Pilot-scale Evaluation of Oxy-fuel Combustion of Anthracite Coal with CO$_2$ Capture

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3rd IEA Oxy-Combustion Conference
(Ponferrada, Spain 9-13 September 2013)
Overview

- Introduction
- CanmetENERGY’s Integrated Oxy-fuel Pilot Plant
- Vertical Combustor Research Facility
- CO₂ Capture and Compression Unit
- Pilot-scale Test Parameters
- Presentation of Data
- Summary of Key Observations
- Future Work
**Introduction**

- Overall objective of this work is to study the behavior of an oxy-fuel coal combustion system with integrated CO$_2$ capture and compression.

- This will be achieved by gathering and comparing data sets taken from the pilot-scale and pre-commercial scale facilities at CanmetENERGY and CIUDEN’s respective laboratories.

- Total of six pilot-scale tests scheduled to be performed at CanmetENERGY, of which preliminary data is presented here.
CanmetENERGY’s Integrated Oxy-fuel Pilot Plant

0.3 MW<sub>th</sub> Oxy-fuel Vertical Combustor Research Facility (VCRF)

Details of CO<sub>2</sub>CCU

Synthetic Flue Gas System

CO<sub>2</sub> Capture and Compression Unit (CanCO<sub>2</sub>)
Vertical Combustor Research Facility

- Advanced flexible combustion research platform;
  - Firing Rate 0.3 MWth (1.0 X 10^6 Btu/h)
  - Fuels: Natural gas, Oil, Emulsion, Pulverized coal, Pet coke, Coal Slurry, etc.
  - Operational modes: air and oxy-fuel
  - Fully instrumented and equipped with standard pollution control devices (e.g. baghouse, ESP, activated carbon, sulfur scrubbers, etc.)

- Synthetic flue gas generation facility.
CO₂ capture and compression - CanCO₂ Research Facility

- CanCO₂ is operating based on CanmetENERGY’s proprietary low-temperature auto-refrigeration physical separation process.
- Trailer-mounted transportable CO₂ capture and compression unit (3 tons/day)
- Operates as a multi-pollutant control unit (i.e., removing NOₓ, SOₓ and Hg, while capturing and processing CO₂)
CanCO₂ Research Facility - Flow Diagram

- Vent Stream
- Expander 2
- Warm HX
- Expander 1
- Cold HX
- Multi-stage Compression
- Drier
- Flue Gas Stream
- CO₂ Stream
- Compression for pipeline transportation
- Mass Flow & Concentration Measurement Points
Pilot-scale Test Parameters

- Firing rate: 0.3 MW\text{th}; approximately 40-45 kg/h of coal
- Flow path:
  - Combustor \to Baghouse \to Condensing heat exchanger (CHX1) \to CanCO_2, \textit{recycle after CHX1};

- \textit{No sulfur scrubbing}
- SO_\text{x} and NO_\text{x} capture within the CanCO_2
- Fuel type: Anthracite from Spain

Proximate Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>% Weight</th>
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<tbody>
<tr>
<td>Moisture</td>
<td>3.91</td>
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<td>Ash</td>
<td>35.09</td>
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<tr>
<td>Volatiles</td>
<td>9.42</td>
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<tr>
<td>Fixed Carbon</td>
<td>51.58</td>
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Ultimate Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>% Weight</th>
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<tbody>
<tr>
<td>Carbon</td>
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<tr>
<td>Hydrogen</td>
<td>1.98</td>
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<tr>
<td>Nitrogen</td>
<td>0.82</td>
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<tr>
<td>Total Sulfur</td>
<td>1.27</td>
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<tr>
<td>Oxygen</td>
<td>2.53</td>
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</table>
Experimental Results - VCRF Concentration Data

Collection Points

Gas Stream Measurement Points
\((CO_2, O_2, CO, SO_2, NO_x)\)

Air/CO\(_2\)
K-Tron

VC
Heat Exchangers

FD Fan

ESP

Bag House

CHX 1

CHX 2

CO\(_2\) Rich Flue Gas

CO\(_2\)CCU

ID Fan

ID Recycle Fans

Recycled Flue Gas

CO\(_2\)

2\(^{nd}\) O\(_2\)

3\(^{rd}\) O\(_2\)

Vent
Experimental Results - VCRF Data

Combustor Outlet - CO₂ & O₂

Avg. CO₂ ~ 90%

Combustor Outlet - SO₂ & NOₓ

Avg. O₂ ~ 3%

Instrument Check

Coal Reload

Coal Reload

Coal Reload

Instrument Check
Experimental Results - VCRF Data continued

CanCO₂ Experiments

Zone of Interest

Combustion Flue Gas Stream

Steady State

Furnace Temperature Profile

~ 8 m

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Leadership en écoInnovation
Experimental Results - CanCO₂ Data

Inlet Flue Gas Stream to CanCO₂

- Avg. CO₂ ~ 90%
- Avg. O₂ ~ 3.75%
- Avg. SO₂ ~ 2400 ppm
- Avg. NOₓ ~ 700 ppm

Incoming flue gas stream has moisture content of: ~ 4.5%
Experimental Results - CanCO₂ Data continued

Product Stream

- CO₂ purity > 97%

- SO₂ ~ 400 ppm
  - Consistent with values upstream of dryer
  - Normal given the properties of SO₂

- NOₓ ~ 300 ppm
  - Levels higher than expected, based on previous testing
*Note, in spite of vent stream CO₂ concentrations, which approach ~80%, overall CO₂ recovery is approximately 75%
Summary/Findings

- Combustion of anthracite coal posed on problems, overall good performance
  - Typical flue gas composition: 90% CO₂, 3% O₂, 7% moisture, 2500 ppm SO₂, 800 ppm NOₓ, CO < 100 ppm
- Minimal air infiltration noted, estimated at less than 5%
- CanCO₂ perform very well with a CO₂ recovery of 75% inline with simulation results.
- Capture of SO₂ and NOₓ was observed in the CanCO₂, as demonstrated by the low levels of pollutants in the vent and product streams
  - 400 ppm SO₂ and 300 ppm NOₓ in product stream
  - Less than 100 ppm of SO₂ and NOₓ in vent stream
Future Work

- Complete the remains pilot-scale tests at CanmetENERGY
- Follow-up pilot-scale testing with pre-commercial testing at CUIDEN’s oxy-fuel facility
- Compare and analyze the two data sets
- Collect more detailed data on the $\text{SO}_x$ and $\text{NO}_x$ capture within the the multistage compression block of the CanCO$_2$