Wayne Brown

ETX Systems

Wayne Brown holds Bachelors (1988), Masters (1991), and PhD (1998) degrees in Chemical Engineering, all from McGill University. Wayne worked for Syncrude Canada at both the Mildred Lake operating facility (1991-94) and at the Edmonton Research Center (1998-99). He worked at McGill University as an Assistant Professor from 1999-2004, where he ran a successful research program. Wayne is listed as principal investigator on a number of patents and patent applications in diverse areas including oil sands processing and biomedical engineering. He is registered as a professional engineer in the province of Alberta, and was a founding member of Envision Technologies Corp., the company under which the IYQ Upgrader was developed. He is responsible for the technical work carried out at ETX Systems, where he holds the position of Chief Technology Officer.

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ABSTRACT

I³Q Upgrading at a 1 bbl/d Scale

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CTO, ETX Systems

All thermal upgrading processes are subjected to the same fundamental chemistry and physics. A serious challenge inhibiting technology development in heavy oil has been how to quantify these underlying processes for such an ill-defined system as oil. Fortunately, research breakthroughs over the past 20 years have provided technology developers with a workable framework through which to understand the intricate relationship between the many chemical and physical processes that drive the end result during the upgrading of heavy oil stocks. In general, it has been established that product yields and qualities are affected by the balance between mass transfer and reaction kinetics. This model is a breakthrough, in that it provides a focus for the development of new upgrading technology.

With these underlying fundamentals, ETX Systems has developed a new upgrading technology, I³Q Upgrading. To displace existing upgrading methods, new technologies must exceed benchmarks with respect to liquid yields, product qualities, and economics. While many concepts have achieved two of these three hurdles, I³Q Upgrading achieves all three: Liquid yields are increased by 6%, while an equivalent increase in hydrogen retention is realized. These benefits are achieved with 30-40% less capital investment, compared to delayed coking. The attributes of the technology result in a decrease in the environmental footprint associated with heavy oil development.

As part of its development plan, ETX Systems has built and operated a pilot plant at a 1 bbl/d scale, based on the I³Q Upgrading concept. Designing a fluidized bed process, complete with circulation of hot solids, is a challenging undertaking, as industry participants will attest. Commissioned in the fall of 2007, the bulk of 2008 was spent resolving numerous challenging technical issues, most of which were related to scale. Having met these challenges, the unit has since achieved the original set of technical objectives of the project, namely providing field support for the original yield and quality claims assigned to the I³Q Upgrading technology. The results, which have been formally vetted by independent third parties have exceeded original expectations. Motivated by these results ETX Systems is continuing along its development path, having embarked on a project aimed at proving commercial operability at a scale of 2,000 bbl/d.

The talk will focus on the challenges faced during the piloting exercise, and the results derived from it. The data clearly demonstrate the advantage of lowering operating temperatures with respect to both yield and quality. Some time will be devoted to introduction of the I³Q Upgrading technology, and the anticipated plans for its development.
The Challenge

- How to meet future energy demands in the face of:
  - Diminishing conventional oil resources
  - Escalating capital costs
  - Unstable oil prices
  - Environmental uncertainties
  - Political uncertainties
  - Challenging capital markets
Role of Technology

- Use technology to:
  - Improve economics
    - Reduce capital
    - Better use of resource
  - Improve environmental footprint
    - Facilitate integration with environmental technologies
    - Better use of resource
The Growing Emphasis on Primary Upgrading

- Primary upgrading converts pitch into distillable liquids
- Primary upgrading benchmark is a century old
- Significant performance gap relative to “ideal coking”

From I.A. Wiehe, “Process Chemistry of Petroleum Macromolecules”
Comparing Primary Upgrading Technology is Simple…

- The technology metrics are:
  - Liquid yield
  - Liquid quality
  - Capacity / Capital

- The winner achieves benefits in some categories, but compromises in none
…but Finding the Winning Concept is Difficult

- Current picture of upgrading science

  - How to meet opposing constraints in liquid and vapour phases with a single technology?
IYQ Upgrading Leverages Current Understanding

- Thin films limit liquid severity

- Decoupling of vapour and liquid phase residence times allow constraints of vapour phase to be met without compromising capacity

- Reactor characteristics enable reduction in operating temperature which benefits both yield and quality
Temperature Dictates Fate of Hydrogen

- Final distribution of hydrogen among coking products is significantly affected by reaction temperature
- Positively affects qualities

<table>
<thead>
<tr>
<th>Reaction Temperature</th>
<th>Liquid Products</th>
<th>Gas</th>
<th>Coke</th>
</tr>
</thead>
<tbody>
<tr>
<td>450°C</td>
<td>83%</td>
<td>8%</td>
<td>9%</td>
</tr>
<tr>
<td>470°C</td>
<td>82%</td>
<td>9%</td>
<td>9%</td>
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<tr>
<td>500°C</td>
<td>79%</td>
<td>13%</td>
<td>8%</td>
</tr>
<tr>
<td>530°C</td>
<td>74%</td>
<td>18%</td>
<td>8%</td>
</tr>
</tbody>
</table>
Demonstration of IYQ Upgrading at 1 bbl/d

- Objective was to provide additional support for yield and quality claims
- Full coke circulation
Assessing Yield Benefit

- For a given technology, coke production has been shown to be relatively insensitive to temperature.

- Therefore, to assess relative impact of temperature, focus on split between gas and liquid production.
Assessing Yield Benefit (cont’d)

- For once through yields, performance measured based on product produced per quantity of feed consumed
Gas Yields Show Benefits

- Sulfur release indicates excellent data consistency

![Graph showing correlation between bed temperature and yield](image-url)
Coke and Gasoil Yields Consistent with Expectations

- Coke yields relatively insensitive to temperature
- Bulk of yield benefit lies in gasoil
Assessing Quality Benefit

- Primary factor driving quality is hydrogen content
- Hydrogen content of gas is much higher than liquids
- Olefinic character of gas related to severity of treatment
Quality metrics support IYQ Upgrading Claims

- Indications that overcracking dramatically reduced

![Graph showing the relationship between bed temperature and ratio with H2S, ratio with H/C, and H/C (mol/mol). The graph depicts a rise in ratio with H/C and H/C (mol/mol) as the temperature increases.]
Hydrogen Losses to Gas Phase Reduced

- Conservative?
Assessing Performance

- Must consider unreacted pitch
Results Support Claims on Once Through Basis

- More liquids produced per amount of pitch reacted
- Liquids are of higher quality
Recycle to Extinction

- Model in good agreement with experimental data

<table>
<thead>
<tr>
<th>Product</th>
<th>Yield (Mass %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model</td>
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<tr>
<td>Product Liquids</td>
<td>76.1</td>
</tr>
<tr>
<td>Pitch</td>
<td>14.2</td>
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<tr>
<td>Coke</td>
<td>6.5</td>
</tr>
<tr>
<td>Gas</td>
<td>3.0</td>
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<tr>
<td>H2S</td>
<td>1.2</td>
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</table>
Advantage Leveraged Upon Recycle

- Link between once through and recycle to extinction well established

<table>
<thead>
<tr>
<th>Product</th>
<th>Mass Yields (%)</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>I(^{\text{Y}})Q Upgrading</td>
<td>Fluid Coking</td>
<td>I(^{\text{Y}})Q Advantage</td>
</tr>
<tr>
<td>Liquids</td>
<td>66.4</td>
<td>60.8</td>
<td>+5.6</td>
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<tr>
<td>HGO</td>
<td>41.6</td>
<td>36.5</td>
<td>+5.1</td>
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<tr>
<td>LGO</td>
<td>13.2</td>
<td>11.6</td>
<td>+1.6</td>
</tr>
<tr>
<td>Naphtha</td>
<td>11.6</td>
<td>12.7</td>
<td>-1.1</td>
</tr>
<tr>
<td>Coke</td>
<td>25.7</td>
<td>28.3</td>
<td>-2.6</td>
</tr>
<tr>
<td>Gas</td>
<td>7.9</td>
<td>10.9</td>
<td>-3.0</td>
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<table>
<thead>
<tr>
<th>Product</th>
<th>Volume Yields (%)</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Liquids</td>
<td>76.7</td>
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<tr>
<td>HGO</td>
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<tr>
<td>LGO</td>
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<td>13.5</td>
</tr>
<tr>
<td>Naphtha</td>
<td>16.1</td>
<td>17.6</td>
</tr>
</tbody>
</table>
Commercial Implementation

- Recent commercial projects advertise yields of 80% (vol/vol) from implementation of delayed coking (whole bitumen basis)

- Through lower operating temperatures \( \text{I}^\text{YQ} \) Upgrading achieves liquid yields of 90% with:
  - Increased hydrogen retention
  - Lower capital investment

- \( \text{I}^\text{YQ} \) performance adds $8 of value per barrel processed
Upgrading without Compromise

- Current results support that IYQ Upgrading can deliver:
  - Improved liquid yields with;
  - Improved product qualities

- Previous studies show a reduction in capital cost of ~30% relative to competing alternatives (Jacobs Consultancy)

- Therefore, IYQ Upgrading can deliver on all three metrics
Beyond the 1 bbl/d Pilot

- ETX Systems has followed a rigorous development path
- Gating process requires third party evaluation at each stage
- Key activity remaining is to prove operability
Proving Operability

- Project involves testing implementation with 2,000 bbl/d reactor feed
- Land purchased in Belle Plaine, SK to support this undertaking
Questions?

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