1st Post Combustion Capture Conference

Development of Carbon Dioxide Removal System from the Flue Gas of Coal Fired Power Plant

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Yukio Ohashi1, Takashi Ogawa1, Kensuke Suzuki2

1Toshiba Corporation, 1 Toshiba Fuchu, Tokyo 183-8511, Japan
2Toshiba Corporation, 1-1-1 Shibaura Minato-ku, Tokyo 105-8001, Japan
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Toshiba Corporation Organization

< Digital Products Group >
- Digital Products & Service Company
- Network & Solution Control Center
- Storage Products Company
- TOSHIBA TEC CORPORATION

< Electronic Devices & Components Group >
- Semiconductor Company
  - Toshiba Mobile Display Co., Ltd.

< Infrastructure Systems Group >
- Power Systems Company
  - Thermal & Hydro Power Systems & Services Div.
  - Social Infrastructure Systems Company
    - TOSHIBA ELEVATOR AND BUILDING SYSTEMS CORPORATION
    - Toshiba Solutions Corporation
    - TOSHIBA MEDICAL SYSTEMS CORPORATION

As of April 1, 2011
Toshiba’s Energy Products & Services

- **Thermal Power Plants**
- **Nuclear Power Plants**
- **Hydro Power Plants**
- **Photovoltaic & Renewable Energies**
- **Steam Turbines**
- **Turbine Generators**
- **C&I Systems**
- **T&D Systems**
- **Smart Grid / Smart Communities**
- **Hydro Turbines**
- **Hydro Generators**
Toshiba’s Thermal Power Plant Turbines

- **Wide range Output and Steam Condition**
  - Turbine Configuration
  - Last Stage Bucket series
- **High Efficiency**
  - State-of-the-Art Steam Path Technology
- **Multipurpose**
  - Conventional Power Plant
  - Combined Cycle Power Plant
  - CHP Plant

Toshiba is the one of most experienced power system turbine providers in the world
Toshiba Turbine Power Plants - Worldwide

Total: 1,896 Units, 168,267 MW  (As of March 2011)
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Advanced High Efficiency Cycles and CCS technology play vital role in reduction of CO₂ in the Thermal Power Plant arena
Substantial CO₂ reduction is realized by Integration and Optimization of Both High efficiency Turbine Cycles and CCS technology
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System Verification and Implementation

Screening of Absorbents and Evaluation of System Performance Improvement by Simulation

Evaluation of Basic Properties and Absorption Performance

Performance / Degradation Evaluation by Small Loop

Overall Demonstration at Mikawa - PCC Pilot Plant

Design of Full Scale Demonstration Plant
Toshiba PCC Pilot Plant at Mikawa

Location:
Sigma Power Ariake Co., Ltd.
Mikawa Power Plant
Omuta City, Fukuoka, Japan

Plot Plan:
- PCC Pilot Plant
- Turbine Unit #2
- Steam Turbine Test Facility
- ESP
- FGD
- Stack
- Boiler
- Turbine Unit #1
47.5 MW Coal Fired

Mikawa: Toshiba’s Showcase of Low Emission Thermal Power Technology
# PCC Pilot Plant - Specification

![Mikawa PCC Pilot Plant](image)

## Table 1 Pilot Plant Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Mikawa Thermal Power Plant SIGMA POWER Ariake Corp.</td>
</tr>
<tr>
<td>Source Gas</td>
<td>Flue Gas of Coal-Fired Boiler</td>
</tr>
<tr>
<td>Treated Gas Flow Rate</td>
<td>2100Nm$^3$/h</td>
</tr>
<tr>
<td>CO$_2$ Concentration</td>
<td>Approx. 12%</td>
</tr>
<tr>
<td>CO$_2$ Capture Ratio</td>
<td>90%</td>
</tr>
<tr>
<td>Captured CO$_2$</td>
<td>10t-CO$_2$/day</td>
</tr>
<tr>
<td>Impurities</td>
<td>SOx, NOx, Dust, etc</td>
</tr>
<tr>
<td>Solvent</td>
<td>TS-1 Solvent</td>
</tr>
</tbody>
</table>
### PCC Pilot Plant - Schedule and Tests

<table>
<thead>
<tr>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>11</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering &amp; Permits</td>
<td>Material Procurement, Manufacturing &amp; Construction</td>
<td>Commiss</td>
<td>Testing Period-1 Mod</td>
</tr>
</tbody>
</table>

### Operating Hours to Date: 4308 Hours (as of February 24, 2011)

#### Cumulative Operating Hours

- **Process Evaluation**: Ensure Stable Operation and Good Measurement Accuracy
- **Performance Tests**: Seek Higher CO₂ Capture Efficiency and Lower Capture Energy
- **Absorbent Life Test**: Assess Absorbent Degradation by Live Flue Gas
- **Load Change Tests**: Evaluate Response at Transient Operations

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Results - CO₂ Recovery Energy (2010)

CO₂ Recovery Energy: 3.2 ~ 3.3 GJ/t-CO₂ @ 90% Capture
Results - Performance Degradation (2010)

Performance Stable over 2800 Hours of Continuous Operation
Results - Solvent Degradation (2010)

No Detrimental Degradation after 2800 Hours of Continuous Operation
Results - Solvent Degradation (2010)

No Detrimental Degradation after 2800 Hours of Continuous Operation
Results - Solvent Degradation (2010)

Amine Degradation lower than Conventional Amine Technologies
Results - Amine Emissions (2010)

Amine Emissions are Controlled, Evaluated and Monitored
Corrosion Coupon Tests

No Substantial Degradation is found to Present
Results - CO$_2$ Recovery Energy (2011)

PCC Pilot Plant System Modified in 2011 to Improve CO$_2$ Rich Loading

CO$_2$ Recovery Energy : $\sim$ 2.6 GJ/t-CO$_2$ @ 90% Capture
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Solvent Screening - Simulation

Thermodynamic Simulation Conducted to Search for Improved Performance

Future Solvent Candidates are Screened through Simulation
Solvent Screening – Bench Scale Test

Test Results of Bench-scale Test Facility

- CO₂ Recovery Energy [GJ/t-CO₂]
  - TS-1 (△ T=5K)
  - △ T=10K
  - △ T=8K
  - △ T=5K

Evaluation of Promising Solvents are Conducted at Bench Scale
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Summary

- Toshiba Corporation holds a well respected history as leading and reliable thermal power plant technology supplier in the global market.

- Toshiba has positioned Carbon Capture as one of the key technologies to decarbonize thermal power plant.

- In view of actual application to power plants, Toshiba constructed its PCC Pilot Plant in Mikawa (Japan), which works to actual live flue gas of a coal fired thermal power plant. The plant has accumulated more than 4300 hours of operation to date.

- High performance of Toshiba solvent system was proven in 2010 tests, and was improved further by system modification made in 2011.

- Toshiba’s search for improved performance solvents and system application continues through its comprehensive system verification and implementation program.
Thank You!

For more information, contact:
Mr. Kensuke Suzuki
Group Manager - CCS Plant Planning Group
Thermal & Hydro Power Systems & Services Division
Toshiba Corporation   Power Systems Company
e-mail: kensuke1.suzuki@toshiba.co.jp