



**LOW NO_x BURNER MODIFICATION
SUBSTANTIAL NO_x REDUCTION MAY BE ACHIEVED
EVEN FROM AN EXISTING LOW NO_x BURNER**

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ABSTRACT

PEPCO's (now Mirant), Chalk Point Units 1 and 2 are 355 MWe opposed fired B&W supercritical double reheat boilers. An eastern bituminous coal is burned in the units. Each boiler has twenty-four (24) coal burners located on the front and rear walls. The units had been retrofitted with Riley CCV low NO_x burners and overfire air in 1994 and 1995. While some NO_x reduction was achieved, the use of overfire air aggravated previously existing lower furnace slagging problems. The units were due to be modified with a Gas Reburn System in an effort to improve NO_x emissions. The burners were upgraded with RJM's patented Low NO_x coal burner components. This upgrade reduced burner NO_x by 30% from the low NO_x burner baseline and reduced slagging problems in the lower furnace.

Time is of the utmost importance to any utility and this project was executed on a very tight schedule. The first unit to be retrofit was a week away from beginning its outage and the components had to be delivered in five (5) weeks in order to maintain the current outage schedule. The installation of the equipment was completed in just two (2) weeks. The second boiler was completed on a very similar schedule.

INTRODUCTION

PEPCO's Chalk Point Generating Station Units 1 and 2 are 355 MW coal fired units. Steam is produced by Babcock and Wilcox opposed fired boilers burning eastern bituminous coal. The boilers each have twenty-four (24) Riley Stoker CCV low NO_x burners, installed in 1994 with Overfire Air (OFA) ports. Burners are arranged on the front and rear walls in three (3) rows of four (4). These units had a full load NO_x emission rate in excess of 0.9 lb/mmBtu while utilizing OFA.

The boiler is very shallow at 32 feet deep, which does not leave room for the flames to expand fully before they exit out of the furnace. The flames in the bottom two rows of burners turn down into the hopper and strike the hopper slope. The closeness of the slope and the high heat release of the furnace contribute to slag buildup on the hopper slope. The slag builds up and bridges the ash pit opening. Ultimately, this has the possibility of forcing the unit offline to clear the slag. Use of the OFA that was supplied with the Riley burners as part of its low NO_x retrofit was believed to exacerbate the slag buildup. Under reducing conditions the ash melting temperature is lowered and the slag becomes fluid. There is also less air velocity in the lower furnace and the ash is more likely to drop out. Burner eyebrows have always been problematic and drop off and fall onto the hopper slope; all these contribute to higher slag deposition rate on the hopper slope and results in a significant problem for Chalk Point.

A Gas Reburn system was designed to provide additional NO_x reductions, however the slagging problem had not been addressed in the Gas Reburn design. With the unit operating in the Non-Gas Reburn mode, the Overfire Air system had the capability to reduce the burner fuel air ratios much lower than their current values. Lower burner fuel air ratios had the potential to increase furnace slagging problems. Chalk Point turned to RJM with its patented burner modifications for reducing NO_x and slag. RJM presented a way to reduce burner NO_x 30%, (to levels of 0.6 to 0.7 lb/mmBtu), without the use of OFA, reduce eyebrow formation, keep CO and LOI low and reduce slagging in the lower furnace. An added bonus would be the additional NO_x reduction that could be obtained during summer by allowing the burners to be run at a lower stoichiometry.

The program was placed on high priority as Unit 2 was about to begin an extensive outage to install the reburn system. RJM promised the components in five (5) weeks from a P.O., which left two (2) weeks in the outage to install the burner modification. Since there was not sufficient time for baseline testing of Unit 2, the baseline testing was done on Unit 1.

UNIT DESCRIPTION

The boiler is a mid 60's vintage Babcock and Wilcox supercritical boiler. The units are double reheat units. The main steam flow is 2500 kpph. The units burn eastern bituminous coal. The original burners were B&W S type. The SH and RH temperature are 1050°, 1005° and 1005° respectively. Six (6) pulverizers feed 24 burners in an opposed arrangement. Each row of burners has four (4) burners with three (3) rows on the front and three (3) on the rear. The furnace is a very short 32 ft deep and 48 feet wide. In 1994 Riley installed 24 new CCV burners and overfire air ports to reduce NO_x. The unit has a wrap around windbox with splitter dampers for to optimize windbox airflow. Individual burners also have an automatic shroud to allow adjustment and balancing of the airflow to each burner. The burner is a single register type with a fuel divider in the coal pipe for NO_x reduction.

PRERETROFIT OPERATION

The original annual average baseline NO_x for this unit is 1.35 lb/mmBtu before the Riley conversion. After the Riley burner installation annual emission rates of 0.72 lb/mmBtu were achieved while balancing the slagging and the low NO_x requirements of the unit.

CONTRACT SCHEDULE

Gas Reburn decisions were made well in advance of February 2000. In fact, much of the equipment had arrived on site when RJM started talking to Chalk Point about reducing their slagging and minimizing the use of OFA in pursuit of NO_x reductions. When the contract was set, RJM's engineers had five (5) weeks to engineer, design, fabricate and deliver on site to Unit 2. Unit 1 was ordered after positive results from Unit 2 were seen with some very minor field rework during the outage. So, after achieving these results with some very minor field rework during the outage, RJM was able to deliver on an extraordinary schedule. The order for Unit 1 was subsequently placed with a schedule of six (6) weeks delivery. Unit 1 was a duplicate system and design.

Ease of Installation

The modification of the burners consisted of installing the four (4) components into the existing register. The new coal pipe, the coal distribution disk, the coal spreader and the flame stabilizer.

BURNER DESIGN

The limited time available compressed the schedule for burner upgrade design and fabrication. As soon as the order was placed the design process was started. The baseline and upgraded Computational Fluid Dynamics (CFD) model was the most important aspect of the design process. A CFD Combustion single burner model was performed. RJM utilizes the software Fluent to perform CFD modeling. Fluent solves equations for velocity, pressure, momentum, turbulence and reaction species within a computational grid structure. An iterative solution is performed until inputs and outputs from each grid cell do not change from one iteration to the next. Fluent is recognized as the CFD standard for the combustion industry. The International Flame Research Foundation (IFRF), the research arm of the combustion industry, uses it to validate their results. RJM first creates a baseline model to validate the performance of the model; if the results of the baseline model correspond to the baseline field results an acceptable model can be created of the low NO_x modification. A comparison of the results of the baseline and upgraded burner temperature and NO_x profiles are shown in Figures 1 & 2.

Repetitive iteration of the model showed that a two (2) zone burner would provide the most NO_x reduction with the least change in other performance factors i.e. CO, LOI, exit temperature and reliability. The two (2) zone arrangement would consist of the existing single zone register and a flame stabilizer added to the end of the coal pipe.

Flame Stabilizer

A flame stabilizer provides a defined Internal Re-circulation Zone (IRZ) in the near combustion zones to stabilize the fire. It is important that this IRZ is small and well defined. An excessively large IRZ creates too much turbulence and high NO_x as a result. The flame stabilizer creates a secondary air zone when acting in combination with the existing register. This is accomplished by the use of radially and circumferentially staged coal flame stabilizers mounted on the outside of the coal pipes. The remaining secondary air is injected in a low or non-swirl mode outside the primary combustion zone. This will allow the burner registers to be set in the nearly full open position and remove any inconsistencies between burners caused by the registers. The quantity of air is effectively controlled in the primary combustion zone where the majority of the NO_x emissions are formed. The coal flame stabilizer is a patented commercial product of RJM Corporation installed on over 4,000 MW of coal-fired utility boilers. The Riley air diverter was removed and the RJM flame stabilizer was added.

Coal Pipe

In addition to the flame stabilizer forming the two (2) zone burner, the coal pipe was redesigned. The venturi in the coal pipe was removed and the coal pipe was extended. The venturi tends to force the coal into the center of the coal jet, which lengthens the flame and increases the LOI. The coal pipe must be set correctly within the throat to properly feed coal into the IRZ formed by the flame stabilizer.

Coal Spreader

RJM's coal spreader segments the coal into streams. Coal streams are targeted into the air lean zones created by the flame stabilizer. Initial stages of devolatilization occur under a reducing environment. Fuel bound nitrogen reduces to elemental Nitrogen instead of oxidizing to NO_x.

Coal Distribution Disk (CDD)

The CDD is located downstream of the coal inlet elbow, prior to the coal spreader. Typically a coal rope is developed from the elbow. In order to achieve low NO_x with minimal impact on fly ash, LOI coal ropes must be eliminated. The CDD breaks up the coal rope and produces a homogeneous coal stream. The Riley coal distribution system was removed and the RJM CDD was added. The final burner arrangement is shown in Figure 3.

RESULTS

Air Corrections

In addition to the specific modifications to the burner to correct combustion, certain air and fuel corrections must be resolved in order to achieve the maximum NO_x reduction with minimum LOI and CO formation. This also has the advantage of reducing flame length in the short furnace and minimizing the pockets of substoichiometric gas that increases the chances of

fluidizing the ash more than necessary. The fuel and air must be balanced not only to each burner but also within the burner. The fuel and air must exit the end of the burner in a fashion that provides a consistent circumferential flow of air and fuel to the combustion process. The air must be balanced to each burner and also all around the inlet to the burner. If the air is not balanced around the inlet to the burner, the fuel and air will not mix in the locations designed into the burner; LOI, CO or longer than necessary flame will result. RJM uses its proprietary Air distribution Analysis (ADA) to measure the airflow between burners and around the inlet to the burners. The probe measures 24 points around the circumference of the burner outlet. Each of the individual points indicates the distribution of air at the critical exit of the burner. Figure 4 shows the results of the mass airflow measurement to each burner on both units. The baseline air balance showed that three (3) burners on Unit 1 were outside the $\pm 5\%$ and five (5) burners on Unit 2 were outside $\pm 5\%$. The rear burners have an average of 3% more air than the front burners. Most importantly the front bottom mill or “D” mill had an average of -4.25% less air than the rest of the burners. This was a contributory factor in the slagging of the lower hopper. Correction of the airflow to this lower mill on Unit 2 seemed to minimize the slagging in the hopper. The airflow on Unit 1 was not adjusted.

Register Adjustment

The register on the existing Riley burner was adjusted primarily to minimize the flame impact on the bottom of the furnace. The lower center flames and the next row up were shortened. The second row was shortened to allow the lower flame room to expand.

Spreader Adjustment

The coal spreader is used to optimize LOI and NO_x . Retracting the spreader raises the NO_x and lowers LOI. The results of the spreader position are shown in Figure 5. The spreader was moved from -2 to $+2$ inches and the NO_x decreased 14% while the LOI increased almost 50%. The spreader is currently in the flush position.

NO_x

Final NO_x at full load on both units ranged from 0.55 lb/mmBtu to 0.65 lb/mmBtu with only cooling airflow through the new OFA system. Slagging was reduced substantially without having any forced outages for the 2000 Ozone season. Comparing the 1999 Ozone season to the 2000 season, the NO_x was reduced from 0.815 lb/mmBtu to 0.54 lb/mmBtu. Of course some of this reduction was associated with tuning and the cooling airflow in the new OFA system. The NO_x reduction attributed to the burner modification is 30%. Figure 6 shows NO_x vs. Load before and after comparing January of 2000 to January of 2001. Using January shows the NO_x reduction without the extra tuning efforts that occur during the Ozone season. As one can see, the NO_x reduction at full load is only a part of the story.

Eyebrows

The Chalk Point units were plagued by burner eyebrow formation that would often drop off and add to the slagging and bridging problem in the ash hopper. Formation of eyebrows is the

results of improper flow of air around the burner combined with slagging fuels and large refractory zones facing the furnace. If the airflow departs from the burner in a narrow stream the external recirculation zone becomes excessive. Its strength results in high temperature ash thrown against the flat face of the throat refractory. The problem is exaggerated by high slagging ash, unbalanced burners resulting in local reducing zones and substoichiometric combustion. RJM's attention to balance, correcting burner flow problems, correction of the proper internal recirculation zone and stressing setting all the burners to the same register position often results in reduction in eyebrow formation.

Hopper Slagging

The unit experienced no forced outages associated with slagging in the lower furnace as a result of the burner modification. There were some events of slagging in the lower furnace associated with testing and tuning of the gas reburn system. There was some slagging associated with changes in coal that resulted in longer flame lengths which eventually led to load reductions to shed slag. However for the most part, if the combustion system was operating in a normal manner with the correct fuel, than no unit de-ratings occurred because of slag.

LOI

LOI increasing during a low NO_x burner retrofit or modification is a well-known phenomenon. RJM predicted that the LOI increase should be limited to 50%. This was an aggressive number considering the effort that the plant had placed on reducing LOI. Tracking LOI at the plant was a regular event that resulted in reductions from 8% in January 1997, to less than 4% at the beginning of the outage; see Figure 7. These remarkable reductions in LOI from carefully operating the units and attention to details were disrupted by the burner and reburn optimization and tuning. After tuning of the burners was complete the LOIs on both units were slightly less than 5%, well within the prediction. LOI increased from an average of 3.5 to 5% well within our prediction and guarantee.

Unit Specific Differences

Unit 2 was completed and placed in service first. The NO_x reduction predicted and the slagging reductions were achieved with very little tuning effort. The very short depth of the furnace limited the tuning to balancing the airflow and adjusting the registers to minimize flame impingement on the furnace hopper slope. Burner tuning ended at that point and reburn tuning began. In the meantime installation of Unit 1 was completed and the burner tuning lessons learned were quickly applied to Unit 1. After reburn tuning was complete, optimization of the burners began to gain more NO_x reduction and reduce LOI to contract requirements. The effect of spreader position was tested with its well known trade off between NO_x and LOI; see Figure 5. Economizer mapping to find and reduce LOI and oxygen deficiencies located a windbox damper that was causing low O₂ on one (1) side of the unit. Correction of these problems and setting of the spreader to reduce LOI to contract requirements resulted in meeting performance guarantees. After completion of Unit 2, LOI was measured on Unit 1 and it was found to

require no optimization, meeting performance guarantees. The unit consistently ran better than Unit 2 in all categories and it was jointly decided that it should be left alone and allowed to run.

Effect of OFA

As part of the reburn system, the existing OFA ports were removed and ports were added to support the gas reburn system. The benefit of the new OFA system was tested with the newly modified burners. The intent was to lower the NO_x during the Ozone season without the need of burning high cost natural gas. The new ports have extensive flow measurement instrumentation and the amount of OFA when the ports are closed is estimated at 8 - 10%; fully open they are capable of 25% flow. Approximately 8% of the combustion air is needed to keep the ports cool. The Riley ports were designed for 15% OFA. Figure 8 shows the effect of varying the OFA rate on NO_x and LOI. Overall, a 15% NO_x reduction was achieved with 15% air passing through the OFA ports. The LOI increased to an average of 10%. The OFA was limited to 15% to maintain the lower furnace stoichiometry and reduce slag.

Benefits

The project was successful. The cost of the modification was repaid in one short Ozone season. The outage extended into June effectively shortening the payback time. The benefit/cost analysis assumed a NO_x allowance price of \$500.00/ton. Increases in the price of allowances will further improve the return on this investment. There is also an added benefit of the reduction of unit de-ratings caused by slag.

Either Author may be contacted for questions by Email at the following addresses. Dave Leissner at david.leissner@mirant.com or Ed Schindler at eschindler@rjmcop.com.

Figure 1

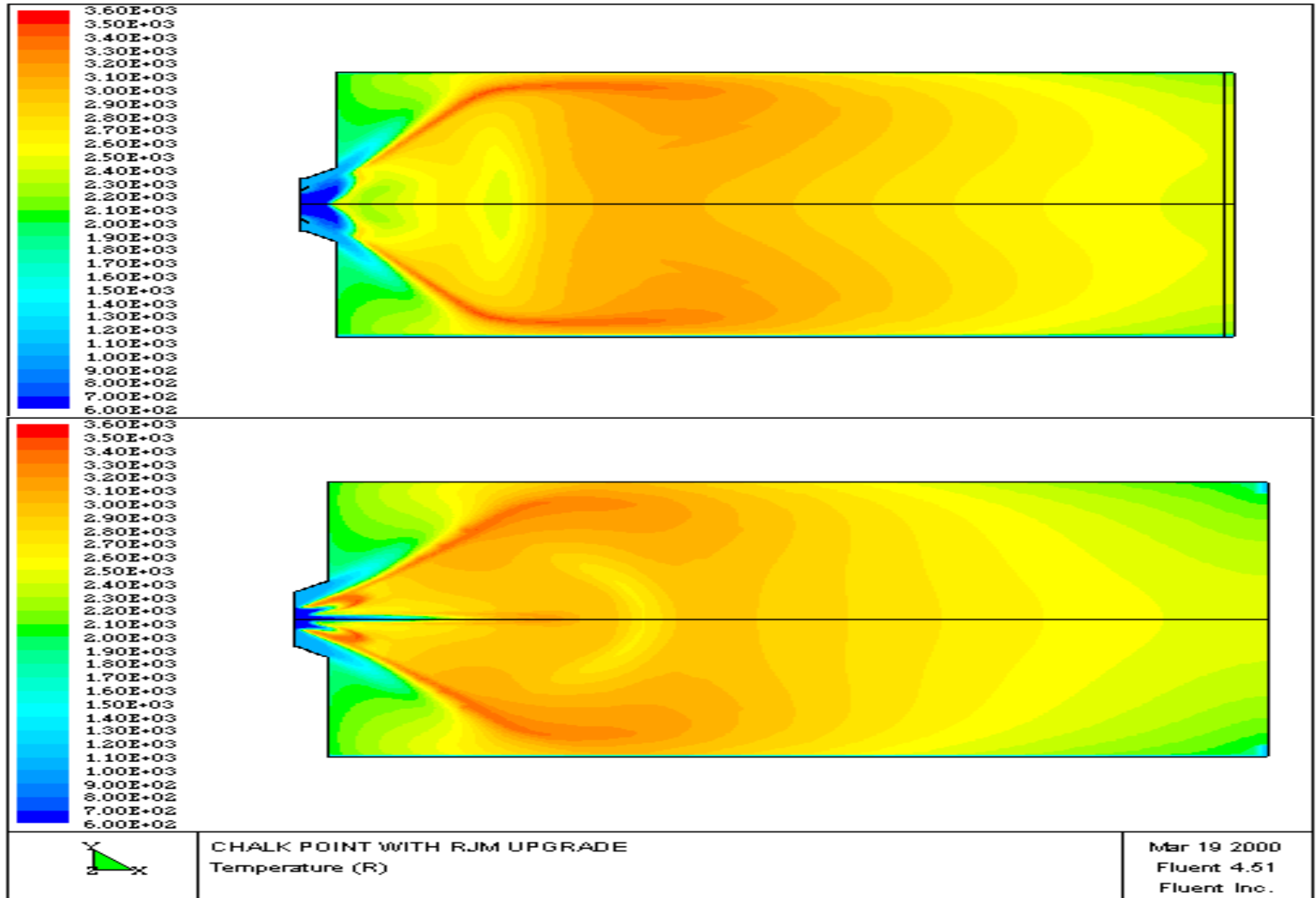
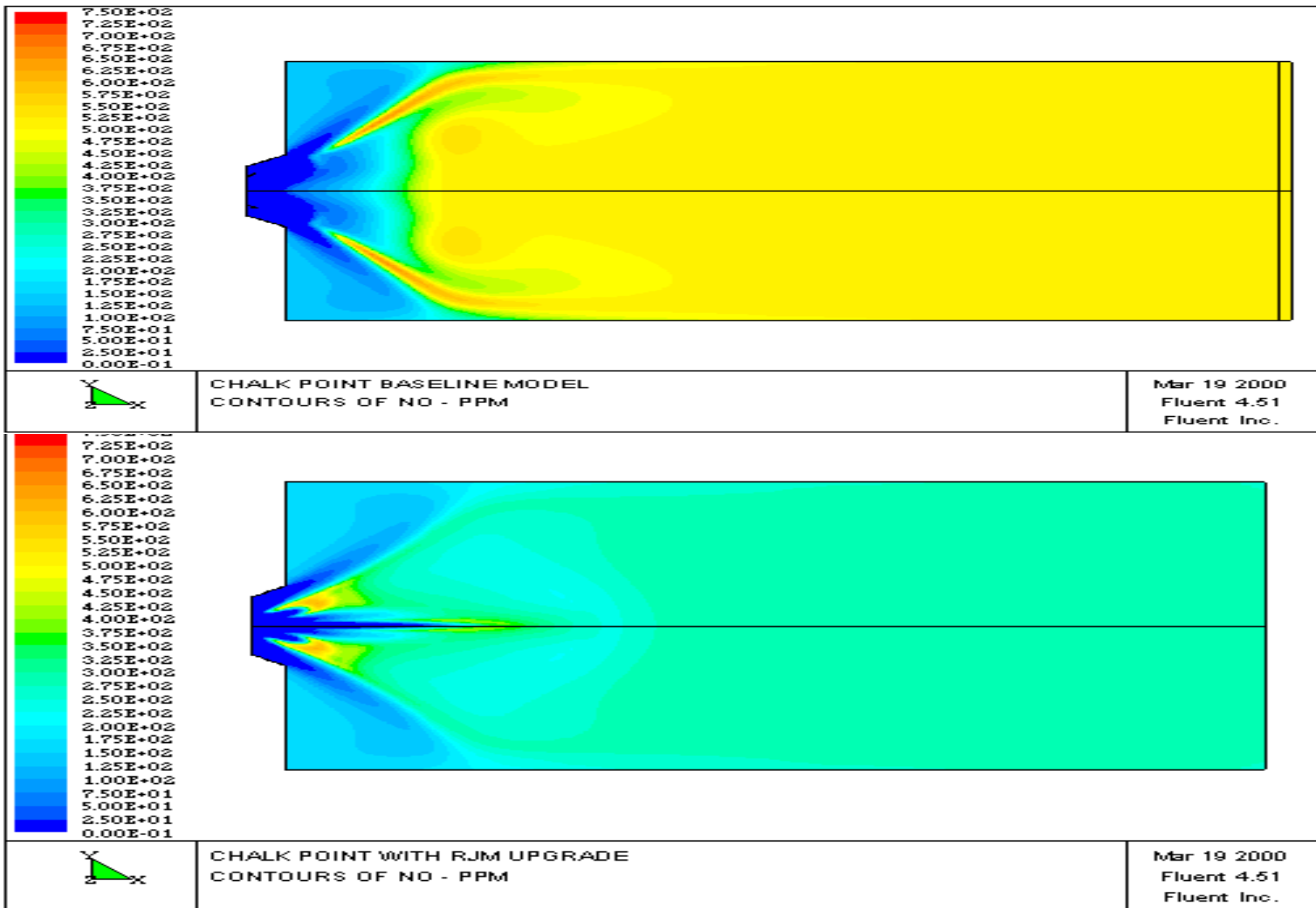


Figure 2



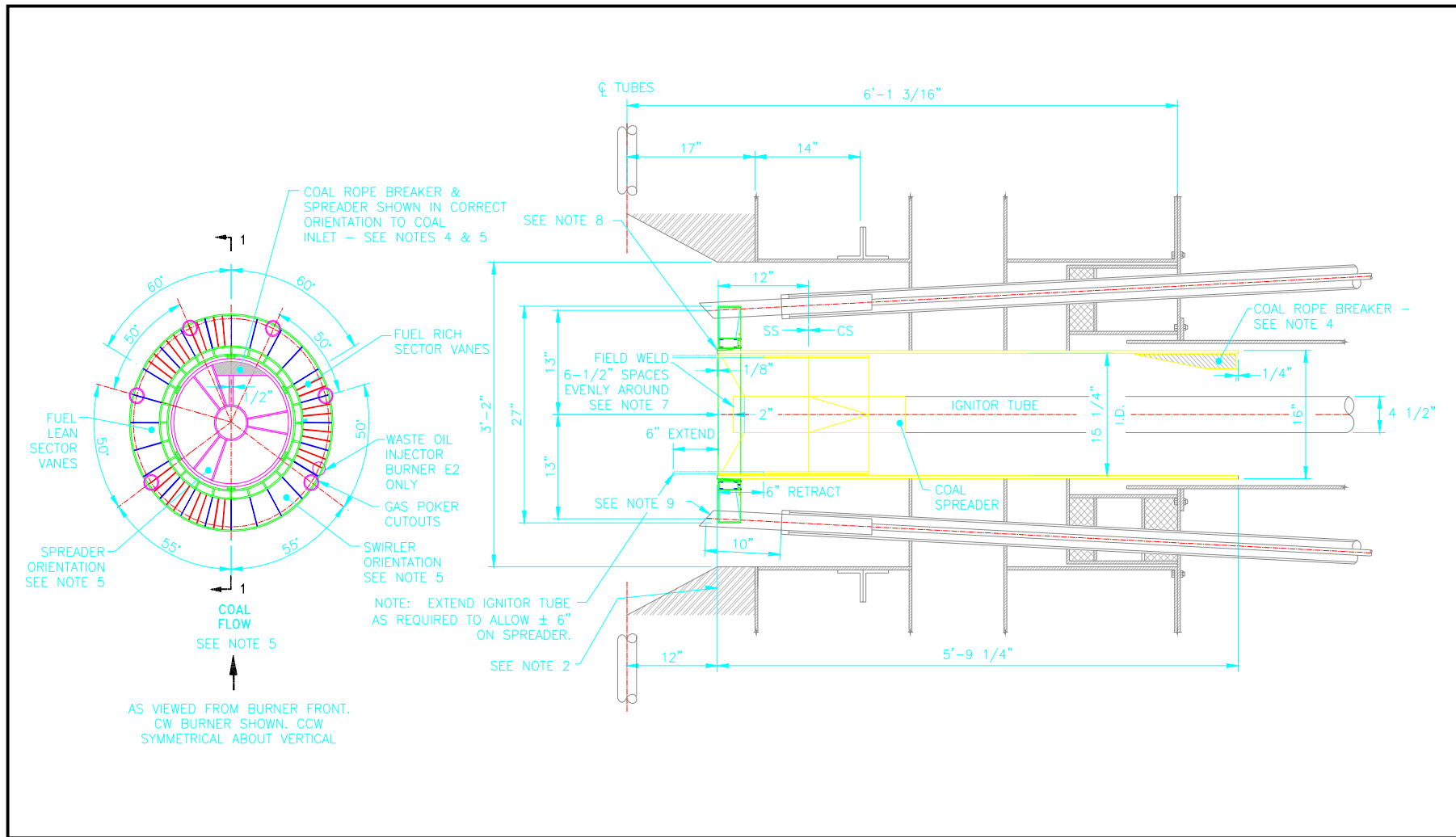


Figure 3
Burner Arrangement

Figure 4

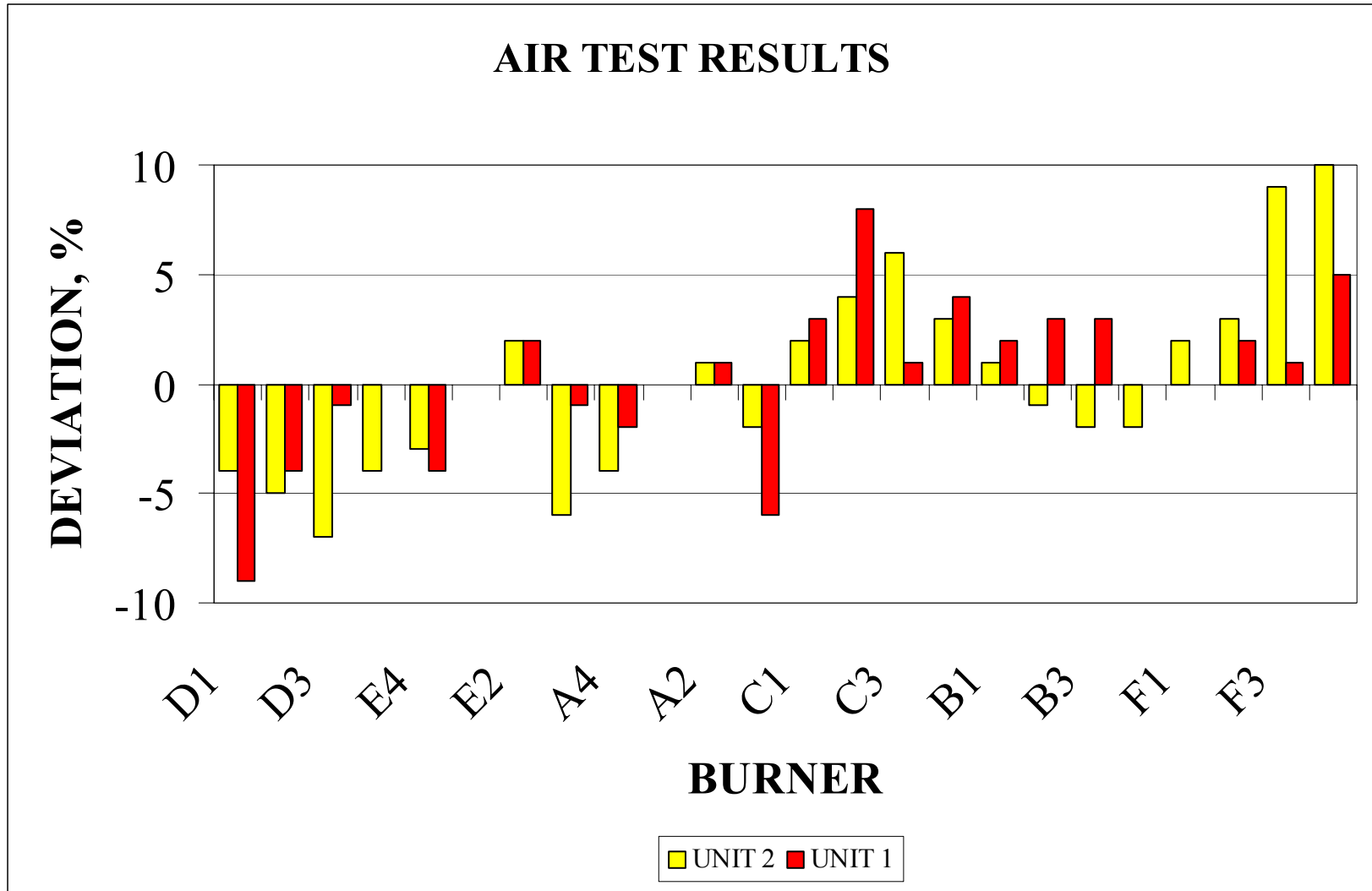


Figure 5

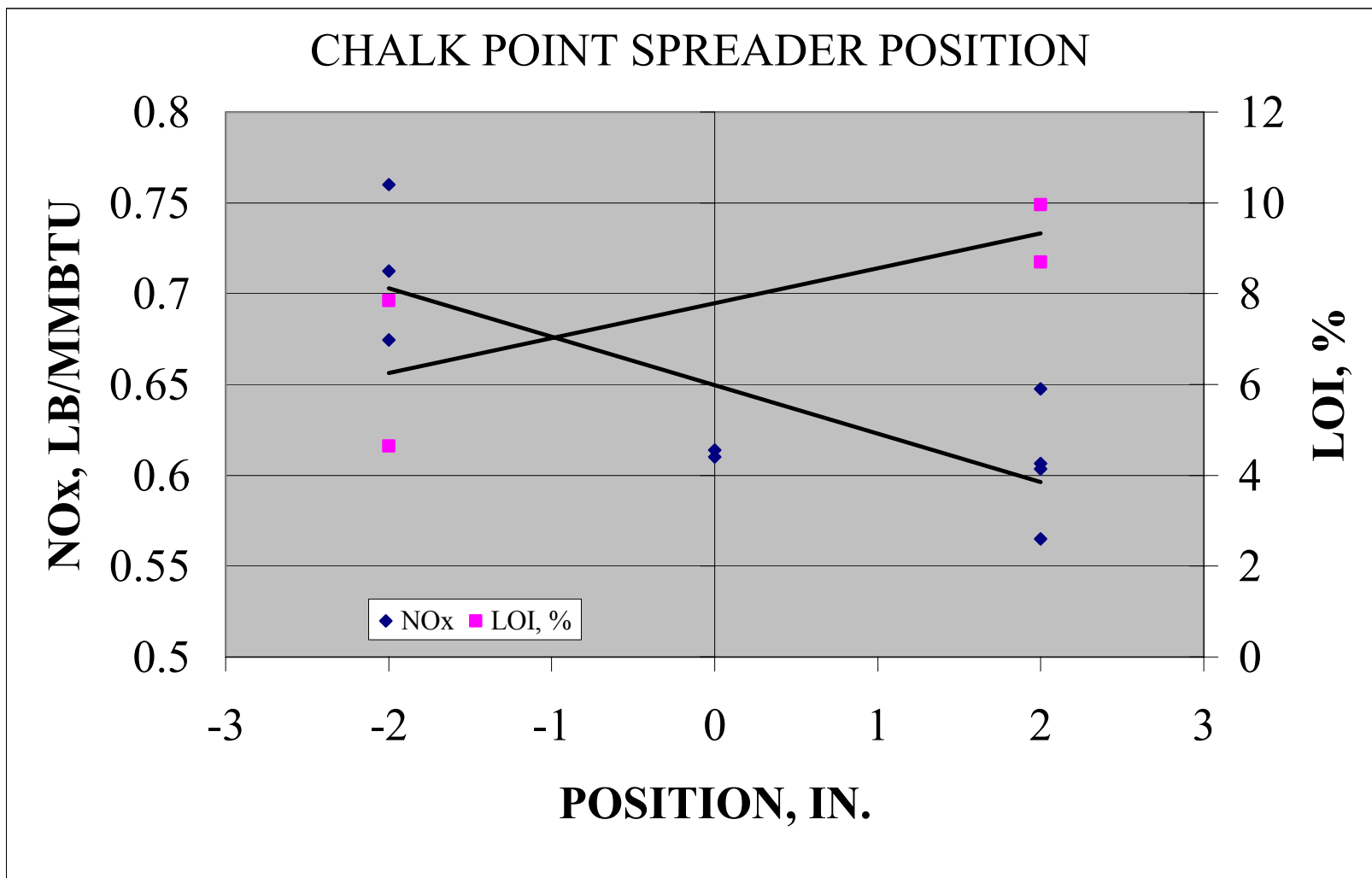


Figure 6

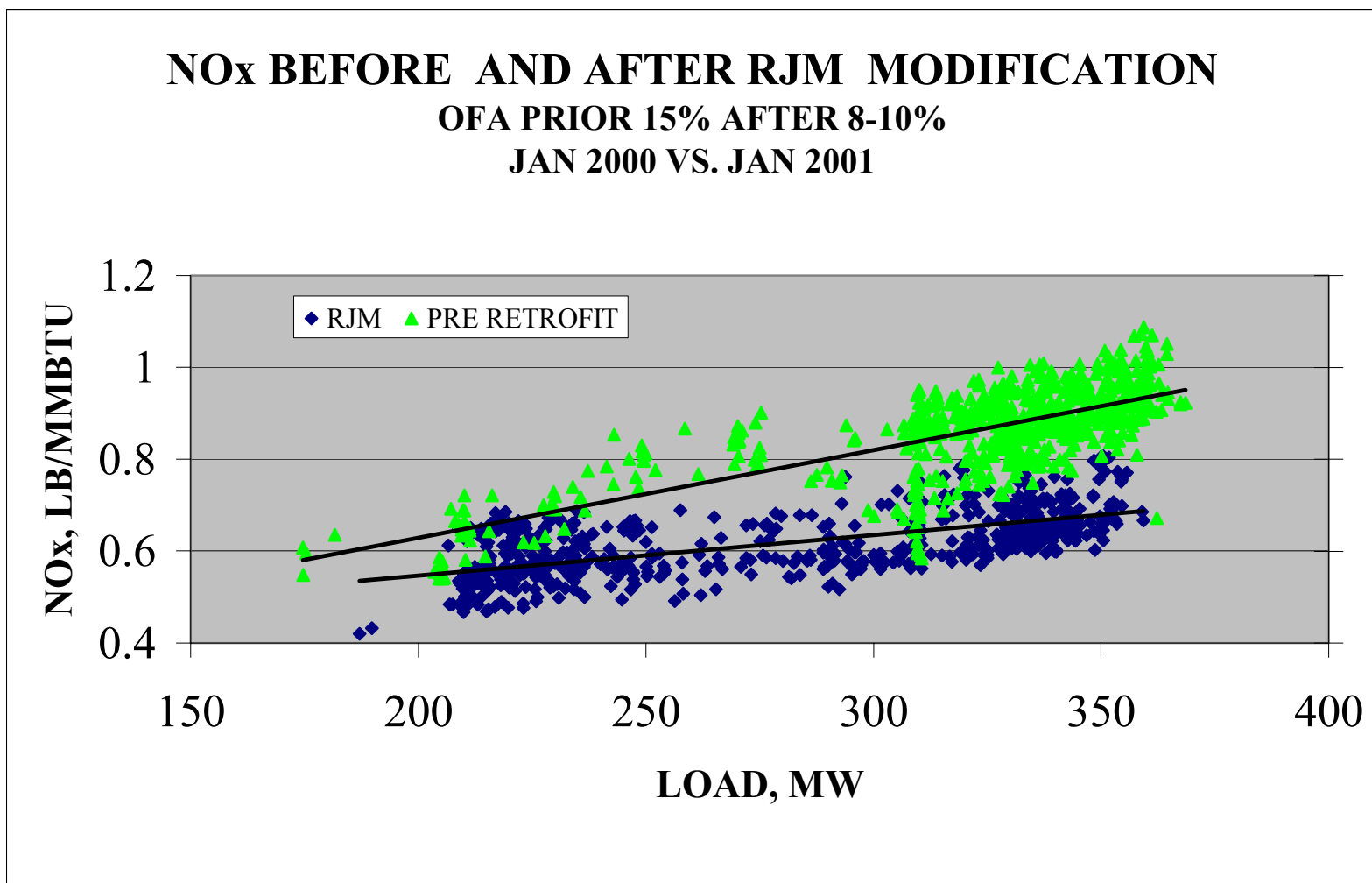


Figure 7

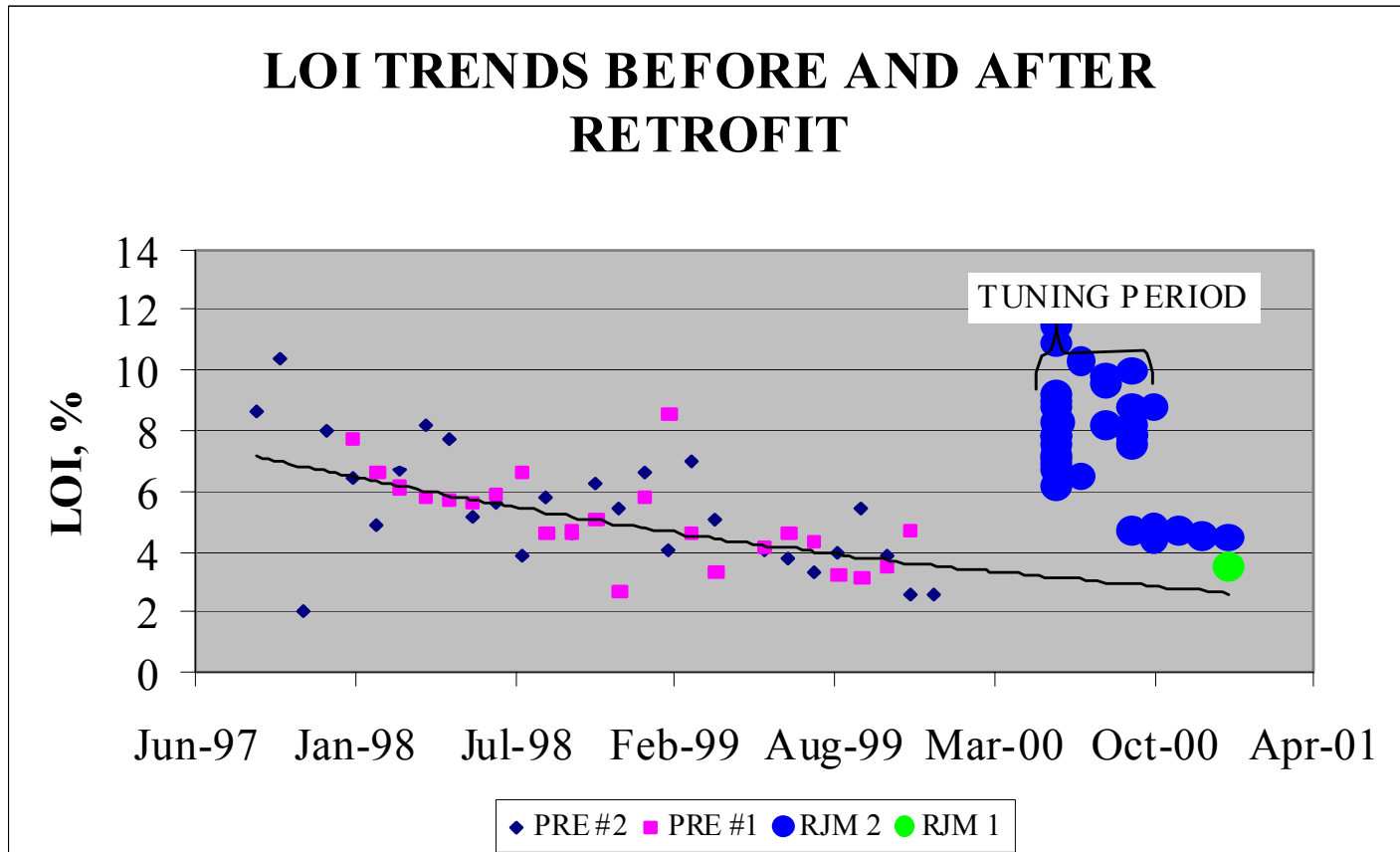


Figure 8

