12th MEETING of the INTERNATIONAL POST-COMBUSTION CO2 CAPTURE NETWORK

MHI's Recent Post Combustion CO2 Capture Achievements and Developments

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1. MHI’s CO2 Recovery Technology

Process Flow for Amine Absorption

Advanced Amine Solvent ‘KS-1’
- High CO2 Loading
- Low Solvent Degradation
- Low Corrosion
- No Corrosion Inhibitor

Flue Gas Quencher (Cooler/Deep FGD)

Pre-treated Flue Gas

Flue Gas Outlet

CO₂ Purity 99.9 %

Reboiler

Steam
1. MHI’s CO2 Recovery Technology

Nanko Pilot Plant

PLANT OUTLINE

Location: Nanko Power Plant, Osaka, Japan
Capacity: 2 T/D
Start Up: 1991
Feed Gas: Natural gas fired boiler

- Purpose of the Plant
  1. Development of Energy Minimizing Solvent
  2. Process Improvement

Commercial Plants

- Obtained data are used for design feedback

Malaysia
Japan
India
India

Coal Fired Demonstration Plant
MHI’s Flue Gas CO2 Recovery Improved Process

- 15% steam consumption reduction over MHI’s conventional process
- Advanced process demonstrated at MHI’s Nanko Pilot Plant & already integrated in a Commercial Plant
- Process Features
  Utilize lean solvent and steam condensate heat for regeneration inside the stripper
- Performance
  *Steam Consumption: 15% reduction compared to conventional process

Note: Steam = 3 BarG Saturated

Patent Application submitted in various countries
2. MHI’s Commercial Achievements

MHI’s CO2 Capture Plants under Commercial Operation

**Malaysia**
- Client: Petronas
- Start-up: 1999~
- CO2 Source: Nat. Gas Reformer
- Capacity: 200 t/d
- Product: Urea

**India**
- Client: IFFCO
- Location: Aonla
- Start-up: Dec 2006~
- CO2 Source: Nat. Gas Reformer
- Capacity: 450 t/d
- Product: Urea

**Japan**
- Client: Chemical Co.
- Start-up: 2005~
- CO2 Source: Nat. Gas Boiler
- Capacity: 330 t/d
- Product: General use

**India**
- Client: IFFCO
- Location: Phulpur
- Start-up: Dec 2006~
- CO2 Source: Nat. Gas Reformer
- Capacity: 450 t/d
- Product: Urea

**India**
- Client: NFCL
- Start-up: Mar 2009~
- CO2 Source: Nat. Gas Reformer
- Capacity: 450 t/d
- Product: Urea
2. MHI’s Commercial Achievements

Map of MHI commercial CO2 capture plant sites

- 1999 Malaysia 200 Mt/d
- 2005 Japan 330 Mt/d
- 2006 India (Aonla) 450 Mt/d
- 2006 India (Phulpur) 450 Mt/d
- 2009 Bahrain 450 Mt/d
- 2009 Abu Dhabi 400 Mt/d
- 2009 India 450 Mt/d
- 2010 Pakistan 340 Mt/d
- 2010 Vietnam 240 Mt/d
- 2010 Vietnam 240 Mt/d
3. MHI’s long term 10 t/d CO2 capture demonstration tests from a coal fired boiler

Outline of the Demonstration Plant

**Plant Outline**

- **Solvent**: KS-1
- **Capacity**: 10 T/D
- **Feed Gas**: Coal Fired Boiler (14.1 v% CO$_2$)
- **Start-up**: July 2006
- **Location**: Nagasaki, Japan

<table>
<thead>
<tr>
<th>Table 1 Specifications of CO$_2$ recovery demonstration plant</th>
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<tbody>
<tr>
<td><strong>Items</strong></td>
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<tr>
<td>Installation location</td>
</tr>
<tr>
<td>Flue gas source</td>
</tr>
<tr>
<td>Amount of flue gas to be treated</td>
</tr>
<tr>
<td>CO$_2$ recovery efficiency</td>
</tr>
<tr>
<td>CO$_2$ recovery capacity</td>
</tr>
<tr>
<td>CO$_2$ concentration</td>
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<tr>
<td>Other impurities</td>
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<tr>
<td>Solvent</td>
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</table>
3. MHI’s long term 10 t/d CO2 capture demonstration tests from a coal fired boiler

**Efficiency and capacity of CO2 recovery**

1. CO₂ recovery efficiency > 90%
2. CO₂ recovery capacity exceeded our expectations following >5,000hrs of demonstration operation

![Graph showing CO₂ recovery efficiency and capacity over time](image)
3. MHI’s long term 10 t/d CO₂ capture demonstration tests from a coal fired boiler

Heat consumption & Product Quality

Specific heat consumption required for CO₂ Recovery
Approx. 750 kcal/kg-CO₂ (730-820 kcal/kg-CO₂)

- Higher performance than that for natural-gas-fired boiler case
- Improved process reduces steam heat input by a further 15%
  (630-700 kcal/kg-CO₂)

Recovered CO₂ Product Purity

<table>
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<tr>
<th>Actual performance of commercial plant with a natural-gas-fired boiler</th>
<th>Actual performance of this demonstration plant</th>
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<tr>
<td>99.9 % or more</td>
<td>99.9 % or more</td>
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MHI’s CO₂ Recovery process applied to a coal fired boiler achieves a high CO₂ product purity
### Coal Fired Long Term Demonstration Plant - Results

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Result</th>
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<tbody>
<tr>
<td>• Achieve long term stable operation</td>
<td>✓ &gt;5000 hours of near continuous operation</td>
</tr>
<tr>
<td>• Confirm effect of various impurities on CO2 capture process &amp; equipment</td>
<td>✓ Advanced know-how of the impacts of dust, SO2 and NOx</td>
</tr>
<tr>
<td>• Achieve high CO2 purity performance</td>
<td>✓ &gt;99.9% achieved</td>
</tr>
<tr>
<td>• Confirm heat consumption required for CO2 recovery</td>
<td>✓ 730-820 kcal/kg-CO2 (Improved process reduced by a further 15%)</td>
</tr>
<tr>
<td>• Record pressure loss observed in the cooler and absorber</td>
<td>✓ No major pressure fluctuations</td>
</tr>
<tr>
<td>• Confirm process can be applied to coal fired flue gas</td>
<td>✓ Yes - KM-CDR Process can be applied to coal fired power stations</td>
</tr>
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</table>

**Graphs:**
- **Flue gas cooler pressure loss**
- **Absorber pressure loss**
4. Large Scale Plant Design

Multi-Pollutant Test Plant (FGD & CO2 Capture) Absorber 1 by 1 Scale Test Facility (400 MW equivalent)

Commercial Scale Tests Conducted:
- Extensive Liquid Distribution Tests
- Rectangular Absorber
- Panel Design
5. Process Improvements

- MHI is continuing work on various process improvement initiatives aimed at further reducing the heat input for CO2 regeneration and thus reducing the cost, energy penalty impact and environmental emissions of PCC.

- New heat optimization system in CO2 recovery process can achieve approximately 10% steam consumption reduction over MHI’s improved process.
6. Phased approach to commercialization for Coal application

MHI’s roadmap to commercialization for coal fired boilers

MHI’s Operating Experience

- Pilot plants (1-2 t/d)
- Small scale demonstration plant (10 t/d)
- Commercial plants (200-450 t/d)
- Experience with natural gas and coal
7. Conclusions

(1) MHI has an extensive PCC R&D History - over 17 years

(2) MHI has multiple commercial delivery of PCC plants (up to 450 t/d scale)

(3) CO$_2$ capture was successfully demonstrated on coal fired flue gas using a 10 t/d test plant located in southern Japan

(4) MHI has experiences in large structured packing absorber for FGD and large CO2 stripper.

(5) MHI has developed energy saving processes that further reduce the energy penalty of PCC on the power plant.

(6) Medium scale demonstration of PCC, including US demonstration (500t/d) which is under construction and expected on stream in 2011, is the next important step leading to commercialization of the technology for coal fired boilers.

(7) MHI continues development of energy efficient solvents and processes leading to reliable commercial CO$_2$ capture solutions for fossil fuel power generation sector.

MHI’s CO$_2$ recovery process will provide an important counter measure against global warming