

Breakthrough Technology in Coal Firing

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ABSTRACT

ClearStack's multi-pollutant reduction Ashworth Gasifier-Combustor™ is a breakthrough technique that reduces the major air pollutants associated with coal combustion and encapsulates these pollutants into saleable byproducts. The benefits that can be achieved include major reductions in traditional pollutants (mercury, NO_x, SO₂, heavy metals, and PM), co-firing with biomass, along with reductions in landfill requirements of ash due to acceptable quality of ash for cement and slag for asphalt use. Limestone is added with the coal to capture sulfur, mercury and other heavy metal air toxics. Further, up to 15% biomass can be fired with coal to help meet EPA Renewable Energy Standards (12.5% biomass by 2021). It is a low cost multi-pollutant reduction technology that can be easily retrofitted to existing coal-fired boilers or installed with new boilers.

The pollutant removal efficiencies achieved make this well suited for compliance with various boiler regulations facing the paper industry including Boiler MACT, NAAQS, Regional Haze, and upcoming regulations striving to reduce mercury emissions (Minimata Convention) and carbon emissions. Considering that the long-term alternatives are costly for each mill that operates a coal-fired boiler, ClearStack provides the best combination of capital and operating costs along with pollutant removal efficiencies.

INTRODUCTION

The ClearStack Ashworth Gasifier-Combustor is a three-stage pulverized coal oxidation technique that dramatically reduces the major air pollutants (NO_x, SO₂, Hg and other air metal toxics) associated with coal combustion. ClearStack's patented air-blown slagging gasifier (oxygen plant not required) design provides excellent pollutant removal efficiencies with minimal added power demand.

The technology promises to be a low cost multi-pollutant reduction technique for existing pulverized coal-fired units that can also provide much greater fuel flexibility. It can handle lower grade and less expensive waste coals, raw coals with high ash content, and biomass (eligible for renewable energy credits in several state programs). With its current environmental controls for many existing boilers, they will be unable to meet the applicable industrial boiler MATS standards without additional investment. By retrofitting the Ashworth Gasifier-Combustor it is feasible to burn a lower cost coal and meet all applicable MATS limitations.

LINCOLN DEVELOPMENTAL CENTER DEMONSTRATION

The Ashworth Gasifier-Combustor demonstration [1] took place at the Illinois Department of Human Services, Lincoln Developmental Center in Lincoln, IL. The boiler used for the demonstration had a name plate rating of 27,000 lb/hr of steam at 150 psig.

Test Results at Lincoln

The gasifier itself was very easy to operate after going through the typical start-up problems. One could switch from natural gas to coal and back to natural gas without any trouble. The gasifier design modifications were successful in increasing sulfur capture and reducing NO_x emissions compared to the FPC CAIRE combustor.

NO_x Emissions

Nitrogen oxides (NO_x) emissions were as low as 0.095 lb/10⁶ Btu (40.8 g/GJ) with coal firing using the three-stage combustion technique. The unit was gas capable and when firing natural gas only, at similar conditions, NO_x emissions were 0.048 lb/10⁶ Btu (20.6 g/GJ). A Continuous Emissions Monitoring System (CEMS) was also used.

SO₂ Emissions

Sulfur dioxide (SO₂) emissions were reduced to 1.70 lb/10⁶ Btu (731 g/GJ) for a high sulfur Illinois coal that yielded uncontrolled SO₂ emissions of 6.14 lb SO₂/10⁶ Btu (2639 g/GJ) - a 72 % reduction using 80% minus 200 mesh limestone. This reduction was achieved with a limestone Ca/S ratio of 0.85 providing for 85% utilization of the calcium injected. With the use of a finer, more reactive limestone (99.6% minus 325 mesh) even greater reductions with a Ca/S ratio of 1.0, 90 to 100% are projected.

Carbon Conversion

The carbon conversion achieved was 99 wt. % with CO emissions of 15 to 30 ppmvd at 3% O₂. Carbon in the gasifier slag was 0.1 to 0.2 wt. % and carbon in the fly ash was around 5 wt. %, making it suitable for use in cement manufacturing. With such high carbon conversion and significant mercury reduction without the need for activated carbon injection, the Ashworth Gasifier design avoids high loss on ignition (LOI) levels and carbon carryover problems that can be created by low NO_x burners and/or activated carbon injection for mercury capture.

Mercury Reduction

The Detroit Edison Fuel laboratory analyzed all of the solids streams entering and exiting the Ashworth Gasifier-Combustor system. Mercury reduction was surprisingly high (93 to 100 wt%) based on solids analyses. In addition, what was also impressive is that the mercury that was captured did not leach.

Other Air Toxics and Halides Reductions

From trace element analyses of other metal toxics in the slag and fly ash nearly all of the antimony, arsenic, barium, beryllium, cadmium, cobalt, chromium, copper, lead, molybdenum, nickel, selenium, silver and vanadium were captured and around 80% of the manganese was captured. The Toxicity Characteristic Leaching Procedure (TCLP) tests showed the regulated concentrations of Ag, As, Ba, Cd, Cr, Hg, Pb, and Se in the leachate were all well below the EPA regulatory limit for both the fly ash and the slag. Leachate testing was completed by Detroit Edison, as shown in Table I.

Table I. Fly Ash and Bottom Ash Toxicity Characterization Leaching Procedure Tests

Metal Toxic	Fly Ash	Bottom Ash	Regulatory Limit
	mg/l	mg/l	mg/l
Ag	0.0000	0.0002	5
As	0.0334	0.0005	5
Ba	0.5460	0.1750	100
Cd	0.4842	0.0002	1
Cr	0.1201	0.6335	5
Hg	0.0000	0.0000	0.2
Pb	0.0276	0.0080	5
Se	-0.0113	-0.0008	1

Testing also showed 26 wt% fluoride capture and 14 wt% chloride capture by the fly ash with a Ca/S ratio of 0.85. With a higher Ca/S ratio and finer limestone (discussed later), halide capture should increase.

Renewable Energy Use

With this technology if biomass is available and conventional coal is used (less than 10 wt% moisture) it could replace some 10 -15% of the coal, thus conserving our fossil fuel resources and help a utility meet imposed renewable energy standards.

ECONOMIC COMPARISON W/SCR PLUS WET SCRUBBER PLUS HG REMOVAL

The ClearStack Technology is well suited for either a new plant application or as a retrofit technology to provide additional environmental controls and/or renewable power credits. Below are retrofit cost comparisons of the Ashworth Gasifier-Combustor with Wet Scrubbing (WS) to remove SO₂ and Hg plus Selective Catalytic Reduction (SCR) for NO_x Control. The SCR + WS was designed to match the environmental performance of the Ashworth Gasifier-Combustor.

The multi-pollutant reducing Ashworth Gasifier-Combustor is seen to be some 38% of the capital cost and 36% of the operating cost compared to the SCR + WS technologies. The analysis does not include any credit for other air metal toxics (80-100%) that are removed by the gasifier.

The Ashworth Gasifier-Combustor allows a utility to sell its fly ash and slag; carbon in fly ash is low and metal toxics won't leach from either the fly ash or the slag.

Carbon Emissions Comparison

The carbon emissions are projected to be considerably lower for a retrofit to the Ashworth Gasifier-Combustor when compared to a SCR/WS technology due to the difference in auxiliary power load required for fans and pumps. The boiler pressure drop is not increased with the gasifier as it would with the other technologies and high pressure pumps aren't required. See Fig. 1 for a comparison in the CO₂ emissions:

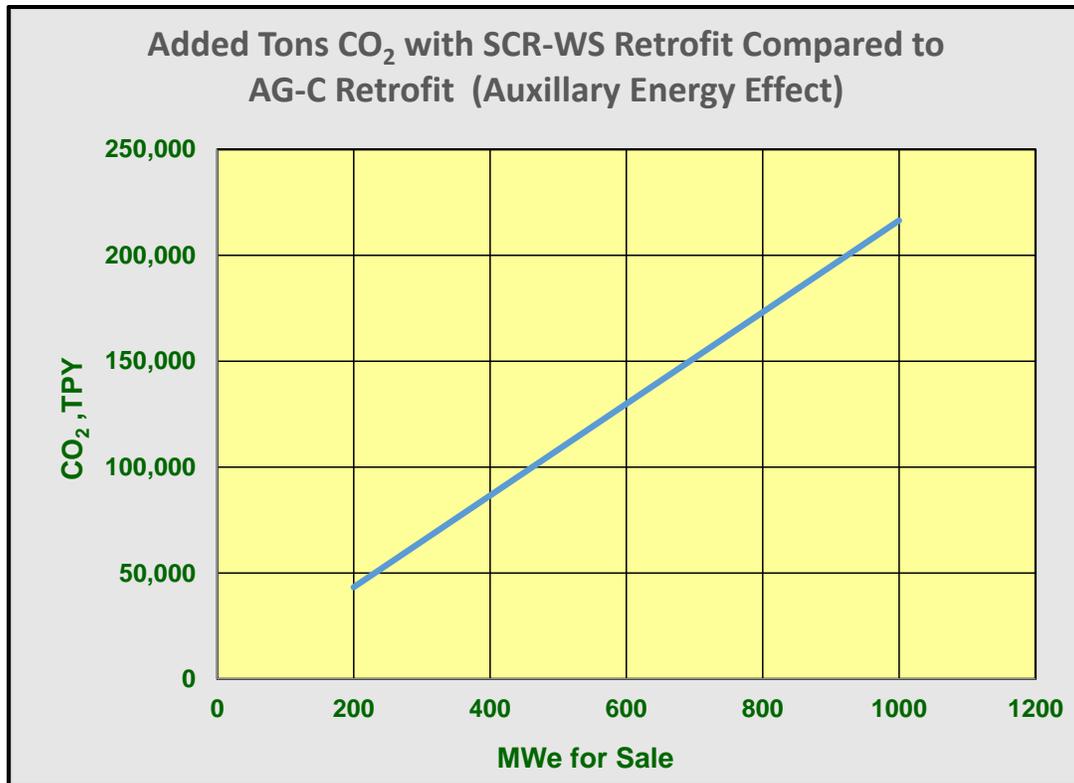


Figure 1. Impact of Auxiliary Power Demand on CO₂ Emissions.

Crawfordsville Project

The ClearStack technology has been selected by the Sterling Energy Group as the lowest cost technology alternative for their Crawfordsville coal repowering project in Indiana. The boiler to be retrofitted is Unit #6, a B&W boiler with a Riley Stoker spreader stoker. The gasifier will be placed on the front of the boiler and will replace the existing spreader stoker feeders. The system will be sized to fire 158 Million Btu/hr of feed coal, and will consist of installing a refractory lined water tube gasifier, a second stage partial oxidization unit and an over fire air system.

In addition to the avoided cost for emissions controls, Sterling will have the capability to reduce the cost of coal by switching from stoker coal to run-of-mine grade coal. This is possible due to the installation of a pulverizer, which will also eliminate the coal bed in the boiler, resulting in a much improved response time for the boiler for power demand swings from the grid.

One of the intended benefits of the Crawfordsville project will be to provide a commercial demonstration of the technology. This will provide documentation of the thermal and emissions removal efficiencies along with the reliability. Potential customers will be able to see the system in operation and potentially conduct trials to evaluate the impact of their current coal or potential coal options on the gasifier performance and operating conditions.

A simplified process flow diagram for the Crawfordsville retrofit is shown in Fig. 2. The new equipment for the boiler rebuild is shown in blue and includes the limestone feed system along with the gasifier and slag quench tank. A pulverizer, distributive controls (DCS), and over fire air will also need to be added.

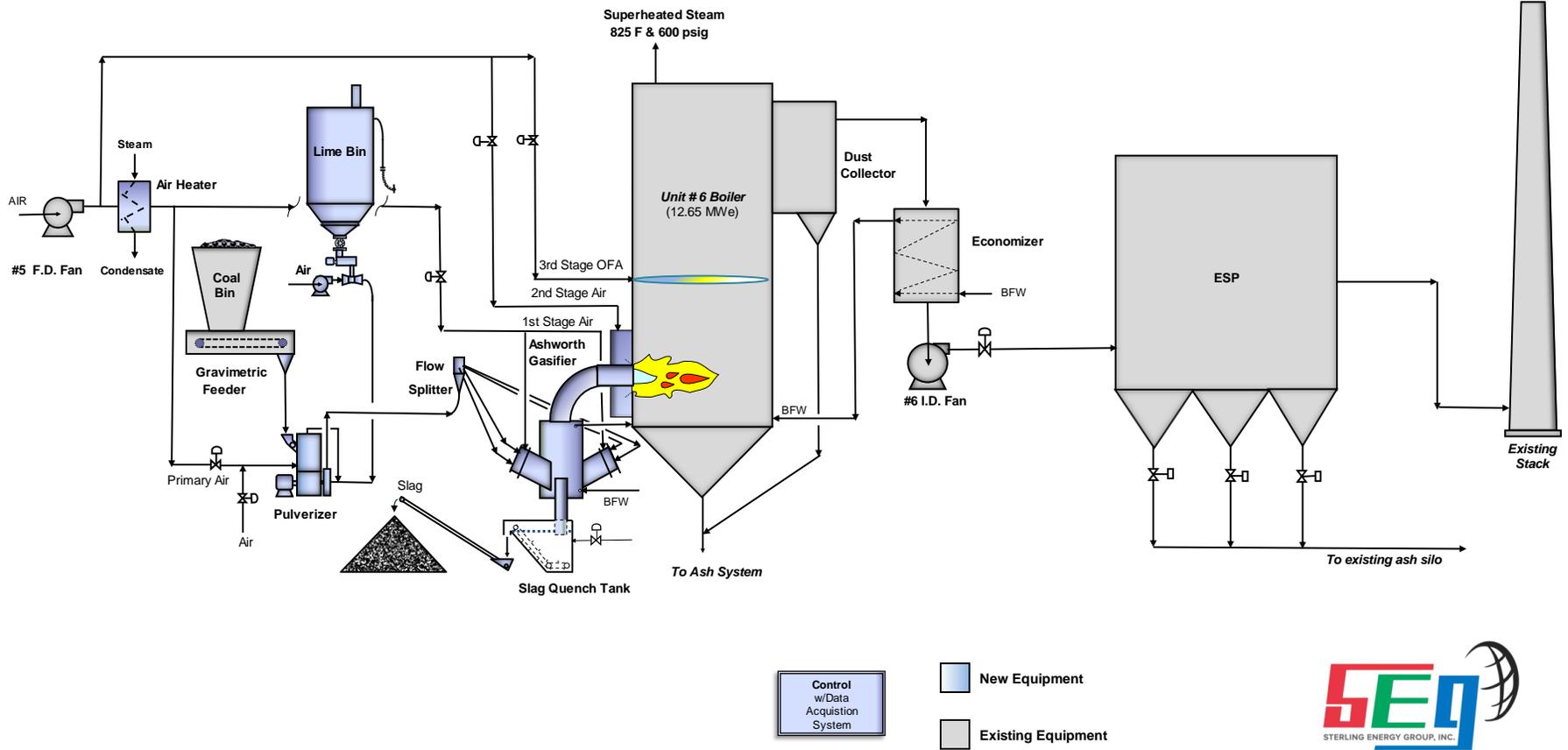


Figure 2. Simplified process flow diagram of Ashworth Gasifier-Combustor.

CONCLUSION

The Ashworth Gasifier-Combustor is a recommended technology for mercury control because it also provides multi-pollutant control (NO_x, SO₂, Hg, halides and other air toxics) associated with coal combustion. It allows much greater fuel flexibility, from waste coal to high ash coal to co-firing with biomass and is easy to retrofit to existing boilers. Unlike SCR, the Ashworth Gasifier-Combustor reduces rather than increases sulfur trioxide (SO₃) emissions that create opacity (bluish-white haze). It also does not require noxious chemicals such as ammonia, as does SCR.

There are also no vapor plumes as seen with wet scrubbers. It takes a much smaller equipment footprint than backend techniques and does not increase the net heat rate of the unit like SCR and Wet Scrubbers do because of the increased auxiliary power required due to increased pressure drop through the flue gas system. The ClearStack slag and fly ash products are also non-hazardous.

Reference:

- [1] *Ashworth Combustor Demonstration Final Report*, ClearStack Combustion Corporation for the Illinois Department of Commerce and Community Affairs and the Illinois Clean Coal Review Board, May 15, 2003.

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