BOILER OPTIMIZATION FOR MULTI-POLLUTANT CONTROL: MERCURY AND NO_x EMISSIONS[1]

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ABSTRACT

Mercury emissions control is an important issue for the coal-fired power industry nowadays. Mercury emissions are impacted by factors such as coal type, type of environmental control equipment installed on the unit, and boiler operation and fly ash characteristics. There is then the potential of modifying the boiler operating conditions, through operational changes to the boiler control settings, to affect and control mercury emissions. It is interesting to note that some of the operational changes that result in reductions in mercury emissions also result in reductions in NO_x emissions. A combustion optimization project for NO_x emissions reduction was conducted at a 160 MW wall-fired unit equipped with rotating air preheaters and cold-side electrostatic precipitator, and firing sub-bituminous coals. Testing demonstrated that NO_x emissions were reduced at full load by 20 percent from baseline levels. Simultaneously, optimization of combustion/back-end conditions and sootblowing resulted in reductions in mercury of 32 percent at the stack.

INTRODUCTION

In December 15, 2003 the U.S. Environmental Protection Agency (EPA) proposed the Clean Air Mercury Rules (CAMR). These rules were signed on March 15, 2005, and published in the Federal Register on May 18, 2005. The CAMR establishes a "Cap-and-Trade" Program for all existing and future coal-fired electric generating units. The cap-and-trade regulation would set a Phase I cap of 38 tons of mercury (Hg) and yield a reduction of 23 percent by 2010, based on sulfur dioxide (SO_2) and nitrogen oxide (NO_x) co-benefit controls. Phase II would impose a 15 tons of Hg cap, yielding a reduction of 69 percent by 2018.

As a consequence of these Hg regulations many utilities are interested and actively seeking cost-effective technologies that can effectively be used for multi-pollutant control, of the type referred in Phase I of the CAMR. Technologies that offer high levels of Hg control for different utility boilers, burning various types of coal, are estimated to have high costs of compliance. Activated carbon (AC) is the most promising control technology commercially available for reducing Hg emissions from coal-fired power plants. This technology is still evolving in terms of cost and its Hg control effectiveness for the wide spectrum of U.S. coals. Estimates of costs associated with the use of treated AC are in the range of $7,000 to $9,000 per pound of Hg

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removed on units burning sub-bituminous coals and having only cold-side electrostatic precipitators (ESPs). In addition, issues that need to be addressed in adopting this technology include long term availability of the carbon sorbents, retrofit potential, balance-of-plant impacts, and captured fly ash contamination and salability.

The Lehigh University Energy Research Center (ERC) has performed studies to investigate the impact of boiler operating conditions on Hg emissions from coal-fired power plants. In these studies, data obtained from full-scale field testing, while firing bituminous coals confirmed the role operating conditions play on Hg speciation and control, and the potential of using boiler control settings to enhance the "natural" capture of Hg in the boiler. Power plant data have shown that the percentage of Hg emitted from different plants varies widely, from approximately 10 to 90 percent of the Hg in the coal. At combustion temperatures, Hg is present as elemental vapor (Hg^0). However, due to processes, which occur naturally in the boiler, by the time the flue gas reaches the back-end of the boiler, the Hg is present not only as Hg^0, but also as various oxidized forms (Hg^{2+}) and as particulate-bound Hg. The extent of mercury speciation and control in coal-fired boilers is influenced by the boiler operating conditions. For example, excess air levels and cleanliness levels of the heat transfer surfaces in the convective pass of the boiler have a direct impact on the fly ash characteristics, the flue gas residence time and the temperature profile, and these parameters have been found to play an important role in Hg oxidation and adsorption into the fly ash.

This paper reports results of full-scale testing at DTE Energy's St. Clair Station Unit 4 to demonstrate the co-benefit of boiler optimization for low-NO_x and low-Hg operation. Combustion optimization was performed using Boiler OP, an intelligent software developed by the ERC. St. Clair Unit 4 is a 160 MW front wall-fired unit equipped with two rotating air preheaters and a cold-side electrostatic precipitator. Testing was performed with a blend of Western sub-bituminous coals, with an average mercury content of 0.042 ppm_w. The OhioLumex-915 MiniCEM analyzer was used to monitor the flue gas for total gaseous Hg at the stack. Optimization of combustion/back-end conditions and sootblowing resulted in reductions in NO_x of 20 percent and in mercury of 32 percent, respectively, from baseline levels at full load operation. The modified boiler control settings resulted in improved steam temperatures and slagging conditions, with a modest impact on unit heat rate. The testing demonstrated that a combined low-NO_x/low-Hg strategy, based on optimized boiler operation, can potentially provide lower cost NO_x Ozone Season compliance and mercury CAMR-Phase I compliance (at above the 23 percent Hg reductions required by 2010). In addition, the test results also demonstrated that reductions in Hg emissions by modifying boiler operations, solely or in combination with AC injection, might help reduce the cost of Hg emissions compliance for the utility industry. For this particular unit, the estimated annual savings in AC is in excess of $100,000.

UNIT DESCRIPTION

St. Clair Unit 4 is a 1953 vintage Babcock and Wilcox (B&W) unit, with a maximum rating of 158 MW (with combined coal and oil firing). The unit is fired seasonably on 100 percent Western U.S. coal or with a blend of 85/15 percent Western/Eastern U.S. bituminous coal. The unit is equipped with twelve single-register burners located on the front-wall. Five pulverizers supply the coal to the twelve burners arranged in two rows, six burners per row. St. Clair Unit 4 has a year-round NO_x limit of 0.40 lb/MBtu. Burner modifications of the original B&W swirl burners were performed in

2004 by ACT, Inc., for low-NO_x operation. The low-NO_x firing system also has a single elevation of four overfire (OFA) ports for additional combustion staging.

The boiler is subcritical, with a single reheat. Steam temperature control is achieved through attemperating sprays and a convective pass flue gas damper. The furnace operates with a balanced draft. A serious problem at St. Clair Unit 4 is high-temperature slagging at the superheater section. As the slag accumulates on the back-pass, the unit becomes induced draft (ID) fan limited. The flue gas near the vicinity of the superheater pendant is monitored with on-line optical pyrometers, which have a line-of-sight through ports near the furnace exit plane (furnace exit gas temperature, FEGT, indication). In order to prevent the flue gas temperature from exceeding the ash fusion temperature threshold, the FEGT is maintained below 1,950 deg. F by a combination of furnace and convective pass sootblowers activated on a sequential schedule and by a deslagging practice that consists of load cycling to 40 MW every second-day. St. Clair Unit 4 is equipped with two air preheaters (APHs), of the rotating type, with bypass dampers to maintain a back-end average temperature setpoint of 160 deg. F. The particulate control equipment on this unit consists of a six-field electrostatic precipitator. The nominal ESP operating temperature is 290 deg. F and its specific collection area (SCA) is 700 ft^2/1,000 acfm.

TECHNICAL APPROACH

The ERC has developed a practical approach for combustion optimization for NO_x emissions reduction that includes boiler inspection and tuning, parametric testing, neural network modeling, mathematical optimization and implementation of results. The ERC approach uses Boiler OP, an intelligent software applied with success at 30 units, that cover a range of boiler and firing system designs, and fuel types. There is a range of options for implementation of the combustion results that include programming of new control curves, on-line advisory and closed-loop control. For this project, the first option was opted.

The boiler inspection and tuning of St. Clair Unit 4 was performed in February and March 2005. Items that needed to be addressed in preparation for the combustion optimization test program were identified and corrected, including calibration and maintenance of excess oxygen (O_2), carbon monoxide (CO) and FEGT probes, maintenance of out-of-service sootblowers and installation of CEGRIT in-situ fly ash samplers. In the combustion tuning tests, the secondary air flow distribution between burners was balanced within ± 10 percent by adjusting the burner shrouds. Modifications to the coal pipe orifices were also made to balance the coal pipe flow situation.

Parametric testing was performed between May and Jun, 2005, at full load conditions, 100 percent coal firing. These tests included combinations of excess O_2, OFA register position, burner secondary air and shroud biases, burner coal spreader position, mill coal flow bias, and superheat damper position. A combination of data collected automatically by the plant PI System and data collected manually was used for Boiler OP. Off-line data included fly ash unburned carbon content or LOI and net unit heat rate. Changes in unit heat rate were calculated using a heat and mass balance model of the unit. Fly ash samples were collected by the CEGRIT samplers and analyzer on-site at St. Clair. Only the operating parameters affected by the changes in the test parameters were considered for the heat rate calculations. The values of the heat rate are, therefore, relative and indicate changes in unit performance due to systematic changes in test parameters. A database was created from the parametric test results. Combustion/NO_x emissions characteristics were obtained from the data. The data were used to create neural networks by Boiler OP, to establish functional relationships between emissions, performance and boiler controllable parameters. The mapping functions developed by the neural networks were then used by the Boiler OP optimization algorithm to determine optimal boiler control settings, based on an objective of minimum NO_x emissions at best unit heat rate, within prescribed constraints (main and hot reheat steam temperature at below 1,010 deg. F, FEGT at below 1,950 deg. F, CO emissions less than 100 ppm_v, stack opacity below the mandated limit of 20 percent).

Mercury testing was performed after the combustion optimization part of the project was completed, and optimal boiler control settings for lowest NO_x emissions were found. These tests were performed in October 2005, during the field verification of the low-NO_x settings. In addition to the boiler control settings associated with the low-NO_x operation, other parameters investigated for Hg emissions control included reduced APH back-end flue gas temperature and sootblowing. Hg parametric testing was conducted with 100 percent Western U.S. coals and at full load (115 MW); however, unit availability provided test results with one mill out-of-service configuration (95 MW). The test coal consisted of blend of Western U.S. coals, 40 percent Decker, 40 percent Spring Creek and 20 percent Wyoming.

On-line Hg measurements were performed at the stack, using the OhioLumex-915 continuous emissions monitor (CEM). This instrument works based on the principle of thermo catalytic conversion and cold vapor atomic absorption for detection of Hg. The OhioLumex system used at St. Clair Unit 4 consisted of a filter unit, a conversion unit and the analyzer. Associated Teflon lines were maintained at 400 deg. F to prevent sample loses. The Hg CEM was set to run 24 hours a day on a 10-second sampling frequency, except for maintenance, trouble-shooting and calibration. A single span gas (10 $\mu g/nm^3$ Hg in nitrogen) bottle was used for system calibration. System calibration and filter changing was performed on a daily basis, except in cases when replicates of calibration and filter change were required for measurement checks. The OhioLumex CEM was run with automatic blowback and zero correction every 30 minutes.

As-fired composite coal samples from all operating feeders were obtained three times a day for documentation of the coal Hg content (average level and variability). In addition, samples of fly ash for every test run were collected from the individual eight hoppers that compose the first two rows of the ESP. The ESP hoppers are evacuated continuously assuring that the samples were representative of the test conditions. For each test run, the emptied sampling hoppers were put on by-pass to accumulate fly ash representative of the test operating conditions. The coal and fly ash samples were analyzed for Hg content. Particulate-bound Hg in the coal and fly ash samples was measured by a Leco AMA-254 Hg analyzer. This instrument is based on the principle of atomic adsorption spectrometry and designed for the direct Hg determination in solid and liquid samples without the need of sample chemical pre-treatment.

RESULTS

Combustion Optimization

The average baseline NO_x emissions were found to be 0.275 lb/MBtu at full load, with all five mills in-service. These NO_x emissions are below the 0.40 lb/MBtu limit are the baseline emissions resulting from the as-found boiler control settings used by the operators. NO_x emissions were found to be a strong function of excess O_2, OFA shroud position, burner shroud position and secondary air swirl vane register position, in that order. The other test parameters were found to have a second order effect on NO_x. To illustrate some of the parametric test results, Figure 1 shows NO_x emissions as a function of average economizer excess O_2 and OFA shroud position. NO_x emissions were found to decrease approximately by an average 0.10 lb/MBtu per percent average reduction in O_2 concentration. In addition, the impact of the OFA registers was found to be effective only between the 0 to 60 percent range, due to the register design.

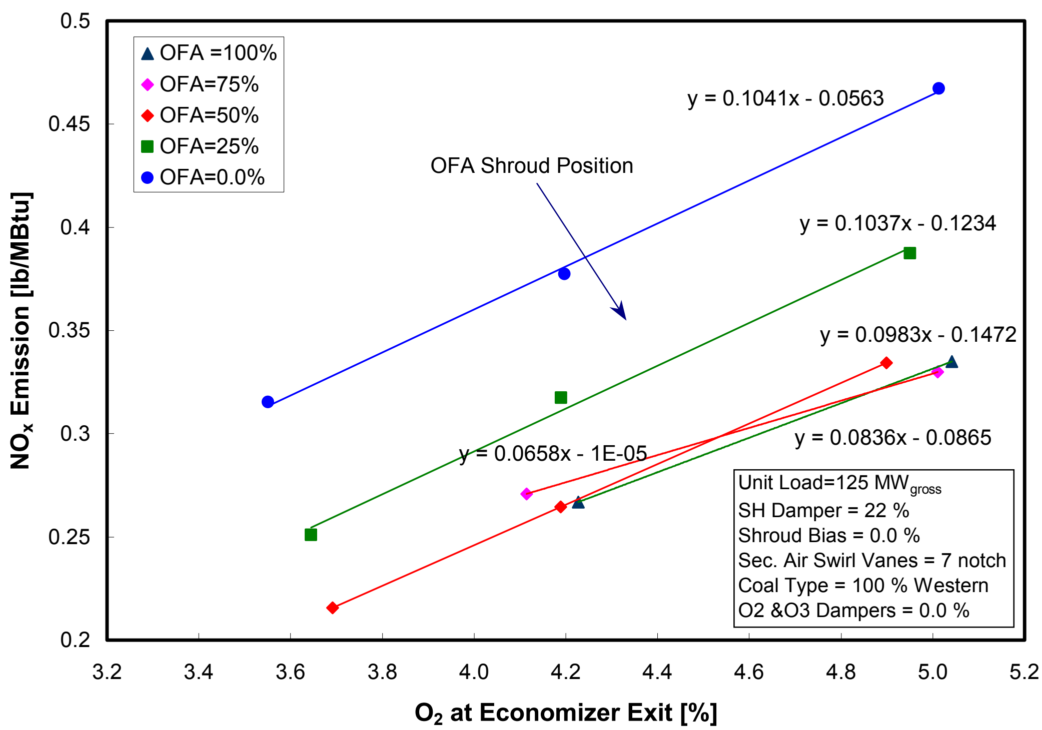

Figure 1: Economizer Excess O_2 vs. NO_x Emissions at Various OFA Positions

To illustrate the impact of excess O_2 and OFA shroud position on other parameters of interest, Figure 2 shows the relationship between these two boiler control settings and FEGT. As expected, lowering plant excess air would result in a reduction in the volume of gases that are heated by the combustion process, leading to increased flue gas temperatures. Additionally, at lower excess O_2 levels, the average FEGT level decreases as the OFA registers are opened.

The average fly ash LOI level for all the tests was found to be 0.5 percent. As it is the case with Western U.S. coals, it was found that the fly ash LOI level was insensitive to the economizer exit O_2 and other boiler operating parameters. For the range of O_2 tested (approximately 3.5 to 5.0 percent), the changes that were found in fly ash LOI were of the order of 0.15 percent. Lower O_2 levels could not be tested due to the constraints in FEGT and CO emissions.

Neural network models were developed for prediction of NO_x, unit heat rate and FEGT as a function of the controllable boiler operating parameters. Figures 3 and 4 show the results of sensitivity analyses on these models. The predicted effect of average O_2 levels on NO_x emissions and heat rate is presented in Figure 3 for different levels of OFA shroud positions ranging from 0 to 100 percent, with 25 percent increments. The absolute values of unit heat rate used in the calculations and predicted by the networks are used for reference and do not have physical meaning, since they only reflect the impact of the corresponding test conditions on heat rate. It was found that increased excess O_2 results in an increase in both main and reheat steam temperatures, reducing the unit heat rate, and compensating for the increase in stack losses associated to higher excess air levels. Both main and reheat steam temperatures are controlled by attemperating sprays at St. Clair 4. However, the station has almost no control on the steam temperatures due to limited attemperating spray flow rates.

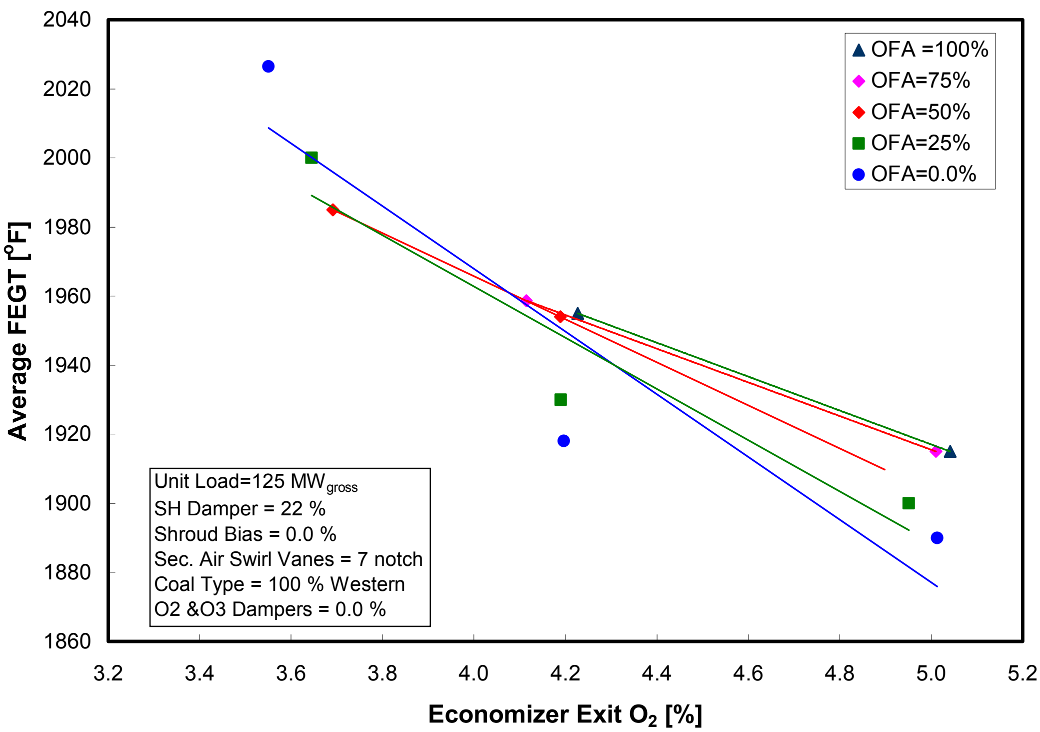

Figure 2: Economizer Excess O_2 vs. FEGT at Various OFA Positions

Figure 4 illustrates NO_x emissions and heat rate as functions of burner shroud bias and the secondary air registers at three secondary air register positions (2, 7, and 9 notches). The model results indicate that there is a slight increase in heat rate as the burner shroud bias is increased from –8 to + 10 percent. As the burner shroud bias is increased from –8 to +10 percent, there is also a gradual increase in NO_x emissions at all three secondary air register positions. The impact of burner shroud bias on NO_x emissions and heat rate becomes more pronounced as the secondary air register is moved from 2 to 9 notches. The model suggests that the maximum impact of the combination of burner shroud biases and secondary air register positions on heat rate can be as large 60 Btu/kWh.

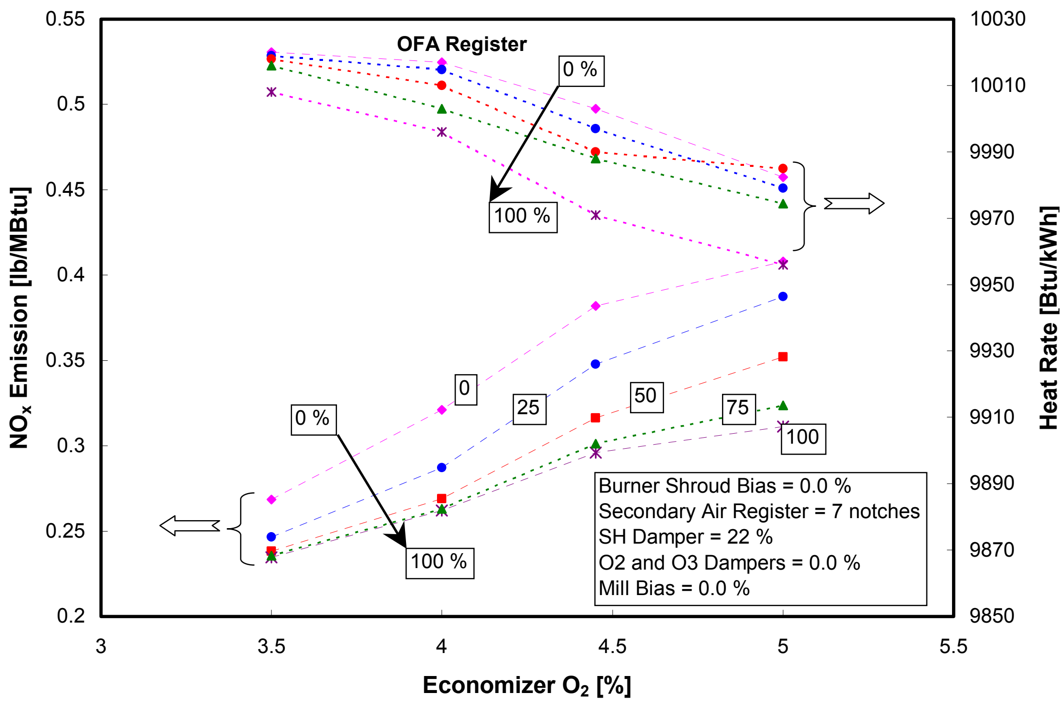

Figure 3: Predicted NO_x and Heat Rate vs. O_2 and OFA Position

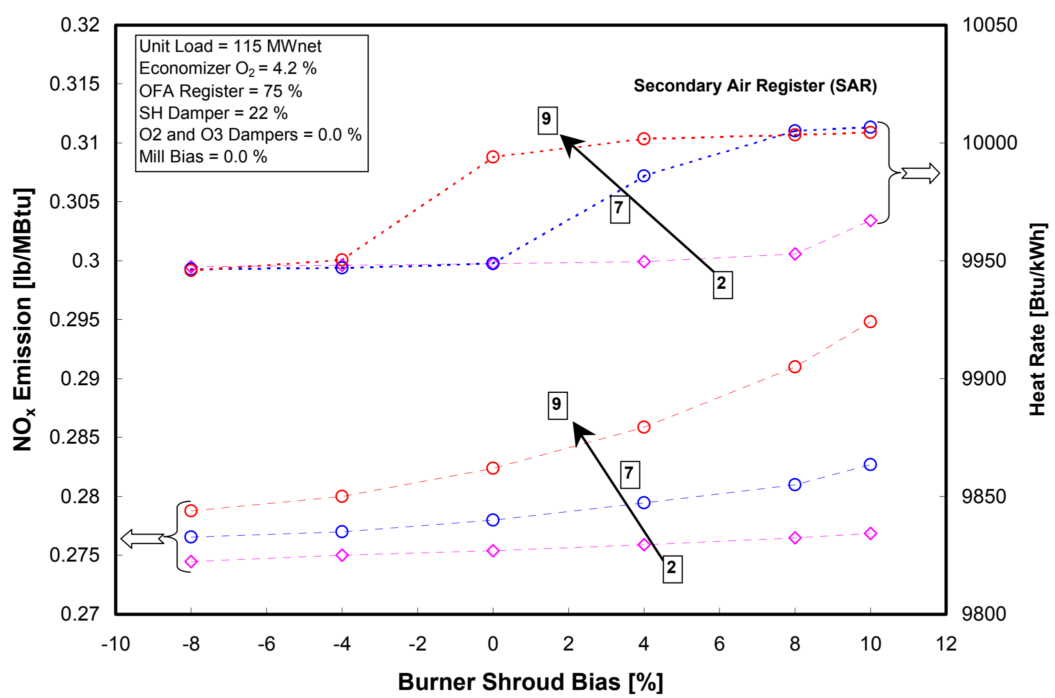

Figure 4: Predicted NO_x and Heat Rate vs. Burner Shroud and Swirl Register Position

The Boiler OP optimization tool was used to determine optimal boiler control settings for full load for the range of target NO_x levels obtained from the parametric tests. Optimal settings which result in minimal impact on unit heat rate were also found for the lowest available NO_x operation (within the prescribed constraints). Optimization results are presented in Figure 5, where unit heat rate is presented as a function of NO_x emission level. Heat rates are expressed as differences with respect to the minimum heat rate value obtained from all test points. The filled circles in Figure 5 indicate the optimal settings determined by Boiler OP. The test data (indicated by open diamonds) show that for each NO_x level there is a range of boiler setting combinations, with an associated heat rate range. The as-found baseline settings were found to result in a NO_x level of approximately 0.275 lb/MBtu and a relative heat rate penalty of 40 Btu/kWh. Figure 5 indicates that optimal control settings (within the prescribed unit constraints) are available for low-NO_x operation between the baseline level of 0.275 lb/MBtu and 0.250 lb/MBtu, with the added benefit of heat rate reduction of approximately 30 Btu/kWh. The lowest NO_x emissions level that could be achieved within the prescribed constraints is 0.220 lb/MBtu level. This is a 20 percent reduction with respect to the baseline level obtained with the as-found settings the operators use regularly. The recommended optimal boiler control settings were: excess O_2 below 3.8 percent (until reaching the FEGT and CO limit), OFA shrouds at 90 percent, a burner shroud bias of -10 percent, burner secondary air registers moved to the 7 notch mark, and the superheat dampers set at 10 percent open. These settings, if used during the Ozone Season will result in an increase in heat rate of approximately 12 Btu/kWh as compared to the heat rate level with the as-found baseline settings. For the rest of the year (when NO_x trading is not financially beneficial), different optimal settings may be employed to achieve a better heat rate but more moderate levels of NO_x. Based on these results, recommendations for the controllable parameters were provided for the available range of target NO_x levels, in the form of curves to be programmed into the combustion control system.

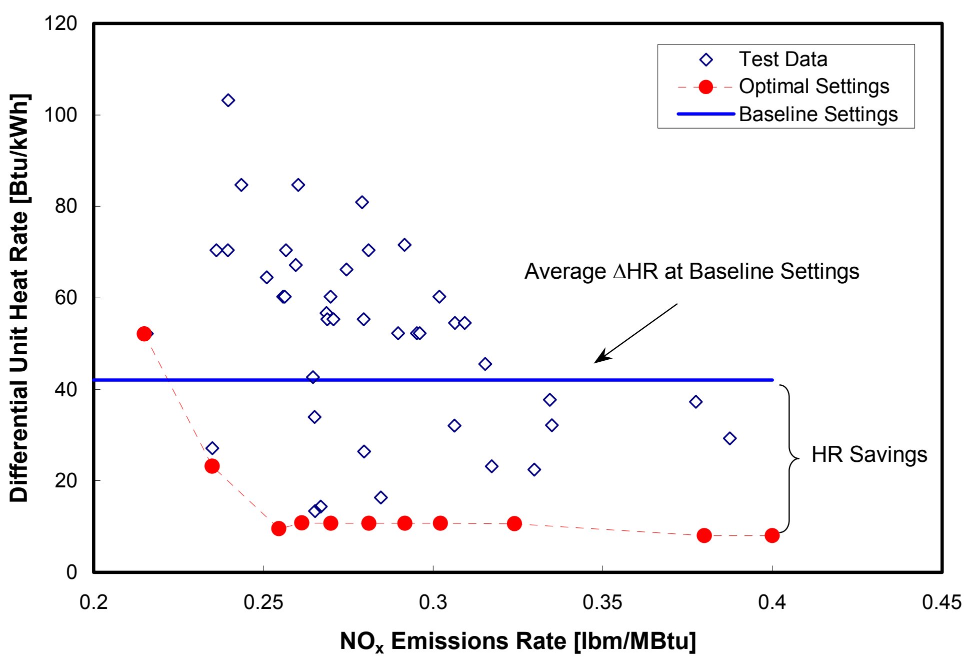

Figure 5: NO_x Emissions vs. Heat Rate Map with Optimal Settings

Mercury Emissions Optimization

Mercury testing was performed in combination with the week of verification tests that are part of the combustion optimization test program for NO_x reduction. The low-NO_x settings introduce reductions in excess air and increases in combustion staging, which beneficially conditions the fly ash for enhanced Hg capture. Additional parameters were tested for additional Hg emissions reduction included reduced back-end flue gas temperature and convective pass sootblowing. St. Clair Unit 4 APHs are equipped with recirculation dampers for back-end temperature control, which can be used for back-end flue gas temperature manipulation.

A total of 13 coal samples was collected for St. Clair Unit 4 during the five days of Hg testing. The test coal used was 100 percent Western U.S. sub-bituminous, composed of 40 percent Decker, 40 percent Spring Creek and 20 percent Wyoming. Analysis results for Hg concentration in the coal are included in Figure 6. The average Hg content in the coal for the test period was 0.0423 ppm_w (on a wet basis), ranging from 0.025 to 0.060 ppm_w. The variability in the amount of mercury in the coal was found to be large (the average standard deviation for the entire test week was approximately ±74 percent); however, the variability in the Hg content in the coal was random.

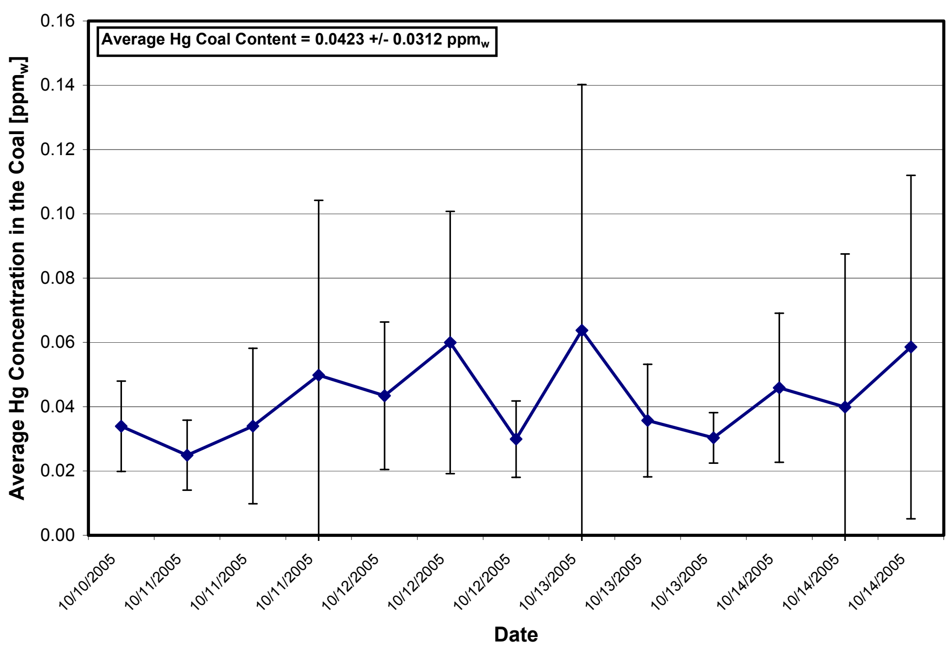

Figure 6: Variability of Mercury in the Coal

Results on the impact of low-NO_x operation on Hg emissions are shown in Figure 7. For the Hg and excess O_2 data in Figure 7, the unit started at 95 MW in the morning and at combustion conditions that result in high NO_x emissions (high excess O_2 of approximately 5.6 percent, OFA register closed to 20 percent and unbiased burners settings) and was ramped to 115 MW, while maintained at relatively high NO_x conditions. In going from 95 to 115 MW, the excess O_2 level was reduced from 5.6 to approximately 4.3 percent, the OFA registers were opened to 75 percent and the burner shrouds and swirls were biased for some NO_x reduction. At 3:00 pm the optimal low-NO_x settings were introduced. These settings reduced the excess O_2 to approximately the 3.7 percent level, opened the OFA to the 90 percent opening and introduced the recommended low-NO_x biases to the burners and convective pass superheater damper. As it can be seen on Figure 7, these changes resulted in a reduction in Hg emissions, a few hours later, from the baseline Hg level at full load of approximately 4,100 ng/m^3 to the 3,500 ng/m^3 level, almost a 15 percent reduction. The reduction in Hg from the level the Hg emissions were at 95 MW, and baseline conditions, was of 26 percent.

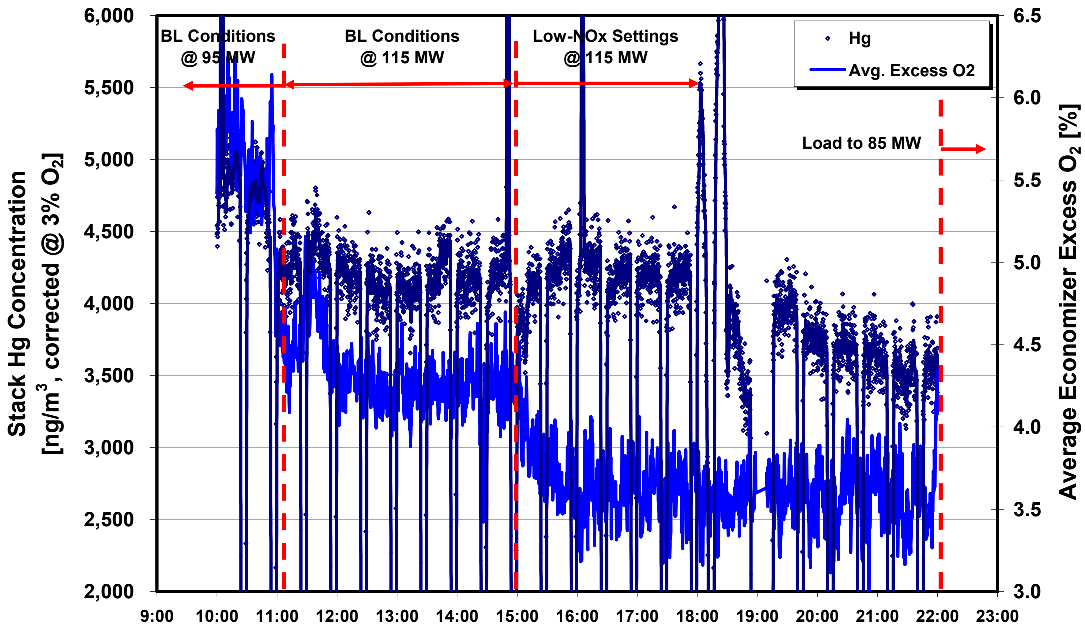

Figure 7: Impact of Low-NO_x Settings on Mercury Emissions

The impact of flue gas temperature on Hg emissions was investigated by making use of the APH recirculation damper and selective sootblowers in the convective pass and the APH. Tests in this area indicated that Hg is sensitive to the flue gas temperatures and correlates well with the APH average gas outlet temperature, suggesting that reduced back-end temperatures and a cleaner APH will result in lower Hg emissions (an approximated 15 percent maximum Hg reduction). Figure 8 shows a graph obtained from plotting the stack Hg concentration and the average APH gas outlet temperature, the correlation between both parameters indicates an effect of approximately 60 ng/m^3 reduction in Hg per degree change in flue gas temperature.

Finally, the operation at low-NO_x settings was combined with aggressive sootblowing in the downstream convective pass and the APH. The normal sootblowing strategy for St. Clair Unit 4 schedules cleaning of the APHs twice a day. These retractables were activated on a 4-hour basis. The sequence for the other retractables in the convective pass was aggressively scheduled every 3-hours. The combination of ash conditioning due to the low-NO_x settings, and enhanced oxidation due to low flue gas temperature conditions resulting from the aggressive convective pass and APH cleaning resulted in an Hg emissions level below the 3,000 ng/m^3 level, at 2,790 ng/m^3 in average. This is 32 percent reduction from the Hg level at full load from baseline conditions. Figure 9 shows the OhioLumex CEM data under the low-Hg operating conditions. Later in that day, the unit load was reduced to 95 MW (one mill out-of-service). The operator was asked to maintain the low-NO_x boiler control settings at this mill configuration. As can be seen from Figure 9, the Hg emissions remained low, 2,690 ng/m^3 on average. This represents a 44 percent reduction from the baseline Hg emissions level at 95 MW. The NO_x level for that period was approximately 0.223 lb/MBtu, which validated the results obtained from the combustion optimization test program, and demonstrated the co-benefit of the NO_x control approach.

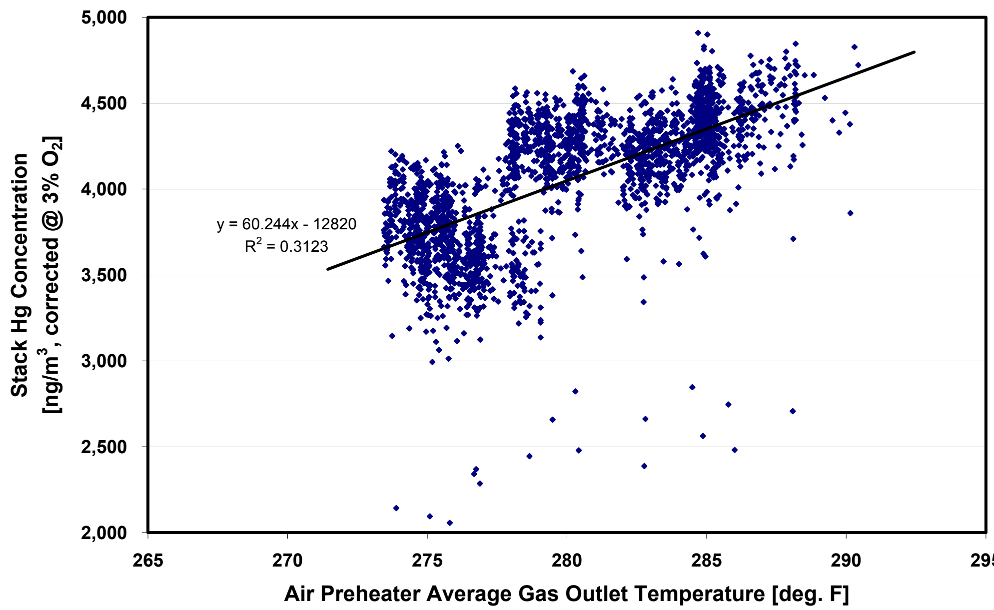

Figure 8: Mercury Emissions vs. Air Preheater Gas Outlet Temperature

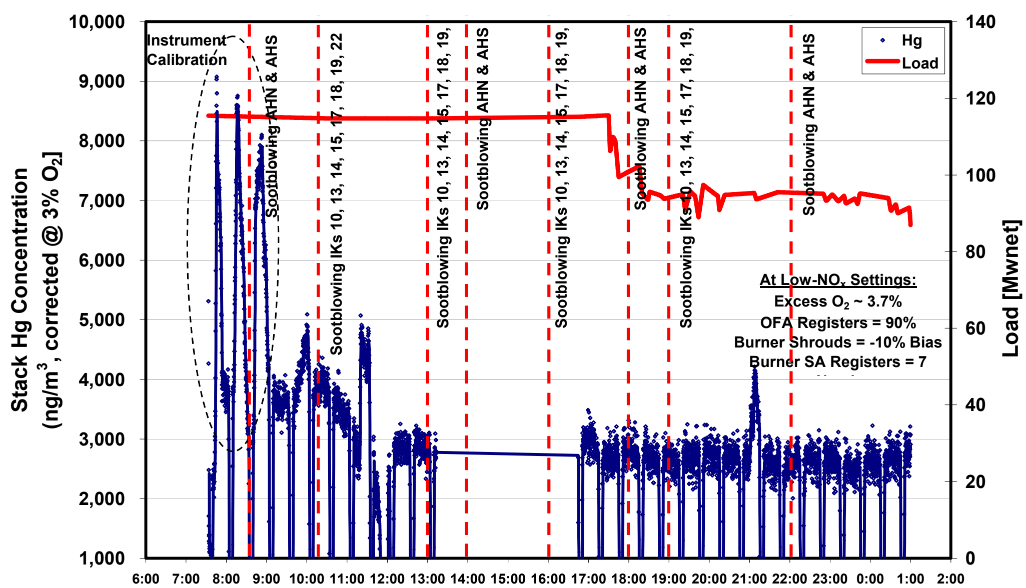

Figure 9: Low Mercury Emissions at Optimal Settings

A summary of the fly ash sample analysis results is included in Figure 10. Figure 10 shows Hg concentration results in the fly ash for samples collected from tests run at baseline conditions, and at conditions that result in reduced Hg emissions. The results displayed in Figure 10 correspond to the average of six individual analyses run on each particular fly ash sample. It is evident, from the results that the low-Hg conditions result in Hg loadings in the ash that more than double the Hg concentration in the ash for the baseline conditions. These results are interesting, especially, when the unburned carbon levels in the ash or LOIs at St. Clair Unit 4 were very low, ranging from 0.09 to 0.47 percent. However, Hg removal has been reported as high as 90 percent in some full-scale testing, using Western U.S. coals. In cases such as these, removal depends on flue gas temperature, the level of unburned carbon in the ash and the catalytic effects of inorganic ash constituents, non of which have been fully identified. Although, the Hg adsorption capacity of the inorganic fraction of the ash is typically low, certain fly ashes with low carbon content have been found to exhibit a significant Hg capture, and the St. Clair Unit 4 ash may be one of those ashes.

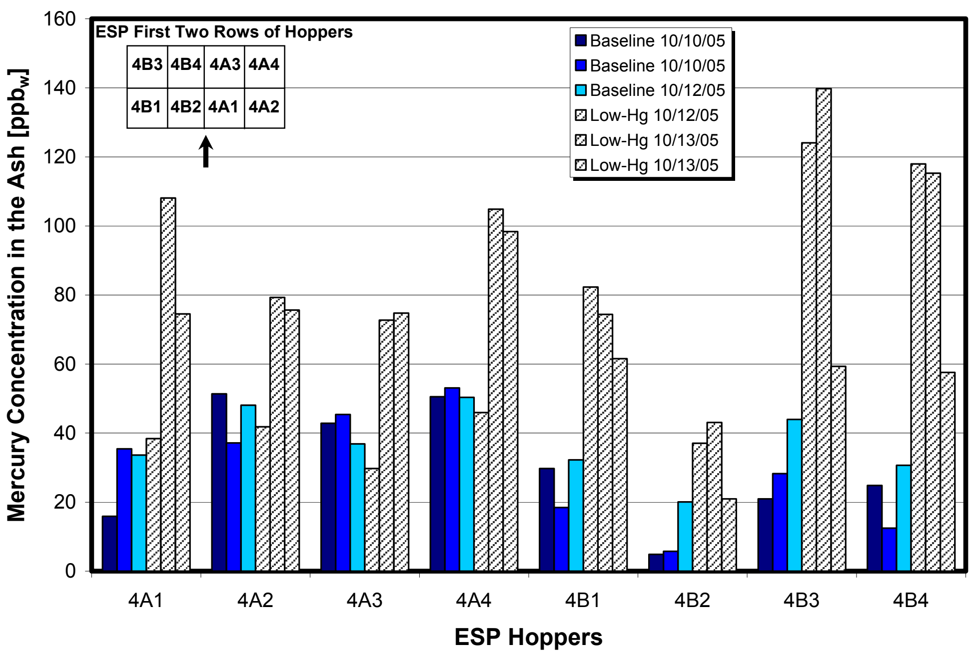

Figure 10: Mercury Content in the Ash for Different Operating Conditions

CONCLUSIONS

Combustion optimization testing of St. Clair Unit 4 for NO_x control was performed using the Lehigh University's intelligent optimization code Boiler OP. Testing was performed at full load and with a blend of 100 percent Western U.S. coals (40 percent Decker, 40 percent Spring Creek and 20 percent Wyoming). Recommended low-NO_x boiler control settings allowed operation at the 0.220 lb/MBtu level, within specified operational constraints, such as a 1,950 deg. F FEGT limit to control high-temperature slagging. The NO_x emission limit for this unit is 0.400 lb/MBtu. This represents a 20 percent reduction in NO_x, with respect to the baseline level obtained with as-found settings the operators use regularly. Additional testing for Hg was also performed to investigate the impact of low-NO_x operation and additional boiler optimization on Hg emissions. The field tests results indicated that the optimized low-NO_x settings, together with reductions in flue gas temperature and aggressive convective back-pass sootblowing, resulted in Hg emissions at the 2,700-2,800 ng/nm^3 level. This represents a 32 percent reduction in Hg emissions from baseline levels, which perfectly complies with the 23 percent Hg reduction imposed by Phase I of the CAMR. The recommended low-NO_x/low-Hg operating strategy for full load operation is based on the following operating settings/sequences included in Table 1.

Table 1: Recommended Low-NO_x/Low-Hg Operating Strategy

Parameter	Settings/Sequence
Economizer Excess O_2 [%]	3.8
OFA Register Opening [%]	90
Burner Swirl Register [Notches]	7
Burner Shrouds Bias [%]	-10
Convective Pass Sootblowing IKs 10, 13, 14, 15, 17, 18, 19, 22	Every 3 hours
Air Preheater Sootblowing AHN & AHS	Every 4 hours
Expected NO_x [lb/MBtu]	0.220
Expected Hg [ng/m^3]	2,700-2,800

The recommended optimized operation represents a reduction in NO_x emission of 0.055 lb/MBtu with respect to baseline NO_x emissions, which is estimated to provide an annual savings of $273,240/year during the Ozone Season. These settings will result in a heat rate penalty of 12 Btu/kWh compared to the baseline settings. The fuel cost increase due to this heat rate penalty is estimated to be less than $10,000/yr. The assumptions used in these cost savings calculation include a fuel blend cost of $1.25/MBtu, heat rate of 12,500 Btu/lb, unit capacity factor of 0.85, and a NO_x credit of $2,400/ton. Additionally, if the total gaseous stack Hg emissions can be reduced at full load to the 30 percent mark, by enhancing the "naturally-occurring" mercury capture at St. Clair Unit 4 by modification to boiler control settings; this will reduce the cost of Hg emissions compliance by DTE Energy. Recent estimates of costs associated with the use of brominated activated carbon are an average of $8,000 per pound of Hg removed, on units burning sub-bituminous coals, and having cold-side precipitators. Assuming a 30 percent reduction compliance level is required by 2010 by the State of Michigan, with an average baseline mercury emissions level of 4,100 ng/m^3 for St. Clair Unit 4, a reduction of the required 13 lbs of mercury by control settings modifications would represent an annual savings in activated carbon of approximately $103,000. There would be additional savings associated with the postponement of the cost of an injection system until 2018 (CAMR – Phase II).