VESTA SNG Methanation Technology

Solid fuels to SNG applications

Amec Foster Wheeler Italiana (a Wood Company)
Solid Fuel to SNG

The Methanation Reactions are Highly Exothermic

\[ \text{CO} + 3 \text{H}_2 \rightarrow \text{CH}_4 + \text{H}_2\text{O} \quad \Delta H = -205 \text{ kJ/mole} \]

\[ \text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O} \quad \Delta H = -165 \text{ kJ/mole} \]
The recycle of CH4 product to syngas is the standard process to handle the exothermic reactions for competing technologies.

Process characteristics:

① Recycle compressor to handle the exothermic reactions (a lot of product gases go through circulation, as a heat transfer medium)

② Complex adjustment of the feed gas to achieve on-spec SNG
Solid Fuel to SNG - Competing technologies

- Gasification Block
- Adjustment of H2/CO Ratio 3:1
- CO2 Removal H2S Removal
- SNG Process

**Gasification**
- Different Technologies
- Differences in H2/CO
- Differences in CH4

**CO Conversion**
- Sour Gas Shift

**Purification**
- Physical Solvent Complex scheme to separate H2S from CO2

**SNG Process**
- Exothermic Reaction
- Expensive Reactors Material
- High temperature Superheater
- Recycle at high temperature
- Recycle Compressor

© wood. 2018
Solid Fuel to SNG - Competing technologies

Gasification Block
Adjustment of H2/CO Ratio 3:1
CO2 Removal H2S Removal
SNG Process
SNG

SNG Process
Exothermic Reaction
Expensive Reactors
Material
High temperature Superheater
Recycle at high temperature
Recycle Compressor

Criticalalities
H2/CO Ratio
Coke formation
Recycle mandatory
Temperature runaway
Brick lined reactors
Unsafe Operation
Metal dusting risk
Limitation in train size

© wood. 2018
Effect of H2/C ratio in competing technology on SNG product quality
Solid Fuel to SNG – VESTA Technology

► VESTA - Can we do more for you?
  ► Can we avoid high temperatures?
  ► Can we avoid recycle compressors?
  ► Can we avoid brick lined vessels?
  ► Can we avoid high alloyed steel?
VESTA technology review

The VESTA technology is a once-through operation

Process characteristics:
► No recycle compressor
► CO$_2$ and H$_2$O control heat of reaction
► Easy to control
Solid Fuel to SNG – Technologies comparison

Available Technologies

VESTA Technology

© wood. 2018
Solid Fuel to SNG - VESTA technology

**SOLID FUEL**

Gasification Block

H2S Removal

SNG Process / CO2 removal

SNG

---

**Gasification**

- All gasification technologies are compatible with the Novel VESTA Process
- High efficiency / WHB / dry type are more beneficial

**Purification**

- H2S removal
- Carbonyl removal
- Fine Purification
- No H2/CO ratio adjustment

**SNG Process / CO2 removal**

- No limitations of H2/CO ratio
- Neither coke formation nor metal dusting risk
- Low alloyed steel reactors
- Low severity WHB
- No Recycle Compressor
- Final CO2 removal (high quality)
Effect of H2/C ratio in VESTA technology on SNG product quality

The feed composition under different H2/C conditions

Effect of feed gas with different H2/C ratio on crude SNG composition
VESTA technology - catalyst

Catalyst (high temperature methanation)

- Methanation reactors filled with proprietary Clariant catalyst
- High stability, robust under different conditions
- Suitable for the operating range 230-700 °C (higher than conventional methanation catalysts)
- High CO and CO₂ conversion
- No carbon deposition
- Long operational history and industrial references
- Available as pre-reduced catalyst for simple start-up

<table>
<thead>
<tr>
<th>Name</th>
<th>SNG 5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Tablet</td>
</tr>
<tr>
<td>Size (mm)</td>
<td>4.7 x 4.7</td>
</tr>
<tr>
<td>NiO%</td>
<td>53.5~59.5</td>
</tr>
<tr>
<td>Bulk Density (g/ml)</td>
<td>1.15 ± 0.10</td>
</tr>
<tr>
<td>Particle Density g/ml</td>
<td>1.93</td>
</tr>
<tr>
<td>Crush Strength (Newtons)</td>
<td>&gt;75</td>
</tr>
<tr>
<td>BET Surface Area (m²/g)</td>
<td>140</td>
</tr>
<tr>
<td>Pore Volume (ml/g)</td>
<td>0.22</td>
</tr>
<tr>
<td>Operation Temperature, °C</td>
<td>250~550</td>
</tr>
</tbody>
</table>

© wood. 2018
VESTA technology - catalyst

Catalyst (high temperature methanation)

The temperature profile of VESTA methanators, running for 4000 hours
VESTA technology - catalyst

Catalyst (high temperature methanation)

Clariant experience in methanation

1970: Lurgi/Sasol SNG process in South Africa: isothermal + adiabatic,

1977-1990: first commercial COG to SNG plant in JP operated with Clariant catalysts
COG inlet: 25.000 Nm3/h

1980-2000: SNG pilot plant in Louisville/US; Basic Development of SNG 5000 catalyst, 10 Nm3/h

1970:

1977-1990: first commercial COG to SNG plant in JP operated with Clariant catalysts
COG inlet: 25.000 Nm3/h

2000-2010: development of SNG 5000 improved SNG catalyst, R&D center Louisville/US

2013

2014

2015

SNG 5000 at Dakota Gasification; catalyst start-up in 2015; 1.6 bn Nm3/a

CO2 to SNG (Audi): Clariant Catalyst > 2 year on-stream; 1.4 m Nm3/a green CH4

SNG5000 at Wison pilot plant, 100 Nm3/h SNG

© wood. 2018
VESTA technology - lower CAPEX/OPEX

VESTA technology reduces the investment and energy consumption of purification devices

Gas volume changes before and after methanation

Partial pressure change of CO2

<table>
<thead>
<tr>
<th>Tower diameter</th>
<th>Conventional</th>
<th>VESTA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>Wash Column</td>
<td>6.5</td>
<td>4.6/5.2</td>
</tr>
<tr>
<td>CO₂ Production Column</td>
<td>4</td>
<td>4.4</td>
</tr>
<tr>
<td>H₂S Enrichment Column</td>
<td>6.5</td>
<td>5.2</td>
</tr>
<tr>
<td>Hot Regeneration Column</td>
<td>6.6</td>
<td>5</td>
</tr>
<tr>
<td>Tail Gas Wash Column</td>
<td>5.8</td>
<td>5</td>
</tr>
</tbody>
</table>

Comparison of main towers
VESTA technology - steam flexibility

► VESTA provides full flexibility of steam quality
  ▶ Temperature: 450 to 500°C
  ▶ Pressure: For all industrial applications
VESTA technology evaluation

► VESTA is suitable for all types of gasifiers

Fixed Bed  
Dry Feed WHB  
Dry Feed Quench

► The following comparison is based on Dry Feed WHB gasifier
Worth to include all the sections downstream the gasification scrubber up to the CO2 removal.

We can offer an integrated SNG / Acid Gas Removal solution with suitable process guarantees.
VESTA technology evaluation

VESTA has lower CAPEX

<table>
<thead>
<tr>
<th>Equipment cost comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competing Technology</td>
</tr>
<tr>
<td>SAVING ON EQUIPMENT COST</td>
</tr>
</tbody>
</table>

- The comparison accounts for the acid gas removal (H2S and CO2), the CO Shift and Methanation.
- Syngas from Dry feed WHB gasification
VESTA technology evaluation

VESTA has lower Energy Consumption (OPEX)

<table>
<thead>
<tr>
<th>Production / Consumption figure (GB30179-2013)</th>
<th>Competing Technology</th>
<th>VESTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL %</td>
<td>BASE</td>
<td>15 % better</td>
</tr>
</tbody>
</table>

- Comparison according to the Norm GB30179-2013
- Comparison based on integrated SNG Acid Gas Removal scheme
VESTA Pilot Plant

Wood has signed a cooperation agreement with Clariant International AG ("Clariant") and Wison Engineering Ltd ("Wison Engineering") to build a pilot plant to demonstrate the Wood VESTA SNG technology. All the parties have a large experience in the coal industry.

Pilot plant:

- Designed for a production capacity of 100 Nm³/h of SNG and includes all reactors and control system in order to completely demonstrate a real plant in addition to the verification of the chemical reactions
- Erected in Nanjing, China
- Two test campaigns have been carried out in 2014 and 2015/2016 to successfully demonstrate a continuous operation at 100% SNG production meeting the Chinese natural gas grid specification, and to test different operating parameters.
VESTA Pilot Plant

Design drawing and real pilot plant with methanation reactors
Full range of pilot test for VESTA SNG technology

- Effect of low S/G ratio on carbon deposition of catalyst
- Effect of different feed composition on reaction
- Effect of different H₂/C ratio on reaction
- Effect of different S.V. on reaction equilibrium
- To verify the low temperature activity of the catalyst and high temperature stability
- Verify the anti-toxic ability of the catalyst
Examples of VESTA Technology application

• Coal to SNG
• Petcoke to SNG
Coal to SNG – VESTA Technology application

In some areas of the world, natural gas demand cannot be satisfied by import with the consequent requirement to exploit coal reserves to produce fuel by means of SNG.

**TECHNICAL DATA**

Feedstock: Bituminous coal: LHV equal to 25,870 kJ/kg and sulphur content of 1.1% wt (dry, ash free)

Flowrate: 100 t/h

SNG production: 34,800 Nm³/h

Electrical power production: 0 MWe net (*)

(*) Gross electrical power production 53 MWe
Coal to SNG – VESTA Technology application
Petcoke to SNG – VESTA Technology application

Considering a 200,000 BPSD refinery processing an average crude, 100 t/h of petcoke are produced.

TECHNICAL DATA

Feedstock: petcoke from a DCU, LHV equal to 32450 kJ/kg and sulphur content of 6.7% wt (dry, ash free)

Flowrate: 100 t/h (*)

SNG production: 37,800 Nm³/h (362 MWth)

Electrical Power production: 60 MWe net suitable to satisfy refinery needs

(*) Petcoke : 75 t/h to SNG production and 25 t/h to power station.
Petcoke to SNG – VESTA Technology application
Wood performed a study to assess the performance and costs of two Polygeneration plants, based on the coal gasification process and aimed at the production of Substitute Natural Gas (SNG)

- Case #1: Medium-pressure (40 barg) Coal Gasification Process, with dryfeed system and Synthesis Gas Cooler.
- Case #2: High-pressure (85 barg) Gasification Process, quench type and slurry-feed system.

**DESIGN BASIS**
- Plant capacity: 2,000 MWth SNG min
- Electric power produced by means of dedicated steam turbines
- Coal-fired Circulating Fluidized Bed (CFB) boilers to meet the additional steam production of the plant for power generation
- Methanation unit based on the VESTA technology, producing SNG
Polygeneration plant application with VESTA (Case #1)
Polygeneration plant application with VESTA (Case #1)

### Polygeneration Case #1 Performance Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EABC Flowrate (as received)</td>
<td>t/h</td>
<td>130.1</td>
</tr>
<tr>
<td>Indonesian coal Flowrate (as received)</td>
<td>t/h</td>
<td>403.3</td>
</tr>
<tr>
<td>Coal Flowrate (as received)</td>
<td>t/h</td>
<td>533.3</td>
</tr>
<tr>
<td>Coal LHV (as received)</td>
<td>kJ/kg</td>
<td>23,054</td>
</tr>
<tr>
<td>Coal HHV (as received)</td>
<td>kJ/kg</td>
<td>24,369</td>
</tr>
<tr>
<td><strong>THERMAL ENERGY OF FEEDSTOCK(A)</strong></td>
<td>MWth (LHV)</td>
<td>3,415</td>
</tr>
<tr>
<td><strong>THERMAL ENERGY OF FEEDSTOCK(A')</strong></td>
<td>MWth (HHV)</td>
<td>3,610</td>
</tr>
<tr>
<td>Thermal Power of Raw Syngas exit Scrubber (B)</td>
<td>MWth (LHV)</td>
<td>2,816</td>
</tr>
<tr>
<td>Thermal Power of Clean Syngas to CMD (C)</td>
<td>MWth (LHV)</td>
<td>64</td>
</tr>
<tr>
<td>Thermal Power of Clean Syngas to SNG (D)</td>
<td>MWth (LHV)</td>
<td>2742</td>
</tr>
<tr>
<td>Syngas treatment efficiency ((C+D)/B x 100)</td>
<td>% (LHV)</td>
<td>99.6</td>
</tr>
<tr>
<td>Thermal Power of SNG (E)</td>
<td>MWth (LHV)</td>
<td>2035</td>
</tr>
<tr>
<td>SNG efficiency (E/D x 100)</td>
<td>% (LHV)</td>
<td>74.2</td>
</tr>
<tr>
<td>Gasification to SNG efficiency (E/A x 100)</td>
<td>% (LHV)</td>
<td>59.6</td>
</tr>
<tr>
<td>Steam turbine electric power output</td>
<td>MWe</td>
<td>314.7</td>
</tr>
<tr>
<td><strong>GROSS ELECTRIC POWER OUTPUT</strong></td>
<td>MWe</td>
<td>314.7</td>
</tr>
<tr>
<td>Gasification Section units consumption</td>
<td>MWe</td>
<td>52.7</td>
</tr>
<tr>
<td>ASU consumption</td>
<td>MWe</td>
<td>137.4</td>
</tr>
<tr>
<td>Power Island units consumption</td>
<td>MWe</td>
<td>8.6</td>
</tr>
<tr>
<td>CO₂ Compression and Dehydration unit consumption</td>
<td>MWe</td>
<td>81.0</td>
</tr>
<tr>
<td>Methanation unit consumption</td>
<td>MWe</td>
<td>22.6</td>
</tr>
<tr>
<td>Utility Units consumption</td>
<td>MWe</td>
<td>13.5</td>
</tr>
<tr>
<td><strong>TOTAL ELECTRIC POWER CONSUMPTION</strong></td>
<td>MWe</td>
<td>515.9</td>
</tr>
<tr>
<td><strong>NET ELECTRIC POWER IMPORT</strong></td>
<td>MWe</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Polygeneration plant application with VESTA (Case #2)
## Polygeneration Case #2 Performance Summary

<table>
<thead>
<tr>
<th>OVERALL PERFORMANCES</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EABC Flowrate (as received)</td>
<td>t/h</td>
<td>0.0</td>
</tr>
<tr>
<td>Indonesian coal Flowrate (as received)</td>
<td>t/h</td>
<td>643.4</td>
</tr>
<tr>
<td>Coal Flowrate to gasification (as received)</td>
<td>t/h</td>
<td>596.2</td>
</tr>
<tr>
<td>Coal Flowrate to CFB boiler (as received)</td>
<td>t/h</td>
<td>47.2</td>
</tr>
<tr>
<td>Coal LHV (as received)</td>
<td>kJ/kg</td>
<td>22,336</td>
</tr>
<tr>
<td>Coal HHV (as received)</td>
<td>kJ/kg</td>
<td>23,233</td>
</tr>
</tbody>
</table>

| THERMAL ENERGY OF FEEDSTOCK to gasification (A) | MWth (LHV) | 3,699 |
| THERMAL ENERGY OF FEEDSTOCK to gasification (A') | MWth (HHV) | 3,847 |
| Thermal Power of Raw Syngas exit Scrubber (B) | MWth (LHV) | 2,757 |
| Thermal Power of Clean Syngas to CMD (C) | MWth (LHV) | 0 |
| Thermal Power of Clean Syngas to SNG (D) | MWth (LHV) | 2748 |
| Syngas treatment efficiency ((C+D)/B x 100) | % (LHV) | 99.7 |

| Thermal Power of SNG (E) | MWth (LHV) | 2093 |
| SNG efficiency (E/D x 100) | % (LHV) | 76.1 |
| Gasification to SNG efficiency (E/A x 100) | % (LHV) | 56.6 |

| TOTAL THERMAL INPUT (gasification + CFB boiler) (F) | MWth (LHV) | 3919.9 |
| Coal to SNG efficiency (E/F x 100) | % (LHV) | 52.4 |
| Steam turbine electric power output | MWe | 326.1 |
| GROSS ELECTRIC POWER OUTPUT | MWe | 326.1 |

| Gasification Section units consumption | MWe | 49.4 |
| ASU consumption | MWe | 158.1 |
| Power Island units consumption | MWe | 11.1 |
| CO₂ Compression and Dehydration unit consumption | MWe | 76.8 |
| Methanation unit consumption | MWe | 12.9 |
| Utility Units consumption | MWe | 17.8 |
| TOTAL ELECTRIC POWER CONSUMPTION | MWe | 326.0 |

| NET ELECTRIC POWER EXPORT | MWe | 0.1 |
Experience transfer

- Wood has a great deal of experience in hydrogen plants where syngas is produced, shifted and cleaned-up.

- Wood has a great deal of experience in power generation following a gasification unit (designed, engineered, constructed and started-up one of the largest IGCC in the world).

- Wood have a great deal of experience in AGR systems from all available Licensors.

- Wood has the capabilities to engineer complex control systems for the simultaneous operation of multi-unit complexes.

- Wood completed two BDP relevant to methanation and purification, sold the first license, and is ready to globally commercialize the VESTA technology.
Thank you

For VESTA enquiries, please contact SNG@woodplc.com

Questions and Answers?!