Flue-Gas Water as a Resource for Carbon-Capturing Power Plants

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Basic Process Outline

• Combust fuel in directly-supplied (not air-carried) oxygen.
  – Undiluted products of combustion

• Capture combustion products to capture the CO₂ component

• Cooling and compression (part of the capture process) produce condensed flue-gas water
Combustion Products

air-firing

- CO₂ 13.7%
- H₂O 9.2%
- N₂ 73.4%
- O₂ 3.5%
- SO₂ 0.2%

oxy-firing

- CO₂ 60.8%
- H₂O 32.7%
- N₂ 2.1%
- O₂ 3.5%
- SO₂ 0.9%
Water/energy: The Oxy-Combustion with Integrated Pollutant Removal (IPR) effort

- Water previously released to the atmosphere now presents a resource
  - Energy (heat recovery)
  - Heat-exchange medium
  - Combustion-optimization (completion of combustion)
Air-Firing

Combustion products

Boiler

Air to move fuel

Air for O₂

Fuel
Air-Firing

- Coal chemical energy
- Heat to Steam
- Generator Output
- Boiler/UBC loss
- Thermodynamic Loss
- Sensible Stack Heat loss
- Latent Stack Heat Loss
- Flue Gas Treatment
Oxy-Firing/IPR

- Energy released in combustion is recovered through integration of feedwater heating and flue-gas cooling.
- Water is a by-product of this energy recovery.
Oxy-Firing/IPR

Recovered thermal power from oxygen plant

Boiler/UBC loss

Oxygen Plant Power

Generator Output

Coal chemical energy

Heat to Steam

Recovered Thermal Power From Compression And Exhaust Stream

Latent Exhaust Heat Content

Sensible Exhaust Heat Content

Compression Power

Exhaust Compression Loss
Water Opportunities

- Pollutants that now interact with atmospheric water are capturable from point-source liquid water
- Correctly applying recovered energy and water within the thermal cycle can maximize fuel efficiency (more fully using the energy entering with the fuel)
- Flue-gas water massflow offsets massflow of water required for thermal power production
Questions for research

- Highly-efficient purification processes for released water
- Optimal full-use applications for recovered water
- Economic opportunities for material recovered during water purification
What we are finding in IPR

• May be able to use less water in Flue-Gas Desulphurization (FGD)
  – Sulfur capture effective at pressure
• Species reporting at intercooler locations
Recovering Water – Process Condensates

From H1

- Ba, 0.09
- Ca, 68
- Cr, 40
- Cu, 2.5
- Fe, 232
- Hg, 0.091
- Mo, 5.7
- Ni, 26
- NO3, 118,073
- SO4, 64,377
- Zn, 4.1

The graph shows the concentration of various elements in parts per million (ppm) extracted from H1. The pH is also indicated.
Recovering Water – Process Condensates

From V4

- Ca, 75 ppm
- Ba, 0.05 ppm
- Cl, 9.3 ppm
- Cr, 13 ppm
- Fe, 163 ppm
- Hg, 3.2E-04 ppm
- Ni, 6.6 ppm
- NO3, 994 ppm
- SO4, 3,025 ppm
Recovering Water – Process Condensates

From V8

- Ca, 81 ppm
- Cr, 3.0 ppm
- Cu, 0.9 ppm
- Fe, 2.9 ppm
- Mg, 3.9 ppm
- Mo, 2.0 ppm
- Na, 10,853 ppm
- NO₂, 1,437 ppm
- NO₃, 4.0 ppm
- SO₄, 13,375 ppm
- Solids, 699 ppm

pH
One Possible Approach

- Combustion products, entraining fine particulate (not caught in cyclone) sent counter-current to flue-gas-water spray to remove the bulk of the particles left.
  - Scrubber may employ bases to react with the SOx if needed.
One Possible Approach

- The scrubber traps gas constituents that are water soluble as well as chemicals that leach out of the particles trapped in the scrubber.
  - Particles trapped by the scrubber are filtered out.
  - Scrubber water $\rightarrow$ Treat for reuse as spray
One Possible Approach

- Treatment for water-offset applications
  - pH-swing precipitation and filtration
  - Demineralization (using ion exchange resins)
  - Testing for usage
  - Reuse in the cooling loop (IPR, or Plant at large)
  - Release
Summary

- Recovering energy leads to recovering water
- Water removes pollutants from $\text{CO}_2$
- Chemically adjusting water for thermal-cycle application
- Preventing release of those pollutants with returned water
Thank you for your attention.
## Exhaust Composition

<table>
<thead>
<tr>
<th></th>
<th>Conventional after economizer</th>
<th>Oxyfuel exhaust after splitter</th>
<th>After 1&lt;sup&gt;st&lt;/sup&gt; compression</th>
<th>After 2&lt;sup&gt;nd&lt;/sup&gt; compression</th>
<th>After 3rd compression</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas Flow (kg/hr)</strong></td>
<td>1,716,395</td>
<td>409,083</td>
<td>364,367</td>
<td>354,854</td>
<td>353,630</td>
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<tr>
<td><strong>Vol flow (m³/hr)</strong></td>
<td>1,932,442</td>
<td>483,092</td>
<td>72,623</td>
<td>15,944</td>
<td>661</td>
</tr>
<tr>
<td><strong>Inlet Pressure (psia)</strong></td>
<td>14.62</td>
<td>15.51</td>
<td>62</td>
<td>264</td>
<td>1,500</td>
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<tr>
<td><strong>Inlet Temperature (°F)</strong></td>
<td>270</td>
<td>500</td>
<td>342</td>
<td>323</td>
<td>88.2</td>
</tr>
<tr>
<td><strong>Density (kg/m³)</strong></td>
<td>0.8882</td>
<td>0.8468</td>
<td>5.017</td>
<td>22.26</td>
<td>534.6</td>
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<tr>
<td><strong>H₂O (fraction)</strong></td>
<td>0.0832</td>
<td>0.3322</td>
<td>0.0695</td>
<td>0.00994</td>
<td>0.0004</td>
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<tr>
<td><strong>Ar (fraction)</strong></td>
<td>0.0088</td>
<td>0.0115</td>
<td>0.0163</td>
<td>0.01730</td>
<td>0.0175</td>
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<tr>
<td><strong>CO₂ (fraction)</strong></td>
<td>0.1368</td>
<td>0.6131</td>
<td>0.8662</td>
<td>0.92161</td>
<td>0.9305</td>
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<tr>
<td><strong>N₂ (fraction)</strong></td>
<td>0.7342</td>
<td>0.0090</td>
<td>0.0128</td>
<td>0.01359</td>
<td>0.0137</td>
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<tr>
<td><strong>O₂ (fraction)</strong></td>
<td>0.0350</td>
<td>0.0250</td>
<td>0.0353</td>
<td>0.03755</td>
<td>0.0379</td>
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<tr>
<td><strong>SO₂ (fraction)</strong></td>
<td>0.0020</td>
<td>0.0091</td>
<td>0.0000</td>
<td>0.00000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>