Next Generation Ultra-low NOx Burners for Refinery and Petrochemical Process Heaters

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Summary

The Air Quality State Implementation Plan for Texas requires the refineries and chemical plants in the Houston-Galveston area to reduce NOx emissions by 90% over the next six years. This requirement will be implemented by providing each furnace with an "emission allotment" based on the heat release for that unit. Under the 90% reduction requirement units of 40 million Btu/hr to 100 million Btu/hr will be allowed to emit no more than 0.015 lb NOx per million Btu fired. Units of 100 million Btu/hr or more are limited to 0.01 lb NOx per million Btu fired. Low NOx technology has always been "technology driven by regulatory requirement" and this new regulation along with tightening NOx emission limits in California have spurred a new round of low NOx burner development. However, these process heaters generally utilize natural draft burners which somewhat limits design options and thus NOx reduction options. In addition these applications burn wide ranging fuel compositions, often including high percentages of hydrogen.

In order to meet this latest emissions challenge, development work at John Zink Company has proceeded along multiple development paths that include combinations of lean premix combustion, quasi-flameless combustion, internal furnace gas recirculation, multiple stages of fuel injection and lifted flame technology. The development work has been done on full-scale prototype burners (4 to 10 million Btu/hr) under simulated field conditions. This presentation describes the development and application of several burners utilizing combinations of these technologies that achieve emissions as low as 6 PPM NOx under operating conditions typical in a refinery and chemical plant process heater firing a wide variety of fuel gas compositions.

Commercial burners have been fabricated and installed in the field at several locations starting in early 2001. Field test data show significant NOx reductions over previous ultra-low NOx burner designs.

One burner, the LM 300 has been developed for "round flame" applications and is capable of firing a full range of refinery and petrochemical fuel gas compositions. This burner uses a combination of three stages of fuel injection combined with internal furnace gas recirculation and lean "lifted" flame technology. Development testing showed that this burner produced NOx emissions at or near 10 PPM up to 20 PPM depending on operating conditions utilizing a wide range of fuel gases.

Applications to date range in size from about 6 MMBtu/hr per burner up to 20 MMBtu/hr per burner. Most applications have been vertical cylinderical process heaters with a few “cabin” style heaters. All applications have been multiple burner installations. Field data shows NOx emissions ranging from 15 to 30 PPM and are less than half of the emissions of previous generation low NOx burners in these applications.

Another development is a burner designed for flat flame applications fired across a hearth or up a refactory wall. The LPM-F burner utilizes part of the fuel to supply all of the combustion air through high efficiency venturi eductors. This produces a lean-premix primary flame that significantly reduces both thermal and prompt NOx. The remainder of the fuel is injected through staged fuel injection tips. This staged fuel entrains significant quantities of furnace gases prior to mixing with the products of combustion from the lean-premix flame. The staged fuel thus oxidizes under the high temperature, dilute oxygen conditions seen with “flameless” combustion. Because of the significant quantity of inert combustion products mixed with both the fuel and oxygen the prompt NOx formation is minimized and thermal NOx is significantly decreased since the temperature rise due to reaction is minimized.

NOx emissions from this burner during development testing ranged from 9 to 12 PPM compared with 60 to 75 PPM NOx for a conventional baseline burner. In the first field application 32 conventional burners producing 160 to 180 PPM NOx were replaced in an atmospheric crude heater. The LPM-F burners produced 15 to 16 PPM NOx and generated a more uniform thermal pattern in the furnace. This burner has been demonstrated on fuels containing as much as 65 vol% Hydrogen.

A recent development is a round flame burner utilizing lean-premix primary combustion and quasi-flameless staged combustion. Development testing of this burner has shown NOx emissions of 6 to 8 PPM with a range of fuel gases up to 50 vol% Hydrogen. In-furnace probing with a water-cooled probe confirmed that the overall flame length with the lean-premix design is actually shorter than previous low NOx burner designs. Emissions as low as 6 to 7 PPM have even been seen with furnace temperatures as high as 2200 ^{o}F during development. Field data for a refinery application is expected to be available in April.