Lurgi’s Methanation Technology for Production of SNG from Coal

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Gasification Technologies Conference 2008
October 5 -8, 2008
Overview

- Lurgi – Member of the Air Liquide Group
- Market Evaluation
- Chemistry of Methane Production
- Process Concepts
- Factors for Optimum Process Design
- Case study of SNG Production
- Summary
Founded in **1902**, 

Present in **75 countries**, 

**More than 40,000** employees, 

**8 R&D centers**: each year **200 patents** registered, 

**1 million** customers across various industries and healthcare activities 

**€11 800 million** in sales (2007) 

**Lurgi** joined the group in 2007
Solutions provider for gasification: diversity of technologies

FEEDS
- Heavy Residues
- Petcoke
- Coal
- Biomass

SYNGAS GENERATION
- Gasification
- CO shift
- Sulfur Removal (Rectisol Stage 1)

SYNGAS PURIFICATION
- CO2 Removal (Rectisol Stage 2)
- PSA / Membrane
- CO Cold Box
- Sulfur Recovery

MANUFACTURING FROM SYNGAS
- Chemicals Synthesis
- Methanol Synthesis
- Nitrogen wash + Hydrogen
- Methanation
- Turbine
- Fischer Tropsch

PRODUCTS
- CO2
- Hydrogen for Refineries
- Chemicals
- Fertilizers
- Synth. Natural Gas (SNG)
- Power
- Synfuels
- Syngas for DRI
- Sulfur
Optimized solutions provider for the SNG route

FEEDS
- Heavy Residues
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- Coal
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SYNGAS GENERATION
- Gasification

SYNGAS PURIFICATION
- Sulfur Removal (Rectisol Stage 1)
- CO shift
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MANUFACTURING FROM SYNGAS
- Methanation

PRODUCTS
- CO2
- Synth. Natural Gas (SNG)
- Sulfur
- USA is short on natural gas and very long on coal
- Gasification technology can augment North American natural gas supplies and LNG imports
- Adds value to US coal reserves
- Increased energy diversity
- National energy security implications
- Existing Infrastructure of pipelines and combustion turbines
- Method to reduce carbon penalty associated with coal

**Market Evaluation – U.S. Project Drivers**

**Chart:**
- **TCF:**
  - Domestic Production
  - Domestic Consumption
  - The US is growing increasingly short on natural gas supply

Methanation Reactions

\[
\begin{align*}
CO + 3H_2 & \rightleftharpoons CH_4 + H_2O + \Delta H \\
CO_2 + 4H_2 & \rightleftharpoons CH_4 + 2H_2O + \Delta H
\end{align*}
\]

CO Shift Reaction

\[
CO + H_2O \rightleftharpoons CO_2 + H_2 + \Delta H
\]

All reactions appear simultaneously. Methanation reactions are highly exothermic. Lower temperatures are favorable for methane yield.

One-stage synthesis would lead to adiabatic temperature increase \( \Delta T \) of 400°C (720°F) to 600°C (1080°F) depending on initial methane content.

Staged Recycle Process necessary
Block Flow Diagram for Superheating Steam Production

Feed Preheater → Reactor 1 → SS1 → B1 → Reactor 2 → B2 → Reactor 3 → BFW Preheater

SNG Product

Optional Steam Import

Feedstock

SS: Steam Superheater
B: Boiler
BFW: Boiler Feed Water

Process Condensate
Block Flow Diagram for Saturated Steam Production

Feedstock → Feed Preheater → Reactor 1 → B1 → BFW1

Reactor 2 → B2 → BFW2

Reactor 3 → BFW3

SS: Steam Superheater
B: Boiler
BFW: Boiler Feed Water

Typ. no flow
Factors for Optimum Process Design

**Methane Yield vs. Steam Value**

- High process temperatures require advanced compressor design
- High process temperatures require refractory lining, expensive reactor material or special reactor design
- High process temperatures are favorable for maximum energy usage via HP steam and electrical energy production in turbines
- High process temperatures are achieved by higher CO content in the gas to the first Reactor
Pressure

- Higher process pressures favor methane formation, however the influence is not as pronounced as lower process temperatures.

- Lower process pressures can reduce exothermal reaction slightly.

- Lower process pressure are limited by equipment size (transportation limit) or limit the capacity respectively (parallel trains).

**Methane content from gasifier**

- Less methane from gasifier results in higher CO concentration and thus more produced water by the methanation reaction.

- Water concentration has only marginal effect on SNG quality.

- High concentration of methane in feed gas reduces methane of the product gas (applying the same configuration).
Basis for Methanation Case Study

**SNG product specification:**
- Product flow rate = 100 MM SFCD
- HHV > 975 BTU / SCF
- Methane content > 95% (mole)

**Feed gas composition**
- H₂/CO = 3.4 mole/mole
- CO₂ = 1.5 % (mole)
- Inerts = 0.6 % (mole)
- CH₄ depending on gasifier type (0.0%; 7.5%; 16.2%mole)

**Superheated Steam condition**
- 900 °F @ 885 psig
Considered configurations

The following variations have been considered:

Feed gas composition produced in different gasifier types:
1. High Temp Gasifier \((HTG)\)
2. High Temp. Gasifier with Chemical Quench \((HTGwCQ)\)
3. Fixed Bed Dry Bottom Gasifier \((FBDB)\)

Type of steam production:
A. Saturated HP steam only
B. Only HP steam produced in Methanation is superheated
C. HP steam is imported to maximized superheated HP steam production

Comparison of final reactor design
I. Isothermal Reactor
II. Adiabatic shaft Reactor
Utility figures vs. produced saturated steam:
(for feed gas coming from Fixed Bed Dry Bottom Gasifier)

- Saturated steam (Ex boiler): 580 000 lb/h
- HP BFW: 590 000 lb/h
- Power for Compressor: 10 100 000 HP
- Recycle flow rate: 500 MM SCFD
### Amount of steam superheated in Methanation unit:

<table>
<thead>
<tr>
<th></th>
<th>High Temp Gasifier</th>
<th>High Temperature Gasifier with Chemical Quench</th>
<th>Fixed Bed Dry Bottom Gasifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam produced only in Methanation unit</td>
<td>910 000 lb/h</td>
<td>690 000 lb/h</td>
<td>480 000 lb/h</td>
</tr>
<tr>
<td>Additional steam imported and superheated in Methanation unit</td>
<td>1 450 000 lb/h</td>
<td>1 080 000 lb/h</td>
<td>740 000 lb/h</td>
</tr>
</tbody>
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Results of Case Study (cont’d)

General results:

- The methane quality can either be achieved by:
  - 2 Shaft reactors plus 1 Isothermal reactor
  - 4 Shaft reactors
- Up to 100% more HP steam can be superheated compared to HP steam produced inside Methanation unit
- 20% more saturated HP steam compared to superheated HP steam is produced (for FBDB)

In case HP steam is superheated (scenario B. and C.):

- The recycle flow rate increases by 142% (for HTG vs. FBDB)
- The first Methanation Reactor Diameter is 43% bigger (for HTG)
- 60% more steam are produced for HTG vs. FBDB based on CO intake
Summary of Case Study

- SNG quality most sensitive to reactor inlet temperature
- Sufficient heat is available to superheat more HP steam than produced inside Methanation
- The more methane is produced in the gasifier, the less HP steam is produced.
- A final Isothermal reactor reduced the number of reactors
- Increased CAPEX for superheated steam production due to:
  - Refractory requirement in first reactor for superheated steam production
  - Bigger diameter of first reactor
- Soot formation is catalyzed by nickel and soot itself

- Metal dusting tendency (increases by pressure and CO content)

- Higher process temperatures favor deactivation of active nickel sites on catalyst

- Higher CO partial pressures favor formation of nickel carbonyl, i.e. minimum temperature limit is shifted to higher temperatures
Optimal Methanation process concept depends on type of feed gas as well as plant utility integration.

Design of a proper Methanation plant needs a lot of know-how and catalyst experience.

Lurgi has designed and licensed the only industrial scale SNG plant from coal.

The DGC reference is the only commercial CCS application.

SNG from coal is a viable option!
Thank you

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