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Oxy-Fired Tangential Boiler Development and Large-Scale (15 MW_{th}) Validation

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1. Introduction

New technologies are required to enable the power industry to meet the global demand for electric power, while controlling emissions of CO_2. Oxy-combustion technology is one of the most promising CO_2 capture technologies in terms of performance, life cycle costs, and development time, and it can be employed for both new plants and retrofit for existing power plants. As a result of this perspective, Alstom has been involved in numerous research projects and initiatives for the development of oxy-combustion technology. Alstom's development has reached the large pilot plant scale and is currently executing comprehensive oxy pilot scale projects at the Schwarze Pumpe 30 MW_{th} Oxyfuel Plant (started operation in September 2008) and at the Boiler Simulation Facility 15 MW_{th} (started oxy-fired operation in September 2009). The knowledge being gained from these oxy-combustion pilot projects is very encouraging and is a solid basis for the design, construction and operation of a oxy-combustion large-scale demonstration plant.

This paper focuses on results from the 15 MW_{th} testing being conducted under Alstom's Oxy Tangentially Fired Boiler Development Project, located in Windsor, CT, USA. This project is also supported by the US DOE, the Illinois Clean Coal Institute, the North Dakota Industrial Commission, and a group of utilities. The project has provided detailed information on oxy-combustion behavior and the implications on boiler design and operation. Testing has been performed over a broad envelope of operating conditions to address various oxy process scenarios. Boiler performance investigations have included combustion behavior, heat transfer characteristics, ash deposition

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and pollutant formation. Performance changes between air and oxy-firing during testing of lignite, subbituminous and bituminous coals have been measured and analyzed, and are discussed.

2. 15 MW_{th} Oxy Combustion Test Program

The purpose of this program is to develop and test oxyfuel tangentially fired technology for retrofit and new boilers applications. The overall objectives include:

- Design and develop an innovative oxyfuel system for both new and existing tangentially-fired boiler units that minimizes overall capital investment and operating costs;
- Evaluate impacts of oxyfuel process parameters and boiler design parameters on boiler performance and operation during 15 MW_{th} tangentially-fired testing;
- Assess the performance of a range of coal types under oxy-firing conditions;
- Evaluate and improve engineering and simulation tools for oxy-combustion by applying detailed test data obtained

Central to the program is testing in Alstom's 15 MW_{th} T-fired Boiler Simulation Facility (BSF) in Windsor, CT, which has generated detailed performance data under representative tangential fired boiler conditions. Photographs of the BSF after modification for oxy-combustion testing are shown in Figure 1. Computational fluid dynamic (CFD) simulations were used to help establish test facility design requirements, test matrix development, and to assess alternate designs and operating conditions. Primary combustion test parameters evaluated included:

- Gas recycle rate
- Recycle gas take-off location
- Distribution of gas recycle into the furnace
- Excess oxygen
- Oxygen injection location and distribution

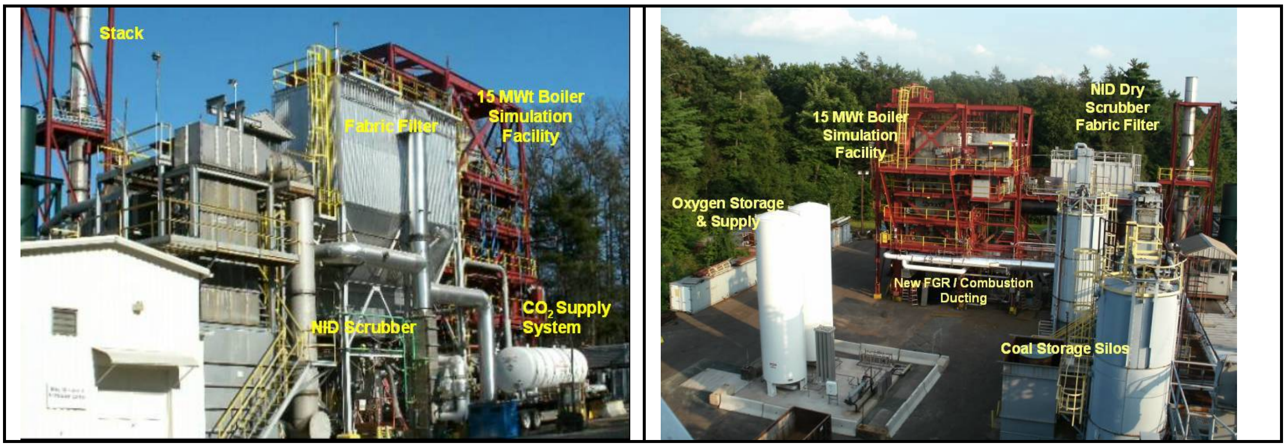

Figure 1 – Alstom 15 MW_{th} Boiler Simulation Facility After Oxy-Firing Modifications

Tests have addressed combustion, pollutant behavior, heat transfer, ash slagging and fouling, and fireside corrosion. Key measurements taken during the test campaigns included:

- Operating conditions- online data acquisition system (flows, temperatures, pressures)
- Heat transfer – waterwall test panels, convection tubes, heat flux probe measurements

- Gas composition at various locations (CO_2, O_2, H_2O, NO_x, SO_2, total hydrocarbons)
- Furnace and convection pass gas temperature distributions – suction pyrometer
- Mercury, trace metals, and SO_3 measurements at selected locations
- Deposition and corrosion probes - analyze the probes and collect deposits for further evaluation
- Detailed furnace mapping – temperature, gas composition, particulate sampling

Four test campaigns have been completed and two more are scheduled to be completed before September 2011. Testing to date has been conducted with North Dakota lignite, Powder River Basin subbituminous coal, a low-sulfur West Virginia bituminous coal and a high-sulfur Illinois bituminous coal.

3. Results

Results of the 15 MWth oxy-combustion tests are promising. Testing has been conducted under various oxy-combustion process scenarios, and over a broad range of boiler design and operating parameters. Test results reveal no technical barriers that would impede development and commercialization of oxy-combustion for CO_2 capture technology. Facility operating experience and a summary of test results characterizing combustion performance, emissions and thermal performance will be discussed in the paper and are highlighted briefly below.

Overall, combustion performance was very good during both air and oxy testing with all four of the coals tested applying Alstom's tangential firing system design. Results demonstrate operation at low excess oxygen levels during oxy-firing while maintaining low unburned carbon and low CO emissions. Minimizing excess oxygen in the boiler is important during oxy-combustion to reduce both oxygen production and gas processing costs.

The NO_x emissions during oxy-firing were typically less than 50% of the NO_x levels during air firing at comparable firing conditions. NO_x emissions measured during baseline air firing in the BSF were consistent with utility boiler experience. NO_x levels as low as 0.05 lb/MMBtu (22 g/GJ) were obtained for all four test coals under oxy-combustion using Alstom's low NO_x firing technology. Depending on plant permitting requirements, boiler selective catalytic reduction equipment may not be needed and only minimal NO_x removal needed downstream in or after the gas processing unit. Higher SO_3 concentrations were measured during oxy-firing compared to air firing. The higher SO_3 concentrations are associated with higher SO_2 concentrations during oxy-firing. The net conversion rate of SO_2 to SO_3 appeared to be similar during both air and oxy-fired tests. Higher SO_3 concentration coupled with higher moisture content in the flue gas results in substantially higher acid dewpoints during oxy-combustion, which must be considered in the boiler and downstream equipment design.

Furnace temperatures and heat transfer could be changed during oxy-fired tests by varying flue gas recycle rate, oxygen injection location and oxygen concentrations in the oxidant streams. Furnace heat absorption and furnace heat flux profiles during oxy-firing could be controlled to similar levels as those measured during air firing. These results show that substantial modifications to boiler pressure parts are not required for conversion of existing units. The ability to adjust gas recycle rate and oxygen distribution to the boiler can provide greater operating flexibility and additional means for operation control.

CFD simulations, using the ANSYS/FLUENT™ code with a number of proprietary submodels incorporated to better simulate oxy-combustion, were used to assess several boiler operating options and compared with experimental measurements. Simulations compared well with detailed probe mapping measurements and provide greater insight into behavior under various oxy-combustion conditions. These results are used to support and optimize the boiler and overall oxy-combustion system design.