Reinhold Environmental Ltd.

2008 NOx-Combustion Round Table & Expo Presentation

February 4-5, 2008 in Richmond, VA

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2008 WPCA
NO_X ROUNDTABLE

COMBUSTION

AND

NO_X

101

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NO_X FORMATIONS

- NO_x is defined as the total of NO and NO_2
- NO = Nitric Oxide
- NO_2 = Nitrogen Dioxide
- Stack emissions are typically over 95% NO

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TYPES OF NO_X PRODUCTION

- Prompt NO_x
  Neither fuel or thermal NO_x, requires carbon present to form
- Thermal NO_x
  Produced from the nitrogen in the combustion air
- Fuel NO_x
  Produced from the nitrogen in the fuel

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PROPORTION OF NO_X

- Natural Gas

  Almost all thermal NO_x, due to very low nitrogen content of the fuel

- Oil

  20-40% thermal NO_x and 60-80% fuel NO_x

- Coal

  20% thermal NO_x and 80% fuel NO_x

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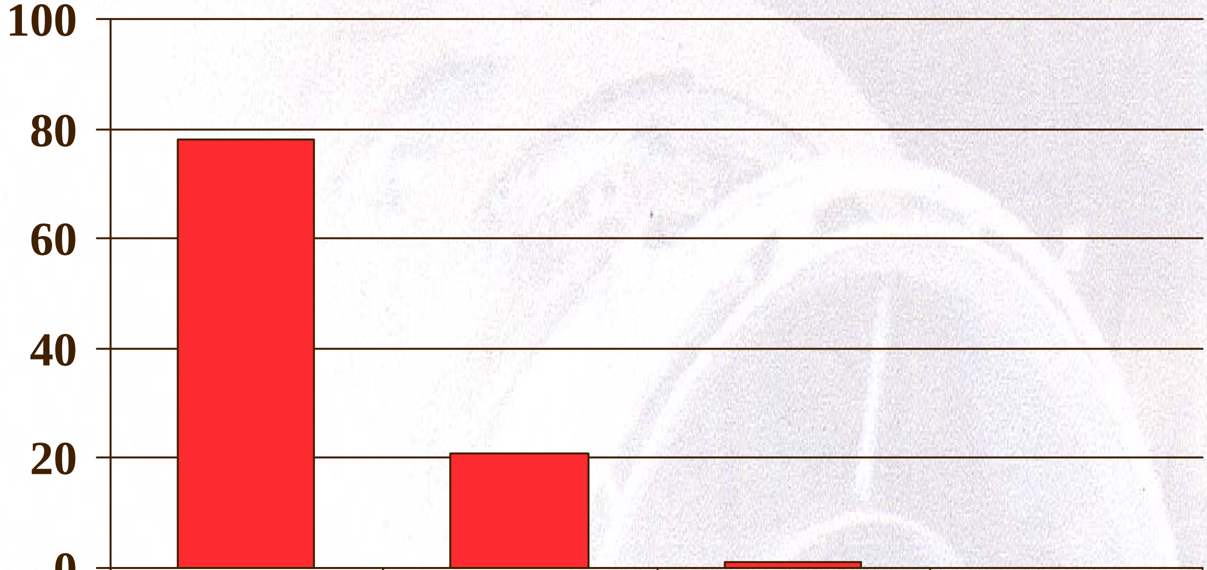
COMPOSITION OF AIR



	Nitrogen	Oxygen	Argon	Carbon Dioxide
■	78.09	20.95	0.93	0.03

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FACTORS AFFECTING NO_X

- **Time**
  The amount of time that the burning lasts
- **Temperature**
  Temperature to which fuel and air are subjected
- **Turbulence**
  The mixing of the fuel and air

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TIME

- The time required for fuel burn out is a function of the particle size
- To provide complete burnout, the particle size should be kept to a minimum
- Fuel/air mixing rates regulate the burn rate and thus the resulting average combustion temperature

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TEMPERATURE

- Most NO_x is produced at temperatures above 2800°F
- To minimize NO_x, the average combustion temperature should be kept as low as possible
- The flame can be lengthened to provide more time for burnout and therefore lower combustion temperatures

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EFFECT OF HEAT RELEASE RATE

- As the heat release rate in the furnace increases, the resulting combustion temperature also increases
- Older furnaces were designed to have small furnaces and therefore have higher burner zone heat release rates.
- Newer NSPS units were designed with larger furnace with cooler burner zones.

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TURBULENCE

- Turbulence is required to completely mix the fuel and combustion air
- To much turbulence promotes rapid burning and high NO_x production
- Low NO_x combustion mixes fuel and combustion air more slowly and in more stages to reduce NO_x production

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STOICHIOMETRY

- Stoichiometry refers to the relative amounts of fuel and combustion air
- 100% stoichiometry or a stoichiometric ratio of 1.0 represents the exact amount of combustion air required to completely burn the fuel
- Excess air is the amount of air supplied above 100% stoichiometry

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STOICHIOMETRY AND NO_X

- The stoichiometry in the burner zone is less than 100% to minimize the mixing of air and fuel at the high temperatures present
- The remaining combustion air and any excess air is mixed as overfire air

BURNER STOICHIOMETRY

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- The stoichiometry provided by primary air is as low as 60%
- Secondary air raises the overall stoichiometry to approximately 80% - 100%
- The remaining combustion air and excess air provides an overall stoichiometry of approximately 130%, for coal

STOICHIOMETRY ISSUES

- When the stoichiometry in the burner zone is very low, below 90%, this creates a reducing (oxygen deficient) zone.
- Reducing atmospheres increase the potential for corrosion due to sulfur in the fuel forming H_2S
- Reducing atmospheres also increase the potential for slagging in the furnace

EXCESS AIR

- Fuel and air do not perfectly mix
- If 100% air were supplied, not all fuel would combust
- Excess air provides the amount of air required to compensate for the inefficiencies of mixing

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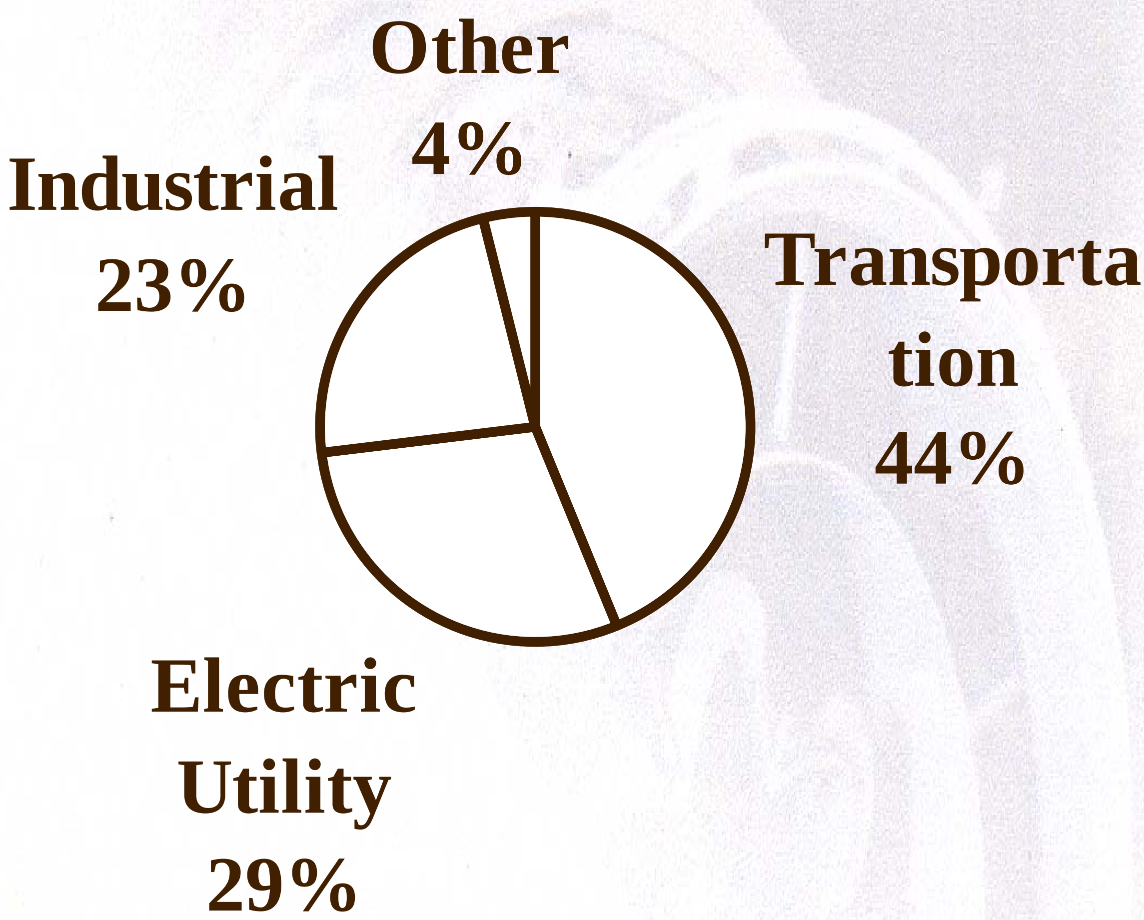
NATIONAL NO_X INVENTORY



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CLEAN AIR ACT

- New Source Performance Standards (NSPS)
- Best Available Control technology (BACT)
- Reasonably Available Control technology (RACT)

COMBUSTION CONTROL TECHNIQUES

- Low excess air
- Biased firing
- Low NO_x burners
- Overfire Air

COMBUSTION CONTROL TECHNIQUES

Low Excess Air

When the excess air is very low, below 90%, this creates a reducing (oxygen deficient) zone.

Reducing atmospheres increase the potential for corrosion due to sulfur in the fuel forming H_2S

Reducing atmospheres also increase the potential for slagging in the furnace

There is no cost to operate at low excess air. If corrosion or slagging occur, costs associated with poor performance or waterwall wastage must be considered.

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COMBUSTION CONTROL TECHNIQUES

Overfire Air

The most effective method of reducing NO_x is to add overfire air to a combustion system.

Today most combustion systems already have overfire air.

Too much overfire air results in a reducing atmosphere in the furnace potentially leading to waterwall corrosion issues.

The goal is to penetrate all of the flue gases rising from the burner levels past the overfire airports.

Installing overfire air on an older unit involves installing overfire air ports, waterwall panels and ducts.

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COMBUSTION CONTROL TECHNIQUES

Low NO_x Burners

Low NO_x burners are designed to manage the contact of fuel and air to minimize the production of NO_x during combustion.

The goal is to minimize the contact of the air and fuel in the high temperature zone of combustion.

Typically low NO_x burners can be installed in the existing furnace. It is not usually necessary to replace the waterwall panels for the existing burners.

BURNER AIR FLOW

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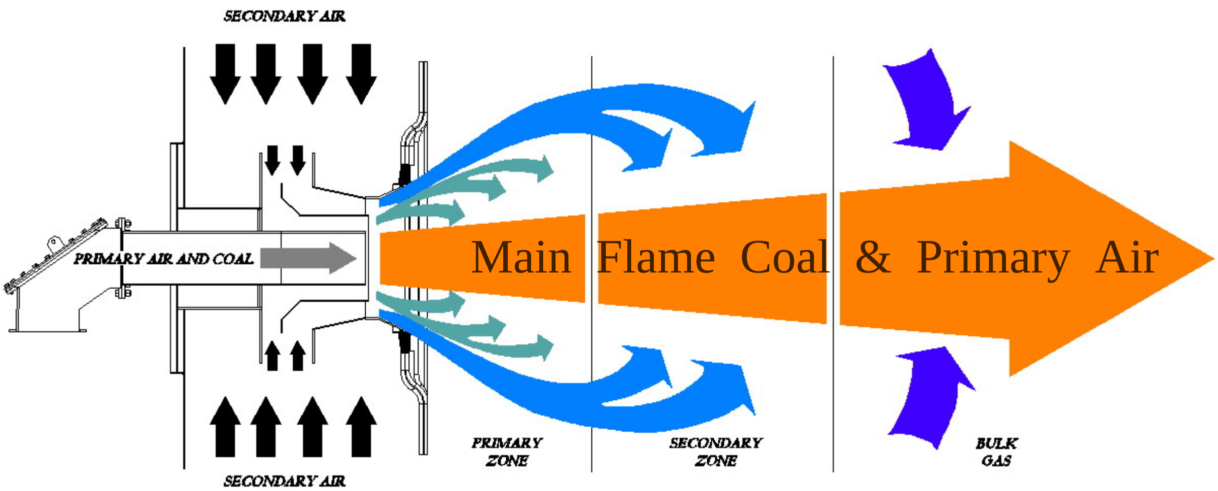

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LOW NO_X BURNER FLAMES

Traditional long low luminosity flame

Intense bright flame

COMBUSTION CONTROL TECHNIQUES

Biased Firing

Biased firing involves varying the air to fuel ratio on different burners and/or different burner rows.

The effect is to create areas of fuel rich mixtures reducing the contact with nitrogen from the air.

There is no cost associated with biased firing. However, if the burners are tuned to operate with biased firing, operating flexibility involving taking burner rows out of service is reduced.

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NO_X CONTROL CONSTRAINTS

- Combustion efficiency
- UBC effects
- Flame stability
- Flame impingement
- Waterwall slagging
- Waterwall corrosion
- Heat transfer
- Boiler operation
- Steam temperatures

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NO_X CONTROL CONSTRAINTS

Combustion Efficiency

Combustion efficiency is affected by the quantity of excess air and the unburned carbon.

The higher the amount of excess air used, the flue gas losses increase.

As combustion is staged, the potential for increasing the unburned carbon increases.

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NO_X CONTROL CONSTRAINTS

UBC Effects

The use of overfire air removes combustion air from the burner zone. This reduces the mixing and completion of combustion in the burner zone.

Low NOx burners typically reduce the peak combustion temperatures. This reduction in combustion temperature, promotes incomplete burnout of the carbon in the coal.

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NO_X CONTROL CONSTRAINTS

Flame Stability

The combination of reduced combustion air and lower flame temperatures, can potentially cause flame stability issues.

Flame stability issues include:

Coal skirts, unburned coal leaving the burner throat with the flame ignition point further away from the burner throat.

Pulsating flames can be created when the ignition of the coal is unstable and pockets of coal and air ignite and extinguish.

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NO_X CONTROL CONSTRAINTS

Flame Impingement

In many older furnaces, the depth from the front wall with the burners to the rear wall is relatively shallow.

Many low NO_x burners produce long low temperature flames. These longer flames may actually reach the rear wall.

Flame impingement raises the metal temperature of the waterwall tubes.

In addition, the products of combustion are deposited on the waterwalls, leading to corrosion issues.

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NO_X CONTROL CONSTRAINTS

Waterwall Slagging

As previously discussed lower excess air levels, create reducing atmospheres which promote slagging.

When combined with long flames, products of combustion are more readily deposited on the waterwalls.

Cooler combustion temperatures also aid in solidifying the components of slag once they are deposited on the tubes.

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NO_X CONTROL CONSTRAINTS

Waterwall Corrosion

Similar to the slagging issues, corrosion is promoted by the reducing atmosphere created in the combustion zone.

Corrosion is particularly a problem when the sulfur content in the coal is 1% and higher.

The sulfur in the coal is converted to H_2S during combustion. When deposited on the waterwalls, corrosion takes place and the tubes suffer from accelerated wastage.

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NO_X CONTROL CONSTRAINTS

Heat Transfer

Today's low NOx burners are better at matching the heat transfer conditions of the furnace.

The lower combustion temperatures and longer flames create conditions that differ from those of the original burners in the furnace.

NO_X CONTROL CONSTRAINTS

Boiler Operation

Boiler operation concerns include, burner turndown, flame support requirements resulting from flame stability issues and increased sensitivity to mill issues.

With reduced combustion air to the burners, burner turndown can be compromised.

Flame stability may require increased ignition support. In addition, reduced flame stability, puts greater demands on the performance of the mills.

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NO_X CONTROL CONSTRAINTS

Steam Temperatures

The use of overfire air modifies the combustion and temperature profile in the furnace.

In addition, high levels of overfire air can create secondary combustion above the burner zone. This secondary combustion increases the steam temperatures of SH surfaces hanging above the furnace.