Commercialization of Mitsubishi IGCC/Gasification Technology

October 10, 2011

Photo: 250MW IGCC Demonstration Plant @Nakoso, Japan

MITSUBISHI HEAVY INDUSTRIES, LTD.
MHI’s Business Portfolio

Contribute to Both

the **Power Generation** and

the **Chemical Industries** through

Proven Gasification Technology

- **Air-Blown Gasifier with H-T GT for IGCC**
  
i.e. for Power:
  
  World Highest Plant Efficiency and Economy
  
ex. 250MW IGCC Demonstration Project

- **O2-Blown Gasifier for Chemical Products**
  
i.e. for SNG, CTL, NH₃, etc.:
  
  High Efficiency and Minimum Utility Consumption including Aux. Power
# MHI’s Approach to the Market
- Formation of Single Point Responsibility

## Gasifier
(Air-blown for Power / O2 Blown for Chemical)
- **The World Highest Plant Efficiency**
  - Minimum ASU
  - Dry Coal Feed System
- **Wide Variety Coal Applicability**
- **High Reliability Membrane Waterwall Structure (same as conventional boilers)**

## Low Calorie Gas Firing Gas Turbine
- **Abundant Supply Record of BFG/COG Firing Gas Turbine**
- **Operation Flexibility for Calorific Change of Fuel Gas**

## GTCC Plant
- **World-wide Abundant Experience of EPC Contracts**

## OEM/R&D Capability + System Integration Capability

## Realizing High Efficiency – High Reliability IGCC / Gasification Plant
MHI’s Typical Business Schemes
for Commercial Projects

MHI executes projects step by step in order to make commercial plants come true reliably and economically.

- Owner’s Request
- Scoping Study
- FS
  - Evaluation of Coal by MHI 24T/D Pilot Plant
  - Primary Evaluation of Candidate Coal Properties
  - Guesstimate Plant Cost & Performance
  - FEED Proposal
  - Emission Data
  - Scoping Study
  - Basic Engineering as Real Projects
  - Plant Layout
  - Project Schedule
- FEED or EPC (LNTP)
  - Estimate Plant Cost & Performance
  - Project Schedule
  - Support by Supervisors or Technical Advisors
- Long Term Maintenance Support
- Commissioning
  - Construction
  - EPC
    - Procurement
    - Engineering (Detail)
  - IGCC Commercial Plant
MHI Air-Blown IGCC System

① Highly Efficient Gasifier (Air-Blown)

② Highly Efficient Gas turbine (High Temperature)

③ Small ASU for N2 Production (for Coal Transportation and Inerting)

④ System Integration capability is MHI’s key factor of strength.

Essentially different from the other Oxygen-blown technologies.
Why IGCC?

The World Highest Efficiency and Lowest Emission

Plant footprint can be reduced, too.

- Coal fired 600°C USC Plant = 100%
- USC: Ultra Super Critical
- More reduction by coupling CCS
- Plant Efficiency: 110-120%
- CO2 Emission: 75%
- Ash Emission: 70%
- Circulating Water: 75%
- Plant Footprint: 40%
Features of MHI Air-Blown IGCC

Realize the Lowest Cost with Various Advantages

• Highest Plant Efficiency Because of Air-Blown Gasifier for IGCC

• Flexibility for Variety of Coal Including Brown Coal Because of 2-Staged Dry Coal Feed and “Fine” Coal Pulverizing System

• Higher Reliability & Easier Maintainability with Membrane Waterwall Configuration

• Effective Utilization of By-Product like Discharged Molten Slag, Recovered Sulfur, etc.

• High Plant Efficiency by “F” or “G” Type High Temp. GT and High Reliability from Abundant “Low Calorie Gas Firing” GT
The world highest efficiency is achieved by Air-Blown IGCC.
The Air-Blown IGCC is MHI’s original technology.

Assumption: Same gas turbine applied

- MHI Air-Blown IGCC: 48%
- O2-Blown IGCC: 43 - 45%
- USC Conventional: 42%
- World-Average Conventional: 33%

Efficiency:
- +15 point %
- Efficiency: 45% Up
- CO2: 30% Down
"Variety of Coal" Experience

MHI Gasifier successfully gasified all coals including Lignite, accumulating more experience day by day!
Comparison in CAPEX w/ CO2 Capture

CAPEX of MHI Air-Blown IGCC with CO2 Capture is the lowest!!

![Graph showing comparison in CAPEX and Net Output]

- MHI Air-Blown IGCC
- The Other Technologies

**CAPEX (%):**
- MHI Air-Blown IGCC: 100
- The Other Technologies: 92, 97

**Net Output (%):**
- MHI Air-Blown IGCC: 110
- The Other Technologies: 105

**CAPEX ($/kW):**
- MHI Air-Blown IGCC: 100
- The Other Technologies: 97

**CAPEX ($):**
- MHI Air-Blown IGCC: 100
- The Other Technologies: 92
Present Status of 250MW IGCC Demonstration Project (Nakoso)

Project is going on Schedule.
Operation started Sep. 2007
- 100% Load
- 2,000hrs. Continuous Operation finished
- Coal Change / Load Swing / Efficiency Improvement, etc.
- 5,000hrs. Durability Test finished ⇒ Subsidy from METI ended

<table>
<thead>
<tr>
<th>Year</th>
<th>Engineering</th>
<th>Construction</th>
<th>Operation</th>
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<td>2012</td>
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<tr>
<td>2013</td>
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</table>

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The earthquake (@M9) and tsunami attacked the Demo. Plant on Mar. 11, 2011. All facilities flooded 2 m above the ground level and piping, etc. damaged, but the plant shut down quite in safe, with neither dangerous situation like syngas leakage nor explosion.

No fatal damage due to the earthquake-resistant design of main equipments.

After 4.5 months restoration, the plant came back on July 28, continuously operating at full load for 1,500 hrs.
# 250MW IGCC Demonstration Project (Nakoso) - Targets & Accomplishments -

<table>
<thead>
<tr>
<th>Performance</th>
<th>Targets</th>
<th>Achievements</th>
<th>Note</th>
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<tbody>
<tr>
<td>Output</td>
<td>250MW</td>
<td>250MW</td>
<td></td>
</tr>
<tr>
<td>Efficiency (Net, LHV)</td>
<td>&gt; 42.0%</td>
<td>42.9%</td>
<td></td>
</tr>
<tr>
<td>Carbon Conversion</td>
<td>&gt; 99.9%</td>
<td>&gt; 99.9%</td>
<td></td>
</tr>
</tbody>
</table>

| Emission             | SOx     | < 8 ppm      | 1.0 ppm                  |
|                      | NOx     | < 5 ppm      | 3.4 ppm                  |
| Dust                 | < 4 mg/m³N | < 0.1 mg/m³N |                           |

<table>
<thead>
<tr>
<th>Operational Flexibility</th>
<th>Coal Kinds</th>
<th>Bituminous Sub-bituminous</th>
<th>Chinese, PRB 2 Indonesian Subs Colombian</th>
<th>Continuously expanding</th>
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</thead>
<tbody>
<tr>
<td>Start-up Time</td>
<td>&lt; 18 hr</td>
<td></td>
<td>15 hr</td>
<td></td>
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<tr>
<td>Minimum Load</td>
<td>50%</td>
<td></td>
<td>Less than 50% (36%)</td>
<td></td>
</tr>
<tr>
<td>Ramping Rate</td>
<td>3%/min</td>
<td></td>
<td>3%/min</td>
<td></td>
</tr>
</tbody>
</table>

| Reliability             | Long-term Continuous Operation | 2,000 hr | 2,039 hr |                      |
|                        | Long-Term Reliability Run     | 5,000 hr | 5,013 hr |                      |

- All of the demonstration targets have been achieved.
- Future plan focuses on the further improvement of operational flexibility.
Contribution of Mitsubishi CCT for CO2 Reduction

Mitsubishi CCT

- Development of Advanced Technology in Japan
- CO2 Reduction Benefit

Economical/Technological Support from Japan

- High Efficiency Power Generation (IGCC)
- CO2 Reduction
- Chemical Production (Gasification)
- CO2 Reduction

Environmental Protection (AGR, CCS, etc.)

- Economical/Technological support from Japan contributes to resolution of energy/environmental Issues.
- Also benefits the global CO2 reduction issue.

Economical Support from Each Country
 Contribution of Mitsubishi CCT for CO2 Reduction

CCT Supporting and Nearby Coal Producing Countries

CCT Supporting Schemes
- Japan — System Infrastructure Export Bi-lateral CO2 Off-set
- Australia — Energy Transformed Flagship
- USA — DOE Loan Guarantee Program
- EU — NER (New Entrants’ Reserve) 300

CCT Promoting Countries
- Australia
- China
- USA
- Indonesia
- EU
- India
- Asian Countries

Milestone for Commercial Plant Projects Development by MHI
- Feasibility Study : 2011
- FEED* or EPC** Contract : 2012
  * Front End Engineering & Design
  ** Engineering, Procurement & Construction
- COD of Commercial Plants : 2016～17

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Clean Coal Projects MHI is undertaking

Air-blown IGCC in China

CPI Langfang Project
• 400～500MW Class IGCC
• Bituminous Coal

Project Development Schedule
2010 MOU Agreed
2011 Feasibility Study
2012~ Commercialization

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Clean Coal Projects MHI is undertaking

Oxygen-blown IGCC and Gasification for Chemicals in USA

Gasifier Island

Such polygeneration provides the 400 MW integrated Gasification Combined Cycle (IGCC) plant operational flexibility to better match market demand. For instance, the plant will produce more fertilizer in the evening when less electricity is needed, which optimizes the economic use of the facility.

The plant will capture 90% of the CO₂ produced and transport it to an adjacent oil field, where it will be used for enhanced oil recovery and sequestered in deep, underground geological formations, furthering California’s low carbon power policies, adding to domestic oil production, and replacing imported high-carbon fertilizer with domestic low-carbon fertilizer.

The project has selected Fluor as its Engineering, Procurement and Construction contractor and has also selected the Oxygen-Blown Gasification technology of Mitsubishi Heavy Industries Ltd.

Extraction from “marketwatch.com”
Clean Coal Projects MHI is undertaking

Oxygen-blown Gasification for SNG in Indonesia

MHI and MC to Collaborate with Indonesia in Large-scale Substitute Natural Gas Synthesis Project Using Low Rank Coal

Extraction from “news.tradingcharts.com”

Tokyo, Sep 29, 2011 (JCN Newswire via COMTEX) -- Mitsubishi Heavy Industries, Ltd. (MHI) and Mitsubishi Corporation (MC) have agreed with the Indonesian government to collaborate in a large-scale substitute natural gas (SNG) synthesis project using Indonesia’s abundant low rank coal (LRC) which is conducted by MHI/MC and Indonesian partners (government institution and private company), as a follow up of Indonesia-Japan Energy Round Table held in November 2010. A feasibility study (F/S) has already gotten under way with support from the Indonesian and Japanese governments. MHI, MC and Indonesian partners plan to complete the F/S by March 2012, targeting inauguration of commercial operation at a new SNG synthesis plant in 2017.
Technological Innovation
Coming Very Soon

• Further Efficiency Improvement
  - Adopting Higher Temperature Innovative Gas Turbine, J-Class and more
  - Applying Newly Developed Energy Conservation System

• Utilization of Lower Grade – Higher Moisture – Coal
  - From Bituminous and Sub-bituminous to Lignite and Brown Coal
Scenario of Efficiency Improvement

- **Gross Thermal Efficiency (LHV%)**
  - 40
  - 45
  - 50
  - 55
  - 60
  - 65
  - 70

- **Year**
  - 1990
  - 1995
  - 2000
  - 2005
  - 2010
  - 2015
  - 2020
  - 2025

- **Technology Categories**
  - USC (Coal)
  - NGCC (Natural Gas)
  - Air-Blown IGCC (Coal)
  - Air-Blown IGCC (Coal)
  - J type GT
  - F or G type GT
  - D type GT (Demo. Plant)
  - 1,700°C GT
  - IGFC

- **Combined Cycle**
  - Triple Combined Cycle

- **Fuel Sources**
  - Coal
  - Natural Gas
  - Hot gas Clean-up System

- **Efficiency Targets**
  - 1,700°C GT
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

[60Hz] Commercial Plant
Strategic Planning  R&D / Design  Design Implementation  Ready for FOB  Commercial Operation
2009 2011 2013

IGCC Application
G type IGCC Commercialization
Development of J type IGCC
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)

Europe
(78.1 bil. ton)

China
(114.5 bil. ton)

Russia
(157.0 bil. ton)

India
(56.5 bil. ton)

Indonesia
(4.3 bil. ton)

Australia
(76.6 bil. ton)

Canada
(6.6 bil. ton)

U.S.A
(242.7 bil. ton)

Colombia
(7.0 bil. ton)

South Africa
(48.0 bil. ton)

Other Africa
(5.2 bil. ton)

Other Asia
(41.9 bil. ton)

Near Future Expanding

Present Applicability

MHI Technology

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

Pre-Drying**

Mine-mouth IGCC

Mine-mouth Synfuel/Chemical Production

Synthesis (or other Chemical) Plant

Gasifier

Pre-Drying*

Diesel Engine

GTCC

Synfuel

NH3, etc.

*Pre-Drying may be applied to the future expanding part, to more moistened lignite.

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Scenario of High Moisture Coal Utilization

Managing moisture is the “Key.”

Lignite
@60% Moisture Content

Bituminous Coal
@60% Moisture by Wetting

Pre-drying characteristics are different!
Summary

- Air-Blown 250 MW IGCC demonstration plant has successfully achieved targets and been proving commercial serviceability.

- Dry feed, 2 stage O$_2$-Blown Gasifier achieved minimizing oxygen and auxiliary power consumption.

- Based on the results, MHI has started undertaking commercial projects for the Air-Blown IGCC with F or G type Gas Turbine and O$_2$-Blown Gasifier.

- Further efficiency improvement is planned by applying innovative Gas Turbine (J type and 1700 degC Class) and newly developed energy conservation systems.

- Lower grade, higher moisture coal comes to be effectively utilized very soon.
“Mitsubishi’s Contribution for Energy and Environment Solutions”