Changing Refinery Configuration for Heavy and Synthetic Crude Processing

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Why Should I Even Think About Running Synthetics?

- Oil sands deposits in Western Canada are huge
  - 1.7 trillion barrels total oil in place
  - 174 billion barrels of recoverable oil with existing technology
  - Cumulative production since 1967 only 4 billion barrels

- Recoverable reserves could increase dramatically with improved technology
Bitumen-derived Crudes Replacing Declining Conventional Crudes from Western Canada

Upgraded Bitumen/SCO
Non-Upgraded Bitumen
Conventional Heavy
Conventional Light

Thousands of Barrels per Day

Source: Purvin & Gertz, 2005
Synthetic Crudes and Bitumen Blends Available in Market

Bitumen Production
(Mining or In-Situ)

Upgrading

Condensate

DilBit

Heavy SCO

SynDilBit

SynBit

Light SCO

Light Synthetic Crude Oil (SCO)

Light Crude Refineries

Medium Crude Refineries

Heavy Crude Refineries

Source: Purvin & Gertz, 2004
Diluent Shortages will Make SynBits the Dominant Heavy Crude from Western Canada

Source: Purvin & Gertz, 2005
Western Canadian Select (WCS) Will Become a New Benchmark Crude

- Became available in January 2005
  - Currently at 350 KBPD
  - Expected to reach 500 KBPD by 2008
- Each batch contains:
  - Condensate
  - Hydrotreated synthetic crude
  - Heavy conventional crude
  - Medium conventional crude
  - Cold Lake bitumen
  - Athabasca bitumen
Bitumen-derived Crude Composition Different from Conventional Crudes

- WTI
- Arab Light
- ANS Blend
- Lloyd Bow
- DilBit
- WCS
- SCO

Components:
- Resid
- Vacuum Gas Oil
- Distillate
- Naphtha/LPG

Vol-%
Processing Bitumen-derived Crudes Affects All Areas of the Refinery

**Bitumen Blends**
- High resid content
  - Coking or SDA required
- High contaminant level
  - High-severity hydrotreating
- High VGO content after resid conversion

**Synthetic Crudes**
- No resid content
  - Blending with other heavy crudes
- Low-quality distillate
  - High-severity hydrotreating
- Large volume of low-quality VGO
  - FCC feed pretreatment
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Additional VGO Conversion Required!
Increasing Distillate Demand Will Change Refinery Product Slate

- Distillate demand growing faster than gasoline demand
- Increased dieselization of U.S. vehicle fleet
- VGO conversion will shift from FCC to hydrocracking for distillate production

**USA G:D Ratio Forecast**

Source: Purvin and Gertz 2005 GPMO
Adding 25% Synthetic VGO Reduces FCC Yields

- **LPG**
- **Gasoline**
- **LCO**
- **CSO**

**Crude Blend**
- Brent
- Brent + Sweet Blend
- Brent + Sour Blend
**Bitumen-derived VGOs are Hydrogen Lean and Contaminant Rich**

<table>
<thead>
<tr>
<th>Property</th>
<th>Lt. Arabian VGO</th>
<th>Cold Lake VGO</th>
<th>Athabasca VGO</th>
<th>Coker HGO</th>
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</thead>
<tbody>
<tr>
<td>Gravity, °API</td>
<td>22.7</td>
<td>16.3</td>
<td>14.2</td>
<td>11.4</td>
</tr>
<tr>
<td>Sulfur, wt-%</td>
<td>2.10</td>
<td>3.10</td>
<td>3.77</td>
<td>4.99</td>
</tr>
<tr>
<td>Nitrogen, wppm</td>
<td>820</td>
<td>1380</td>
<td>1854</td>
<td>4032</td>
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<tr>
<td>Hydrogen, wt-%</td>
<td>12.47</td>
<td>11.38</td>
<td>10.80</td>
<td>10.43</td>
</tr>
<tr>
<td>Total Aromatics, vol-%</td>
<td>58</td>
<td>60</td>
<td>69</td>
<td>76</td>
</tr>
</tbody>
</table>
Integration of Hydroprocessing and FCC Operation is the Key to Processing Bitumen-derived Crudes

FCC Feed Hydrogen Content Must be Optimized
What is the Right Hydrogen Content for FCC Feed?

Gasoline Yield, Vol-%

- Vacuum Gas Oil
- Ebullated-bed Gas Oil
- Coker Gas Oil
- Hydrocracker Bottoms

Hydrogen Content, Wt-%

- 11.4
- 11.6
- 11.8
- 12
- 12.2
- 12.4
- 12.6
- 12.8
- 13
- 13.2
- 13.4
- 13.6
- 13.8

UOP 4525A-12
FCC Feed Pretreat Economics Improve as Feed Quality Worsens

- Tougher Feeds - Higher NPV
- Economics
- Improve as Feed Quality Worsens

- Inc Op Costs, $MM/yr
- ISBL Costs, $MM
- NPV, $MM

- Brent
- Brent + Sweet Syn. Blend
- Brent + Sour Syn. Blend
- Arab Light
- Arab + Sweet Syn. Blend
- Arab + Sour Syn. Blend

- UOP 4525A-14
FCC Feed Pretreating is Not Always the Right Solution

- FCC capacity still limited by high VGO content of bitumen-derived crudes
- High-quality distillate fuels cannot be produced in an FCC unit
Hydrocracking Required to Convert Incremental VGO and Produce Right Product Mix

Unionfining™ → Diesel → FCC → Gasoline

Unicracking™ → Gasoline → FCC → Diesel

FCC → Gasoline
Is the Once-through Unicracking Process the Right Choice?

- Higher yields of naphtha and distillate
- Higher quality FCC feedstock
- Flexibility to adjust conversion for seasonal demand
Once-through Unicracking Process Produces FCC Feed with High Hydrogen Content

- Naphtha
- Kerosene
- Heavy Diesel
- FCC Feed

16 mm Smoke Point
45 Cetane No.

H₂

Feed

61.5

64

5

12

17

30

60

R-1

R-2
Increased Conversion Produces
Higher-quality Fuels

Kerosene Smoke Point, mm

Diesel Cetane Index

Conversion, wt-%

Conventional VGO Feed

Smoke Point

Cetane Index
Separate-hydrotreat Configuration Provides Flexibility

Independent Control of Distillate and FCC Feed Qualities
Advanced Partial-conversion Unicracking (APCU) Integrates FCC Feed Pretreatment with ULSD Production

VGO Feed → Co-feed

HT Rx → Enhanced Hot Separator

HC Rx → EHS

PT Rx → AMINE

H₂ → SEP

Fractionation

ULSD

FCC Feed
Unicracking Process is the Right Choice for Converting Incremental VGO

- Optimizes FCC feed hydrogen content
- Produces high-quality distillate fuels to meet growing demand
- Diesel produced can meet all ULSD specs
- Product slate can be seasonally adjusted
- Small incremental capital cost to upgrade from FCC feed pretreating to Unicracking process
Summary

- Bitumen-derived crudes will be an increasing crude component for northern US refiner.
- Significant processing implications will prompt both resid and VGO hydroprocessing conversion.
- ‘Intelligent’ hydroprocessing solutions will be required to cost effectively accomplish the upgrading of synthetic crudes.