Enhanced Gas CoFiring Experience at Orlando Utilities

Paper # 98

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ABSTRACT

With the implementation of MATS, the pending Clean Power Plan, depressed gas prices and an increasing emphasis on renewables, traditional coal-fired generating assets are looking for flexible solutions.

Starting with the October 2012 outage, Stanton Energy Center began a long-range program to utilize increasing levels of natural gas in dual locations within Unit 1. High volume natural gas igniters replaced the existing oil-fired igniters in 2012 and Fuel Lean Gas Reburn for NOx reduction and upper-furnace use of natural gas was implemented in 2015. As the latest step in this program, Stanton is replacing two levels of the existing igniters with Breen's Dual-Orifice CoFiring igniters in 2016.

This paper will document the environmental and performance results of each of those steps, the lessons learned during implementation, and project the long term impact of this combined coal/gas firing technology on long term compliance with MATS and CPP objectives.

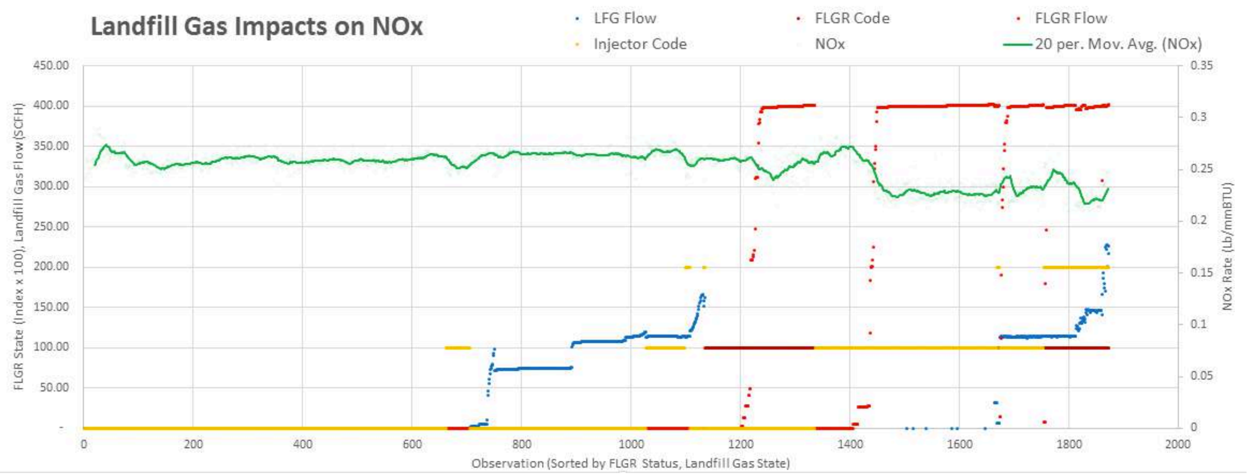
INTRODUCTION

Many plants use natural gas as a start-up and burner stabilization fuel. Generally, gas igniters are sized for 10% of the maximum heat input of the associated burner (NFPA Class 1) and are designed for intermittent use. Cofiring, as we apply the term, applies to continuous utilization of both fuels with the amount of natural gas vs. total heat input up to 35%. There are several approaches to simultaneous introduction of both fuels into the lower and upper combustion zones. A prior paper on this topic spoke in detail on the work done to introduce additional volumes of natural gas through existing igniter locations. This paper will touch on advances made through additional installation of dual volume igniters. The focus, however, be on work done during 2015 to implement the first Fuel Lean Gas Reburn system on a wall-fired unit boiler equipped with Over-Fire Air.

UPDATE ON GAS COFIRING

The goal of the total project at Orlando Utilities/Stanton Energy Center is to secure a high level of fuel flexibility to enhance the unit's commercial and environmental footprint. Stanton has contractual obligations to burn ever-increasing quantities of locally generated Landfill gas containing roughly half the BTU content of pipeline grade natural gas. Additionally, the plant and its management are highly aware of the positive impacts that both Landfill and Natural Gas. The initial implementation of the Dual Orifice gas igniters has been focused on providing the ability to fire landfill gas even when the mill group corresponding to the igniter group is not in service.

Landfill gas combustion has a minor impact on NOx release as shown in the graph below:

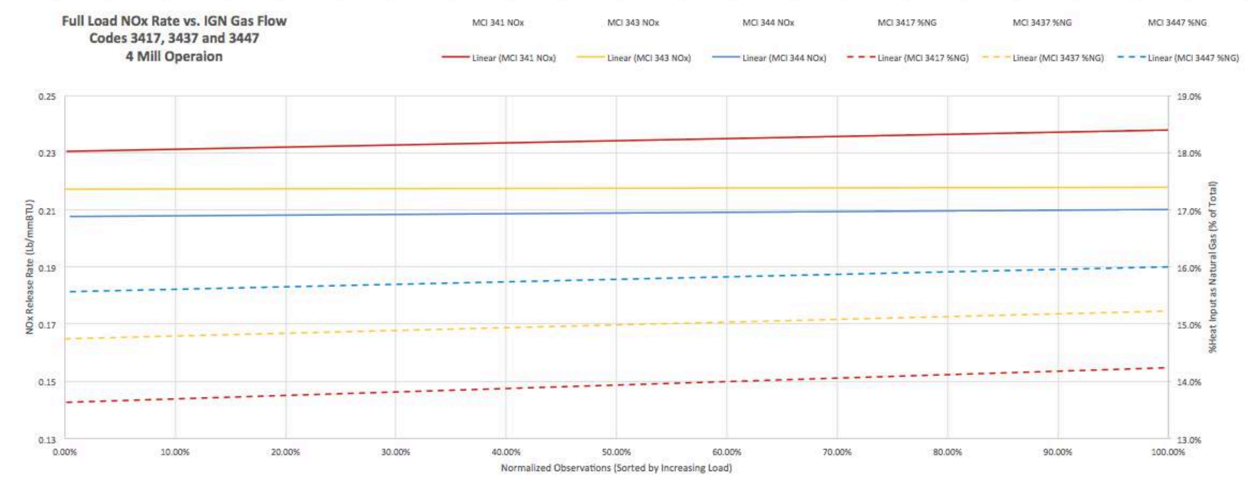


A full explanation of the graph above will be provided later in this paper. It is sorted first by the presence of FLGR injection (dark red line), then by FLGR Injector configuration (yellow line). Within the second sort field FLGR injection rates and Landfill Gas injection rates are shown. Details of FLGR impact will be explained later, but it is important to understand that landfill gas, even though it is inferior to pipeline natural gas, has a positive, though minor, influence on total NOx emission rate.

The graph below shows the relationship between pipeline natural gas utilization and total unit NOx emission rates. The burner configuration for this data reflects full load operation with three mills and supplemental gas. The burner levels in service are:

Middle Row – Front Wall / Bottom Row – Front Wall / Bottom Row – Back Wall

Support gas levels for this data range from just below 14% of total heat input to 16% of total heat input.



The axis values have been adjusted to separate the data. NOx emission rate data is the solid lines with values on the left axis. Corresponding percentage of heat input as Natural Gas is the dashed line with values on the right axis. All six lines are linear trend lines with the data sorted by increasing gas heat input. Finally, the data sets are different in total size so the X-axis has been normalized to reflect 0% – 100% of observations.

It is clear that as natural gas heat input increases, the corresponding NOx release rate is reduced. Tabulation of the above data shows:

NOx Release Rate (Lb./mmBTU)	**NG Heat Input %**	**Reduction in NOx Rate**	**Increase in NG %**
.139	.234		
.150	.258	7.33%	7.34%
.158	.209	5.06%	4.31%

This data reflects roughly 3200 data samples.

The relationship between increase in CoFire NG and NOx reduction is close to 1:1. This is higher than prior data for the same site, but this data set takes more variables (like CO compliance and mill configuration) into account, which prior data did not.

The Dual Orifice CoFire igniters installed at Orlando/Stanton utilize a concentric firing approach with a 20 mmBTU, forced draft, core igniter and a secondary annulus for variable gas introduction.

Much has been written on this in early papers so only two small photos have been included here for reader clarification.

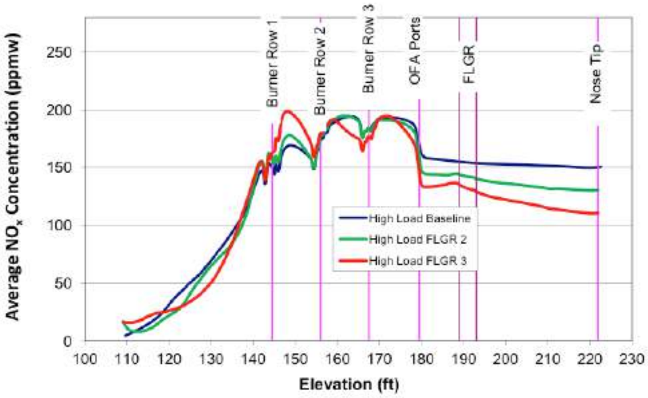
Above – End view of an 80 mmBTU total throughput Dual Orifice Igniter

Right – Installed view of a non-retractable Dual Orifice Igniter system

UPDATE ON FUEL LEAN GAS REBURN

The original Fuel Lean Gas Reburn system at Orlando/Stanton 1 was commissioned in July 2015. The original design featured slotted injectors passing gas through webbing penetrations.

Reaction Engineering executed initial CFD modeling with the following predictions:



The project expected to see initial NOx reduction in the range of 15% - 25% depending on injection velocities, angular orientation and allowable CO levels at the economizer.

In reality the initial operation showed to interesting results:

1) Total NOx reduction observed was essentially zero, and
2) The observed CO dropped, almost immediately, to near zero.

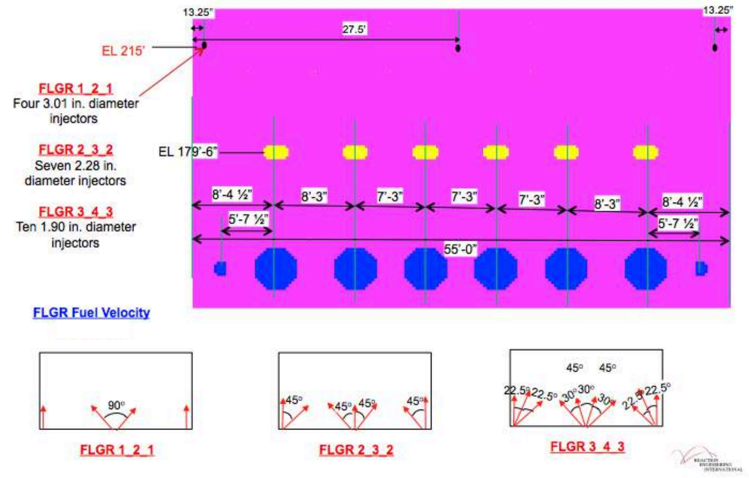
Many discussions between Orlando, Breen and Reaction Engineering resulted in the following:

1) When the desired level of coal was removed from the furnace and replaced by natural gas above the OFA, corresponding levels of air were not moved. This lead to increase air in the furnace, which lowered the CO, but increased the NOx. The natural gas at the upper level then reversed the total NOx increase.
    a. Takeaway 1 – Furnace Stoichiometry needs to be maintained to avoid increasing furnace exit NOx,
    b. Takeaway 2 – Allowing the observed actions to occur may provide a means for lowering overall plant CO without increasing NOx
2) The slotted injectors changed the overall geometry of the injected gas plume. The revised geometry increased the overall surface area of the plume and reduced the inner, fuel rich, region. This lead to a reduced process effectiveness
3) The injection location of the slotted injectors, being just above the OFA ports, resulted in the natural gas being injected into a very high temperature zone. Kinetic reactions at that temperature caused the required fuel-rich zone to disperse too rapidly, reducing the effectiveness of the process.

ORLANDO STANTON 1 FLGR 2.0

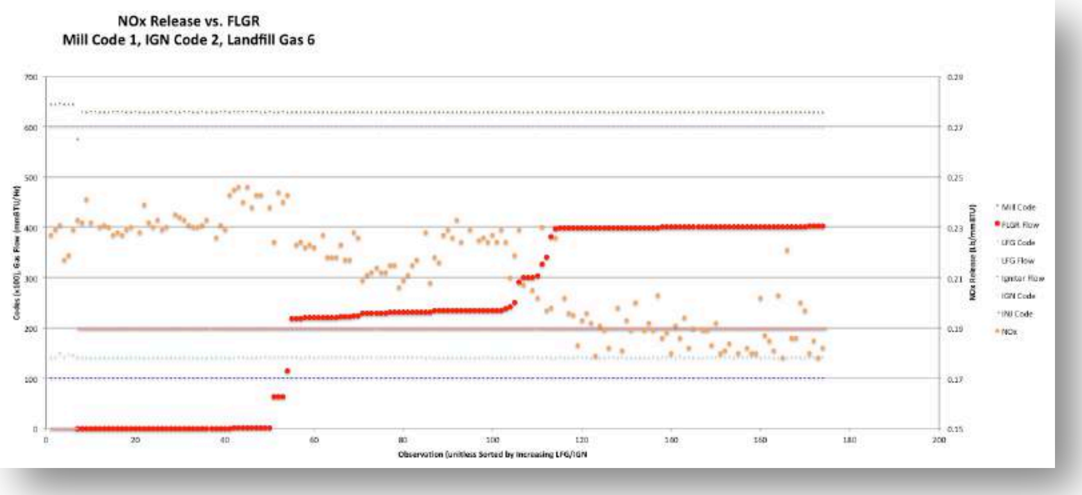
Based on the above findings and takeaways it was decided by all parties to move the injectors higher in the furnace and to replaced the slotted design with a more traditional, round, injector. Design modifications were made and new injectors were installed into three existing observation ports on the 11th floor. These ports (all on the front wall) were oriented with one near each sidewall and a third near the center.

A variety of injector placement, orientation and volume models were run. The picture below shows three early options with orientation 3/4/3 offering a starting point.

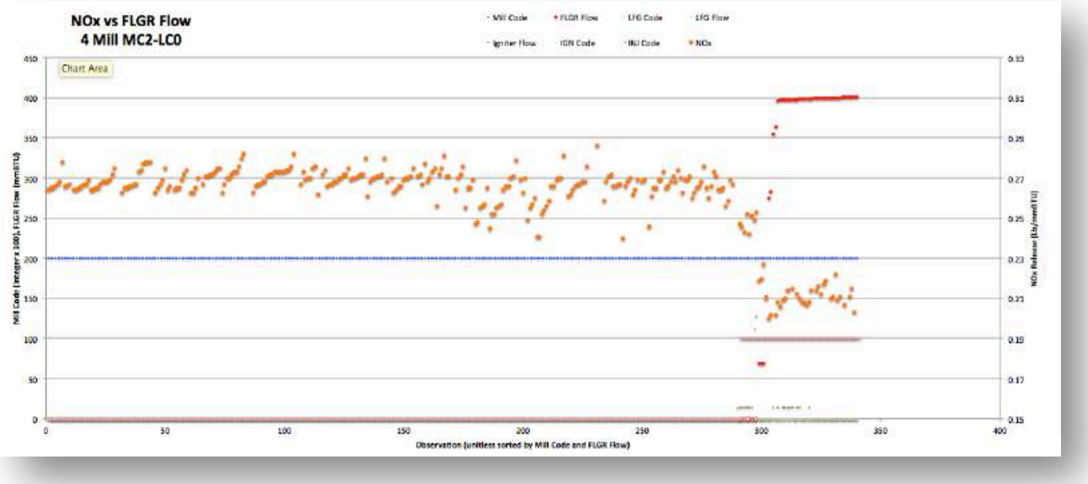


Additional consideration needed to be given to the injection velocity (one condition referenced in the above case). With access only available from the front wall, but with two burner levels available on the back wall, modeling suggest that NOx patterns may exist in the rear that would be difficult to reach from the front wall.

Based on various options, the system was re-commissioned in the fall of 2015 with some results shown below:

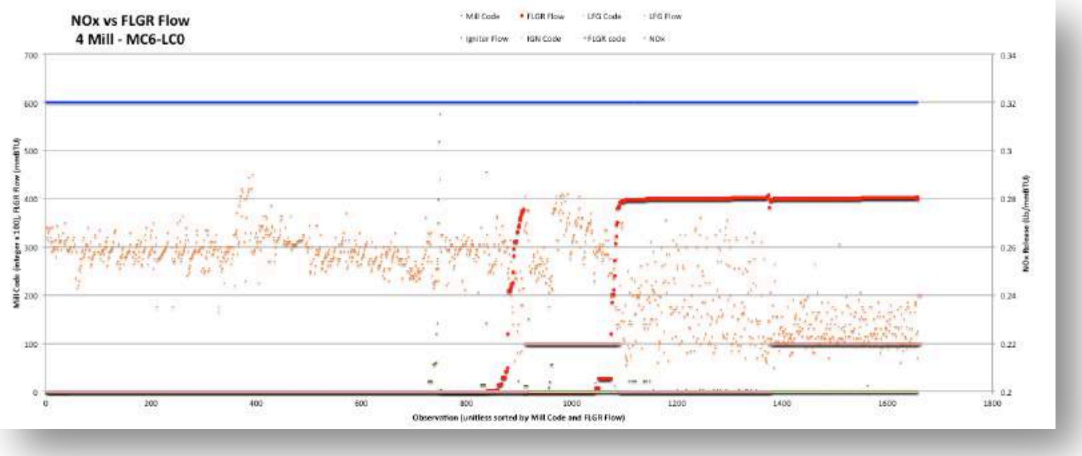


This graph shows comparative results with varying levels of FLGR gas flow. In this case the mill configuration, igniter gas flow and landfill gas flow were all held constant with only FLGR gas flow being adjusted. Observation shows that the baseline NOx of 0.23 Lb/mmBTU dropped a small amount with 200 mmBTU of FLGR flow but showed significantly better reductions (down to just under 0.19 Lb/mmBTU) with 400 mmBTU of FLGR gas flow.



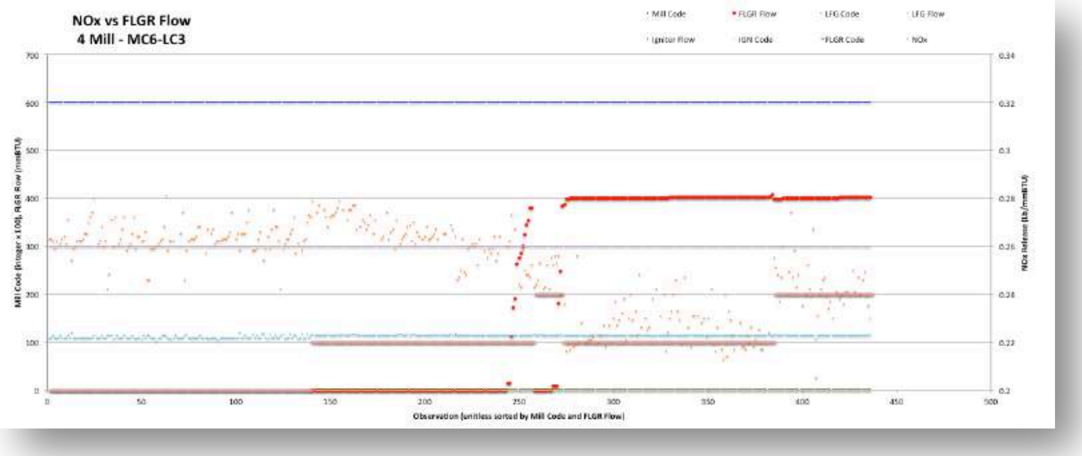
The graph above shows operation at full load with four mills and no igniter or landfill gas flow. The pink line below the FLGR NOx data depicts the utilization of Injector Design 1. As mentioned earlier, the injectors are positioned in three locations with (in the end) three injectors at each location. It became an important design objective to be able to control both the angular direction as well as the nozzle velocity of the natural gas.

For comparison, the graph below shows full load operation with a different, four mill, mill configuration. The red trace shows that FLGR flow was at 400 mmBTU/Hr. from observation 1100 until the balance of the test. The NOx data points under the FLGR curve show wide separation in value from observation 1100 until 1350. Then the NOx values drop and become much more cohesive. This data change reflects a nozzle change from the initial, open design to a flared, high-velocity, design.



The pictures below show a straight and an angular flare design. The angular design is the result of some significant engineering and design work to allow specific selection of injection angle and injection velocity based on the size and displacement of the outlet portion. The second picture shows the two injectors as they are mounted for simultaneous insertion into a 6” port.

The last graph below shows data from full load operation, four-mill configuration, and fixed igniter and landfill gas. The data differences show implementation of a second generation, super-high velocity injector that showed inferior results.



RESULTS AND OBSERVATIONS

The data compiled covers 42,000 data points spanning work from September 1, 2015 through December 15, 2015. The goal of the combined CoFire/FLGR project is to achieve a weighted average NOx emission rate over all loads of less than 0.190 Lb./mmBTU.

Operation of the unit on 100% Coal with no CoFiring makes this goal challenging as the baseline with 100% Illinois Basin Coal is in the 0.26 Lb./mmBTU range. Achievement of the desired goal requires a NOx reduction of 27%. With the current, three-port/front wall injection scheme the best results have been in the 22% range. Unit operation with natural gas and landfill gas volumes approaching 18% of total unit heat input has given results closer to the objective.

CO release has always been a limiting factor in the deployment of Fuel Lean Gas Reburn. All of the data compiled has been analyzed for compliance effects on CO rate. All of the results shown above reflect CO levels in compliance with the plant's operating permit.

COMMERCIAL AND ENVIRONMENTAL CO-BENEFITS

Beyond the data presented here, the following environmental impacts have been documented in earlier papers:

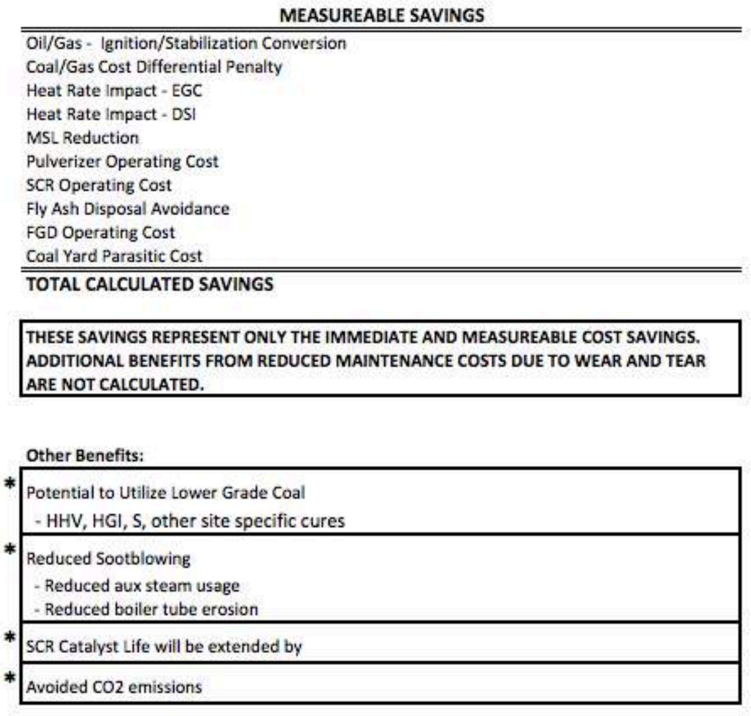
Impact of 1% heat input converted from Coal to Natural Gas:

SO2	1% reduction
NOx	1% reduction from Cofire/2% reduction from FLGR

SO3	1% reduction
Particulate	1% reduction
Mercury	1% reduction
CO2	0.6% reduction

Commercial Co-Benefits

The following commercial benefits of coal/gas cofiring have been documented and reported elsewhere:



MEASUREABLE SAVINGS
Oil/Gas - Ignition/Stabilization Conversion
Coal/Gas Cost Differential Penalty
Heat Rate Impact - EGC
Heat Rate Impact - DSI
MSL Reduction
Pulverizer Operating Cost
SCR Operating Cost
Fly Ash Disposal Avoidance
FGD Operating Cost
Coal Yard Parasitic Cost
TOTAL CALCULATED SAVINGS

THESE SAVINGS REPRESENT ONLY THE IMMEDIATE AND MEASUREABLE COST SAVINGS. ADDITIONAL BENEFITS FROM REDUCED MAINTENANCE COSTS DUE TO WEAR AND TEAR ARE NOT CALCULATED.

Other Benefits:

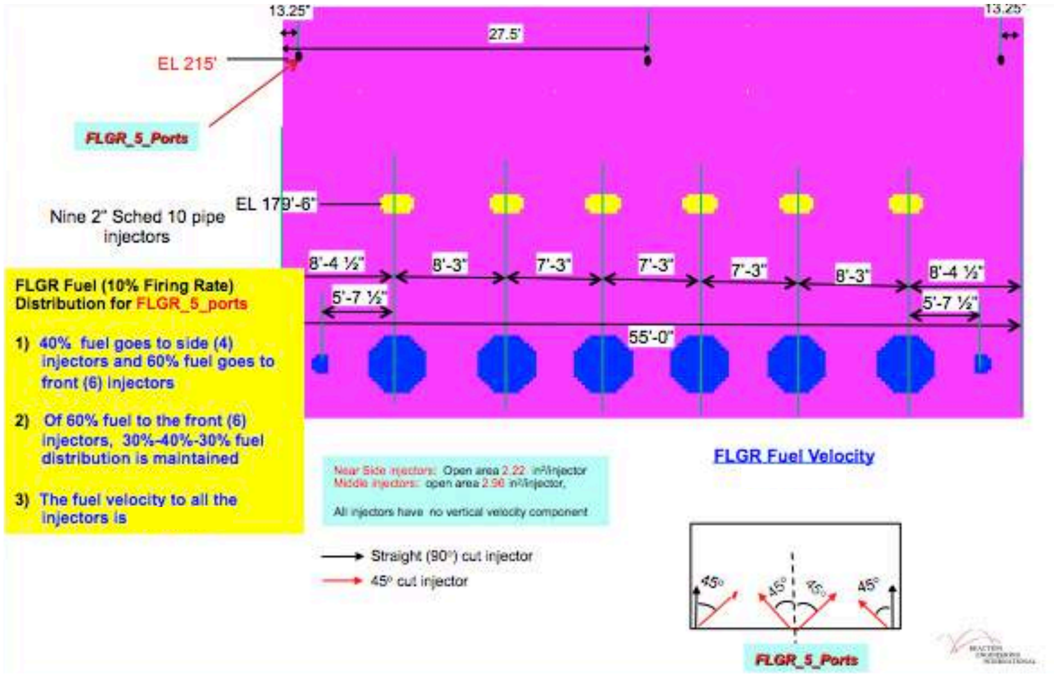
*	Potential to Utilize Lower Grade Coal - HHV, HGI, S, other site specific cures
*	Reduced Sootblowing - Reduced aux steam usage - Reduced boiler tube erosion
*	SCR Catalyst Life will be extended by
*	Avoided CO2 emissions

FUTURE WORK PLANNED

Two major efforts are still underway as of this writing:

1) Implementation of two side-wall ports for better gas coverage into the rear furnace areas, and
2) Development of a rigorous test/deployment program designed to provide OUC/Stanton with an automatic operating algorithm that will result in NOx emissions consistent with the overall goals of the program.

FIVE PORT IMPLEMENTATION



FLGR Fuel (10% Firing Rate) Distribution for FLGR_5_ports

1) 40% fuel goes to side (4) injectors and 60% fuel goes to front (6) injectors
2) Of 60% fuel to the front (6) injectors, 30%-40%-30% fuel distribution is maintained
3) The fuel velocity to all the injectors is

Near Side injectors: Open area 2.22 in²/injector
Middle injectors: open area 2.90 in²/injector,

All injectors have no vertical velocity component

Straight (90°) cut injector
45° cut injector

The picture above describes a near-final implementation of 5 injection ports. In reality, due to some physical constraints with placing the sidewall openings and routing of the gas headers, the ports were moved forward on the side wall to a location roughly halfway between the front and back wall.

Because four injectors were added (two on each side), the size and number of injectors on the front wall had to be adjusted to conform to the maximum available FLGR gas from the pressure reducing station.

TEST PLAN & CONTROL

The following statistical analysis was performed against the operating data from 9/1/2015 through 12/15/2015:

Load-Mill Code		Observations	FLGR ON	Load-Mill Code		Observations	FLGR ON	Load-Mill Code		Observations	FLGR ON
10	24%	3101	437	20		51	42	30		0	0
11	46%	5933	595	21		0	0	31		0	0
12	25%	3145	141	22		364	24	32		0	0
13		181	15	23	29%	1418	318	33	23%	4094	52
14		309	19	24	38%	1832	107	34	36%	6503	536
15		12	0	25		95	0	35		480	0
16		112	0	26	17%	828	20	36	20%	3561	25
17		23	8	27		186	34	37	13%	2422	1092
18		0	0	28		0	0	38		67	57
19		11	0	29		68	0	39		862	344
		12827	1215			4842	545			17989	2106

For simplicity of the paper the Igniter operating codes and the Landfill gas operating codes have been omitted.

In fact, less that 10% of the total low load and mid load conditions have been tested with FLGR and of those, none have been tested with the redesigned injector velocity. Of the tests run at full load, less more than half were run on an operating condition that is rarely used in practice.

These points are brought out in this document to strongly emphasize to the reader the importance of developing a rigorous test plan that exercises the operating conditions most important to the plant staff.

CONCLUSIONS

This is the first Fuel Lean Gas Reburn system to be implemented on a unit following installation of low-NOx burners and overfire-air ports. These modifications have significantly changed the base operating practices of power plants and require a re-evaluation of how the technology is approached.

Using a baseline NOx number of 0.26 Lb./mmBTU, and considering different operating regimes between three and four mill operations, NOx reduction between 15% and 22% have been experienced. These results are in-line with the CFD predicted results after adjustments to early assumptions.

Placement of additional sidewall injectors and adjustment of the injection angle and velocity of the front-wall injectors suggests that reductions in NOx in excess of 25% are practical.

As a side benefit, the early disappearance of CO with adjusted furnace stoichiometry suggests that this technology may also be of value in reducing undesirable CO effects (SNCR applications for example).

ACKNOWLEDGEMENTS

We would like to publicly acknowledge the following, whose support and encouragement made the progress to date possible:

1) The Management, Technical and Operations staff at Stanton Energy Center, whose understanding and support through all phases of prototype and modified testing was crucial,
2) The technical staff at Reaction Engineering who have been very cooperative in running multiple iterations of models as we gained a broader insight into the total process,
3) The engineering staff at Stantec Engineering who went above and beyond in providing the plant design and modifications (several times)