Small to Medium Scale GTL with Microchannel Process Technology

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TOYO’s technology line-up for gas utilization

Natural Gas

100MMscfd

All TOYO’s proprietary technology except Ammonia

Microchannel syngas generation, now under development for GTL, enables methanol/DME plant on the ship.

Shift Conversion CO₂ Removal NH₃ Synthesis

0.9 million ton/y NH₃

Mid-scale LNG (partnership with CHART) & F-LNG (partnership with MODEC)

10,000 bpd GTL

10,000 bpd GTL

GTL

FT Synthesis

Methanol Synthesis

Methanol Dehydration

1 million ton/y MeOH

0.7 million ton/y DME

DME

NH₃

Urea Synthesis

0.9 million ton/y NH₃

1.6 million ton/y Urea

Urea

Natural Gas Liquefaction

0.8 million ton/y LNG

LNG

FT Synthesis

Methanol Synthesis

Methanol Dehydration

GTL

MeOH

DME

NH₃

Urea

LNG

Mid-scale LNG (partnership with CHART) & F-LNG (partnership with MODEC)
Why GTL?

- Large spread between crude vs. gas price

- Converting crude 1 bbl at 5.8 million btu,
  - Crude price $90/bbl corresponds to $16/million btu
  - Current US gas price (Henry-Hub) is $3-4/million btu

- Crude oil have a premium value ($13+/million btu) over the gas, mainly due to oil is liquid

- It is forecasted the price spread will continue in the future

- Converting cheap natural gas or associated gas to synthetic crude will create added values

- Penalization to associated gas flaring will drive GTL further
Target gas reserves of *Micro-GTL*

Large-Scale LNG or GTL such as projects in Qatar

*Micro-GTL* is focusing on the small to medium scale gas fields.

800+ fields: 0.5 – 2 TCF (13 – 54 bcm)

1 tcf ≡ LNG 15 million ton (1,000,000 ton/Y x 15 years) or GTL 15,000 bpd for 20 years
Three(3) companies alliance of Micro-GTL

TOYO ENGINEERING

• Founded in 1961
• Based in Chiba, Japan; over 10,000 employees
• Provider of R&D, design, engineering, equipment procurement, construction, test operations, and technical guidance
• Plant design experience spans over 50 years and more than 1,500 projects

MODEC

• Founded in 1968
• Turnkey supplier of FPSOs vessels, Tension Leg Platforms and semi-submersibles
• Owns and operates number of FPSOs worldwide
• Recognized by the Offshore Technology Conference for innovative technology for its MOSES Self Stable Integrated Platform (SSIP) TLP.

VELOCYS

• Battelle spin-off company in 2001
• Oxford Catalyst Group
• Commercializing Microchannel Process Technology
• 70 U.S. Patents
• 60 employees
For on-shore application where compactness is less prioritized, Micro-FTR can be integrated with various conventional syngas generation processes.
Close integration of exothermic reaction and endothermic reaction in micro channel accelerates the process by 10 to 1,000 times by reducing heat and mass transfer distance and resistance between process fluids and channel walls.

System volume can be reduced by 10 times compared with conventional hardware.
Fischer-Tropsch Synthesis

- Fischer Tropsch Synthesis (FT Synthesis) originates from Franz Fischer (1877-1947) and Hans Tropsch (1889-1935) who successfully developed liquid fuel synthesis from syngas at the Kaiser Wilhelm Institute for Coal Research in 1920s.

- FT chemistry can be viewed as a polymerization reaction expressed by the following chemical reaction formula:
  \[(2n + 1) \text{H}_2 + n \text{CO} \rightarrow \text{C}_n\text{H}_{2n+2} + n \text{H}_2\text{O}\]

- Applying polymerization kinetics, a simple one-parameter equation can describe the entire product distribution, referred to as the Anderson-Shultz-Flory (A-S-F) distribution:
  \[W_n = (1-\alpha)^2 \cdot n \cdot \alpha^{n-1}\]
  where:
  - \(n\) = Carbon number
  - \(W_n\) = Weight fraction of product with carbon number \(n\)
  - \(\alpha\) = Chain growth probability

- The higher the value of \(\alpha\) the longer the average chain length.
Typical FT product distribution

FT Product Blend: Carbon Number Distribution by simulated GC  \( \alpha = 0.91 \)
# Typical properties of FT product (synthetic crude oil)

<table>
<thead>
<tr>
<th>Property</th>
<th>FT Synthetic Crude</th>
<th>Arabian Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>46.5</td>
<td>32.3</td>
</tr>
<tr>
<td>Sulfur</td>
<td>&lt;&lt; 1 ppm</td>
<td>1.9%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>&lt; 10 ppm</td>
<td>1,100 ppm</td>
</tr>
<tr>
<td>Pour Point</td>
<td>+60 deg.C</td>
<td>-18 deg.C</td>
</tr>
<tr>
<td>Diesel Fraction</td>
<td>50%</td>
<td>46%</td>
</tr>
<tr>
<td>Heavier Fraction</td>
<td>40%</td>
<td>42%</td>
</tr>
</tbody>
</table>
Advantages of microchannel reactor

- Significant reduction of reactor volume and catalyst volume
- Shorter residence time minimizes possibility of coking.
- Uniform temperature profile in reactor and reaction controlled at more desirable condition
- Smaller foot print of plant
- Reactor built-in module enables easier transportation and shorter construction period.
Commercial SMR and FTR bundled into pressure containment shell (PCS)

- Multi-reactor blocks together with manifolds are put in a pressure containment shell (PCS).
- In addition to heat preservation and safety reservation, PCS plays the role of steam drum for FTR.
- Size of the basic reactor block will be maintained and the reactor blocks with PCS will be numbered up in accordance with the plant capacity.
Micro-GTL off-shore application study
(1,000 bpd GTL)
1,000 bpd *Micro-GTL* on 100,000 bpd FPSO
- 10 mmscfd associated gas = 1,000 bpd FT products

1,000 bpd *Micro-GTL* unit
approx. 20% of total deck space
**Micro-GTL on-shore application**

- Compactness is less prioritized compared to off-shore application.

- Combination of other kinds of syngas generation processes and **Micro-FTR** will also be a viable option.

- The syngas generation processes can be **box-type conventional SMR, Autothermal Reformer (ATR)**, or **Partial Oxidation (POx)** including coal gasification, biomass gasification and waste gasification.
Typical process performance of *Micro-GTL*

<table>
<thead>
<tr>
<th>Description</th>
<th>Typical Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthetic Crude Yield</td>
<td>100 BPD/MMSCFD</td>
</tr>
<tr>
<td>Carbon Efficiency</td>
<td>65 to 75%</td>
</tr>
</tbody>
</table>

Notes:
- The above figures are typical figures for process ISBL and subject to change depending on feedstock and site conditions.
- Product upgrading and utility facilities are excluded.
**Micro-GTL expecting future**

- **Offshore GTL-FPSO**
  - Capacity 5,000 ~ 15,000 bpd
  - Add fluidity by mild hydrocracking

- **Associated gas treatment for FPSO**
  - Capacity 1,000 ~ 2,000 bpd
  - Syncrude is blended into crude oil

- **Onshore GTL**
  - Capacity 100 ~ 15,000 bpd
  - Stranded gas utilization
  - Biomass to liquids (BTL)
  - Final products like diesel by hydrocracking
**Micro-GTL** module fabricated in Thailand
Demonstration status and the next

- **Micro-GTL demonstration unit** was installed in Brazil and it is now under final stage for commercialization.

- Fully integrated GTL process with Micro-SMR and FTR is being demonstrated, producing **synthetic crude oil product**. Overall process performance and mechanical integrity are being proven.

- Efforts are being made for establishing mass-production system of Micro-SMR & FTR, and catalyst supply chain.
FT oil product from demonstration unit
**Summary**

- **Associated petroleum gas** is becoming a burden of oil producers due to recent stricter movements in environmental policies such as suppression, inhibition or penalization to flaring. In case of off-shore oil production, the burden will get more serious due to limited space and availability of re-injection wells.

- **Micro-GTL** technology achieves process intensification and significant improvements in volumetric efficiency. *The concept has been successfully demonstrated in Brazil* and the technological development is under final stage.

- **Micro-GTL** is applicable for **both of onshore and offshore** and provides suitable economical and ecological solution for **associated petroleum gas treatment** and **small to medium size gas reserve utilization**.
Thank you for your attention

A part of this R & D for off-shore GTL application is being implemented in collaboration with ClassNK (NIPPON KAIJI KYOKAI) under the scheme of “the collaborative investigation by the industry requests”. TOYO and MODEC would like to extend special thanks to ClassNK.