Pilot plant results for advanced CO$_2$ capture process using amine scrubbing

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General information

- **Project name:**
  Development of a technology for highly efficient zero-emission coal-fired power units integrated with CO₂ capture.

- **Objective:**
  Basic aim of this stage of research is to elaborate and test the CO₂ capture process from exhaust gases of working power unit on pilot scale.

- **Principal:**
  National Research and Development Center (Poland)

- **Project duration:**
  1.04.2010 – 31.03.2015 (60 months)

- **Executors:**
  TAURON Polish Energy, TAURON Production, Institute for Chemical Processing of Coal (ICPC)
Clean Coal Technology Centre in Zabrze (Upper Silesia, Poland)
About TAURON Polish Energy

TAURON Polish Energy is a corporation grouping Polish companies from the energy sector and is the second (after Polish Energy Group) in terms of size as an electricity producer in Poland.

Companies included in TAURON Polish Energy:
- TAURON Production consists of 7 electric facilities, which produce electricity and steam from fossil fuels (4,671 MWe electric power installed and 1,496 MWt thermal power reachable).
- TAURON Ecoenergy consists of 35 hydroelectric power plants and 4 wind farms (133 MWe).
- Southern Carbon Concern involved in coal mining (2 hard-coal mines).
- Others companies involved in energy and heat sales and distribution.
About TAURON Production – electric facilities

- Electric power installed: 330 MWe
  Maximal thermal power: 465.9 MWt
- Electric power installed: 165 MWe
  Maximal thermal power: 85 MWt
- Electric power installed: 1155 MWe
  Maximal thermal power: 196 MWt
- Electric power installed: 1535 MWe
  Maximal thermal power: 371.6 MWt
- Electric power installed: 666 MWe
  Maximal thermal power: 36.5 MWt
Stage realization procedure scheme

- Literature data analysis
- ICHPW studies for industry
- Design office support
- Center of Clean Coal Technologies, ICHPW

PBZ „Coal Chemistry”

Laboratory research

Modelling and optimization

- Assumptions for pilot plant
- Research program
- Data analysis

Construction of pilot plant

Pilot research

- Assumptions for Demonstration Plant
- Design office support
- Experts’ support

Absorbent selection

Participation of Tauron

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ICPC CO₂ capture process scale-up strategy

Experimental apparatus of CO₂ absorption kinetics and equilibrums in amine blends

Lab stand for CO₂ capture process – 5 m³/h

PDU for CO₂ capture process – 100 m³/h (ICPC Zabrze)
The Mobile Pilot Plant flow diagram
Pilot Plant location at Łaziska Górne, Poland
The Mobile Pilot Plant commissioning – 26.04.2013
Łaziska Górne Power Plant (TAURON)

- Column diameter: 300 mm
- Column height: 15,0 m
- Number of devices: 40
- Measurements: 180 points
- Solvent: 30% MEA solution
- Solvent stream: up to 1600 dm³/h
- Gas stream: up to 200 m³/h
- Tested gas: Flue gases from pulverized hard-coal boiler
Pilot Plant research at TAURON Power Plant (Łaziska Górne)

Key process parameters at steady-state:
- CO₂ outlet stream [kg/h]
- Stripper’s top temperature [°C]
- Flue gas inlet stream [kg/h]
- Inlet CO₂ concentration [% vol.]
- Outlet CO₂ concentration [% vol.]
Test results – campaign 10

- CO$_2$ removal rate [%]
- CO$_2$ concentration [% vol.]
- Regeneration energy demand [MJ/kgCO$_2$]
- Effect of heating power
- Effect of absorption pressure
- Effect of desorption pressure
- Effect of absorption temp.
- L/G ratio

<table>
<thead>
<tr>
<th>CO$_2$ removal rate [%]</th>
<th>CO$_2$ concentration [% vol.]</th>
<th>Regeneration energy demand [MJ/kgCO$_2$]</th>
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<tbody>
<tr>
<td>96.3</td>
<td>3.83</td>
<td>11.72</td>
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<tr>
<td>94.2</td>
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<tr>
<td>10.21</td>
<td>3.92</td>
<td>10.21</td>
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Effect of CO$_2$ inlet stream concentration on removal rate and regeneration energy demand

![Graph showing CO$_2$ removal rate and reg. energy demand as a function of CO$_2$ inlet stream concentration.](image)

- CO$_2$ removal rate:
  - 90.9%
  - 93.3%
  - 96.6%

- Reg. energy demand:
  - 3.88%
  - 4.50%
  - 5.32%

CO$_2$ inlet stream concentration [% vol.]:
- 12.17%
- 9.94%
- 8.14%
Effect of L/G absorber load ratio on removal rate and regeneration energy demand
Effect of reboiler heat duty on removal rate and regeneration energy demand

CO$_2$ removal rate

CO$_2$ concentration

Reg. energy demand

Reboiler heat duty [kW]

% vol CO$_2$

CO$_2$ concentration

Reg. energy demand

Reboiler heat duty [kW]
Split streams versus single stream amine configuration

Split streams process configuration (Case A)

Single stream process configuration (Case B)

Single stream to the top of absorber process configuration (Case C)
Split streams versus single stream amine configuration-streams CO$_2$ fraction

**Case A**
- Inlet stream: 13.48
- Middle of the absorber: 10.45
- Outlet stream: 1.84

**Case B**
- Inlet stream: 13.48
- Middle of the absorber: 7.01
- Outlet stream: 1.99

**Case C**
- Inlet stream: 13.44
- Middle of the absorber: 6.18
- Outlet stream: 2.69

Lean stream to top and semi-lean to middle of absorber
Lean stream directed to top and middle of absorber
Lean stream to top of absorber
Split streams versus single stream amine configuration-results

<table>
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<tr>
<th>Scenario</th>
<th>CO₂ Removal Rate</th>
<th>CO₂ Concentration</th>
<th>Reg. Energy Demand</th>
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<tbody>
<tr>
<td>Case A</td>
<td>88.6</td>
<td>13.48</td>
<td>3.78</td>
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<tr>
<td>Case B</td>
<td>87.8</td>
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<tr>
<td>Case C</td>
<td>83.6</td>
<td>13.44</td>
<td>3.98</td>
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</table>
Effect of regenerator internal heating on removal efficiency and regeneration energy

- CO₂ removal rate: With regenerator internal heaters - 91.4%, Without - 84.4%
- CO₂ concentration and Reg. energy demand: With - 11.26% and 3.80, Without - 11.21% and 3.90
### Mobile Pilot Plant research summary at TAURON facilities

#### 2013 Łaziska Górne Pilot Plant research summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Number of campaigns</td>
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<tr>
<td>Number of tests</td>
<td>118</td>
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<tr>
<td>Operation time</td>
<td>550 h</td>
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<tr>
<td>CO₂ removed</td>
<td>approx. 20000 kg</td>
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</table>

#### 2014 Jaworzno Pilot Plant research summary

<table>
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<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
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<td>Number of campaigns</td>
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<tr>
<td>Number of tests</td>
<td>110</td>
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<tr>
<td>Operation time</td>
<td>400 h</td>
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<tr>
<td>CO₂ removed</td>
<td>approx. 17600 kg</td>
</tr>
</tbody>
</table>
Operational difficulties

- CO₂ concentration fluctuations in inlet flue gas stream
- Inlet flue gases pipeline drainage
- Additional Venturi scrubber demister due to flue gases moisture
- Rapid corrosion in blower
Block diagram of demo CCS PLANT

Integration with Power Plant

Desulfurization

Amine scrubbing

CO₂ compression

Demo Plant Capacity = 175 tonnes of CO₂/h
Summary

- Plants are remarkable organisms capable of carrying out complex processes with facile operation.
- Extending the idea of photosynthesis, they can use carbon dioxide to produce oxygen, which is essential for life on Earth.
- This process is not only limited to the photosynthesis within plants but can also be extended to other renewable energy sources such as algae and biofuels.
- The benefits of using renewable energy sources are numerous, including reduced carbon footprint, increased energy security, and economic growth.
- Technological advancements in the field of renewable energy have led to the development of new materials and processes that can enhance efficiency and reduce costs.
- The Institute of Chemical Processing of Coal has been recognized for its contributions to the field with the Grand Prix at the EXPOCHEM 2013 event.
- The award recognizes the institute’s work in developing carbon capture technology and providing services such as research, training, and expert advice.
- The Institute’s efforts in advancing the field of chemical processing of coal are commendable and set a benchmark for future research and development in the industry.
**STRATEGIC RESEARCH PROGRAM – ADVANCED TECHNOLOGIES FOR ENERGY GENERATION**

**TASK No. 1** – „Advanced technologies for energy generation: Development of a technology for highly efficient zero-emission coal-fired power units integrated with CO₂ capture”

Project co-financed by the National Centre of Research and Development in the framework of Contract SP/E/1/67484/10, dated 05 May 2010.

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Thank you for attention