OTM Solid State Combined Reformer Progress Update

GSTC 2017
Colorado Springs
Praxair’s OTM Combined Reformer

Why:
The most efficient process to produce syngas for chemicals

What:
Oxygen-based syngas supply system without the oxygen plant

SMR inputs → ATR outputs

How:
Solid-state air separation combined with reforming in a robust ceramic membrane within a modular, scalable package
Step Change Syngas Technology

Multi-process combined reforming

Solid state combined reforming with OTM

Combined reforming in a single integrated efficient package
Modular Syngas Technology

Combined reforming in a single integrated efficient package
Furnace Design and Scale-Up

Panel

Pack

Train

Simplified modular scale-up

1000BBL/d

50BBL/d

5BBL/d

Modularly Constructed System

Multi Module “Train”
Robust System Operation

- Site NG → Syngas
- 50,000 scfd Syngas
- +150 on/off syngas cycles
- Multiple deep thermal cycles

No ceramics failures through 44 week torture test
OTM Pilot System

New reactor and infrastructure for commercial scale panel operation
OTM Field Demonstration

- USGC 2019 Startup
- Up to 8MMscfd syngas feed to MeOH plant

Evaluating OTM field demonstration project
OTM Platform

- **Syngas platform**
  - Can be optimized for MeOH, H₂, GTL, CO
  - High NG conversion efficiency

- **Modular syngas offering for CO, Chemicals, GTL**
  - “Oxygen free” alternative to POx, ATR and Combined Reforming
  - Opportunity to pursue small CO where O2 is not available and ASU is difficult to justify
  - 10% – 15% more efficient than SMR for MeOH and GTL
  - Advantages validated by third parties (technology licensors)

Paradigm shift for methanol and GTL economics
Typical Process Flowsheet- NG to syngas
OTM Platform: Large Methanol

- Joint evaluations with major licensor and producer
- Greenfield methanol plants: 1000 – 3000 metric tons/day

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<th>SMR + ATR + ASU (CR)</th>
<th>SMR</th>
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<tr>
<td>CO₂ emissions</td>
<td>Base</td>
<td>+16%</td>
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<tr>
<td>NG Consumption</td>
<td>Base</td>
<td>+13%</td>
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<tr>
<td>Operating cost</td>
<td>Base</td>
<td>+7%</td>
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<tr>
<td>Capital investment</td>
<td>Base</td>
<td>-9%</td>
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<td>15 yr IRR, %</td>
<td>14.1%</td>
<td>14.9%</td>
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<tr>
<td>Net income*, $MM/yr</td>
<td>82</td>
<td>84</td>
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<th>OTM CR</th>
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<tr>
<td>-29% (142,000 t/yr)</td>
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<td>-4% ($5 MM/yr)</td>
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<tr>
<td>-18% ($175 MM)</td>
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<tr>
<td>18.4%</td>
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<td>113</td>
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*3000 mT/d; MeOH @ $350/mT
Technology Readiness

- Achieved commercial ceramic performance targets
  - Extraordinary progress on flux, strength, creep life, degradation
  - Robust glass-ceramic seals

- Proved unique combined reforming process
  - Demonstrated at single and multi-panel levels
  - Robust to system-start up, shut-down, trips, and transients

- On-Track with Supply Chain and Cost Reduction
  - Tube manufacturing capacity increased to 8 MM scfd syngas/yr
  - Qualifying external parties for high volume substrate manufacturing
  - Shops qualified to manufacture panel array modules
  - Delivering on key capital cost reduction targets

Ready for industrial scale demonstration
Questions?

A Global Leader

Thank you!