REINHOLD ENVIRONMENTAL Ltd.

2012 Coal to Gas Conversion Round Table & Expo Presentation

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Fuel Lean Gas Reburn (FLGR)
Amine Enhanced FLGR (AE-FLGR)

Coal to Gas PCUG Conference

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OCT / 2012

The Balance of Power

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Regulations:
MATS
CSAPR
NAAQS
Coal Residuals
Wastewater
GHG BACT

Economics:
Fuel Cost
Fuel Flexibility (Coal V/S Gas)
Cost of Compliance
Demand
Repower?
Retire Plants?

THE BALANCE OF POWER

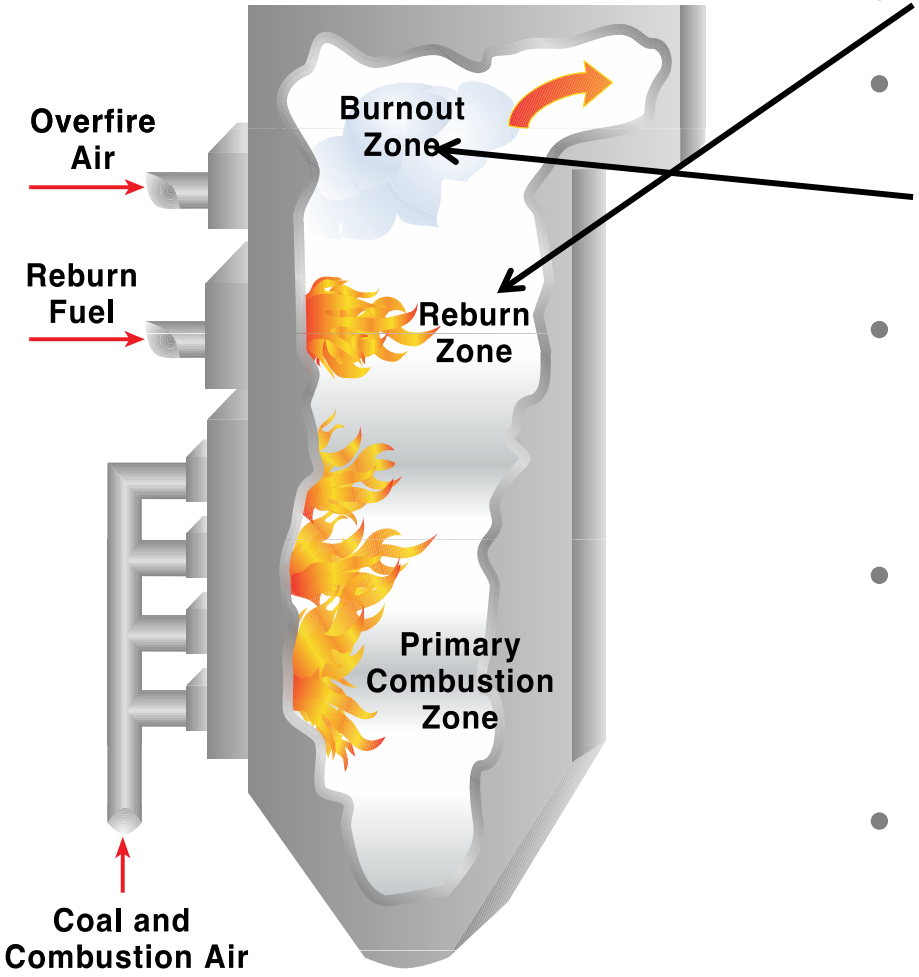
Coal to Gas Conversion Strategy

Partial Natural Gas Conversion

Fuel Lean Gas Reburn (FLGR) + Natural Gas Co-Fire

Fuel Lean Gas Reburn

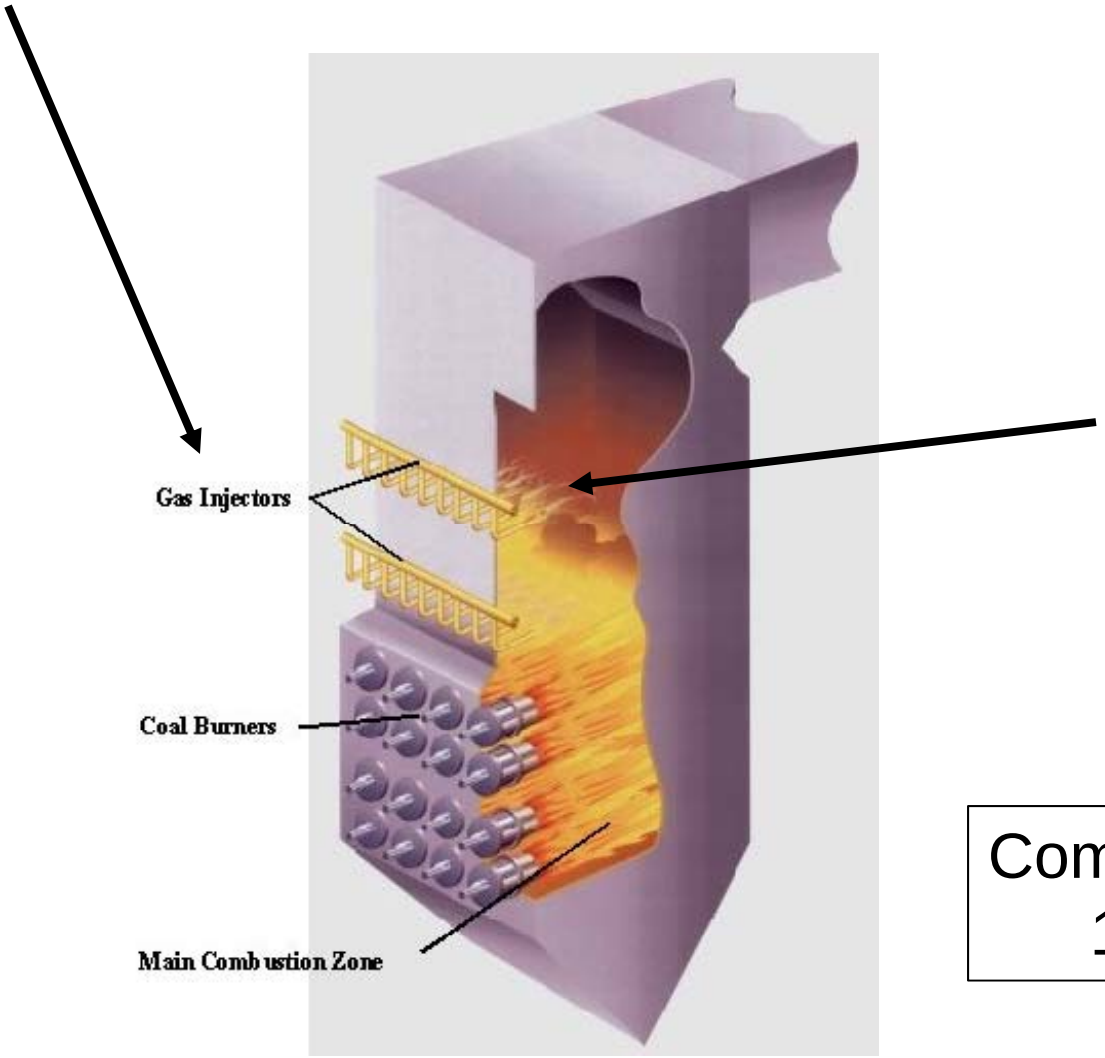
Conventional Reburn



- 10-30% Heat Input Blanket
- High CO formation requires Completion Air to complete combustion
- Completion Air addition can lead to formation of additional NO_x
- High reducing environment blanket leads to wall wastage issues
- Actual NO_x performance peaks at about 10% heat input with controlled CO

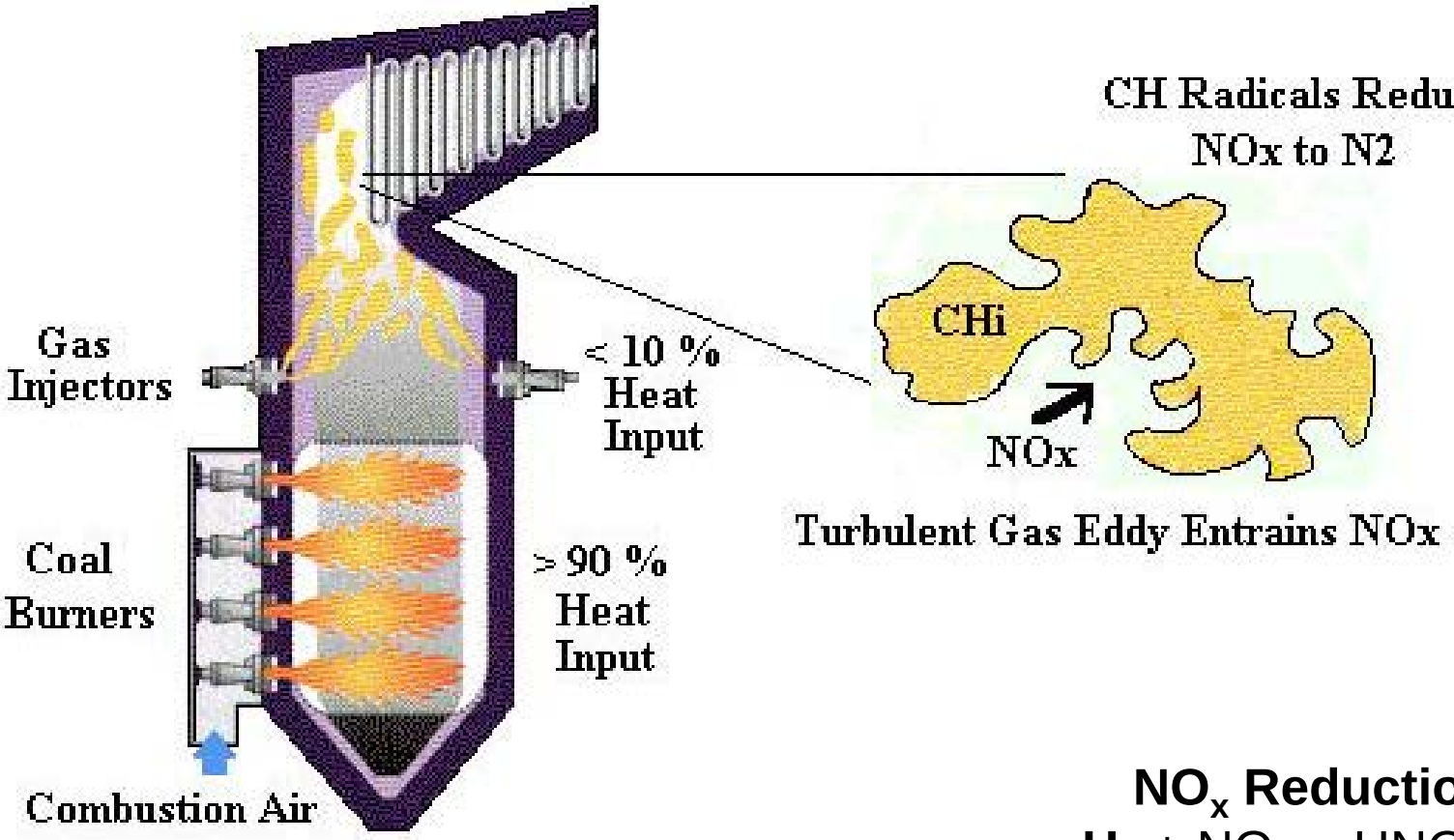
Fuel Lean Gas Reburn (FLGR)

- **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

Commercially applied in 13 Utility Boilers!



NO_x Reduction:

H_2 + NO → HNO + H

CO + HNO → HCN + O_2

CH_i + NO → HCN + H_iO

HCN + NO → N_2 + CO + H

Rough Chemistry

- Natural Gas Injected in Upper Furnace in amount sub stoichiometric to total flue gas oxygen,
- Localized gas pockets create fuel RICH zones:
  - CHx + NOx -> .CN + .NH2 + H2O
  - NOx + .NH2 -> N2 + H2O
  - NOx + .CN -> N2 + CO
  - NOx + CO -> N2 + CO2
- Upon re-entrance into O_2 rich zones, CO completes to CO_2
- When passing the 1750 F temperature zone, NHi radicals provide a secondary SNCR action

FLGR V/S Conv. Reburn

- **Avoids Wall Wastage issues**
  - Fuel rich eddies limited to high NO_x regions
  - Localized to the center of the furnace, away from the walls
- **Avoids high CO**
  - Excess O_2 interacts with the CO after the fuel rich eddies break down and mix into the bulk flue gas

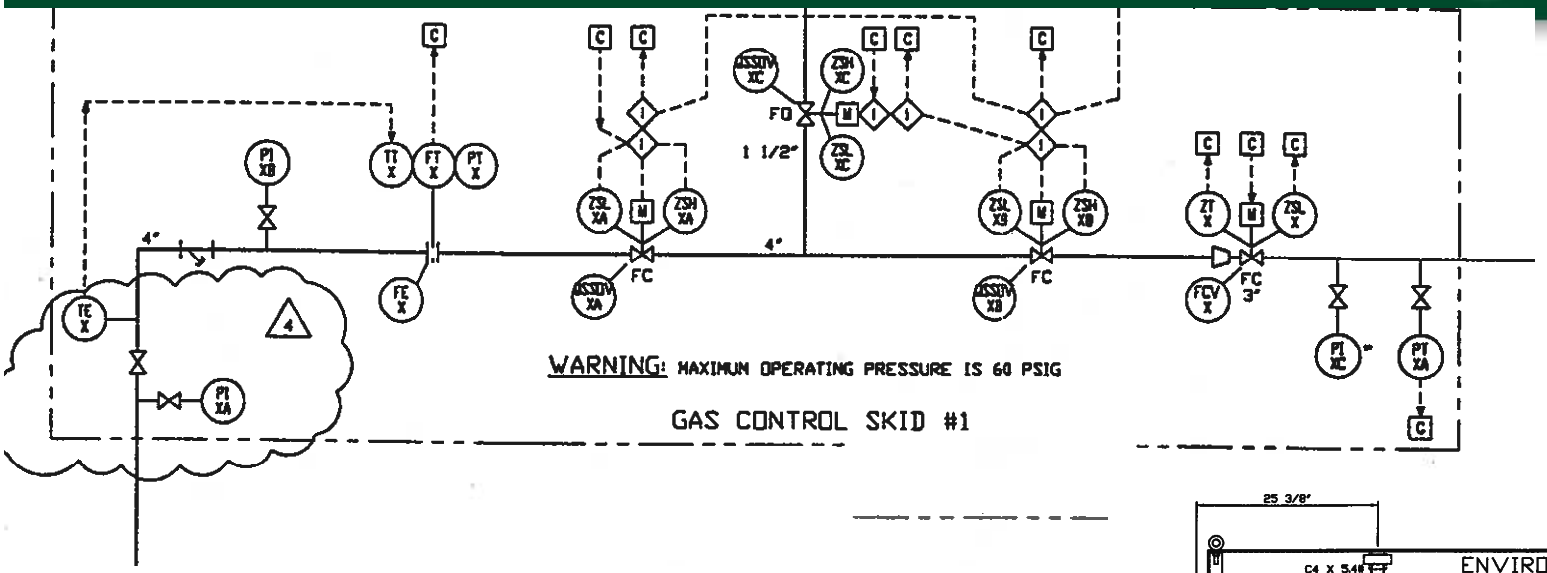
FLGR Installations - 13 Boilers

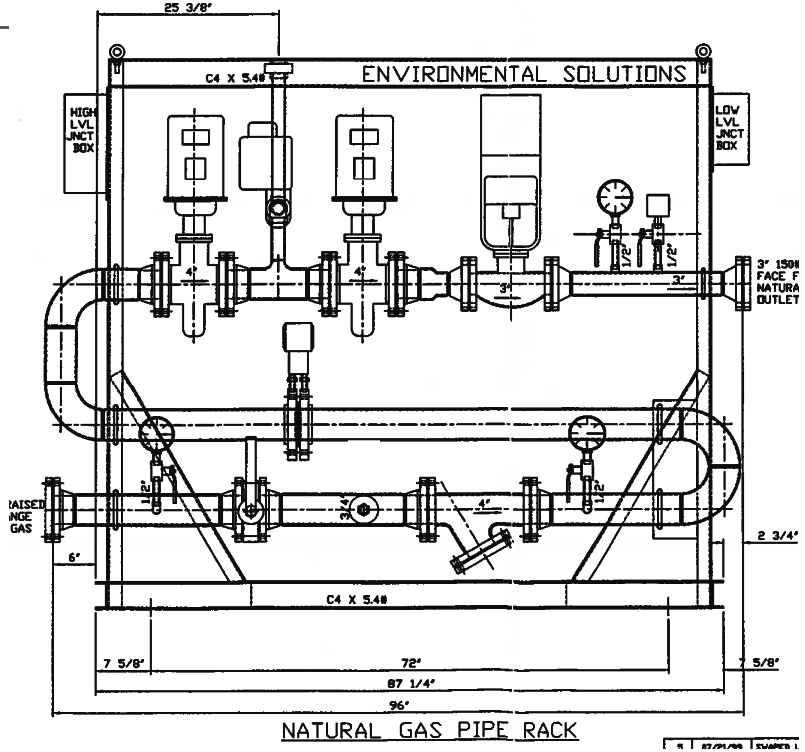
- **Duquesne Light Company Pittsburgh, PA**
  - *Elrama Power Station (1999)*
  - *3 x 100 MW Roof-Fired Units*
- **Commonwealth Edison Chicago, IL**
  - *Joliet Station 9 (1997)*
  - *340 MW Cyclone*
- **Public Service Electric & Gas Trenton, NJ *(with SNCR)***
  - *Mercer Station (1998)*
  - *2 x 326 MW Wall Fired (4 boilers)*
  - *Hudson Station (2001)*
  - *1 x 550 MW Opposed-Wall Fired*
- **Wisconsin Electric Power Company Milwaukee, WI *(with SNCR)***
  - *Pleasant Prairie Unit 1 (1999)*
  - *640 MW Turbo Fired*
- **Duke Power Company Charlotte, NC**
  - *Riverbend Unit 7 (1998)*
  - *150 MW Tangentially Fired*
- **Carolina Power & Light Raleigh, NC *(with SNCR)***
  - *Asheville Unit 1 (2000)*
  - *200 MW Wall Fired*
- **Ontario Power Generation Hamilton, Ontario**
  - *Nanticoke Station (2001)*
  - *510 MW Opposed-Wall Fired*

Main Pressure Reducing Station

- Manual and automatic blocking valves
- Pressure regulators
- Flow and Pressure Transmitters
- Safety Vents

Gas Distribution/Control Skids

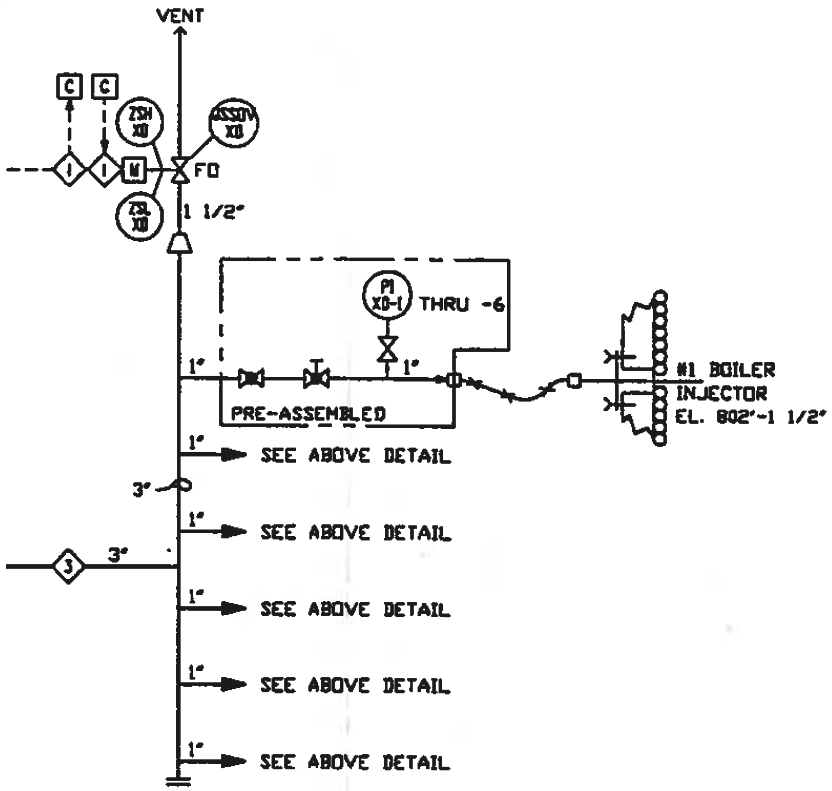


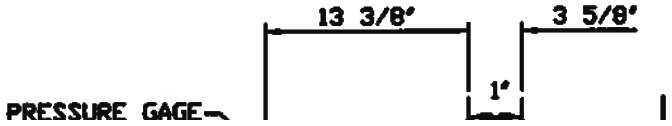


Gas Distribution/Control Skid

- Manual and automatic blocking valves
- Safety vents
- Pressure and flow transmitters
- Pressure reducing valve
- Flow control valve

Injectors - FLGR



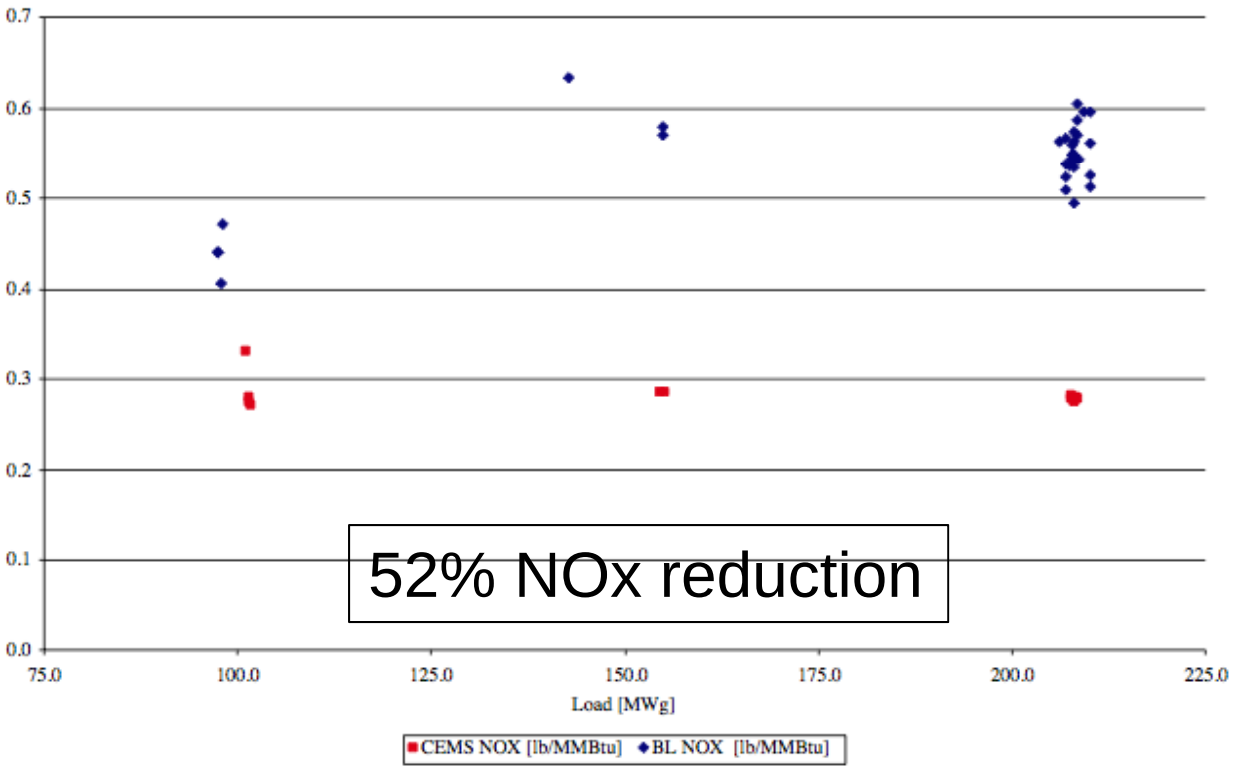


- Safety Vent
- Local Pressure Indicator
- Safety interlock limit switch on lance insertion

AE-FLGR

- **Simultaneous injection of Natural Gas and Urea through the same lances**
- **FLGR NO_x reaction followed by an SNCR NO_x reaction gives enhanced NO_x reduction**

Figure 5. Latest Optimization and Baseline Dat



52% NOx reduction

Scorecard on Reburning, 6/1/2004

Project Description/ Technology	Utility/Operator	Location	Reburning Technology Provider	Combustor	Coal	Size, MWe (gross)	Reburn Fuel Heat Input, %	Thermal Efficiency Loss, %	Baseline NOx, lb/ million Btu	Controlled NOx, lb/ million Btu	Target NOx Reduction, %	Actual NOx Reduction, %	Reburning Capital Cost, $/kW	Reburning Levelized Cost with Gas at $5/million Btu	Current Status of Reburning	Comments
Gas Reburning (GR) + Sorbent Injection (SI)	Illinois Power (now Dynegy)	Hennepin Unit 1, Hennepin IL	Energy & Environmental Research Corp. (now GE Energy)	T-fired	IL bituminous	80	18	1	0.75	0.25	60	67	300 MWe: 17	300 MWe: $2114/ton NOx	Demo 1/91-1/93 Not operating	DOE Clean Coal project. High price of natural gas. NOx reduction covered by other units.
Gas Reburning (GR) + Sorbent Injection (SI)	City Water, Light & Power	Lakeside Unit 7, Springfield IL	Energy & Environmental Research Corp. (now GE Energy)	Cyclone	IL bituminous	40	23	1	0.97	0.39	60	60	300 MWe: 17	300 MWe: $2114/ton NOx	Demo 5/93-10/94 Not operating	DOE Clean Coal project. High price of natural gas. NOx reduction covered by other units.
Gas Reburning (GR) + Low-NOx Burners (LNB)	Public Service of Colorado (now Xcel)	Cherokee Unit 3, Denver CO	Energy & Environmental Research Corp. (now GE Energy)	Wall-fired	Colorado bituminous	172	12.5	1	0.73	0.26	70	64	300 MWe: 12	300 MWe: $2535/ton NOx	Demo 11/92-1/95 Decommissioned	DOE Clean Coal project. LNB plus OFA meets NOx emissions requirement
Coal Reburning	Wisconsin Power & Light (now Alliant)	Nelson Dewey Unit 2, Cassville WI	Babcock & Wilcox	Cyclone	IL bituminous (Lamar) & PRB subbituminous	110	25 - 30	1	0.82	Lamar 0.39, PRB 0.34	50	Lamar 52, PRB 55	110 MWe: 66; 605 MWe: 43	110 Mwe: 2.4 mils/kWh 605 Mwe: 1.6 mils/kWh	Demo 12/91-12/92 Decommissioned	DOE Clean Coal project. Overfire air (OFA) meets NOx emissions requirement
Micronized Coal Reburning	NYSEG (now AES)	Milliken Unit 1 (now AES Cayuga), Lansing NY	Energy & Environmental Research Corp. (now GE Energy)	T-fired	Pittsburgh bituminous	148	14	1.5	0,35	0.25		29	300 MWe: 14	300 MWe: $1023/ton NOx	Demo 3/97-4/99 Operating	DOE Clean Coal project. LNB provides 39% NOx reduction. Total NOx reduction = 68%
Micronized Coal Reburning	Eastman Kodak	Kodak Park Unit 15, Rochester NY	Energy & Environmental Research Corp. (now GE Energy)	Cyclone	Pittsburgh bituminous	60	17	0.5	1.36	0.59	> 50	57	300 MWe: 56	300 MWe: $571/ton NOx	Demo 4/97-10/98 Operating	DOE Clean Coal project. Meets N.Y. State RACT requirement of 0,60 lb NOx/million Btu
Gas Reburning	NYSEG (now AES)	Greenidge Unit 4, Dresden NY	Energy & Environmental Research Corp. (now GE Energy)	T-fired	Bituminous	109	10		0.50	0.25		50			Startup 1996 Not operating	High price of natural gas
Gas Reburning	Ohio Edison (now FirstEnergy)	Niles Station, Niles OH	Combustion Engineering/ Energy Systems Associates	Cyclone	Ohio bituminous	108	8-18		1.10	0.55	50	50			Installed and operated 1988 Decommissioned	First commeercial application of reburning in U.S. Not operating due to high price of natural gas
Gas Reburning	Baltimore Gas & Electric (now Constellation)	C.P. Crane Unit 1, Baltimore MD	Energy & Environmental Research Corp. (now GE Energy)	Cyclone	Bituminous	200	25								Startup 1998	
Gas Reburning	Baltimore Gas & Electric (now Constellation)	C.P. Crane Unit 2, Baltimore MD	Energy & Environmental Research Corp. (now GE Energy)	Cyclone	Bituminous	205	25									
Gas Reburning	Tennessee Valley Authority	Allen Unit 1, Memphis TN	Energy & Environmental Research Corp. (now GE Energy)	Cyclone	Subbituminous	330	7		0.86			65				
Gas Reburning	Conectiv	Edge Moor Unit 4, Edge Moor DE	Energy & Environmental Research Corp. (now GE Energy)	T-fired	Bituminous	177										
Gas Reburning	Potomac Electric	Chalk Point Unit 1, Aquasco MD	Energy & Environmental Research Corp. (now GE Energy)	Wall-fired	Bituminous	364										
Gas Reburning	Potomac Electric	Chalk Point Unit 2, Aquasco MD	Energy & Environmental Research Corp. (now GE Energy)	Wall-fired	Bituminous	364										
Gas Reburning	Allegheny Power	Hatfield Unit 2, Masontown PA	Energy & Environmental Research Corp. (now GE Energy)	Cell burner	Bituminous	576									Brief test; successful	High price of natural gas
Gas Reburning	Allegheny Power	Hatfield Unit 3, Masontown PA	Energy & Environmental Research Corp. (now GE Energy)	Cell burner	Bituminous	576									Installed, never tested	High price of natural gas
Fuel Lean Gas Reburning (FLGR)	Duquesne Light	Elrama Units 1-3, Elizabeth PA	Energy Systems Associates	Roof-fired	Bituminous	3x100	5-10					25-30			Startup 1999 Not operating	High price of natural gas
Amine-Enhanced FLGR	Public Service Electric & Gas	Mercer Units 1-2, Trenton NJ	Fuel Tech/ Energy Systems Associates	Wall-fired	Bituminous	2x320	5-10					25-30			Startup 1999 Not operating	High price of natural gas
Amine-Enhanced FLGR	Public Service Electric & Gas	Hudson Unit 2, Jersey City NJ	Fuel Tech/ Energy Systems Associates	Opposed-fired	Bituminous	600	5-10					25-30			Startup 2000 Not operating	High price of natural gas
FLGR	Duke Energy	Riverbend, Mt Holly NC	Energy Systems Associates	T-fired	Bituminous	140	5-10					25-30			Startup 1998 Decommissioned	High price of natural gas
FLGR	Ontario Power	Nanticoke Unit 6, Canada	ESA Environmental Solutions	Wall-fired	Bituminous/ PRB blend	500	5-10					25-30			Startup 2000 Decommissioned	High price of natural gas
FLGR	Commonwealth Edison	Joliet, Joliet IL	Energy Systems Associates	Cyclone	Bituminous	340	5-10					25-30			Startup 1997 Decommissioned	High price of natural gas
Amine-Enhanced FLGR	Carolina Power & Light	Asheville, Arden NC	Fuel Tech/ Energy Systems Associates	Wall-fired	Bituminous	207	5-10					25-30			Startup 2000 Not operating	High price of natural gas
FLGR	Wisconsin Electric Power (We Energies)	Pleasant Prairie, Pleasant Prairie WI	Fuel Tech/ Energy Systems Associates	Wall-fired	Bituminous	616	5-10					25-30			Startup 1999 Not operating	High price of natural gas
Coal Reburning	Louisville Gas & Electric (E.ON US Holdings)	R.D. Green Units 1 & 2, Sebree KY	Energy & Environmental Research Corp. (now GE Energy)	Wall-fired	Bituminous	2x293			0.45	0.25		44			Operating	
Gas Reburning	Eastman Kodak	Kodak Park, Rochester NY	Babcock & Wilcox	Cyclone	Pittsburgh bituminous	2x50	18		1,25	0,60		52			Startup 1998 Operating	Meets N.Y. State RACT requirement of 0,60 lb NOx/million Btu
Gas Reburning	Eastman Kodak	Kodak Park Unit 43, Rochester NY	Babcock & Wilcox	Cyclone	Pittsburgh bituminous	62	18		1.35	0.60		56			Startup 1999 Operating	Meets N.Y. State RACT requirement of 0.60 lb NOx/million Btu
Gas Reburning	Long Island Electric (now KeySpan)	E.F. Barrett Station, Island Park NY	ABB Combustion Engineering		Gas/oil	200						50				
Gas Reburning	Scottish Power	Longannet, Scotland		Wall-fired		700						42-49				
Gas Reburning		Ladyzhin Unit 2, Ukraine	ABB Combustion Engineering	Wall-fired, wet bottom	Ukraine bituminous	300	15-18		0.82	0.41	50	50			Startup 1992 Operating	
Coal Reburning		Ladyzhin Unit 6, Ukraine	GE Energy	Wall-fired, wet bottom	Ukraine bituminous	300	15-18				50				Planned	
Gas Reburning		Johban-Kyoudo Unit 9, Japan	IHI		Oil/coal	600									Operating	
Gas Reburning	Tokyo Electric Power	Yokohama Units 2 & 4, Japan	IHI		Gas/oil	175									Operating	
Gas Reburning	Tohso Co.	Unit 3, Japan	IHI		Coal	150									Operating	
Coal Reburning	Cheng Loong Corp.	Taiwan				20						55			Startup 9/2002 Operating	
Coal Reburning	Corn Belt Energy	Elkhart IL	Riley Power	Slagging	IL bituminous	91	10-15		0,6	0,2	67				Startup Spring 2007	Part of DOE-sponsored Low-Emissions Boiler System (LEBS) project
Coal Reburning	Beilun Power	Ningbo, China				5x600					50					Potential project
Coal Reburning	ENEL (now Interpower)	Vado Ligure Unit 4, Savona, Italy	Powergen, UK		Ashland (US)	320	20	Minimal	0.50	0.27	50	46			Decommissioned	LOI high due to restricted combustion zone
Oil Reburning	New Brunswick Power	Coleson Cove, St. John, NB	Babcock & Wilcox	Opposed wall-fired	Bunker C/ Orimulsion	3x350	25		1.00	0.22		78			Commissioning in progress	

FLGR Reintroduction

- **An FLGR system at a Duke Energy plant is being re-commissioned to explore:**
  - Effects of FLGR
  - Co-Firing
  - Fuel Flexibility
  - BOP

- **Current Status**
  - Control system has been exercised and evaluated
  - Instrumentation will be tested in the next few weeks
  - System checkout planned within the month

Gas Co-Firing (25 to 40%)

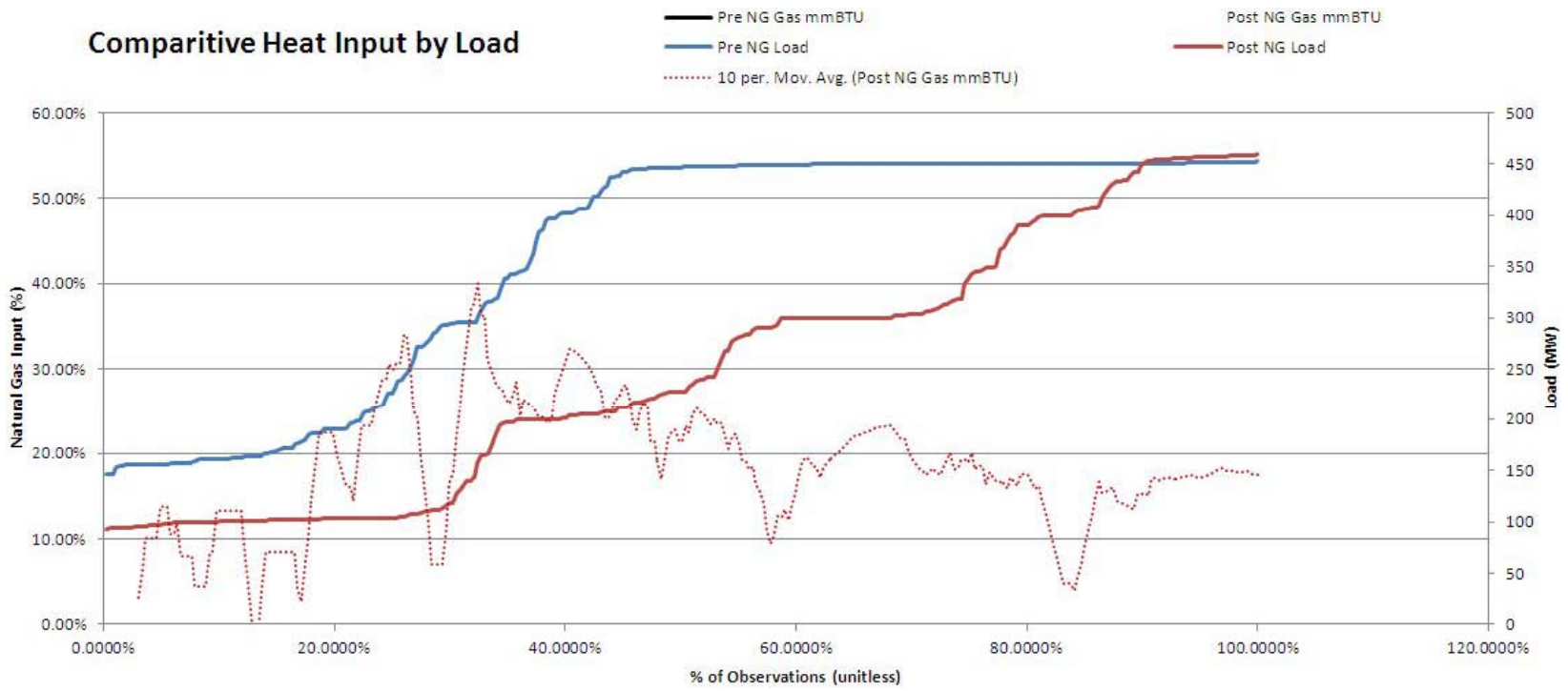
Partial V/S Complete conversion

- **Improper heat transfer surfaces for low emissivity gas flames**
  - Derates
  - Capital Cost to retube
- **Fuel-Flexibility**
  - Gas prices return to $4+/MMBtu
- **New Source Review**
  - Gas to Coal
  - Coal to Gas

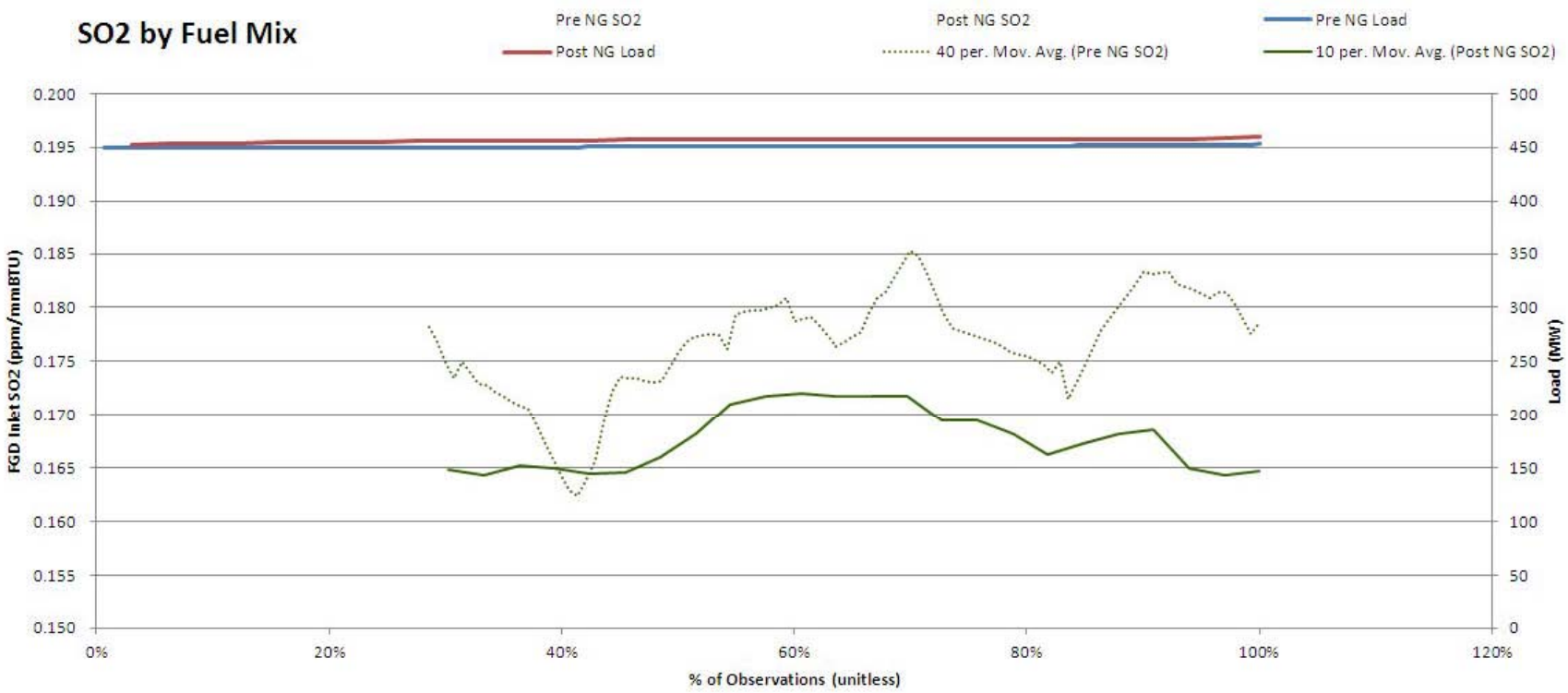
Benefits of Partial Conversion

- **Environmental**
  - Reduced NO_x
  - Reduced SO_2
- **Operational**
  - Reduced SO_3/AbS Issues
  - Reduced need for DSI at low loads for Blue Plume
  - Salvage of small environmentally challenged units without large capital expenditure

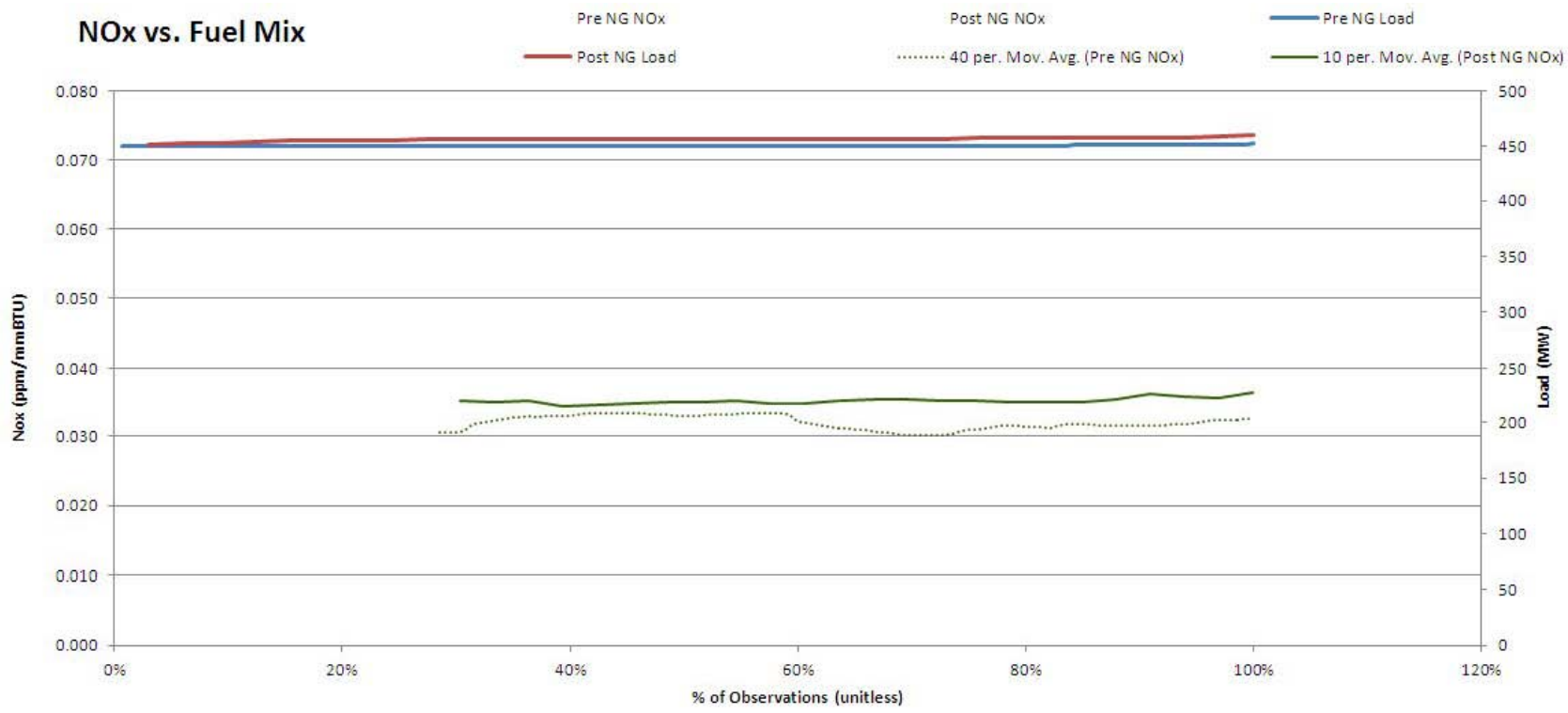
Gas Igniter Heat Input vs Load



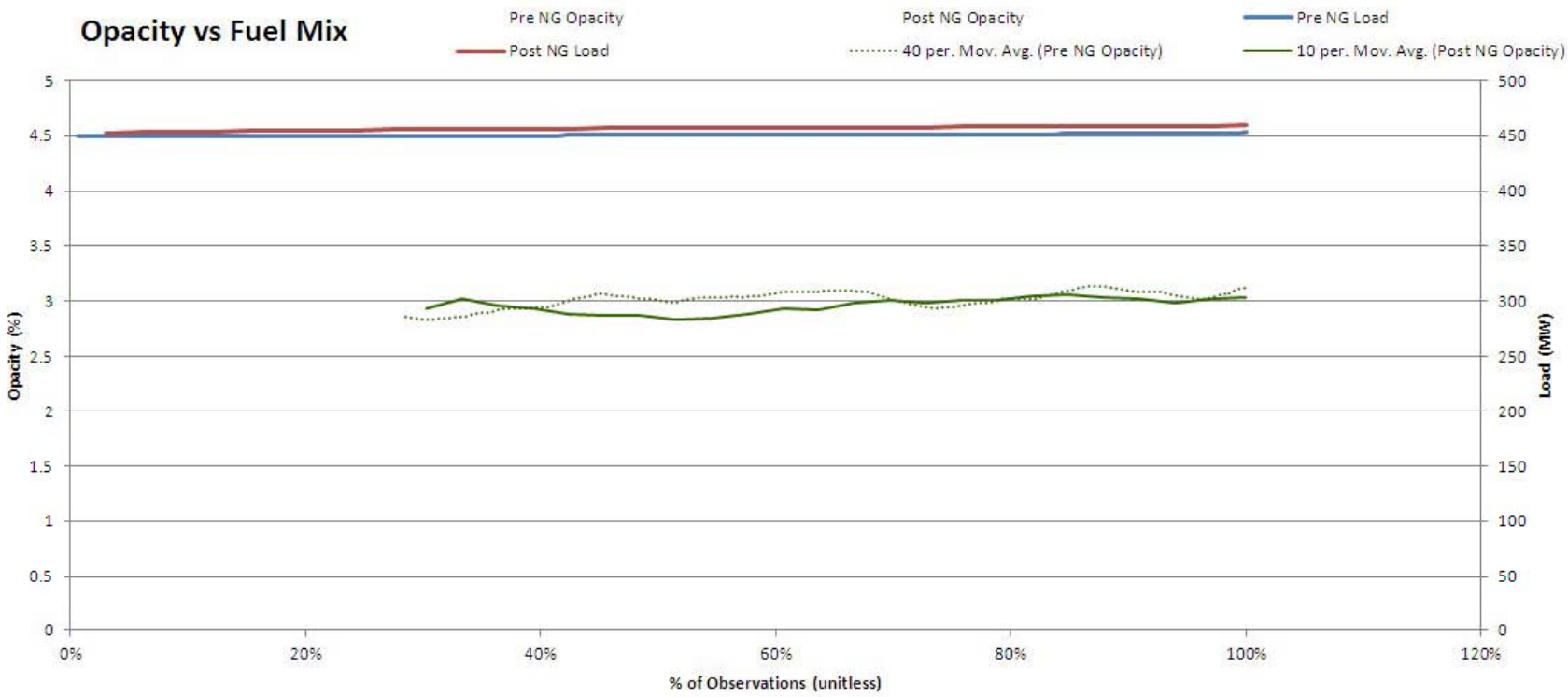
SO2 vs. Fuel Mix



NOx vs. Fuel Mix



Opacity vs. Fuel Mix



High Volume Controlled Igniters

- **Breen Energy is working towards designing a high volume controlled igniter for gas co-firing through existing coal burners**

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Thank you!

Questions?