BIOGRAPHY

Paul W. Kamienski
ExxonMobil Research and Engineering Company (EMRE)

Dr. Kamienski is a Licensing Director with ExxonMobil Research and Engineering Company (EMRE) and is located in Fairfax, Virginia. He is responsible for all technology licensing activities in Europe. Paul is also responsible for licensing EMRE’s heavy feed conversion technology portfolio, which includes EMRE’s FLEXICOKING™ Technology.

Paul received his B.S. in Chemical Engineering from the University of Massachusetts, and his M.S. and PhD from the University of Minnesota. He has 35 years of experience in the petroleum refining industry with expertise in R&D, technology development and application, strategic planning and technology licensing. Paul has an extensive background in heavy feed conversion having conducted research in and managed R&D&E programs in both hydro-conversion and thermal processing. He has a number of patents and published articles in both technical and management journals.

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Upgrading Oil Sands Bitumen with FLUID COKING and FLEXICOKING™ Technologies

*1Paul W. Kamienski, 2Craig McKnight, 1Glen Phillips, *2Boyd Rumbal
1ExxonMobil Research and Engineering Company (EMRE)
Syncrude Canada, Ltd
*Presenters

Heavy crudes and oil sands bitumen in Alberta, Canada represent a substantial fraction of worldwide crude reserves, and there has been continuing interest in recovery and upgrading of these hydrocarbon resources into pipelineable crudes or synthetic crudes, which can be further processed into finished transportation fuels. EMRE’s FLUID COKING and FLEXICOKING™ technologies are ideally suited for this difficult upgrading requirement.

FLUID COKING employs a fluidized bed reactor that thermally converts the heavy hydrocarbons into light gases, liquids, and coke, concentrating the metals and much of the sulfur in the coke. Combustion of some of this coke provides the process heat, and the remaining coke is either sold as solid fuel or stored at the resource site for later recovery. FLUID COKING has been used commercially for over 50 yrs to convert a wide variety of heavy feeds, and currently there is more than 400 kBD of operating capacity in North America. Three units and about 300 kBD of this capacity are operated by Syncrude Canada Ltd in northern Alberta. Syncrude's experience with FLUID COKING for upgrading oil sands bitumen, including their new large 8-3 unit, will be highlighted and key features of FLUID COKING technology will also be discussed.

FLEXICOKING extends FLUID COKING by integrating fluid bed steam (air gasification) of coke to produce a CO / H2 rich fuel gas that when used helps meet fuel and energy requirements of a bitumen recovery and upgrading complex. Light gas and liquid yields are about the same as the FLUID COKING process. Process heat for the thermal conversion and gasification steps is provided by partial combustion of coke. Most of the remaining coke is gasified, and the resulting gas is desulfurized with FLEXSORB™ technology to produce a large volume of clean, lower joule fuel gas. There are currently five FLEXICOKING units operating around the world and a sixth is currently under construction in Greece. There is increasing interest in the FLEXICOKING technology in many parts of the world. Locations with a large demand for clean fuel or electric power, and where natural gas is high priced or not readily available, are especially interested. FLEXICOKING can be particularly attractive for SAGD applications in Alberta, which require very large quantities of energy for both recovery and upgrading. Operating principles of the FLEXICOKING integrated gasification system will be discussed, and will be compared with more expensive oxygen gasification processes.
FLEXICOKING™
Coking and Integrated Steam / Air Gasification

ExxonMobil Research & Engineering Company
Paul Kamienski

Overview

- Heavy Crudes / Tar Sands Upgrading Technologies
- FLUID COKING Technology
- Syncrude Tar Sands Upgrader and 8-1, 8-2, 8-3 FLUID COKING Units
- FLEXICOKING Produces Clean Fuel Gas Instead of Coke
Global Heavy Crude

Global total 4-7 trillion barrels in place
# Heavy Crude Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Athabasca Bitumen</th>
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<th>Cold Lake Blend</th>
<th>Syncrude Sweet Blend</th>
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<tr>
<td>Nitrogen, ppm</td>
<td>4000</td>
<td>3740</td>
<td>3230</td>
<td>630</td>
<td>800</td>
</tr>
<tr>
<td>CCR, wt%</td>
<td>13.4</td>
<td>12.9</td>
<td>11.0</td>
<td>0.0</td>
<td>1.08</td>
</tr>
<tr>
<td>Vanadium, ppmw</td>
<td>222</td>
<td>182</td>
<td>152</td>
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<td>1.6</td>
</tr>
<tr>
<td>Nickel, ppmw</td>
<td>87</td>
<td>65</td>
<td>57</td>
<td>&lt;0.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Asphaltene, wt%</td>
<td>17.5</td>
<td>16.0</td>
<td>13.4</td>
<td>&lt;0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>TAN</td>
<td>3</td>
<td>1</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt, lb/1000 bbl</td>
<td>40</td>
<td>20</td>
<td>15-20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Gerald W. Bruce -Jacobs Consultancy-
Presented at the 4th Conference on the Upgrading and Refining of Heavy Oil, Bitumen, and Synthetic Crude Oil
Edmonton, Alberta, Canada September 25-27, 2006
Tar Sands Extraction Approaches

**Mining:**

- Canadian Natural Resources mining/upgrading: 135,000 barrels/day
- ConocoPhillips Surmont Insitu Ph 1: 25,000
- Devon Jackfish Insitu Ph 1: 30,000
- Encana Christina Lake Ph 1A-1B: 18,000
- Jacos Pilot insitu: 7,000
- MEG Energy Pilot: 3,000
- Nexen Long Lake Insitu Upgrader Phase 1: 70,000
- Petro Canada MacKay River Insitu: 30,000
- Petrobank Insitu pilot: 2,000
- Shell Muskeg River Mine: 155,000
- Suncor Base Plant mining/insitu/upgrading: 350,000
- Syncrude mining/upgrading: 350,000
- Total: 1,175,000

**SAGD:**

Remaining Established Crude Bitumen Reserves

<table>
<thead>
<tr>
<th></th>
<th>Billion Barrels</th>
<th>Billion m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineable:</td>
<td>31.2</td>
<td>4.96</td>
</tr>
<tr>
<td>In Situ:</td>
<td>141.5</td>
<td>22.49</td>
</tr>
<tr>
<td>Total</td>
<td>172.7</td>
<td>27.45</td>
</tr>
</tbody>
</table>

**Projects – Under Construction**

<table>
<thead>
<tr>
<th>Projects</th>
<th>Status</th>
<th>Est. Start Up Production</th>
<th>Bitumen Capacity Barrels/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Devon Jackfish Insitu Ph. 2</td>
<td>Construction</td>
<td>2011</td>
<td>35,000</td>
</tr>
<tr>
<td>Encana Christina Lk. Insitu Ph. 1C</td>
<td>Construction</td>
<td>2010</td>
<td>40,000</td>
</tr>
<tr>
<td>Imperial Keari Phases 1-3</td>
<td>Construction</td>
<td>2012-2018</td>
<td>300,000</td>
</tr>
<tr>
<td>MEG Energy Christina Lk. Insitu Ph. 2A</td>
<td>Construction</td>
<td>2009</td>
<td>22,000</td>
</tr>
<tr>
<td>Shell Exp 1 (Jackpine Mine Ph. 1A/MFM facilities)</td>
<td>Construction</td>
<td>2010</td>
<td>100,000</td>
</tr>
<tr>
<td>Staloli Hydro Leiser Demo Insitu</td>
<td>Construction</td>
<td>2009</td>
<td>10,000</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>507,000</td>
</tr>
</tbody>
</table>
What Does It Take to Get a Barrel of SCO from Tar Sands?

Mining
4.3 tonne Material

Extraction
2.0 tonne Oil Sand (1.29 barrel bitumen)

OR
~ 10-15 Nm3 Natural Gas

1 barrel SCO (Synthetic Crude Oil)

FLEXI

DLK/FLK

EXxonMobil
Research and Engineering

5th NCUT Upgrading and Refining Conference
Edmonton, Alberta, Canada. September 14-16, 2009
FLUID COKING Technology

- Developed by ExxonMobil Research and Engineering Company (EMRE) as an Extension of FCC Fluid Solids Technology
  - Heavy feed injected into fluidized coke bed with feed rings / nozzles
  - Partial combustion of coke in heater and coke circulation provides heat for reaction
  - Scrubber preheats feed, separates coke fines, and sets recycle cut point
  - Liquid products split in down stream fractionators
  - Coke pneumatically convey and stored in silos for fuel coke market
FLUID/FLEXICOKING vs. Delayed Coking

**FLUID COKING/FLEXICOKING**

- Liquid Product Yields Slightly Higher Than in Delayed Coking
- Continuous Process
  - Staffing requirements low
  - Steady state operations
  - Avoids process & equipment thermal cycles
- Handles Virtually Any Pumpable Hydrocarbon Feed
- Coke Has Multiple Roles
  - Heat transfer medium
  - Low value coke supplies process heat
  - Low value coke produces low cost gas for refinery fuel (FLEXICOKING)

**DELAYED COKING (DLK)**

- Liquid Product Quality Higher Than Fluid Bed Coker
- Cyclic Process
  - Staffing requirements high
  - Short drum cycles (12-18 hours)
  - Fractionator performance from “unsteady operations”
  - Drum stressing from temperature cycles
- High CCR Feeds Can Coke Furnace
  - More frequent spalling/decoking
  - Feed “dilution,” derating thru-put
- Coke Is Only a Reaction Product
  - High cost fuel gas supplies process heat
<table>
<thead>
<tr>
<th>FLUID COKING/FLEXICOKING</th>
<th>DELAYED COKING (DLK)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coke Product</strong></td>
<td><strong>Coke Product</strong></td>
</tr>
<tr>
<td>– FLUID COKING produces less than Delayed Coking</td>
<td>– Produces significant amount of coke</td>
</tr>
<tr>
<td>– FLEXICOKING produces only ~1 wt% FF coke at 30% higher capital cost (Estimate: $4800/Bbl Feed/SD)</td>
<td>– Different kinds of coke (shot vs. sponge) depending on properties of feedstock</td>
</tr>
<tr>
<td><strong>Utilities</strong></td>
<td><strong>Utilities</strong></td>
</tr>
<tr>
<td>– Little or no fuel gas use</td>
<td>– Large amount of fuel gas use for furnace</td>
</tr>
<tr>
<td>– High net steam generation</td>
<td>– Almost zero net steam generation</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
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</tr>
<tr>
<td>– FLUID COKING offgas scrubbed to meet sulfur emissions</td>
<td>– Open coke piles becoming problematic</td>
</tr>
<tr>
<td>– FLEXICOKING coke gas desulfurized to make low sulfur fuel for refinery use</td>
<td>– Require low sulfur fuel gas to meet sulfur emission limits</td>
</tr>
</tbody>
</table>
FLUID COKING: A Proven Commercial Technology

• First Commercial Application in Billings, Montana in 1954 Over 50 years Ago
  – Over 350 Cumulative Years of Operating Experience
• Significant Improvements in Capacity, Reliability and Run Length
• Currently 7 Operating Units Process >420 kb/D of Heavy Feeds

<table>
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<tr>
<th>COMPANY</th>
<th>LOCATION</th>
<th>CURRENT FEED RATE, kb/D</th>
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<tbody>
<tr>
<td>ExxonMobil</td>
<td>Montana</td>
<td>10</td>
</tr>
<tr>
<td>Valero</td>
<td>Delaware</td>
<td>52</td>
</tr>
<tr>
<td>Imperial Oil</td>
<td>Canada</td>
<td>21</td>
</tr>
<tr>
<td>Valero</td>
<td>California</td>
<td>28</td>
</tr>
<tr>
<td>Syncrude 8-1</td>
<td>Canada</td>
<td>110</td>
</tr>
<tr>
<td>Syncrude 8-2</td>
<td>Canada</td>
<td>110</td>
</tr>
<tr>
<td>Syncrude 8-3</td>
<td>Canada</td>
<td>95</td>
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New Large Syncrude Unit Started Up in 2006
Syncrude Upgrader

• Located in Fort McMurray, Alberta
Syncrude Upgrade

- **Ownership:**
  - Imperial Oil Resources: 25%
  - Conoco-Phillips Oil Sand Partnership II: 9.03%
  - Mocal Energy Limited: 5%
  - Murphy Oil Company Ltd.: 5%
  - Nexen Oil Sands Partnership: 7.23%
  - Petro-Canada Oil and Gas: 12%

- **Size:** Design of 129 million barrels per year
  - Produces High Quality Synthetic Crude (33 API)
  - Transported to market via Pembina Syncrude Pipeline
Syncrude Operating Commercially 31 Years!

1978

Diluted Bitumen -> Atmospheric Bottoms -> FLUID COKERS (2) -> All Distillates -> HYDROTREATERS (4) -> Synthetic Crude Oil

DILUENT RECOVERY (2)

2009

Diluted Bitumen -> DILUENT RECOVERY (3) -> Atmospheric & Vacuum Bottoms -> All Distillates -> HYDROTREATERS (6) -> Synthetic Sweet Premium

DILUENT RECOVERY (3)

FLUID COKERS (3)

VACUUM DISTILLATION (1)

HYDROPROCESSOR (1)
Syncrude Achieve Significant Quality Improvement

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FLEXICOKING:
Coke Gasified in Integrated Steam Air Gasifier

- Produces Clean CO/H₂ Fuel Gas Product Instead of Coke
- FLEXSORB® Hindered Amine Reduces H₂S to Low Level
- Nitrogen Diluent Reduces BTU Content, But
- FLEXIGAS Burned in Refinery or Third Party Furnaces / Boilers

FLEXIGAS Users:
- Pipestill Furnaces
- Hydrogen Plant Furnaces
- Refiner Furnaces
- Steam Superheaters
- Waste Heat Boilers
- Power Plant Boilers
- Third Party Consumers
FLEXICOKING Produces a Significant Quantity of Valuable Clean Fuel Gas

**FLEXIGAS Clean Fuel Gas**

<table>
<thead>
<tr>
<th>Composition, mol%</th>
<th>Metric</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO/H₂</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>N₂</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td></td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Rates</th>
<th>Metric</th>
<th>English</th>
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<tbody>
<tr>
<td>Coke Gassified, mtons / hr</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Flexigas, mtons / hr</td>
<td>351</td>
<td></td>
</tr>
<tr>
<td>Heating Value, kj / kg (BTU / SCF)</td>
<td>4,800</td>
<td>128</td>
</tr>
<tr>
<td>Heat Rate, MW (th) (MBTU / hr)</td>
<td>460</td>
<td>158</td>
</tr>
</tbody>
</table>

**FLEXIGAS Users:**
- Pipestill Furnaces
- Hydrogen Plant Furnaces
- Reformer Furnaces
- Steam Superheaters
- Waste Heat Boilers
- Power Plant Boilers
- Third Party Consumers
FLEXICOKING
Operating Commercially for 30 Years

- TOA Oil - First Commercial Unit S/U in 1976, Expanded in 2002
- Currently 5 Units Operating With a Total Capacity of ~200 kb/D
- New Unit for Hellenic Petroleum in Greece
  - Currently under construction at Elefsina Refinery site

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<td>Shell</td>
<td>California</td>
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</tr>
<tr>
<td>ExxonMobil</td>
<td>Netherlands</td>
<td>42</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>Texas</td>
<td>42</td>
</tr>
<tr>
<td>Hellenic</td>
<td>Greece</td>
<td>21</td>
</tr>
</tbody>
</table>
FLEXICOKING Unit – ExxonMobil Rotterdam

- Started Up in 1986
- Currently 42 kb/D
- Gasifier in Center (green)
- Coke Silos on Left
- Heater and Reactor / Scrubber on Right
Rotterdam Refinery Fuel Gas Grid

Rotterdam Site

Steam Drivers

LJG Grid

Flare

Furnaces

RHJG Grid

Treat Gas Consumers

Power former

WSP

Air Products

Air Liquid

HJNG Grid

LPG Vaporizer

Offgas

EuroGen

Gas Terra

Rotterdam Site

Outside Parties

Driver Switch Program

ERTO

Electric Drivers

Steam Condenser

Treat Gas Consumers

Power Grid

Refinery Power Consumers

Co Generation

Sales Gas Treating

Gas Terra

ExxonMobil

Research and Engineering

5th NCUT Upgrading and Refining Conference
Edmonton, Alberta, Canada. September 14-16, 2009
TOA Oil FLEXICOKING Unit, Japan

FLEXICOKING Unit
Started up in 1976 (21 kb/SD)
Current Capacity: 27 kb/SD
Fluid Solids Vessels:
  • Gasifier on Left,
  • Heater in Center
  • Reactor on Right
Earthquake-Proof Structure

FLEXIGAS Users:
  • Refinery Furnaces 50%
  • Power Plant Boilers 50%
Keihin Refinery Participates in Wholesale Electricity Business

- Operation Began in 2003 in Co-operation with Other Electric Power Company
- LCG is Supplied as Fuel for Steam-Generating Boiler
- Steam is Used for Power Generation and also by Refineries
- Stable Supply of Electricity and Steam
Summary

- Significant Oil Sands Reserves in Western Canada
  - Remote location and requires significant upgrade for downstream processing

- FLUID COKING Commercially Proven Heavy Feed Upgrading Technology
  - Continuous Fluid Bed Process similar to FCC, heat of reaction provided by partial coke and coke circulation
  - Produces similar products to other coking processes

- Syncrude summary points messages
  - Includes three large Fluid Coking units
  - Produces high quality pipelineable synthetic crude
  - Recent start up of new 8-3 unit significantly added to processing capability

- FLEXICOKING Offers Another Option for Oil Sands Upgrading
  - Produces large quantity of clean fuel gas product instead of coke
  - Fuel gas can be used to meet energy requirements of complex
    - Mine or SAGD resources recovery
    - Upgrade furnaces and boilers or power production