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Evolving Oxy-Burner Firing Principles and a Pilot-scale Burner Design into a Utility Boiler Firing System

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1. Introduction

This paper will provide a description of the design methodology of an oxy-coal firing system for utility boilers. In preparation for this design work an understanding of the oxy-combustion flame characteristics were developed through testing of a 3.0 MBtu/hr oxy-coal research burner. This burner was developed by Siemens and REI and was based on an existing Siemens commercial burner. The versatile design of this burner allowed multiple configurations of introducing oxygen, coal and FGR, for optimization based on flame characteristics suitable for retrofit application (temperatures, stability, burnout, CO and NO_x). The purpose here was not necessarily to optimize *this* particular burner for oxy-coal, but rather to develop *general principles* relevant to most wall-fired systems, with the oxy-research burner serving as but an example of how these general principles can be implemented in practice.

Experiments were performed in the University of Utah's pilot-scale pulverized coal furnace, using the oxy-coal research burner to evaluate flame behavior under air- and oxy-fired conditions. Particularly oxy-fired conditions expected to be relevant for burner retrofit have been investigated. Video detailing the flame shape and stability along with furnace emissions for each of these conditions has been collected, providing insight into particular retrofit strategies.

In support of the pilot-scale testing and to understand the resulting flame behaviour, REI has performed CFD simulations of various strategies of oxy-combustion within the pilot-scale furnace and full-scale boilers. Siemens utilized the results from the pilot scale testing and from CFD simulation to evolve the pilot-scale burner design into a utility boiler firing system that will provide similar heat transfer behaviour to the air-fired system, while limiting the balance of plant impacts.

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2. Differences Between Air and Oxy-fuel Combustion

Oxy-coal combustion has been found to differ from air combustion in several ways, including flame temperature, combustion reaction kinetics such as coal ignition and char burnout, flame stability, NOx, and unburned carbon (UBC) in ash. These characteristics have been shown through pilot-scale testing to have an impact on flame behavior. In addition, differences in flue gas volume and heat capacity when retrofitting an air-fired utility boiler for oxy-combustion may have a significant impact on heat distribution throughout the boiler. However, additional degrees of design freedom in the combustion system is provided by oxy-combustion, and will be utilized to overcome these issues.

3. Firing System Design Considerations

The design O_2 and FGR rate for oxy-fuel combustion will affect the heat transfer and combustion conditions. Burner design must be coordinated with the overfire air system, to insure that the boiler performance remains unchanged or within the operational range of the steam temperature controls. The firing system refers to this coupled relationship between OFA and burner.

As with any retrofit application, the burner all of its components must be installed within the confines of the existing windbox/burner compartment confines. In addition, all of the oxy/FGR devices added to the burner must be designed to fit within the burner air dampers with minimum interruption to the flow paths.

The critical design condition of the burner will be the ability of the burner to perform well under both air and oxy combustion. Therefore, the design will be a compromise of flow and velocity profiles for the best combustion under each condition. On the secondary air side, some adjustment will be possible through the use of air flow dampers. For the primary flow stream, design is limited by the minimum velocity at which coal will fall out of suspension and potentially lead to coking and burner fires.

Consideration of the pilot-scale test data have also identified aspects of scale that must be considered due to the effects of boundary conditions, flow momentum in larger flow areas, mechanical interferences, etc..

The single most important burner characteristic is flame stability. The more stable and wider the operating range of flame stability, the better the combustion and boiler performance will be for a given burner. Therefore, incorporation of the oxy/FGR components to an existing burner should minimize changes to the significant components of the burner.

Identification of components providing operational flexibility and flame stability will be discussed. Where possible, anticipated changes and/or design features of those components will be described.

4. Summary

Burner design for both oxy and air fired combustion is a challenging task. Pilot scale testing has been completed to determine the effect of various operating conditions on combustion performance. This test data is valuable in determining burner design parameters for a full scale burner.

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The benefits and modifications required of a commercial burner design show that such dual firing capability is possible. However, due to the wide variation in burner operating velocities and mass flows, the final design will represent the best compromise of design for optimal performance for each firing condition.

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