2nd Oxyfuel Combustion Conference

700 MWe Oxycombustion Reference Plant Performance and Costs

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oxycombustion; Large Scale Pilot and Demo Projects: Techno-Economic evaluation

1. Introduction

Babcock & Wilcox Power Generation Group, Inc. (B&W PGG) and Air Liquide (AL) have been collaborating on development of oxycombustion for carbon capture since 2000. This joint effort has included testing in B&W PGG's1.5 MWth, 1.8 MWth, and 30 MWth test facilities, several techno-economic studies, and proposals to demonstrate and test oxycombustion at small commercial scale. These efforts led to the proposal of a 150 MWe plant in the western United States (US) in 2009 and the 2010 award of the 200 MWe FutureGen 2.0 project located in the state of Illinois.

In anticipation of a successful commercial-scale project and in recognition of the need to prepare for the next step, B&W PGG and AL initiated an effort to develop a 700MWe gross reference plant in late 2009. In the summer of 2010 the Electric Power Research Institute (EPRI) contracted with B&W PGG to publish the engineering and economic analysis so that results could be placed alongside a comparable scope study for post-combustion capture[1]. The work to set the design basis and process/mechanical design was initiated in late summer and an interim report on the plant design and performance was issued at the end of 2010[2]. In early 2011 the costs were estimated and analyzed, culminating in a final report[3].

For comparative purposes, two plant designs were developed and evaluated; 1) a baseline air-fired design and 2) an oxycombustion plant with the same gross output as the baseline air-fired plant. *(At the time of this writing the costs are not yet available but will be presented at the conference.)*

700 MWe OXY REFERENCE PLANT DESIGN

Both the baseline and oxy reference plant designs were developed on the same design basis to produce 700 MWe of electric generation. The plant location for determining site conditions and labor rates is Kenosha, Wisconsin. The design fuel is a sub-bituminous coal with a higher heating value of 8400 Btu/lb (19,538 kJ/kg) and a sulfur content of 0.32% by weight. Current air emissions limits (see Figure 3) were used as the design basis for particulate, NOx, SOx, mercury and acid gases. It was desired to design the oxy plant as the next-of-a kind installation assuming a commercial scale oxy-fuel project had been successful in providing the data and experience to make commercial guarantees. As such, state-of-the-art, commercially available components were used in the

[1] *An Engineering and Economic Assessment of Post-Combustion CO_2 Capture for 1100°F Ultra-Supercritical Pulverized Coal Power Plant Applications. Phase II Task 3 Final Report.* EPRI, Palo Alto, CA:2010. 1017515.

[2] *Engineering and Economic Analysis of of Oxy-Fired 1100°F Ultra-Supercritical Pulverized Coal Power Plant with CO_2 Capture: Interim Report.* EPRI, Palo Alto, CA: 2010. 1022191. (In publication.)

[3] *Engineering and Economic Analysis of of Oxy-Fired 1100°F Ultra-Supercritical Pulverized Coal Power Plant with CO_2 Capture: Final Report.* EPRI, Palo Alto, CA: 2011. (In preparation.)

designs and an advanced supercritical steam cycle with turbine throttle conditions of 3765 psia (259.6 bar) pressure and 1100ºF (593ºC) main and reheat steam temperatures was selected for both the baseline and oxy plants.

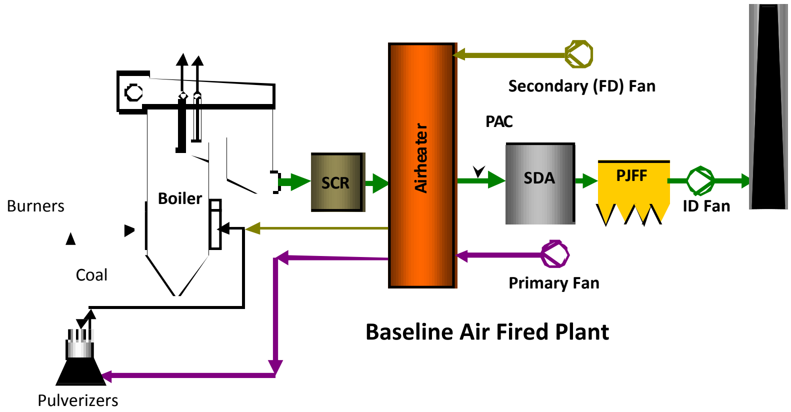

Figure 1: Baseline Air-Fired Plant

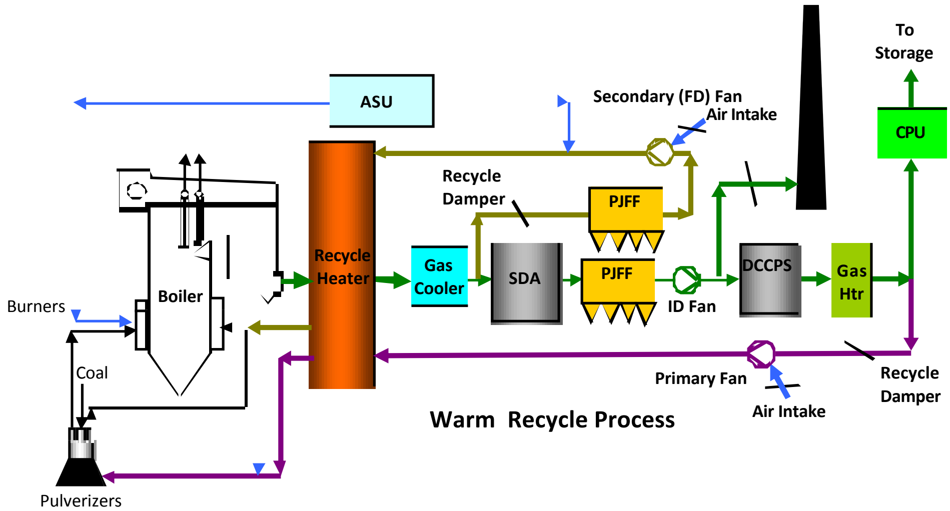

Figure 2: Oxy-Reference Plant (Warm Recycle Process)

For both the baseline and the oxy plants, auxiliary power, overall plant performance (net output and heat rate), and consumables and waste streams were assessed and steam cycle, combustion, and gas processing heat and mass balances were developed. Plot plans showing the arrangement of the major equipment were prepared as well, along with major system process flow diagrams. For the air-fired plant, a typical arrangement of primary and forced draft (FD) fans is used to introduce air into the process. The air quality control system (AQCS) for the baseline air-fired plant begins with the combustion system which employs low NOx burners and over-fire air ports, followed by selective catalytic reduction (SCR) for NOx control. To meet the particulate and SO_2 emissions criteria while also controlling acid gases, a dry scrubber using a spray dryer absorber (SDA) followed by a pulse jet fabric filter (PJFF) was selected. Powdered activated carbon (PAC) injection upstream of the SDA is used for mercury control (see Figure 1).

Selection of the oxy combustion process configuration was based on the results of an internal integration study by B&W PGG and AL in 2008 which was motivated by the results of the study published by the U.S. Department of Energy (DOE) [4]. Given the low sulfur content of the coal, the “warm recycle” configuration was selected (see Figure 2).

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[4] *“Pulverized Coal Oxycombustion Plants”*, DOE/NETL-2007 1291 Rev. 2 August 2008.

Nearly pure oxygen (>95% in this study) from a cryogenic air separation unit (ASU) is fed as the oxidant into the combustion process. With the "warm recycle" process, flue gas for the secondary recycle stream is taken upstream of the SDA at just under 400ºF (204ºC) to allow reasonable PJFF bag materials. Following the PJFF the flue gas passes through the forced draft (FD) fans, oxidant is added, and is sent back through the recycle heater to the boiler windbox. To prevent loss of costly oxidant to the compression and purification unit (CPU) stream, a recycle heater with a special internal arrangement is used. Since only particulate is removed, the secondary stream remains uncontrolled relative to sulfur and moisture content.

Due to the warm secondary recycle, the recycle heater flue gas outlet temperature is significantly higher than the airheater outlet for the baseline plant so heat is recovered to the boiler feedwater via the gas cooler. This partially offsets the reduction in fuel efficiency by reducing steam turbine extraction and producing more electricity. Following the gas cooler, the flue gas remaining after extracting the secondary recycle stream is sent through the SDA and PJFF, through the induced draft (ID) fan and then into the direct contact cooler/polishing scrubber (DCCPS). The DCCPS is designed to reduce the exiting flue gas temperature to achieve the desired moisture level to the CPU while also removing much of the remaining SO_2. After slight reheating, the gas is split between the primary recycle stream and the CPU. The CPU removes nearly all of the remaining pollutants while capturing 90% of the CO_2 produced, and pressurizes the 99.99% pure CO_2 stream to pipeline pressure for transport to storage. The result is a plant that produces near zero air emissions while achieving a high net plant efficiency (see Figure 3) and low relative cost. *(The presentation will provide more detail on the equipment design and arrangement, plant performance parameters for baseline and oxy plants, and overall economic results.)*

Plant Performance	**Baseline Plant**		**Oxy Plant**	
Gross Plant Output	697,778 kW		703,696 kW	
Auxiliary Power	40,801 kW		192,982 kW	
Net Plant Output	656,977 kW		510,714 kW	
Net Plant Heat Rate (HHV)	8,743 Btu/kWh		10,798 Btu/kWh	
Net Plant Efficiency	39.0 % HHV		31.6 % HHV	
	Design Basis	Predicted	Design Basis	Predicted
NO_x	0.03 lb/MBtu	0.02 lb/MBtu		< 1ppmv
SO_2	0.03 lb/MBtu	0.03 lb/MBtu		< 1ppmv
PM_{10} (Filterable & Condensable)	0.018 lb/MBtu	0.0099 lb/MBtu		< 1ppmv
Hg	90% reduction	6.694×10^{-7} lb/MBtu		< 1ppmv
CO	0.08 lb/MBtu	0.08 lb/MBtu		0.06 lb/MBtu
CO_2	No Capture	213.40 lb/MBtu 0.933 ton/MWh_{net}	90% Capture	21.6 lb/MBtu 0.117 ton/MWh_{net}

NOTE: All heat input figures (Btu, MBtu) are HHV basis

Figure 3: Plant Performance and Air Emissions