Reinhold Environmental Ltd.

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Preparing For Combustion Tuning

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Preparation for Burner Tuning & Design

Both preparing for combustion tuning and specifying new low NO_x burners both require attention to detail to produce the best results.

For tuning burners:

Proper preparation = Best performance

For specification of new burners:

Good Design Information = Guarantees

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Preparation for Burner Tuning & Design

Proper preparation is the most important step for both tuning and designing low NOx burners.

Burner tuning and design are relatively straightforward processes. Both are based on empirical data from known operational databases.

Thus, for the best outcome during burner tuning or the best burner design, complete and diligent preparation most likely accounts for 90% of the success of these projects.

Why is Preparation Important?
Why Do Plants Invest in NO_x Reduction?

Why do utilities spend significant effort to purchase, operate and maintain equipment for the reduction of NO_x:

Local, state and federal mandates for the reduction of NO_x.

As a side effect of the regulations, NO_x credits are financial “incentives” to reduce NO_x. These credits can either be sold as a revenue stream or banked to offset future expenditures by the utility in the event NO_x credits are needed for the operation of one or more units.

With this investment and ongoing operational and maintenance costs, getting the best performance or specifying the right equipment is essential. The right investment upfront yields the most cost effective solution over the long term.

NO_x and Related Boiler Operation

Any application of low NOx burners to reduce the NOx levels in a furnace interacts with other performance conditions of the furnace/boiler.

Therefore, achieving the lowest possible NOx levels is a compromise between lowering NOx while balancing the effects on the related furnace/boiler performance conditions.

Attempting to achieve the lowest NOx levels at any cost can cause a significant impact to the furnace and boiler performance.

Proper Preparation = Optimum Performance

Proper preparation will insure that each of the operational conditions affected by the application of low NOx burners will be optimized.

- Combustion efficiency (maximize)
- UBC effects (minimize)
- Flame stability (maximize)
- Flame impingement Minimize/eliminate)
- Waterwall slagging (minimize)
- Waterwall corrosion (minimize)
- Heat transfer (maintain design conditions)
- Boiler operation (maintain proper conditions)
- Steam temperatures (maintain steam temps/spray flows)

Differences Between Old and New Burners

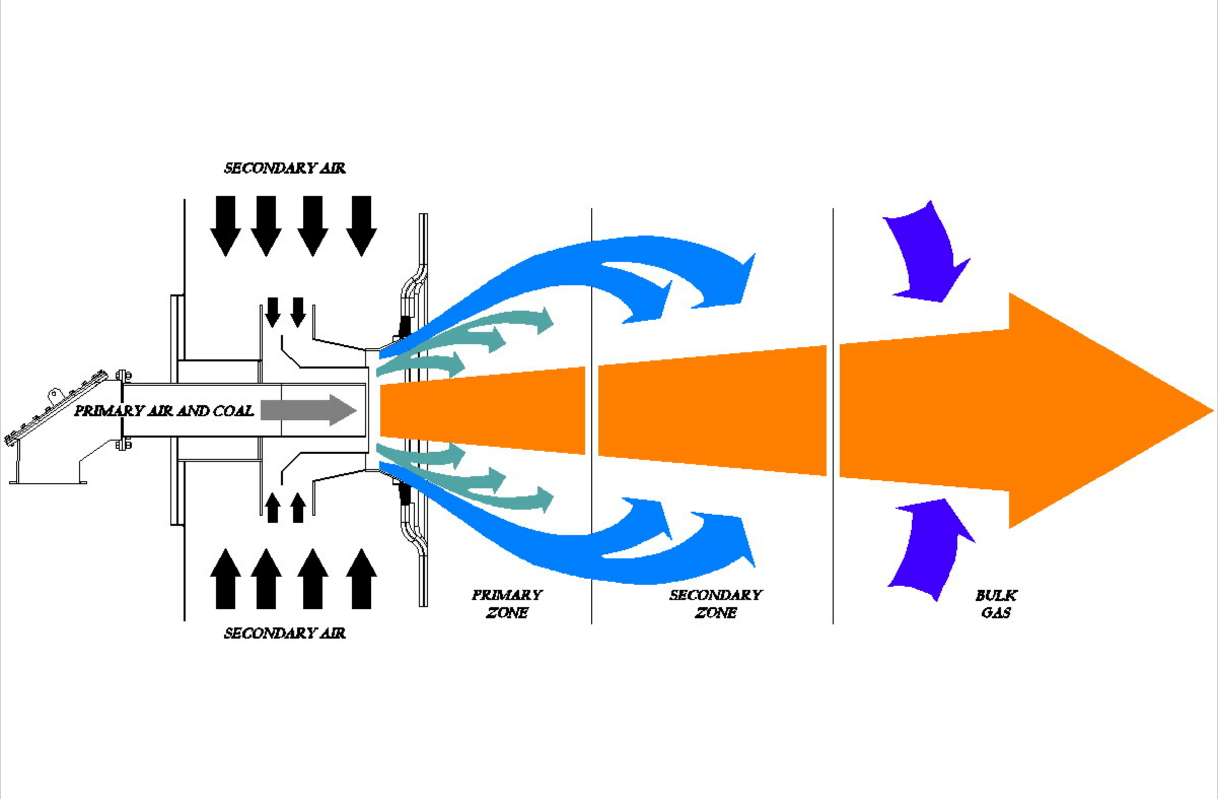
The old style non low NO_x burners main goal was to combust as much of the fuel as possible in as small a furnace as possible. This made the cost of the furnace low and the efficiency of combustion high.

Non low NO_x burners mixed all of the air and fuel immediately to create a very hot and turbulent flame.

Conversely, the main principle of low NO_x combustion is the management of both air and fuel to produce the optimum combination of combustion efficiency and lowest possible emissions.

Low NO_x burners separate the air and fuel, staging the mixing throughout the combustion process.

Air and Coal Mixing in a Low NO_x Burner



The mixing of the combustion air and coal in a low NOx burner is achieved in a staged process throughout the flame and with the addition of overfire air, throughout the furnace.

SECONDARY AIR FLOW

TUNING CONDITIONS

Secondary Air Flow Issues

There are a number of issues that can affect the ability to operate the combustion system at the lowest possible NO_x levels. Some of these issues are as follows:

- Poor air flow distribution in the burner windboxes
- High pressure drop in the secondary air ducts reducing the available pressure to the burner and overfire air windboxes
- Plugged air heater baskets reducing the available pressure to the burner and overfire air windboxes
- Random plugged air heater baskets causing continuously fluctuating windbox pressures

Poor Air Flow Distribution in the Burner Windboxes Effect On NO_x

Low NO_x burners and the combustion created by them is defined by the design conditions of the burners. With poor air flow distribution, each of the burners is operating at different air flow and stoichiometric conditions. In addition, poor air flow can cause poorly distributed air flow, with one side of the burner having too much air and the other not enough.

Secondary Air Flow and Burner Stoichiometry

When the stoichiometry in the burner zone is below 100%, this creates a reducing (oxygen deficient) zone. The following negative impacts on the operation of the boiler are created in a reducing atmosphere:

- Potential increases in corrosion due to sulfur in the fuel forming H_2S
- Potential increases in slagging rates in the furnace
- Increased CO levels
- Increased unburned carbon levels

When the stoichiometry in the burner zone is above 100%, this creates an oxidizing (oxygen rich) zone. The following negative impacts on the operation of the boiler are created in an oxidizing atmosphere:

- Potential increases in NO_x levels

Poor Air Flow Distribution in the Burner Windboxes Effect On NO_x

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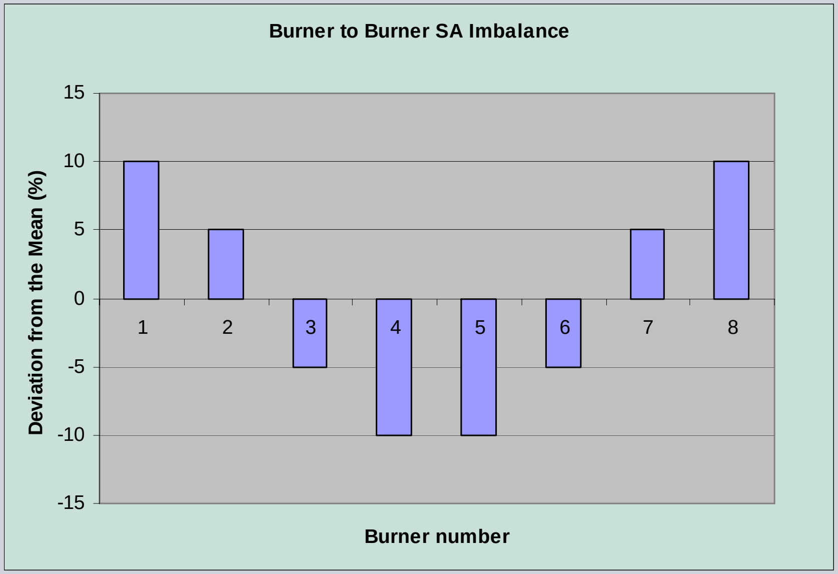

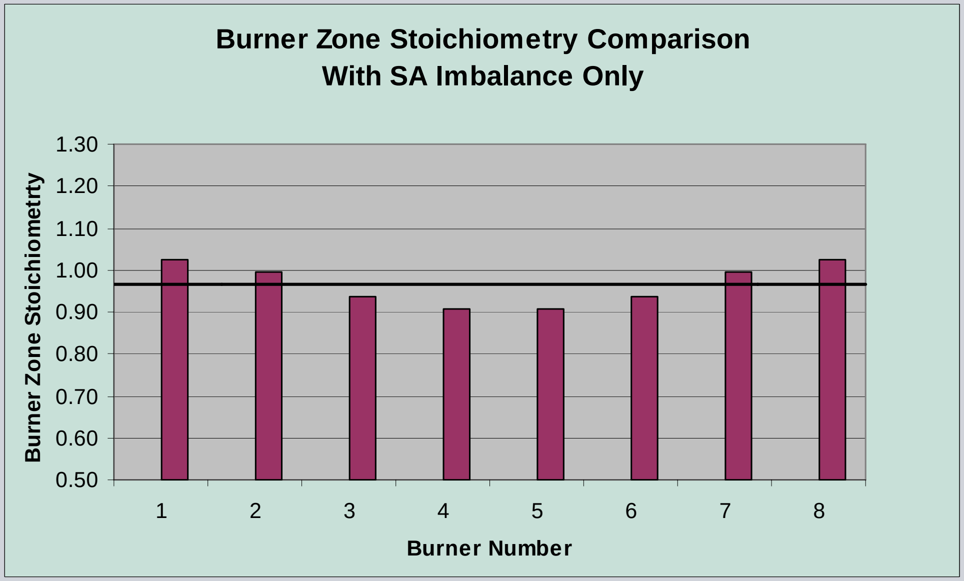

The chart on the left shows a secondary air flow imbalance with more air flow to the outboard burners, typical of a side fed windbox.

The chart on the right shows the variation in the stoichiometric ratio between burners, asssuming an equal coal flow to all burners.

When combined with coal flow imbalances, the effect is much greater.

Poor Air Flow Distribution in the Burner Windboxes Remedy

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A secondary air flow model of the windboxes and subsequent design, fabrication and installation of flow correcting turning vanes and baffles can correct poor windbox flow patterns.

Improving Secondary Air Distribution Utilizing CFD Modeling

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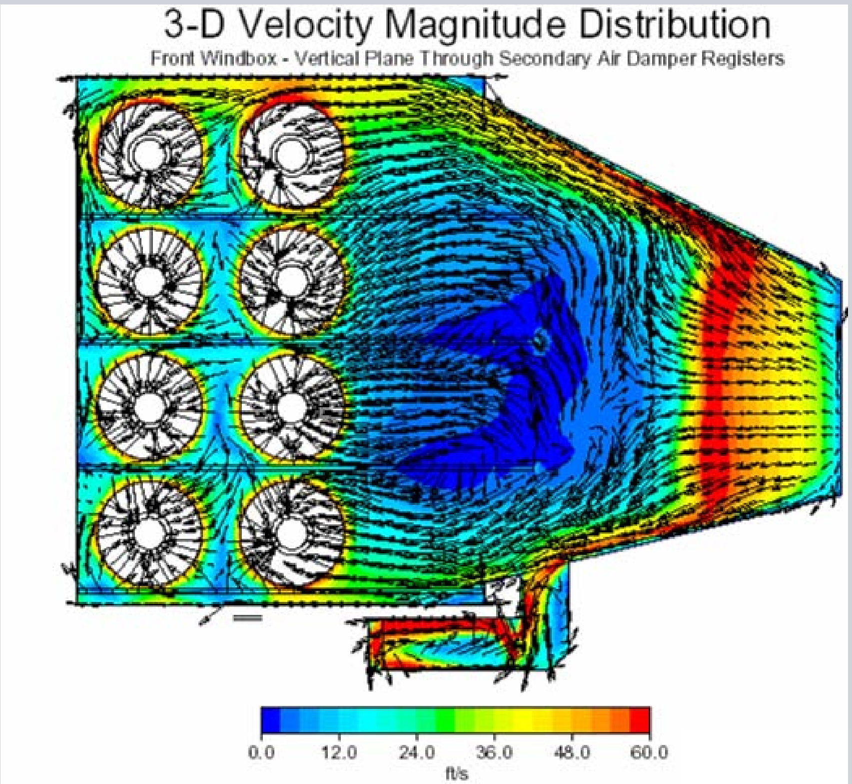
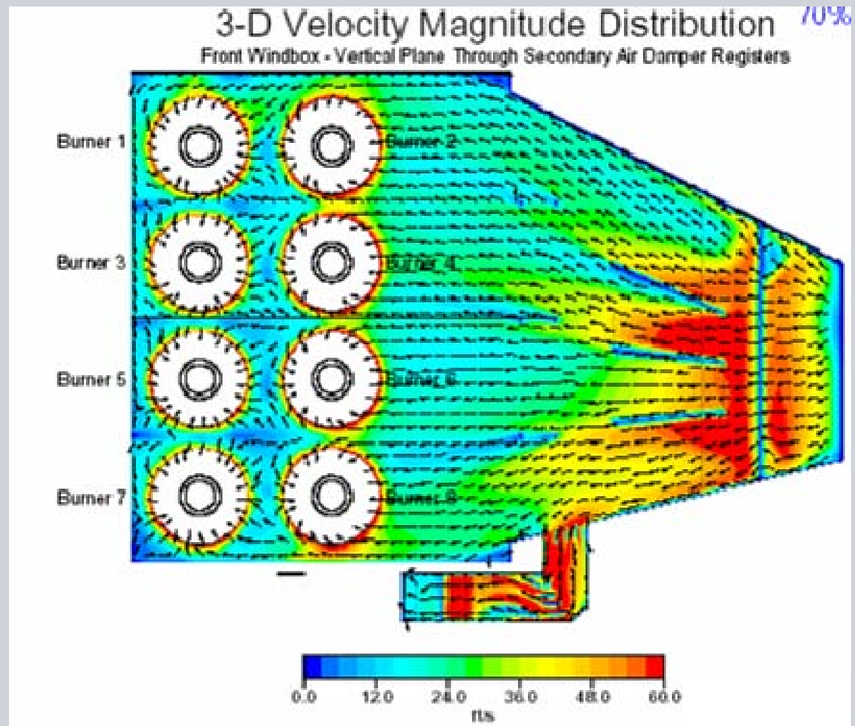
700 MW Unit with 7 Mills and 28 Burners

Windbox Modification



As- Found Condition



Siemens Remedy

Baffles and turning vanes have been added to correct flow distribution.

High Pressure Drop in the Secondary Air Ducts Effect on NO_x

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High pressure drop in the secondary air ducts leads to low available pressure in the burner and overfire air windboxes. Higher levels of windbox pressure, allow the burners to provide the pressure drop, providing a better flow distribution. In these cases the burners may be at one end of the air register adjustment, reducing the ability to balance the burners. In some cases, available pressure is utilized to force more air flow to the overfire air system.

High Pressure Drop in the Secondary Air Ducts
Remedy

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A secondary air flow model of the secondary air flow ducts and subsequent design, fabrication and installation of flow correcting turning vanes and baffles can reduce the pressure drop, providing higher available windbox pressures.

Secondary Air Duct Pressure Drop
Reducing Pressure Drop

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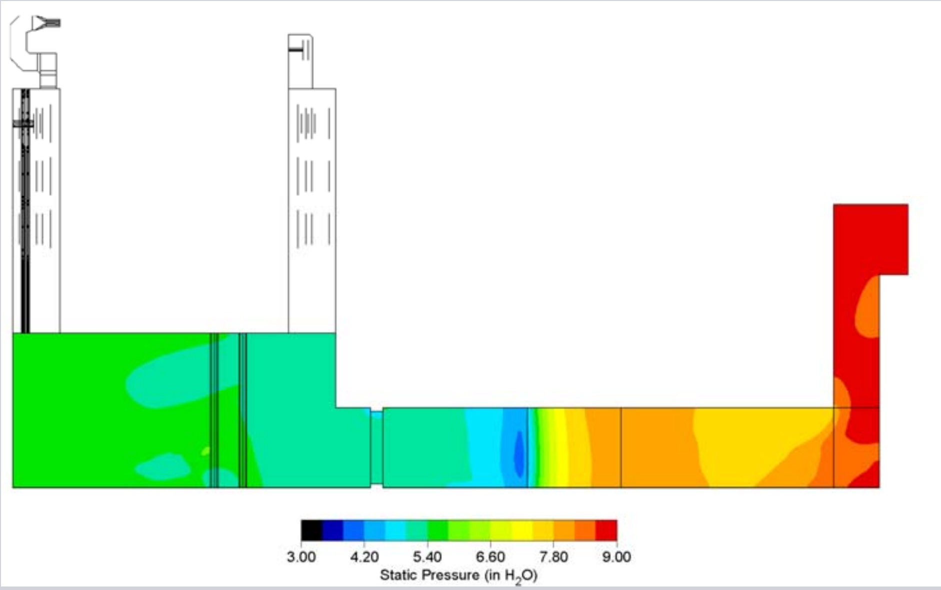
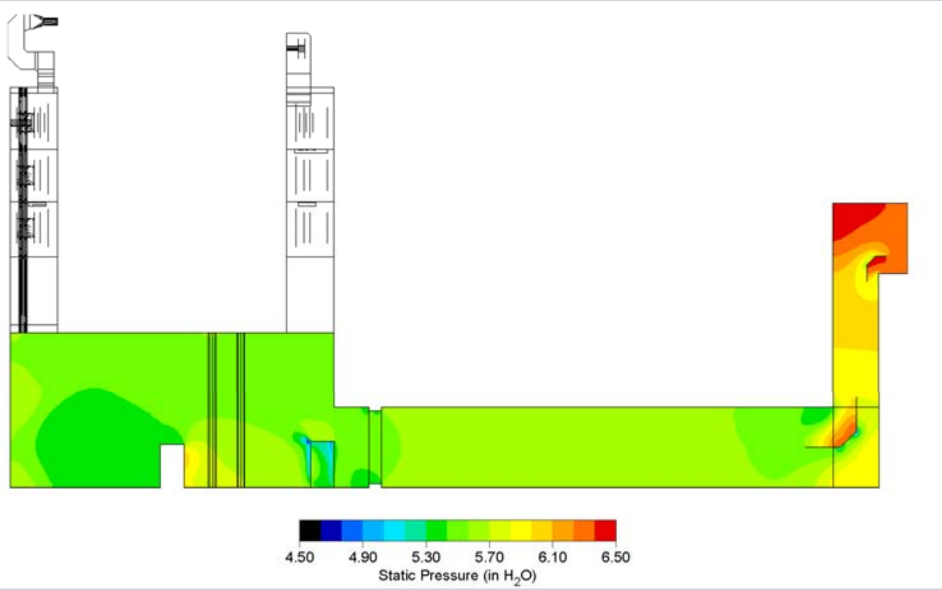


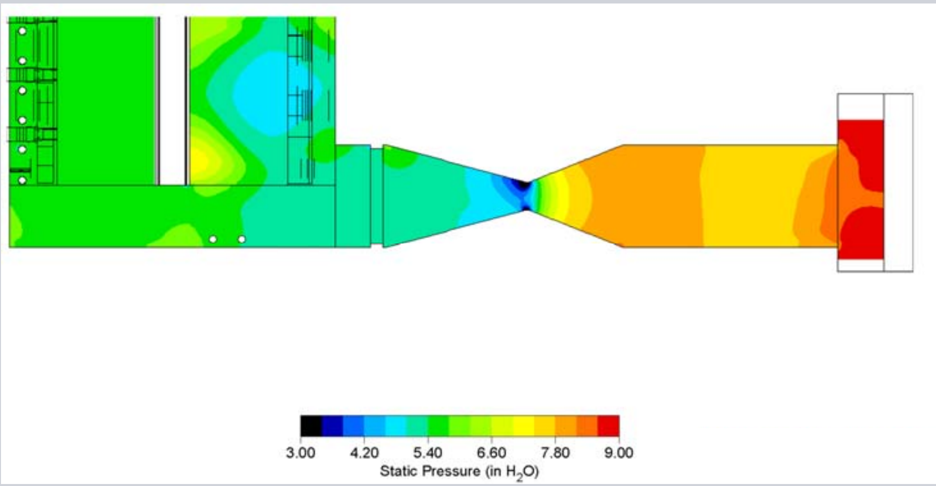
Existing Ductwork



Revised Ductwork

The above results of CFD modeling illustrate the ability to reduce pressure drop in the secondary air duct, from the air heater to the burner windbox, through the addition of turning vanes. In this case, the air flow measuring venturi was also removed, maximizing the reduction in pressure drop.

Secondary Air Duct Pressure Drop
Reducing Pressure Drop



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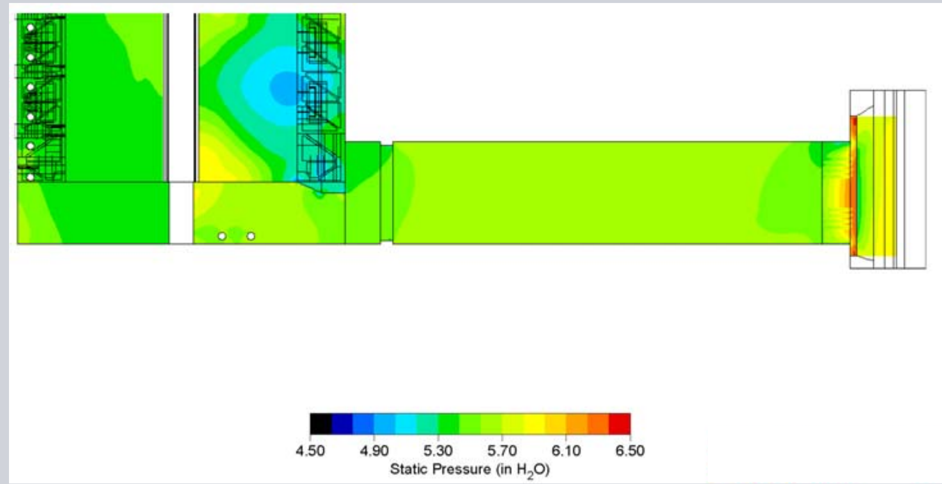

Revised Ductwork

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Secondary Air Flow Issue: Plugged Air Heater Baskets

Plugged air heater baskets reduce the available pressure to the burner and overfire air windboxes.

Effect on NO_x:

There is no direct effect on NOx. However, the indirect effect on NOx is the reduced available windbox pressures for the burners and overfire air. This reduced available pressure may affect the ability to balance and tune the burners properly. In addition, the reduced pressure restricts the ability to “force” more air into the overfire air system for maximum NOx reduction.

Remedy:

Clean or replace air heater baskets.

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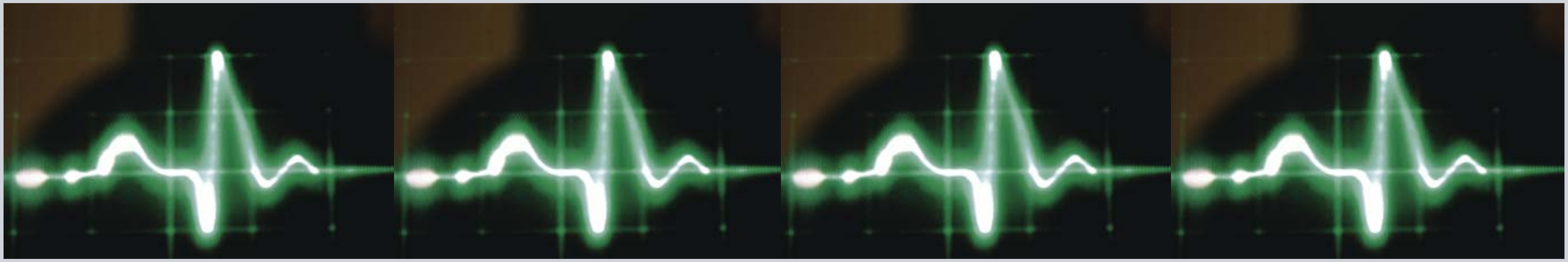
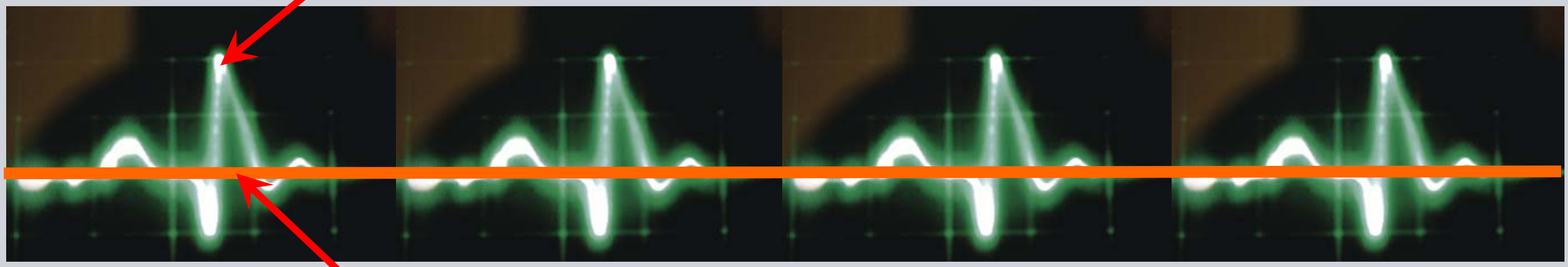
What do a heartbeat and secondary air flow control have in common?



NOTHING

Good heartbeat

Bad secondary air flow control



Bad heartbeat

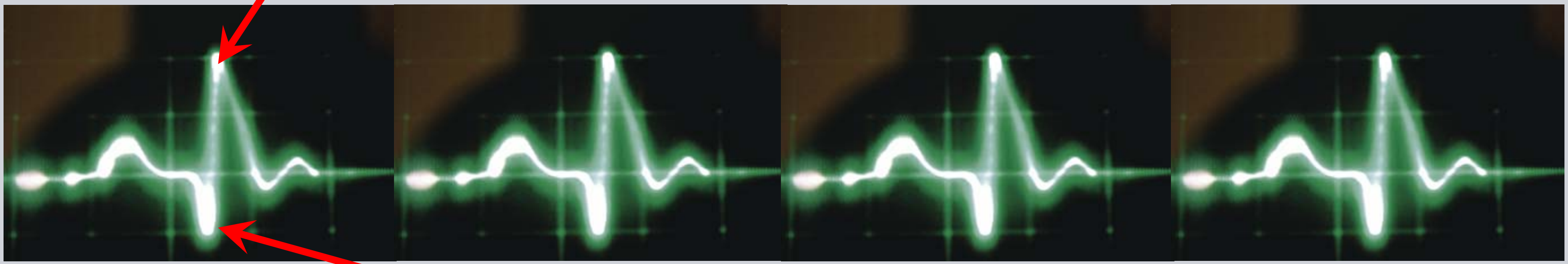
Good secondary air flow control

Random Plugged Air Heater Baskets Effect on NO_x

Since any combustion process is most effective in a steady state condition, significant fluctuation in the secondary air flow causes constant fluctuation in the stoichiometry at each of the burners. Randomly plugged air heater baskets causes continuously fluctuating windbox pressures.

In addition, NOx is optimized as a compromise with CO, unburned carbon, corrosion and slagging rates.

Random Plugged Air Heater Baskets Effect on NO_x



High secondary air flow:

Higher NO_x levels
Lower CO levels
Lower UBC levels
Lower potential corrosion rates
Lower potential slagging rates

Low secondary air flow:

Lower NO_x levels
Higher CO levels
Higher UBC levels
Higher potential corrosion rates
Higher potential slagging rates

Random Plugged Air Heater Baskets Remedy

Clean or replace plugged air heater baskets.

COAL FLOW BALANCING

TUNING CONDITIONS

Coal Fineness

Typical fineness guidelines:

70% thru 200 mesh

99% thru 50 mesh

The percent of the coal passing the 50 mesh screen is of most importance to the unburned carbon levels in the ash with low NO_x burners.

Coal fineness has a minimal impact on the NO_x levels. However, as has been repeated, NO_x is optimized as a compromise with unburned carbon levels. The percent passing through the 50 mesh screen has the largest impact on the UBC levels. Thus, the better the fineness, the more tuning flexibiity there is to make adjustments for NO_x optimization.

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Coal Fineness Optimization

Achieving the best possible coal fineness levels involves adjustments and/or maintenance to the mills.

The simplest method of increasing the fineness to acceptable levels is by adjusting the classifier on the mill.

Some mill have static classifiers built in to the mills. These require a mill outage to be adjusted.

Relatively few mills have dynamic classifiers. These classifiers can be adjusted with the mill on line. The adjustment is typically changing the speed of the rotating element in the classifier.

Coal Flow Balance

Typical coal flow balance between coal pipes on each mill are ± 10%.

In some cases one mill may be out by a bit more than this.

It is also relatively important to have all mills operating at similar coal flow levels to each other.

Biasing of the coal flow between mills can raise or lower the overall NOx in the furnace (depending on which mills have more or less coal flow). In addition, it is then also important to bias the secondary air flow to maintain the proper stoichiometry at all of the burners. This condition also limits the operational flexibility of the unit.

Coal Flow Balance Optimization

There are a number of things that affect the coal flow balance between coal pipes on a mill. Coal flow imbalances are somewhat influenced by imbalanced primary air flows (but not always). The following are potential sources of coal flow imbalances in the coal pipes:

- Length and geometry (bends) of the individual coal pipes
- Coal pipe velocities
- Condition of any existing coal flow devices (orifices, etc.)
- Air flow maldistribution in the mills
- Coal Roping at mill outlets and in coal pipes

Coal Flow Imbalance Effect On NO_x

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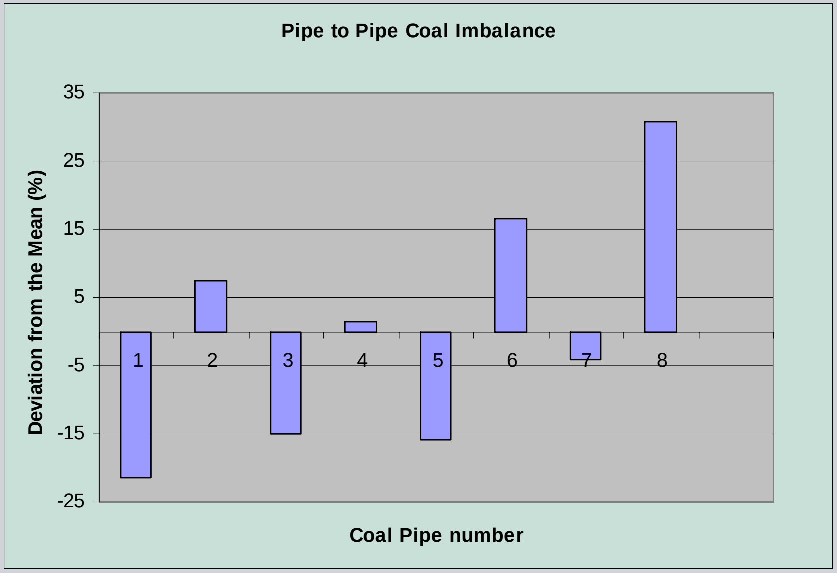

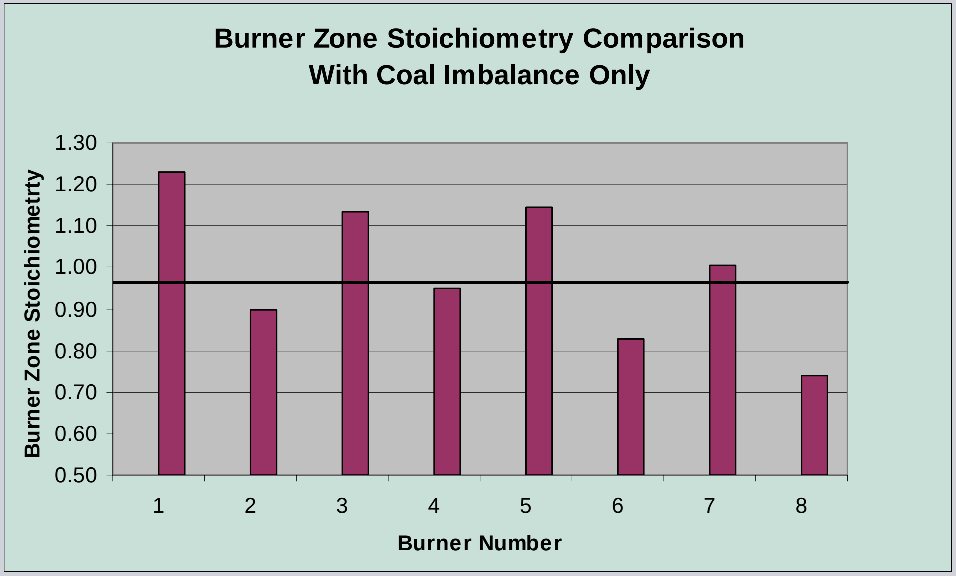

The chart on the left shows a test case burner to burner coal flow imbalance.

The chart on the right shows the variation in the stoichiometric ratio between burners, asssuming an equal secondary air flow to all burners.

When combined with secondary air flow imbalances, the effect is much greater.

Coal and Secondary Air Flow Imbalance Effect On NO_x

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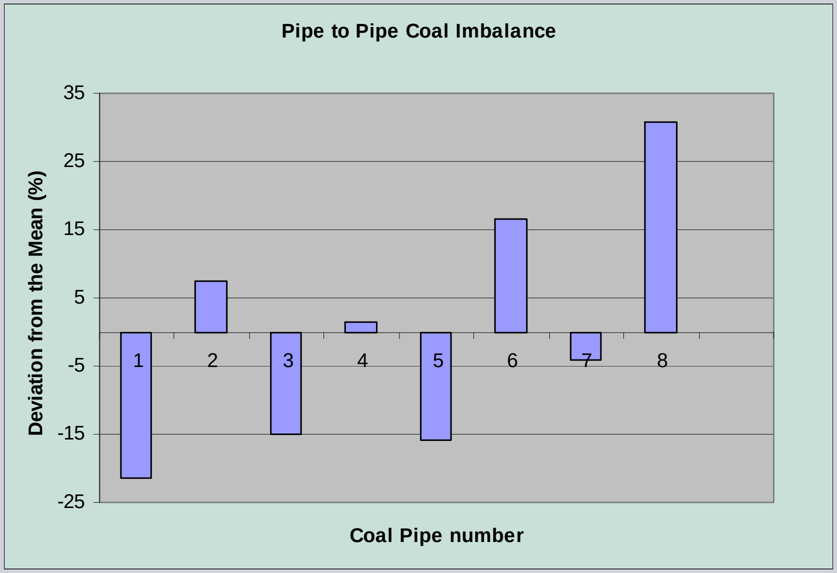

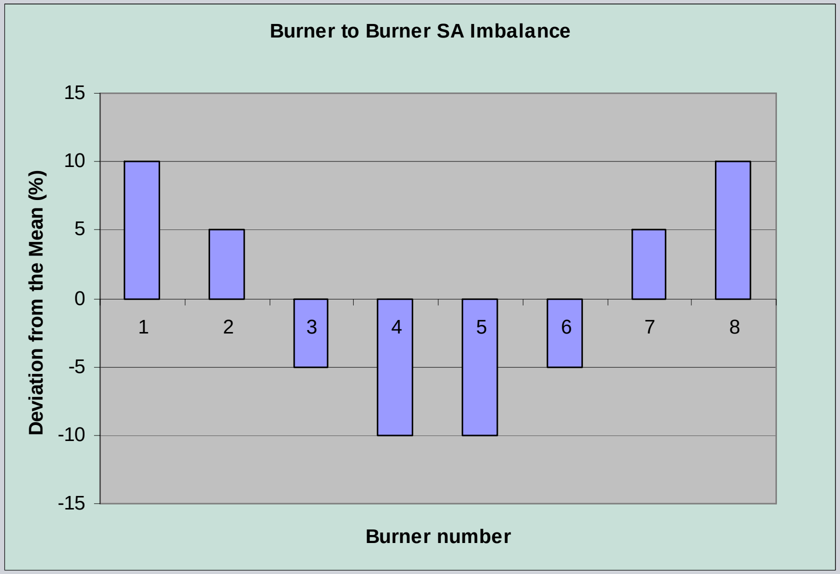

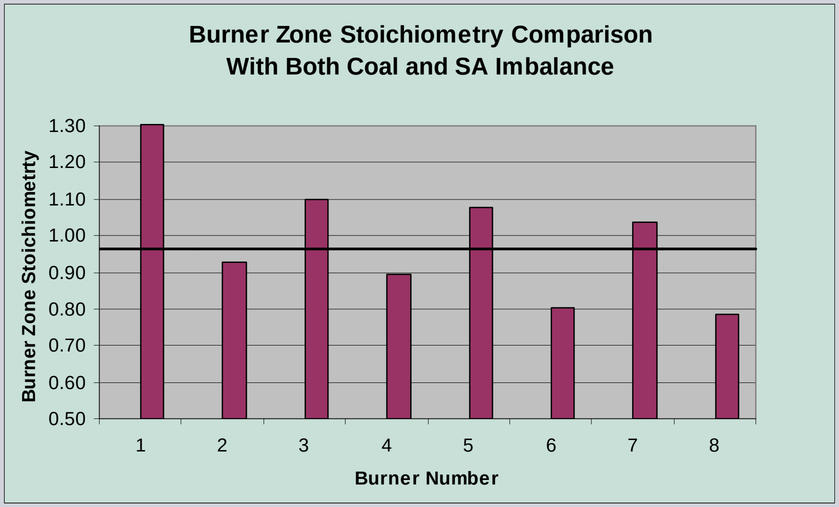

The charts above show burner to burner coal and secondary air flow imbalance.

The chart on the left shows the variation in the stoichiometric ratio between burners, based on the above imbalances.

Coal Flow Balance Optimization Remedy

Coal (and primary air) balancing can be achieved through the installation of fixed orifices or adjustable coal balancing valves. These devices essentially equalize all of the coal pipes, to account for the length and geometrical differences between pipes.

It must be noted that the ability to balance the coal (and primary air) flow may be limited by conditions within the mill itself.

One important note is that the application of balancing devices is limited by the coal pipe velocities.

When the coal pipe velocities are very low, near which the coal settles out of the flow, it is not possible to use these devices as the velocity will become so low and coal will settle out. In addition, if a specific pipe has high coal flow and low air velocity, this cannot be corrected.

Coal Flow Balance Optimization Remedy

Coal

Balancing

Valve

One remedy for coal flow imbalances between coal pipes is an externally adjustable coal balancing valve. This offers the ability to balance coal flow between pipes without taking the mill out of service.

Coal Flow Imbalance and Fineness Optimization Remedy

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In some cases it is not possible to correct coal fineness or coal flow imbalance issues with devices external to the mills.

In this case, adjustments or maintenance must be performed on the mills. Some adjustments can be made without major maintenance (adjusting spring tensions, ball charge, adjusting fixed vane classifiers, etc.).

In other cases, it is necessary to perform maintenance on the mills. This would include items such as; replacing mill tires, repairing mill tables, replacing an entire ball charge, etc.

Coal Roping

Coal roping in coal pipes is caused by the geometry of the pipe runs.

With permission from Airflow Sciences Corporation and EPRI

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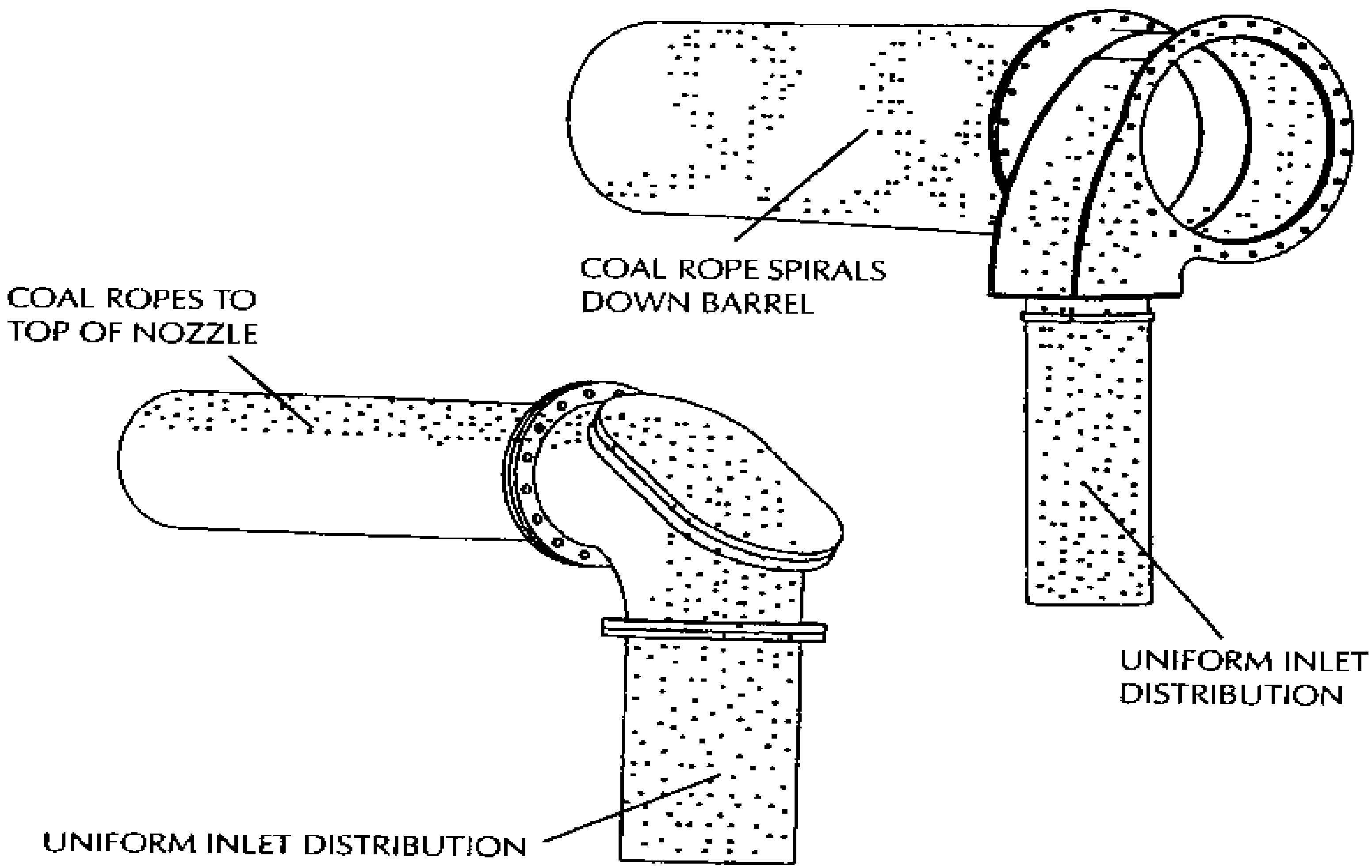
Coal Roping



Coal Roping Remedy

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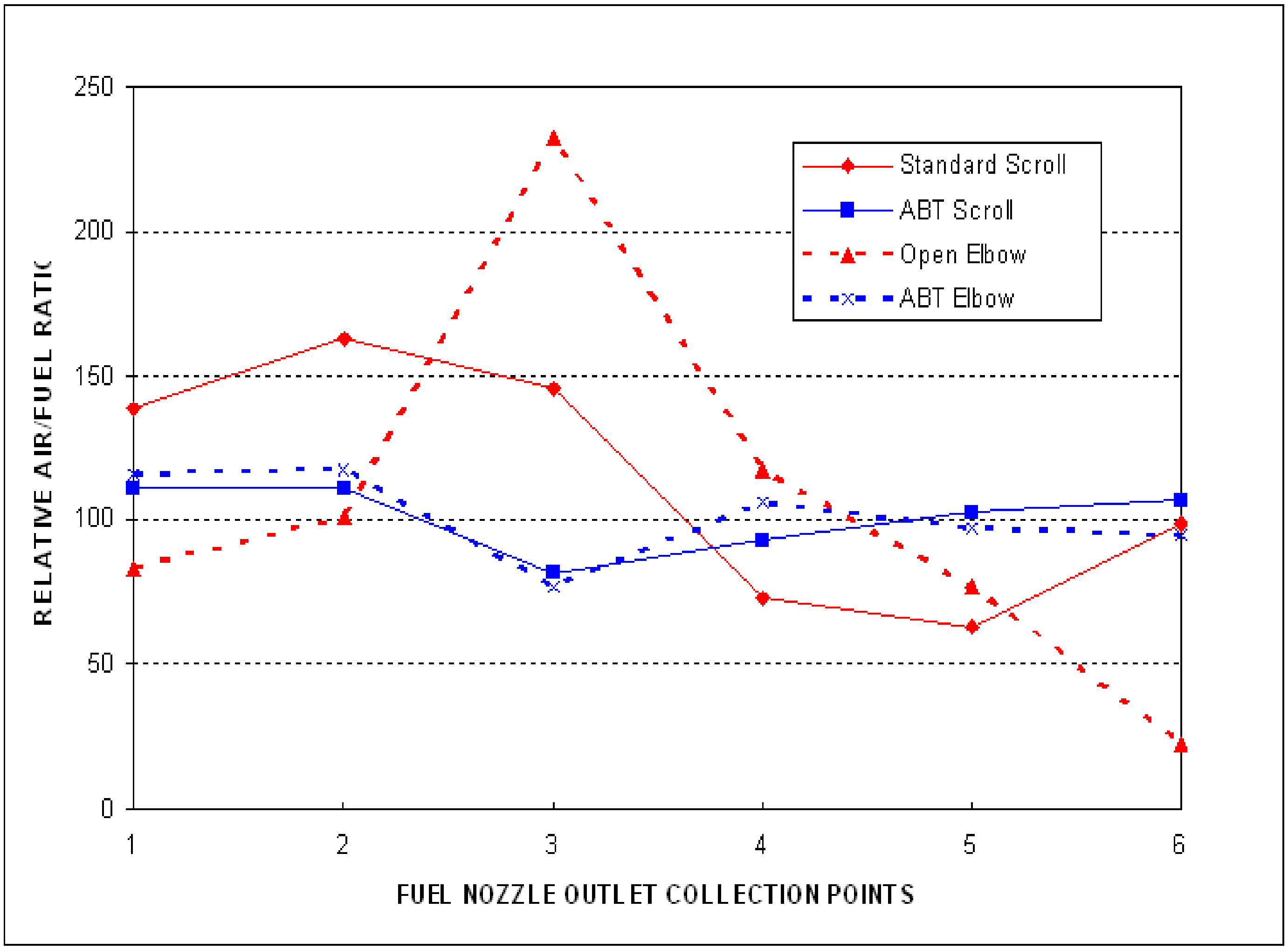
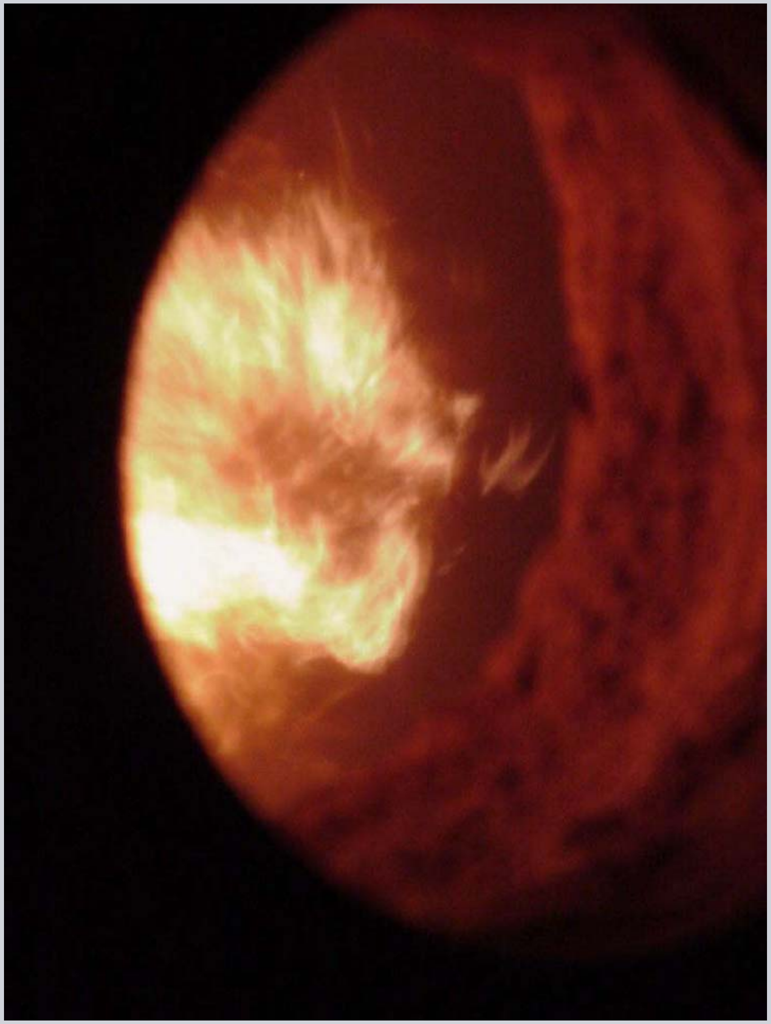
It is not feasible to correct coal roping within the coal pipes.

Installing coal flow distribution devices in the burner elbow and/or barrel can redistribute the coal flow more evenly at the burner nozzle.

It is at this point where the coal distribution effects the combustion process.



Burner Flame Shape Generated From Poor Burner Nozzle Fuel Distribution



Burner Flame Shape Generated With Good Burner Nozzle Fuel Distribution

PRIMARY AIR FLOW

TUNING CONDITIONS

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Primary Air Flow Issues

There are a number of issues that can affect the ability to operate the combustion system at the lowest possible NO_x levels. Some of these issues are as follows:

- Poor air flow distribution in the coal pipes
- Poor air flow distribution through the mill
- Incorrect air flow indication

Poor Air Flow Distribution in the Coal Pipes

Poor air flow distribution in the coal pipes is caused by some of the following conditions:

- Length and geometry (bends) of the individual coal pipes
- Coal pipe velocities
- Condition of any existing coal flow devices (orifices, etc.)

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Incorrect Air Flow Indication

Probably the most common cause of primary air flows that deviate from the design conditions of the burners is incorrect primary air flow indication.

There are two basic causes of incorrect primary air flow indication. They are as follows:

- Incorrect calibration of the existing flow measuring devices/control system factors

- Poor locations for the flow measuring devices.

Effect of Incorrect Primary Air Flow

All burners are nothing more than flow device “orifices”. As such, they operate best at the design air flow and associated pressure drop.

Pressure drop is known to vary as the square of the velocity.

To illustrate how increased primary air flow affects the pressure drop, the following two examples are offered:

Primary air flow 10% high
  Pressure drop = $(1.10)^2 = 1.21$

Primary air flow 15% high
  Pressure drop = $(1.15)^2 = 1.32$

Incorrect Air Flow Indication
Incorrect Calibration

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Most often the primary air flows indicated by the control system deviates from the actual primary air flow.

Most cases involve situations where the documentation suggests that the calibration is correct. However, upon testing the two do not match.

The actual versus the indicated primary air flows should be periodically checked and recalibrated as necessary.

Where the operational conditions of the mills dictate that the primary air flows must be higher than the design curves, this presents operational issues with the burners. There is no remedy for existing burrners. When specifying new burners, it is imperative that the actual (by test, not indication) primary air flows are provided for the design of the burners.

Why is Preparation Important?
Why Do Plants Invest in NOx Reduction?

Returning to the original reason for minimizing NO_x produced from coal fired boilers:

Local, state and federal mandates for the reduction of NO_x.

As a side effect of the regulations, NO_x credits are financial “incentives” to reduce NO_x. These credits can either be sold as a revenue stream or banked to offset future expenditures by the utility in the event NO_x credits are needed for the operation of one or more units.

What will NO_x credits be worth in the next 1, 2 and 5 year periods?

Why is Preparation Important?
Why Do Plants Invest in NOx Reduction?

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Anyone care to spin the NO_x credit predicting calculator?

Why is Preparation Important?
Why Do Plants Invest in NOx Reduction?

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NO_x will continue to be generated in increasing quantities to keep pace with the increasing population and associated electrical demands.

It is therefore an almost certainty that NOx credits will increase in value over the long term.

QUESTIONS??

QUESTIONS??