Coker</td>
<td>88</td>
</tr>
</tbody>
</table>

**Coke quality is improved:**
- Lower Sulfur and metal
- Up to Anode grade coke

**Additional Conversion with Coker**

- Distillates: +8%
- Coke: -10%
UCO to Coker Unit

- **Commercial Reference:** Asia Location, under commissioning
- **Maximize** the use of existing assets:
  Combination H-Oil + Coker reaches 94% of VR conversion
SDA Integration

- **Unlock** sediment constraints for H-Oil® UCO and concentration of Asphaltens in the pitch
- **Reduced CAPEX** in comparison with Coker Unit
- **High Incremental Conversion** for refinery with pitch disposal
- Pitch is better than Coke for hydrogen production in Gasification

**Commercial References:**
- Hengli Crude to Paraxylene Complex. H-Oil unit has started-up
Each H-Oil Design is unique to fit Refiner’s VR destruction objectives.
Selection of Light Crude to Maximize Straight Run Naphtha

Technology Providing Maximum Conversion and Potential for naphtha

Steam Cracker / Aromatic Complex

Diesel HDT/ HCK

Partial to full Cracking of Middle Distillate Cut to Naphtha

VGO Hydrocracker

Selection of Scheme/ Catalytic System for Naphtha Maximization

Refining & Petrochemicals Integration

How to Increase Naphtha Production?
Crude to Chemical Options
Aromatics Production
**Crude to PX Project - Feed and Products**

- **Feed 400,000 BPSD of crude oil**
  - 60% Arabian Heavy
  - 30% Arabian medium
  - 10% Marlim

- **Product Requirement**
  - 211,000BPSD of Heavy Naphtha for PX production
  - Co-Production of high quality gasoline, diesel & jet fuel
  - Production of Group III Lube Base Oil
  - Minimization of residue production
Crude to PX - Conversion Block

Heavy sour crude 20 MTA

HN = Heavy Naphtha
LN = Light Naphtha

ADU
AGO
VDU
AR

HN = Heavy Naphtha

Ebullated bed HCK H-Oil®

Full Conversion HCK HyK™

Solvent Deasphalting Solvahl™

SR VGO HCK HyK™

Stein Cracker

Aromatic Complex ParamaX®

Kero Pool

Diesel Pool

Group III Lube Complex

Gasification

Highly efficient scheme

90 wt.% conversion on VR

45 wt.% heavy naphtha yield

Margin capture by converting lowest value VR to high value molecules

REFCOMM GALVESTON 2019 - TX, US, 2 MAY 2019
Crude to Chemical Options

Olefins Production
World-class Integrated Project – Asia Location
Petrochemicals & Fuels Production

Refinery Capacity
400,000 BPSD

Production (kta)

Petrochemicals Price

Fuels Price

Crude • Middle East Light & Heavy
• Arabian Medium
• Brazil Frade

Concentration
Crude

CDU & VDU

C₅/C₆ Isom. & Aromatics Block

Conversion Block

Steam Cracker & C4 units

Ethylene
Propylene
Benzene
Paraxylene
Gasoline
Kero
Diesel

Crude
Naphtha
MD
Residue

Methanol

Refinery Capacity
400,000 BPSD

Crude

Middle East Light & Heavy
Arabian Medium
Brazil Frade

RefComm GALVESTON 2019 - TX, US, 2 MAY 2019
Same VR Conversion

- **Case Study 1**
  High transportation fuel and Paraxylene Products

- **Case Study 2**
  Less transportation fuel but high Paraxylene and Olefins production

Chemical Complex design has a large panel of technologies to cover from Maxi PX to Maxi Olefins.

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**Products Distribution for the two cases studies**

Comparison Aromatics and Olefins Production

<table>
<thead>
<tr>
<th></th>
<th>Transportation Fuels</th>
<th>PX</th>
<th>Benzene</th>
<th>Ethylene</th>
<th>Propylene</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMta</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

Aromatics

Olefins

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⚠️ **Flexibility in the design is Key to maximize products value**
Olefins Market : Steam Cracker Complex

- PyOil are:
  - High content of CCR
  - High Asphaltenes
  - Typically burned in the refinery due to low value on the market

PyOil – Steam Cracker Tar Oil

- IBP = <400F
- T50 = 700F
- EBP = 1300F
- API = -1
- CCR = 20%
- Asphaltenes = 15%
PyOil Co-processed in H-Oil Unit

- Two Recent Awards: Crude to Chemical complex with pyOil in the H-Oil feed

**Initial Case:** PyOil to Fuel

**Design Case:** PyOil is sent to the H-Oil Unit

PyOil is hydrogenated and converted

PyOil Value is more than double

Hydrogen = 2.8 $/MMBtu
H-Oil: Capturing Value from the Heavy Ends

- Petrochemicals demand growth higher than that of fuels

- Crude Oil-to-Chemical complexes offer many advantages:
  - Expanding into higher growth markets
  - Mitigating risks related to raw material and product price variations
  - Improving asset profitability

- Crude Oil-to-Chemical projects implementing advanced technologies is a way to catch these opportunities

- Ebullated Bed Residue Hydrocracking H-Oil® has commercially proven High Conversion Operation