CO$_2$ Absorption Pilot Plant – Design, Commissioning, Operational Experience, and Applications

Agnes von Garnier, Dr. Andreas Orth and Tobias Stefan, Outotec GmbH
Dr. Volker Giesen and Raquel Fernández Rodiles, BASF SE

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CO₂ scrubbing unit

CO₂ scrubbing

Gas cleaning

CFB pilot plant
Outline

- Objective: demonstration of Circofer® process
- Integration in Circulating Fluidized Bed (CFB) pilot plant
- Design aspects
- Commissioning and first operational experience
- Further plant applications
Options for iron and steelmaking

**Electric steelmaking**

- Scrap (+ pig iron)
- Fine ore
- Lump ore
- Coal
- Pelletizing plant
- Shaft furnace
- Electric arc furnace (EAF)
- Steel
- H₂

**Oxygen steelmaking**

- Conventional blast furnace
- Coal
- Lump ore
- Sinter/pelletizing plant
- Blast furnace
- Hot metal
- Oxygen converter (BOF)
- Steel
- Scrap
- 65%
- O₂

- Smelting reduction
- Fine ore and coal
- Air / O₂
- Coal
- Circofer® (1 stage)
- Hot DRI and char
- AusIron
- Slag
- Hot metal
- Steel
- Pig iron

**Circored®**
- Natural gas
- DRI/HBI
- 5%
- 30%

**Circofer®**
- H₂

**ICEPE June 22, 2011 – CO₂ absorption pilot plant**
Outotec’s direct reduction processes

Iron ore
- Lumps
- Fines

Reductant
- Coal
- Gas

Process
- SL/RN
- Circofer
- Circored

Product
Direct reduced iron (DRI)
Circofer process flowsheet

Coal & Iron ore

Coal crushing & drying

Pneumatic transport

Stage I

Preheating

Stage II

Heat generator

Steam boiler

Boiler feed water

Multiclone

Venturi scrubber

Steam to CO₂ scrubbing

CO₂ scrubbing

CO₂

Steam

Hot compaction

Air, O₂, coal

Offgas to waste heat recovery

Process gas compressor

Ausiron

Flash reactor

N₂

Process gas heater

Pig iron

Slag

Air

O₂ generator

Gas

Solids
700 mm CFB pilot plant
Integration in CFB pilot plant

Operation with H₂ as fluidization gas, open circuit
Integration in CFB pilot plant

Operation in closed circuit, fluidization with recycling gas

Pilot plant expansion 2009-2010

CO\textsubscript{2} absorption pilot plant

Compression

Scrubbing

Cooling

Pilot plant expansion 2009-2010

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Gas preparation

- Compression to approx. 5 bar
  - 355 kW liquid ring compressor
    - No temperature increase
    - Decreasing dust load

- Gas cleaning and cooling
  - New high pressure scrubber (Outotec design)
  - Gas cooler
CO$_2$ absorption pilot plant

CO, H$_2$, N$_2$ < 1 % CO$_2$

5 bar

1.3 bar

CO$_2$ Absorber

Reflux Drum

Gas Condenser

Closed Circuit Cooling Water Supply

After Burning Chamber

Fresh aMDEA$^\text{TM}$ distilled H$_2$O

Reboiler

anti-foaming agent

from CFB Plant
to CFB Plant

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CO₂ absorption pilot plant under construction
Commissioning

- During coal gasification test campaign
  - up to 750 Nm$^3$/h tar and dust loaded gas
  - CO$_2$ removal efficiency > 80%
  - CO$_2$ content in incoming gas significantly higher than design
  - Filters successfully removed solids and tars

- During Circofer test campaign
  - < 0.5 % CO$_2$ in recycled gas
  - CO$_2$ removal efficiency > 95%
  - 100 Nm$^3$/h scrubbed gas recycled to CFB via electrical gas heater
  - additional N$_2$ added for sufficient fluidization
Commissioning during Circofer campaign

Typical operational data

<table>
<thead>
<tr>
<th>gas</th>
<th>after liquid ring compressor</th>
<th>after CO₂ absorption unit</th>
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</thead>
<tbody>
<tr>
<td>temperature</td>
<td>° C</td>
<td>50</td>
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<tr>
<td>pressure</td>
<td>kPag</td>
<td>450</td>
</tr>
<tr>
<td>volume flow</td>
<td>Nm³/h</td>
<td>400</td>
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<td>gas composition (dry)</td>
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<td></td>
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<tr>
<td>CO₂</td>
<td>%-vol.</td>
<td>13.5</td>
</tr>
<tr>
<td>CO</td>
<td>%-vol.</td>
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<tr>
<td>H₂</td>
<td>%-vol.</td>
<td>12.2</td>
</tr>
<tr>
<td>CH₄</td>
<td>%-vol.</td>
<td>1.0</td>
</tr>
<tr>
<td>O₂</td>
<td>%-vol.</td>
<td>0.1</td>
</tr>
<tr>
<td>N₂</td>
<td>%-vol.</td>
<td>Balance</td>
</tr>
</tbody>
</table>
Commissioning during Circofer campaign

Typical transient behavior during start-up of CO₂ scrubbing plant

![Graph showing gas composition over time](image-url)
Conclusion and further plant capabilities

Features
- CO$_2$ and H$_2$S co-absorption
- Tars and dust load can be handled

Applications
- Cleaning of process gases from
  - Iron ore direct reduction
  - Coal and biomass gasification
- Development of Outotec‘s sustainable energy technologies
- Reduce carbon footprint
  - coal and biomass based energy production
  - oil winning from oil shale (Enefit process)
- Carbonate Looping, Oxyfuel

Removed gas to be used
- in other processes
- for underground storage (CCS)