Experiences in commissioning and operation of CIUDEN's Technological Development Plant under oxycombustion conditions

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Commissioning & Experimental activities

Test facility description - CFB schematic diagram

Challenges faced
- Air in-leakage / Infiltrations
- Leakages
- Temperature losses

Lessons learnt - Corrective actions adopted
Commissioning & Experimental activities

FIRST OPERATIONAL EXPERIENCES AT CIUDEN’S CENTRE

Fuels

<table>
<thead>
<tr>
<th>Blend</th>
<th>Anthracite 70% w</th>
<th>Pet-coke 30% w</th>
<th>Oxycombustion hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blend 1</td>
<td>Anthracite / pet-coke 20/80 (% w)</td>
<td></td>
<td>900</td>
</tr>
<tr>
<td>Blend 2</td>
<td>Anthracite 50% w</td>
<td>Pet-coke 50% w</td>
<td>900</td>
</tr>
<tr>
<td>Blend 3</td>
<td>Anthracite 80% HV</td>
<td></td>
<td></td>
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<tr>
<td>Blend 4</td>
<td>Biomass 20% HV</td>
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</tbody>
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MORE THAN 2,000 OPERATING HOURS IN OXYCOMBUSTION!

Fuels

BLEND 1 Anthracite 70% w Pet-coke 30% w BITUMINOUS

BLEND 3 Anthracite 80% HV

BLEND 2 Anthracite 50% w Pet-coke 50% w

BLEND 4 Biomass 20% HV

SUB-BITUMINOUS COAL

COLD COMMISSIONNING:
- Signals tested
- Control loops adjustment
- All systems in operation

First Fire with coal: June 2011

HOT COMMISSIONNING:
- Different functionality test carried out
- Tuning of controls
- Steady state conditions
- Smooth transition between air-oxi modes with automatic control

First test in oxycombustion: November 2011

FLEXIBURN

Demonstration of flexible high-efficiency CFB combustion technology in air and oxy-modes for CCS

Total hours of operation > 1,500
Total hours in oxycombustion mode > 900

Technologies development for CO₂ oxy capture, inland transport and storage in deep saline aquifer formation supporting FID of a demo 300 MWe Circulating Fluidised Bed (CFB) supercritical oxycombustion plant.

Total hours of operation > 1,300
Total hours in oxycombustion mode > 900

CIUDEN Ponferrada, 9th – 13th September 2013
es.CO$_2$ - Schematic diagram

1. Fuel Preparation System
2. 15-30 MWth CFB Boiler
3. Gas Cleaning System
4. Mix and Preheating System

- Biomass
- Gasifier
- Torch
- Gas Clean up
- Oxygen Storage and Vaporisation
- Preheating train
- Expander
- Compression and Separation Unit
- CO$_2$ Transport Test Rig

CIUDEN
Ponferrada, 9$^{th}$ – 13$^{th}$ September 2013
es.CO₂ - Fuel preparation system
Circulating fluidised bed boiler (CFB) – Systems involved
Circulating fluidised bed boiler
Schematic diagram (CFB)
## Premises

<table>
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</table>
| - Recirculated gases composition in oxycombustion  
  *Concentrations increase 4-5 times in oxycombustion (SOx, NOx, etc)* |
| - CFB technology: **DeSOx & DeNOx in bed** |
| - Recirculated gases: **Wet – High moisture**  
  *Used for solid transportation - handling* |
| - Measurement & instrumentation assurance strongly implemented.  
  *Facilities fully monitorized*  
  *Instrumentation calibrated and tested periodically according to procedures* |
| - Sealing systems - **CO2 Consumption and costs to be optimized** |
## Detection

<table>
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<tr>
<th>CHALLENGES - IMPACTS OBSERVED</th>
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<tbody>
<tr>
<td><strong>Air in-leakage</strong></td>
</tr>
<tr>
<td><strong>Infiltrations</strong></td>
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</table>
| **Leakages** | **External Acidic condensations - depositions** | | • Damages in the installation  
• Health and Safety issues |
| **Temperature losses** | **Acidic condensations**  
**Corrosion** | | • Blockages in solids transport lines  
• Damages in the installations |

### Diagram:

- **CO\textsubscript{2}**: 76.46%
- **O\textsubscript{2}**: 4.68%
- **CO\textsubscript{2}**: 75.82%
- **O\textsubscript{2}**: 7.91%
Air infiltration – Equipment & Sensitive Areas

Expansion joints
Textile

Flange unions
Bolted connections
Equipment

Sealing systems
Stationary - In motion
Static sealing - CO2?

Consistent concentration of CO2 in the flue gases - higher of 80% v/v d.b
Leakages – Equipment & Sensitive Areas

**Acidic depositions**
- Flanges
- Expansion Joints

**Corrosion**
- Pipelines
- Dead-legs

**Acidic condensations**
- Fans
- Drains?

Recirculated gases line - positive pressure
## Temperature losses – Equipment & Sensitive Areas

### SECTIONS AND PARTS NOT PROPERLY ISOLATED / INSULATED

<table>
<thead>
<tr>
<th>Section</th>
<th>Issue</th>
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</thead>
<tbody>
<tr>
<td>Gates, Valves, Hangers</td>
<td>Cold parts</td>
</tr>
<tr>
<td></td>
<td>“Gas cooled”</td>
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<tr>
<td>Expansion joints, Fans, Pipes</td>
<td></td>
</tr>
<tr>
<td>Dead-legs</td>
<td>Leakages</td>
</tr>
<tr>
<td></td>
<td>No gas circulation</td>
</tr>
<tr>
<td></td>
<td>“Gas cooled”</td>
</tr>
<tr>
<td>Solids transport lines</td>
<td>Blockages</td>
</tr>
<tr>
<td></td>
<td>“Unavailabilities”</td>
</tr>
</tbody>
</table>

- **Gates, Valves, Hangers, Expansion joints, Fans, Pipes**
- **Dead-legs**
  - “noncirculating lengths of pipe”
- **Solids transport lines**
  - “intermittently”
Corrective Actions adopted - I

Replacement of Expansion Joints

- Metallic with pipe ends and inner tube.
- Materials: Stainless steel or anticorrosive coating.

Replacement of Flange unions

- Welded flange unions instead of bolted
- Leak-proof equipment

Insulation needed
Corrective Actions adopted - II

**Insulation**

- ✔ Removable insulation
  - Facilitate inspection & maintenance activities
- ✔ Drainages for eventualities

**Solids transport lines**

- ✔ Heat tracing mechanisms
  - Design - Absence of condensation
    - *Intermittent feed*
- ✔ Purge lines

**Sealing systems**

- ✔ Dynamic seals in fans
  - Multi-part & self adjusting seal rings
- ✔ Sealing with CO2 for eventualities
## Lessons learnt

### General Recommendations

To be considered in the design phase:

- **The gas passages should be as hermetic as possible**
- **Infiltrations, leakages and cold points have to be avoided**
- **Optimize costs and prevent possible unavailabilities**

- **Leak-proof** equipment

- ✓ Valves, gates, etc; **fully tight on closing**. Proper isolation *(avoid Dead – legs)*

- ✓ Materials – Insulation - corrosion resistant

- ✓ Expansion joints. Metallic - stainless-steel / anticorrosive coatings

- ✓ Importance of **solids handling** systems (CFB technology requirements)
Acknowledgments

- Part of the work presented is co-financed under the FP7 Programme and the European Union's European Energy Programme for Recovery programme
“In my mind, pilots are key to the global implementation of CCS at the moment. They’re building our knowledge base and they’re key to building public confidence in our technology to get us to larger-scale implementation”.

John Gale
General Manager of the IEA GHG R&D Programm

Thanks for your attention

For further information, please contact
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