'Post-combustion capture from natural gas combined cycle plants'

IMechE -18th May 2010

Mathew Hunt, Business Development Manager – PCC Group
Pramurtta Majumdar – Specialist Engineer – PCC Group
Doosan Heavy & Doosan Power Systems are part of the Doosan Group – the oldest and one of the most successful Corporations in Korea

- Doosan Group is active in Project Management, Construction, Engineering and Manufacturing of power plants, industrial facilities, desalination, engines and construction equipment
- Manufacturing facilities: world-leading, fully integrated power plant manufacturing facility in Changwon, Korea & Vina, Vietnam

[$USD, 2008]
Doosan invested in market since 1996, significant increase in investment from 2006/7 to ensure strong position for future

1996
- 160KWt at Doosan ERTF*

2007
- Doosan Hire BCG to advise on emerging CCS market

2008
- Doosan invest into HTC taking 15% & exclusive rights to CCS technology

2009
- 40MWt Full size Oxycoal Burner at Doosan ERTF*

2009/10
- ERTF* Converted to Amine Test Facility

2009/10
- Basin Electric & SSE Demonstration Projects

2012/14
- Full Power Plant Demo Expected 100-250MW

2013/16
- Large Scale Power Plant with CCS

2020
- Forecast to be fully commercialised by 2020

2020
- Full commercial CCS market

* Emissions Reduction Test Facility
** Boston Consulting Group
'Post-combustion capture from natural gas combined cycle plants'
POST COMBUSTION CARBON CAPTURE TECHNOLOGY

Stack
Absorber
Stripper
Storage Tanks
Control Room
CO₂ Export
Compression
Condenser
Lean Rich Exchanger
Reboiler

Doosan Babcock Energy

© Doosan Babcock Energy
PCCC for Gas Turbine Plants

• A top-level assessment of TECHNICAL interface issues pertaining to the operation of gas turbine plants either in simple cycle or in combined cycle mode affecting the post combustion carbon capture (PCCC) process are considered:

  – Primary Features of Gas Turbine Plants influencing PCCC
  – Compatibility with diverse fuel compositions
  – Pressure AND temperature variation
  – Carbon capture during start-up transients
  – Power vs. Steam Maps
  – Steam availability for regeneration
  – Variability of Steam properties
  – HRSG process for compatibility with PCCC
  – HRSG layout for compatibility with PCCC

• Retrofitting existing CCGT plants with PCCC would be based on design considerations outline above
Primary Features of Gas Turbine Plants influencing PCCC

• Gas Turbine Plants can operate on simple cycle (incomplete Brayton cycle) or combined cycle (bottoming cycle to Brayton cycle) for highest efficiency and power output.
• Capability of operation with a wide variety of fuels with varying carbon contents, including bio-diesel.
• Primarily operated as Peak Load plants, with rapid response to transients as in merchant plants.
• Combined cycle operation with HRSG’s with triple pressure reheat steam.
• Supplementary firing in HRSG’s.
• PCCC for Gas Turbine Plants would have to consider the variety of fuel sources available at a particular site at different times.

• The compatibility of the absorber for carbon dioxide (amine based for Doosan) would have to be evaluated with all the chemical properties of the fuel sources.
GT Plants are operated both in simple cycle and combined cycle with HRSG.

The flue gas exit pressure at DCC inlet would vary with HRSG pressure drop similar to load following on a coal fired plant.

The placement of a blower (in series) to counteract PCCC pressure drop would effect GT exit pressure and/or HRSG heat transfer regimes. Therefore the ΔP would be part of the design of the absorber.

Inlet temperatures to PCCC would be affected by supplementary firing in HRSG. The DCC is designed to accommodate this.
PCCC for Gas Turbine Plants- carbon capture during start-up transients

### 7FA technical specifications

<table>
<thead>
<tr>
<th></th>
<th>CC</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output (MW)</td>
<td>827</td>
<td>211</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>57.5</td>
<td>30.5</td>
</tr>
<tr>
<td>Heat rate (Btu/kw-hr, LHV)</td>
<td>5634</td>
<td>8872</td>
</tr>
<tr>
<td>NOx (ppmv; @ 15% O2)</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>NOx per start (lbs) – conventional start</td>
<td>373 lbm/start$^2$</td>
<td>27 lbm/start$^2$</td>
</tr>
<tr>
<td>CO per start (lbs) - conventional start</td>
<td>2142 lbm/start$^2$</td>
<td>126 lbm/start$^2$</td>
</tr>
<tr>
<td>CO (ppmv)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>PM 10 lb/hr, total/combustion only</td>
<td>334</td>
<td>18.9</td>
</tr>
<tr>
<td>VOC (ppmv)</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>UHC (ppmv)</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Liquid fuel capability</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>GT turndown (% base load)</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Fast start capacity (10 minutes)</td>
<td>50% GT load</td>
<td>144 MW</td>
</tr>
<tr>
<td>NOx per start (lbs) – CC Rapid Response/SC Fast Start$^4$</td>
<td>32 lbm/start$^5$</td>
<td>14 lbm/start$^5$</td>
</tr>
<tr>
<td>CO per start (lbs) - CC Rapid Response/SC Fast Start$^4$</td>
<td>162 lbm/start$^5$</td>
<td>58 lbm/start$^5$</td>
</tr>
</tbody>
</table>

- Gas Turbine Plants are subjected to frequent starts and stops as Peak Load Plants.
- Frequent starts and stops significantly increase CO emissions (to several multiples of normal operation values).
- Lack of Steam during open cycle start-up makes solvent regeneration for PCCC very difficult. Either a aux boiler required or a simple bypass depending on client.
- Response time for PCCC plant (with chemical kinetics) to start-up requirements of simple cycle and/or combined cycle are and process designed accordingly.
Power vs. Steam Maps for predicting power and steam export needs with or without SF are vital for evaluating operational flexibility to encompass carbon capture regimes.
PCCC for Gas Turbine Plants- Steam availability for regeneration

- Triple pressure HRSG (w or w/o supplementary firing) for three steam injection points are widely used.
- Doosan patent on Steam Extraction and Return pending
PCCC for Gas Turbine Plants - variability of Steam properties

- Steam properties for regeneration are widely variable for the third pressure HRSG tap-off.
- Typical variability of properties within Single Pressure HRSG’s are illustrated below.
- Regeneration of Lean Solvent in Re-Boiler accommodates this wide variety of design conditions prevalent in a triple pressure HRSG.

![Graphs showing steam flow vs. steam pressure for different temperatures with and without supplementary firing.]

**Without Supplementary Firing**

**Typical**

**With Supplementary Firing**
Additional steam requirement for PCCC can be most easily incorporated with an external deaerator. This provides robust operational flexibility together with simpler phosphate dosing for Flow Assisted Corrosion (FAC) rather than the inherently more complicated All Volatile Treatment (AVT) regime.
PCCC for Gas Turbine Plants - HRSG layout for compatibility with PCCC

• Vertical arrangement can create additional pressure drop issues
• Additional plot space required for PCC plant
• Planning consent for additional plant if retrofitted

• Horizontal HRSG’s (shown on right) are more suitable for integration with PCCC plants than vertical HRSG’s (shown above) due to low level tie-in’s
Thank you for your attention and any questions?