GTL Technology Advancements
World Petroleum Conference – ORYX GTL site visit

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Sven Godorr, Executive Manager Research and Technology

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1. GTL Process and Technology Partners

2. Reforming and Air Separation

3. Fischer-Tropsch Catalyst and Reactor

4. Environmental and Product
The Sasol Slurry Phase Distillate (SPD™) Process

Technology Partners for ORYX GTL
The Sasol Slurry Phase Distillate (SPD™) Process
Gas to Liquids (GTL)

Sasol has more than 55 years experience in development of Fischer-Tropsch catalysts, reactors and processes producing fuels, chemicals and power.

The GTL process is an integrated mass and energy balance the comprises all of the unit operations found in Chemical Engineering Science.

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Reforming and Air Separation
Heat Exchange Reforming Development

• Methane Reforming is a key processing step for GTL - converts natural gas / methane into syngas feeding Sasol’s Slurry Phase Reactor for the synthesis process.

• Sasol and partners have a leading position with advanced heat exchange reforming technology - Sasol operates a commercial unit in Secunda.

• Sasol is studying the application and accelerated commercialisation of exchange reforming for new GTL ventures to significantly improve the GTL value proposition.
Reforming and Air Separation
Heat Exchange Reforming Impact

• Improved efficiency
  - Overall carbon efficiency: up to 10%
  - CO₂ footprint intensity: up to 30%

• Lower Total Cost of Ownership (TCO)
  - For same oxygen requirement - GTL production capacity: up to 25%
  - Taking advantage of technology benefits and associated economies of scale - capital cost of syngas production
Reforming and Air Separation
GTL Synthesis gas generation - Current reference

S-Removal
Pre-reforming
Fired Heater
Autothermal Reformer
Steam Production

Steam Export

Natural Gas
Oxygen
Boiler Feed Water

⇒ ORYX GTL a commercial reference for low steam to carbon ratio operation using Haldor-Topsøe ATR technology

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Reforming and Air Separation
Haldor Topsøe Exchange Reforming (HTER)

- Increase in synthesis gas capacity from the same O₂ capacity
- Increase in plant-wide carbon efficiency

<table>
<thead>
<tr>
<th>Base Case</th>
<th>HTER-s</th>
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<tbody>
<tr>
<td>Plant-wide GTL carbon efficiency (%)</td>
<td>73-74</td>
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Much of the predicted efficiency benefit that HTER-s can bring could be realised, even with technology risk mitigation measures included.

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<tr>
<th></th>
<th>Base case</th>
<th>HTER-s risk mitigated</th>
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<tbody>
<tr>
<td>Plant-wide GTL carbon efficiency (%)</td>
<td>~73</td>
<td>&gt;78</td>
</tr>
<tr>
<td>Plant-wide GTL thermal efficiency (%)</td>
<td>~57</td>
<td>~61</td>
</tr>
<tr>
<td>Ton CO₂/bbl product</td>
<td>0.13</td>
<td>0.10</td>
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ITM Oxygen opens up further opportunities to improve thermal efficiency.
1. GTL Process and Technology Partners

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• Continued investment in R&D and leading edge innovation remains key

• Sasol has three R&D centers located in South Africa, the Netherlands and Scotland

• R&D facilities employ over 600 people with more than 120 of PhD graduates

• In both the High Temperature and Low Temperature hydrocarbon synthesis environments, Sasol has developed new generations of reactor technology

• Budget (FY2011/12): ~ US$ 140 million
FT Catalyst Developments
Integrated Research Approach

Molecular modeling

Literature/Academia

Develop and test hypothesis

Real catalyst samples

Advanced characterization

Model systems

Synchrotron, Trieste

18 papers in 1990-2000, 20 papers in 2010!
Primary deactivation mechanisms for GTL Co catalyst

- Sintering
  - Co crystallites combine into “islands” reducing active area
- Carbon deposition
  - Carbon covers active Co crystallites reducing active area

Transmission Electron Microscopy Images

Fresh catalyst

Operating catalyst

Scanning Tunnelling Microscopy Images of polymeric carbon (graphene)
Based on a fundamental understanding a 3 step oxidative regeneration process was developed on laboratory scale.

Successful regeneration process has been designed and scaled up to demonstration scale.

Regeneration increases the catalyst useful life, decreasing it effective cost and is a valuable tool for catalyst management.
Better cobalt distribution allows improved catalyst activity and stability

Improvements in alumina support
- Enhances catalyst mechanical and synthesis stability
- Allows more severe hydrodynamic conditions

Next generation catalyst will lower GTL operating cost by
- Improving catalyst productivity
- Allowing higher reactor intensities
FT Reactor Developments
Approach to Reactor Engineering

Integrated design tools
- Computational Fluid Dynamics
- Finite Element Analysis
- Discrete Element Modelling
- Design data from semi-commercial demonstration unit
- Hydrodynamic data from Cold Models

Analysis of commercial data
- 400 bbl/day FT Design Reactor
- 2 500 bbl/day Sasol Wax
- 16 000 bbl/day ORYX GTL
FT Reactor Developments
Reactor Intensification

- Develop an intensified slurry phase reactor to increase production capacity without increasing shell size
- Reactor development combined with further catalyst development

Enhanced performance through increased volumetric conversion efficiency

* Feasibility study

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FT Reactor Developments
Reactor intensification demonstration data
FT Reactor Developments

Intensified reactor engineering

- Concept demonstrated on a semi-commercial scale
- Conceptual study completed
- Full 3D model developed
  - Checked manufacturability
  - Clashes
- Generic mechanical checks done
- Process checks completed
- Reactor now ready to be offered commercially
- Reactor Capital saving of approximately 25% per bbl
FT Catalyst and Reactor Developments
Catalyst losses: Catalyst and Process improvements
1. GTL Process and Technology Partners

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Currently installed at ORYX GTL (2006)

Not a ZLED design

Robust

Large amount of biosludge produced

Large footprint
Current GTL effluent treatment technology offering

High quality produced water enables ZLED design

5-10% less biosludge produced

30-40% footprint reduction

20-30% cost reduction
Environmental Tomorrow – Anaerobic membrane bioreactor (AnMBR) process

- Future GTL effluent treatment technology
- Feed directly from FT
- Further footprint reduction
- 20-30% further cost reduction
- Large energy reduction in removing primary column
- Organics in feed converted to biogas and re-used
Environmental
GTL Fuels significantly improve local air quality

Emissions performance of GTL diesel

- Substantial benefits even against Euro V type fuels
- Benefits also realised in blends

Ref: STFR

“Greenhouse Gas Emission Evaluation of the GTL Pathway”
American Chemical Society Journal Environmental Science & Technology

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Increase diesel yields
- Alternative Product Work-up technology suppliers
- Improved hydroprocessing catalysts/technology
- Oligomerisation/Alkylation technologies

Jet Fuel / Kerosene
- Technology available

Wax Extraction / Chemicals / Base Oils – Value Adds
- Suite of technologies available – require appropriate business opportunity
Sasol is well positioned, with our partners in

- Technology Development
- Optimized Operating Facilities
- Business Development

to secure sustained increased in the value of commercializing GTL