CO$_2$ Capture in a 300 kW$_{\text{th}}$ Indirectly Heated Fluidized Bed Pilot Plant: Operating Experience and Results

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Outline

• Introduction

• Design of the 300kW\textsubscript{th} pilot plant

• Plant operating experience

• Results from operation

• Conclusions
Introduction

Process scheme

Decarbonized flue gas

Flue gas from power plant

CO₂ to compression

Standard carbonate looping

<table>
<thead>
<tr>
<th>Process Name</th>
<th>Temperature</th>
<th>Reaction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CARBONATOR</td>
<td>650 °C</td>
<td>CO₂ + CaO → CaCO₃ + Heat</td>
<td>CO₂ + CaO → CaCO₃ + Heat</td>
</tr>
<tr>
<td>CALCINER</td>
<td>900 °C</td>
<td>CaCO₃ + Heat → CO₂ + CaO</td>
<td>CaCO₃ + Heat → CO₂ + CaO</td>
</tr>
<tr>
<td>COMBUSTOR</td>
<td>1000 °C</td>
<td>Heat</td>
<td>Heat</td>
</tr>
</tbody>
</table>

- No oxygen for calciner → **high efficiency**
- No coal in calciner → **few impurities** (sulfur, ash), **low deactivation**
- Almost **pure CO₂** stream at calciner exit
- Very **high efficiency** (1-1.5 % points higher than for standard CaL)
300 kW<sub>th</sub> pilot plant

Process scheme

Energy Systems and Technology
Prof. Dr.-Ing. B. Epple

Patent number: EP 10 174 156.9
300 kW_{th} pilot plant

Overview

Carbonator:
- 300 kW_{th} flue gas load
- TSI = 30-60 kg (CaO/CaCO_{3})
- 80 % CO_{2}-capture

Calciner:
- Heat duty ~ 180 kW
- TSI ~ 400 kg (CaO/CaCO_{3})

Combustor:
- Thermal power ~ 310 kW
- Propane fired
- TSI ~ 600 kg (silica sand)
300kW th pilot plant
CaL reactor system

- CFB Carbonator
  - High carbonator velocities
  - High flue gas throughput
  - High gas-solid contact
  - Internal solids recirculation

- BFB Calciner
  - Low calciner velocities
  - High resident times
  - Low temperatures realizable
  - „Mild“ calcination conditions
  - Low attrition rates

- Coupling components made of heat resisting steel
300kW th pilot plant
Heat pipe heat exchanger (HPHE)
300kW<sub>th</sub> pilot plant
Heat pipe design

- Heat source
- Heat sink
- Liquid
- Vapor
- Capillary structure
- Combustor ~1000°C (Evaporation)
- Adiabatic section
- Calciner ~ 900°C (Condensation)
300\textsubscript{th} kW pilot plant
Impressions
Plant operating experience

Pressure profile CaL cycle

<table>
<thead>
<tr>
<th>Height [m]</th>
<th>Pressure [mbar]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonator</td>
<td>LS Int. Rec. Carb</td>
</tr>
<tr>
<td>L-Valve Carb-&gt;Calc</td>
<td>Calciner</td>
</tr>
</tbody>
</table>

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Plant operating experience
Temperature profile

Δt ≈ 100K
Results from operation

Overview

- > 500 hours of stable plant operation in 300 kW pilot
- > 300 hours of CO₂ capture with approx. 20 tons of CO₂ captured
- Maximum CO₂ capture rates > 90 % (av. around 80 %)
- Heat pipes worked excellently
- Maximum power in the combustor up to 370 kW
- Maximum heat transferred by heat pipes > 200 kW
Results from operation
Capture efficiency vs. temperature

- Each data point is steady state for at least 1 hour
- Capture efficiency w/o cooling system up to 70 %
- Capture efficiency w/ cooling system up to 80 %
- Capture efficiency w/ realistic flue gas > 90 %
- \( \text{H}_2\text{O} \) volume flow limited due to steam generator

\( \rightarrow \) Steam has a very positive effect on the \( \text{CO}_2 \) capture efficiency
Conclusions and outlook

Feasibility of the indirectly heated carbonate looping process successfully demonstrated in a 300kW\textsubscript{th} pilot plant

• > 500 hours of coupled fluidized bed operation
• > 300 hours of stable CO\textsubscript{2} capture
• CO\textsubscript{2} capture efficiency > 90 % achieved
• Pilot plant hydrodynamically stable
• Heat pipes show excellent performance

Further work

• Long-term pilot testing
• Coal and biomass combustion for heat generation
• Concepts for CO\textsubscript{2} capture from lime and cement industry
• Scale-up of the process
Acknowledgements

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Questions?

300kW\textsubscript{th} indirectly heated CaL pilot plant

1MW\textsubscript{th} standard CaL pilot plant

CaL test facility at TUD