Progressing of high efficient and clean coal technologies

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Director
Boiler Business Strategy Planning Dept.
Boiler Products Headquarters
Mitsubishi Hitachi Power Systems, LTD
1. Introduction of Mitsubishi Hitachi Power Systems
2. Supercritical / Ultra-Supercritical Power Plant
3. Advanced Clean Coal Technology
1. Introduction of Mitsubishi Hitachi Power Systems
Integration in the Thermal Power Generation Systems Field

Mitsubishi Hitachi Power Systems, Ltd (MHPS)

Name: MITSUBISHI HITACHI POWER SYSTEMS, LTD.

Head Office: Yokohama, Kanagawa, JAPAN

Representatives:
- Koji Tanaka (Chairman of the Board)
- Takato Nishizawa (President and CEO)

Capital: 100 Billion JPY

Effective Date: February 1, 2014

Employees: 23,000 (incl. 7,600 outside Japan)
MHPS has 54 companies in 24 countries.
MHPS’s Business Field

Products & Services

Gas Turbine Combined Cycle (GTCC) Power Plants

Integrated coal Gasification Combined Cycle (IGCC) Power Plants

Boiler & Turbine Generation Plants

Geothermal Power Plants

Steam Turbines

Boilers

Environmental Plants SCR Systems, FGD Systems

Gas Turbines

Generators

Power Generating Plant Peripheral Equipment

SCR Systems

Plant Control System

Fans

Fuel Cells (SOFC)

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MHPS Activities in Ukraine

- **OJAC Alchevsk and Steel Works**
  - Alchevsk Iron and Steel Works GTCC 450MW
    - No.1 GT M701S(DA) x 1 (100MW), ST x 1 (50MW)
    - No.2 GT M701S(DA) x 1 (100MW), ST x 1 (50MW)
    - No.3 GT M701S(DA) x 1 (100MW), ST x 1 (50MW)

- **Regenza**
  - Dneprodzerzhinsk GTCC 150MW
    - M701S(DA) x 1 (100MW)
    - ST x 1 (50MW)

- **Zmiivska (Centroenergo)**
  - 1 x 300MW Boiler rehabilitation
2. Supercritical/Ultra-Supercritical Power Plant
Comparison of Coal Fired Plant Thermal Efficiency by Individual Countries

Source: International comparison of fossil power efficiency and CO2 intensity - Update 2013, Ecofys
History of steam condition and thermal efficiency in Japanese thermal power plant

- Higher steam temperature and pressure improve thermal plant efficiency
- In other words, SC/USC technology provides economical power production, fuel energy saving, lower carbon emission and environment-friendly
MHPS can provide various power plants best suited for various kinds of coal based on abundant experiences.
In initial design stage, many points are considered, such as operability, construction and anti-slagging.

- **Sufficient distance between SH panels**: For easy construction and anti-slagging.
- **Suitable furnace sizing**: Against slagging characteristics.
- **High performance combustion system**: Low NOx burner and vertical type pulverizer.
- **Optimized SH/RH arrangement**: Based on static and dynamic simulation.
- **Gas biasing damper**: For RH temperature control.
Harmful NO is decomposed into harmless N2 and H2O by catalytic action

\[ 4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O} \]

Harmful SO2 is recovered as harmless gypsum (CaSO4)

\[ \text{SO}_2 + \text{CaCO}_3 + 2\text{H}_2\text{O} \rightarrow \text{CaSO}_4 \cdot 2\text{H}_2\text{O} + \text{CO}_2 \]

One-stop AQCS solution by MHPS

World lowest level emission (SOx, NOx, PM) can be achieved by applying the integrated AQCS system

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### Latest USC Plant

#### Tokyo Electric Power Co., Ltd
**Hirono #6**

<table>
<thead>
<tr>
<th>Output</th>
<th>600 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Steam Flow</td>
<td>1,770 t/h</td>
</tr>
<tr>
<td>Main Steam</td>
<td>600 °C / 24.5 MPag</td>
</tr>
<tr>
<td>Reheat Steam</td>
<td>600 °C</td>
</tr>
<tr>
<td>Commercial Operation</td>
<td>2013/12</td>
</tr>
<tr>
<td>Fuel</td>
<td>Bituminous Coal</td>
</tr>
</tbody>
</table>

#### Germany Project Boxberg R

<table>
<thead>
<tr>
<th>Output</th>
<th>670 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Steam Flow</td>
<td>1,760 t/h</td>
</tr>
<tr>
<td>Main Steam</td>
<td>600 °C / 29.3 Mpag</td>
</tr>
<tr>
<td>Reheat Steam</td>
<td>610 °C</td>
</tr>
<tr>
<td>Commercial Operation</td>
<td>2012/10</td>
</tr>
<tr>
<td>Fuel</td>
<td>German Lignite Coal</td>
</tr>
</tbody>
</table>

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South Africa Project Medupi, Kusile

- SC technology is applied to South African Project
- 2 projects, total 12 boilers are under construction and commissioning

<table>
<thead>
<tr>
<th><strong>Medupi</strong></th>
<th><strong>Kusile</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Output : 6 x 800MW</td>
<td>Output : 6 x 800MW</td>
</tr>
<tr>
<td>Main Steam Flow : 2,288 t/h</td>
<td>Main Steam Flow : 2,288 t/h</td>
</tr>
<tr>
<td>Main Steam : 564 °C/ 25.7 MPag</td>
<td>Main Steam : 564 °C/ 25.7 MPag</td>
</tr>
<tr>
<td>Reheat Steam : 572 °C</td>
<td>Reheat Steam : 572 °C</td>
</tr>
<tr>
<td>Fuel : Bituminous Coal</td>
<td>Fuel : Bituminous Coal</td>
</tr>
</tbody>
</table>
China Qinbei #1,2

• Anthracite firing boiler with conventional combustion system

Output : 600MW x 2
Main Steam Flow : 1,900 t/h
Main Steam : 566 °C/ 24.1 MPag
Reheat Steam : 566 °C
Commercial Operation : 2004/12, 2005/3
Fuel : Chinese Anthracite (VM: 8~15%)
Minimum Load 45%
(Without Support Fuel)
Combustion System
Opposed Firing
(Direct Firing)
NR Burner
MPS Mill
Activities at Indian Market

MHPS has contributed to Indian power generation CCT originated from Japan through the JV with Indian company, Larsen & Toubro, Ltd.
Global Activity with SC/USC Technology

Indian Project Rajpura #1

- Rajpura #1 was placed under commercial operation from Feb 1\textsuperscript{st}, 2014
- This unit was constructed by joint venture established by MHPS and Indian local company Larsen & Toubro, Ltd.
- Fuel is Indian high ash content bituminous coal (ash content is 30%)
- Local staff performed engineering/manufacturing/construction/commissioning works under MHPS’s instruction
- High efficiency and reliability of Japanese leading CCT were also proved in India

Output : 700MW
Main Steam Flow : 2,322 t/h
Main Steam : 565 °C / 24.1 MPag
Reheat Steam : 593 °C
Thermal efficiency : Approx. 4 ~ 5% better\textsuperscript{*1}

<table>
<thead>
<tr>
<th>Fuel Property</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>HHV (kcal/kg, A.R.)</td>
<td>4,560</td>
</tr>
<tr>
<td>Fuel Ratio (-)</td>
<td>1.20</td>
</tr>
<tr>
<td>Moisture (A.R. %)</td>
<td>11.8</td>
</tr>
<tr>
<td>Ash (A.R. %)</td>
<td>27.5</td>
</tr>
</tbody>
</table>

Project Schedule

48.5 months from LNTP to COD was achieved.

\textsuperscript{*1}: Relative value as compared with Sub-critical plant (16.7MPag, 538/538°C)
3. Advanced Clean Coal Technology

Integrated coal Gasification Combined Cycle
What is IGCC?

- Higher efficiency through coal gasification process coupled with a combined cycle (CC) system.
- Reduce CO2 emission by high efficiency and prevent global warming.

**Outline of IGCC System**

*Integrated coal Gasification Combined Cycle*

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**IGCC Projects in Japan**

(Demonstration and Commercial Plant)

- TEPCO Fukushima IGCC Project (2020～)
  - Nakoso site, Hirono site
- Osaki CoolGen Corp.
  - Osaki CoolGen Project (Demo. 2017-)
- Joban Joint Power Co.LTD
  - Nakoso #10 (Demo. 2007-, Commercial 2013-)
Nakoso 250MW IGCC Plant

Major Specification

- **Output**: 250 MW (gross)
- **Gasifier**: Air-blown Dry Feed
- **Gas Clean-Up**: MDEA (Methyldiethanolamine)
- **Gas Turbine**: M701DA GT (1 on 1)
- **Plant Efficiency**: 42% (LHV, net)

Project Schedule
- **Operation Started**: Sep. 2007
- **Commercial Operation**: July. 2013

Nakoso 250MW IGCC Demonstration Plant achieved all the following targets.

- Excellent Performance (Highest Efficiency, Less Environmental impact)
- Higher Reliability (World record of continuous operation 3,917hr)
- Fine Operability (Load change rate >3%/min)
- Fuel Flexibility (Verified applicability for low-rank coal, 10 kinds coals)

 Converted to **the First Commercial IGCC Plant** in Japan.

(Total operating hours are approx. 30,000 hrs.)

*JSME* Medal for Technology (2013) Awarded

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Commercial-scale IGCC Project

- High Efficiency by using state of the art Gas Turbine
- Lower CO2 emission intensity than the latest USC coal fired power plant.
- Fuel Flexibility for high moisture Low Rank Coal
- Highly Reliable system verified in Nakoso 250MW IGCC plant

Major Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td>540 MW (gross) 480 MW (net)</td>
</tr>
<tr>
<td>Gasifier</td>
<td>Air-blown Dry Feed</td>
</tr>
<tr>
<td>Gas Clean-Up</td>
<td>MDEA (Methyldiethanolamine)</td>
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<tr>
<td>Gas Turbine</td>
<td>M701F GT (1 on 1)</td>
</tr>
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MHPS’s Policy for Clean Coal Technology

◆ MHPS shall be continuously developing Clean Coal Technology to improve plant efficiency and reduce CO$_2$ emissions.

◆ MHPS shall contribute to Environmental Conservation and CO$_2$ Emission Reduction to provide Japanese clean coal technology worldwide.