Heavy Crude Processing

SK Handa
Engineers India Limited

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Introduction

• **Challenges Facing Refinery**
  – Conventional Crude Production
  – Growing Energy Demand
  – How to meet energy demand
  – Have we reached peak oil production

• **Unconventional Feedstocks**
  – Heavy Oil & Oil Sands
  – Heavy Crude Quality
  – Processing Options for Heavy Crude

• **Syn Crude Economic Data**

• **Conclusions**

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Challenges Facing Refinery

- Process heavy, high sulphur cheaper feedstocks
- Bottom of the barrel processing to improve margins
- Improve fuels quality to meet new specifications
- Reduce emissions to meet environmental norms
- Flexibility to meet changing market demands
- Processing of unconventional feedstocks
- Reduction in CO2 emissions
Regional Crude Oil Production

- **Increasing**
  - Middle East
  - CIS
  - Africa
  - Canada

- **Flat**
  - United States
  - Latin America
  - Asia

- **Declining**
  - Europe

*Million Barrels per Day*
Heavy Sour Crude Production

Observations:

- Total heavy sour crude production is expected to reach **700 MMTPA** (14 million B/D) by Yr. 2020, an increase of over 2.5 MM B/D over year 2010 production.

- The largest increases will come from the Middle East & Canada.
Growing Energy Demand

Most countries rely on few energy producing nations that control abundant hydrocarbon reserves.

- Current global oil production is about 82 MMbpsd, 75% of it is conventional crude oil.
- Total estimated reserves of conventional oil of top 17 producers is 1.2 trillion bbls.
- At the current oil production rate, the balance life of the conventional crude oil reserves is nearly 54 years.

Looking forward to Yr 2030, forecast global oil demand is estimated to reach 116 MM bpsd.

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How to Meet Growing Energy Demand

- Curb demand on consumer side

- Increase supply of raw oil. This requires:
  - Exploitation of unconventional oil reserves
  - Advanced processing technology
  - New innovations for renewable fuels
Have We Reached Peak Oil

- Global oil production in recent past was largely focused on maximising ‘Easy Oil’. This focus has already shifted to unconventional oils.

- World oil reserves have already started becoming –
  - Sour
  - Heavier
  - More acidic
  - Harder to produce or recover

- Deteriorating crude quality requires –
  - Increased production cost
  - Needs enhanced oil recovery methods
  - Increased processing cost

The available statistical data of the crude oil reserves shows that conventional oil production is already past its peak.
Year–vise Oil Production in Non-OPEC & FSU Countries

OGJ, 9 Feb 2004 (Jan-Nov 2003)
After the peak conventional oil production this century, the refineries are required to necessarily & increasingly incorporate unconventional feedstock processing technologies around a core of existing conventional oil refining assets.
Conventional & Un-conventional Oil Reserves

- **Current share** of unconventional sources in the total output is about 25%. This is expected to rise to 40% of global oil supply by the year 2015.

- **Unconventional oil reserves** are estimated to be about 6 trillion barrels.

- **Conventional oil reserves** are estimated to be 1.2 trillion barrels.
<table>
<thead>
<tr>
<th>Location</th>
<th>Crude Type</th>
<th>Estimated Reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta (Canada)</td>
<td>Bituminous</td>
<td>85% of world’s recoverable bitumen reserves</td>
</tr>
<tr>
<td>Orinoco Belt (Venezuela)</td>
<td>Extra-Heavy</td>
<td>90% of world’s extra heavy reserves</td>
</tr>
</tbody>
</table>
# Rajasthan Crude Characteristics Comparison

<table>
<thead>
<tr>
<th>Property</th>
<th>Rajasthan Crude</th>
<th>Arab Mix Crude (50:50 by wt.)</th>
<th>Bombay High Crude</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>27.06</td>
<td>30.77</td>
<td>39.2</td>
</tr>
<tr>
<td>Sulphur, wt%</td>
<td>0.34</td>
<td>2.37</td>
<td>0.142</td>
</tr>
<tr>
<td>Total Acid Number (TAN), mg KOH/g</td>
<td>0.49</td>
<td>&lt; 0.2</td>
<td>0.107</td>
</tr>
<tr>
<td>Pour Point, Deg C</td>
<td>(+)48</td>
<td>(-) 15</td>
<td>(+)7.2</td>
</tr>
<tr>
<td>CCR, wt%</td>
<td>8.65</td>
<td>6.0</td>
<td>0.968</td>
</tr>
<tr>
<td>Ni+V, ppmw</td>
<td>10.7</td>
<td>48</td>
<td>2.1</td>
</tr>
<tr>
<td>Wax Content, wt%</td>
<td>25.8</td>
<td>2.8</td>
<td>10.6</td>
</tr>
</tbody>
</table>
# Rajasthan Crude Product Yield Comparison

<table>
<thead>
<tr>
<th>Yield (Wt%)</th>
<th>Rajasthan Crude</th>
<th>AM</th>
<th>BH</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCO</td>
<td>73.3</td>
<td>48.8</td>
<td>30.4</td>
</tr>
<tr>
<td>VGO</td>
<td>43.8</td>
<td>26.2</td>
<td>23.9</td>
</tr>
<tr>
<td>VR</td>
<td>29.5</td>
<td>22.6</td>
<td>6.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yield (Wt%)</th>
<th>RAJASTHAN</th>
<th>ARAB MIX</th>
<th>BOMBAY HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAC RESIDUE</td>
<td>30.91</td>
<td>22.06</td>
<td>6.51</td>
</tr>
<tr>
<td>VGO</td>
<td>44.14</td>
<td>26.15</td>
<td>22.226</td>
</tr>
<tr>
<td>DIESEL</td>
<td>17.37</td>
<td>19</td>
<td>26.31</td>
</tr>
<tr>
<td>KEROSENE</td>
<td>6.327</td>
<td>12.27</td>
<td>19.41</td>
</tr>
<tr>
<td>NAPHTHA</td>
<td>1.239</td>
<td>1.98</td>
<td>1.63</td>
</tr>
<tr>
<td>LPG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1-C2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Heavy Oil & Oil Sands Bitumen Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Heavy Oil</th>
<th>Bitumen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, 0 API</td>
<td>20 ~ 22</td>
<td>7 ~ 19</td>
</tr>
<tr>
<td>Density, Kg/M3</td>
<td>920 ~ 950</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>Sulphur, wt%</td>
<td>3 ~ 4.5</td>
<td>&gt; 4</td>
</tr>
<tr>
<td>Viscosity, cP</td>
<td>&gt; 30,000</td>
<td>&gt; 100,000 @ 25°C</td>
</tr>
</tbody>
</table>

New innovative technologies are needed to upgrade the extra-heavy oil / bitumen feedstocks.
## Heavy Crude Quality

<table>
<thead>
<tr>
<th>Property</th>
<th>Comment</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>API</td>
<td>Typically, oil gravity approaches water, requiring a diluents to separate water from hydrocarbon</td>
<td>Water / Oil separation</td>
</tr>
<tr>
<td>Sulphur</td>
<td>High sulphur levels requiring hydrotreatment</td>
<td>Corrosion</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>High nitrogen levels requiring H2 for removal, producing NH3</td>
<td>Corrosion</td>
</tr>
<tr>
<td>Metals Ni/V/Fe</td>
<td>High catalyst replacement</td>
<td>Catalyst deactivation</td>
</tr>
<tr>
<td>Metals Na/Ca/As</td>
<td>Alkaline metals, special guard bed / catalysts for removal</td>
<td>Corrosion / catalyst deactivation</td>
</tr>
<tr>
<td>Asphaltenes</td>
<td>Potential for fouling, may cause frequent maintenance shutdown</td>
<td>Fouling</td>
</tr>
<tr>
<td>Naphthenic acids</td>
<td>High levels will cause corrosion</td>
<td>Corrosion / fouling</td>
</tr>
<tr>
<td>Chlorides</td>
<td>Typically associated with alkaline metal</td>
<td>Corrosion</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Too high to pump; requires diluents</td>
<td>High transportation / pumping cost</td>
</tr>
</tbody>
</table>
Technology Options for Heavy & Bituminous Crude Processing

• Blending with light crude oil
  - Light crude required for blending is in short supply
  - Limited application in processing large volumes of heavy oil
  - Cannot be applied to bituminous crudes without prior upgrading

• Upgrading for integrating as refinery feed
  - Upgraders remove contaminants, produce high-value, light sweet synthetic crude oil (SCO)
  - Upgrader can be On-site or Off-site based on location relative to production facility
  - Synergy of upgrader with upstream production facility or downstream refining facility is specific to each case

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Processing Steps for Upgrading Heavy Oil / Bitumens

1. Mining or In-Situ
2. Extra-Heavy Oil / Bitumen
3. Blend Assay
4. Diluent Recycle
5. Upgrader
6. On-site or Off-site
7. Light sweet SCO
8. Blending
9. Heavy crude oil

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Primary Upgrading Process Selection

**Delayed Coking**

- Offers low liquid product yield due to 25~35% coke make & ~10% gas make.
- Products have high aromatic content, not suitable for FCC feedstock.
- Not favorable from environmental considerations.
- Coke disposal by gasification.

**SDA & Hydroconversion**

- Super critical solvent extraction gets high DAO yield (70~80%).
- DAO is of high quality achieved by selectively removing solid asphaltenes.
- Without SDA, hydroconversion may suffer from shorter cycle length caused by catalyst fouling.
- Pitch disposal by gasification.

Delayed coking is not an ideal option for upgrading heavy / bituminous feedstocks though it requires lower capital investment.

SDA combined with Hydroconversion can produce higher liquid volume of better quality Syncrude but the capital cost is higher.

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Onsite Upgrading with SDA & Hydroconversion

- Heavy Feed Central Processing Facility
- Diluent Recovery
- Vacuum Distillation
- Solvent Deasphalting
- Asphalt Gasification
- Air Separation
- Syngas Treating & Conditioning
- Sulfur Recovery
- Hydroconversion
- Distillates
- DAO
- VTR
- Sulfur Recovery
- Light sweet SCO
- LPG
- Fuel Gas
- Sour gas
- Hydrogen
- Sour Gas
- Syngas
- Oxygen
- Steam for SAGD
- Syngas for SAGD Fuel
- Air Separation
- Hvy Oil from Well
- Diluent Recycle
- Syngas for SAGD Fuel
Offsite Upgrading with SDA & Hydroconversion

- Diluent Recovery
- Vacuum Distillation
- Distillates
- DAO
- VTR
- Solvent Deasphalting
- Asphalt
- Syngas
- Oxygen
- Air Separation
- asphalt Gasification
- Syngas Treating & Conditioning
- Gas Turbine
- Steam
- Power

- Light sweet SCO
- LPG
- Fuel Gas
- Sulphur
- Sour Gas
- Hydrogen
- Sour gas
- Hydroconversion
- Sulfur Recovery
- Diluted Hvy Oil

- Diluent Recycle
The estimated development cost of a grassroots project in Alberta sands with production capacity of 100,000 bpsd of bitumen & Syncrude oil quality of 36\(^0\) API is:
- 21 $/bbl over a 20 year project life

Based on existing operating cost of Orinoco belt, the unit development cost for Syncrude oil quality of 32\(^0\) API is:
- 10 $/bbl over a 20 year project life

- Canadian Syncrude is a traded commodity.
- Syn crude is priced about 2~3$/bbl lower than low sulphur benchmark crudes.
## Product Result of Hydroconversion Processing of Heavy Oil

<table>
<thead>
<tr>
<th>Property</th>
<th>Bitumen Feed</th>
<th>Syncrude Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>API gravity</td>
<td>17.5</td>
<td>35.0</td>
</tr>
<tr>
<td>Sp. Gravity</td>
<td>0.9497</td>
<td>0.8498</td>
</tr>
<tr>
<td>S, wt%</td>
<td>1.22</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>N, wt%</td>
<td>0.3</td>
<td>0.13</td>
</tr>
<tr>
<td>Metals, wppm</td>
<td>77</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>CCR, wt%</td>
<td>7.4</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>535+ °C, wt%</td>
<td>41.7</td>
<td>5.0</td>
</tr>
</tbody>
</table>

### Typical Syn Crude Product Yields

<table>
<thead>
<tr>
<th></th>
<th>Naphtha</th>
<th>Kero</th>
<th>Diesel</th>
<th>VGO</th>
<th>VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield, wt%</td>
<td>20.2</td>
<td>30.9</td>
<td>16.5</td>
<td>27.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>
### Syn Crude Processing – Impact on Refinery Operation

<table>
<thead>
<tr>
<th>Syncrude Type</th>
<th>Processing Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet hydrotreated syncrude</td>
<td>• Higher percentage of VGO in syncrude require more secondary processing capacity  &lt;br&gt;• FCC conversion &amp; gasoline yields are expected to be lower  &lt;br&gt;• ‘Difficult to remove’ sulphur &amp; nitrogen species makes ULSD production difficult.  &lt;br&gt;• Kero smoke point not met due to high aromatics.  &lt;br&gt;• Production of LOBS by conventional route not possible due to aromatic nature of synthetic VGO  &lt;br&gt;• Syncrudes do not have resid, hence no increase in resid conversion capacity / under utilised resid processing units.</td>
</tr>
<tr>
<td>Sour syncrude</td>
<td>• All the Benefits &amp; limitations of sweet hydrotreated syncrude apply in this case.  &lt;br&gt;• Severe hydrotreating required to make FCC feed of required quality or to produce ULSD  &lt;br&gt;• Additional sulphur plant capacity required  &lt;br&gt;• Metallurgy upgrades may be required to handle these crudes</td>
</tr>
</tbody>
</table>
Potential Gasification Feeds & Products

- Natural Gas
- Refinery Gas
- Vacuum Residue
- Pitch
- Coal
- Pet Coke
- Bio Mass

Gasification Plant

- Combined Cycle
  - CO₂, N₂, S
  - Steam
  - Electric Power
    - H₂
    - CO
    - Fertiliser
    - Chemicals
    - Methanol
    - Acetic Acid
    - Naphtha
    - Jet
    - Diesel
    - Wax

- Chemicals Production

- Fischer Tropsch Reaction

Slag for Construction Material & Metal Recovery

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Conclusions

• Conventional crude oils are fast depleting, have limited residual life.

• Proven reserves of unconventional oil are going to replace conventional oils to maintain the energy demand of the world.

• Commercial exploitation of Unconventional oils is expected to help in stabilising crude oil prices besides providing diversity to the crude supply sources.

• Upgradation of existing refineries is necessary to handle the feedstocks of the future.
Thank you

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