Evaluation of Oxy Combustion for Industrial Boiler Applications

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The idea of using high purity oxygen rather than air as the oxidant in the combustion process is not a new concept. It is already utilized where high temperatures are required, such as in the metal and glass industries. The oxygen combustion concept is now seeing interest outside of these areas as a method for enabling the capture and storage of CO2. This is due to the flue gas products for this type of combustion consisting largely of CO2 and water vapor, from which the CO2 can be separated much more economically than from a typical flue gas stream. However, the very high combustion temperatures generated and the reduced volume of combustion products make this technology poorly suited for use on conventional process heaters and boilers due to the large changes in radiant and convective zone heat transfer that would occur.

To make this concept work without requiring significant design changes to the furnaces and boilers that are in use today, the strategy being employed is to use a diluent to lower the combustion temperatures and generate a similar volume of gas flow through the radiant and convective zones of the furnace or boiler. The most economical and easiest diluent to implement is the recycling flue gas from the boiler exhaust and mixing it with oxygen. This method of implementation allows the use of conventional forced draft burner equipment and would enable oxy combustion to be retrofitted onto existing heaters and boilers.

This paper will summarize the work done to date studying the effects of oxy combustion on burner selection, operation, emissions, and boiler performance.

The idea of using high purity oxygen rather than air as the oxidant in the combustion process is not a new concept. It is already utilized where high temperatures are required, such as in the metal and glass industries. John Zink Company, through which Coen is affiliated as part of the KOCH Chemical Technology Group, has participated with the Glass Manufacturing Industry Council and the U.S. Department of Energy on a project titled "IMPROVEMENT OF OXYFUEL BURNER DESIGN AND OPERATIONS". This project consisted of the conversion of a forehearth furnace from air/natural gas to oxygen/natural gas firing to substantially increase energy efficiency and reduce capital and maintenance costs, and involved CFD modeling of the oxygen combustion process by John Zink's Technology & Commercial Development Group.

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The most economical and easiest diluent to implement is the recycling flue gas from the heater or boiler exhaust and mixing it with oxygen. In the baseline scenario the flue gases are split into two streams. Approximately one third of the flue gas stream is fed to the CO2 separation system and two-thirds is recycled for use as combustion air via a flue gas recirculation fan. The flue gases, which are nominally in the 300 to 400 deg F temperature range, pass through an oxygen injection and mixing station which will add the oxygen required to support combustion and maintain acceptable excess oxygen levels to ensure complete oxidation of the fuel. This oxygen enhanced flue gas mixture is then delivered to the burner windbox and functions as the combustion air.

Since this simulated combustion air is pre-heated, being mostly composed of hot flue gases, the thermal NOx production will be increased. To compensate, additional flue gases can be recycled to achieve the desired adiabatic flame temperature needed for the required NOx production. For a typical low NOx applications in the Canadian Oil Sands (30 to 50ppmvd), the amount of recycled flue gases may need to be increased up to ~80%. In this case the resultant boiler exit gas composition would be 60% CO2, 37% H2O, 3% O2, and trace amounts of nitrogen depending on oxygen purity, tramp air, etc.

From the perspective of the burner equipment, this simulated combustion air is similar in volumetric flow and oxygen concentration to the conditions experienced during operation with standard pre-heated combustion air and typical levels of flue gas recirculation for NOx control. The only notable difference is the very low levels of nitrogen and the higher concentrations of CO2 and water vapor. This allows us to utilize the extensive experience we have with OTSG applications, where Coen has supplied burners on over 300 installations using our DAF™, Delta-NOx™, QLN™, QLN-ULN™, and QLN-II™

burners. This range of proven products allows the selection of the most efficient technology for achieving the required NOx emissions.

Several boiler companies have utilized CFD modeling to study the effects of this operating mode on boiler performance. In general, they have found a minor increase in the furnace heat absorption due to an increase in the emissivity of the hot flue gases and a minor reduction in furnace exit gas temperature. The increased furnace heat transfer resulted in a slight increase in boiler evaporation rate and a slight increase in boiler efficiency. These changes were determined to have a minimal effect on the tube wall metal temperature and therefore little or no reduction in operating life of the boiler. During these studies a range of flame luminosity was used and it was found that the furnace performance was relatively insensitive to this parameter within the ranges considered.

One concern when operating the boiler in this mode at lower firing rates is the possibility of low temperature corrosion. In these cases the boiler flue gas exit temperature can be close to the acid dew point of the flue gas. When oxygen is injected into the mixture the resultant temperature could potentially fall below the dew point. This concern can be addressed through techniques such as increasing the amount of flue gas recirculation to increase boiler exit gas temperature or adding a flue gas by-pass around the economizer to maintain mix temperatures above the dew point. This issue would be jointly addressed between the boiler manufacturer and Coen during the equipment design phase.

Another consideration with oxy combustion is the optimization of oxygen and CO2 purity. Although steps can be taken to minimize tramp air, some air ingress is unavoidable. Once inert gases such as nitrogen and argon are present due to this tramp air, final product CO2 separation is typically required to remove these impurities from the product stream. This allows a lower purity of oxygen to be selected, since any inert gases in the oxygen will also be removed during this process. Several studies into the economics of the process have indicated that using 95% oxygen provided the optimum balance between ASU cost and separation system cost to achieve the desired CO2 purity.