Small Scale GTL - Upstream Sector Leads the Way

Energy Frontiers International
Gas to Market & Energy Conversion Forum
Pittsburgh, 21-23 October 2014

Iain Baxter – Chief Operating Officer
"Upstream Sector Leads the Way"

Why?

(and it's not shale gas!)
Associated gas

- Available at negative, zero or marginal cost
- Available at commercially viable flow rates and durations
- High quality feedstock, often NGL rich, often low contaminants
- Reliable, commercial syngas production available (unlike WTE or BTL)
- Commercial, political and environmental “win-win” for ALL parties
- +20% IRR achievable – wins competition for capital
Flared & reinjected associated gas

800 oilfields with problematic associated gas @ <500MCM/annum

Reserves of 73 bn barrels of oil

Analysis carried out by Wood Mackenzie and Fugro Robertson
Conventional GTL vs CompactGTL

Conventional GTL (e.g. Sasol / Shell):
- Shell Pearl Project: 140,000 bpd
- Capex: >$20bn
- Construction: 7 years
- One reactor:
  - ≈ 20,000 bpd capacity
- 30,000 – 140,000 bpd diesel + speciality synthetic products

CompactGTL Kazakhstan:
- Capex: $300m
- Construction: 2 years
- CompactGTL FT reactors (Containerised modules):
  - ≈ 200 bpd capacity
- 1,000 – 15,000 bpd syncrude or diesel
Pilot plant & training centre
Wilton, UK, commissioned 2008

- Operator training centre
- Full GTL process from gas to syncrude
- Continuous improvement
World class supply chain

- Kawasaki
- Johnson Matthey
- Sumitomo Corporation
- SPP
- Bayer
- Fluor

- Reactor modularisation
- Catalyst suppliers
- Engineering & project management partner
- FPSO Project delivery & expertise
- Consultants
CompactGTL - complete turn-key capability

Planning & FEED
- Economic Appraisal
- Design Concept Selection
- FEED
- Local Permitting
- EPC Contractor Qualification
- Supported by Fluor

Execution
- EPC Contractor Tendering
- High Local Content
- Detailed Engineering
- Procurement
- Construction
- Commissioning
- Fluor Supervisory Support

Operations & Maintenance
- CGTL Turnkey Plant Operations
- Or: Operator Training – UK & Local
- CGTL Reactor Maintenance - Local Facilities
- Local Employment & Investment
A working GTL solution is not just an “FT Island”

Operational impacts must be fully understood for whole plant:

- FT tail gas recycle
- Multiple system interactions
- Utility variability & failure
- Feed gas variability

10,000 bpd Plant
7th March 2014 : MOC between Kazakhstan Oil Ministry & CompactGTL
CompactGTL plant design for Kazakhstan project

Fully integrated plant – remote flare gas

Turnkey project by CompactGTL

Engineering support partner – Fluor

Operational by the end of 2017
Technology
... a bit of car fun

- High performance
- Short intervals between services
- High opex
- Low flexibility
- Highly skilled operation

- Reliable performance
- Long intervals between services
- Low opex
- High flexibility
- General skilled operation
Small scale reactor technology – multiple trade-offs

- Capital Cost
- Performance
- Conversion
- Heat transfer
- Catalyst inventory

- Operating Cost
- Operability/Maintainability
- Product slate
- Reactor Manufacturability
- Robustness / Longevity
Reactor & catalyst configurations
... a long educational journey

- Cross Flow vs Co-Linear
- Channel geometry: “Pigeon hole” vs “letter box”
- “Core in shell” vs simple core
- Maximising FT catalyst inventory
- Single vs staged FT reactors
## Cross flow vs Co-Linear

<table>
<thead>
<tr>
<th>Cross flow</th>
<th>Co-Linear flow</th>
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<tbody>
<tr>
<td>★★★ Header placement / fabrication simplicity</td>
<td>★★★★</td>
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<tr>
<td>★★★★ Core volume utilisation</td>
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<tr>
<td>★★★★ Channel accessibility for catalysts</td>
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<tr>
<td>★ Thermal stress (= core design life for SMR)</td>
<td>★★★★</td>
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<td>★ Temperature uniformity / Process stability</td>
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<td>★★★ Weight</td>
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Channel geometry

Overall channel size is also a critical factor:
Smaller channels = high heat transfer but prone to fouling & higher weight / cost
Larger channels = lower heat transfer but more maintainable & lower weight / cost

<table>
<thead>
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<th>“Pigeon hole”</th>
<th>“Letter box”</th>
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<tr>
<td>🌟🌟🌟🌟 Structural metal inventory</td>
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<tr>
<td>🌟🌟🌟 Number of layers / separator plates</td>
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<tr>
<td>🌟🌟🌟 Common heat exchanger manufacturing</td>
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<tr>
<td>🌟🌟 Overall heat transfer</td>
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<td>🌟🌟 Catalyst temperature uniformity (within each channel)</td>
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“Core in shell” vs simple core

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CompactGTL proprietary mini-channel FT reactor construction

- ASME VIII compliant
- Simple core construction, brazed stainless
- Co-linear flow, high temperature uniformity
- Single phase coolant, minimal fouling
- Ease of catalyst loading / unloading
Maximising FT catalyst inventory

The factors below are not equally weighted, adding to the challenge of developing an optimal commercial solution

<table>
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<th>Structured catalyst inserts</th>
<th>Particles</th>
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<td>◆◆◆◆</td>
<td>Pressure drop</td>
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<td>◆◆◆◆</td>
<td>Fouling management</td>
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<td>◆◆◆</td>
<td>Bulk catalyst loading &amp; removal</td>
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<td>◆</td>
<td>Catalyst inventory per channel</td>
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Single vs staged FT reactors

**Single Stage Fixed**
Conventional & Modular

- Short catalyst life, frequent regeneration
- Low availability, high opex
- Unsuitable for remote site deployment
- Duty + standby reactors just adds cost

**Slurry Bubble Column**

**Two Stage Fixed**

- Catalyst continuously “replaced”
- High availability
- Large, tall reactors
- Unsuitable for remote site deployment

- 3-5 year catalyst life, no regeneration
- High availability, low opex
- Modular reactors
- Perfect for remote site deployment
CompactGTL proprietary 2-stage FT process

- Increased catalyst life
- Increased plant availability
- Suitable for remote locations
- Low OPEX

FT reactor Stage 1
- Syngas feed
- $\text{H}_2\text{O}$ removal
- Syncrude

FT reactor Stage 2
- $\text{H}_2\text{O}$ partial pressure is reduced in each stage, improving catalyst life
- Syncrude
- Tail gas

$\text{H}_2\text{O}$ partial pressure is reduced in each stage, improving catalyst life.
FT Catalyst replacement without plant shutdown

- CompactGTL reactor modules exchanged in pairs for spares
- Plant continues to operate
- No catalyst handling and safety issues on the operational site
- Refurbishment factory can be local to the plant
- = High availability = low opex

12m FT Reactor Modules
• US$ 40 million reactor factory completion by Sumitomo

• MOC with Kazakh government

• US$ 300 million plant announced in Kazakhstan

• US$ 50 million new investment in company

**Wall Street Journal - 30 July 2014**

“In the oil industry, small is rarely beautiful”