Ashworth Gasifier - Combustor Multi-Pollutant Control for Power Plants

Presented by: ClearStack Power, LLC
Gasifier - Combustor Background

12×10^6 Btu/hr 2-Stage CAIRE Gasifier - Combustor @ FWDC

Similar to Rummel Molten Slag Bath Gasifier that removed 70% sulfur in slag w/O_2 firing of alkaline Brown Coal

Emission Results:

NO_x Emissions - 0.25 lb/10^6 Btu
SO_2 Reduction - Up to 59% w/Ca(OH)_2
Gasifier - Combustor Background

40×10^6 Btu/hr 3-Stage Ashworth Gasifier - Combustor @ Lincoln, IL

**Emission Results:**

- NOₓ Emissions - 0.095 lb/10^6 Btu
- SO₂ Reduction - 72% w/Limestone @ (80% - 200 mesh)
- Hg Reduction - 93 to 100%
ClearStack’s Ashworth Gasifier - Combustor

- 3-stage pulverized coal oxidation
- SO₂ reduction: >90+% 
- NOₓ emissions: 0.095 lb/10⁶ Btu
- CO emissions: 7-8 ppm @ 3% O₂ 
- Hg capture in ash: near 100%
- Other air metal toxics capture: 80% (Mn) to 100% (Sb, As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mo, Ni, Se, Ag, Tl, V, Zn) in slag and fly ash
- Acid gas (HCl, HF) reductions
- Reduced Particulate loading to ESP/FF w/ Larger fly ash particulate size that is easier to remove
ClearStack’s Ashworth Gasifier - Combustor

- Air entrained gasifier design able to be retrofitted onto existing coal fired boilers. No oxygen plant required.

- Effective SO$_2$, NO$_x$, Mercury (and other Air Metal Toxics), Cl and F control applied to any boiler type without post-combustion controls

- Provides greater fuel feedstock flexibility - able to handle waste coals, higher biomass blends, higher sulfur coals, etc.

- Produces salable inert dry slag and fly ash - no scrubber sludge byproduct

- Combination 60-80% of reduced fly ash particulate loadings to ESP/FF and larger fly ash size distribution will significantly improve particulate emissions

- Small overall equipment footprint- 7-8 foot diameter gasifier design

- Low power requirement, higher efficiency than backend technologies- Lower CO2 unit emission rate
Sulfur Capture Chemistry

Oxidizing in conventional FGD

Strongly Reducing in Gasifier

Sulfur Capture as CaSO₄

CaO + SO₂ + 1/2 O₂ = CaSO₄

Equilibrium Coefficient, K_p

Temperature, °F

0 500 1000 1500 2000 2500

1 10 100

Sulfur Capture as CaS

CaO + H₂S = CaS + H₂O

Equilibrium Coefficient, K_p

Temperature, °F

2400 2500 2600 2700 2800 2900 3000

1 10 100
Sulfur Capture based on Particle Size

Near 100% Expected Capture Rate, w/99.6% minus 325 mesh

Lincoln @72% Removal

FWDC @ 45.3% Removal

Trendline
\[ y = 226.49x^{-0.342} \]
\[ R^2 = 0.9932 \]

FWDC @ 36% Removal

Hydrated Lime/Limestone Average Particle Size, microns
3-Stage NO$_x$ Reduction (GE-EER Modeling)

Unlike SCR it reduces sulfur trioxide (SO$_3$) emissions that create opacity (bluish-white haze) problems without use of noxious chemicals NH$_3$ or Urea - CO(NH$_2$)$_2$.
NO\textsubscript{x} and CO Emissions

Alstom Analysis for 85 MWe T-Fired Boiler Firing Bituminous Coal

NO\textsubscript{x} = 86 ppm
0.095 lb/10^6 Btu

CO = 7-8 ppm
Carbon Emissions

Auxiliary Power (% of generated power)

- Gasifier - Combustor requires 0.05%
- SCR/WS Combination requires 2.9%
Mercury Capture

Mercury capture in strong reducing alkaline molten slag bath is the result of:

\[ \text{Ca}^\circ + \text{Hg}^\circ = \text{CaHg} \text{ (amalgram)} \]

**Unique to Ashworth Gasifier**

Paul Chu relayed that the coal gasifiers that EPRI tested showed no mercury capture.

*They don’t fire into a molten slag bath!*
Slag and Fly Ash

Slag for asphalt shingles/road bed

Fly Ash for cement (stronger and longer lasting)
### Air Metal Toxics Reduction (Lincoln Developmental Center)

<table>
<thead>
<tr>
<th>Element</th>
<th>Fly Ash (mg/L)</th>
<th>Slag (mg/L)</th>
<th>Regulatory Limit (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag</td>
<td>0</td>
<td>0.0002</td>
<td>5</td>
</tr>
<tr>
<td>As</td>
<td>0.0334</td>
<td>0.0005</td>
<td>5</td>
</tr>
<tr>
<td>Ba</td>
<td>0.548</td>
<td>0.175</td>
<td>100</td>
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<tr>
<td>Cd</td>
<td>0.4842</td>
<td>0.0002</td>
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<tr>
<td>Cr</td>
<td>0.1201</td>
<td>0.6335</td>
<td>5</td>
</tr>
<tr>
<td>Hg</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Pb</td>
<td>0.0276</td>
<td>0.008</td>
<td>5</td>
</tr>
<tr>
<td>Se</td>
<td>-0.0113</td>
<td>-0.0008</td>
<td>1</td>
</tr>
</tbody>
</table>

All below EPA Regulatory Limits
ESP Effect w/Larger Fly Ash Particles

(94 KV ESP)

<table>
<thead>
<tr>
<th>Particle Size</th>
<th>0 - PM$_5$</th>
<th>PM$<em>5$ - PM$</em>{10}$</th>
<th>+ PM$_{10}$</th>
<th>Overall Efficiency</th>
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</thead>
<tbody>
<tr>
<td>Gasifier Fly Ash</td>
<td>0.5%</td>
<td>2%</td>
<td>97.5%</td>
<td>99.32%</td>
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<tr>
<td>Conventional Coal Burner Fly Ash</td>
<td>13%</td>
<td>12%</td>
<td>75%</td>
<td>94.96%</td>
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<tr>
<td>ESP Efficiency</td>
<td>65%</td>
<td>99%</td>
<td>99.5%</td>
<td></td>
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</tbody>
</table>

Gasifier will remove ~ 80 wt. % of the mineral matter so only about 1/4 of the particulate compared to conventional coal burners goes to the ESP and is larger and easier to remove.
Biomass Co-firing Capable

Co-fire 10 - 15% biomass w/coal
Capture corrosive alkalis (Na, K) in gasifier molten slag
170 MWe AG-C Compared to SCR-WS

Ashworth Gasifier - Combustor

Retrofit Cost (T-Fired 170 MWe): $25.6 Million
Operating Cost: $5.5 Million/yr

Selective Catalytic Reduction w/Wet Scrubber

Retrofit Cost (T-Fired 170 MWe): $67.3 Million
Operating Cost: $15.3 Million/yr
Comparison to Post-Combustion Costs

*Actual costs will depend upon site specific layout and equipment condition
Sterling plans to retrofit #6 boiler (12.65 MWe Unit), with the Ashworth Gasifier-Combustor. The unit would then comply with all environmental regulations.
Crawfordsville Boiler #6

#6 B&W Boiler w/Detroit Stoker RotoGrate - Installed in 1965
## Crawfordsville Boiler #6 Retrofit

### Capital Cost Estimate - $2016

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Engineering</td>
<td>$385,000</td>
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<tr>
<td>Detail Engineering</td>
<td>$505,000</td>
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<tr>
<td>Procurement</td>
<td>$1,800,000</td>
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<tr>
<td>Demolition</td>
<td>$65,000</td>
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<tr>
<td>Construction</td>
<td>$2,050,000</td>
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<tr>
<td>Startup/Testing</td>
<td>$240,000</td>
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<tr>
<td>Other (Owners Cost, AFUDC)</td>
<td>$365,000</td>
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<tr>
<td>Sub-Total</td>
<td>$5,410,000</td>
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<tr>
<td>Contingency (~35%)</td>
<td>$1,890,000</td>
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<tr>
<td>Total</td>
<td>$7,300,000</td>
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Conclusions

The ClearStack Ashworth Gasifier-Combustor can be retrofitted onto existing coal boilers to reduce the air emissions ($\text{NO}_x$, $\text{SO}_2$, Hg, other air toxics and halides) to meet MATS and BART standards without post-combustion controls.

It greatly expands coal unit fuel flexibility and can handle waste coal, high ash coal and biomass.

By avoiding post-combustion controls and an oxygen plant, the atmospheric air blown Ashworth Gasifier-Combustor will be more efficient than a conventional Integrated Gasifier Combined Cycle (IGCC) power plant or a Conventional PC boiler with Post Combustion controls.

Requires less space and is less expensive to install and operate than conventional post-combustion control measures.
Additional Information

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