Achieving Single Digit NO_x Emissions Through Dynamically Controlled Flue Gas Recirculation

Background

NO_x emissions have drawn increased attention from the EPA and other environmental agencies as a pollutant for the following reasons:

- NO_x emissions can form nitric acid, resulting in acid rain.
- As an ground-level ozonator, it can contribute to respiratory distress, particularly when combined with aerosols.
- Nox contributes to climate change and global warming

Nitrogen makes up 79 % of atmospheric air, and it is stable, not reacting easily with other elements. At the high temperatures frequently found in any combustin process, however, nitrogen can combine with Oxygen to form nitrogen oxides, typically NO and NO_2, together represented as NO_x. Although most total NO_x is generated from mobile sources - millions of automobiles and trucks, industrial sources such as the burners used in boilers and industrial furnaces constitute much larger sources per unit, and draw regulatory attention as "low hanging fruit".

NO_x formation in burners is frequently categorized as:

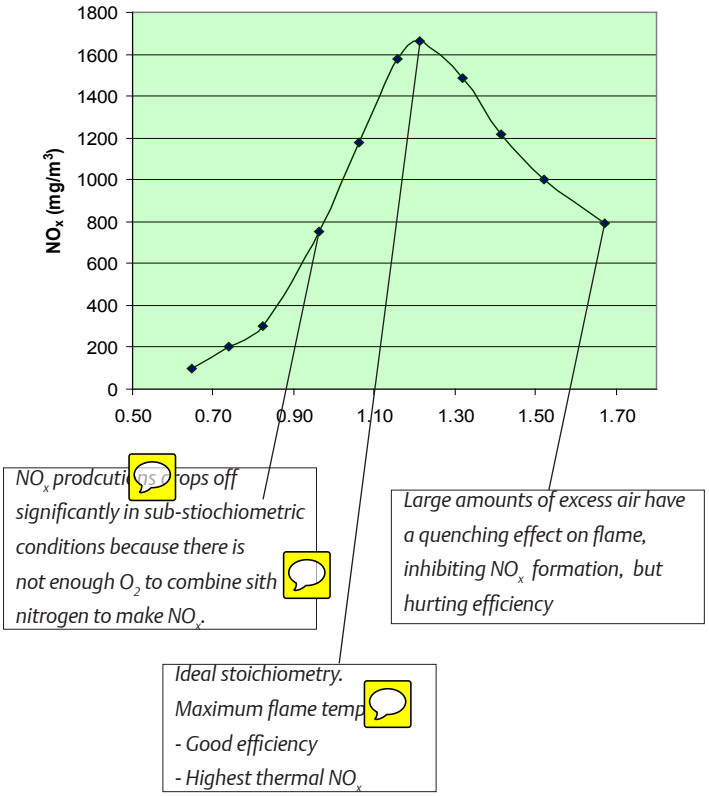
- Fuel NO_x - nitrogen is found in the fuel (usually oils).
- Thermal NO_x - formed in the burner due to high temperatures.
- Prompt NO_x

This third source is generated in the early stages of combustion, and is attributed to the reaction of atmospheric nitrogen with radicals such as C, CH, and CH_2 fragments derived from the fuel.

The best opportunity for reducing the NO_x resulting from industial combustion is to minimize the production of thermal NO_x .

The graphic on the right depicts the production of NO_x as a function of air/fuel ratio.

NO_x as a function of air / fuel ratio



In large power boilers, “staged combustion” techniques operate burners at sub-stoichiometric conditions, and then add air downstream to complete combustion while maintaining lower temperatures throughout.

Low and Ultra low NO_x burners apply the concept of staged combustion right within the burner design.

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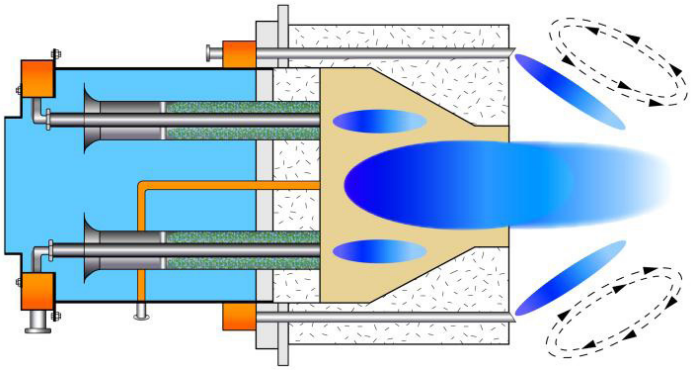

Graphic provided courtesy of Fives N. American Combustion, Inc.

Flue gas recirculation, both internal to the burner and externally are another means to keep flame temperature lower, minimizing NO_x production with little or no efficiency losses.

The pictured Steam Generator utilizes a Fives North American Magna-Flame GLE Ultra Low NO_x Burner, which is a fuel staged burner with a lean premix primary stage and ~70 % of fuel is used in the primary stage.

- Oxidant (air or air + FGR) shown in "sky" blue
- Fuel containing manifolds/pipes are in orange
- Green shaded areas show where lean premix is formed
- Oxidant (air or air + FGR) enters the body from the left hand side
- Primary fuel is the left-most fuel connection on the bottom of the burner. This is ~70 % of the total fuel
- Center fuel is the other smaller fuel connection on the bottom of the burner. It is used to help stabilize the primary flame, it is only ~ 2 % of the total fuel

Secondary fuel is the fuel connection at the top of the burner near the middle. This is ~30 % of the total fuel. The secondary fuel entrains/mixes with flue gases in the radiant section of the steam generator before reacting with the gases from the primary flame. The circular arrows show the entrainment of furnace gases into the secondary internal FGR on second stage.

The unit has a proprietary ratio control algorithms for the fuel stages and < 15 ppm NO_x without FGR.

External Flue Gas Recirculation Flue Gas is mixed into the combustion air going to the burner to control NO_x emissions. An O_2 Analyzer mounted downstream of the mixing point in the windbox is used to control the rate of flue gas injection to the level deterimined to minimize the NOx produced.

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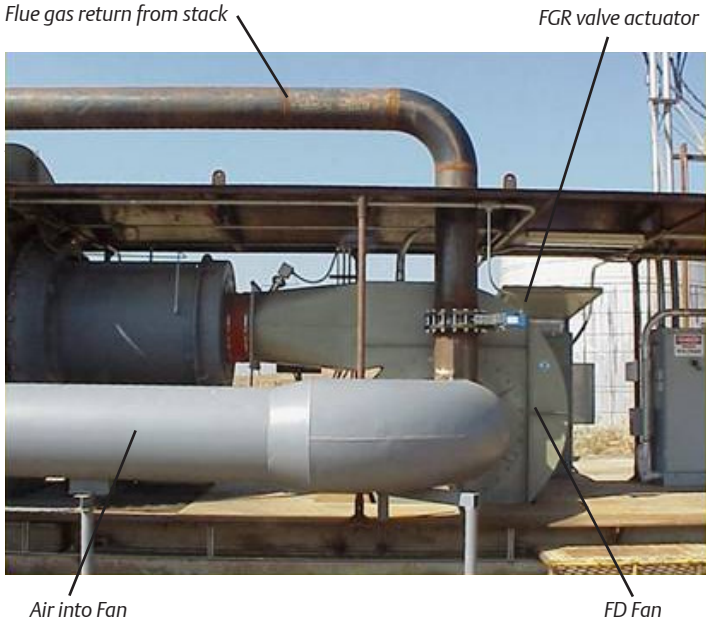
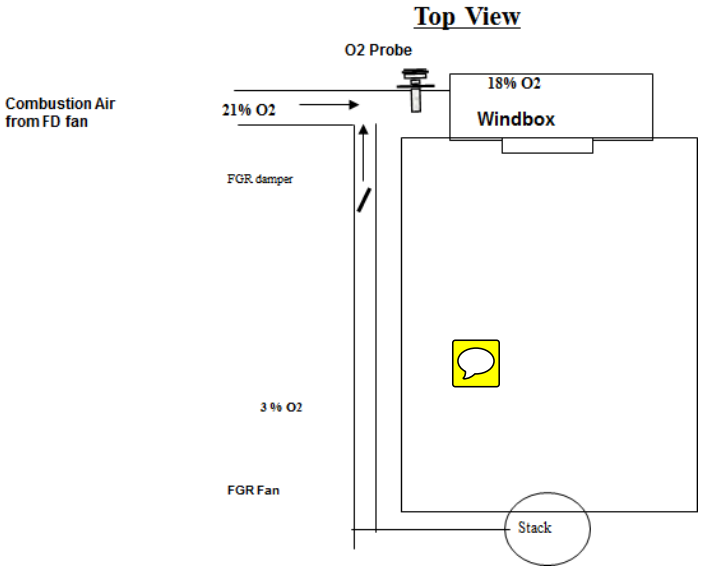


The amount of Flue gas required for recirculation will vary, depending upon

- Changes in the density of combustion air
- Firing rate of the Steam Generator
- Changes in fuel BTU value

Dynamically controlling final FGR rate at the burner windbox has proven to maintain NO_x levels to below 5 PPM 24/7 while maintaining good burner stability.



Rosemount Analytical's 6888 Xi electonics offers a "programmable reference feature which optimmizes the accuracy of the O2 measurmeent by using a bottled gas of low O2 value as reference gas. This optimizes the accuracy of the O2 measurement at the typical FGR levels of 17-19%. Other advantages of using a bottled reference gas is that it contains a constant level of moisture and does not contain oil or other contaminents . A bottle typically lasts for a month.

In summary, Low NO_x Burners, combined with flue gas recirculation has enabled operation with single digit NO_x emissions, without any loss of efficiency. The installed Installed base in the noted application numbers more than 200 units.

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Emerson Process Management
Rosemount Analytical Inc.
Analytical Center of Excellence
6565P Davis Industrial Parkway
Solon, OH 44139 USA
T +1 440 914 1261
Toll Free in US and Canada 800 433 6076
F +1 440 914 1262
US Response Center 800 654 7768
gas.csc@emerson.com

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