Topsoes Ammonia cracking technology – Delivering green Hydrogen

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Fully dynamic green ammonia plant initiated and in operation Q2 2023
24MTPD green ammonia directly coupled to wind and solar power

12 MW
Wind turbines
6 x 2 MW Vestas V90

50 MW
PV power
91 hectare with bi-facial tracker PV panels

10 MW
Power-to-Ammonia
Worlds first green ammonia plant in dynamic mode

Topsoe
Power-to-Ammonia

- Fully flexible operation 10-100% plant load
- No hydrogen storage
- Store energy as NH₃
- Grid balancing
- Available for AE/PEM/SOEC electrolyzer technology

Wind
Sun
NH₃
Power2X

The Energy Technology Development and Demonstration Programme
Topsoe Ammonia Catalysts
Knowledge platform for cracking catalysts

- Leading ammonia synthesis catalysts supplier
  - Strong knowledge base within field
  - Topsoe key competence

- Catalyst for ammonia cracking in same family
  - Necessary to understand differences
  - We co-develop catalyst and technology

- Topsoe ammonia cracking catalyst
  - A range of commercial available catalysts
  - Fine tuned for Topsoe technologies

Why the optimal ammonia synthesis catalyst is not the optimal ammonia decomposition catalyst

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The Topsøe Ammonia Cracking Catalysts
DNK series

- DNK-2R – Medium Temp
  - Co-Fe based
  - A workhorse in existing plants
  - High durability

- DNK-5R – Medium Temp
  - Fe based
  - Proven performance at lower NH$_3$ conc.

- DNK-10 Low Temp
  - Ru based
  - Very high activity catalyst

- DNK-X High temp
  - Ni based catalyst

How do we choose the right catalyst?
Combining catalyst and process technology understanding enable a very strong overall solution

Strong Topsøe experience – need to fit process development
Topsoe ammonia cracking technology
Building upon a strong technology core

- Topsoe Ammonia Crackers in operation for + 30 years
- Existing design for 100-2400 MTPD ammonia feed
- New and optimized design

Scope of supply:
- License
- Basic Engineering Design Package
- Proprietary Hardware
- Catalysts
- Training & Technical Services
Catalytic decomposition of ammonia
Endothermic – need energy to run

Partial oxidation (auto-thermal) – energy
Provided by oxidizing part of the hydrogen.

Electrically heated cracking (eCracker)

Fired ammonia cracker – energy provided by
fired heating (like trad. SMR)
How it works
Topsoe high efficiency ammonia cracker ensures near to full conversion of the ammonia feed to high purity hydrogen.
The Topsøe Ammonia Cracking Technology
Optimise for local optimum

- Large scale plants
  - 5-500 MTPD $H_2$
  - Highly energy efficient process
  - ~97% $NH_3$ to $H_2$
  - Process optimisation built on top of current references
  - May be tailored to the individual demands

- Example: (30 MTPD $H_2$):
  - Energy input - Natural gas: 740 Nm$^3$/t$_{H_2}$
  - Operation pressure 30-50 barg
  - Carbon footprint 15 $H_2$/CO$_2$
  - PSAs for $H_2$ separation – 99.9% purity
  - <1 ppm $NH_3$ in $H_2$
  - Ideal for FCEV - hydrogen fuel
The Topsøe Solutions

- Strong experience from existing plants
  - Both on catalyst and technology
  - Knowledge on all the small details
  - Our expertise area is design of large scale plants
    - >5 MTPD Hydrogen

- We combine knowledge from catalyst and process
  - We can optimise for local infrastructure
  - Adjust for local legislation
  - Available energy source dictates ideal process solution

- SOFC may be a future alternative
  - Generate $H_2 +$ Power
  - Flexible operation

<table>
<thead>
<tr>
<th>Energy is key</th>
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<tbody>
<tr>
<td>Heat source</td>
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<tr>
<td>Natural gas</td>
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<tr>
<td>NH$_3$ (H$_2$)</td>
</tr>
<tr>
<td>Electricity</td>
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<tr>
<td>HP Steam</td>
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Ammonia cracking potential

- Ammonia cracking still market in early phase
  - Where will the market be strongest?

- Hydrogen for transport
  - FCEVs

- Power generation
  - Eg. in combination with gas turbines etc

- Greener refineries

- Replacement of fossil heat sources
  - Steel industry etc.

- Hydrogen as pilot fuel for engines
  - Ships/power etc
Ammonia Cracking

Summary

- Ammonia is an excellent energy vector: fuel and energy storage
- Ammonia cracking – many potential opportunities
- Topsoe have long experience in ammonia cracking
- High TRL level on catalyst + technology
- We can tailor the process to each individual market
Thank you!

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