MHPS IGCC Power Plant

IGCC: Integrated coal Gasification Combined Cycle

June 2, 2014
Product of MHPS  IGCC

IGCC Plants in Japan:

- **250MWe IGCC**\(^1\) @Nakoso(TK) : Commercial Operation since June 30, 2013 (Demo. started 2008)
- **166MWe IGCC**\(^2\) @Osaki : Demonstration, Now under Construction (Demo. will start 2016)
- **540MWe x2 IGCC**\(^3\) @Fukushima(TK) : Now under Project Development

\(^*1\): Air-blown, \(^*2\): Oxygen-blown  TK : Turn Key project
TEPCO develops 500MW class IGCC Plants in Japan

Tokyo Electric Power Company
New Comprehensive Special Business Plan (extract)

- Creating industry and employment through the construction of the world’s most advanced high-efficiency coal-fired power plant

  In Fukushima, the large-scale IGCC facility, employing Japanese clean coal technology, leads the world in proving the technology and attracts global acclaim as a source of clean coal technology and as a symbol of Fukushima’s revitalization

- On the premises of the Hirono thermal power plant (Futaba-gun) and the Nakoso power plant run by the Joban Joint Power Co. (Iwaki City), a 500,000 kW-class trial project involving the construction and operation of a coal-fired thermal power plant using world-leading high-efficiency technology (IGCC)

Detailed Report of the New Comprehensive Special Business Plan

Project Schedule Plan
- Environmental Impact Assessment 2014 (started)
- Start of Construction 2016
- Start of Operation Beginning of 2020s

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Learned form Nakoso 250MW IGCC Plant

Nakoso 250MW Demonstration Project finished in end of March 2013 after achieving all the targets.
- Excellent Performance (Highest Efficiency, Less Environmental impact)
- Higher Reliability
World record of continuous operation
- Fine Operability
- Fuel Flexibility (9 kinds of coal used)
  - Bituminous coal (China, Indonesia, Colombia, Russia)
  - Sub-bituminous coal (USA, Indonesia)

⇒ 540MW Commercial Plants have become “Ready.”

The plant was converted to the First Commercial Plant in Japan and restarted operation from the summer of 2013

JSME Medal for Technology Awarded
(JSME: Japan Society of Mechanical Engineering)
Achievements of Nakoso 250MW IGCC Plant

**Operability (Load Change)**
Verified at 3%/min load change operation which is required as middle range operation.

**Reliability**
Continuous full load operation from July to December of 2013 without any forced outage.

**Environmental Performance**
- Net Efficiency (%-LHV): 42.0, 42.9
- SOx (ppm): 8, 1
- NOx (ppm): 5, 3.4
- Dust (mg/kg): 4, <0.1

Operation history and schedule after the start of commercial operation (June 30, 2014):
- Commercial Operation
- Maintenance and equipment improvement (scheduled)

Average Load Factor >99%
Verification of Fuel Flexibility in Nagasaki

Many kinds of coals had been tested in Nagasaki IGCC verification Plant.

- Bituminous coal
- Sub-bituminous coal
- Lignite (USA/ Texas Lignite, Indonesian Lignite, Australia/Victoria Brown coal)

IGCC firing Lignite

Polish bituminous is well within the MHPS gasification experience. Polish lignite up to approx. 50wt% total moisture can be applied for IGCC without pre-drying. Polish lignite more than 50wt% total moisture also can be applied for IGCC with pre-drying.
MHPS can supply whole IGCC plant with single point responsibility

Gasifier / Gas Clean-up: Clean fuel gas generation from coal with high efficiency

Highly Efficient Gasifier

Wet Gas Clean-up (MDEA)

ASU for N2 Generation *1

Combined Cycle: Efficient Power Generation by fuel syngas

540MW IGCC plant system configuration is same as Nakoso 250MW plant.

*1: ASU for N2 Generation:
- Inerting N2 for coal transportation is produced.
- O2 as a by-product is mixed with air and efficiently utilized as gasification reaction enhancer.
Principal Specification of MHPS 540MW IGCC Plant

<table>
<thead>
<tr>
<th>Item</th>
<th>Major Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>50Hz</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>Bituminous Coal &amp; Sub-bituminous Coal</td>
</tr>
<tr>
<td>Output Gross</td>
<td>540 MW</td>
</tr>
<tr>
<td>Net</td>
<td>480 MW</td>
</tr>
<tr>
<td>Gasifier Oxidizer</td>
<td>Air (O2 Enriched)</td>
</tr>
<tr>
<td>Coal Feed</td>
<td>Dry</td>
</tr>
<tr>
<td>Acid Gas Clean-up</td>
<td>Wet MDEA* 1</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>M701F4 ( \times 1 ) (1 on 1)</td>
</tr>
<tr>
<td>Net Efficiency (LHV)</td>
<td>48 %</td>
</tr>
</tbody>
</table>

Note: Plant performance like output and efficiency depends on site conditions including coal properties.

*1 MDEA: Chemical absorption method using methyldiethanolamine.
# Plot Area Comparison

<table>
<thead>
<tr>
<th>Item</th>
<th>Nakoso 250MW IGCC</th>
<th>540MW IGCC</th>
<th>800MW USC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plot Plan</strong></td>
<td><img src="image" alt="Plot Plan Image" /></td>
<td><img src="image" alt="Plot Plan Image" /></td>
<td><img src="image" alt="Plot Plan Image" /></td>
</tr>
<tr>
<td><strong>Plant Area ※1</strong></td>
<td>20,000m²</td>
<td>30,200m²</td>
<td>47,600m² ※2</td>
</tr>
<tr>
<td><strong>Plant Area (per MW)</strong></td>
<td>80m²/MW [Base]</td>
<td>56m²/MW [70%]</td>
<td>63m²/MW [79%]</td>
</tr>
</tbody>
</table>

※1 : Excluding Utility equipment  
※2 : Power Block : 35,500m²  FGD Aeration(not indicated) : 12,100m²
1. 2-Staged Gasification
   - Combustor / Reductor Configuration
     ① Stable Syngas Production for Wide Variety of Coal
     ② Smooth Slag Discharge Capability
     ③ No Necessity of Quench Gas

2. Char Recycling System
   ① Minimize Unburnt Carbon in Slag
   ② No Black Water from Gasifier
The scale-up of the gasifier follows the established scale-up law from the 200T/D pilot plant. No critical issues expected.

As the result of successful demonstration,

• Scale-up methodology was validated.

• Same methodology is applied to the 500MW IGCC commercial plants at lower scale-up factor.
MHPS Gas Turbine Global Experience

All Units – 789 units
(including 189 units of Takasago Mfd. Mid&Small Class GTs)

M701F4: The Most Experienced Gas Turbine.
Gas Turbine Trend for Fuel Gas Application

G and J Series GT Experience
- G Series Natural Gas
- J Series Natural Gas

F Series GT Experience
- F Series Syngas
- F Series Low BTU Gas (BFG)

D Series GT Experience
- D Series Syngas
- D Series Low BTU Gas (BFG)

Timeline:
- 1980
- 1985
- 1990
- 1995
- 2000
- 2005
- 2010

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The World Highest Efficiency and Lowest Emission for coal can be achieved by MHPS IGCC.

Coal fired conventional power plant USC (Steam Temp. = 600°C) =100%

- CO2: ▲10~20%
- Ash: ▲60%
- Circulating Water: ▲30%

Utilization as a pavement material are possible.

Utilization as a concrete aggregate are possible.

Approx. 60% decrease in volume.
Conclusion

- The 250MW IGCC demonstration plant has been successfully completed by achieving all of its purpose and targets, and was converted to the Commercial Plant in Japan as Nakoso unit No.10 of Joban joint Power Co. and restarted operation from the summer of 2013.

- Based on the experience in the demonstration plant, MHPS is now capable of realizing 540MW-class IGCC commercial plants with high reliability (availability) and economy by reflecting all the accumulated data and lessons learnt.

- A lot of IGCC’s advantages like higher plant efficiency and applicability of coal of lower rank are taken into account. In addition, reduction of CO2 emission, ash discharge and circulating water is envisioned, too.
“MHPS’s Contribution for Energy and Environment Solutions”
MHPS Technology and Products for Power Generation and Chemicals

MHPS is a technology provider and OEM of key components like gasifiers, gas turbines and steam turbines. Also supplies chemical plants and equipments.

MHPS plays a role of the most reliable system integrator for IGCC based on our overall experience and technology.
Lignite Coal Firing Boiler is relatively expensive as larger volume due to lower ash melting temp.

IGCC is suitable for Lignite Coal as the volume of the gasifier is almost same as the bituminous coal firing gasifier.
## Low Calorific Gas Firing Projects Progress

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<thead>
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<th>Year</th>
<th>BFG FIRING</th>
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<tr>
<td>M701F x 1 +ST</td>
<td>Total Operating Hours over 67,000 Hrs</td>
</tr>
<tr>
<td>Installation</td>
<td></td>
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<tr>
<td>Commissioning</td>
<td></td>
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<tr>
<td>Commercial Operation</td>
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<table>
<thead>
<tr>
<th>Year</th>
<th>VR-IGCC</th>
</tr>
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<tbody>
<tr>
<td>M701FV x 1 +ST</td>
<td>Total Operating Hours over 75,000 Hrs</td>
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<tr>
<td>Oct '02 Commissioning with Oil firing started</td>
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</tr>
<tr>
<td>Commissioning with Syngas firing</td>
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<tr>
<td>June '03 Commercial Operation Started</td>
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<table>
<thead>
<tr>
<th>Year</th>
<th>Coal IGCC</th>
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<tbody>
<tr>
<td>M701DA x 1 +ST</td>
<td>Total Operating Hours over 22,000 Hrs</td>
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<tr>
<td>Combustion test</td>
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<tr>
<td>Procurement</td>
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<tr>
<td>Process Construction</td>
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<tr>
<td>GT Installation</td>
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<tr>
<td>Commissioning</td>
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<tr>
<td>Operation</td>
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