Advanced Coal Combustion Technology
McIlvaine Company Hot Topic Hour
April 29, 2010

Sean Black – Business Development Director, Carbon Reduction
OxyCoal™ Combustion Technology Road Map

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>Fundamental Research</td>
<td>Combustion System Demonstration</td>
<td>Field Plant Demonstration</td>
<td>Commercialisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Phase 1**
- Address technology gaps
- Operating experience

**Phase 2**
- Retrofit the existing 70 MWt Clean Combustion Test Facility to operate and test a 40 MWt, commercial-scale OxyCoal™ burner
- Demonstrate optimized combustion
- Develop market proposition

**Phase 3**
- Front End Engineering Design (FEED) activities
- Secure field demonstration project of 100-200 MWe
- Embed technology skills into organisation to support future full scale commercialisation

**Phase 4**
- 1000 MWe OxyCoal™ power plant
- Continue development to drive efficiency gains
- Drive down costs and increase commercialisation
OxyCoal-UK: Phase 2 – Demonstration of an Oxyfuel Combustion System

The OxyCoal-UK: Phase 2 collaborative project is led by Doosan Power Systems and supported by the Department of Energy and Climate Change.
OxyCoal-UK: Phase 2 - Clean Combustion Test Facility (CCTF)
OxyCoal-UK: Phase 2 – Demonstration of an Oxyfuel Combustion System

Oxyfuel firing tests to demonstrate transition from air firing to oxyfuel firing on oil and on coal.

1. Acquire technology
   • Market evaluation
   • Technology selection

2. Product & market development
   • Carry out technology transfer and document processes
   • Provide support to early proposals

3. Demonstration & optimization
   • Secure FEED work
   • Secure large demo projects

4. Commercialization
   • Secure commercial project as part of new build EPC

Technology transferred
CCS Global One Team for Post Combustion Capture

- Boiler OEM with over 160 GW of references
- Significant expertise executing major projects in coal, nuclear and natural gas power plants
- Specific expertise in petrochemical and chemical projects; relationships with major companies
- Global reputation delivering major chemical process columns and equipment through Doosan Mecatec
- Global team, based in Renfrew, Scotland, is developing dedicated expertise, leveraging the capabilities throughout Doosan to push boundaries in CCS

- Leading technology in the field of carbon capture, geologic profiling, oil field analysis and simulation and risk assessment
- World-class process technology and expertise
- Sophisticated process simulation models; developed over many years of pilot testing and validated against several, large-scale commercial facilities
Operation with TKO™ Configuration and RS-2™ Solvent

- Boundary Dam Field Pilot modified to operate with TKO™ advanced process flow scheme and RS-2™ solvent
- 1,400 hour test run demonstrated:
  - High absorption efficiency (~ 85% CO₂)
  - Low solvent degradation rate
  - Low steam consumption
    - <1.1 kg steam: 1kg CO₂ (~ 1,000 BTU/lb)
Process Technology Scale-Up

Doosan and HTC apply no less than three different models, which have each been developed and validated using extended bench-scale and field pilot testing, combined with actual operating data from commercial-scale plants.

HTC have developed a thorough understanding of:
- All physical and chemical properties (kinetics, diffusivity, etc.)
- Operating conditions
- Proper application of numeric modeling tools

International Test Center
1 TPD
Pilot plant treating exhaust from gas turbine
RS-2 and MEA Solvent
TKO™ Flow Scheme

Boundary Dam Pilot
5 TPD
Pilot plant treating slip stream from coal-fired power plant
RS-2 and MEA Solvent
TKO™ Flow Scheme

150 TPD commercial CO₂ capture system treating slipstream from coal-fired power plant
MEA Solvent
Standard Flow Scheme

800 TPD (2 trains) commercial CO₂ capture system treating slipstream from coal-fired boiler
MEA Solvent
Standard Flow Scheme
CCPilot100+

- Amine scrubbing pilot plant using Doosan Power System’s technology
- 100 t/day slip stream on SSE’s Ferrybridge Power Station
  - Largest PCC Demonstration in the UK
- Funding by the project partners, Scottish & Southern Energy, Vattenfall, Doosan Power Systems, TSB, DECC and The Northern Way
- Fast – track, operation in early 2011
- Two year test programme
Doosan Power Systems selected to develop a FEED for a commercial-scale, demonstration plant
- Sized to capture 1.0 MM short tons per year of CO₂ from Basin Electric’s Antelope Valley Power Plant
  - 3,000 short tons per day
  - Treating a 120 MW slipstream

US Rural Utility Service has committed $300 million in loan guarantees

US DOE announced intention to enter into a cooperative agreement with Basin Electric for a $100 million grant