Combustion Diagnostics, Control, Computational Methods & Process Optimisation
University of Kent 2nd May 2013

Low NOx Burner Retrofits with BMS for Process Heater Optimization

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The use of an automated excess air control with Next Generation Burners can not only reduce emissions, but also reduce fuel costs. Therefore, lower emissions can be achieved with lower operating costs.

Introduction

Burner retrofits with combustion air control and fuel gas control in process furnaces are an economical solution to achieving lower NOx emissions levels and less operating costs with existing fired equipment. The optimal excess air level for achieving low NOx emissions and less operating cost is around 8% excess combustion air through the burner. This paper will explore how the GLSF Free Jet Burner design can be used with a combustion air control system to achieve less than 50 mg/Nm3 NOx emissions with 316 C combustion air preheat and 0.68% fuel savings compared to operation at 20% excess air.

Since carbon monoxide (CO) formation normally begins at 5%, excess air is provided through the burner in perfectly sealed furnaces without leakage. The burner operates with flue gas temperatures above 760° C, with excess oxygen (O2) and CO monitoring, and can be operated at 8% excess air. Should slight CO formation occurs, the excess air level should be raised accordingly. Note, if significant CO formation occurs, and then the fuel gas pressure should slowly be reduced to ensure that an explosive reaction does not occur. For safety, the combustion air control system is set important to operate at 8% excess air. If CO formation occurs at 8% air, then the control system will increase the excess oxygen level until CO formation is stabilized at an acceptable level. In such cases, CO formation occurs at approximately 5% excess air, and the furnace should be checked for tramp air leakage.

One of the other primary concerns for the end user operating company is the overall cost of ownership for next generation ultra-low NOx burners. They can have higher maintenance costs versus conventional emission burners. Zeeco provides the lowest maintenance design on the market for similar NOx emissions results. Zeeco has developed a patented next generation ultra-low NOx free-jet burner technology with a compact mechanical footprint. The GLSF Free-Jet Burner produces a flame profile with very limited flame-to-flame interaction for multiple burner installations, while also achieving shorter flame lengths. In order to control the fuel gas to the process burners, combustion air control system is installed to properly and safely operation of the burners and fit within small space requirements.

Zeeco will discuss the use of the Free-Jet burner technology, in conjunction with a burner control system in retrofit applications and the performance gains in both NOx emissions and excess combustion air.

Theory

Description of Thermal NOx Reduction
In order to understand how the Free-Jet design works, we must examine how thermal NOx emissions are formed. For gaseous fuels with no fuel bound nitrogen, thermal NOx is the primary mechanism of NOx production. Thermal NOx is produced when the flame temperature reaches a high enough level to "break" the covalent N2 bond apart and the "free" nitrogen atoms bond with oxygen to form NOx.

Methane & Air with Excess Air
2CH4 + 4(XA)O2 + 15(XR)N2 ---> 2CO2 + 4H2O + (XA)15N2 + (XR)O2

Combustion air is comprised of 21% O2 and 79% N2. Combustion occurs when the O2 reacts and is combined with the fuel (typically hydrocarbon). However, the temperature of combustion is not normally great enough to break all of the N2 bonds, so most of the nitrogen in the air stream passes through the combustion process and remains as diatomic nitrogen (N2) in the combustion products. Some of the N2 does reach high enough temperatures in the high intensity regions of the flame to break apart and form "free" nitrogen. Once the covalent nitrogen bond is broken, the "free" nitrogen is available to bond with other atoms. The free nitrogen, or nitrogen radicals, will react with any other atoms or molecules suitable for reaction. Of the prospects in the products of combustion, free nitrogen will most likely react with other free nitrogen to form N2. However, if another free nitrogen atom is not available, the free nitrogen and oxygen atoms will react to form NOx. As the flame temperature increases, the stability of the N2 covalent bond decreases allowing the formation of more and more free nitrogen and subsequently increased thermal NOx. Burner designers can reduce NOx emissions by reducing the peak flame temperature which in turn reduces the formation of free nitrogen available to form NOx.

The varied requirements of refining and petrochemical processes require the use of numerous types and configurations of burners. The method utilized to lower NOx emissions can differ from application to application. However, thermal NOx reduction is generally achieved by delaying the rate of combustion. Since the combustion process is a reaction between oxygen and a fuel, the objective of delayed combustion is to reduce the rate at which the fuel and oxygen mix together and burn. The faster the oxygen and the fuel gas mix together, the faster the rate of combustion and the higher the peak flame temperature.

Illustration A below plots Peak Flame Temperature vs. Thermal NOx. As you can see, NOx emissions increase as the adiabatic flame temperature increases. Slowing the combustion reaction allows the flame temperature to be reduced, and as the flame temperature is reduced, so are the thermal NOx emissions.

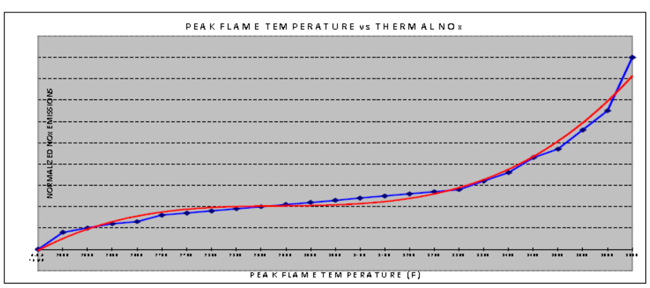

Illustration A: Calculated Peak Flame Temperature vs Thermal NOx Production

One of the best methods of thermal NOx reduction is to mix the fuel gas together with the inert products of combustion before combustion occurs thus, reconditioning the fuel. Since the new mixture is comprised of inert components, the resulting composition burns at a lower peak temperature. To best utilize the inert products of combustion (flue gas) within the boiler, the fuel gas is introduced along the outside parameter of the burner tile in an area where flue gas is present while the boiler is in operation. As the fuel gas passes through the inert products of combustion, mixing occurs which changes the composition of the fuel which stabilizes at the tile exit. Since the new fuel mixture is around 80% to 90% inert for most cases, the resulting flame burns at a lower peak temperature resulting in lower thermal NOx production. The mixing of the fuel gas with the inert products of combustion is called "Internal Flue Gas Recirculation" or "IFGR".

Application

The purpose of the retrofit application was to replace the burners to achieve ultra-low NOx emissions. The following is a description of an application using the principles of reduced emissions and excess air control. A Coker Furnace was retrofitted with sixty four (64) Zeeco GLSF Free Jet burners each operating with a maximum heat release of 2.93 MW. The total maximum heat release of the Coker Furnace was 187.5 MW. The burners were designed to operate in the forced draft mode with 316 C combustion air preheat at 8% excess air. In addition, the furnace was designed to operate with a furnace flue gas temperature of 820 C of the gases exiting the radiant section.

Results

After the sixty-four (64) burners were installed in the Coker Furnace, a third party measured the resulting emissions recorded at the below listed conditions:

Operating Conditions:
Number of Burners: Sixty-four (64)
Burner Heat Release: 2.9 MW per burner
Furnace Heat Release: 185.6 MW per furnace
Excess Air: 8%
NOx Emissions: 49 mg/Nm3
CO Emissions: 5 mg/Nm3
Calculated fuel savings: 0.68% fuel savings compared to operation at 20% excess air

Conclusions

The use of an automated excess air control with Next Generation Burners can not only reduce emissions, but also reduce fuel costs. Therefore, lower emissions can be achieved with lower operating costs. Burner retrofits with combustion air control and fuel gas control in process furnaces are an economical solution to achieving lower NOx emissions levels and less operating costs with existing fired equipment. The optimal excess air level for achieving low NOx emissions and less operating cost is around 8% excess combustion air through the burner. This paper provided an example how the GLSF Free Jet Burner design can be used with a combustion air control system to achieve less than 50 mg/Nm3 NOx emissions with 316 C combustion air preheat and 0.68% fuel savings compared to operation at 20% excess air.