Technical Update of the MHI Air Blown and Oxygen Blown Gasifier

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Manager, IGCC & Gasification
Business Portfolio

Contribute to Both the Power Generation and the Chemical Industries through MHI Coal Gasification Technology

• Air-Blown Gasifier with High Temperature GT for IGCC (i.e. for Power) with the Highest Plant Efficiency and Economical Merits

• Update of Australian ZeroGen Project
  • IGCC Combination with Latest J-type GT technology

• Oxygen-Blown Gasifier for Chemical Products (i.e. SNG, CTL, NH3, etc.) with Minimum Utility Consumption Including Auxiliary Power

• Development of Low Rank Coal Utilization

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Outline of MHI Air-Blown IGCC System

- Gasifier / Gas Treatment Island
  - Highly Efficient Gasifier (Air blown)
  - PAHs / Gas Treatment Island
  - Power Block (Equivalent to typical NGCC Plant)
  - Highly Efficient Gas turbine (High Temperature)
  - Heat Recovery Steam Generator

System integration is the “Key.”
Scenario of Clean Coal Technology Innovation

1. Improvement of Thermal Efficiency
   - Ultra High temp. GT (1,700°C)
   - NGCC (Natural Gas)
   - IGCC
   - USC (coal)

2. CO2 Capture and Storage
   - CO2 Generation (Power Station)
     - High Efficiency IGCC Plant
   - CO2 Capture
     - Low Energy CO2 Capture Technology
   - CO2 Transportation (Pipe Line, etc)
     - High Pressure CO2 Compressor for CCS
   - CO2 Storage
     - Ocean & Underground

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ZeroGen in Australia
IGCC + CCS Commercial Project

- ZeroGen Pty Ltd., owned by the Queensland State Government of Australia decided to develop their world-first IGCC+CCS flagship project with MHI.

- CCC (Clean Coal Council), Queensland State Government, provided official approval to start the commercial scale project (530MW) together with MHI, by highly recognizing the successful results of the 250MW Nakoso IGCC demonstration project.
ZeroGen in Australia
IGCC + CCS Commercial Project

Feasibility Study was successfully completed and further optimization study has started.

Principal Specifications

<table>
<thead>
<tr>
<th>Coal</th>
<th>Australian Hard Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>530 MW gross</td>
</tr>
<tr>
<td>Gasifier</td>
<td>Air Blown. Dry Feed</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>M701G2 GT (1 on 1)</td>
</tr>
<tr>
<td>Carbon Capture</td>
<td>65-90%</td>
</tr>
<tr>
<td>CO2 Storage</td>
<td>2-3 Mil.ton/yr</td>
</tr>
</tbody>
</table>

Major Events

- Coal gasification test using MHI’s Pilot Plant was successfully completed. :April 2010
- FS Report was issued and submitted to the Federal Government. :June 2010
- Third Party Review to the Report was finished to highly evaluated results. :July 2010

Key Milestones

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</thead>
<tbody>
<tr>
<td>Award Pre-Study</td>
<td>Award FS</td>
<td>Commencing FEED</td>
<td>Contract EPC</td>
<td>Start Commissioning</td>
<td>COD</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Project Schedule

- Scoping Study
- Pre-Study
- Bridging Activity
- FS
- Feed
- EPC
- Comm.
Sample test of four (4) candidate coals completed
  - Initial analysis for coal properties
  - Suitability to MHI’s air-blown gasifier evaluated

24t/d Pilot Plant Scale Gasification Test using Design coal
  - Stable slag discharge confirmed
  - No significant slag deposits in the gasifier
  - Suitability of MHI’s air-blown gasifier confirmed
Gasification / Coal Testing

• Stable Slag Discharge

• No significant slag deposits in the gasifier

Confirmed that the Design Coal is well suited for MHI’s air-blown gasifier
IGCC Commercial Plant is Ready
- Typical Expected Performance -

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>Bituminous Coal</td>
</tr>
<tr>
<td>Frequency</td>
<td>50Hz, 60Hz</td>
</tr>
<tr>
<td>Output Gross</td>
<td>600MW, 500MW</td>
</tr>
<tr>
<td>Net</td>
<td>540MW, 450MW</td>
</tr>
<tr>
<td>Gasifier Oxidizer</td>
<td>Air</td>
</tr>
<tr>
<td>Coal Feed</td>
<td>Dry</td>
</tr>
<tr>
<td>Acid Gas Clean-up</td>
<td>Wet MDEA w/o CO2 Cap.</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>M701G x1 (1 on 1)</td>
</tr>
<tr>
<td></td>
<td>M501G x1 (1 on 1)</td>
</tr>
<tr>
<td>Gross Efficiency (LHV)</td>
<td>53% w/o CO2 Cap.</td>
</tr>
</tbody>
</table>

Note: Plant efficiency depends on site conditions including coal properties. Emission and acid gas clean-up process depends on regional regulations.

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**Further Improvement of Efficiency**
- **J Class Gas Turbine Market Introduction**

Delivery of Commercial Units to Begin in 2011. (60Hz)
First Commercial operation Unit in 2013 for 2,900MW (M501J×6)
Kansai Electric Power Company.

[T-Point Verification]

- **Strategic Planning**
- **R&D / Design**
- **Design Implementation**
- **Verification Test**

2011

[60Hz] Commercial Plant

- **Strategic Planning**
- **R&D / Design**
- **Design Implementation**
- **Ready for FOB**
- **Commercial Operation**

2009 2011 2013

IGCC Application

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Oxygen-Blown Gasifier Development - Functions Required for the Gasifier -

• Requirements

<table>
<thead>
<tr>
<th>For Power Generation</th>
<th>For Chemical Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Gasifier Operation</td>
<td>(1) Gasifier Operation</td>
</tr>
<tr>
<td>: Stable Slag Discharge</td>
<td>: Stable Slag Discharge</td>
</tr>
<tr>
<td>(2) Gas Turbine Operation</td>
<td>(2) Higher Production Rate</td>
</tr>
<tr>
<td>: Calorific Value of Syngas (HHV)</td>
<td>: High yield of Usable Gas</td>
</tr>
<tr>
<td>&gt;1,100kcal/m3N</td>
<td>(H2 + CO)</td>
</tr>
<tr>
<td>(3) Higher Plant Efficiency</td>
<td>Less interfering materials and impurities</td>
</tr>
<tr>
<td>: Less Auxiliary Power</td>
<td>(3) Higher Cold Gas Efficiency</td>
</tr>
</tbody>
</table>

• Measures

1. Air-Blown
2. 2-Stage configuration

1. Oxygen-Blown
2. 2-Stage configuration
3. Fuel transportation using CO2/N2 gas
MHI Gasifier Applicable to Chemical Products (Oxygen-Blown)

MHI Can Design and Supply Gasifiers Both for Air-Blown and Oxygen-Blown

- Same “MHI 2-Stage Entrained Flow Gasifier” as Air-Blown Nakoso Project Applied to Oxygen-Blown
  - Can be easily modified to Oxygen-Blown
  - Without changing the basic design of the existing gasifier in operation
  - Important factors duly considered
    (ex. increased heat flux, change in burner, change of carrier gas, impact on SGC)

- 2-Stage Gasification Reduces Oxygen Consumption

- SGC, as Monolithic Structure with Gasifier, Produces Steam and Supplies Auxiliary Power Needed in the Plant

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![Diagram of gasification process](image)

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DME Production from Coal

DME Process has an additional step of DME synthesis (Dehydration) compared with MeOH Process

Methanol and DME synthesis are proven technology adopted in many plants with natural gas

Coal → Gasification → Methanol Synthesis → DME Synthesis → DME

Coal is converted to Syngas by gasification

Syngas is converted to Methanol
\[ CO + 2H_2 \rightarrow CH_3OH \]
\[ CO_2 + 3H_2 \rightarrow CH_3OH + H_2O \]

Methanol is dehydrated to DME.
\[ 2CH_3OH \rightarrow CH_3OCH_3 + H_2O \]

Coal → Synthesis Gas → H2, CO, CO2

DME: dimethyl ether

Saudi Arabia Methanol Plant
AR-RAZI Plant

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Scenario of High Moisture Coal Utilization

Source: WEC Survey of Energy Resources 2008
BP Statistical Review of World Energy 2008

World Total (844.1 bil. ton)

High moist. coal: 41.2 bil. ton
- Scenario of utilization -

Mine-mouth IGCC

Pre-Drying*

Mine-mouth Synfuel/Chemical Production

Pre-Drying*

Gasifier
Synthesis (or other Chemical) Plant

Synfuel
GTCC
Diesel Engine

NH₃, etc.

*Pre-Drying may be applied in the future when high moisture lignite is used.
Commercial Plant with Brown Coal Drying

Coal Drying System

Brown Coal Fired Power Station

Commercial Plant

IGCC or DME

(11,000 t/d class)

Demo Plant

(≈ 200 t/d)

Design/Manufacture

Test

PDU test

(Approx. 6-10 t/d)

National Project of METI

Elemental test


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