Optimizing Selective Non-Catalytic Reduction Systems for Cost-Effective Operation on Coal-Fired Electric Utility Boilers

by

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Abstract

Selective Non-Catalytic Reduction (SNCR) systems have been used to reduce NOx emissions from coal fired electric utility boilers. Experience has shown that the primary cost of reducing NOx with SNCR technology most often is the cost of reagent. It is therefore desirable to reduce the reagent cost to the lowest possible amount while not adversely impacting other aspects of plant operation. Adverse effects that need to be considered in any comprehensive evaluation include impacts on fuel cost as well as impacts of such things as ammonia slip. And, while the parameters that impact performance of an SNCR system are common among boilers, the behavior of these parameters will vary widely between units. Hence, the operators of plants using SNCR for reduction of NOx will frequently find different operating strategies most effective in minimizing the *total* operating cost associated with reducing NOx.

This paper will discuss the operating experience and results of optimization programs at three different coal fired electric utility boilers, each one having different circumstances and each one using a different approach to minimizing the cost of NOx reduction while using SNCR. New England Power utilized advanced instrumentation and controls with changes to soot blower operation to reduce consumption of reagent by over 50% while minimizing adverse impact to heat rate and reducing ammonia slip. Montaup Electric carefully modified its furnace operations to reduce its reagent consumption by over 50% while maintaining design heat rate. Delmarva Power reduced its reagent consumption through modification of furnace operating settings and cofiring of natural gas under some conditions, with a minimal impact to heat rate. This paper will discuss the approaches used at these facilities and will present operating data from the programs.

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Introduction

Selective Non-Catalytic Reduction is a technology that is being used at sixteen electric utility boilers to reduce NOx emissions. It is expected to play a significant role in future U.S. electric utility NOx reduction programs. As with all control technologies, deployment and operation of SNCR will incur a cost. Capital cost is generally low compared to other technologies; however, the cost of reducing NOx through SNCR is driven primarily by variable operating costs - generally dominated by the cost of reagent. Hence, it is normally in the operator's best interest to minimize the reagent consumption and any other costs associated with operating the SNCR system.

Suppliers of SNCR technology generally provide systems designed to meet the guaranteed performance at the conditions where the operator historically runs the unit. Due to a shortage of time and information, the SNCR vendor generally cannot anticipate operating changes to the facility that may benefit the operator when using SNCR technology. Frequently, after the operators have gained some experience with the SNCR system they will discover improved methods of operating the unit.

This paper will highlight successful SNCR optimization programs at three facilities equipped with urea-based SNCR, commonly referred to as NOxOUT. All three facilities are equipped with NOxOUT systems that were meeting or exceeding the expected system performance prior to the optimization. In each case, after having some experience with the NOxOUT system on their unit, the facility operators identified methods of reducing the *overall* cost of reducing NOx while operating the NOxOUT system. In most cases, the operating adjustments discussed here would not have been considered were it not for the existence of the NOxOUT system at their facilities. The three facilities have three uniquely different situations that cause different approaches to be appropriate.

Operating Cost - Discussion

When reducing NOx through combustion controls, reburning, fuel switching, SNCR or another NOx control method, the facility's operating costs may be increased in several ways. Efforts to reduce any single operating cost component could favorably or unfavorably impact the other operating cost parameters. A detailed cost evaluation of NOx reduction technologies should include consideration of all of the effects so that trade-offs can be assessed and the system operation potentially optimized for lower overall cost operation.

SNCR reagent consumption is driven primarily by the baseline NOx level, the controlled NOx level, the gas flowrate (boiler size), the furnace temperature and the effectiveness in distributing the reagent. The last two parameters - temperature and distribution - strongly influence chemical utilization, a measure of the efficiency of the urea in reducing NOx. The outlet NOx and the boiler size are either imposed requirements or fixed parameters. The operator does have the ability, however, to impact the baseline NOx, the temperature of the SNCR reaction and the effectiveness in distributing the reagent. To the extent that the operator can manipulate these variables to reduce the amount of SNCR reagent that is consumed, the impact that these variables have on the plant operating costs need to be included when considering the cost of reducing NOx.

Hence, when adjusting plant parameters in an effort to reduce overall NOx reduction costs, it is essential to capture all of the cost impacts so that the trade offs can be fully understood. The cost components that should be considered include the following:

- The direct cost of operating the urea SNCR system, estimated to be equal to roughly $1.00 per gallon of NOxOUT reagent consumed. NOxOUT reagent, an SNCR reagent that is a 50% (by weight) aqueous urea solution with other additives, usually costs a little under $1.00 per gallon. However, $1.00/gallon was used in this analysis to generate the information presented in this report in order to make the math easy and cover the costs associated with other requirements for operating the system such as plant service air, electric power, maintenance, etc.
- If, for the purpose of enhancing NOx reduction system performance, the furnace is operated at conditions where steam temperatures are not optimal, Heat Rate will be poorer. The additional cost of operating the unit at a particular load will be referred to as the Heat Rate Penalty. The operator can alter steam temperature by adjusting burner tilts, soot blowing or other means. The Heat Rate Penalty is specific to the boiler and is typically a function of superheat and reheat steam temperatures.
- When a premium fuel, such as natural gas, is substituted for the primary fuel in order to reduce combustion NOx and urea consumption, the additional cost of this premium fuel should be considered and balanced against the savings from reduced urea consumption. The Fuel Premium is determined by multiplying the cost difference between gas and coal in ($/MMBTU) times the heat input of the gas.
- If the boiler is capacity limited as a result of operation of the NOx reduction system, the value of lost MW-hr incurred should be included in the costs. In most cases, a reduction in capacity is not necessary. But, a reduction may be necessary for some facilities. The value of lost megawatt hours is determined by multiplying the lost MW by the value of a MWhr for that day and time. It is important to recognize that during the summer months there are often high-demand days when the value of lost capacity could be very costly. For the purpose this analysis, capacity reduction was not considered as a means to optimize NOx reduction system operation.

The aforementioned costs do not include the heat rate penalty that is associated with evaporation of water carrier or incomplete combustion as indicated by LOI. These are costs that have been considered by previous investigators and are acknowledged but not investigated in this paper.

Costs that should be evaluated in a more comprehensive analysis include additional maintenance that might be associated with some of the operating conditions evaluated in these programs.

Effects of Process Variables

Baseline NOx level
To reduce chemical consumption it is generally most effective to first pursue a strategy of minimizing the NOx produced by the combustion of fuel, thereby reducing the amount of NOx that must be reduced. This can be done through some modification of the primary combustion process, changing of fuel to natural gas, or though the use of reburning prior to the SNCR system. However, once baseline NOx has been reduced, it is possible to make other process adjustments that can significantly improve the SNCR process economics. The adjustments generally focus on improving reagent utilization.

Reagent Utilization
Reagent utilization is a measure of the effectiveness of the reagent in reducing NOx. It is the objective of the SNCR user to maximize utilization to minimize the cost of reagent. Utilization is mathematically equal to the percent reduction divided by the Normalized Stoichiometric Ratio (NSR, the stoichiometric ratio of reducing reagent to NOx, normalized with the balanced chemical equation). If the utilization is 50%, for example, then that means twice as much urea is being used as that predicted by a balanced chemical equation of the SNCR reaction for urea. Utilization is very strongly affected by initial NOx, controlled NOx, furnace temperature, ability to distribute the reagent, and the concentration of other species, such as CO and O_2. In commercial SNCR systems, utilization is typically between 20% and 60%.

For example, Figure 1 shows % NOx reduction and % utilization plotted against NSR for an SNCR system. NOx reduction will increase with NSR. However, the slope of the curve becomes shallow with increasing treatment rates, indicating that further NOx reductions are only possible with much higher treatment rates. This is also reflected in the utilization, which drops rapidly at first and then drops less rapidly to near 20%.

Effects of Temperature on Utilization - It is well established that SNCR has a reasonably narrow temperature window in which to properly react the reagent. If the temperature is too high, poor NOx reduction and poor chemical utilization will result. If the temperature is too low, high ammonia slip will result. In the region where operation is best, operators will balance improved reduction or utilization against the risk of high ammonia slip (see Figure 2). Since a high furnace temperature generally means low utilization and low utilization means high chemical consumption, it is desirable to inject urea at the lowest possible temperature without incurring high ammonia slip levels. Figure 3 shows the relationship between utilization and Furnace Exit Gas Temperature (FEGT) at one facility tested under conditions where the process was being pressed for very high reductions. Chemical utilization was near 20% at the time and FEGT was adjusted to determine sensitivity of utilization to temperature. The relationship is very clear. In this case, a 20°F drop in FEGT resulted in nearly a 4% improvement in utilization. This relationship may be more or less pronounced for any particular facility. In some boilers, it may be desirable to operate the boiler under conditions where steam temperatures may be less than optimal for good heat rate because the value of the improved reagent consumption will more than compensate for the additional fuel cost.

Injector Optimization - Distribution of urea plays a critical role in chemical utilization. Injector type and location are critical design decisions when a vendor engineers an SNCR system. SNCR technology vendors normally perform computer simulation with computational fluid dynamic modeling to select injector locations and type. The modeling is normally performed in conjunction with a test program where furnace temperature and gas species measurements are taken. Once installed, these injectors must be adjusted to ensure that atomization and distribution are optimal. Annual adjustment of the injectors with more frequent checking of injector set points is recommended for best performance. Figure 4 shows the results of injector optimization of a NOxOUT system that had been installed and operated intermittently for about 18 months. The system had been optimized 12 months earlier. The NOx and flowrate values on Figure 4 are five-minute rolling averages. While maintaining the boiler conditions and SNCR injection steady, the liquid flowrate and atomization air setpoints were adjusted on the distribution modules. The objective during injector optimization is to improve NOx reduction and ammonia slip solely by improving reagent distribution through adjustment of atomization, injector orientation, or nozzle tip changes. Ammonia slip measurements were monitored continuously during these tests and there were no indications of high ammonia slip. As can be seen from Figure 4, an improvement in NOx of about 0.04 lb/MMBTU was achieved simply through adjustments to nozzle atomization parameters. And, if we were to control at the original outlet NOx level, chemical consumption could be reduced. As a result of this work, new injector atomization set points were established at this facility.

Fig. 1. Red'n and Utilization vs. NSR

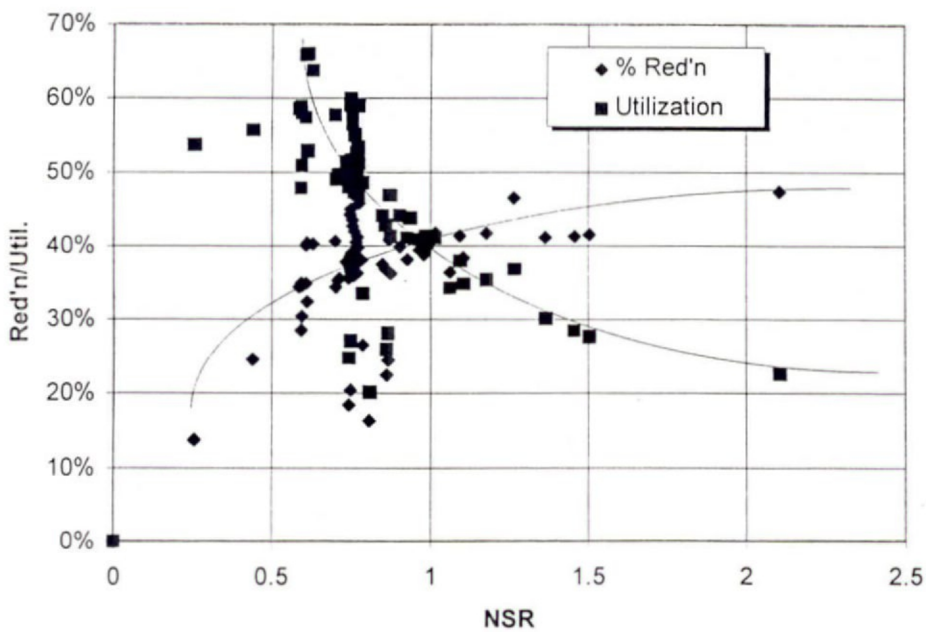


Figure 2. Effect of Temperature on NOx Reduction and Ammonia Slip

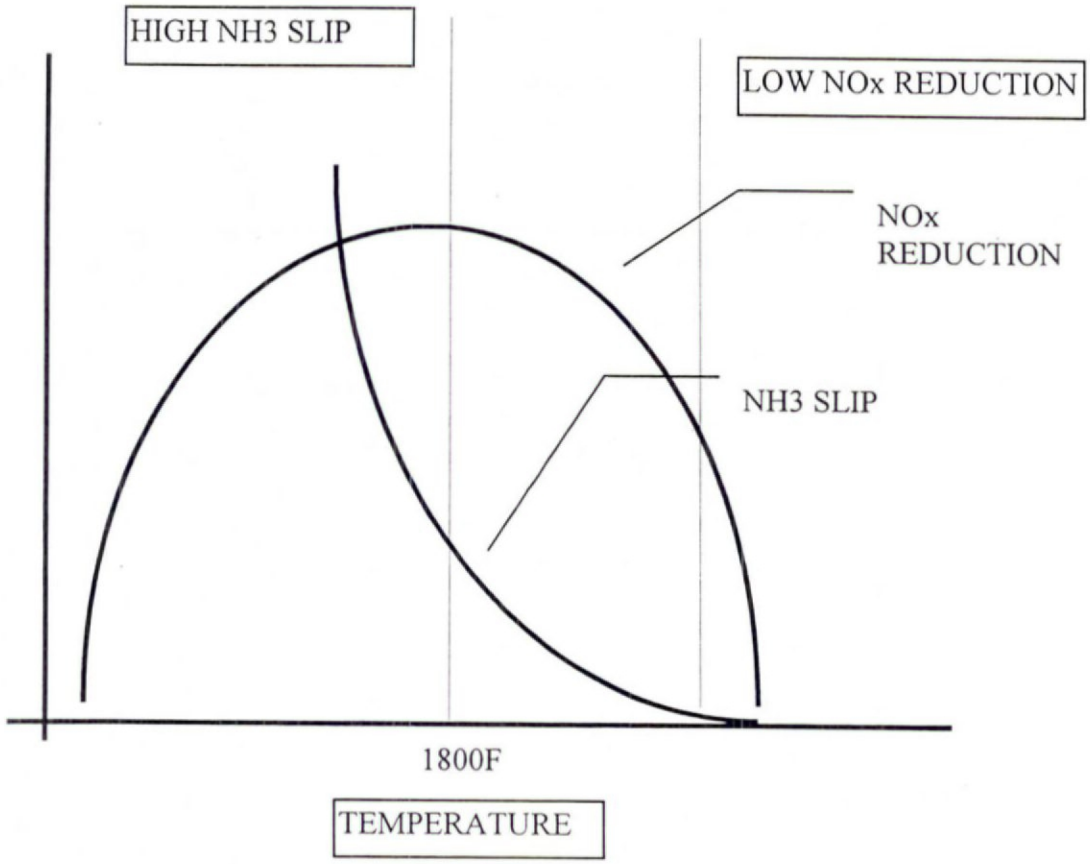


Fig. 3. Utilization vs. FEGT data

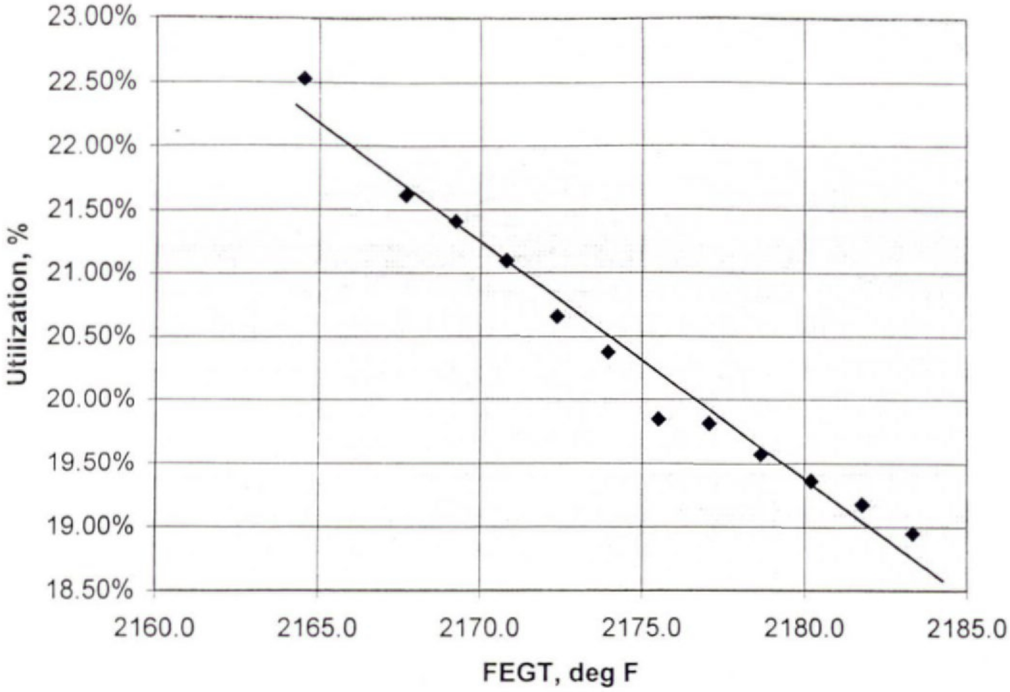
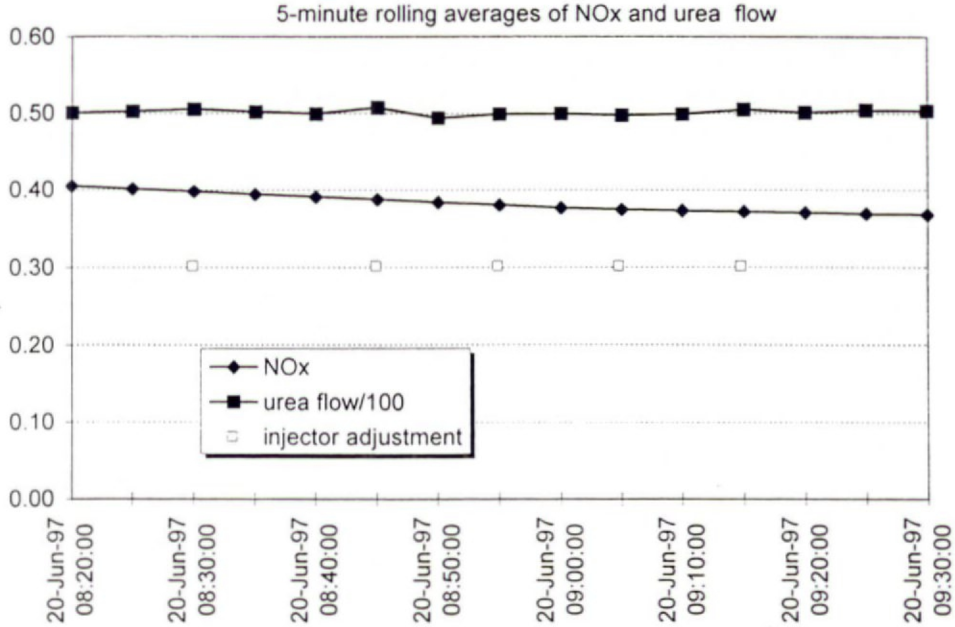


Fig. 4. Urea Nozzle Optimization

5-minute rolling averages of NOx and urea flow



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Delmarva Power, Edge Moor #3

Delmarva Power Company operates an 84 MWe (gross) tangentially-fired pulverized coal boiler (unit #3) at its Edge Moor generating station. The boiler is a natural circulation, single drum radiant boiler with a dry bottom. The furnace has four corners and four levels of tilting, tangentially fired coal buckets. The boiler can also fire oil or gas. Unit #3 operates on dispatch typically in a load following mode.

In cooperation with the Delaware Natural Resource Environmental Control Agency, in 1995 Delmarva voluntarily installed a NOxOUT urea-based Selective Non-Catalytic Reduction system to demonstrate this technology. Optimization during initial commissioning demonstrated that NOx could be maintained below 0.38 lb/MMBTU under all design operating conditions with low levels of ammonia slip and reagent consumption at expected design levels[1]. The NOxOUT system has been operated intermittently during the Ozone Season since commissioning for the purpose of demonstrating the operation of the system. Optimization of the furnace during the summer of 1996 demonstrated that NOxOUT reagent consumption could be improved from what was achieved during initial commissioning. However, Delmarva believed that further reductions in operating cost might be possible and another optimization program was performed in the summer of 1997.

Results of Optimization -
In addition to injector optimization, during the Edge Moor #3 optimization program several furnace firing conditions were evaluated against the conditions for original SNCR vendor optimization. The controlled NOx objective was 0.40 lb/MMBTU. Under the firing conditions that the SNCR was originally designed to operate at, the baseline NOx was 0.70 lb/MMBTU at full load (85 MWg) and 0.60 lb/MMBTU at mid load (65 MWg). The objective of modifying the firing conditions was to reduce baseline NOx while also considering the cost of impact on the plant heat rate.

Under the varied firing conditions, data was collected to characterize the major cost components of operating the NOxOUT system at these different firing conditions.

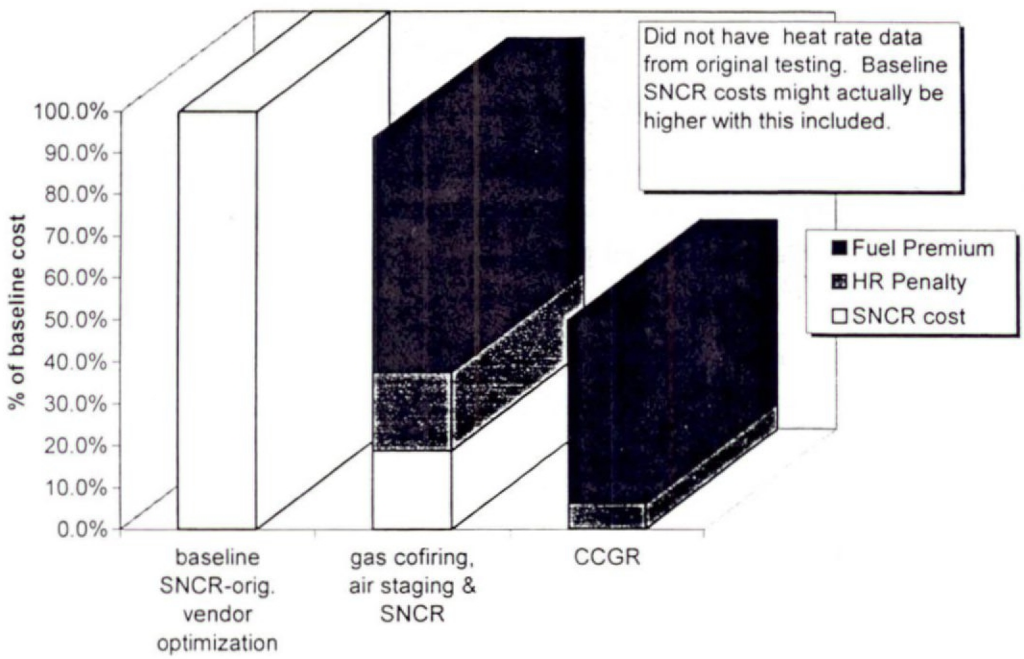
Full Load Testing - Figure 5 shows the operating cost breakdown of controlling NOx under different firing conditions expressed as a percentage of the total operating cost of controlling NOx at the baseline conditions for the SNCR system. Unfortunately, data on the heat rate penalty was not available for the baseline condition at 100% coal. Therefore, the total cost at the baseline condition might actually be higher.

As shown, gas cofiring with vertical air staging in the primary combustion zone resulted in over 80% reduction in urea consumption with a moderate heat rate penalty. Also, the gas cofiring condition produces a substantial fuel premium cost that raises the total cost of controlling NOx with this firing condition to nearly the cost of the baseline urea cost.

During this test period it was not possible to operate at full load with 100% coal due to permit limitations. Therefore, testing the vertical air staging condition at 100% coal could not be performed. It is believed that this firing condition would produce a much more cost-effective method of operation than the baseline condition. For the same reason, *simulated* Close-Coupled Over Fire Air (CCOFA) with 100% coal was not tested at this load.

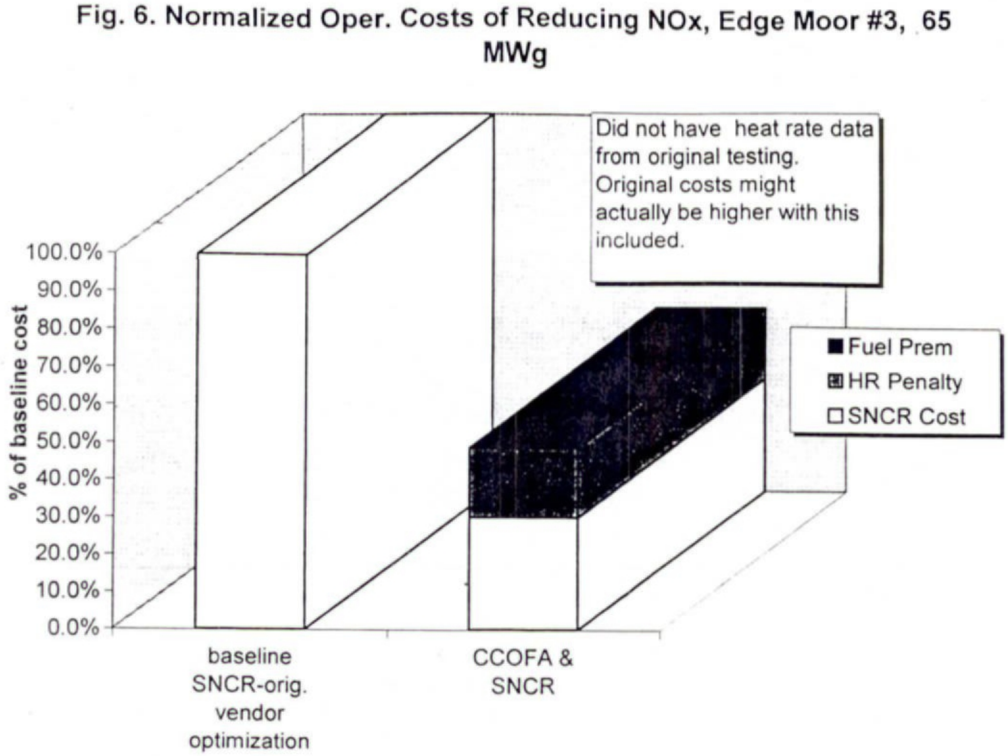
The furnace was also tested in a *simulated* close-coupled gas reburn mode (CCGR), which resulted in the lowest cost of any condition tested at this load. Coal mils B, C, and D were operating, gas was applied to the top gas burner, and air dampers were set for simulated CCOFA. Under this condition it was possible to achieve below 0.40 lb/MMBTU without operating the SNCR system. A minimal heat rate penalty was experienced under this condition with a significant fuel premium. The fuel premium is based upon gas prices at the time of testing. The total operating cost of reducing NOx in this manner is just under 50% of the operating cost of the baseline SNCR. This condition shows that the operator can benefit from low gas prices when available by using gas to very effectively reduce the SNCR reagent cost.

Fig. 5. Normalized Oper. Cost of Reducing NOx, Edge Moor #3, 85 MW



Mid Load Testing **-** Testing at 65 MW showed that *simulated* close-coupled over fire air (CCOFA) could be used to cut the urea consumption by 70%, as shown in Fig. 6. There is a modest heat rate penalty (~19% of baseline SNCR cost) so that, overall, operating cost of reducing NOx is cut by just over 50%. Testing of this condition at 85 MW was not possible due to operating limitations and due to fuel limitations discussed earlier.

Fig. 6. Normalized Oper. Costs of Reducing NOx, Edge Moor #3, 65 MWg



Montaup Electric, Somerset Boiler #8

Montaup Electric Company operates a 112 MWe tangentially-fired pulverized coal boiler (Boiler #8) at its Somerset, MA generating station. The boiler is a natural circulation, reheat, single drum radiant boiler with a dry bottom that is rated at 800,000 lbs/hr steam flow at the superheater outlet at 1,975 psig and 1,000 F. The furnace has four corners and four levels of tilting, tangentially fired coal buckets. Between the four coal buckets in each corner are three oil guns.

In 1994 and 1995, Boiler #8 operated on dispatch typically in a load following mode. During the day and during other high demand periods the boiler operated at or near full capacity. In the evening and on weekends the boiler was frequently reduced to 35% to 55% MCR. In 1996, Boiler #8 has operated as a base loaded unit.

In 1995 Montaup Electric installed a NOxOUT urea-based Selective Non-Catalytic Reduction system to reduce the NOx emissions to levels that comply with the Commonwealth of Massachusetts Reasonably Available Control Technology (RACT) regulations, which required NOx emissions from Boiler #8 to be controlled to below 0.38 lb/MMBTU at all times. The system has successfully maintained NOx levels below required levels with low levels of ammonia slip. Experience with the operation is discussed in previous literature [2, 3].

Results of Optimization-

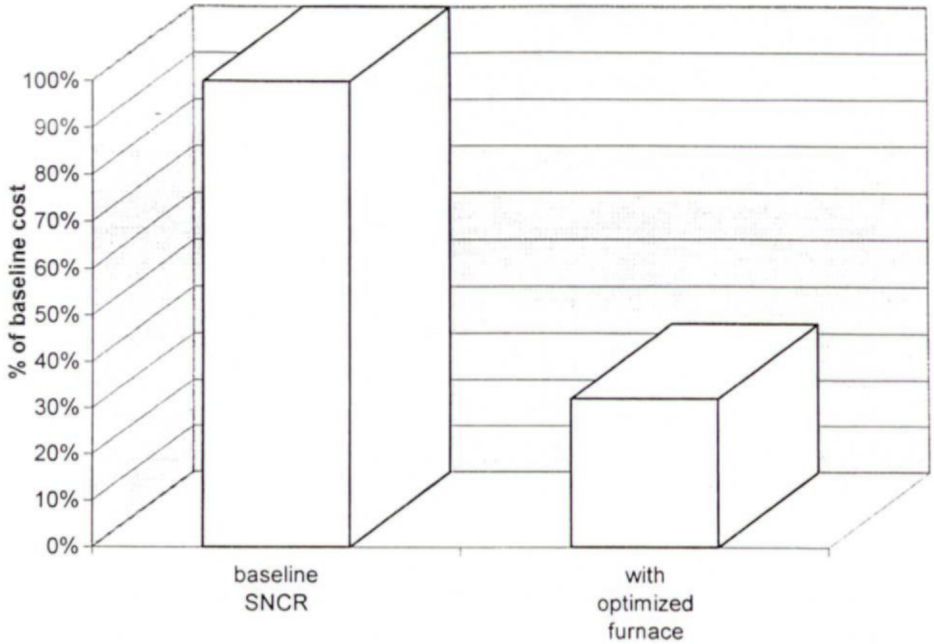
During initial startup and during subsequent optimization, Montaup operators have always maintained an objective of not adversely impacting heat rate. Furthermore, adherence to the turbine manufacturer's operating requirements regarding steam temperature do not permit operating under conditions where heat rate can be adversely impacted in a significant way. This imposes a constraint on what can be done to optimize SNCR operations. Nevertheless, Montaup undertook an aggressive optimization program directed toward reducing their SNCR operating cost while not changing steam temperature.

The fuel and furnace firing conditions of the Somerset #8 boiler are such that it is not necessary to operate furnace wall blowers. Occasional operation of soot blowers is necessary to maintain proper balance between turbine inlet and reheat steam temperatures. Air in-leakage to the boiler is low. Moreover, Somerset #8 is equipped with an Automated Burner Management System (ABMS) and Distributed Control System (DCS). As a result of these features of the facility, Furnace Exit Gas Temperature (FEGT), furnace oxygen, baseline NOx, and other furnace conditions critical to SNCR performance can be maintained at a very consistent level.

It was recognized that a reduction in NOx baseline would be beneficial to urea consumption. However, a reduction in baseline had to be achieved without capital expense and without adversely impacting steam temperatures. In order to reduce the NOx baseline, the furnace operation was modified for air staging with reduced oxygen to about 2.0-2.5% oxygen at the furnace exit. As expected, LOI and CO increased somewhat; however, they have been maintained within acceptable levels. To maintain steam temperatures, burner tilts were put in manual and raised. This raised the furnace slag level, and FEGT was raised to about 2,350°F immediately prior to the secondary superheater pendant. After a few weeks of manual control of burner tilts, the slag level increased sufficiently that the burner tilts could be put back in automatic. The facility has operated in this condition for over one year. It has maintained an uncontrolled full-load NOx baseline of about 0.45-0.49 lb/MMBTU as opposed to the original, uncontrolled, full-load baseline of 0.65 lb/MMBTU.

Operation of the SNCR system to reduce emissions below 0.38 lb/MMBTU has substantially changed since implementing these changes to operation. First, injection at full load had previously been in zones 3 and 4 of this four-zone NOxOUT system. Current operation requires operation of only four of the zone 4 injectors at full load, which reduces the air and dilution water requirement by more than 60%. Recent characterization testing of this operating mode showed that FEGT is currently 2350 °F, approximately 150 °F higher than the FEGT under the original baseline SNCR conditions. Ammonia slip continues to be extremely low. The urea consumption has been reduced about 66% (see Figure 7), without an adverse impact to heat rate.

Fig. 7. Normalized Oper. Cost of reducing NOx, Montaup Electric, Somerset boiler #8

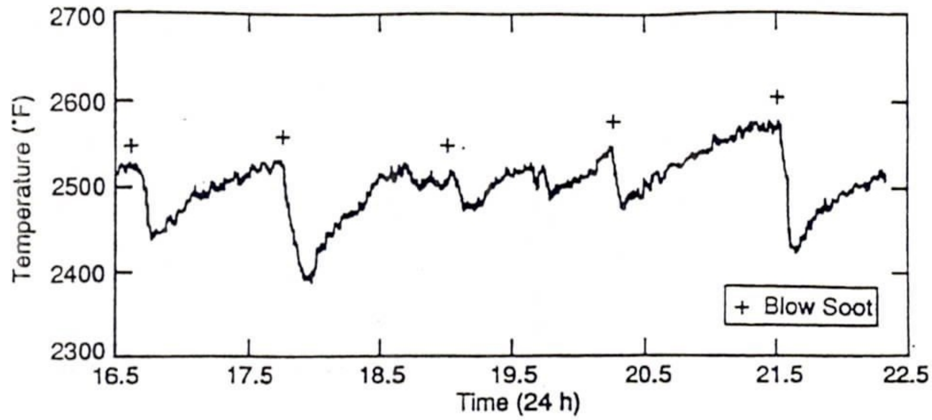


New England Electric, Salem Harbor #3

New England Power (NEP) operates four units at Salem Harbor. The three coal-fired units were the first commercial applications of SNCR on coal-fired utility units in the U.S. Salem Harbor #3 is a 150 MW, wall-fired dry-bottom boiler. It is equipped with urea SNCR (NOxOUT), Low NOx Burners (LNB) and Separated Over Fire Air (SOFA) for control of NOx to 0.30 lb/MMBTU. NEP installed the LNBs and SOFA after they installed the SNCR to SH #3. Prior to installation of the LNB's and SOFA or NOxOUT, NOx emissions averaged 1.00 lb/MMBTU. The LNB's and SOFA reduced NOx to the NOxOUT system from 1.00 to 0.43 lb/MMBTU. The site does not have natural gas. As a result, there are no additional options for further reducing NOx baseline to the SNCR system at SH #3.

Unlike the previous two examples, the SH #3 furnace experiences significant slagging in the furnace with much FEGT variability. Furnace wall blowing was historically performed on a schedule for the purpose of controlling steam temperatures. Figure 8 shows data taken over a six-hour period in 1994, prior to the recent optimization program. With this level of FEGT variability, and considering the general trends indicated on Figures 2 and 3, high chemical utilization with low ammonia slip would not be possible without a control system that could rapidly sense the changes in FEGT and adjust the injection rate and location accordingly. At the time the SNCR system was originally installed (1993), such a control system was not available. In order to avoid high ammonia slip conditions, the SNCR system was operated in a manner that produced lower reagent utilization than would be possible in a unit without the FEGT variability.

Fig. 8. Furnace Exit Gas Temperature (FEGT) at Salem Harbor over six hours[4].



The SNCR system that was originally installed at Salem Harbor #3 incorporated the state-of-the-art for the technology at the time. Because sensors were not available for temperature or ammonia measurement, the original SH #3 NOxOUT system was controlled primarily in a feed-forward manner based upon the measured steam flow and the coal mills in operation. The NOx signal from the CEMS was compared with a setpoint for a slow-adjusting feedback trim.

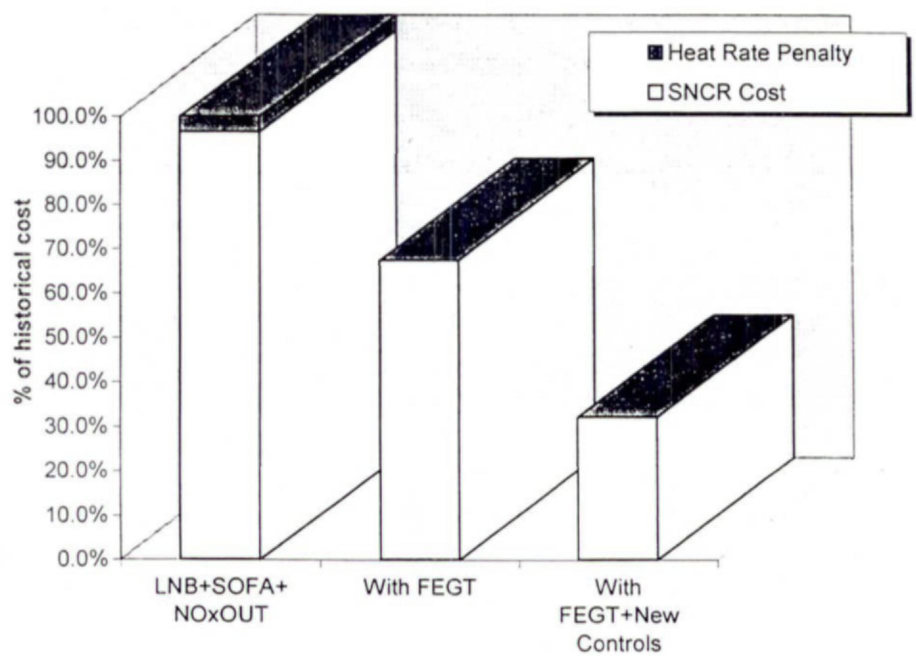
When the NOxOUT system was originally installed in 1993 - prior to the LNB and SOFA - the reagent consumption was rather high as a result of the need to reduce NOx from 1.00 lb/MMBTU to about 0.30 lb/MMBTU. About eight months after the NOxOUT system was installed, the LNB and SOFA retrofit reduced the baseline to the NOxOUT system to about 0.43 lb/MMBTU. This, of course, had the expected benefit with regard to reagent consumption, reducing reagent consumption about 60%. This also had a relatively minor impact on heat rate because it was more difficult to maintain steam temperatures as a result of the combustion system retrofit.

It was believed that there was still significant room to improve reagent consumption if a means to address the variable FEGT could be implemented.[4] However, a commercially available approach did not exist during the first years of system operation. In 1996, a new control system - implementing sensors and control methods previously unavailable for SNCR control - was installed and demonstrated at Salem Harbor #3.

The new control system - provided by the original SNCR system vendor, Nalco Fuel Tech, - utilizes signals from optical FEGT instruments and steam flow to control the injection zones and injection rate.[5] Two FEGT instruments were supplied to monitor both sides of the split furnace. Piping modifications were also made to the NOxOUT system in order to provide the system independent injection zone control, which had not been provided on the original system. With the use of the FEGT instruments, the control system could more accurately track the proper injection point in the furnace and respond to rapid system changes. With the piping changes, the NOxOUT system could effectively bias the reagent injection rate between levels in response to changes in temperature. Another feature of the control system is the use of a continuous ammonia slip signal that indicates transients of high ammonia slip. With this signal, the NOxOUT control system can detect and respond to conditions that would otherwise produce high ammonia slip.

The benefits of this control system are presented in Figure 9, which shows the total operating cost of NOx reduction, including reagent consumption rate and heat rate penalty (normalized to the historical 1994, 1995 and early 1996 values). It is notable that the FEGT instrument was installed prior to placing the new control algorithms in operation. With the FEGT instrument, the operators modified their soot blowing operations, which created a benefit to the reagent consumption and eliminated the heat rate penalty that previously existed. With the full controls in place, reagent consumption was about 33% of the historical 1994, 1995, and early 1996 values. In addition to the improvement in reagent consumption, Salem Harbor #3 experienced a significant reduction in ammonia slip[5].

Figure 9. Normalized Oper. Cost of Reducing NOx, Salem Harbor #3



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Summary

In this report, operators of three different facilities equipped with urea SNCR (NOxOUT) found ways of operating the facility in a manner that significantly reduced the total operating cost of reducing NOx when using the SNCR system. In all cases the systems were initially providing the designed and guaranteed performance that the vendor originally promised. However, with experience, the operators found methods of improving on the performance of the system. And, although each situation involved the same technology on coal-fired boilers, significantly different methods were employed to improve the performance. Below, the key features of these programs and lessons learned are discussed.

- Reducing the baseline NOx will usually produce the greatest improvement in urea consumption. This can be done through combustion adjustments, reburning, or fuel substitution. However, these methods will frequently increase other operating costs - most notably, fuel cost - which must be considered in any analysis. At Edge Moor, Somerset and Salem Harbor the operators found methods of operating the boilers that significantly reduced baseline NOx. In all cases, the improved reagent consumption was balanced against other costs, such as increased heat rate and/or the additional cost of firing a premium fuel. Edge Moor #3's gas availability gives it certain flexibility during summer months when gas is less expensive. Somerset's ABMS enables it to maintain furnace conditions that offer low NOx and good heat rate, enabling large reductions in reagent consumption. At Salem Harbor, the LNB + SOFA retrofit provided a substantial reduction in NOx with a small penalty to heat rate.
- In cases where NOx has been minimized, efforts to improve reagent utilization should be taken. Of the parameters the operator can impact, reagent utilization is most affected by reaction temperature and distribution. Providing that distribution is optimized, the operator must optimize utilization with respect to temperature, which requires balancing reagent savings against the risk of high ammonia slip and/or increased heat rate. On furnaces such as at Salem Harbor #3 that have highly variable FEGT's at any fixed load due to slagging, oxygen control, or other reasons, this balance can be very delicate. Newly developed instrumentation and control methods used at Salem Harbor offer the ability to maintain this balance and realize the dual benefits of reduced reagent consumption - lower operating cost with lower ammonia slip - while avoiding the risk of high ammonia slip during transients. In the cases of Edge Moor and Somerset, unlike Salem Harbor, FEGT is fairly stable. Therefore, at these facilities it is easier to optimize reagent injection with respect to temperature without additional instrumentation. At these two facilities the control system improvements used at Salem Harbor - if implemented at Edge Moor or Somerset - would provide operating benefits, but not as great as those experienced at Salem Harbor.

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