AMP/PZ emissions

Maasvlakte pilot plant measurements and modelling

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Content

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  › Measurement campaign: corrosion, performance, emissions
  › Pilot configuration and measurement set-up
  › Settings
  › Results AMP/PZ

› Aspen Plus modelling
  › Comparison with literature
  › Comparison with pilot plant
  › Modelling of a double washing section
Pilot plant measurement set-up
Pilot plant measurement set-up

Flue gas details:
Connected to coal fired power plant
1250 m³/h flue-gas (@ 12% CO₂)
250 kg/h CO₂ capture
90% of CO₂ capture

Absorber:
8 m height
Dumped Packing: IMTP 50
Diameter: 650 mm

Wash section:
2 m height
Dumped Packing: IMTP 50
Cooled water recycle over bed
Pilot plant measurement set-up

- FT-IR (Laborelec) connected to clean gas exhaust of the pilot.
Settings

- Operation near 90% capture
- Variation of absorber temperature and wash water flow

Settings used:

<table>
<thead>
<tr>
<th>Wash flow (l/min)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean T (°C)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>max</th>
<th>20</th>
<th>10</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>0</th>
<th>10</th>
<th>20</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

- Each setting maintained for 30-50 minutes
Pilot plant measurement set-up

- Measurement conditions:
  - Environmental permitting delayed until winter:
  - Demi water etc. frozen in periods of frost
Results: accuracy of readings

- Temperatures [°C], condensate tank level [%], PZ [mg/Nm³]

Flow: 0 10 20 max max 20 10
T: 40 40 40 40 35 35 35

AMP [mg/Nm³]

T: bed top T
T abs. out
condensate tank level
PZ
AMP

Flow: 0 10 20 max max 20 10
T: 40 40 40 40 35 35 35

AMP [mg/Nm³]

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T abs. out
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AMP [mg/Nm³]

T: bed top T
T abs. out
condensate tank level
PZ
AMP
## Results

› Process trends

(more results in modelling section)

<table>
<thead>
<tr>
<th>T&lt;sub&gt;lean&lt;/sub&gt; AMP-PZ °C</th>
<th>40</th>
<th>40</th>
<th>40</th>
<th>35</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wash flow l/min.</td>
<td>10</td>
<td>20</td>
<td>max</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>T abs. gas out °C</td>
<td>50.2</td>
<td>46.6</td>
<td>46.0</td>
<td>39.8</td>
<td>50.7</td>
</tr>
<tr>
<td>T top abs. bed °C</td>
<td>53.4</td>
<td>52.8</td>
<td>53.0</td>
<td>45.8</td>
<td>57.3</td>
</tr>
<tr>
<td>T wash-liq. in °C</td>
<td>29</td>
<td>38</td>
<td>39</td>
<td>34</td>
<td>40</td>
</tr>
<tr>
<td>H&lt;sub&gt;2&lt;/sub&gt;O vol%</td>
<td>11.7</td>
<td>9.9</td>
<td>9.4</td>
<td>6.9</td>
<td>11.8</td>
</tr>
<tr>
<td>AMP mg/Nm&lt;sup&gt;3&lt;/sup&gt;</td>
<td>233</td>
<td>113</td>
<td>94</td>
<td>45</td>
<td>159</td>
</tr>
<tr>
<td>PZ mg/Nm&lt;sup&gt;3&lt;/sup&gt;</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Capture percentage</td>
<td>92</td>
<td>89</td>
<td>88</td>
<td>88</td>
<td>89</td>
</tr>
</tbody>
</table>
Results: AMP trends

AMP emission

Lean temperature

AMP emission mg/Nm³

T over wash section [°C]
Results: AMP trends

Absorber top temperature

Lean temperature

Absorber top temperature (gas-phase) [°C]

T over wash section [°C]
Aspen Plus modelling

- Starting point: merged, unaltered AMP-PZ model (Aspen Plus)
- Comparison pure component vapour pressures with literature: exact match
- Model structure
- Comparison with pilot
Aspen modelling: model set-up

- Only absorber and wash section modelled
- Wash section: 2 equilibrium stages
- Absorption: 3 stages at 70% of equilibrium: ~90% capture
- Emissions very temperature dependent: absorber top temperature and Cleangas out temperature are input (solvent flow and wash flow used to attain T’s)
- All parameters of column input streams are input data to simulation (except for solvent and wash flows)
Aspen modelling

Results one setting:
~25 l/min wash, lean T: 40°C
Aspen modelling

- **Results at 40°C lean temperature** *(blue numbers: model)*
  - Capture trend OK
  - Calculated wash- and lean solvent flows near to pilot readings
  - Absolute value AMP emission close to Aspen readings
  - The AMP results of model and pilot being close *indicates* that no significant entrainment has occurred.

<table>
<thead>
<tr>
<th>T(lean) °C</th>
<th>Wash flow l/min</th>
<th>AMP mg/Nm³</th>
<th>PZ mg/Nm³</th>
<th>H₂O vol%</th>
<th>Capture %</th>
<th>Tg Abs, out °C</th>
<th>Tg wash out °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>10</td>
<td>233</td>
<td>12</td>
<td>11.7</td>
<td>92%</td>
<td>50.2</td>
<td>53.4</td>
</tr>
<tr>
<td>40</td>
<td>8.4</td>
<td>273</td>
<td>22</td>
<td>12.2</td>
<td>90%</td>
<td>50.2</td>
<td>53.9</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
<td>113</td>
<td>14</td>
<td>9.9</td>
<td>89%</td>
<td>46.6</td>
<td>52.8</td>
</tr>
<tr>
<td>40</td>
<td>max</td>
<td>119</td>
<td>10</td>
<td>10.3</td>
<td>90%</td>
<td>46.6</td>
<td>53.1</td>
</tr>
<tr>
<td>40</td>
<td>26.4</td>
<td>94</td>
<td>15</td>
<td>9.4</td>
<td>88%</td>
<td>46.0</td>
<td>53.0</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>102</td>
<td>8</td>
<td>10</td>
<td>90%</td>
<td>46.0</td>
<td>53.1</td>
</tr>
</tbody>
</table>
Aspen modelling

Results summary: parity plots

- Good fit AMP results
- PZ: range is OK
Aspen modelling

Results for a double washing section

- Washing sections do not work if they are not cooled or fed with clean water
- Very high AMP and PZ washing efficiency possible
- Wash flow and cooling duty very high: optimisation needed
  (extra benefit: closed water balance)

Result for 800 MW ASC with capture plant:

<table>
<thead>
<tr>
<th>section:</th>
<th>Absorption</th>
<th>lower wash</th>
<th>higher wash</th>
</tr>
</thead>
<tbody>
<tr>
<td>T gas out °C</td>
<td>60</td>
<td>47</td>
<td>35</td>
</tr>
<tr>
<td>T liquid in °C</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>liquid feed flow kg/s</td>
<td>1300</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>AMP mg/Nm³</td>
<td>3875</td>
<td>46</td>
<td>0.16</td>
</tr>
<tr>
<td>PZ mg/Nm³</td>
<td>298</td>
<td>1.4</td>
<td>0.00</td>
</tr>
</tbody>
</table>
General conclusions

› Operation near steady state due to short measurement times

› Some fluctuations in especially PZ emission, likely due to stripper operation.

› Fair washing efficiencies for AMP with different wash water flows

› Emission could be lowered further with more cooling

› Results Aspen simulation in fair agreement with pilot results
  › An indication that entrainment is very limited: further research needed
  › Aspen can be used to evaluate double wash section for AMP/PZ
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The research leading to these results has received funding from the projects CESAR and CLEO.

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