REINHOLD ENVIRONMENTAL Ltd.

2013 Coal to Gas Conversion Round Table & Expo Presentation

October 29, 2013, in Chattanooga, TN / Sponsored by Southern Company

Enhanced Gas Cofiring
Commercial & Environmental Benefits

Presented by: Cal Lockert/Breen Energy

Presented to: Reinhold Coal/Gas Conversion Conference

October, 2013

What is driving our industry?

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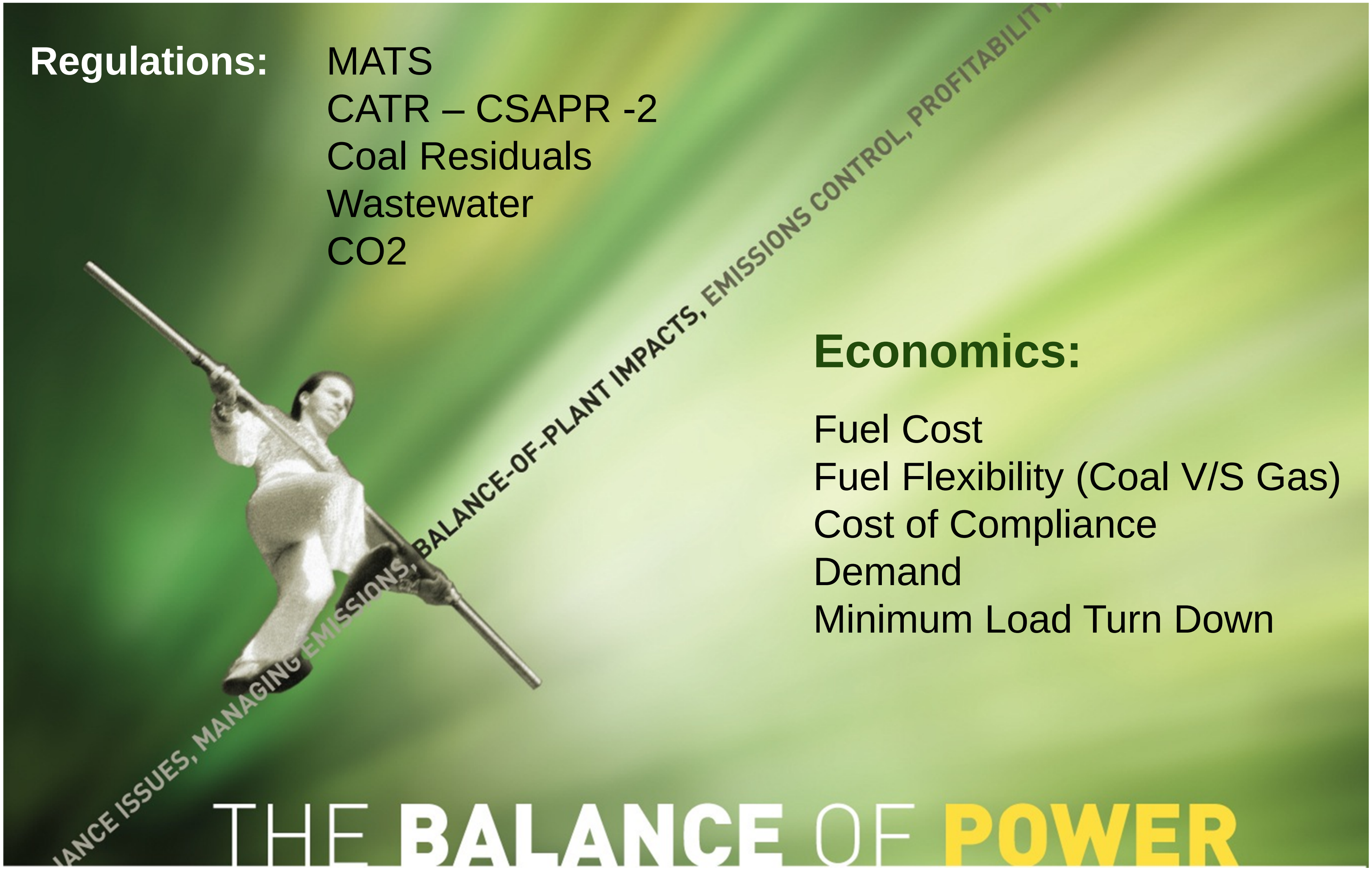
Regulations:

MATS
CATR – CSAPR -2
Coal Residuals
Wastewater
CO_2

Economics:

Fuel Cost
Fuel Flexibility (Coal V/S Gas)
Cost of Compliance
Demand
Minimum Load Turn Down



The total cost of Generation

- **Simplistically, the cost to generate power is the combination of:**

  - ***The direct cost of Generation*** - Fuel cost, unit heat rate, manpower, etc.
  - +
  - ***The indirect cost of Generation*** – Generation below cost at Min Load, Forced outages, severe unit cycling, etc.
  - +
  - ***The cost of Environmental Compliance*** – Capital Equipment cost plus the cost of operating that equipment (SCR, FGD, DSI, ESP, etc.

Natural Gas vs. Coal

- **There is an active dialog over conversion of traditional Coal units to Natural Gas units.**
- **To move this discussion along, we are focused on preserving the existing coal fleet as a "Coal Burning" fleet.**
  - Coal remains the primary fuel
  - Gas is the supplemental, or Cofire, fuel
  - The volume and placement of the gas should be controllable based on the current needs of the unit

Enhanced Gas Cofiring

- **This presentation will cover actual case experiences with utilization of natural gas and coal in the same boiler**

  - High Output Gas Igniters for delivery of 20% (or more) of the total heat input of the unit at the igniter level,
  - Fuel Lean Gas Reburn for delivery of up to 10% of the total heat input of the unit at a location above the OFA.

When properly deployed, significant commercial and environmental benefits can be derived

Enhanced Gas Cofiring

Cofiring Sweet Spots

There is no "One Size Fits All" solution. Each plant has a unique set of issues to overcome that can be aided by natural gas cofiring:

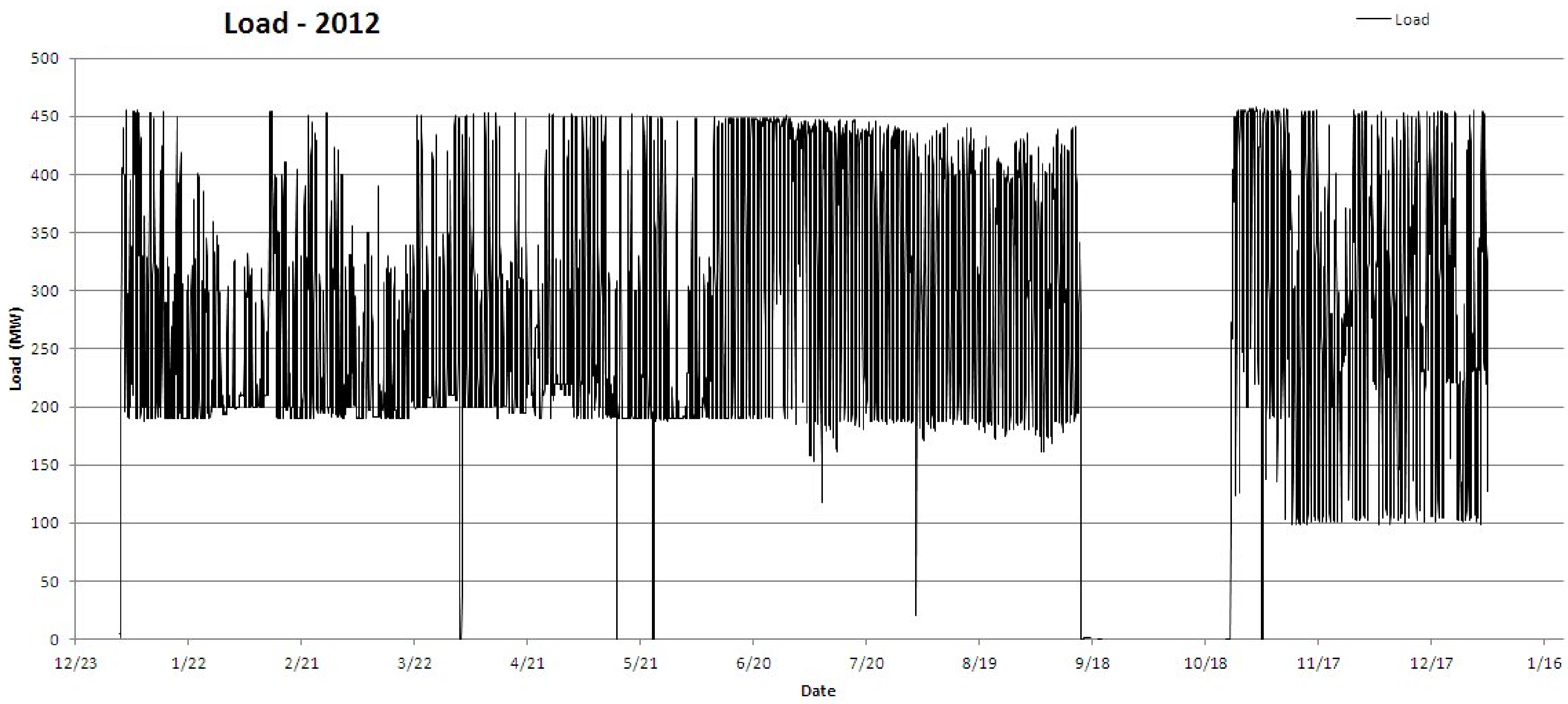
1. **Minimum Load Reduction for Cycling Units**
2. **Environmental and Commercial benefits from "dirty" BTU dilution**
3. **NOx Reduction from upper furnace utilization of natural gas as a reducing agent**

Case Study: Load/Emissions Study

Study Background

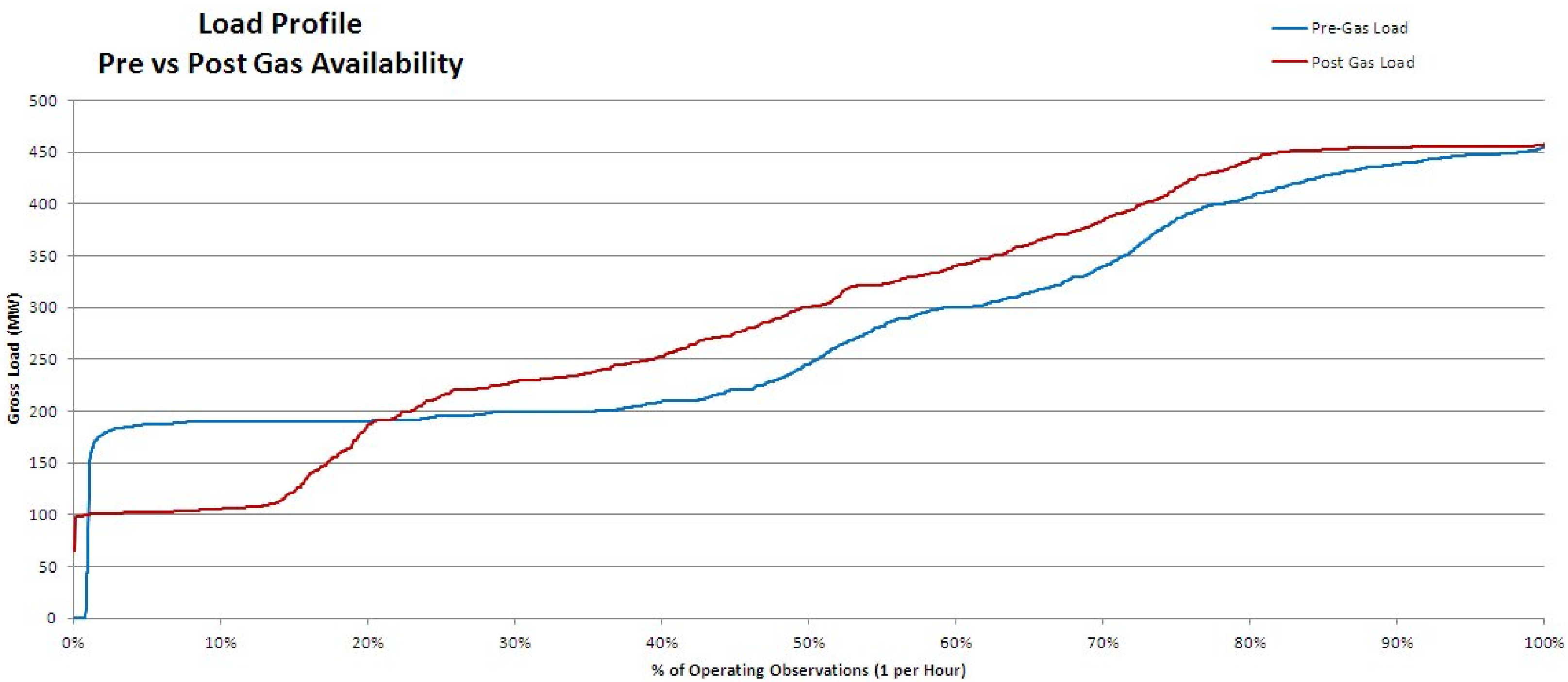
- **Roughly 400 MW, opposed fired construction**
  - 3 rows of 6 burners – Front
  - 2 rows of 6 burners – back
- **During a fall outage in 2012 the oil igniters were replaced with natural gas igniters with 20 mmBTU heat input, max, each.**
- **This study explores the operation and environmental results of the post outage operation.**

2012 Load Plot



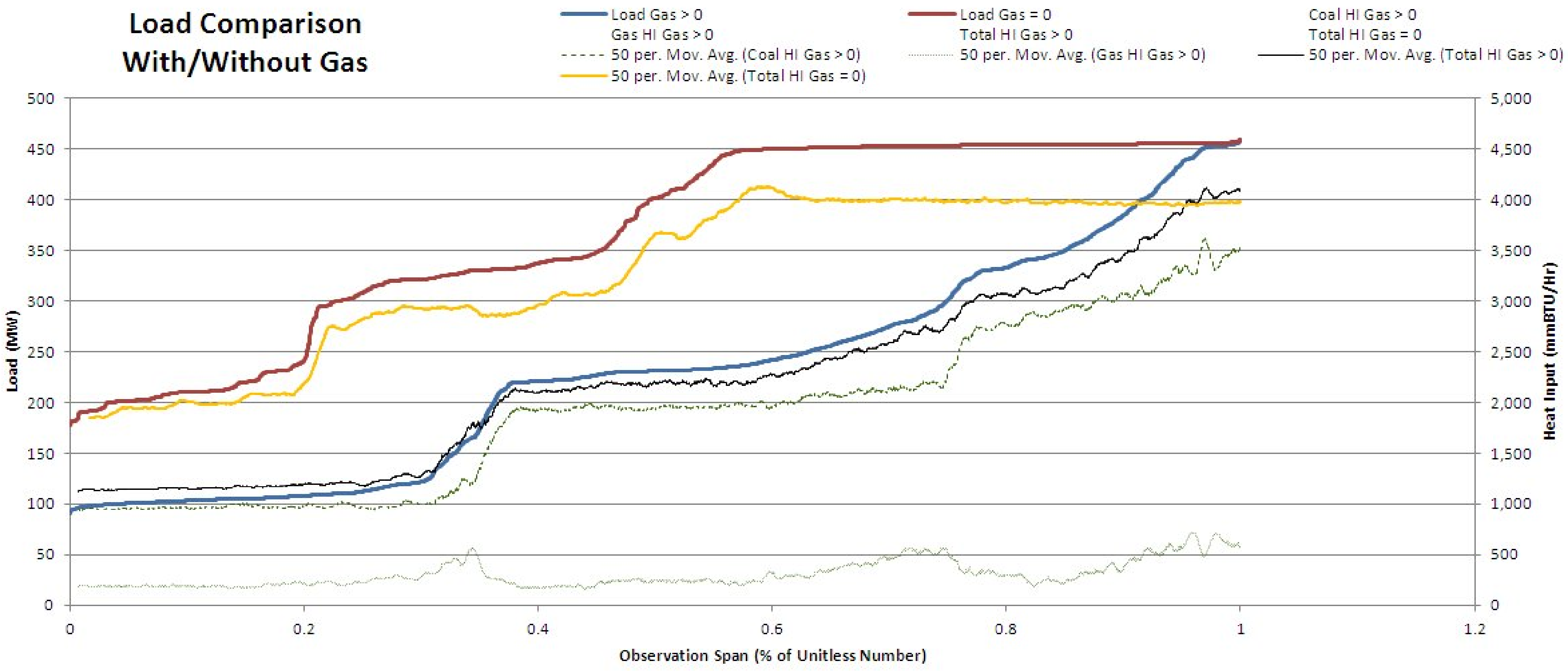
Source: EPA Acid Rain Database

Pre/Post Outage Load Profile

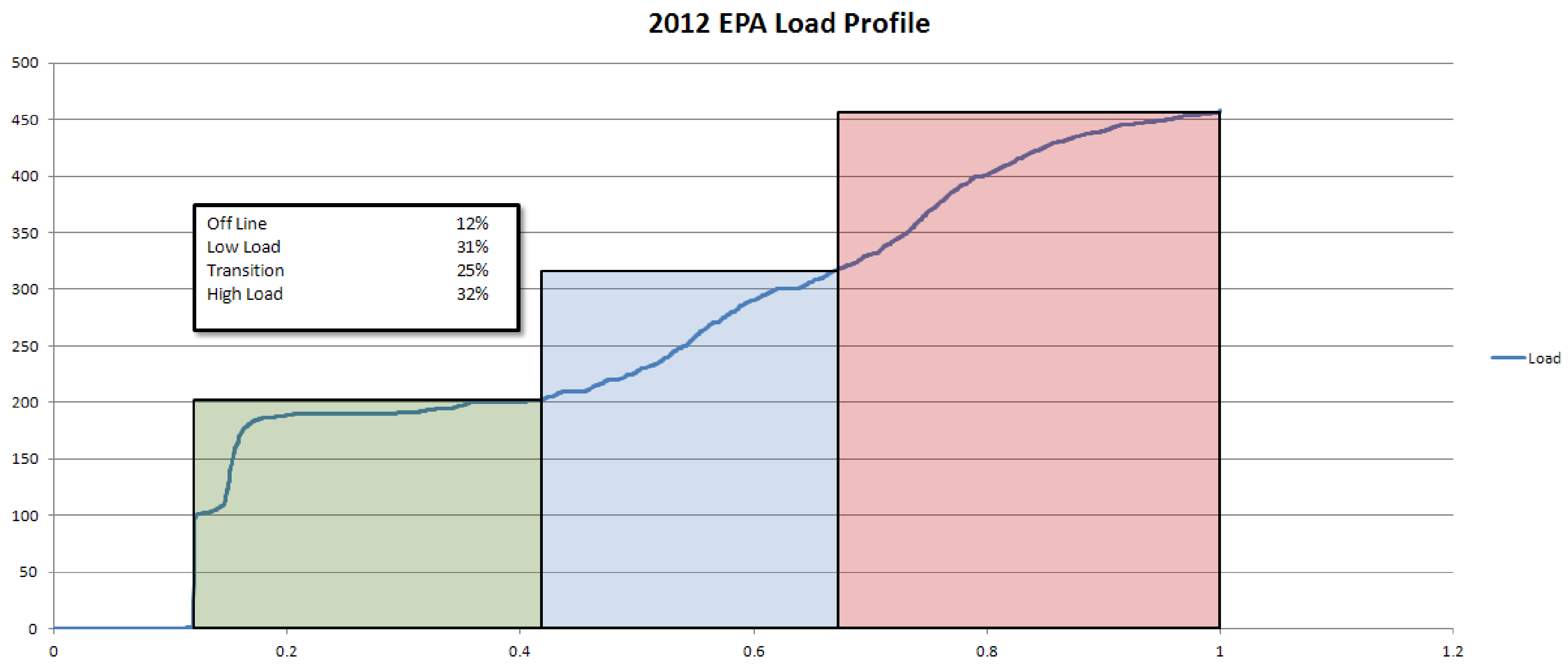


Reduction in Minimum Operating floor was derived from avoidance of SCR MOT issues (due to reduction in SCR Inlet SO3) and ability to run safely on 1 mill instead of two

Pre/Post Outage Fuel Use



Load Distribution



“Sweet Spot” Evaluation

Value of Low Load Reduction

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Low Load Impact		
% Gas Heat Input		40%
Fuel Cost Differential	$	2.40
Total BTU/Hr. Current		1829
Total BTU/Hr. Expected		1017
Total Hours at Low Load		1,583
Total HI at Old MSL		2,895,307
Total HI at New MSL		1,609,911
Fuel Cost at Old MSL	$	10,423,105
Fuel Cost at New MSL	$	7,341,194
Fuel Savings from New MSL	$	3,081,911

- SO_3 reduction allows a reduction in SCR MOT
- Single Mill at Low Load allows a further reduction in MSL

Reduction from 190MW to 100 MW for 2715 annual hours of minimum load operation saves just over 2,000,000 mmBTU per year.

At $3.60/mmBTU this is an annual fuel savings of $7.2 Million.

It is up to the listener to determine for their own plant if the reduced MWHrs could have been sold and at what price. This valuation will reduce the total savings, but not materially in our opinion.

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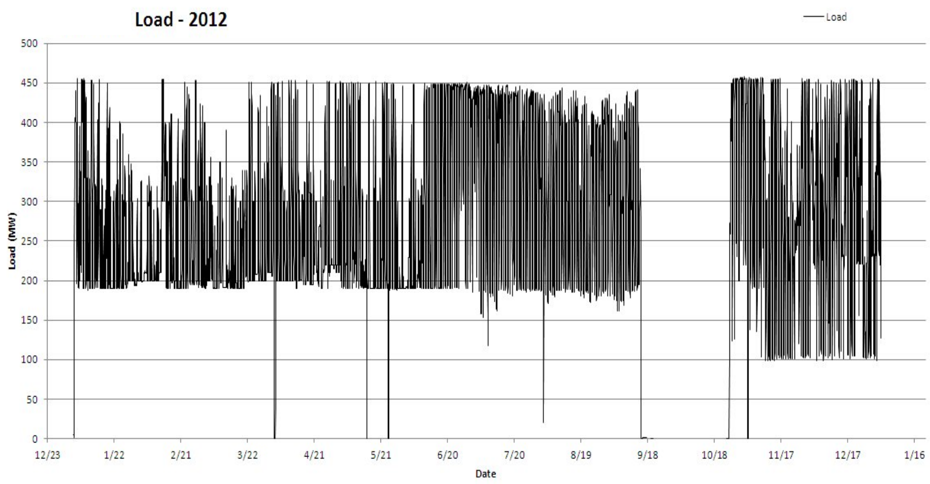
Clearly the cost of gas, being higher than the cost of coal, will increase the cost of generation at Min load and reduce the overall benefit.

Considering the above situation, if 40% of the total unit Min load heat input is natural gas then the following net fuel cast savings can be realized:

50% Fuel Cost Differential = $5.3 Million
100% Fuel Cost Differential = $3.2 Million

Other Benefits at Low Load



The previous analysis only explores the reduction in fuel cost from a drop in minimum load.

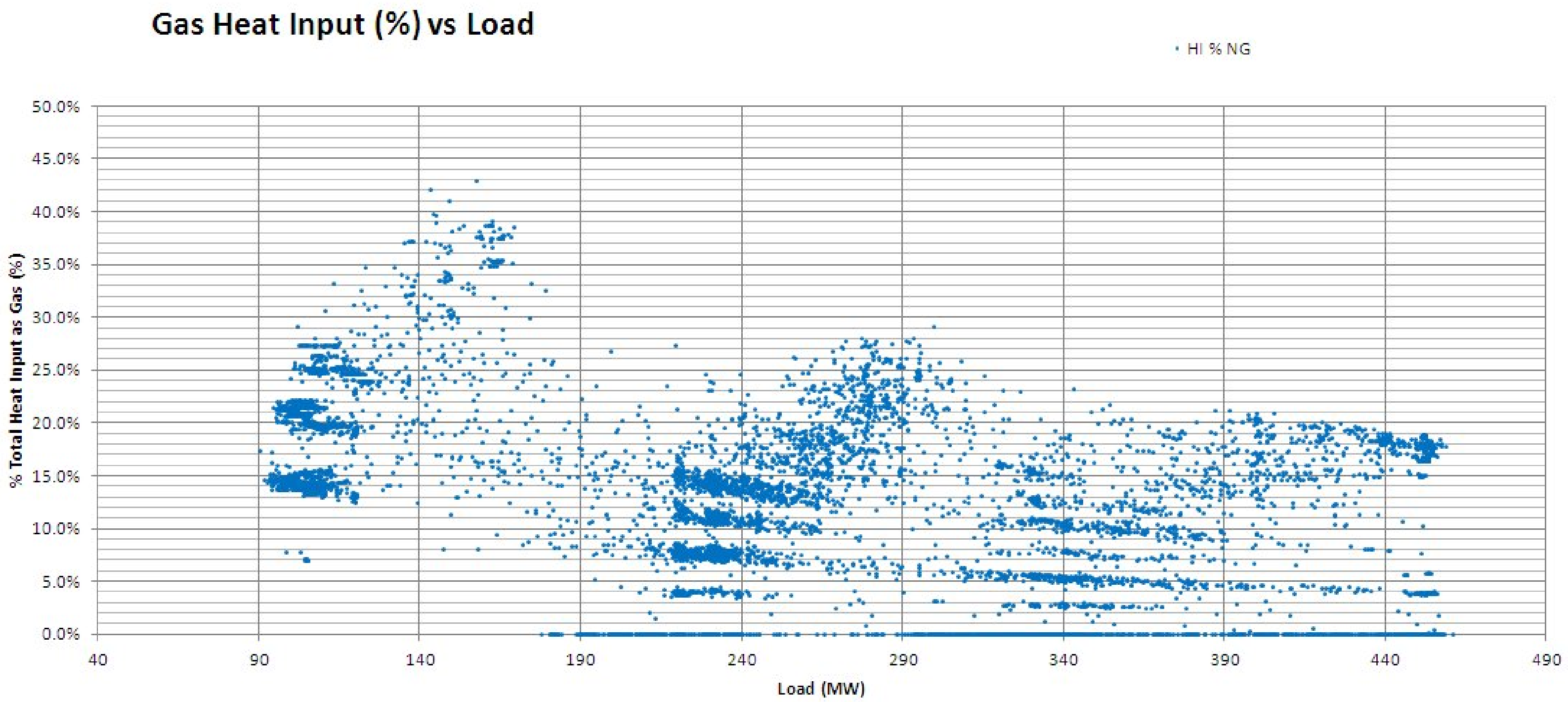
But there are other benefits:

- Reduction in Mill wear and Maintenance
- Reduction in SCR catalyst deactivation rate – lower gas flow equates to lower poisons and extended operating life
- Improved Dispatch flexibility – dropping unwanted MW from one larger unit may allow redistribution of load to more efficient units

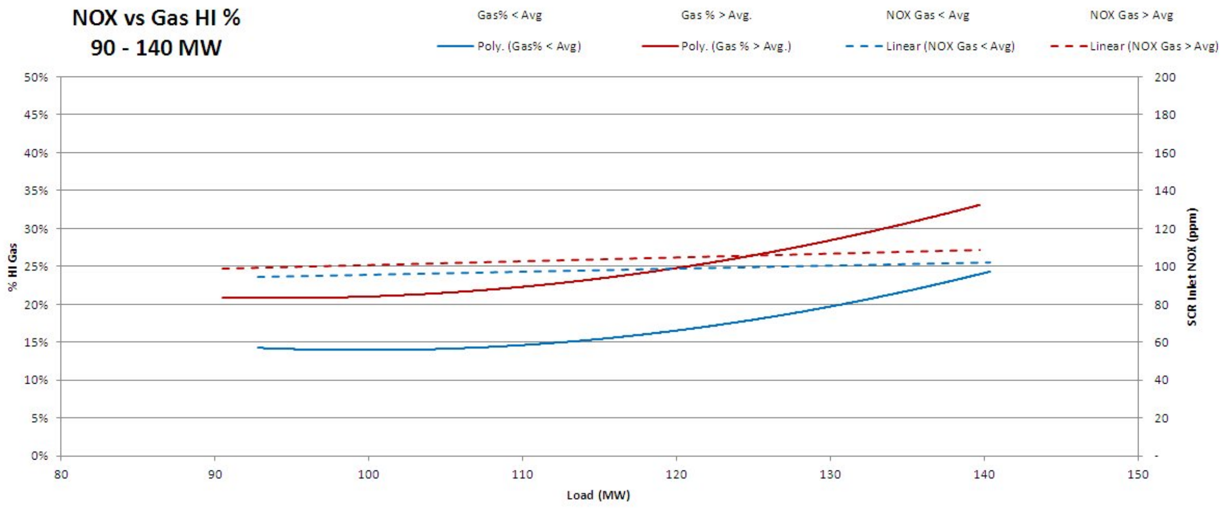
- If high volume gas igniters are replacing existing oil igniters the reduction in ignition/stabilization fuel costs can be dramatic as well.

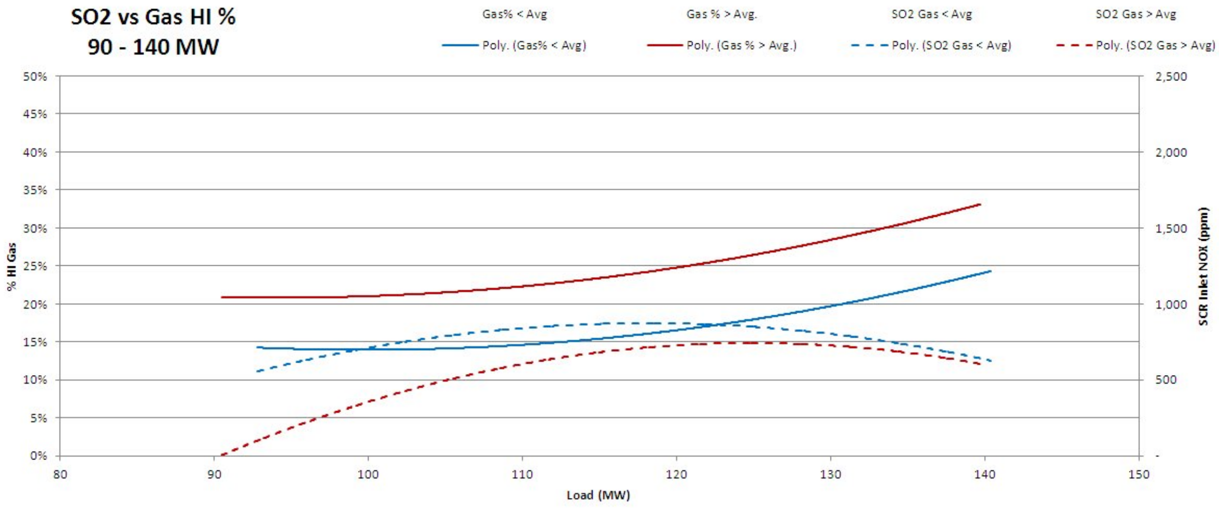
Environmental Impacts

Gas Heat Input vs Load



NOx/SO_2 vs Gas – 90-140 MW





At Low loads, an increase in NG Heat Input resulted in a increase in NOx and a decrease in SO2

NOx/SO_2 vs Gas – 190-250 MW

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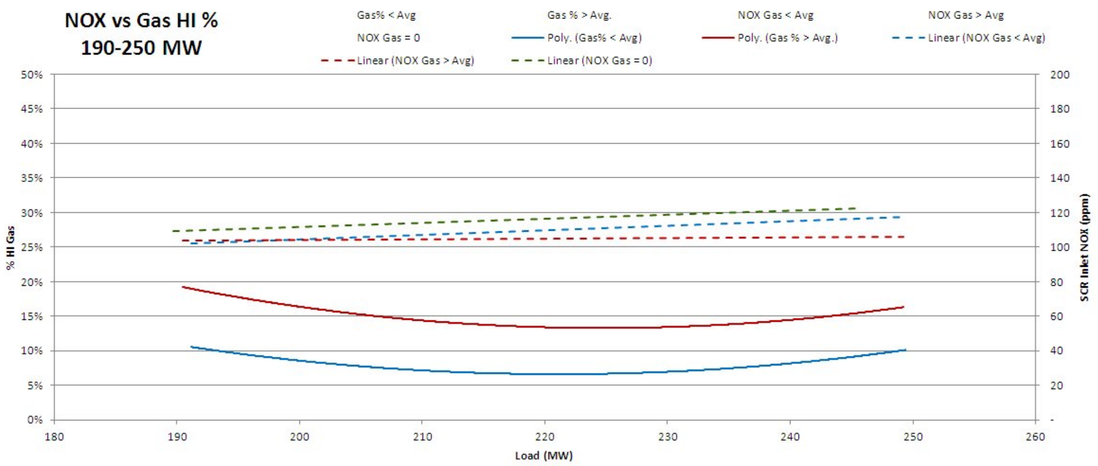
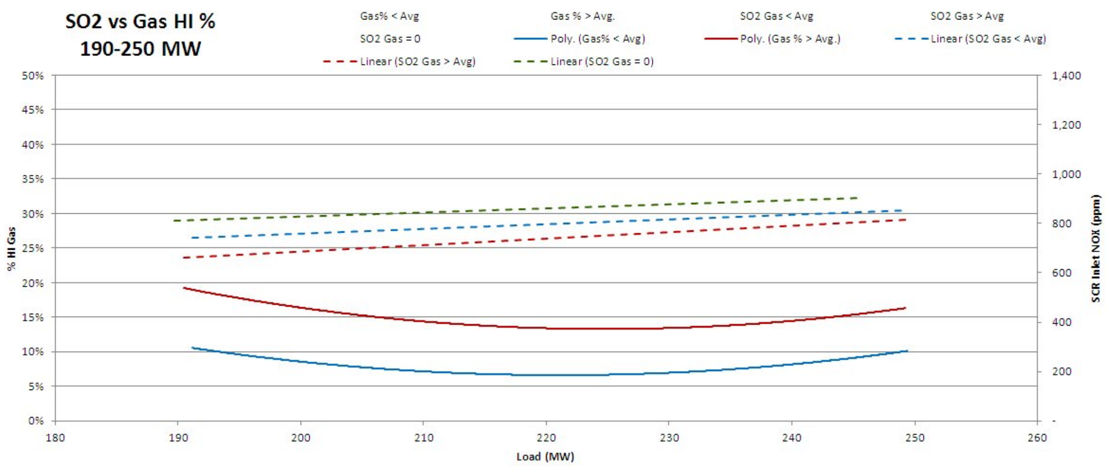
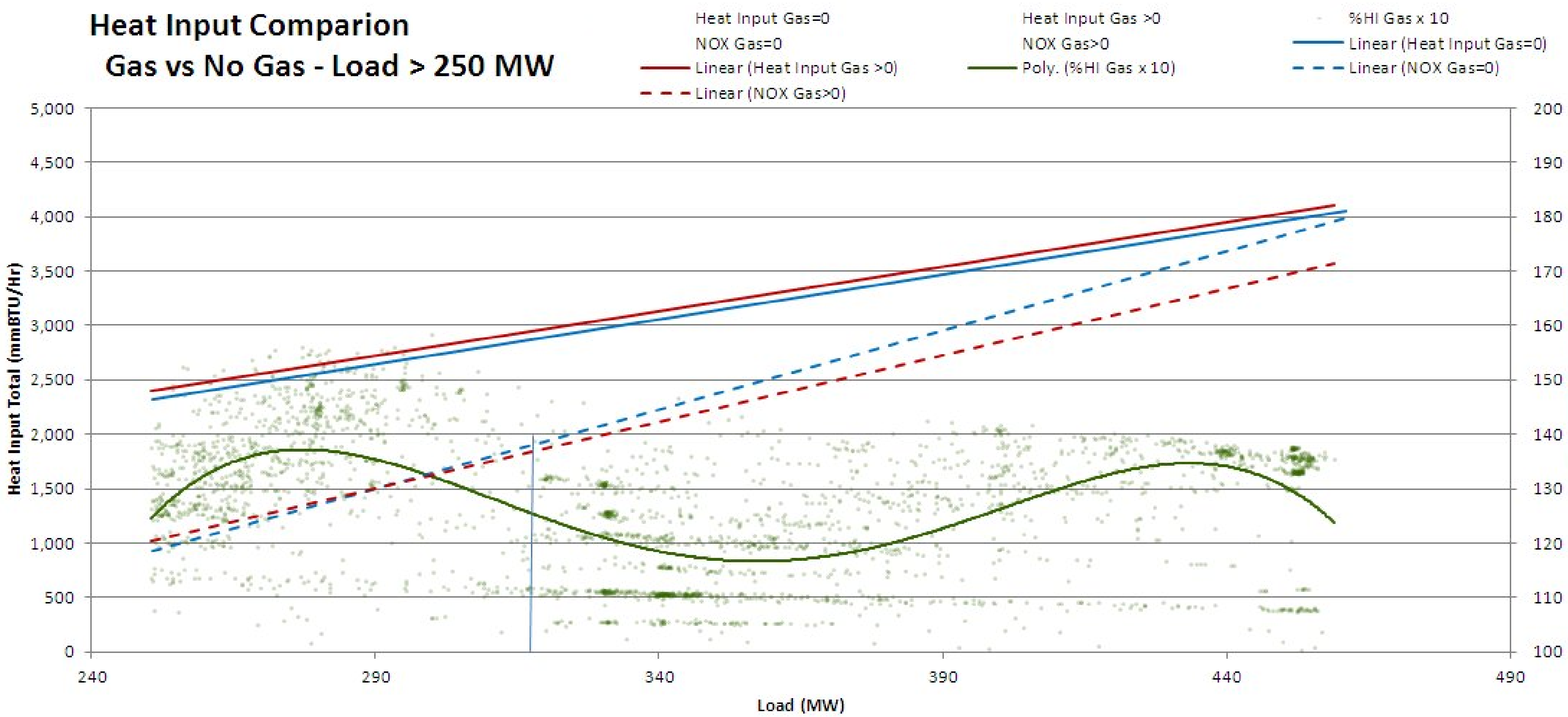




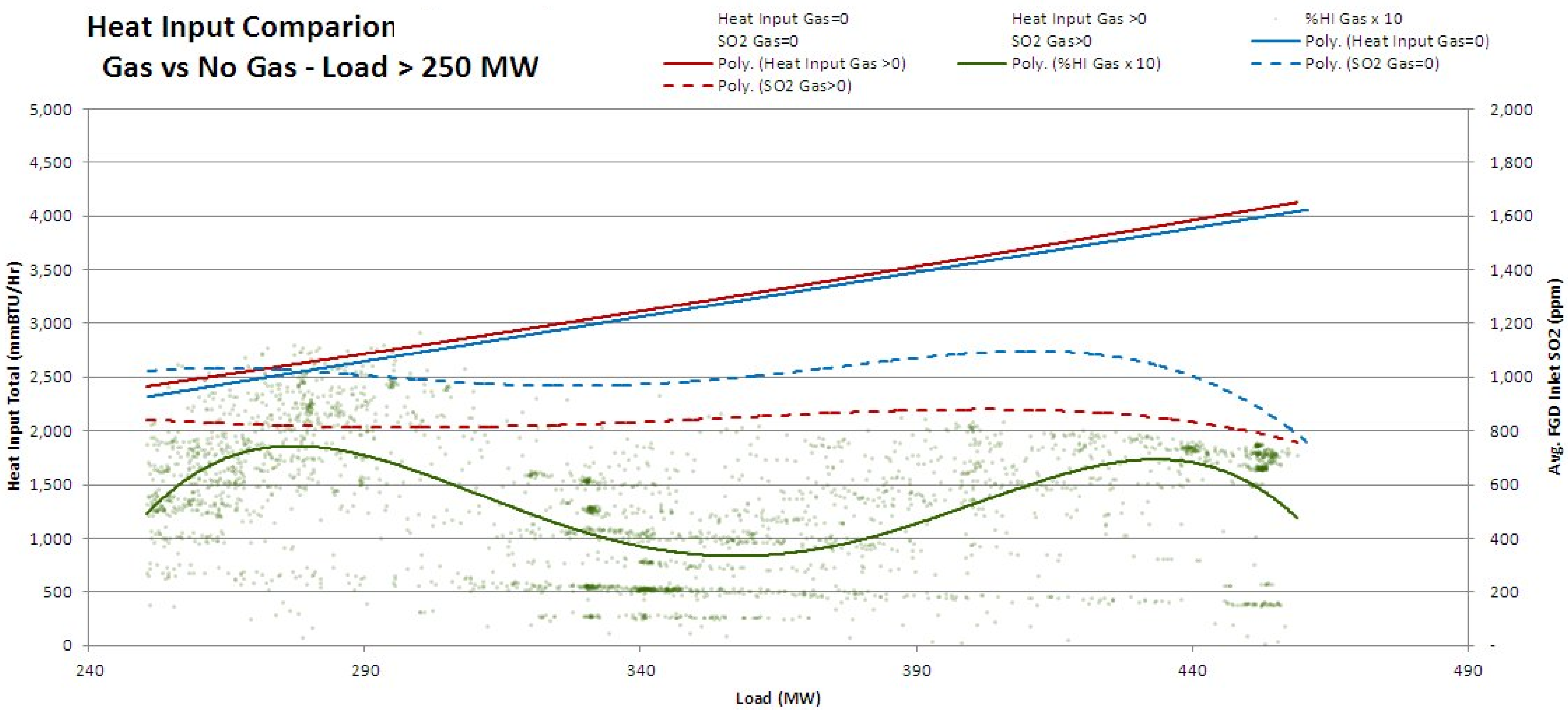
At Mid-range loads, an increase in NG Heat Input resulted in a consistent reduction in NOx and SO2

NOx/Heat Rate vs Gas – High Load



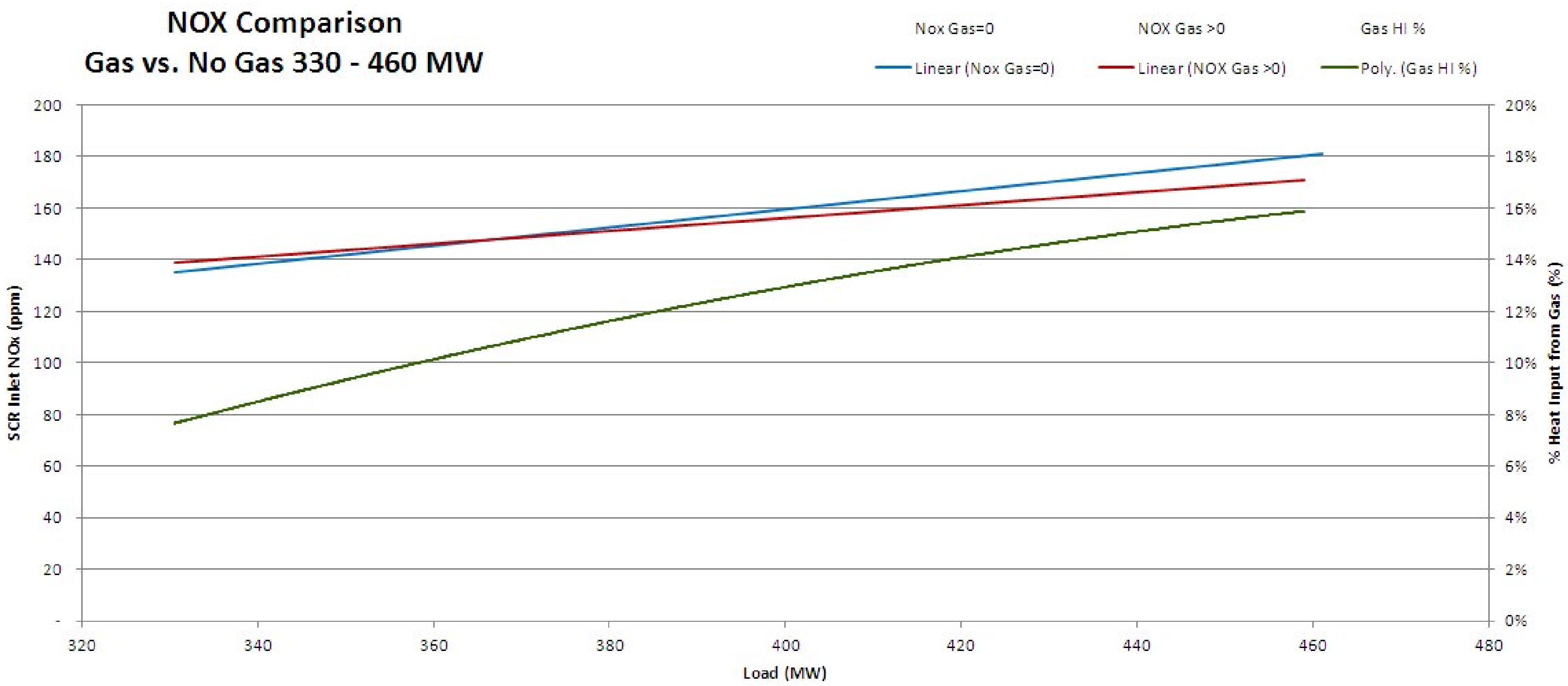
At Full Load a 16% NG Heat Input resulted in a 1.5% increase in Heat Rate

SO2/Heat Rate vs. Gas – High Load



In general, the drop in SO2 followed the Displacement of Coal with Natural Gas on a percentage basis.

Gas vs Nox 330-460 MW



At Full Load a 16% NG Heat Input resulted in a 4.6% reduction in SCR Inlet NOx

Gas vs. CO_2 330 – 460 MW

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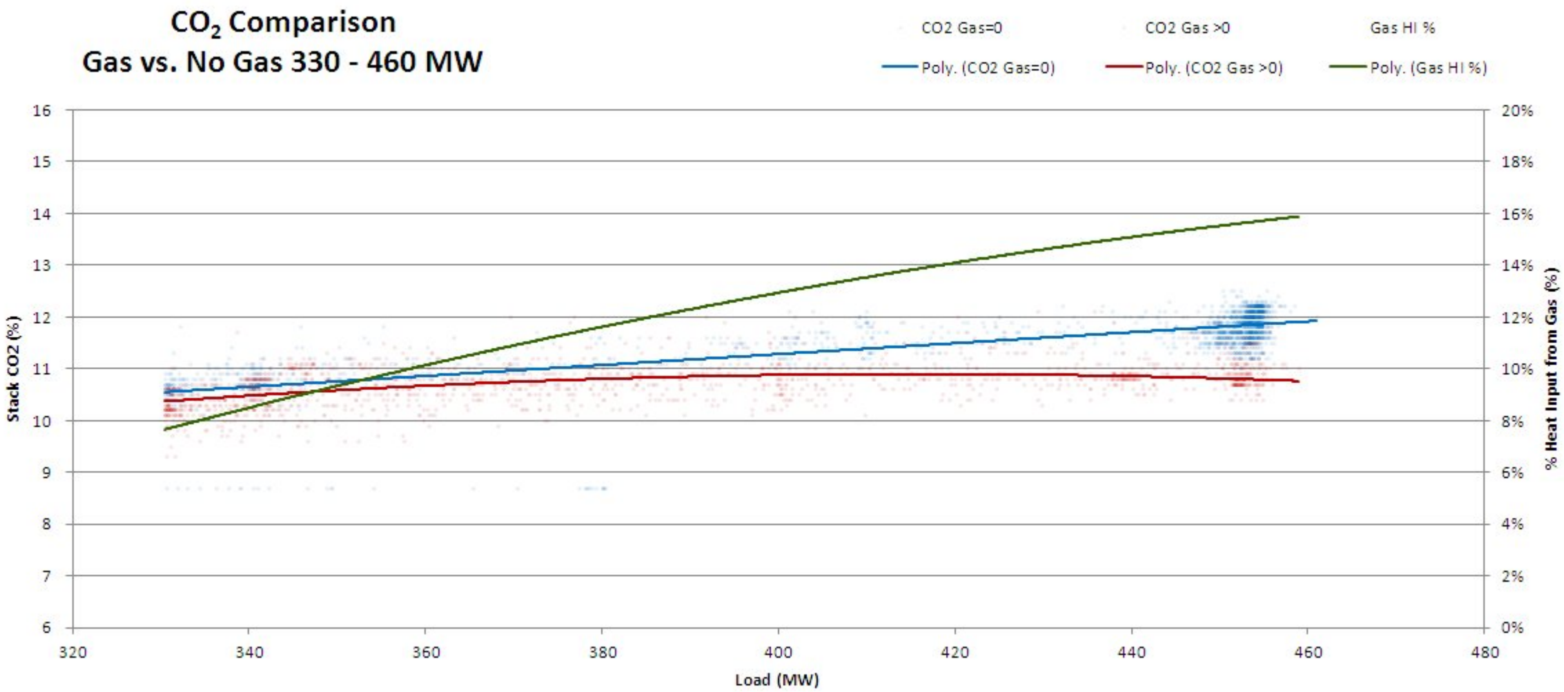

Load	CO2 Gas = 0	CO2 Gas > 0		% Redux
340	10.65	10.48		1.65%
400	11.29	10.88		3.65%
460	11.92	10.75		9.81%

At full load, 16% NG Heat Input gas a 9.8% reduction in CO2

Secondary Commercial Benefits

Commercial Impact Points

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If replacement of some portion of the coal Heat Input with Natural Gas provides reductions in NOx, SO_2, Mercury and Particulate, what commercial impact might that have:

We explored the following:

- Ammonia DeNOx reagent usage
- FGD Limestone usage
- FGD sludge disposal cost
- SO3 Treatment cost
- Mercury Treatment cost
- Flyash disposal cost

NOx Impact as Installed

Operating Data			
Load Point	=	461	MW
Coal HHV		12,000	BTU/Lb
Nominal Heat Rate	=	9.951	mmBTU/MW
Nominal Heat Input Max	=	4,082	mmBTU/Hr
Nominal Coal Use		170	Tons/Hr.
SCR/SNCR in place ?	=	yes	
Nominal Inlet Nox	=	0.4	Lb/mmBTU

SCR/SNCR Performance				
		NOX	NH3	Urea
Mole Weight		46	17	60
Reagent Utilization Rate			1	2
NSR			1	1.5
Delivered Reagent Price ($/Ton)			$ 825	$ 560
SCR Reagent Cost per Ton NOx	=	$ 304.89	$/Ton	
SNCR Reaget Cost per Ton NOx	=	$ 547.83	$/Ton	

FLGR Performance			
FLGR NOx Removal	0%	-	Tons
FLGR Heat Input Cost	0%	$ -	/Hr.
Cofire NOx Removal	8%	0.065	tons
CoFire Heat Input Cost	16%	$ 522.48	/Hr.
Gas NOx Cost/Ton NOx	=	$ 8,000.00	$/Ton
Gas Nox Reagent Savings/Hr	=	$ 19.91	$/Hr.

Annual savings in ammonia usage is based on $19.91/Hr savings and 2800 hours/year at full load = $55,750 (not particularly significant

FGD and ESP Impacts

SO2 Impact			
SO2 Concentration (Coal)	=	3.80	Lb/mmBTU
SO2 Mass	=	7.76	Tons/Hr.
Mole Weight of SO2	=	64	
Mole Weight of CaCO3	=	100	
Mole Weight of CaSO3	=	136	
Purity	=	90%	
Reagent Cost per Ton SO2	=	$ 78.13	
Reagent Cost per Hour	=	$ 605.90	
Gas Adjusted Cost per Hour		$ 508.96	
Gas SO2 Reagent Savings/Hr.	=	$ 96.94	$/Hr.
CaSO4 Produced	=	18.31	Tons/Hr.
CaSO4 Disposal Cost	=	$ 366.23	$/Hr.
Gas CaSO4 Disposal Savings/Hr.	=	$ 58.60	
Gas Total FGD Savings/Hr.	=	$ 155.54	

SO3 Impact			
SO2 Concentration (Coal)	=	3.80	Lb/mmBTU
SO2 Mass	=	7.76	Tons/Hr.
SO3 Mass @ Conv. Rate	2%	387.8	Lb/Hr
Sorbent Required at NSR (Coal)	4	1435	Lb/Hr
Sorbent Reqd. Gas Adjusted		1,205	Lb/Hr
Sorbent Cost at $/Ton	200	$ 143.48	$/Hr.
Sorbent Saving from Gas	=	$ 22.96	$/Hr

Particulate Impact			
Ash % of Coal	=	10%	%
Original Ash Load @ %FA	70%	11.9	Tons/Hr.
Reduction in FA from Gas	=	1.90	Tons/Hr.
Baseline LOI	6%		
BTU Value of LOI	=	24.49	mmBTU
Increase in LOI from FLGR	-2%	$ (8.16)	/Hr.
Decrease in LOI from CoFire	2%	$ 8.16	/Hr.
Net Change in LOI from Gas	=	$ -	
Gas Ash Disposal Savings	=	$ 38.10	

FGD Reagent savings based on 16% displacement of coal with NG.

Disposal savings for FGD and ESP streams is based on $20/ton disposal cost.

SO3 Impact is from avoided sorbent usage

Gas Impact Summary

Full Load Impact			
% Gas Heat Input		16%	
Fuel Cost Differential		$ 0.40	per mmBTU
Total BTU/Hr.		4082	mmBTU
Fuel Cost Increase/Hr		$ 261.24	$/Hr
Fuel Cost Increase/yr		$ 732,303.90	
NOx Reduction		5%	
Nox Reagent Savings		$ 19.91	$/Hr
		$ 55,818.27	
SO2 Reduction		16%	
SO2 System Savings		$ 155.54	$/Hr
		$ 436,013.23	
SO3 Reduction		16%	
SO3 System Savings		$ 22.96	$/Hr
		$ 64,351.21	
Particulate Reduction		16%	
Particulate System Savings		$ 46.26	$/Hr
		$ 129,678.82	
Net Cost Difference/Hr		$ 16.57	
Hours at Load	32%	2803.2	
Cost of Gas Use		$ 46,442.37	

- Incremental cost of gas over coal totaled $732,304/yr.
- Total Commercial Impact of Reduced NOx, SO2, SO3 and Particulates totaled $685,861/yr.
- The net cost of gas use for this plant was: $46,442.

As a general rule, if gas pricing is at a 25% premium over coal then the secondary commercial benefits approximate the fuel cost differential

The value of reduced CO_2 , low load set point and reduced oil usage provide benefits over and above these commercial items.

High Volume Gas Ignition

Traditional Coal Firing

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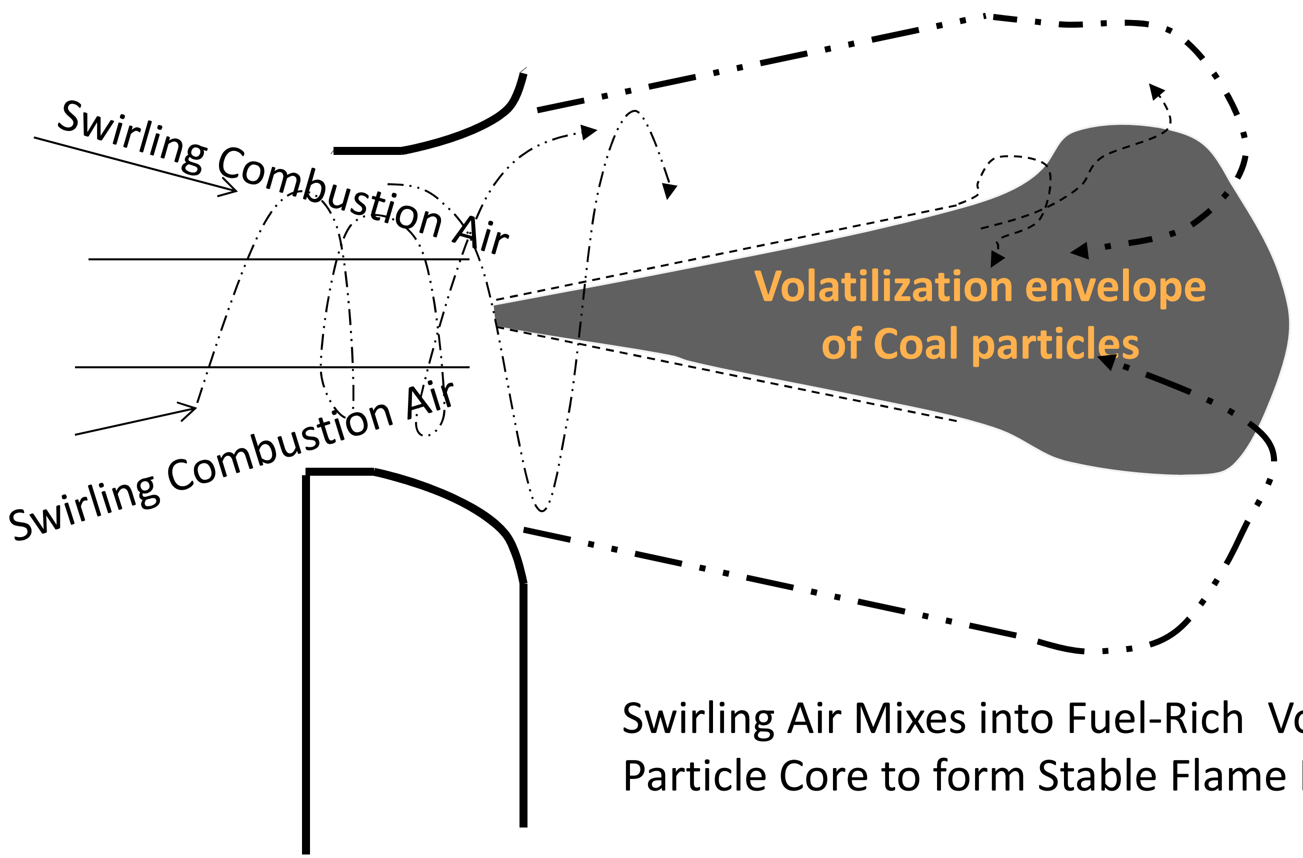
Air-mixing at Base of Primary Combustion Zone

Coal Particles Volatilize to form a stable flame front
at the Base of the Flame



Recirculation of Air into continuing Particle Combustion Mechanisms

Swirling Air Mixes into Fuel-Rich Volatilized Gases of Particle Core to form Stable Flame Holding Base

Circumferential Co-Fire

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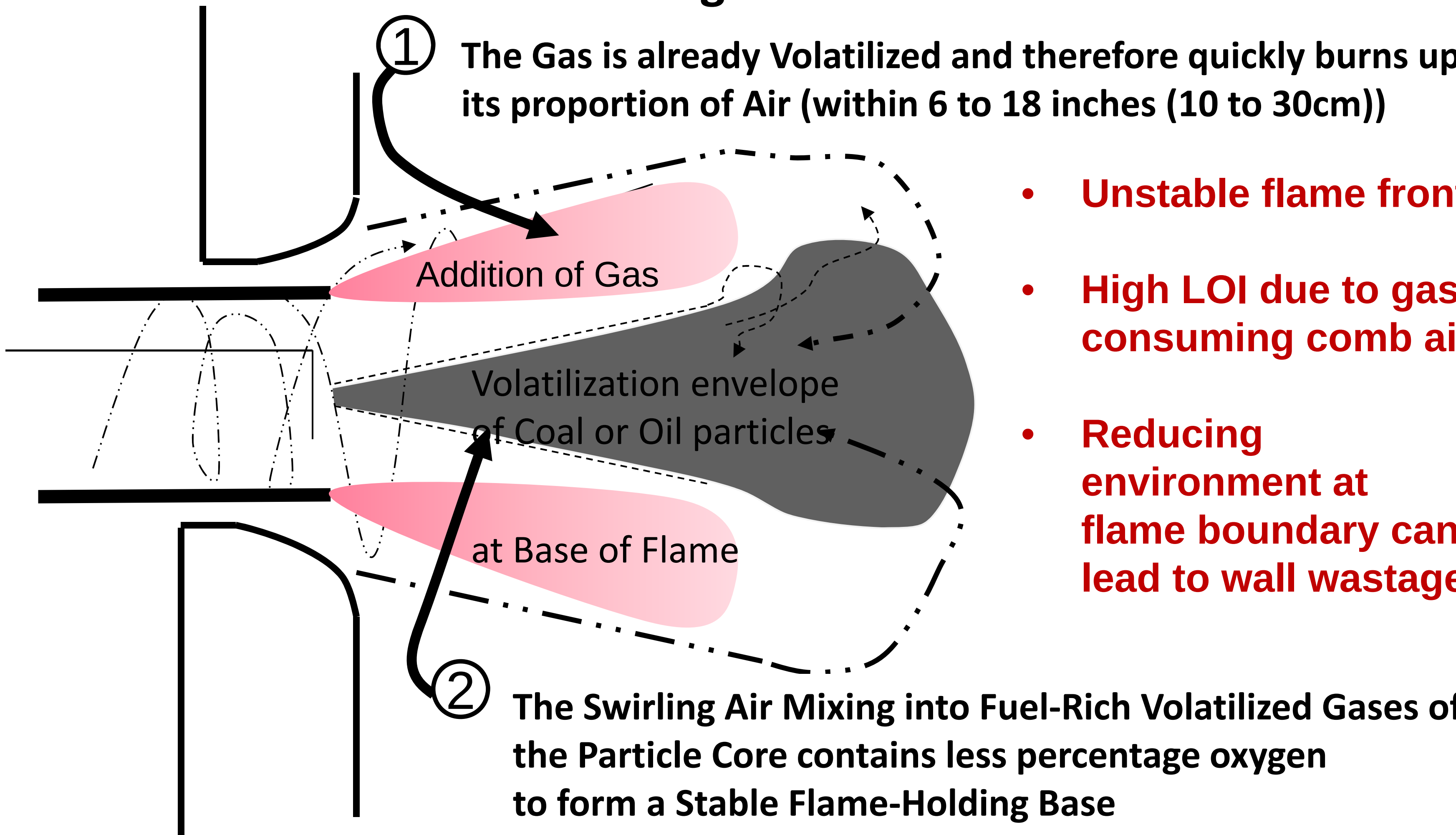
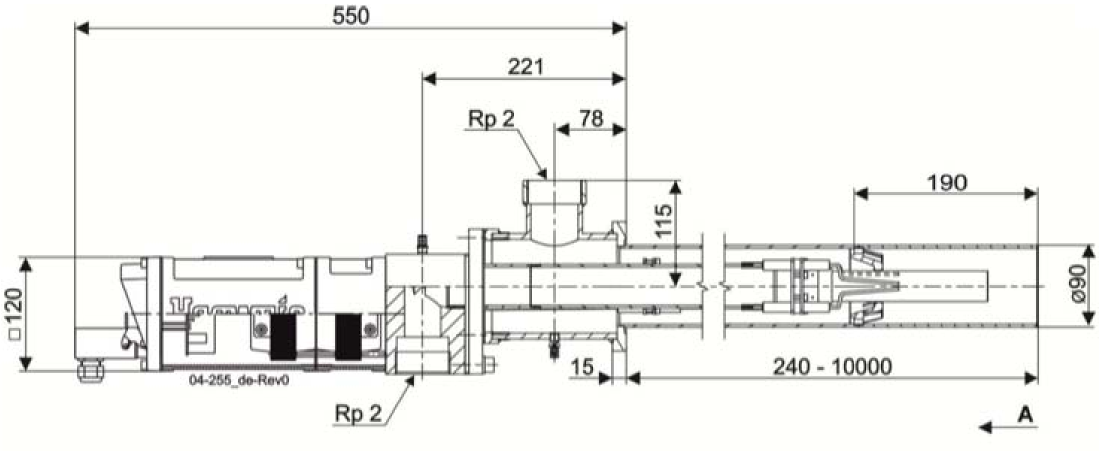
Addition of Gas Fuel Through the same Burner



- **Unstable flame front**
- **High LOI due to gas consuming comb air**
- **Reducing environment at flame boundary can lead to wall wastage**

High Volume NG Ignition

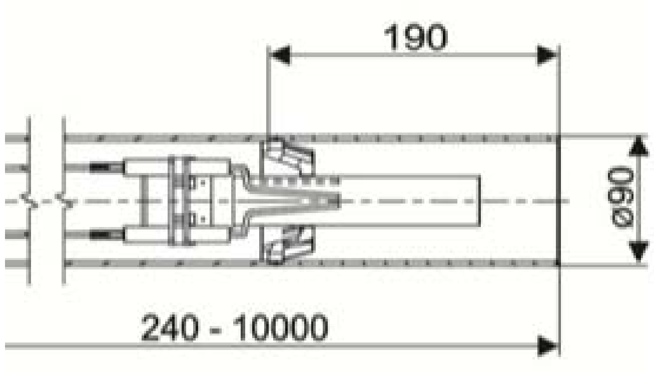


- A quick industry survey shows that many furnaces are designed with burners in the general range of 15 MW. I.e., our case study plant had 30 burners for 420 MW (14 MW/burner)

- A typical Igniter in the 15 – 20 mmBTU/Hr range has a 4” OD similar to the Durag PDA-2 shown above.

- The Host site opted for a 20 mmBTU max throughput igniter.

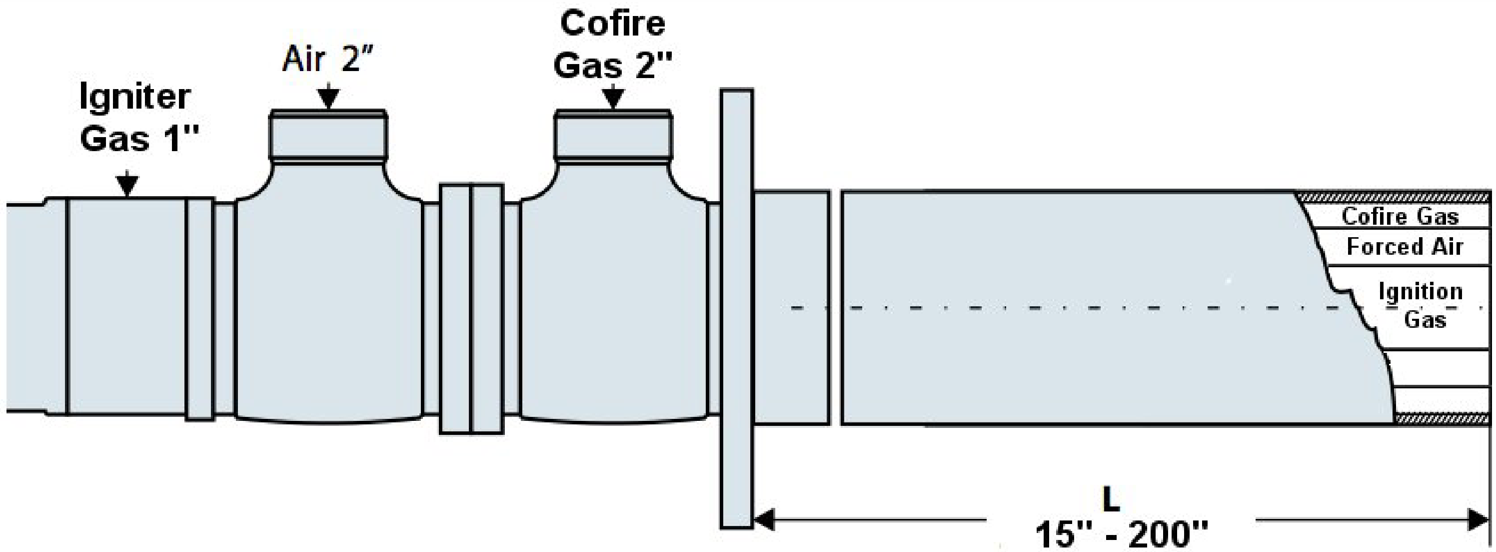
The Business End



- A 4" OD barrel with an internal gas spud of 1.5 " provides stable ignition flame generation when supported by forced combustion air through the balance of the injector

- As long as external combustion air is provided to support the introduced gas, a continuous duty gas ignitor won't affect the performance of the coal flame.
- However, introduction of gas volumes beyond the supplied combustion air will both increase the velocity of the gas stream and starve the coal flame of needed secondary air.

The Cofire Igniter



- The Cofire Igniter provides Class 1 performance through the inner igniter (sized to site conditions).
- When BMS permissives have been satisfied, and when additional heat input is required, Cofire Gas is introduced through an annulus surrounding the primary igniter.
- The system can be sized and tuned to place the correct amount of cofire gas in the correct orientation to support both coal flame stability and gas-only heat input.

High Flow Coal/Ignition Interaction

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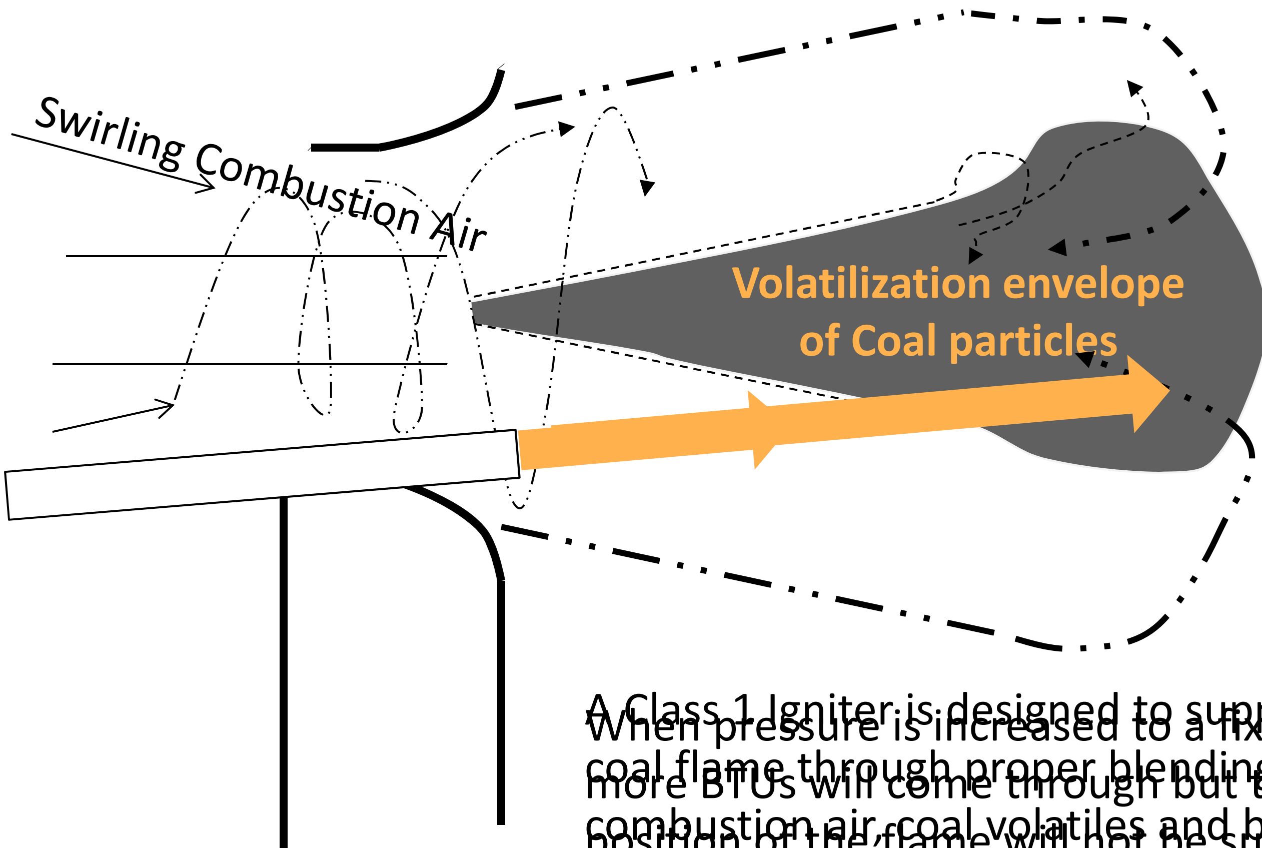
Air-mixing at Base of Primary Combustion Zone



A Class 1 Igniter is designed to support and stabilize the coal flame through proper blending of natural gas, combustion air, coal volatiles and burner secondary air.

When pressure is increased to a fixed geometry igniter, more BTUs will come through but the velocity and position of the flame will not be suitable for the burner

High Flow Coal/Ignition Interaction

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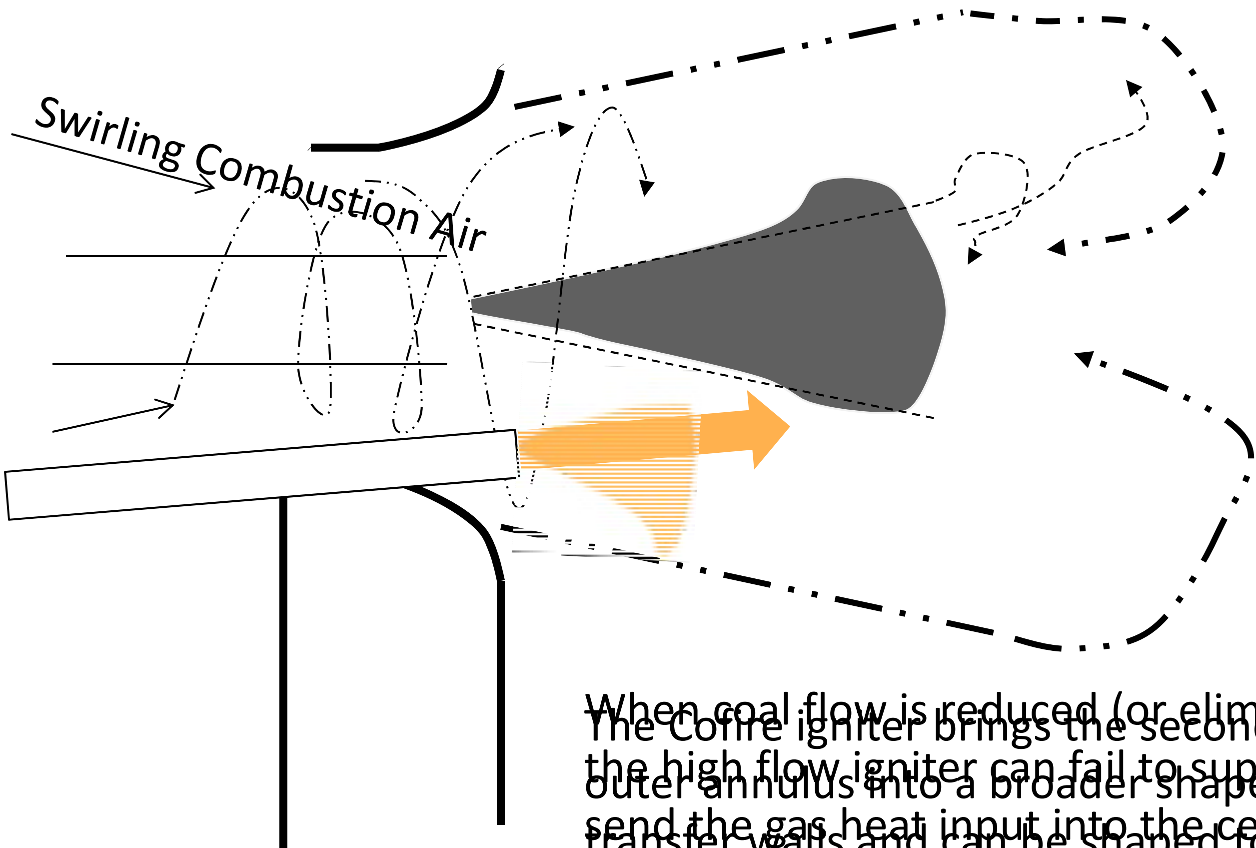


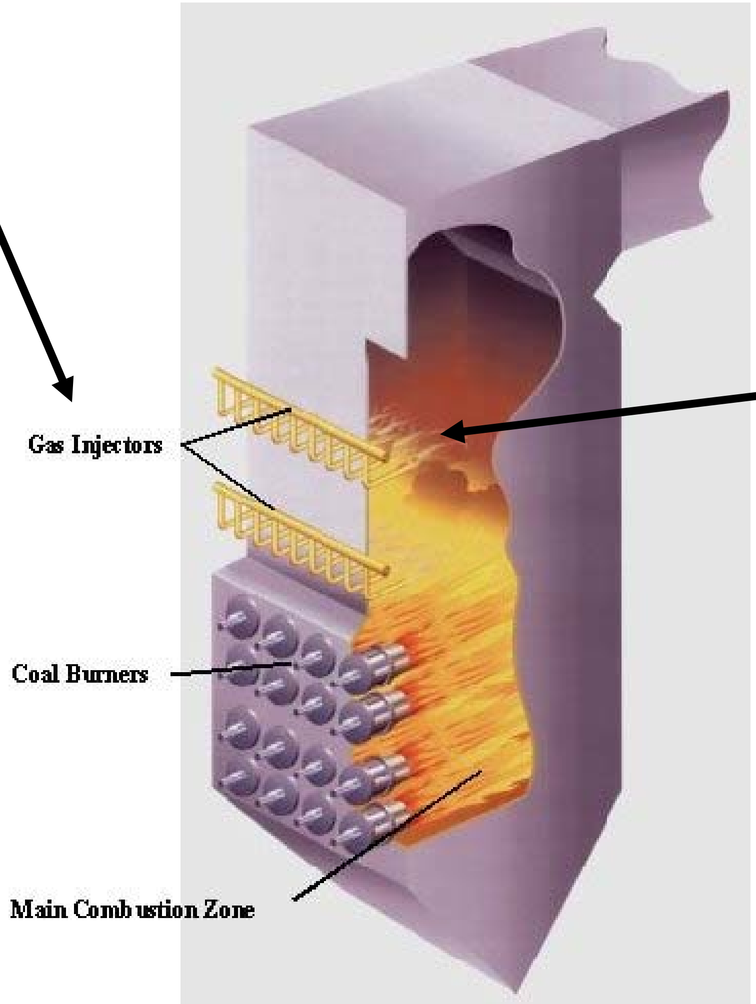
When coal flow is reduced (or eliminated) at light load, the high flow igniter can fail to support the flame and send the gas heat input into the center of the boiler.

The Cofire igniter brings the secondary heat from the outer annulus into a broader shaped, closer to the heat transfer walls and can be shaped to match the flame boundary.

FLGR NOx Reduction Project

Fuel Lean Gas Reburn (FLGR)

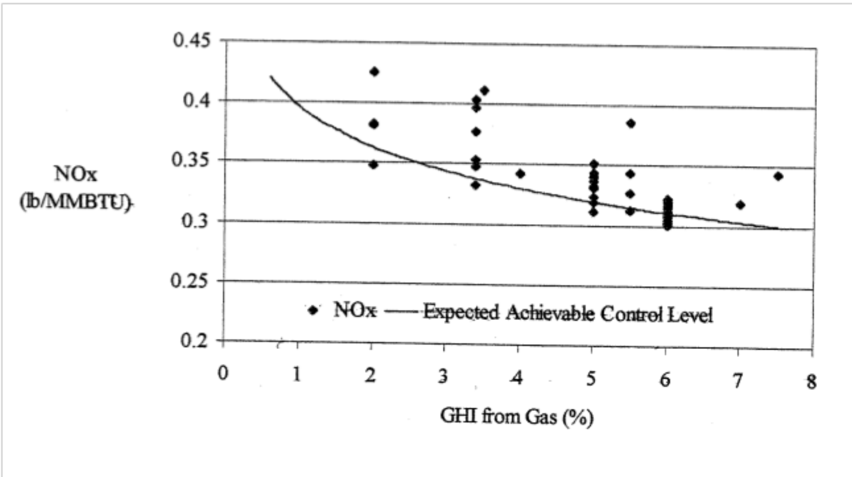
- **Injects 3 to ~10% of Fuel into Upper Furnace**

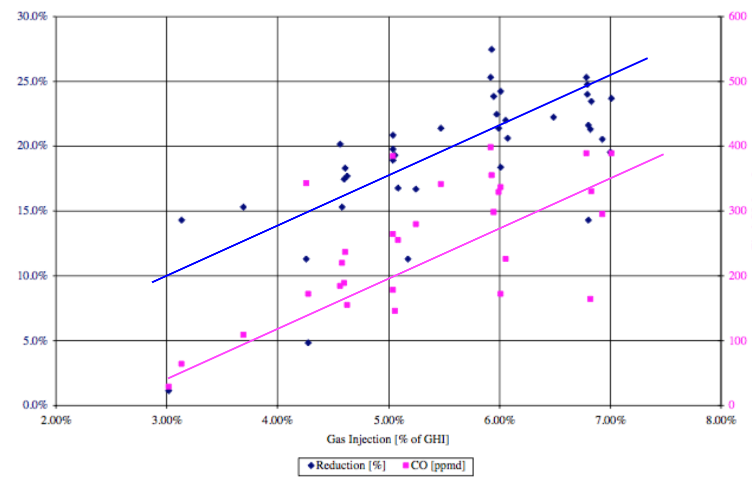


- Locally Fuel-rich Pockets with-in Fuel-lean Upper Furnace

- 3 - 5% NO_x Reduction for each 1% Fuel

Historical Data On NOx Removal





13 System were deployed between 1998 – 2001.

On average a 5% - 7% Gas Heat Input realized a 25% - 30% reduction in NOx prior to the current SCR location

CO has been a limit to the amount of NG used, but new understandings of injection location and CO:CO2 completion air have minimized this limitation.

FLGR Impact at Host Plant

FLGR Impact		
NOx Reduction		33%
Total Gas Reagent Savings		$ 82.14
NOX Reagent Differential		
Cofire Reagent Savings		$ 19.91
Net FLGR-Based Savings		$ 62.23
Hours at Load	57%	4993.2
Gain From FLGR vs Cofire		$310,707.18

- **Moving 5% of the current 16% gas input from the burner level to the upper furnace**
  - No change in fuel cost
  - 25% Additional NOx reduction
- **Total Potential NOx reduction from current baseline = 33%**
- **NOx reduction expected at both Mid load and High load.**

- **Savings in reagent use alone from diverting gas to the FLGR exceeds $310,000/yr.**
- **Additional benefits in reduced catalyst ABS issues (if any) and reduced ammonia slip thresholds have not been included.**

Conclusions

Conclusions

- **The hose site introduced 20% Heat Input Igniters to replace the existing oil igniters.**
- **Environmental performance improvement and commercial benefits have both been verified.**

- **The site is now looking to place 5% of the total 16% NG HI at the FLGR location to derive additional environmental and commercial benefit from the existing gas supply.**

- **The site is looking to implement first generation Cofire Igniters to remedy certain operational issues with the existing igniters.**

Questions?