Development of Amine Absorbents for Post-Combustion Capture

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**Project overview**

**A-COS Project** (Development of an Advanced CO$_2$ Capture System)

Project Leader: KEPCO Research Institute

Research Periods: NOV, 2008 ~ OCT, 2014 (7 Years)

Financially supported by the Korean government & participating companies

Participants:
KEPCO, KEPCO E&C, Daelim co. Posco Power and 5 Power companies
KEPCO (Korea Electric Power Company)

**Major Business**

Transmission & Distribution
100% market share in Korean power market

**Generation**
92% market share in Korean power market

**Others**

1. KEPCO E&C (77.9%)
   - Engineering Service
2. KEPCO NF (96.4%)
   - Nuclear Fuel
3. KEPS
   - Maintenance & Repair
4. KEPCO KPS (75.0%)
   - IT Service
5. KEPCO KDN (100%)
6. Kdn
   - Mobile & Internet Service
7. KPS
   - Import & Supply of LNG
8. LG U+ (7.5%)
   - Retail Metering
9. KEPID (29.0%)
   - KDHC (19.6%)
   - District Heating

KEPCO: Assets: W99.6 Trillion
Revenues: W39.4 Trillion

**GENCOs' Asset and revenues are as of Dec 31, 2010**

*% of KEPCO's ownership, Assets and Revenues as of Dec 31, 2010
** Including only major subsidiaries and affiliates of KEPCO other than 6 GENCOs
Overall objectives

- Develop post-combustion CO$_2$ separation technology by alkanolamine absorbents at coal-fired power station

- Develop absorbents with improved regeneration energy compared to MEA (Reduce regeneration energy more than 30% than MEA)

- CO$_2$ capture process design and demonstration plant construction (2 TPD CO$_2$ capture plant (2010), 200 TPD until 2013)
Strategy

1st Stage: `2008~11
- Test bed
  - 2 TPD Test bed
  - Develop advanced absorbent
  - Reduce regeneration energy

2nd Stage: `2012~14
- Pilot Plant
  - 200 TPD Pilot Plant
  - Search innovative absorbent
  - Process innovation

3rd Stage: `2015~20
- Demonstration
  - 100~300 MW

Goal
- Development of an Advanced CO₂ Capture System

Energy
- < 3.2 GJ/tonCO₂
- 2.5~3.0 GJ/tonCO₂
- < 2.5 GJ/tonCO₂
Location of test bed for CO$_2$ capture

- **Boryong Power Station**
  - branch of KOMIPO
  - 5,800 MWe (Coal)
  - CO$_2$ Capture Test Bed
  - 2TPD (2010), 200TPD (2014)

- **Seoul Power Plant**
  - branch of KOMIPO
  - 387 MWe (LNG)
  - CO$_2$ Capture Test Bed
  - 2TPD (2001)
Solvent development procedures

- Amine synthesis
- Commercial amines
- Reaction enthalpies

Fast Screening
(Over 500 amines)

Molecular modelling

V-L Equilibrium

Bench scale test
(2 m³/hr, 10 m³/hr)

- Degradation
- Corrosion
- Foaming properties
- Volatility

Pilot plant Test (2 TPD)

Solvent property measurement

Kinetics

Process simulation
(AspenPlus)

Economic Evaluation

Process simulation
(AspenPlus)
Research facilities

- Fast Screening
- V-L Equilibrium
- Degradation
- Corrosion

- CFD & Molecular simulation
- Bench unit
- Pilot plant (2TPD)
- Economic Evaluation
Test results: Screening test

- Quantification of an absorbent capacity
- Fast screening of candidate absorbents
Test results: Heat of Reaction

- KoSol series show lower heat of reaction than MEA
Test results: Degradation

Degradation

Oxidative degradation

Comparison of the solvent performance

KoSol Series are less degraded than MEA
Test results: Corrosion

Corrosion measurement:

- MEA: 60 mpy
- KoSol-4: 3~4 mpy
- KoSol Series: 93% lower corrosion rate than MEA (Test coupon: carbon steel at 120°C)

Optical analysis of the test coupons:

Before Test: MEA 30%
KoSol-3
KoSol-4

KoSol Series are less corrosive than MEA.
Test results: Bench-scale facility

Bench scale facility

Experimental Condition
- CO$_2$ concentration: 11~15%
- Gas volume: 2 m$^3$/h
- Reboiler: Electric heater
- Packing: Random packing

Experimental Condition
- CO$_2$ concentration: 11~15%
- Gas volume: 10 m$^3$/h
- Reboiler: Electric heater
- Packing: Random packing
Test results: Bench-scale facility

CO₂ Regeneration Energy (Bench scale test)

(CO₂ removal rate / CO₂ concentration in flue gas)

- MEA 30%: 3.85 GJ/ton CO₂
- KoSol-3: 2.83 GJ/ton CO₂
- KoSol-4: 2.52 GJ/ton CO₂

(92 / 14.7%)
(90 / 14.4%)
(90 / 14.9%)
Test results: 2TPD Test bed

- **2TPD Test bed**

- **Location:** Boryung power Plant, Korea
- **Capacity:** Flue gas 350 m$^3$/hr
  - CO$_2$ Recovery 2 Ton/day
- **Start Up:** 2010
- **Packing:** Random packed
Test results: 2TPD Test bed

Test Schedule

- Jan, 23rd: KoSol-3 campaign (1st, 68 days)
- Jan, 23rd ~ 28th: washing / solvent change
- March, 1st ~ 21st: MEA campaign (1st, 20 days)
- March, 22nd ~ 24th: washing / solvent change
- April 2nd ~ May 14th: Long run operation (KoSol-3, 1,000 hours, 43 days)

Test & Analysis

Key variable

DOE

Analysis

- Statistical analysis

Optimal Condition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Figures</th>
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<tbody>
<tr>
<td>Flue gas</td>
<td>Sm³/h</td>
<td>/</td>
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<tr>
<td>L/G</td>
<td>L/Sm³</td>
<td>/</td>
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<td>Stripper pressure</td>
<td>kg/cm²g</td>
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<td>Flue gas temp.</td>
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<td>Lean amine feeding</td>
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<td>Rich amine feeding</td>
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**Test results : 2TPD Test bed**

**Test Results (MEA_30% Campaign)**

- **CO₂ removal : 92.9%**
- **Regeneration Energy : 3.83GJ/tCO₂**
- **Steam consumption : 150kg/h**
Test results: 2TPD Test bed

Test Results (KoSol-3 Campaign)

CO₂ Removal rate (average): 90.6%

Regeneration energy: 3.0~3.2 GJ/tCO₂
Future plan: 200 TPD Pilot Plant

2TPD Test results

Basic Design

Layout Drawing

Economic Evaluation

200 TPD Pilot Plant Construction start at Jan, 2012
Conclusion & Future works

**Conclusion**

a. Development of advanced amine absorbents (KoSol-3) for CO$_2$ capture
   - Decreased regeneration energy
     - **BSU: 2.8 GJ/ton CO$_2$ / Test bed: 3.0~3.2 GJ/ton CO$_2$**
   - less corrosive than MEA

**Future works**

a. Process optimization (2TPD)
   - Random to Structured packing (Absorber)
   - Absorber Inter-cooling system
   - etc.

b. 200TPD Pilot plant construction
THANK YOU
FOR YOUR ATTENTION

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