Autothermal Reforming for efficient and versatile syngas production

Esben Sorensen, Haldor Topsoe Inc.
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Haldor Topsoe Company

- Established in 1940 by Dr. Haldor Topsoe. Private 100% family owned company
- Global market leader in heterogeneous catalysis with a 75 year long track record
- ~2,500 employees in 11 countries across five continents.
- HQ in Lyngby, Denmark, HT Inc. located in Houston ~ 250 employees
- Revenue about $1 billion.

Services:
- Catalysts
- Technology/licensing
- Engineering
- Hardware
- Operation assistance

• Products for the Petrochemical, Refinery and Sustainables business segments
• Founded on the belief that applied fundamental research is key to build and retain a leading position in catalysis
• Up to 10% of revenue spent on R&D

~90% catalyst re-sale in USA
Autothermal reforming in historical perspective

- **1st generation 1958 →**
  - Ammonia,
  - Methanol
  - $\text{H}_2 + \text{CO}$

- **2nd generation 1990 →**
  - Pilot scale development
  - Industrial demonstration

- **SynCOR\textsuperscript{TM} low S/C ATR technology 2002 →**
  - $\text{H}_2 + \text{CO}$,
  - GTL, Methanol, ‘TIGAS\textsuperscript{TM}, Ammonia
  - Small, medium and large industrial scale
Topsoe ATR/oxygen fired reformer: SynCOR™
Safe and innovative reforming

• Safe operation
  • More than 15 years at low S/C ratio
  • Close to 80 years accumulated experience

• Innovative solutions improve reliability
  • Burner technology
  • Refractory linings
  • Catalyst bed solution
    • Target tiles
    • Tailor designed catalyst layers
    • Catalyst bed support
Oxygen-fired reformers
CTS™ burner and combustion chamber

• **CTS™ burner**
  - Intense mixing in turbulent diffusion flame
  - Combustion of hydrocarbons with pure oxygen at fuel-rich conditions
  - Centered flame at high flame core temperatures

• **Combustion chamber**
  - Endothermic reactions in post-flame zone
  - Flow circulation cools refractory
SynCOR GTL™
Syngas production for GTL

- Oxygen
- CO₂-rich recycle steam
- Hydrogen
- Natural gas
- Superheated steam
- Fuel
- Recycle gas compressor
- Fired heater
- Sulphur absorber
- Prereformer
- Superheated steam
- Waste heat boiler/steam drum
- SynCOR™ (ATR)
- Final cooling & separation
- Process condensate
- HP steam
- BFW

- Syngas
Industrial References for SynCOR™ Technology

• Air Products, Rozenburg, Holland
  • In operation since 1988, revamp 2011
  • Production of CO and hydrogen

• Air Liquide, Rozenburg, Holland
  • In operation since 2002
  • Production of CO and oxogas

• Sasol, Sasolburg, South Africa
  • In operations since 2004
  • Production of syngas for GTL and other applications

• Oryx GTL, Qatar
  • In operation since 2006
  • Production of syngas for GTL

• Escravos GTL, Nigeria
  • In operation since 2014
  • Production of syngas for GTL
Topsoe oxygen-fired reformers in syngas units

High reliability

> 99% operation availability for SynCOR™ units
  • Between major turnaround periods
  • Excluding trips caused by events outside the syngas unit

Improvements in plant availability:
  • Longer time between turn-arounds
  • Reduction and management of ruby formation
Novel catalyst bed solution
HTZR™ and RKA-10

• Zirconia-based HTZR™ target tiles
• RKA-10 noble metal-promoted top layer catalyst
• Optimized catalyst loading
• New catalyst support system
• 3-4 years operation between turn-arounds

Effect of RKA-10 on Pressure Drop
SynCOR Methanol™
Methanol Process Optimization by Autothermal Reforming

Reforming accounts for about 40% of plant CAPEX
- ATR enables minimization of S/C-ratio
  - Compact design
  - Favorable CO/CO₂ and low methane slip

High quality syngas gives
- Compact methanol synthesis
- Low compression costs
- Low catalyst costs

Key specifications for syngas:
- \( \frac{(H_2-CO_2)}{(CO+CO_2)} \) ratio close to 2
- High CO/CO₂ ratio
- Low CH₄ content
## Methanol Production SMR vs. SynCOR™

<table>
<thead>
<tr>
<th>SynCOR Methanol™</th>
<th>SMR based MeOH plant</th>
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</thead>
<tbody>
<tr>
<td>10 year old technology</td>
<td>40 year old technology</td>
</tr>
<tr>
<td>Small process flows (S/C=0.6)</td>
<td>Large process flows (S/C=3)</td>
</tr>
<tr>
<td>High syngas reactivity</td>
<td>Low syngas reactivity</td>
</tr>
<tr>
<td>No heat transfer surface operating above 1200°F</td>
<td>Exotic materials for high temperature heat transfer</td>
</tr>
<tr>
<td>Excellent economy of scale</td>
<td>“Linear” economy of scale</td>
</tr>
<tr>
<td>H₂ recovery unit required</td>
<td>Excess H₂ production</td>
</tr>
<tr>
<td>State-of-the-Art NG consumption</td>
<td>10 % penalty on NG consumption</td>
</tr>
</tbody>
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![Diagram showing cost vs. capacity comparison between Tubular reformer and Oxygen plant.](image)

- **Tubular reformer**
- **Oxygen plant**

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**Table Notes:**
- **SMR:** Steam Methane Reforming
- **SynCOR:** Synthesis Gas Cracking and Reforming

**Diagram Notes:**
- The diagram illustrates the cost and capacity comparison between Tubular reformer and Oxygen plant technologies for methanol production.
SynCOR Methanol™
Methanol Production by ATR
Advantage of Oxygen supply opportunities
SynCOR Methanol™

<table>
<thead>
<tr>
<th>5,000 MTPD MeOH plant</th>
<th>Cost USD MM Oxygen import</th>
<th>Cost USD MM Incl. ASU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol Plant (incl. owners cost)</td>
<td>416</td>
<td>536</td>
</tr>
<tr>
<td>OSBL costs (75% of ISBL cost)</td>
<td>254</td>
<td>327</td>
</tr>
<tr>
<td>Total project cost incl. financial exp.</td>
<td>837</td>
<td>1,079</td>
</tr>
<tr>
<td>Annual CAPEX</td>
<td>70</td>
<td>91</td>
</tr>
<tr>
<td>(70/30 Debt/Equity – 8% interest, 15 yr loan)</td>
<td></td>
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</tr>
<tr>
<td>Annual OPEX</td>
<td>280</td>
<td>265</td>
</tr>
<tr>
<td>(3.5 $/MMBTU, 50 $/MT oxygen)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return on investment – 1st year</td>
<td>56%</td>
<td>42%</td>
</tr>
<tr>
<td>(280 $/ton MeOH)</td>
<td></td>
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</tbody>
</table>

Details can be obtained by mailing to els@topsoe.com
SynCOR Ammonia™
Ammonia production by ATR

Ammonia production at S/C ratio of 0.6
- SK-501 Flex™
3% lower specific net energy consumption
Up to 50% savings in make-up water
Lower emissions
Conclusion
Rethinking technology and business opportunities

Topsoe’s SynCOR™
• Enables large capacities in single trains
• Provides attractive economy of scale
• Operation at low S/C enables
  • Process intensification
  • Opportunities for OPEX and CAPEX reductions
  • Low GHG footprint
  • Generation of high quality syngas

Haldor Topsoe
• Continuously improves technology portfolio
• Is a cradle-to-grave partner for petrochemical plant operators

“Most of the world’s GTL capacity uses Topsoe’s ATR technology, and the industry is looking to Topsoe for future advances that will keep us competitive”

Mohamed Farhan Al-Enazi,
Quality Manager, ORYX GTL, Qatar
Thank you for your attention

Business:
We go the extra mile to create lasting value for our customers.

Science:
Our passion for science and innovation strengthens our business.

People:
Topsoe is a great place to work and to have worked.

Society:
We create sustainable solutions that make a difference to the world of today – and tomorrow.