Hybrid Coal-Gasification Retrofit of Power Boilers for
SO₂ & NOₓ Control and Improved Efficiency

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by
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Castle Light PR Corp.
The Clean Combustion System™ (CCS)

- CCS provides SO₂ and NOₓ emission control in combustion with improved efficiency
  - Retrofits all boiler types; Cyclone, Wall-fired, T-fired, Stoker
  - Oxy-fuel Plants; low-cost control of corrosive sulfur compounds
  - May convert gas & oil-fired boilers to coal firing

- Castle Light PR Corp. Provides Technology Management & Licensing
  - evolved from rocket engine programs at Rockwell International in the 1980’s
  - CCS application studies, top level system design, CFD analysis
  - Engineering, Hardware, Equipment Supply, Warrantee; Client installs

- Our subsidiary, Phenix Limited, LLC conducts the CCS engineering tasks

- CCS Objectives:
  - Retrofit of older, smaller (<300MW) power boilers for 20 or more years of competitive dispatch
  - Meet EPA’s Clean Air Interstate Rules (CAIR)
  - Low-cost SO₂ and NOₓ control with improved efficiency
  - Reduced operating cost

- New CCS Developments:
  - Control Mercury,
  - Fire low-cost waste coals (high moisture, high ash)
EPA’s “Clean Air Interstate Rule”

Clean Air Interstate Rule (CAIR)
March, 2005 - (28 Eastern States + WDC)
By 2015, coal-fired plants must reduce:
SO₂ emissions by 7.3 x 10⁶ Tons
NOₓ emissions by 2.7 x 10⁶ Tons

A Clean Combustion System™ (CCS)
clean combusted plant retrofit can meet CAIR
and waiver CAA: NSPS - PSD - NSR.
(see below) www.phenix-limited.com

Each coal-fired plant will receive a permit to pollute (in Tons/yr) and will develop emission credits for operation below that permit, but must apply/buy credits if above that permit.
Conventional Emission Controls

\( \text{SO}_2 = \text{FGD} + \text{Limestone}; \; \text{NO}_x = \text{SCR} + \text{Ammonia}; \)

\( \text{SO}_3 = \text{Trona} ?; \; \text{Hg} = \text{Activated Carbon} ? \)
CCS Hybrid Coal-Gasification

SO$_2$ & NO$_x$ Control Right in the Combustion Step

<table>
<thead>
<tr>
<th>SO$_2$ Emission Reduction</th>
<th>NO$_x$ Emission Reduction</th>
<th>Plant Efficiency</th>
<th>Power Output</th>
<th>Plant Life</th>
<th>Incremental Electricity Cost</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 - 90+ HIGH</td>
<td></td>
<td>No Change</td>
<td>No Change</td>
<td>Slight Extension</td>
<td>2-4 mills/kWh</td>
<td>$75-110 per kW</td>
</tr>
</tbody>
</table>

* CONVENTIONAL COAL-FIRED ELECTRIC POWER PLANT
Hybrid Gasification Schematic
The Clean Combustion System (CCS)
Rockwell International
25 x 10^6 Btu/hr (1 ton/hr) Test Facility (1990)
LNS-CAP Facility
ESSO Site, Cold Lake, Alberta Canada
Boiler Radiant Section
View Forward to Burner
LNS-CAP
Slag to Water Trough
LNS-CAP
Gasification Chamber Inspection
Demonstrated Emissions

$\text{SO}_2 - 0.2 \text{ lb./mmBtu}$ & $\text{NO}_x - 0.15 \text{ lb./mmBtu}$

ESSO LNS-CAP Facility, Cold Lake, Alberta, Canada
CCS-Stoker® Project Description

- **Objective:**
  - Reduce operating cost by half
  - (switch to low-cost high-sulfur Illinois coal – 2.5 lb. SO$_2$/mmBtu)
  - Construction Permit w/ waiver NSPS, PSD; no NSR
  - Emissions Warranty: <0.9 lb. SO$_2$/mmBtu, <0.25 lb. NO$_x$ /mmBtu

- **Project Initiated:** Oct 2005,
  **Commissioning:** Jan 2007

- **Phenix Scope:** Process Design & Engineering;
  - Supply all equipment, hardware, electrical, instrumentation / controls
  - Provide Commercial Warranty & License

- **Client Scope:** Site Construction Management;
  - Equipment Installation,
  - Commissioning & Start-up

- **Project Support:** In part, by the Illinois Department of Commerce and Economic Opportunity through the Illinois Clean Coal Institute and the Office of Coal Development.
Coal-Fired Stoker Boiler
(typical)

CCS Retrofit

Demo:
Stoker, ash pit, brick over grate

New Equipment:
CCS Burner,
Gasification Chamber,
Boiler Instruments,
APH, Mill, FD fan,
BM & Combustion Sys,
HMI & PLC Controls

Replace:
MCC,
Control Panel

Operator Training:
From cold start to automatic full load operation in 5 hrs.
CCS-Stoker® Retrofit
125 mmBtu/h
Gasification Chamber Installation
CCS-Stoker® Equipment Stack Up
Stoker Boiler Furnace Deposits

Typical Examples

Wall Ash Deposits     Exit Fouling Deposits
CCS-Stoker® Operation Observations
Very Little Ash Deposits on Furnace Tubing
No Plugging or Fouling of Back Pass Section

Furnace Walls
Furnace Ceiling
### CCS-Stoker® Retrofit Performance

**Preliminary Results – Full Load Operation**

<table>
<thead>
<tr>
<th>Item</th>
<th>Stoker Base Line Test</th>
<th>Preliminary CCS Performance</th>
<th>% Change from Base Line</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SO₂ Stack Emissions (lb/MMBtu)</strong></td>
<td>1.80</td>
<td>0.72*</td>
<td>- 67.0 %</td>
</tr>
<tr>
<td><strong>NOₓ Stack Emissions (lb/MMBtu)</strong></td>
<td>0.50</td>
<td>0.14 (88 ppm)</td>
<td>- 72.0 %</td>
</tr>
<tr>
<td><strong>Boiler Efficiency</strong></td>
<td>77.0</td>
<td>86.9</td>
<td>+ 12.8 %</td>
</tr>
<tr>
<td><strong>CO₂ Emissions - Ton/yr GW credits (% Reduction)</strong></td>
<td>94,019</td>
<td>73,720</td>
<td>20,300T/y (- 21.6 %)</td>
</tr>
<tr>
<td><strong>Project Cost Recovery (from firing lower cost coal)</strong></td>
<td>~ 3 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Nearly meets CAIR (Clean Air Interstate Rules)*
CCS-Stoker® Operation Observations
Operation @ MCR – Steam Overboard
CCS Features
Improved Operability, Availability & Reliability

- All equipment off-the-shelf & familiar to the Operators
  - Safe, stable operation,
  - Same startup, shutdown and turndown as a PC burner
- Bottom Ash (slag) removed before furnace
  - low particulate/ash load; clean furnace, less soot blowing
- Sulfur removed from furnace gases - near-zero SO$_3$:
  - Allows for lower furnace exit temperatures
  - Minimize water-wall wastage & corrosion,
  - Can use hot boiler exhaust for pulverizer sweep air:
    - Dry the coal – reject moisture
    - Improves coal pulverizer safety from fire & puffs (low O$_2$)
- Improved Boiler Efficiency (2 to +10%)
  - Reduce CO$_2$ emissions
  - High combustion efficiency (LOI < 1%)
- Limestone is only “chemical” required
- No waste water for disposal
CCS Summary
(Key Strategic Issues)

- From Fundamental Combustion Theory to Commercial Operation
- Fire lower cost coals - reduce plant operating cost
- Meets EPA’s new stringent CAIR initiatives for SO$_2$ & NO$_x$
- Allow power plant upgrade with waiver of NSPS & PSD - No NSR
- May generate CO$_2$ – SO$_2$ – NO$_x$ emission credits
- Low Retrofit Cost; maintain older, smaller power boilers competitive - improve capacity factor & dispatch
- Fits within Plant & Boiler Site Footprint
- No waste water discharge
- Ash products have value (sell bottom ash & fly ash)
- No Hazardous or Toxic Chemicals Required

It’s ADVANCED COAL GASIFICATION TECHNOLOGY!
Castle Light PR Programs

- Advanced environmental engineering consulting services.
- Convert / upgrade gas, oil and coal-fired plants:
  - To burn coal with reduced operating cost
  - Extend competitive life for 20 or more years
  - And meet stringent new EPA emission regulations.

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