SECOND GENERATION ADVANCED REBURNING FOR HIGH EFFICIENCY NO_x CONTROL

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Abstract

This project is designed to develop a family of novel NO_x control technologies, called Second Generation Advanced Reburning (SGAR) which has the potential to achieve 90+ NO_x control in coal fired boilers at a significantly lower cost than Selective Catalytic Reduction. The tenth reporting period in Phase II (January 1 – March 31, 2000) included proof-of concept tests in the 10×10^6 Btu/hr Tower Furnace. Several variants of Second Generation Advanced Reburning (SGAR) were studied, including AR-Lean, AR-Rich, reburning + SNCR, and Multiple Injection Advanced Reburning (MIAR). Tests demonstrated that the SGAR performance was the most effective under MIAR conditions achieving maximum overall NO_x reduction of 96%.

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Executive Summary

This project is designed to develop a family of novel NO_x control technologies, called Second Generation Advanced Reburning (SGAR) which has the potential to achieve 90+ NO_x control in coal fired boilers at a significantly lower cost than SCR. The tenth reporting period in Phase II (January 1 – March 31, 2000) included proof-of concept tests in the 10×10^6 Btu/hr Tower Furnace. The objective of the tests was to provide data that could be used to project full-scale performance.

Several variants of Second Generation Advanced Reburning (SGAR) were studied, including AR-Lean, AR-Rich, reburning + SNCR, and MIAR. All variants were evaluated both with and without promoters. The N-agent and promoter consisted of urea and sodium carbonate, respectively. A high-sulfur, bituminous Illinois coal was used as the main fuel for all tests. Natural gas was used as the reburning fuel.

Tests demonstrated that the SGAR performance was the most effective under MIAR conditions achieving overall maximum NO_x reduction of 96%, from 825 ppm to 32 ppm. The Phase II project performance goal to reduce NO_x by up to 95% with net emissions less than 0.06 lb/10^6 Btu has been met.

1.0 Proof-of-Concept Tests

The activities during the tenth reporting period in Phase II (January 1 – March 31, 2000) included proof-of concept tests in the 10×10^6 Btu/hr Tower Furnace described in previous report (Zamansky, V.M., Lissianski, V.V., and Maly, P.M. (1999) Second Generation Advanced Reburning for High Efficiency NO_x Control. *Quarterly Report No. 9, DOE Contract No. DE-AC22-95PC95251*). The objective of the tests was to provide data (along with previously obtained sub-scale results) that could be used to project full-scale performance. Several variants of Second Generation Advanced Reburning (SGAR) were studied, including AR-Lean, AR-Rich, reburning + SNCR, and Multiple Injection Advanced Reburning (MIAR). All variants were evaluated both with and without promoters.

A high-sulfur, bituminous Illinois coal was used as the main fuel for all tests. An air-staging system was applied to the primary burner to simulate a commercial low-NO_x burner, thus providing initial NO_x concentrations similar to those obtained in full-scale boilers. Natural gas was used as the reburning fuel. Reburning fuel transport media included air and nitrogen, which simulates an inert media such as steam. The N-agent and promoter consisted of urea and sodium carbonate, respectively. Basic test conditions were those found to be optimum in previous sub-scale experiments.

1.1 AR-Lean Tests

AR-lean tests were conducted in which the N-agent and promoter were injected along with the OFA at 1925^{o}F. Flow rate of sodium carbonate was varied such that the concentration of sodium in the flue gas varied from 0 to 150 ppm. Reburning heat inputs of 6% and 10% were tested. Figure 1 shows results obtained at 6% reburning. Basic reburning provided 8% and 28% NO_x control with air and nitrogen transport, respectively (promoter concentration equals zero in Figure 1). These values increased to 49% and 65% for unpromoted AR-Lean. Addition of sodium carbonate caused performance to increase significantly. With nitrogen transport, NO_x control increased from 65% with no promoter to 76% with 150 ppm Na.

Figure 2 shows AR-Lean results obtained at 10% reburning. Basic reburning provided 15% and 40% NO_x control with air and nitrogen transport, respectively. These values increased to 51% and 66% for unpromoted AR-Lean. Addition of sodium carbonate caused performance to increase minimally. With nitrogen transport, NO_x control increased from 66% with no promoter to 69% with 150 ppm Na. Thus the promoter was significantly more effective at 6% reburning than at 10% reburning.

1.2 AR-Rich Tests

AR-Rich tests were conducted in which the N-agent and promoter were injected into the fuel-rich reburning zone at 2150^{o}F and OFA was injected at 1925^{o}F. The concentration of sodium in the flue gas was varied from 0 to 150 ppm. Reburning heat inputs of 6% and 10% were tested. Figure 3 shows results obtained at 6% reburning. Basic reburning provided 1% and 21% NO_x control with air and nitrogen transport, respectively. These values increased to 38% and 52% for unpromoted AR-Rich. Addition of sodium carbonate had a minimal impact on performance.

Figure 4 shows AR-Rich results obtained at 10% reburning. Basic reburning provided 12% and 35% NO_x control with air and nitrogen transport, respectively. These values increased to 41% and 58% for unpromoted AR-Rich. Addition of sodium carbonate again had minimal effect. Thus AR-Rich performance was worse than that of AR-Lean, and the promoter had a lesser impact upon performance.

1.3 Reburning + SNCR Tests

Studies were conducted in which reburning was coupled with SNCR. In the first series, OFA was injected at 2350^{o}F and urea and promoter were injected at 1940^{o}F. As shown in Figure 5, NO_x reductions provided by basic reburning at 20 % reburning were

48% with air transport and 66% with nitrogen transport. With addition of urea, performance increased to 64% for air and 74% for nitrogen. Addition of sodium carbonate had minimal effect.

Reburning + SNCR tests were then conducted at 10% reburning. Two additive injection temperatures were tested, including 1855^oF and 2020^oF. OFA remained at 2350^oF for all tests. As shown in Figure 6, basic reburning provided 20% NO_x control with air transport and 58% with nitrogen transport. With additive injection at 1855^oF, NO_x reductions were 47% with air transport and 75% with nitrogen. With additive injection at 2020^oF, NO_x reductions were 51% with air transport and 69% with nitrogen. The promoter again had minimal impact on performance.

In summary, for reburning + SNCR maximum achievable performance was better with additive injection at 1855^oF than at 2020^oF. Similar overall performance levels were obtained at 10% and 20% reburning, although it is noted that at 10% reburning more urea is required and at 20% reburning more natural gas is required.

1.4 MIAR Test Results

Several MIAR variants were tested in an attempt to optimize overall process performance. The first MIAR tests involved AR-Rich + AR-Lean. The first N-agent was injected at 2200^oF. The second N-agent and promoter were injected with the OFA at 2000^oF. Reburning heat input was 10%. As shown in Figure 7, basic reburning provided 15% NO_x control with air transport and 44% with nitrogen transport. AR-Rich NO_x reductions were 42% with air transport and 58% with nitrogen. MIAR NO_x reductions were 75% with air transport and 78% with nitrogen. The sodium promoter had minimal impact on performance.

MIAR tests were then conducted involving AR-Lean + SNCR. The first N-agent was injected along with the OFA at 1980^oF. The second N-agent was injected at 1850^oF. Two reburning heat inputs were tested: 6% and 10%. At 10% reburning, sodium promoter was injected along with the second N-agent. As shown in Figure 8, basic reburning provided 15% NO_x control with air transport and 51% with nitrogen transport. AR-Lean NO_x reductions were 48% with air transport and 64% with nitrogen. MIAR NO_x reductions were 75% with air transport and 84% with nitrogen. The sodium promoter again had minimal impact on performance.

For the MIAR tests at 6% reburning, the sodium promoter was injected along with the first N-agent. As shown in Figure 9, basic reburning provided less than 1% NO_x control with air transport and 26% with nitrogen transport. AR-Lean NO_x reductions were 28% with air transport and 64% with nitrogen. MIAR NO_x reductions were 75% with air transport and 84% with nitrogen. With sodium promoter, NO_x reductions increased to 73% with air transport and 91% with nitrogen.

Figure 10 shows overall NO_x reductions for each process component, including the burner air staging system, which simulates a low-NO_x burner. Staging provided 57% NO_x control. Basic reburning increased this to 70% (only 6% natural gas was used). Adding SNCR increased overall NO_x reduction to 85%. Adding AR-Lean (urea injection with OFA) increased performance to 94%. Overall NO_x reduction for the complete MIAR process, including sodium promoter, was 96%. Figure 11 presents these results as a function of exhaust NO_x emissions. The complete process caused NO_x emissions to decrease from a baseline concentration of 825 ppm to 32 ppm. *Thus the performance goal of Phase II to reduce NO_x by up to 95% with net emissions less than 0.06 lb/10^6 Btu has been met.*

2.0 Future Work

Future activities will include comparison of Tower Furnace results with data from the CTT and BSF to determine the effects of scale upon SGAR performance. The Tower Furnace data will be used in conjunction with the process models to estimate performance in a full-scale boiler.

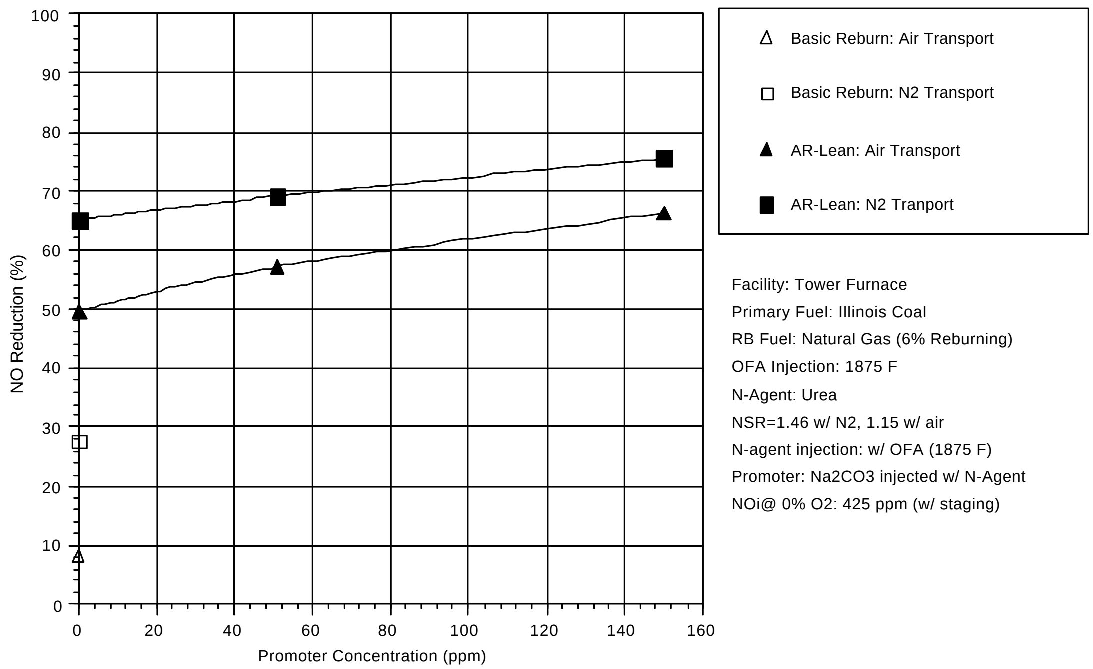

Figure 1. AR-Lean performance vs. promoter concentration at 6% reburning.

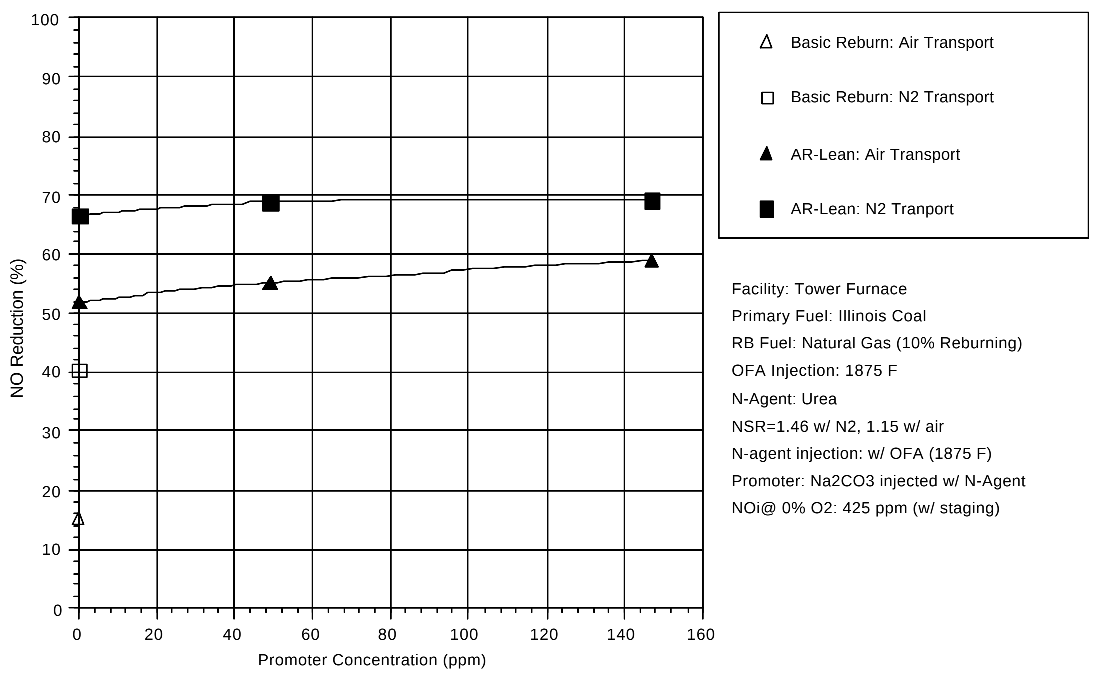

Figure 2. AR-Lean performance vs. promoter concentration at 10% reburning.

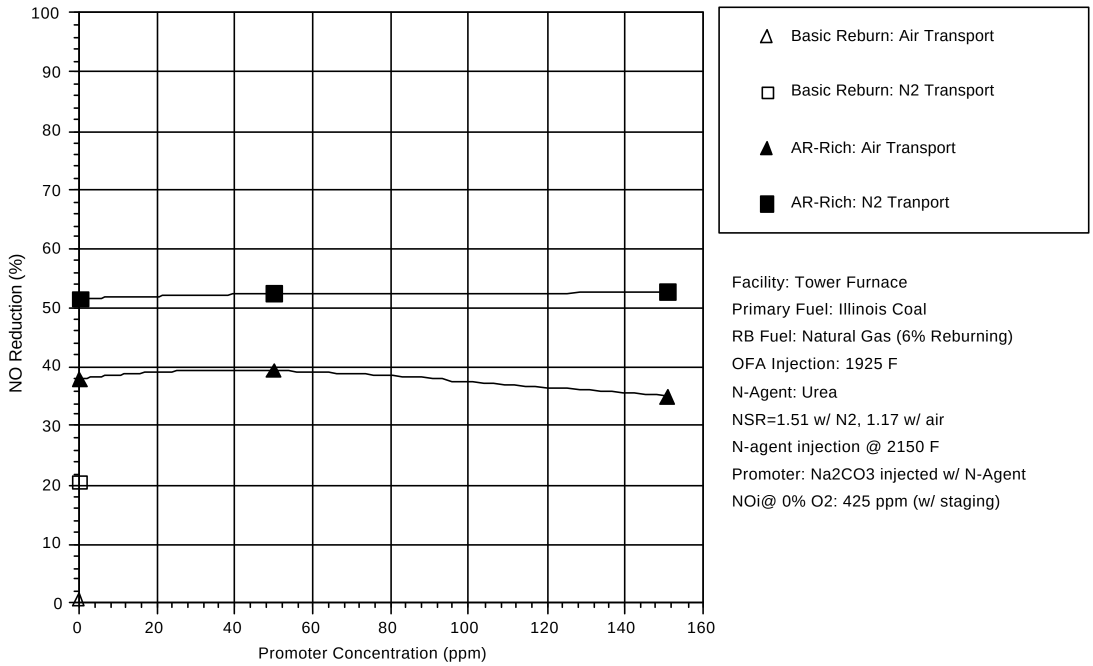

Figure 3. AR-Rich performance vs. promoter concentration at 6% reburning.

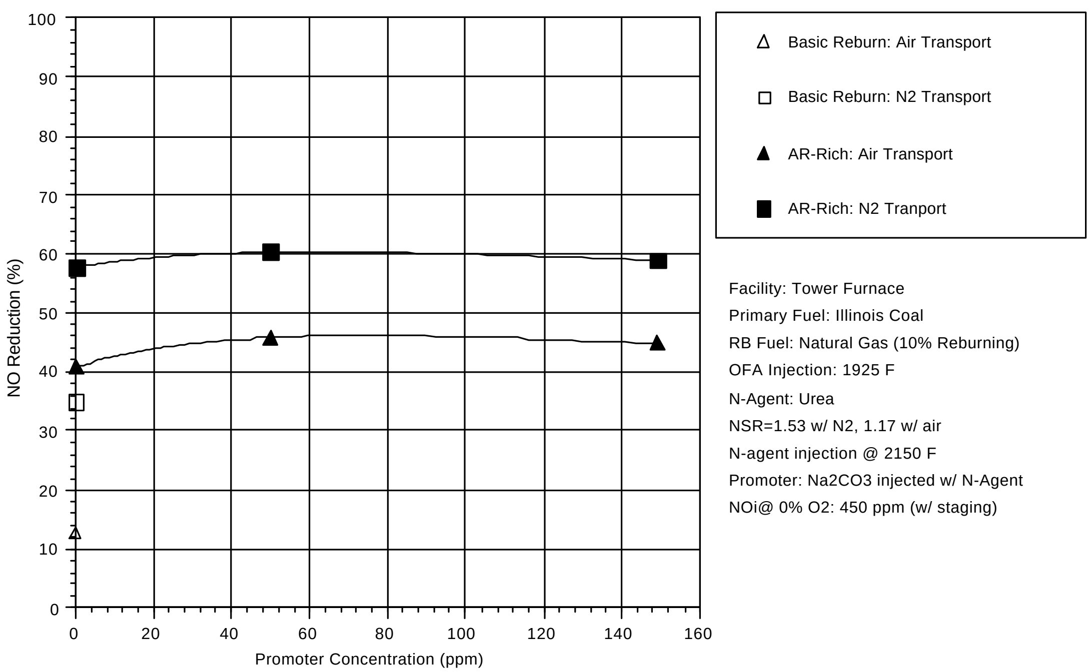

Figure 4. AR-Rich performance vs. promoter concentration at 10% reburning.

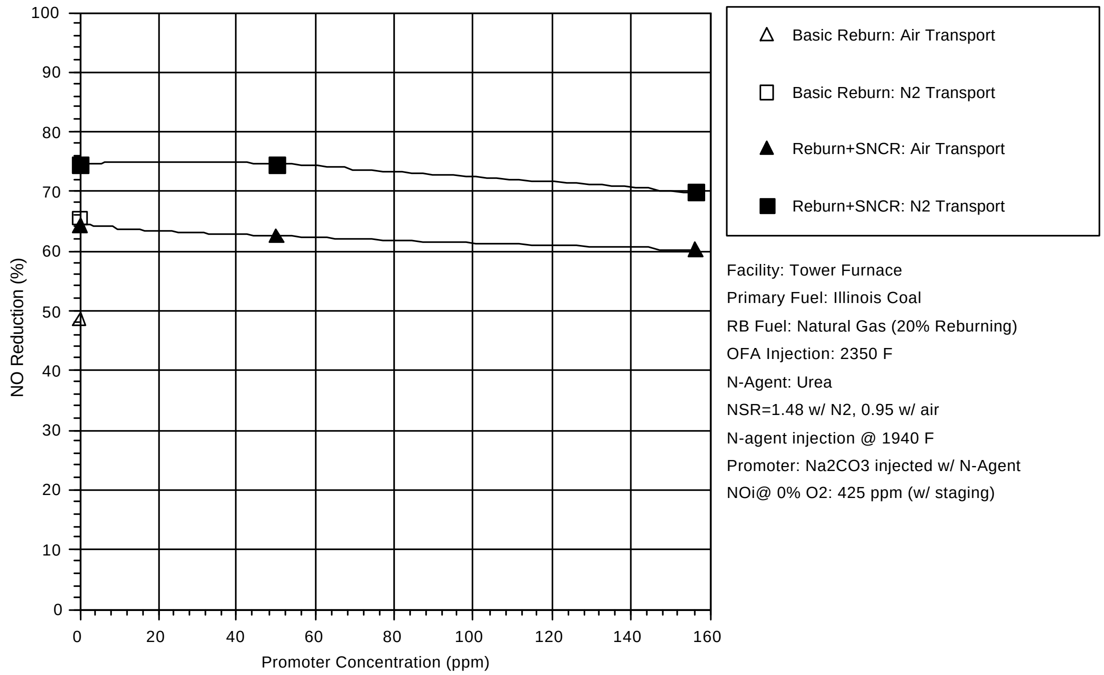

Figure 5. Reburning+SNCR performance vs. promoter concentration at 20% reburning.

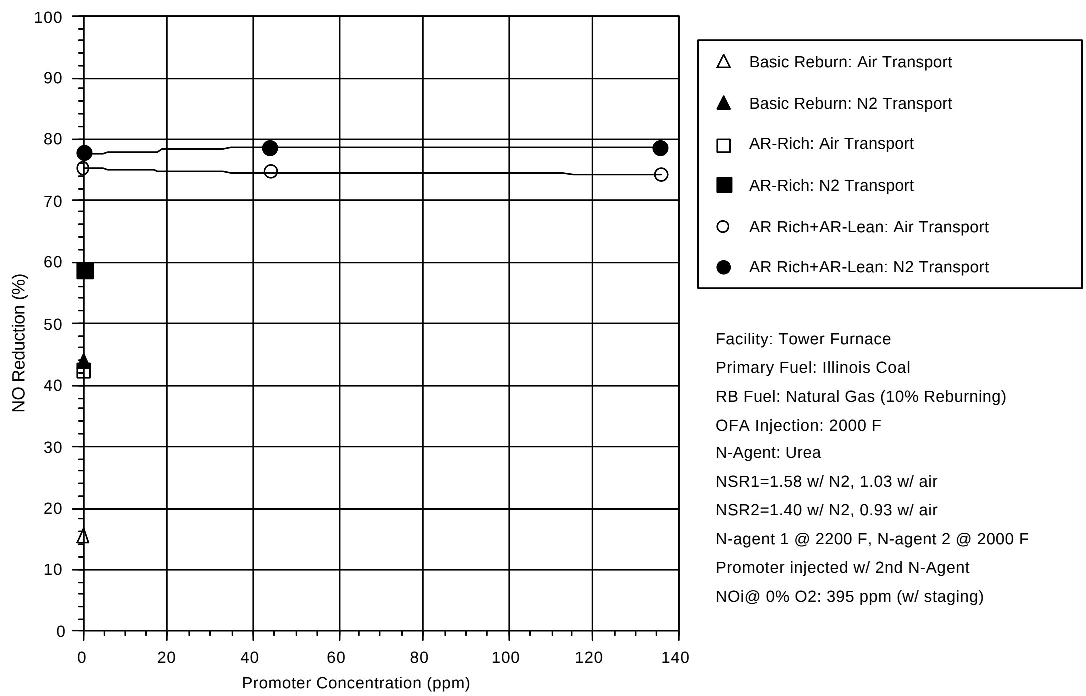

Figure 6. Reburning+SNCR performance vs. promoter concentration at 10% reburning.

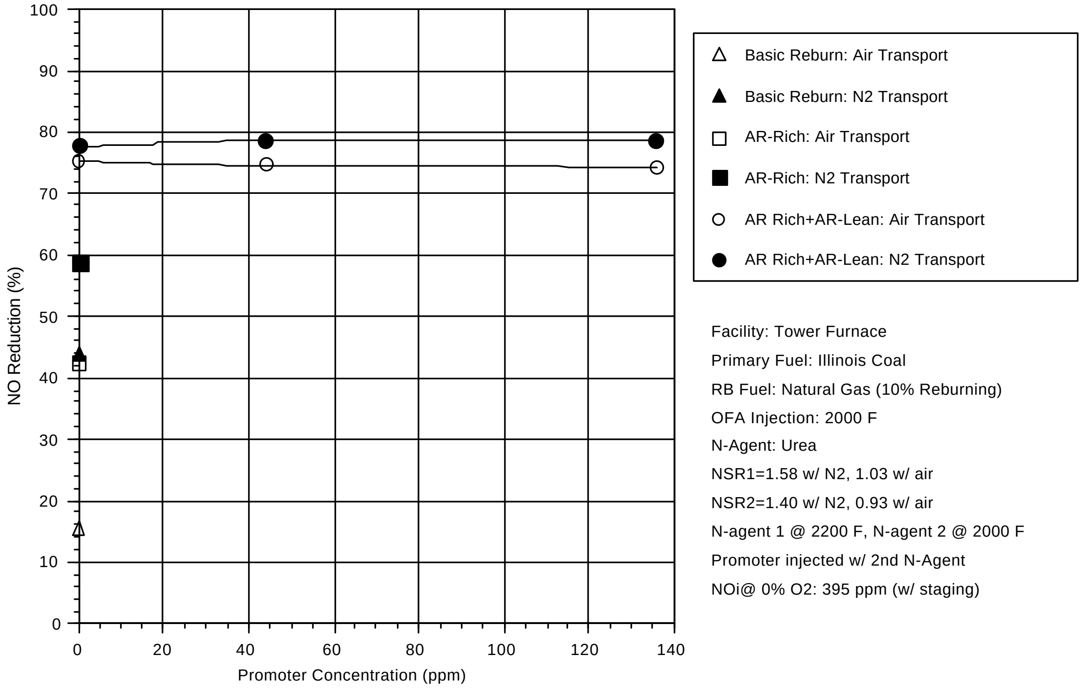

Figure 7. MIAR: combined AR-Lean + AR-Rich performance vs. promoter concentration at 10% reburning.

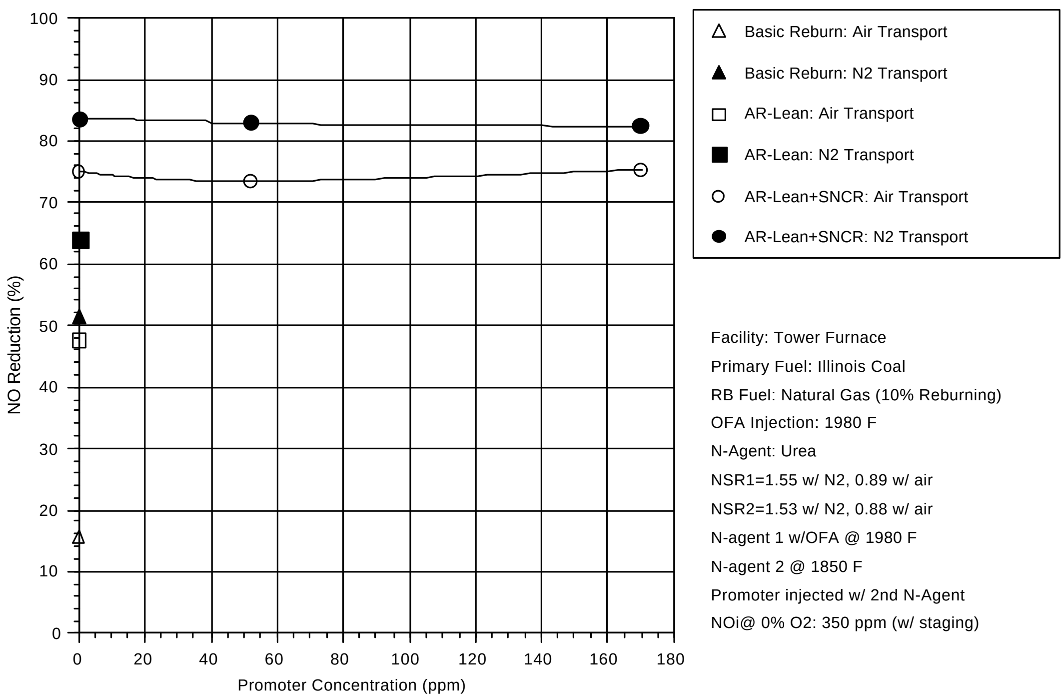

Figure 8. MIAR: combined AR-Lean + SNCR performance vs. promoter concentration at 10% reburning.

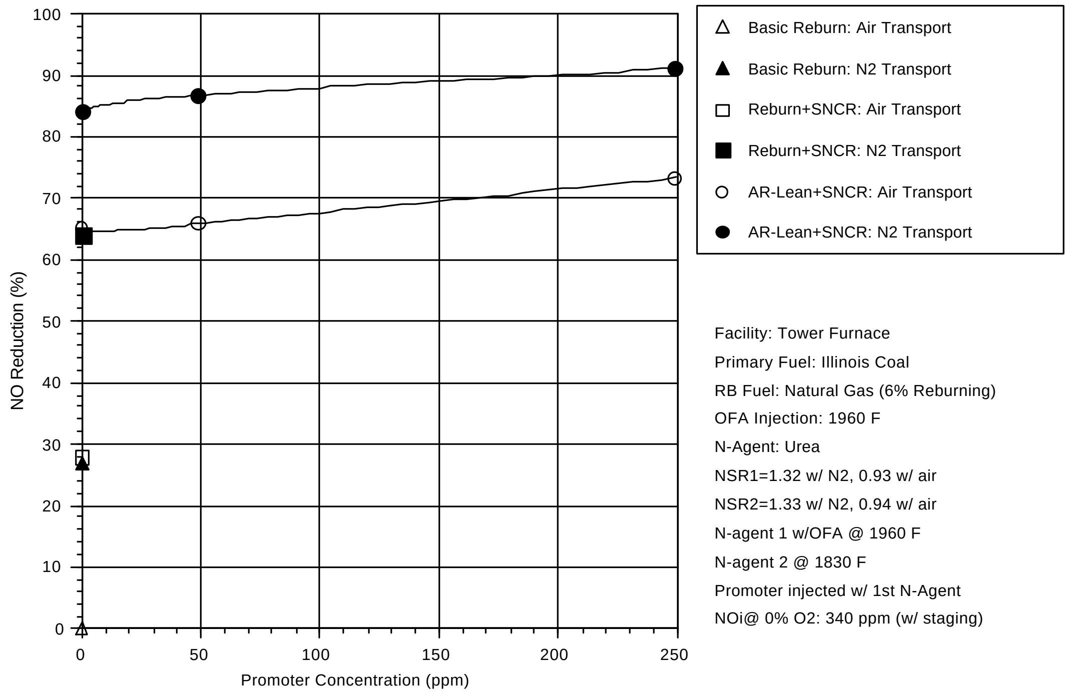

Figure 9. MIAR: combined AR-Lean + SNCR performance vs. promoter concentration at 6% reburning.

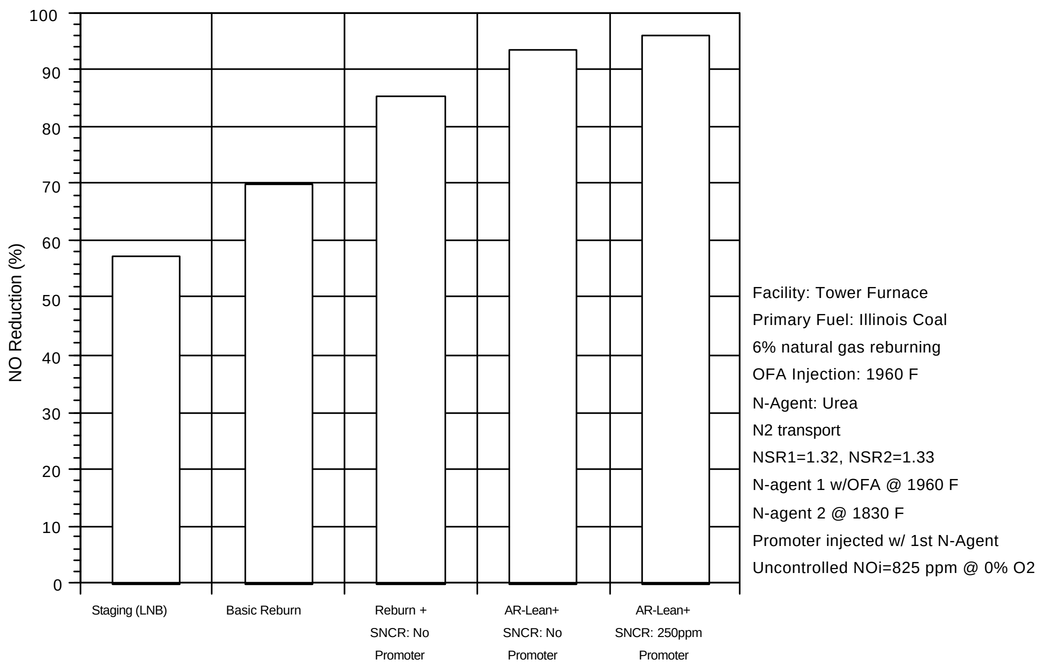

Figure 10. Overall MIAR NO_x reduction.

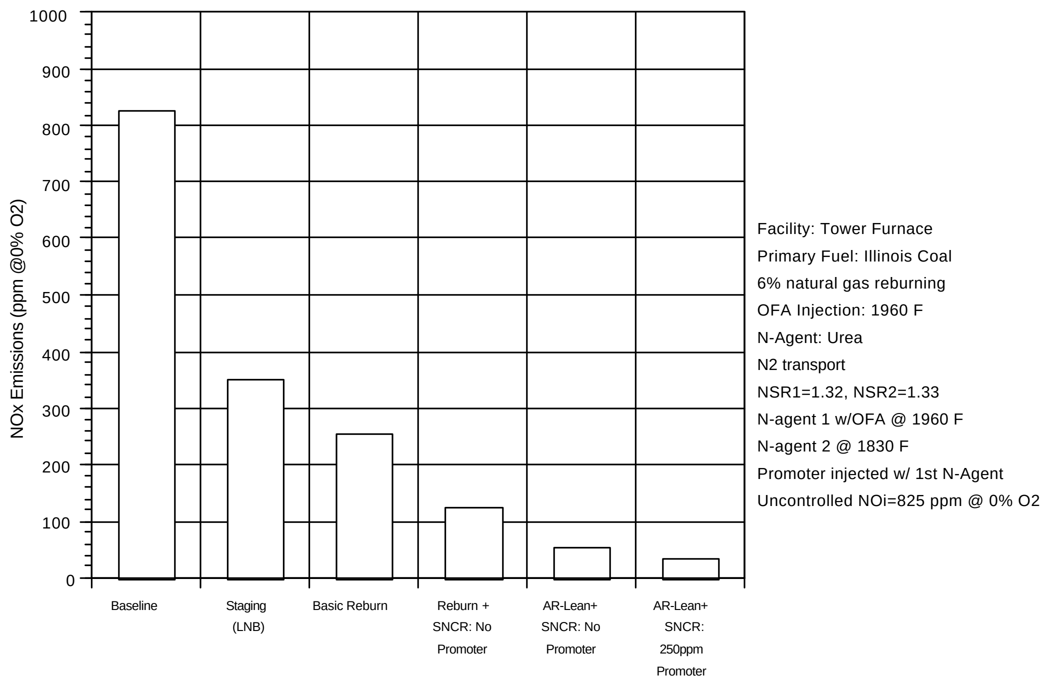

Figure 11. NO_x emissions achieved via MIAR in $10x10^6$ Btu/hr facility.