Coking: Most Widely Used Resid Conversion Worldwide

- Low Pressure Thermal Conversion Process
  - Produce Lighter Liquids for Hydroprocessing to Diesel and Mogas Products
  - Hydrogen Deficient Bottoms Rejected as Fuel Coke with Low Hydrogen Content

Vacuum Resid:
- + 20-40 wt % of Crude
- + H/C: 1.4 – 1.5
Asphaltenes:
- + 10-25 wt% of VR
- + H/C: 1.1 – 1.2

Feed → Products
- 850 - 950 °F
- ~ 15 – 80 psi

Gas: ~ 10 wt %
Liquids: ~ 55 wt%  
  H/C: ~ 1.8 - 2.2
Coke: ~ 35 wt %  
  H/C: ~0.5

- Hydrogen Addition to Asphaltene Rings in Bottoms Inefficient and Costly
  - Typical 4 - 5 Ring PNA Requires 5 - 10 moles H₂ to Saturate / Open / Upgrade
  - Liquids Require Additional Hydroprocessing

- Economics a Strong Function of Site Specific Factors
  - Natural Gas Cost & Hydrogen Availability
  - Price & Market for High Sulfur Coke or Bottoms

FLEXICOKING™ Technology: Integrated Coking and Steam / Air Gasification

- Continuous Fluidized Bed Process
- Capable of Processing Very Heavy Feeds
- Pneumatic Coke Transfer and Closed Storage
- Liquid Product Yields Similar to Delayed Coking
- Coke Gasified to Clean CO/H₂ Fuel Gas

Coking Without the Coke!
FLEXICOKING
The Flexible Resid Upgrading Technology

- Process Description
- Environmental Advantages
- Flexigas For Fuel/Power
- Commercial Applications
FLEXICOKING Process: Integrated Air + Steam Gasifier

Feed (Hot From VDU) → Scrub. → Reactor → Heater → Gasifier → Flexigas

- Feed Rings & Nozzles
- + Heat Exch.
- + Particulate scrub.
- + Recycle cut point
- + Gas to Light Ends
- + Liquids to Fractionator
- Clean Flexigas after Fines & H₂S Removal

- Cold Coke
- Hot Coke
- Air from Blower
- Steam
- Purge coke with Ni & V to silo

ExxonMobil
Extensive Commercial Experience with Heavy Feeds

- High ConCarbon Vacuum Resids*
- Ebullated Bed Hydroconversion Bottoms**
- Solvent Deasphalter Pitch**
- Heavy Venezuelan Crudes**
- Oil Sands Bitumen*

* Fluid Coking
** FLEXICOKING
FLEXICOKING Process: Reactor Product Yields

- Similar to Other Coking Processes – Thermal Conversion
- Feed and Recycle Cut Point Differences can Complicate Comparisons

2000 ktons/yr

Feed Properties

<table>
<thead>
<tr>
<th>Feed</th>
<th>VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal cut point, °C</td>
<td>540</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feed Properties</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Gravity, kg/m³</td>
<td>999</td>
<td></td>
</tr>
<tr>
<td>Sulfur, wt%</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Conradson Carbon, wt%</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Nickel, wppm</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Vanadium, wppm</td>
<td>209</td>
<td></td>
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</table>

Gas & Liquids

<table>
<thead>
<tr>
<th></th>
<th>Wt% FF</th>
<th>LV% FF</th>
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<tbody>
<tr>
<td>C2 – Fuel Gas</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>C3 / C4 LPG</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Total C4-</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>C5 - 221 °C</td>
<td>18.8</td>
<td>25.0</td>
</tr>
<tr>
<td>221-343 °C</td>
<td>14.0</td>
<td>15.6</td>
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<tr>
<td>343-524 °C</td>
<td>32.1</td>
<td>32.3</td>
</tr>
<tr>
<td>Total C5+</td>
<td>64.9</td>
<td>72.9</td>
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</tbody>
</table>

Coke, Wt%

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Product Coke</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Gasified Coke</td>
<td>22.1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23.2</td>
<td></td>
</tr>
</tbody>
</table>
FLEXICOKING Process Produces Clean CO/ H₂ Fuel Gas

- **FEED:** 238 mtons/hr (36 kb/D)
- **GAS:** 27 mtons/hr
- **LIQUIDS:** 155 mtons/hr
- **2000 ktons/yr**

**Flexigas Clean Fuel Gas**

<table>
<thead>
<tr>
<th>Composition</th>
<th>mol%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO/H₂</td>
<td>35.5</td>
</tr>
<tr>
<td>N₂</td>
<td>53.9</td>
</tr>
<tr>
<td>Other</td>
<td>10.6</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
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</table>

**Rates**

<table>
<thead>
<tr>
<th></th>
<th>Metric</th>
<th>English</th>
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</thead>
<tbody>
<tr>
<td>Coke Gasified, mtons / hr</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Flexigas, mtons / hr</td>
<td>330</td>
<td></td>
</tr>
<tr>
<td>Heating Value, kj / Nm³ (BTU / SCF)</td>
<td>4,510</td>
<td>115</td>
</tr>
<tr>
<td>Heat Rate, MW (th) (MBTU / hr)</td>
<td>368</td>
<td>1258</td>
</tr>
</tbody>
</table>

**Flexigas Users:**
- Pipestill Furnaces
- Hydrogen Plant Furnaces
- Reformer Furnaces
- Steam Super heaters
- Waste Heat Boilers
- Power Plant Boilers
- Third Party Consumers

**Gasified Coke:** 53. mtons/hr

**NET COKE:** 3. mtons/hr
High Natural Gas Prices Favor FLEXICOKING Technology

- Delayed Coking Can Be Attractive at Low Natural Gas Prices
  - Fuel Coke Prices and Markets
  - Coke Transportation Logistics
- FLEXICOKING Technology Very Attractive When Natural Gas is Expensive or Unavailable

Net Uplift, $/bbl of Bitumen

1X = $6.50/MMBtu

*Under Permission from SFA Pacific, Inc. SFA Phase 8 Study, October 2009
Evolving Slurry Hydro-conversion Can Be Attractive At Low but Not at High Gas Prices

- High Crude Prices Favor Maximizing Product Liquids
- Low Gas Price Helps Offset Very High Hydrogen Consumption and Cost
- Additional Hydroprocessing Needed to Make Clean Products

Canadian Athabasca Bitumen Upgrading

Net Uplift, $/bbl of Bitumen

1X = $6.50/MMBtu

FLEXICOKING Technology More Attractive at Higher Gas Prices!

*Under Permission from SFA Pacific, Inc. SFA Phase 8 Study, October 2009
Environmental Advantages

- Coke Production, Storage and Transport
- Plot Space Requirements
- Particulate and Hydrocarbon Emissions
- $\text{SO}_x$ and $\text{NO}_x$ and Other Emissions
## Major Differences in Coke Production, Handling, Storage & Plot Space

<table>
<thead>
<tr>
<th></th>
<th>Delayed Coking Process</th>
<th>FLEXICOKING Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coke Production</strong></td>
<td>Major Product, ~30 wt% High Sulfur: ~6 wt%</td>
<td>Small Purge: ~2-3 wt%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low Sulfur: ~3 wt%</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>Open Pits / Dewatering Cranes &amp; Conveyors Stored in Piles</td>
<td>Closed System Pneumatic Transfer Stored in Silos*</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>Very large trains or barges Potential issue for Inland or Suburban refineries</td>
<td>Most gasified Purge coke in a few trucks</td>
</tr>
<tr>
<td><strong>Plot Space</strong></td>
<td>Coke pits &amp; piles add to space requirements</td>
<td>Less than delayed coking</td>
</tr>
</tbody>
</table>

*Sized for coke inventory during turnaround*
FLEXICO KING Technology: Emissions Advantages

**Particulates – Low**
- Closed System; Pneumatic Transfer Between Fluid Bed Reactors & Product Silos
- No Dust from Open Coke Piles & Transport
- No Facilities Needed to Manage Dust from Coke Pit / Pad

**Hydrocarbons – Low**
- Continuous Process and No Frequent Opening and Cycling of Equipment
- No Hydrocarbon Emissions from Cycling of Equipment & Venting Coke Drums
- No Facilities Needed to Manage Vapors from Quench Water System and Coke Pit / Pad

**SO\textsubscript{x} – Low**
- Gasification of Sulfur in Coke Produces H\textsubscript{2}S in H\textsubscript{2} / CO Flexigas
- H\textsubscript{2}S Easily Removed with Hindered Amine to < 10 ppm in Flexigas
- Combustion of Flexigas in Furnaces & Boilers Produces Low Levels of SO\textsubscript{x} in Refinery

**NO\textsubscript{x} - Low**
- N\textsubscript{2} Diluent in Flexigas Lowers Adiabatic Flame Temperature During Combustion
- Results in lower NO\textsubscript{x} Production than Natural or Refinery Fuel Gas
Flexigas As Refinery Fuel

- Flexigas Composition / Combustion Characteristics
- Use of Flexigas Fuel in Commercial FLEXICOKING™ Units
- Design Considerations for Using Flexigas Fuel
### Flexigas Compared to Other Gas Fuels

- Natural Gas and Refinery Fuel Gas are Rich in Methane
- Lower Heating Value Stable Burning Fuel Gases are Rich in CO/H₂
  - Hydrogen Increases Flammability, Combustion Rate, and Reduces Air Required
  - Flexigas a Viable and Economic Source of Clean Fuel

<table>
<thead>
<tr>
<th>Heat Content</th>
<th>Low Joule</th>
<th>High Joule</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flexigas</td>
<td>Blast Furnace Gas</td>
</tr>
<tr>
<td>Fuel Gas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp (vol%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1-C4</td>
<td>1.4</td>
<td>0.1</td>
</tr>
<tr>
<td>H₂</td>
<td>17.8</td>
<td>3.2</td>
</tr>
<tr>
<td>CO</td>
<td>17.4</td>
<td>23.3</td>
</tr>
<tr>
<td>CO₂</td>
<td>10.</td>
<td>11.5</td>
</tr>
<tr>
<td>N₂</td>
<td>48.7</td>
<td>53.7</td>
</tr>
<tr>
<td>H₂O</td>
<td>4.7</td>
<td>8.2</td>
</tr>
<tr>
<td>Total Inerts</td>
<td>63.4</td>
<td>73.4</td>
</tr>
<tr>
<td>Heat Value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BTU/SCF</td>
<td>120</td>
<td>85</td>
</tr>
<tr>
<td>Kcal/m³</td>
<td>1067</td>
<td>756</td>
</tr>
</tbody>
</table>
Flexigas Fuel Utilization

• Flexigas Fuel Rich in CO and H₂
  • Heating value reduced by nitrogen diluent... but
  • Burns with constant heating value (unlike refinery fuel gas)

• Flexigas Burns Very Readily in a Wider Range of Services in a Variety of Commercially Available Burners
  • Process heaters (pipestills, naphtha reformers, hydrogen plant furnaces)
  • Utility boilers (steam generation, steam super heaters)
  • Over-the-fence sales to power plants or other nearby consumers

• Flexigas Burner and Fuel Distribution Costs Are Low
  • Burners commercially available at same cost as conventional burners
  • Low pressure pipes / ducts for distribution
Flexigas: Dual Fuel Burner Assembly

- Refinery Fuel Gas Burner
- Flexigas Burner
- Natural Gas Pilot
Low Joule Gas for Electric Power Generation

- Steam Cycle
  - TOA Flexigas
- Combined Cycle
  - Blast Furnace Gas & MHI GT
- Relative CAPEX for Different Options
TOA Refinery in Wholesale Electricity Business in Japan

- Began in 2003 in Cooperation with Electric Power Company
- Includes Both Steam Turbine and Gas Turbine Power Generation
- Flexigas is Fuel for Steam Boiler & Turbine; Steam Also Used by Refinery
- Stable Supply of Electricity and Steam
- Power Demand Outpaces Refinery Flexigas Production

![Diagram of TOA Refinery and Genex Power Generating Plant]

- Vacuum Residue Fraction:
  - Low Calorie Gas (LCG)
  - High Calorie Gas (C1, C2)
  - FCC HCG Gas
  - LPG (C3, C4)
- Refinery furnaces
- Air & Steam
- FLEXICOKING™ Unit (27 kbd)
- Genex (Power-Generating Plant):
  - Steam Boiler
  - Waste Heat Boiler
  - Gas Turbine
  - Total Power:
    - Gas Turbine: ~80 MW
    - Steam Turbine: ~190 MW
    - Total: ~270 MW
Commercial GTCC Power Production Using Low Joule Gas

- 150 MW & 300 MW Gas Turbine Combined Cycle Power Trains
- Use Mitsubishi Heavy Industries (MHI) Low Joule Gas Turbines
- Low Joule Blast Furnace & Coke Oven Gas from Adjacent Steel Mill Provides Fuel

Material reproduced with permission from Mitsubishi Heavy Industries (MHI). All rights reserved
Investment Capital - Relative Total Investment Cost (TIC)

- **Base Process**
  - Delayed Coker: 1.0
  - FLEXICOKING™ (FXK) UNIT: 1.3*
  - FXX+Steam...

- **Electric Power Options**
  - FXX+GTCC: 2.5
  - DC+CFBB: 2.9
  - DC+IGCC: 3.1
  - 4.0

*Includes Gasifier for Only 30% More Capex than Delayed Coker*
FLEXICOKING
The Flexible Resid Upgrading Technology

- Operating FLEXICOKING Units
- New FLEXICOKING Licensees and Reasons Selected
FLEXICOOKING Technology: Commercially Well Proven!

- Successfully Operating for 35+ years; Current Operating Capacity of 219 kb/d
- New Hellenic Unit Started up 2012; Operating at or above Capacity
- Four More Units in Design with an Additional Capacity of 148 kb/d
- Considerable Interest Worldwide

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>LOCATION</th>
<th>FEED kB/D</th>
<th>FEED Mtons/yr</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOA Oil</td>
<td>Japan</td>
<td>27</td>
<td>1.3</td>
<td>+ Operating Above Capacity</td>
</tr>
<tr>
<td>PDVSA</td>
<td>Venezuela</td>
<td>65</td>
<td>3.3</td>
<td>+ Operating</td>
</tr>
<tr>
<td>Shell</td>
<td>California</td>
<td>22</td>
<td>1.1</td>
<td>+ Operating</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Netherlands</td>
<td>42</td>
<td>2.1</td>
<td>+ Operating Above Capacity</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Texas</td>
<td>42</td>
<td>2.1</td>
<td>+ Operating Above Capacity</td>
</tr>
<tr>
<td>Hellenic</td>
<td>Greece</td>
<td>21</td>
<td>1.1</td>
<td>+ S/U 2012; Operating at Capacity</td>
</tr>
<tr>
<td>PetroPeru</td>
<td>Peru</td>
<td>22</td>
<td>1.1</td>
<td>+ Design Complete; in Detailed Engr.</td>
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<tr>
<td>Rosneft</td>
<td>Russia</td>
<td>50</td>
<td>2.5</td>
<td>+ Design Complete; in Detailed Engr.</td>
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<tr>
<td>Gaspromneft</td>
<td>Russia</td>
<td>40</td>
<td>2.0</td>
<td>+ Basic Design Complete</td>
</tr>
<tr>
<td>Zhonghai (Yingkou)</td>
<td>China</td>
<td>36</td>
<td>2.0</td>
<td>+ In Basic Design</td>
</tr>
</tbody>
</table>

367 18.6
## Primary Reasons for Selecting New FLEXICOKING Units

<table>
<thead>
<tr>
<th>Primary Reasons New Customers Selected FLEXICOKING Technology</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No or Limited Natural Gas</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Clean Gas Consumers (Fuel or Power)</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Coke Market &amp; Transport Issues</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td><strong>Commercially Well Proven Process</strong></td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td><strong>Limited Plot Space</strong></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
FLEXICOKING Technology Summary

✓ Well Proven Technology
✓ Coke Upgraded to Clean Flexigas by Gasification
✓ Flexigas is Suitable as Clean Refinery Fuel
✓ Excellent Fit for Locations with High Natural Gas Prices
✓ Successful Start-up of Latest Unit in 3Q2012