INTEGRATED DRY NO_x/SO_2 EMISSIONS CONTROL SYSTEM:

ADVANCED RETRACTABLE INJECTION LANCE SNCR

TEST REPORT

(NOELL ARIL Test Period: April 20, 1995 - December 21, 1995)
(DPSC Test Period: August 16 - 26, 1996)

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ABSTRACT

The DOE sponsored Integrated Dry NO_x/SO_2 Emissions Control System program (a Clean Coal Technology III demonstration) is being conducted by Public Service Company of Colorado. The test site is Arapahoe Generating Station Unit 4, a 100 MWe down-fired utility boiler burning a low-sulfur western coal. The project goal is to demonstrate up to 70 percent reductions in NO_x and SO_2 emission through the integration of: (1) down-fired low-NO_x burners with overfire air; (2) Selective Non-Catalytic Reduction (SNCR) for additional NO_x removal; and (3) dry sorbent injection and duct humidification for SO_2 removal.

The installation of the burners and overfire air system resulted in a decrease in furnace exit gas temperature of approximately 200°F. The temperature decrease reduced the effectiveness of the SNCR system at low loads. This report documents the third phase of SNCR tests (corresponding to the seventh test phase of the overall program), where an additional injection location was installed to increase the low-load NO_x removal performance. The new injectors consist of a pair of retractable in-furnace lances which were designed to provide a high degree of load following flexibility through on-line adjustments of the injection angle. The majority of the test program was conducted using retractable lances proved by NOELL (ARIL lances). Subsequently, an alternative lance design provided by Diamond Power Specialty Company was evaluated.

Before installation of the lances, the existing wall-injection location was capable of providing only 11 percent NO_x removal at 60 MWe (at an NH_3 slip limit of 10 ppm). With the new lances, NO_x removals in excess of 35 percent are achievable at the same load

and NH_3 slip limit. At loads of 43 to 60 MWe, NO_x removals with the lances range from 37 to 52 percent. At loads greater than 60 MWe, the wall-injection location is more efficient, and at loads of 70 to 100 MWe, NO_x removals range from 37 to 41 percent.

The coal mill-in-service pattern was found to have a large effect on both NO_x removal and NH_3 slip for injection at the new lance location. At 60 MWe, the NO_x removal at the 10 ppm NH_3 slip limit ranges from 28 to 52 percent depending on the mill-in-service pattern. Biasing the coal mills to provide uniform combustion conditions ahead of the injection location was found to be the best option for improving SNCR system performance under these conditions.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Jim Love, Arapahoe Plant Manager, and his maintenance and operating staff for the exceptional cooperation they have provided during this project. Special thanks are also deserved by Mr. Jerry L. Hebb of the Pittsburg DOE Federal Energy Technology Center (FETC), whose contribution is greatly appreciated. The advice and technical support provided by Mr. Jeff Stallings at Electric Power Research Institute (EPRI), has also been of great assistance throughout the project. Last, but definitely not least, is our appreciation to the many PSCo Engineering and Construction personnel and other contractors who have made the Integrated Dry NO_x/SO_2 Emissions Control System a success.

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B&W	Babcock & Wilcox
CEM	Continuous Emission Monitor
cfm	Cubic Feet per Minute
DCS	Distributed Control System
DOE	U. S. Department of Energy
DRB-XCL®	Dual Register Burner - Axially Controlled Low-NO_x
DSI	Dry Sorbent Injection
EPRI	Electric Power Research Institute
FEGT	Furnace Exit Gas Temperature
FERCo	Fossil Energy Research Corp.
FFDC	Fabric Filter Dust Collector
HVT	High Velocity Thermocouple
ID	Induced Draft (fan)
LCP	Local Control Panel
LNB	Low-NO_x Burner
MWe	MegaWatts (electrical)
MWg	MegaWatts (gross)
N/NO	Nitrogen-to-NO Ratio
OFA	OverFire Air
PLC	Programmable Logic Controller
ppm	Parts Per Million
ppmc	Parts Per Million Corrected to 3 percent O_2 level
ppm,d	Parts Per Million, Dry basis
ppm,w	Parts Per Million, Wet basis
PSCo	Public Service Company of Colorado
psig	Pounds per Square Inch Gauge
RATA	Relative Accuracy Test Audit
scfh	Standard Cubic Feet per Hour, measured at 1 atmosphere and 60°F
SNCR	Selective Non-Catalytic NO_x Reduction

EXECUTIVE SUMMARY

This test report summarizes the technical activities and results for one phase of a Department of Energy sponsored Clean Coal Technology III demonstration of the Integrated Dry NO_x/SO_2 Emissions Control System for coal-fired boilers. The project is being conducted at Public Service Company of Colorado's Arapahoe Generating Station Unit 4 located in Denver, Colorado. The project goal is to demonstrate up to 70 percent reductions in NO_x and SO_2 emissions through the integration of existing and emerging technologies including: (1) down-fired low-NO_x burners with overfire air; (2) Selective Non-Catalytic Reduction (SNCR) for additional NO_x removal; and (3) dry sorbent injection and duct humidification for SO_2 removal.

Due to the number of technologies being integrated, the test program has been divided into the following test activities:

- Baseline tests with the original combustion system (completed)
- Baseline tests with the original combustion system and SNCR (completed)
- Low-NO_x Burner (LNB)/Overfire Air (OFA) tests (completed)
- LNB/OFA/SNCR tests (completed)
- LNB/OFA/Calcium Injection tests (completed)
- LNB/OFA/Sodium Injection tests
- LNB/OFA/SNCR Dry Sorbent Injection tests (integrated system)
- Air Toxics Characterization (completed)

Testing performed after the low-NO_x combustion system retrofit showed that in addition to reducing the NO_x emissions significantly, the retrofit also reduced the temperature of the flue gas at the furnace exit by nominally 200°F. Since the SNCR process is very sensitive to changes in flue gas temperature, the effectiveness of the SNCR system at low loads was reduced. Recently, an additional SNCR injection location was installed in order to increase the NO_x removal performance at low loads. The new injectors consist of a pair of retractable in-furnace lances which were designed to provide a high degree of load following flexibility through on-line adjustments of the injection angle. The majority of the tests were completed using ARIL (Advanced Retractable Injection Lances) lances provided by NOELL, Inc. Subsequently, a second lance design provided by Diamond Power Specialty Company (DPSC) was evaluated. This report presents the results of the SNCR tests with the retractable injection lances.

The NOELL ARIL lance test program was conducted over the period of April 20 to December 21, 1995, and the DPSC lance tests were performed between August 16 and August 26, 1996. Completion of these SNCR tests was delayed due to some minor start-up problems with the lance control system, some more serious concerns regarding lance bending due to thermal stress, a planned Arapahoe Unit 4 turbine outage, and a two-week test burn of a Powder River Basin Coal. In total, approximately eleven weeks of SNCR tests were completed. The majority of the testing consisted of parametric variations aimed at defining the optimum injections locations (the existing wall injectors or the new retractable lances), lance injection angle, and chemical injection rate as a function of boiler load. The effect of operating the SNCR system with various coal mill out-of-service patterns was also assessed over the load range.

Ammonia slip is not currently regulated in Colorado. Lacking any regulatory requirements, it was assumed that a 10 ppm slip would be a reasonable target for the process. Figure S-1 shows the NO removal achievable at this limit as a function of load. The figure includes data from both the wall injectors and the ARIL lances, and clearly shows that the addition of the lances has substantially improved the low-load performance of the SNCR system. Before installation of the lances, the wall (Level 1) injectors were capable of providing only 11 percent NO removal at 60 MWe (Smith, et al., 1994b). With the ARIL lances, however, NO removals in excess of 35 percent are achievable at the same load and NH_3 slip limit.

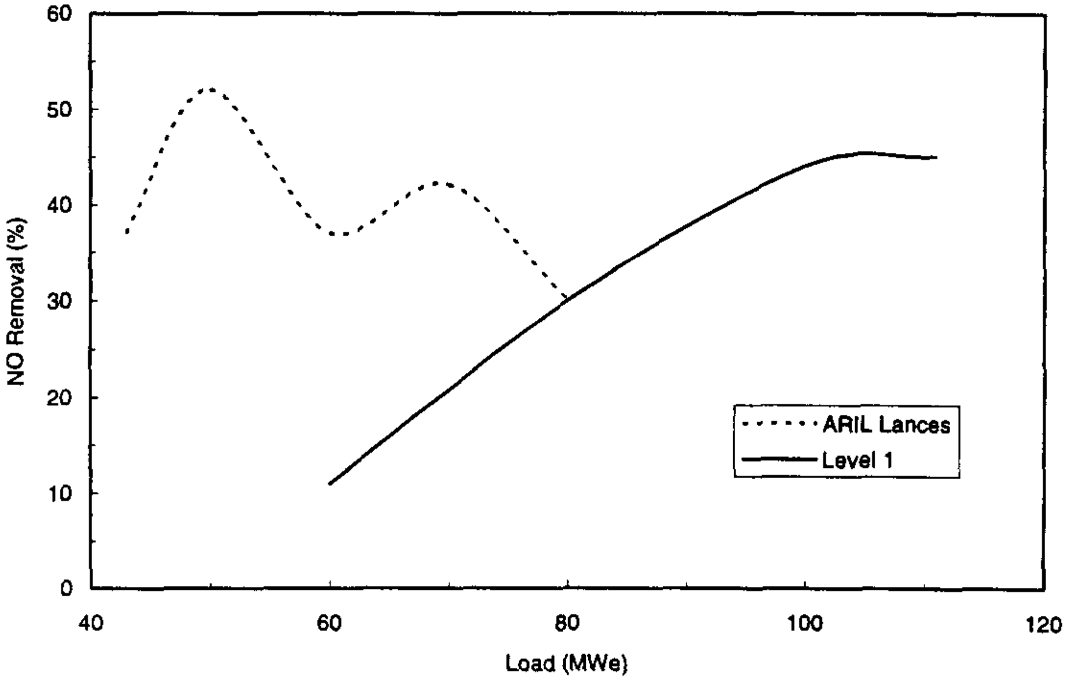

Figure S-1. NO Removal as a Function of Load for NH_3 Slip Limit of 10 ppm

The results of th
location for load
lance location is
lower temperatu
with the ARIL la
At loads of 70 to
ranging from 37
slip limit

This results in a urea distribution along the lance that is not as uniform as with the ARIL lance. As a consequence, the NO_x reduction performance is not quite as good. For instance, at 60 MWe and N/NO = 1, the ARIL lance can achieve 42 percent NO_x removal with less than 5 ppm slip. The DPSC NO_x removal was 36 percent with less than 5 ppm slip. The DPSC did successfully address some mechanical reliability issues and the lower NO_x reduction could possibly be overcome by proper lance location and further optimization.

Overall, the retractable and rotatable lances have significantly extended the low load performance of the SNCR system on Arapahoe 4. The test results of the DPSC lance were sufficiently positive that an additional lance has been ordered, and up to three additional weeks of testing is planned. These results will be included in the project final report.

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INTRODUCTION

Public Service Company of Colorado (PSCo) proposed the Integrated Dry NO_x/SO_2 Emissions Control System to the U.S. Department of Energy (DOE) as part of the third round of the Clean Coal Technology Program (CCT-III). The proposed system was the first demonstration of low-NO_x burners, overfire air (OFA) ports, and urea-based selective non-catalytic reduction (SNCR) on a top-fired-utility-coal boiler. The integrated system also includes dry sorbent injection (DSI) using both sodium- and calcium-based reagents and flue gas humidification to control sulfur dioxide (SO_2) emissions. Figure 1-1 shows a simplified schematic of the integrated system as implemented at PSCo's Arapahoe Unit 4.

The project's overall goal is to achieve up to 70% reductions in the emissions of NO_x and SO_2 through the integration of existing and emerging technologies, while minimizing capital expenditures and limiting waste production to dry solids that can be handled with conventional ash removal equipment. This innovative demonstration project is estimated to cost $27,411,000. It is funded by the DOE (50.0%), PSCo (43.7%), and the Electric Power Research Institute (6.3%).

The DOE and PSCo signed the cooperative agreement for the Integrated Dry NO_x/SO_2 Emissions Control System in March 1991. Installation of the integrated system began in July 1991, and was completed in August 1992. The test program began in August 1992, and all testing was scheduled for completion in late 1994. The addition of a new SNCR injection location has extended the test program through November 1997. Completion of the project is currently scheduled for June 1997.

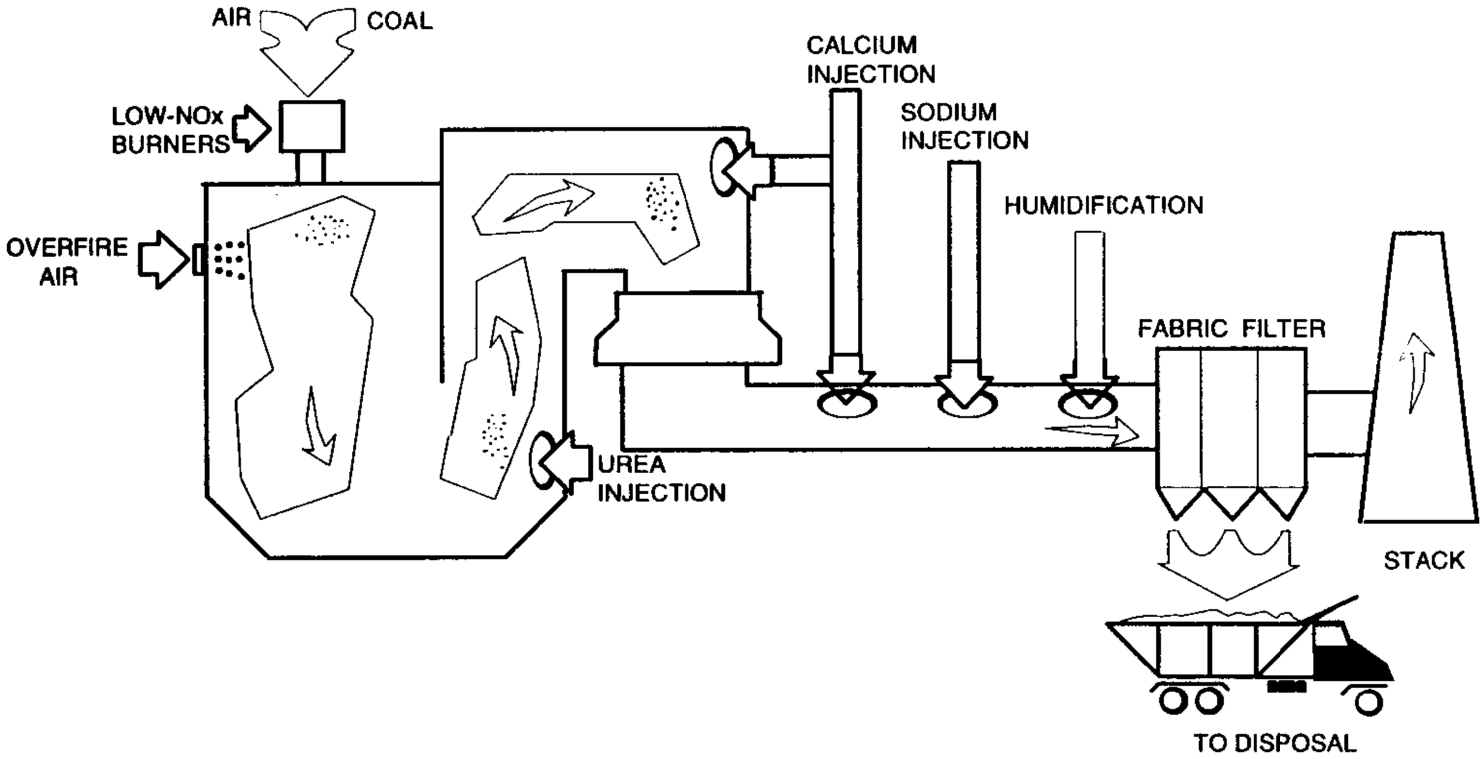

Figure 1-1. Arapahoe Unit 4 Integrated Dry NO_x/SO_2 Emissions Control System

PSCo is the project manager for the project, and is responsible for all aspects of project performance. PSCo has engineered the DSI system and the modifications to the flyash system, provided the host site, trained the operators, provided selected site construction services, start-up services and maintenance, and is assisting in the testing program.

EPRI provided technical assistance and advice on many of the technologies and also contributed to the project funding. B&W was responsible for engineering, procurement, fabrication, installation, and shop testing of the low-NO_x burners, overfire air ports, humidification equipment, and associated controls. They are also assisting in the testing program, and will provide for commercialization of the technology. NOELL, Inc. was responsible for the engineering, procurement and fabrication of the SNCR system. Fossil Energy Research Corp. is conducting the testing program. Western Research Institute is characterizing the waste materials and recommending disposal options. Colorado School of Mines conducted bench scale research on the mechanism and chemical kinetics of NO_2 formation reaction with dry sorbent injection. Stone & Webster Engineering is assisting PSCo with the engineering efforts. Cyprus Coal and Amax Coal are supplying the coal for the project, while Coastal Chemical, Inc. is providing the urea for the SNCR system.

The new SNCR injection location was installed in order to increase the NO_x removal performance at low loads. The new injectors consist of a pair of retractable in-furnace lances which were designed to provide a high degree of load following flexibility through on-line adjustments of the injection angle. This report presents the results of the SNCR tests with the new in-furnace lances. Results from the SNCR test series with the original injection configuration are documented in the Integrated Dry NO_x/SO_2 Emissions Control System: Low-NO_x Combustion System SNCR Test Report, (Smith, et al., 1994b).

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BACKGROUND

PSCo is conducting the project on Unit 4 at its Arapahoe Steam Electric Generating Station located in Denver, CO. Arapahoe Unit 4 is a top-fired unit rated at 100 MWe (megawatt-electric), which began operation in 1955. The boiler fires a low-sulfur (0.4%) Colorado bituminous coal as its main fuel source but also has 100% natural gas capability. PSCo uses Arapahoe Unit 4 as a load-following unit, with a normal capacity factor that ranges from 50 to 60%.

In the original firing configuration, the coal was injected through 12 intertube burners located on the roof of the boiler as shown in Figure 2-1. The intertube burner consists of a splitter box that separates into 20 smaller nozzles that inject the coal and primary air mixture evenly across the furnace roof. Secondary air was injected beside each of the individual coal nozzles, resulting in a checkerboard pattern of coal/primary air and secondary air streams. This firing system had no provision to control the mixing rate of the fuel and secondary air, resulting in high uncontrolled NO_x emissions (approximately 1.10 lb/MMBtu).

The Integrated Dry NO_x/SO_2 Emissions Control System uses low-NO_x burners, OFA, and SNCR to reduce NO_x emissions. The combustion modifications were expected to reduce NO_x by 50%, and the SNCR system was expected to increase the total NO_x reduction to 70%. The combustion modifications at Arapahoe Unit 4 consisted of replacing the intertube burners with Babcock & Wilcox (B&W) Dual Register Burner-Axially Controlled Low-NO_x (D&B-XCL®) burners, and installing three B&W Dual Zone

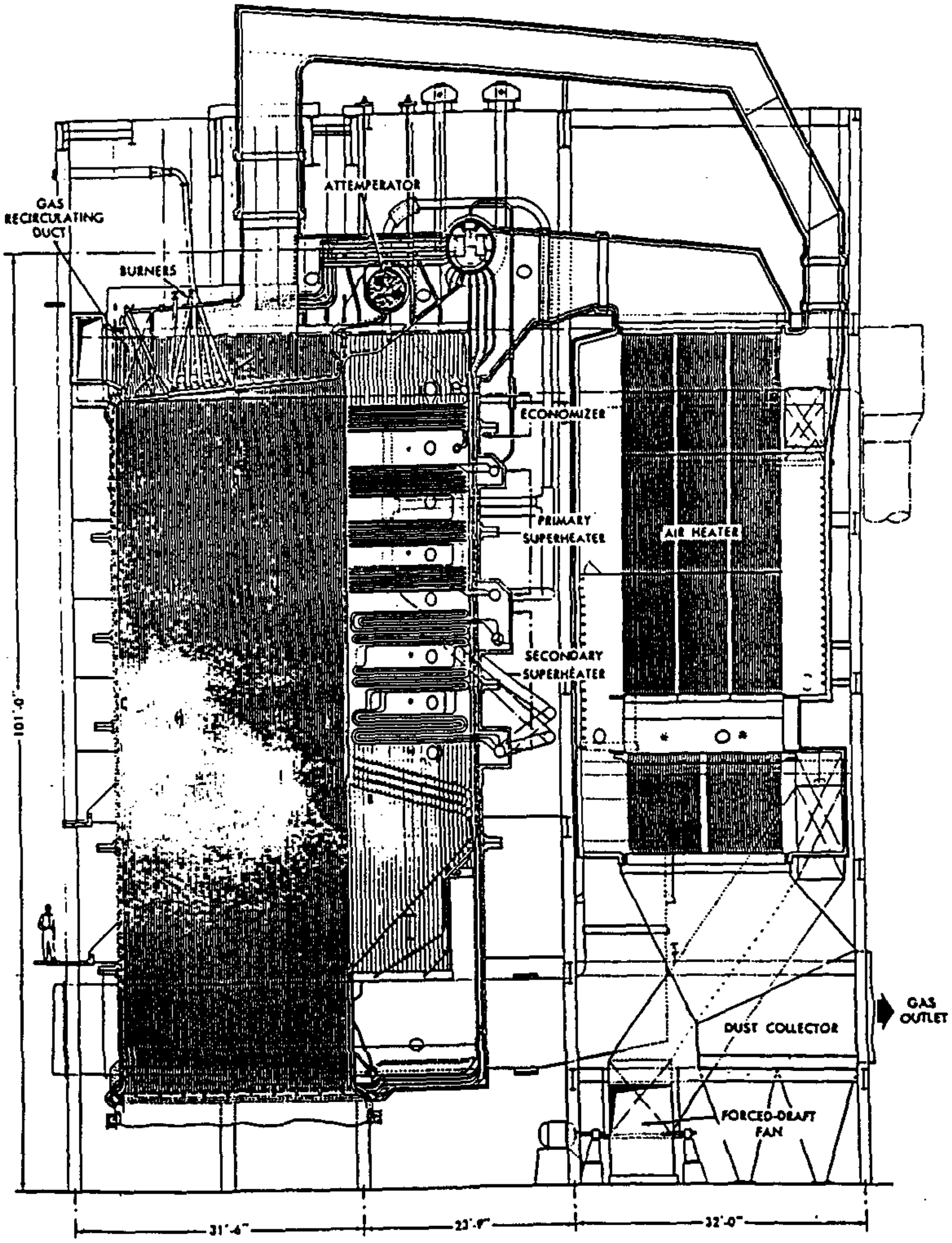

Figure 2-1. PSCo Arapahoe Unit 4

NO_x ports on the east and west sides of the furnace approximately 20 feet below the boiler roof. The 12 new burners were placed in 4 rows of 3 burners as shown in Figure 2-2. The boiler has a full division wall that separates the furnace into two approximately square sections. Each of the four Unit 4 attrition mills supplies primary air and coal to three of the burners. The coal piping allowed each mill to supply two burners in one furnace half and one in the other half.

The SNCR process involves the injection of either urea or ammonia (anhydrous or aqueous) into the combustion products where the gas temperature is in the range of 1600 to 2100°F. In this range, amidogen (NH_2) is released from the injected chemical which then selectively reacts with NO in the presence of oxygen, forming primarily nitrogen (N_2) and water (H_2O). Urea and ammonia each have their own optimum temperature and range within which NO_x reduction can occur. An example of such a temperature "window" is shown conceptually in Figure 2-3. At temperatures above the optimum, the injected chemical will react with oxygen (O_2) forming additional NO_x, thereby reducing the NO_x removal efficiency. At temperatures below the optimum, the injected chemical does not react with NO, resulting in excessive emissions of ammonia (NH_3), referred to as ammonia slip. Urea was selected as the base chemical for the system, because urea, unlike either aqueous or anhydrous ammonia, is not a toxic chemical, and thus on-site storage and handling concerns are minimized. It was also believed that the flue gas temperature in the available injection locations was too hot for efficient NO_x reduction using NH_3, and that urea would provide higher NO_x reductions and chemical utilization.

PSCo selected NOELL, Inc. to design and supply the urea-based SNCR system for the project. During the first phase of the SNCR testing (with the original combustion system), it was found that the NO_x reductions at low load were less than expected. A short-term test using aqueous ammonia achieved greater NO_x reduction than urea at low load. Although ammonia was more effective than urea at low load, it remained desirable to store urea on-site due to safety concerns. NOELL, Inc. subsequently designed and installed a system that allows on-line conversion of urea to ammonia

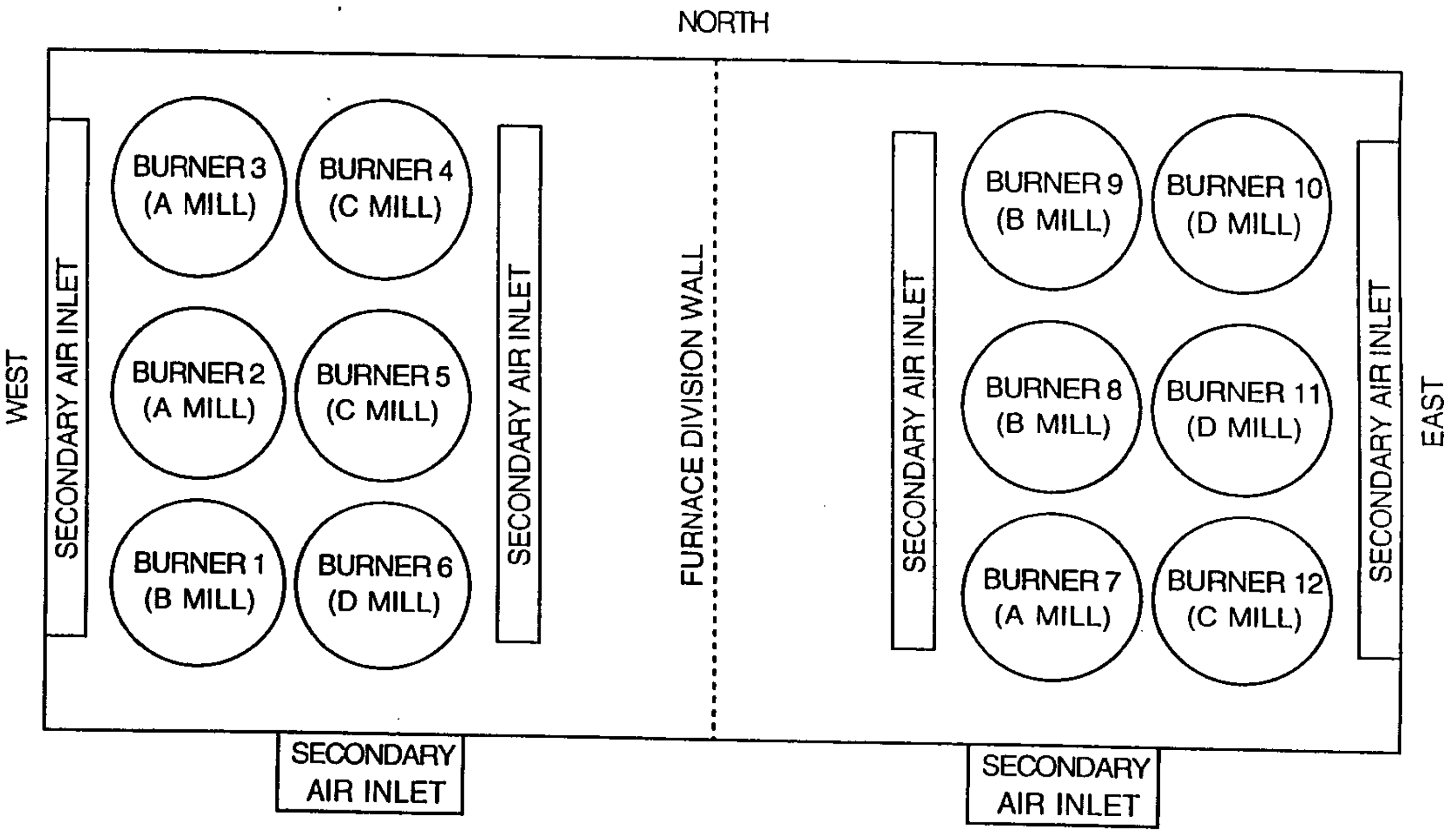

Figure 2-2. Plan View of Burner Arrangement after Retrofit

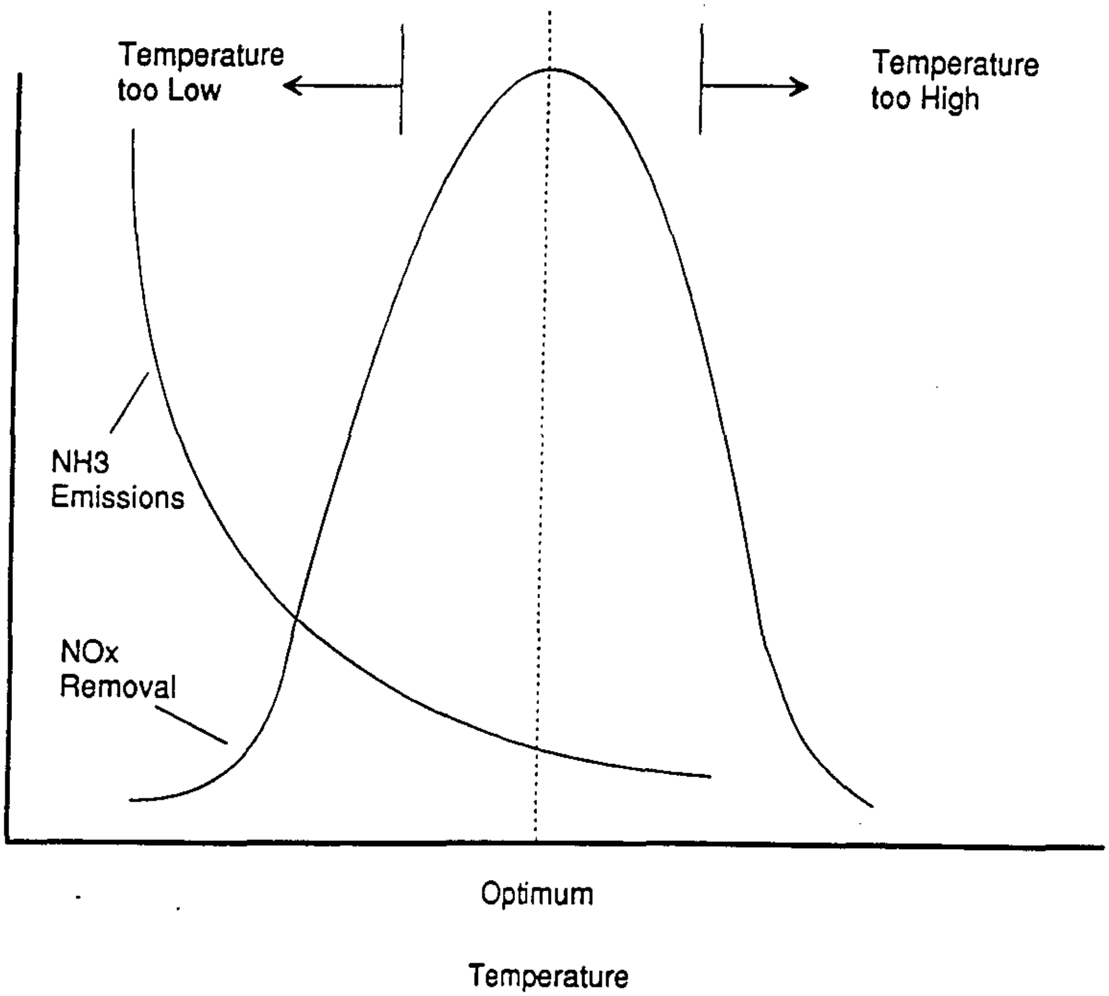

Figure 2-3. Conceptual Temperature Window for the SNCR Process

compounds. The performance of the conversion system was assessed during the second phase of SNCR testing (after the combustion system retrofit). A comparison of the NO_x removals with urea and urea converted to ammonia compounds ("converted urea") is presented in Figure 2-4 (Smith, et al., 1994b). The results show that although the on-line conversion system improved the low load performance, the improvement was not as large as desired at the lowest load (60 MWe). Note that the difference between NO and NO_x emissions was monitored on most tests during all three phases of SNCR testing, and the difference was found to be insignificant within the limits of detection. Thus, for the purposes of this report, NO and NO_x emissions are used interchangeably.

Recently, an additional SNCR injection location was installed to further increase low load performance. The new injection location makes use of a pair of unused sootblower openings in order to avoid the cost of installing new penetrations and the associated outage. Figure 2-5 shows the new location relative to the two existing injection locations on the rear (north) wall of the boiler. The new injectors consist of a pair of in-furnace lances which were designed to provide a high degree of load following flexibility through on-line adjustments of the injection angle.

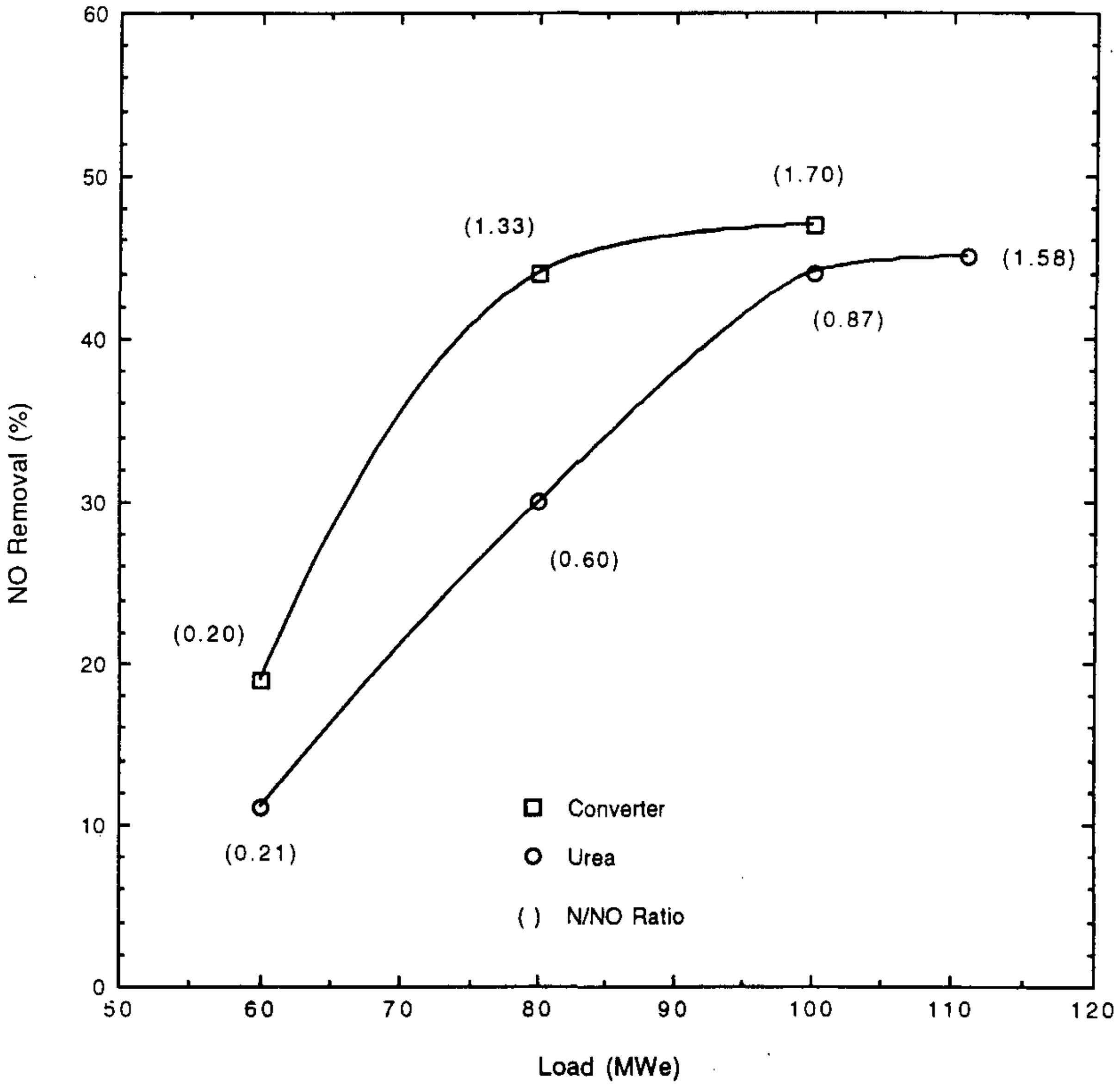

Figure 2-4. Comparison of NO Removals with Urea and Converted Urea for a Fixed NH_3 Slip Level of 10 ppm (Smith, et al., 1994b)

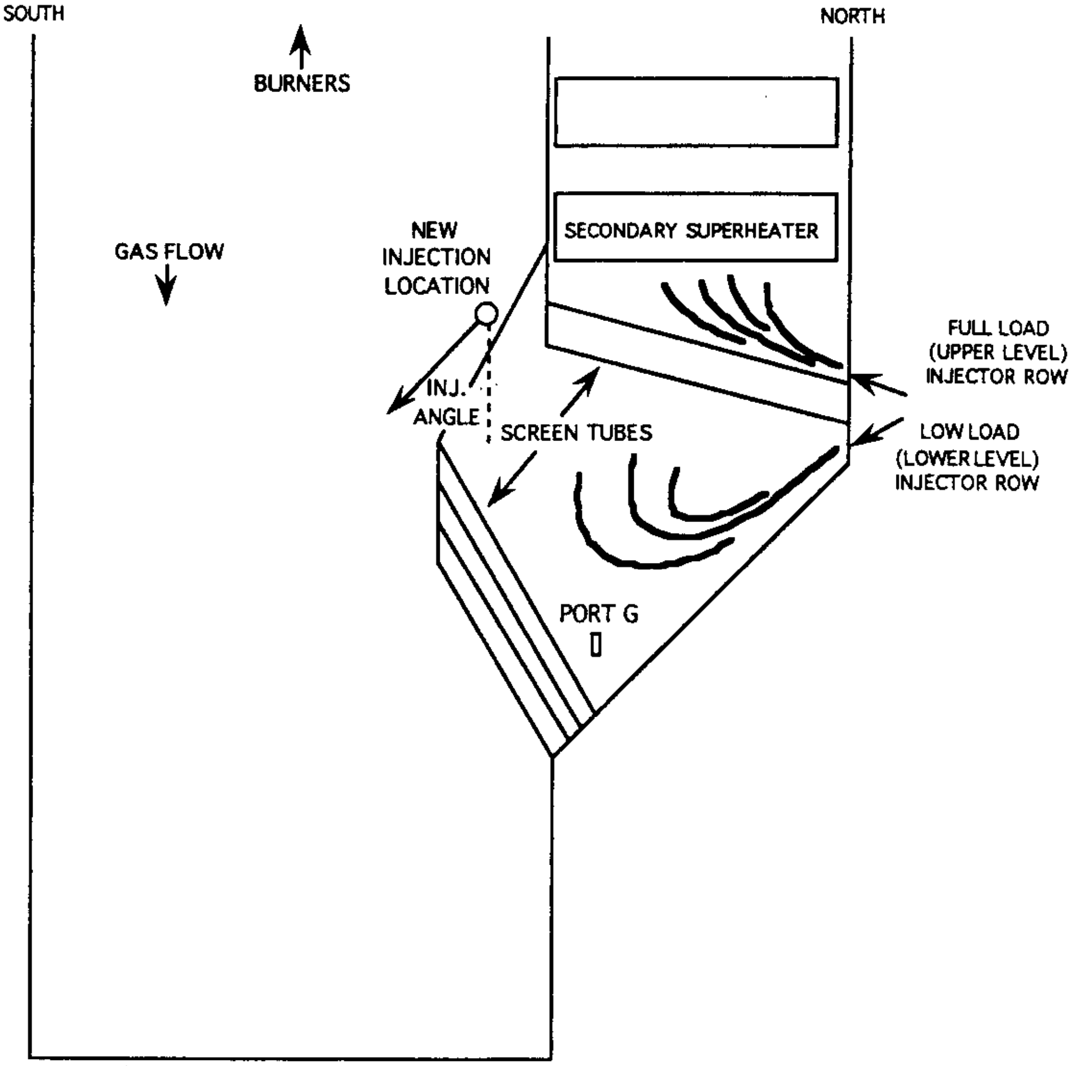

Figure 2-5. SNCR Injection Locations

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SNCR SYSTEM DESCRIPTION

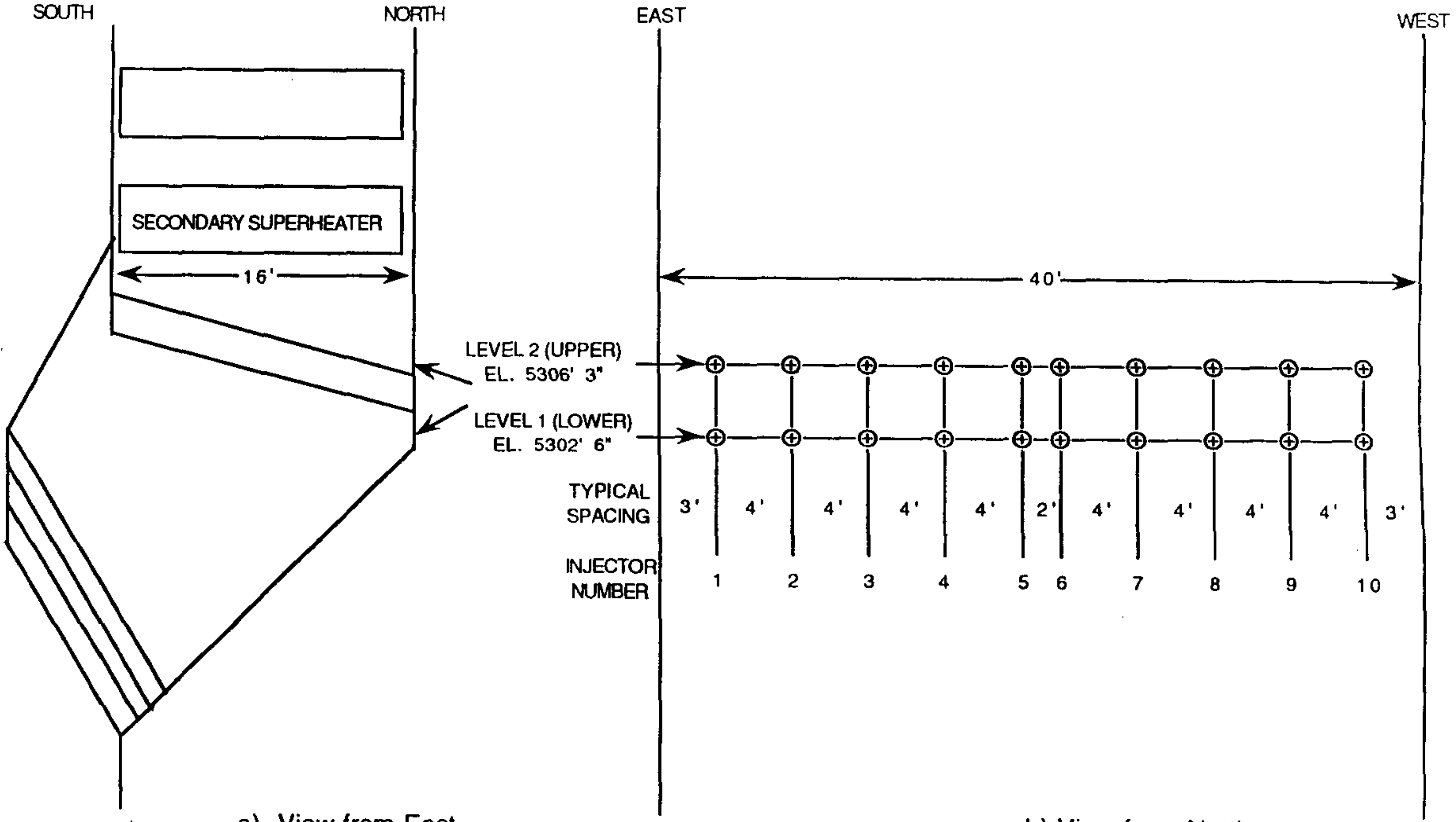
The NOELL, Inc. SNCR system is designed to achieve a high degree of mixing between the flue gas and the reducing reagent in short residence times. Before the detailed design of the SNCR system was completed, the basic temperature distribution and velocity flow patterns within the boiler were characterized through two separate efforts:

1. on-site flue gas temperature measurements using acoustic pyrometry and High Velocity Thermocouple (HVT) measurements, and
2. laboratory cold flow testing using a 1:10 scale model of the Arapahoe Unit 4 boiler.

These two efforts were discussed in detail in the report presenting the results of the first phase of the SNCR testing (Smith, et al., 1993).

As a result of the temperature measurement and cold flow modeling efforts, two rows of ten wall-mounted injection nozzles were installed on the Arapahoe Unit 4 boiler; one at elevation 5302'6" and one at elevation 5306'3". As shown in Figure 3-1, these two levels were placed immediately upstream and downstream of the second set of screen tubes. The injection angle for the lower level of nozzles (Level 1) is oriented 45° down from horizontal, and the angle of the upper level nozzles (Level 2) is 15° above horizontal.

The purpose of two levels of injectors was to provide some means of temperature control for the urea injection system over the load range. The upper nozzles were



a) View from East

b) View from North

Figure 3-1. Arapahoe Unit 4 SNCR Injection Nozzle Location expected to operate in the load range of 80 to 100 MWe. As the load was further reduced and flue gas temperatures decreased, the lower level would be used. During the initial test program, it was found that over the entire load range, either the flue gas was too cold or the residence times too low for effective NO_x reduction at the upper injection level. During injection at the upper level, NH_3 emissions were unacceptably high for all operating conditions. Therefore, the remainder of the tests, prior to installing the ARIL lances, were conducted using only the lower (Level 1) injectors.

Tests performed after the low-NO_x combustion system retrofit, showed that the effectiveness of the SNCR system at low loads was reduced. In addition to reducing the NO_x emissions significantly, the retrofit also reduced the temperature of the flue gas at the furnace exit nominally 200°F (Figure 3-2). Since the SNCR process is very sensitive to changes in flue gas temperature, this reduction made the flue gas temperature too cold for efficient NO_x removal even at the lower (higher temperature) Level 1 injection location.

At the conclusion of the second phase of SNCR testing, NOELL, Inc. proposed the concept of inserting a pair of lances through two unused sootblower openings at the furnace exit. These lances would provide access to a region of more optimal flue gas temperature at low loads. At higher loads, the lances would be retracted from the boiler, and urea injection would shift to the Level 1 injectors. The lances would be air-cooled, and the cooling air would also provide the injection momentum necessary to rapidly mix the urea with the flue gas. Automatic control of the injection angle would allow access to the optimum injection temperature under load following operation. Finally, the liquid flow along the length of the lance could be segmented in order to allow for optimization under various coal mill out-of-service conditions. Proof-of-concept tests were performed with a short lance that treated only a portion of the flue gas on the west side of the boiler. The results of these tests (summarized in Appendix A) showed that the concept had merit, and NOELL, Inc. proceeded with the design and fabrication of the lances.

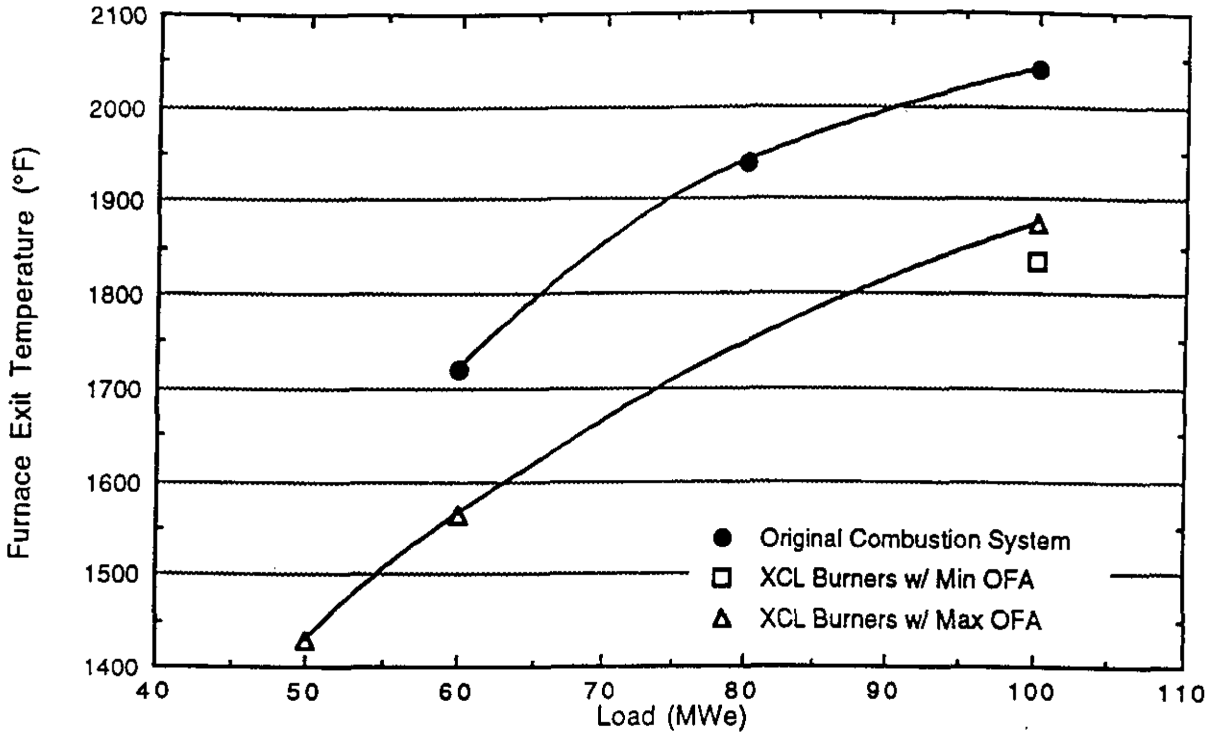


Figure 3-2. Furnace Exit Flue Gas Temperatures

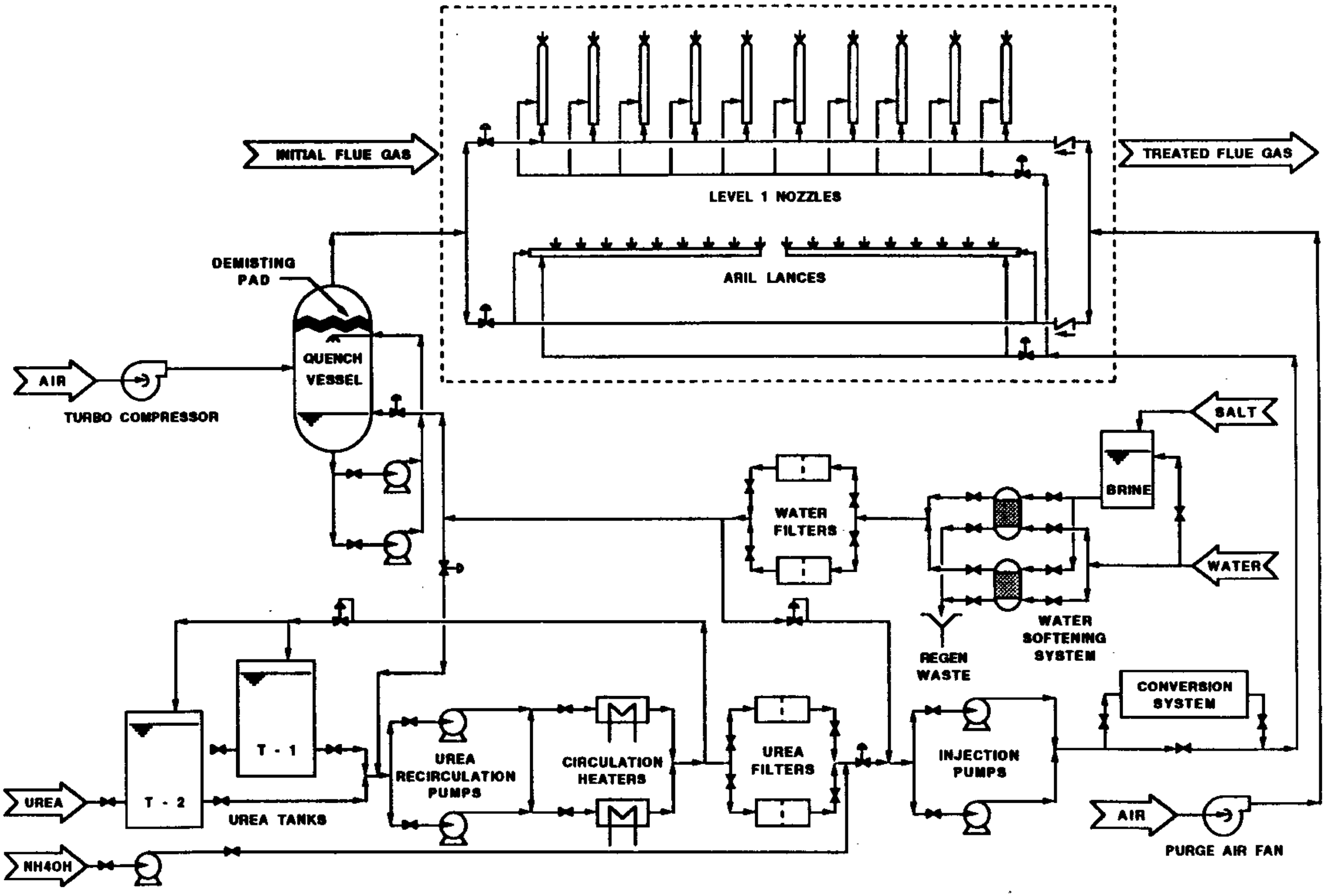


Figure 3-3. Arapahoe Unit 4 SNCR System Flow Diagram

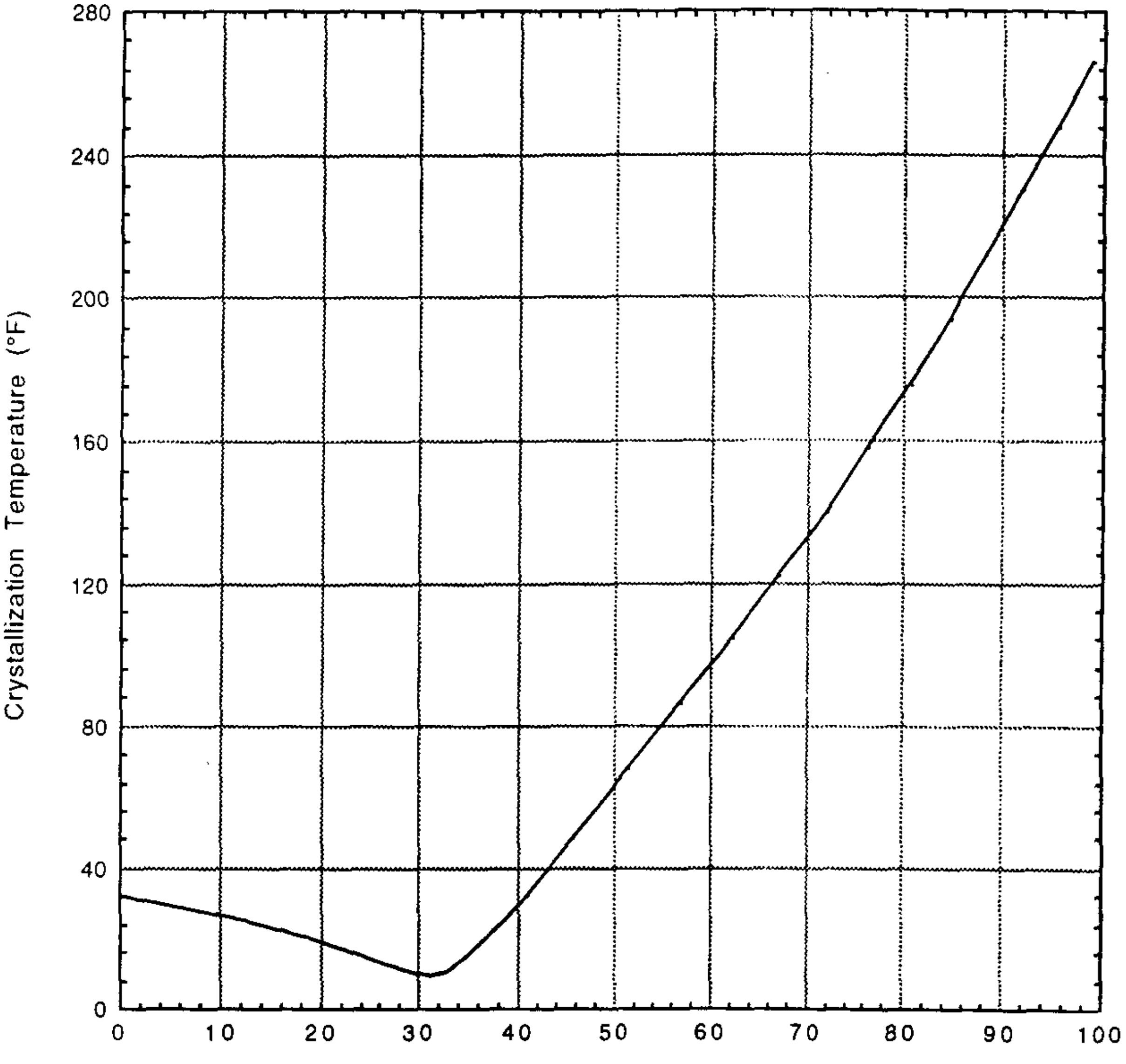


Figure 3-4. Crystallization Point of Aqueous Urea Solutions as a Function of Concentration

The system at Arapahoe Unit 4 uses one of two positive displacement pumps driven by AC variable speed drives. The variable speed drives allow the total liquid flow to be varied from 2.0 to 10.5 gpm. The ability to vary the total flow allows some control over the effective flue gas injection temperature. When flue gas temperature in the injection area is at or below the optimum temperature for effective NO_x removal, low flows are desirable so that the flue gas temperature is not significantly reduced by the evaporation of excess water. When the flue gas temperatures are higher than the optimum, larger flows allow some gas temperature cooling by evaporating the water before the urea begins reacting with the NO_x.

The ammonia conversion system was added after the initial SNCR test phase. This system first heats the diluted urea solution and then passes the chemical over a proprietary catalyst that causes the urea to convert to ammonia-based compounds. The system can be bypassed so that either urea or ammonia compounds may be injected as selected by the control operator. The ammonia conversion system was not utilized during the current phase of testing with the ARIL lances.

The SNCR system at Arapahoe Unit 4 uses NOELL, Inc.'s proprietary dual-fluid injection nozzles to distribute the urea or ammonia compounds evenly into the boiler. A centrifugal compressor is used to supply a large volume (up to 9000 scfm) of medium pressure (4 to 12 psig) air to the injection nozzles to help atomize the solution and rapidly mix the chemical with the flue gas. The volume of air supplied is controlled by variable inlet guide vanes and a variable diffuser assembly, which automatically delivers a preset discharge pressure. Upon exiting the compressor, the air passes through a quench vessel which cools the hot compressed air by recirculating, spraying, and evaporating water. The quench skid has redundant pumps for water recirculation, and the water level within the quench vessel is maintained automatically by the control system.

Purge air is used to keep the Level 1 injectors cool and free of ash build up when not in service. Purge air is also used to cool the lances after they have been retracted from the furnace. The air is supplied by a purge air fan which draws ambient air through a filter and silencer. The air is fed through the air lines not in use, up to the air header on the level not injecting urea, and then through the nozzles.

The urea injection system is controlled by a programmable logic controller (PLC). The PLC is operated using an IBM compatible computer through a man-machine software package, and controls all the functions of the system (equipment on/off, valves open/close, etc.), except for five local control systems in local control panels (LCPs): the two lances, the centrifugal compressor, the circulation heaters and the water softening skid. These LCPs control the equipment and receive the main commands and transmit the key information to and from the PLC. Some of the valves need manual pre-selection for redundant equipment, i.e., urea recirculation pump, quench pump, or filter inlet and outlet valves.

From the local computer, the SNCR system can be either manually set, or operated under automatic control. Under automatic control operation, the urea flow rate is set by a feed forward control function using a boiler load signal. The system also utilizes feedback control to trim the urea flow rate by ±30 percent. The feedback control loop uses a continuous stack NH_3 signal, although, it is also possible to use the stack NO_x signal.

4

MEASUREMENT METHODS

The evaluation of the performance of the NOELL, Inc. ARIL lances required the documentation of gaseous emissions and NH_3 slip levels, as well as boiler operational performance parameters. This section summarizes the measurement methods that were utilized during this phase of the SNCR tests. The test methods were completed according to the "Environmental Monitoring Plan" dated February, 1992. The methods and equipment used for the test program are described in greater detail in the following subsections.

4.1 Gas Analysis Instrumentation

An Altech 180 continuous emission monitoring (CEM) system was purchased as part of the Integrated Dry NO_x/SO_2 Emissions Control System and installed during the low-NO_x combustion system retrofit. The CEM system utilizes a Perkin Elmer MCS 100 infrared gas analyzer which is capable of continuously analyzing eight gas species simultaneously, using a combination of gas filter correlation and single beam dual wavelength techniques.

The analyzer cycles through and measures all eight gas species in approximately 22 seconds. In that time, two readings are made for each gas species to be measured. The first reading is a reference value at a known wavelength and gas concentration (either 0 or 100 percent), and the second is a measured reading to determine the quantity of the desired species in the sample stream. Table 4-1 provides a listing of the full scale range, measurement technique, and interfering species for each of the gases measured.

Table 4-1

Gas Species Measured by Perkin Elmer MCS 100 Analyzer

Measured Species	Range	Measurement Technique	Interfering Species
NO	0-800 ppm	Gas Filter Correlation	H_2O
CO	0-500 ppm	Gas Filter Correlation	H_2O
SO_2	0-800 ppm	Single Beam Dual Wavelength	NH_3, H_2O
NO_2	0-100 ppm	Single Beam Dual Wavelength	NH_3, SO_2, H_2O
CO_2	0-20 volume %	Single Beam Dual Wavelength	H_2O
H_2O	0-15 volume %	Single Beam Dual Wavelength	None
N_2O	0-100 ppm	Single Beam Dual Wavelength	CO, CO_2, H_2O
NH_3	0-50 ppm	Gas Filter Correlation	CO_2, H_2O

Using the gas filter correlation technique, the system takes a reference reading at a known wavelength and a known concentration of gas, usually 100 percent. The system then takes another reading at the same wavelength for the sample gas and records the energy absorbed by the sample. The relative difference in energy is then representative of the concentration in the sample gas.

Likewise in the single beam dual wavelength method, a reference reading is taken at a wavelength where the desired species does not absorb energy (zero percent reference). The system then takes a measured reading at a wavelength where the desired species is known to absorb energy. The relative difference in energy is again representative of the concentration of the species in the sample stream.

Once the ratio of reference to measure energy is calculated, the energy level is corrected to account for interferences via reference tables for each specific gas. After correction for interferences, the data is zero adjusted, converted to the appropriate units, calibration corrected, and output for display and recording.

Since O_2 is not infrared active, the CEM system also contains an Ametek O_2 analyzer. The sample cell is a zirconium oxide closed end tube with electrodes of porous platinum coated onto the inside and outside of the tube. The cell produces a millivolt signal proportional to the relative difference of O_2 inside and outside of the cell. The millivolt signal is converted to percent O_2, scaled (0 to 25 percent), and then displayed and recorded.

All CEM analyzer and sampling system functions, including a daily automatic calibration sequence, are controlled by the MCS 100 PLC. The measured gas concentration data is displayed on a dedicated 486-based computer, which also provides data logging, manipulation and reporting functions.

A Relative Accuracy Test Audit (RATA) was performed on March 5, 1993 in order to verify the accuracy of the CEM system. The audit was performed by TRC Environmental Corp. in accordance with the requirements established in 40 CFR, Part 60, Appendices A and F. Complete documentation of the audit is contained in a separate report (TRC Environmental Corp., 1993), and the results are summarized in Table 4-2.

Table 4-2

CEM RATA Results

Parameter	Relative Accuracy (%)
CO_2 (%, wet)	2.64
Moisture (%)	7.86
O_2 (%, wet)	17.81
NO (ppm, wet)	1.53
NO (lb/MMBtu, wet*)	5.93
NO (ppm, dry)	1.02

* Calculated on an O_2 basis

Acceptance criteria for RATA evaluation of component instruments of the CEM is 20 percent. Based upon the results, all individual parameters were found to be within the acceptance criteria.

4.2 Gas Sampling System

As shown in Table 4-1, the MCS 100 was configured to measure NH_3. This capability imposes special requirements upon the design of the CEM sampling system. In order to maintain the integrity of the sample, the entire sampling system (probe, sample line, pump, flowmeter, and sample cell) must be maintained at 230°C (445°F). Due to these heat tracing requirements, the CEM system was configured to sample from only two different single-point locations. One at the exit of the air preheater in the duct leading to the fabric filter, and one downstream of the fabric filter and induced draft fans, in the duct leading to the common stack for Units 3 and 4.

In order to obtain a representative composite gas sample, as well as provide the ability to look at discrete areas of the flue gas flow, Fossil Energy Research Corp. provided a sample gas conditioning system which would allow sampling from additional unheated sample probes. Although the MCS 100 is utilized as the gas analysis instrumentation, the measurement of NH_3 at the additional sampling locations is not possible due to the lack of high temperature heat tracing. A schematic of the sample gas conditioning system is shown in Figure 4-1. The system can accommodate up to 24 individual sample lines. Up to 12 of these can be composited together and then analyzed. Each of the individual sample streams is dried in a refrigerated dryer where the gas is cooled and the moisture is dropped out in a trap. Each stream then passes through a metering valve and rotameter, after which all the streams are blended together in a manifold and directed to a pair of sample pumps. The rotameters are used to balance the individual flows in order to provide an accurate composite blend. Downstream of the pumps, a portion of the composited sample is diverted to a final pass through the condenser (where the increased pressure aids in the removal of any remaining moisture), through a final particulate filter, and then to the Altech CEM for analysis.

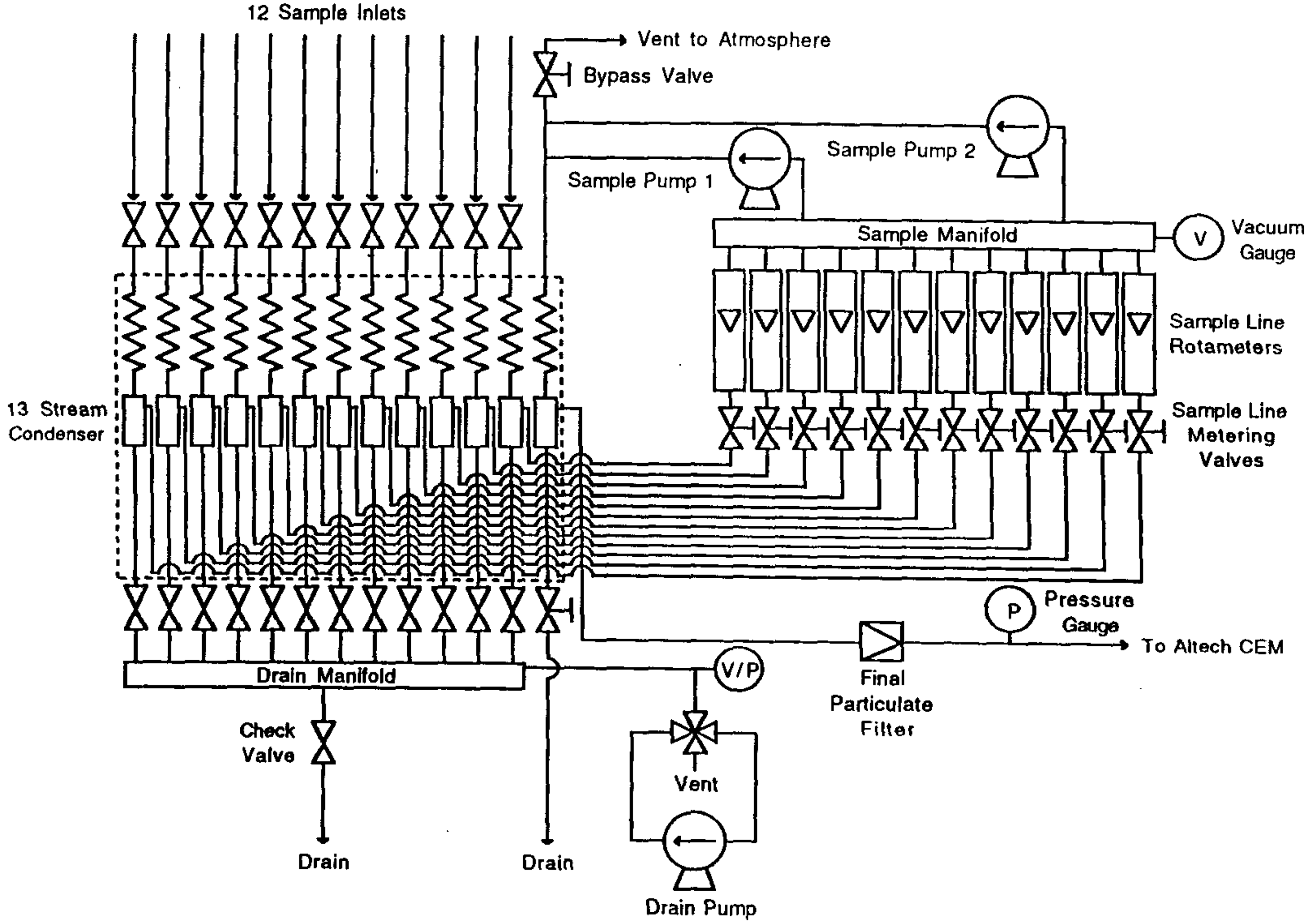


Figure 4-1. Sample Gas Conditioning System

The location of the unheated sample probes during the current phase of testing was identical to that for the first two phases of SNCR tests, namely: 12 probes at the exit of the economizer, 6 probes at the exit of the air preheater, and one probe in the fabric filter outlet duct leading to the stack. The sample probe grid in the horizontal duct at the economizer exit is shown in Figure 4-2. Since this duct is 40 feet wide and only 7 feet deep, an array of probes positioned two high by six wide was deemed adequate to obtain a representative gas sample. The short probes were located at one-fourth of the duct depth, and the longer probes at three-fourths of the duct depth. This spacing vertically divided the duct into equal areas. The use of two probe depths also provided the opportunity to ascertain any vertical stratification of gas species within the duct. Individual sample probes consisted of stainless steel tubing with sintered metal filters on the ends. The sample lines which transported the gas to the sample conditioning system, consisted of polyethylene tubing which was heat traced and insulated to prevent freezing during the winter months.

Figure 4-2 also shows the location of the four O_2 probes at the economizer exit which are used for boiler trim control. The equipment uses *in situ* probes that determine the O_2 concentration on a wet basis. These probes (numbered A, B, C and D) are located approximately three feet upstream of the Fossil Energy Research Corp. (FERCo) grid, and very near probe numbers 3, 5, 7 and 9. The importance of the position of the 12-point grid relative to the four probes was realized during the baseline and retrofit burner tests when it was found that the average O_2 measured from the grid was nominally 1.0 to 1.5% higher than the average indicated in the control room. This difference was attributed to the inability of the four PSCo probes to detect the elevated O_2 levels along the east and west sides of the duct which result from both air in-leakage and overfire air that didn't penetrate to the center of the furnace.

Additional gas sample probes were installed at the air heater exit and the stack (fabric filter outlet duct) locations. Whereas, the 12-point economizer exit sampling grid was utilized for detailed point-by-point measurements, the air heater exit and stack sampling probes were only used to obtain general duct averages at these locations. Therefore,

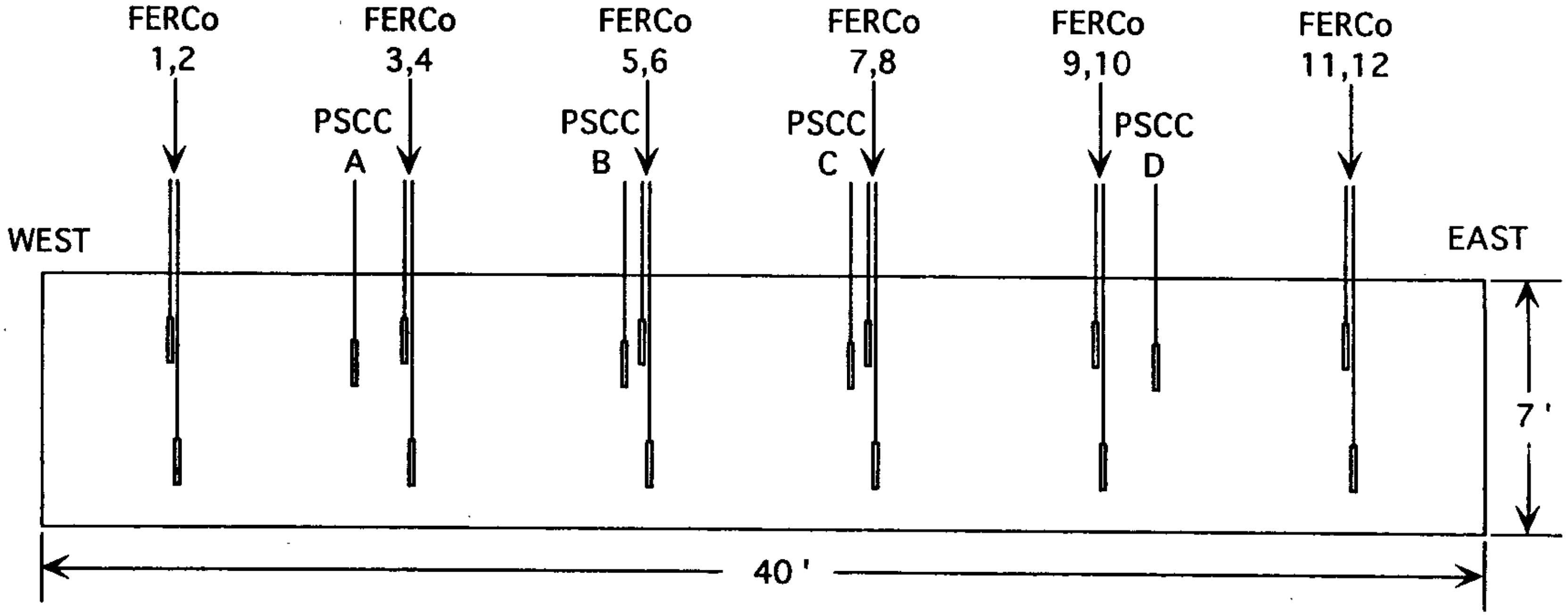


Figure 4-2. Economizer Exit Sampling Locations

only a limited number of probes were utilized at these test locations; six at the air heater exit and a single probe at the stack location. Figure 4-3 shows the location of the probes at the air heater exit. These sample probes and tubing were similar to the installation at the economizer exit. The staggered probes were installed at one-fourth and three-fourths duct depths, similar to the economizer exit. The figure also shows the location of the heated probe for the CEM system at the exit of the air heater. This probe is not in the same plane as the six-point grid, but approximately 3 feet upstream. At the stack sampling location, the heated probe for the CEM system is approximately 20 feet upstream of the unheated probe installed during the baseline SNCR tests. Only a single probe is used for both the CEM and the unheated probe locations since both are downstream of the fabric filter and induced draft fans where little stratification of the flue gas stream is expected. Figure 4-4 shows the installation of the unheated probe in the fabric filter outlet duct. The air heater exit and stock sampling locations were used infrequently during the current phase of SNCR tests. Unless noted otherwise, all CEM gas analysis results presented in this report, are from the economizer exit sampling location.

4.3 NH_3 Measurements

The measurement of NH_3 emissions is an important aspect of quantifying the performance of a SNCR system. Traditionally, batch or wet chemical sampling techniques have been used for this purpose. However, the time delay between the collection of the sample and the delivery of the results, due to the required laboratory analysis, is less than optimal when trying to optimize process performance in a field test situation. Recently, a number of continuous ammonia analyzers have become available, which could provide the on-line performance desirable for a field test program. However, these analyzers are considered to be in a developmental and proving stage, due to difficulties in obtaining and preserving valid gas samples, especially in sulfur-laden environments.

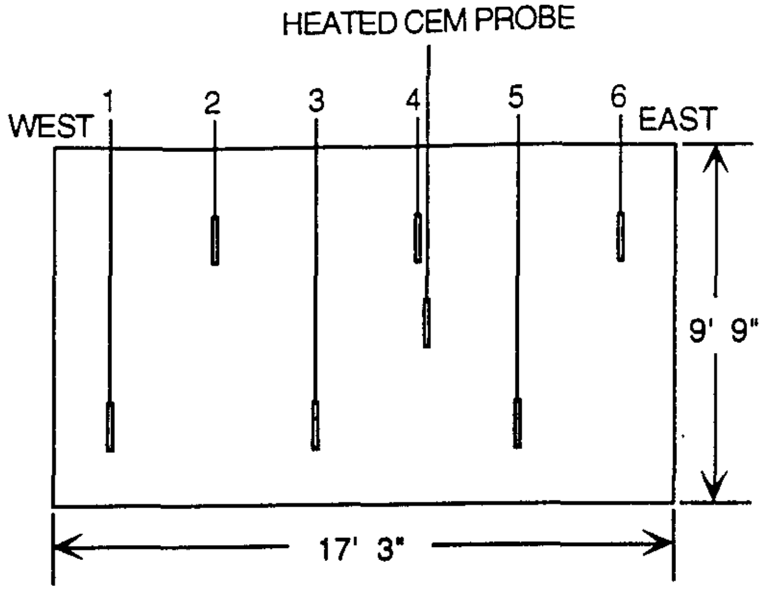


Figure 4-3. Air Heater Exit Sampling Locations

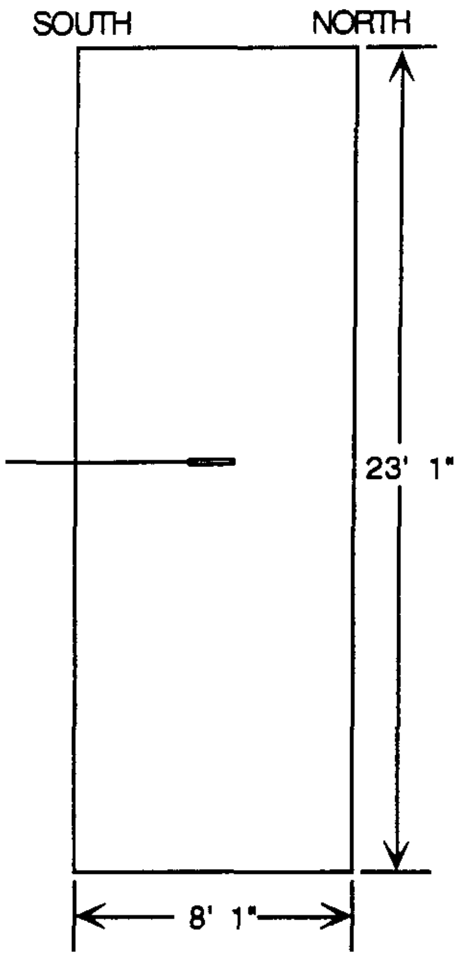


Figure 4-4. Fabric Filter Outlet Duct Sampling Location

Wet chemical NH_3 analysis was the primary measurement used during the current test program. While EPA has published a draft method for the wet chemical determination of ammonia from stationary sources (draft Method 206), the method is most appropriate for stack gas compliance testing (U.S. EPA, 1996). The method described below differs somewhat from the draft EPA Method 206, but has been used by Fossil Energy Research Corp. and others for numerous test and compliance programs. It has been accepted for compliance work by local air regulator districts in California and has been proven accurate. Flue gas samples are withdrawn from the duct through a stainless steel probe, and are then passed through three impingers as shown in Figure 4-5. The first two impingers contain 0.02N sulfuric acid (H_2SO_4) and the final impinger is dry. Nominally two cubic feet of flue gas is passed through the impinger train during each test at a rate of approximately 0.2 ft^3/min. Total sample times were nominally 10 to 12 minutes for each test. At the conclusion of each test, the sample probe, Teflon line, and sampling train glassware are washed with dilute H_2SO_4 into the bottle containing the impinger solution. The sample solution is then analyzed for ammonia.

During the ARIL lance tests, the sample solutions were analyzed on-site using the Direct Nesslerization Method. In this method, the Nessler reagent and a stabilizing agent (EDTA) are added to the sample solution and mixed thoroughly. After the reaction is complete (a minimum of ten minutes is required), the light absorbance of the sample is determined photometrically at 425 nm. The reading is compared to the absorbance of standard solutions to determine the ammonia concentration in the sample. Using this method, an NH_3 emission value could be obtained in a manner of minutes after the completion of a test. The rapid turnaround of NH_3 emission data was used to quickly diagnose and guide the test program during the optimization of the ARIL lance system.

The wet chemical ammonia samples were obtained from a set of six ports located in the air heater exit duct (just upstream of the ports used for the continuous gas analysis samples shown in Figure 4-3). Generally, separate samples were not collected from each port during a single test. Rather, composite samples from groups of ports were

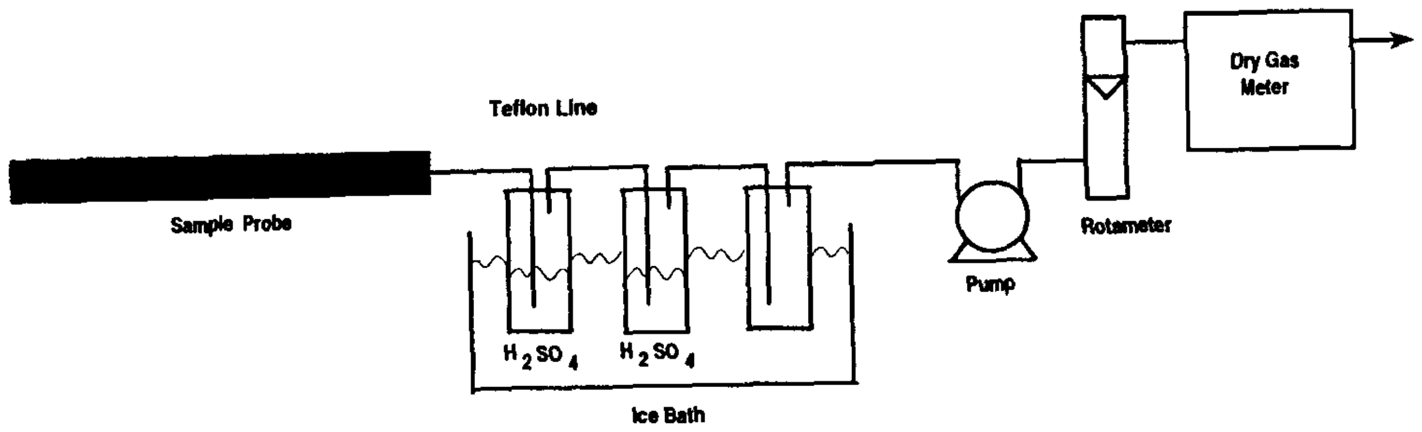


Figure 4-5. NH_3 Sample Train Schematic

obtained, in order to accelerate the testing process. Usually, the three ports on the west side, and the three on the east side, were grouped together such that only two samples were collected per test. Occasionally, pairs of ports were grouped when more detail was needed, or all six were combined when time was limited. In every case, the samples from each port were obtained at a single point located at the center of the duct.

During the previous phase of SNCR testing (Smith, et al., 1994b), point-by-point wet chemical measurements across the duct at the air heater exit location showed that the NH_3 profile was far from uniform. A comparison of the CEM NH_3 measurements at this location to single-point wet chemical measurements made through the port adjacent to the CEM probe (Port Number 4 in Figure 4-3) showed good agreement between the two methods. During the current phase of SNCR tests, the CEM was used frequently as a quick indication of trends in NH_3 slip at the air heater exit. However, it could never be used as an absolute measurement due to the stratification of the flue gas at this location.

Wet chemical measurements made at the stack during the previous phase of tests also showed good agreement with the CEM NH_3 measurements at this location. Both methods also showed that the ash in the fabric filter provided a substantial capacity for the absorption and desorption of NH_3. These tests showed that if the ash in the fabric filter was free of NH_3, it would take up to three hours for NH_3 emissions measured at the exit of the fabric filter to equal that measured at the inlet. Neither CEM nor wet chemical NH_3 measurements were made at the stack during the current phase of tests due to the combination of this "time-lag effect" and the relatively short duration of the parametric optimization tests. CEM NH_3 measurements at the stack are more meaningful during long-term, load-following tests when the SNCR system is operating in the automatic control mode.

4.4 Multipoint Gas Analyzer

A key element of traditional boiler diagnostic testing and SNCR optimization entails detailed characterization of the NO_x, O_2, and CO profiles at the economizer exit. This sampling and analysis is performed on an individual probe-by-probe basis, or a composite of samples is obtained from several different probes. The main disadvantage of this approach is that it is time consuming, and furnace conditions may change during the course of a point-by-point test.

To overcome this limitation, Fossil Energy Research Corp. developed an emission monitoring system capable of simultaneously monitoring the NO_x, O_2, and CO levels for up to twelve separate sample points in the economizer exit duct. This novel analyzer system allows the duct NO_x, O_2, and CO profiles to be characterized in a matter of minutes, as opposed to hours when using traditional duct emission traverse techniques. The monitor uses twelve separate fuel cell analyzers for each gas to obtain simultaneous readings. Highs and lows in the profiles are easily identified, and can be traced back to the furnace to analyze burner performance and O_2 in-leakage. Burner adjustments can be made and immediately analyzed in an interactive mode. With SNCR systems, this multipoint system allows the degree of chemical mixing to be easily assessed and optimized. A photograph of the multipoint analyzer and an example of typical NO_x and O_2 profiles are shown in Figure 4-6.

A software package has been developed to support the multipoint analyzer which permits the display of O_2, CO, and NO_x contour plots on one screen in a three color overlay. The NO_x emissions are displayed on a corrected basis (i.e., corrected to 3% O_2), which automatically accounts for dilution. This feature is helpful in distinguishing regions of the combustion system operating at high O_2 levels from regions where there is furnace in-leakage.

The multipoint analyzer was utilized for a brief period of time during the current phase of SNCR tests at Arapahoe Unit 4. During that time, the CO cells were not used, as only NO_X and O_2 were required in the performance assessment of the ARIL lance system.

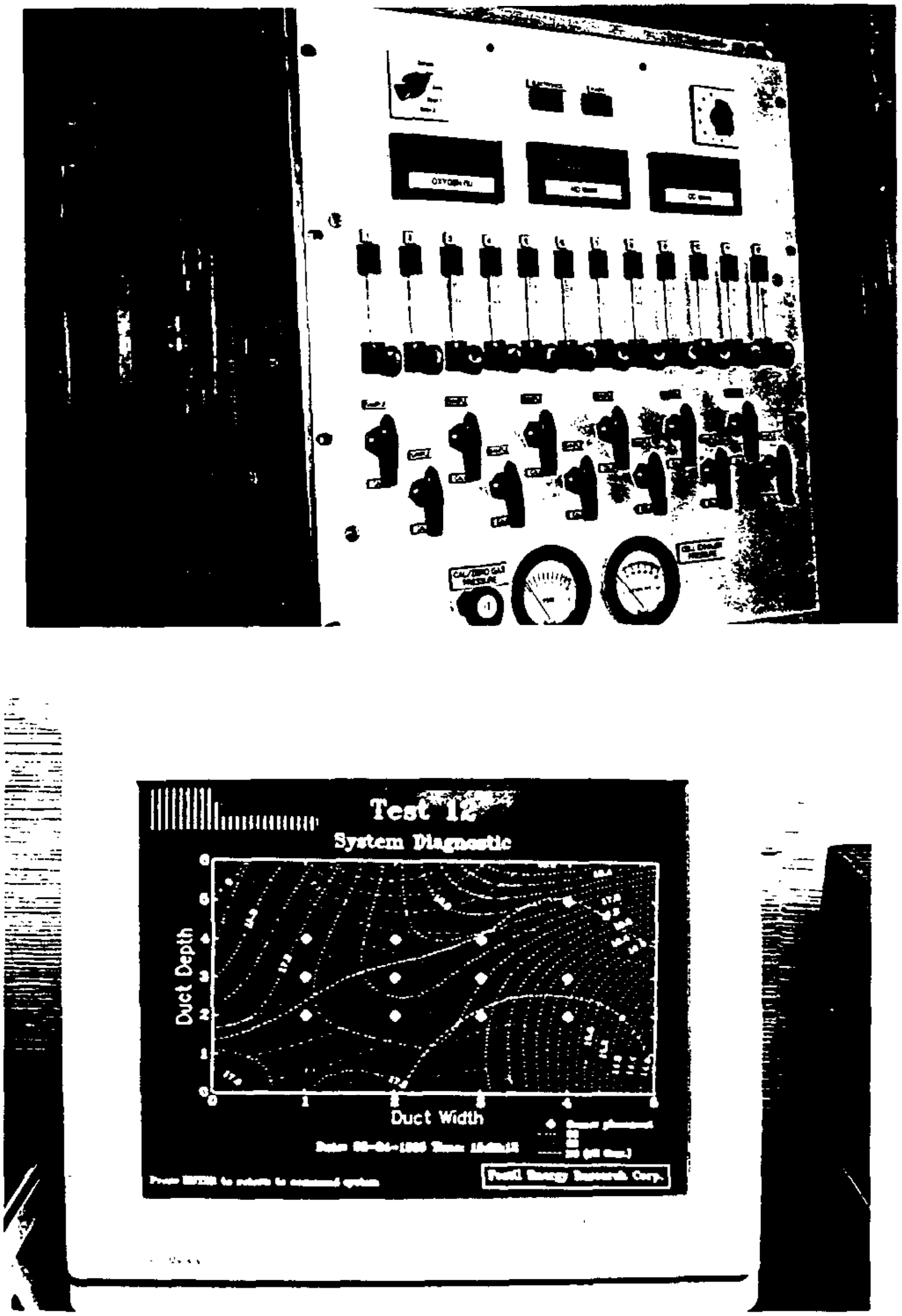


Figure 4-6. Photographs of the 12 Channel Multipoint NO_x, O_2, CO Emissions Analyzer

4.5 Furnace Exit Gas Temperature Measurements

During the current test series, furnace exit gas temperature (FEGT) measurements were made in order to provide a comparison with those recorded during the post-retrofit SNCR tests. The temperature measurements were made using an acoustic pyrometer.

An acoustic pyrometry system, manufactured by Combustion Developments Ltd. Of England, was utilized to provide a continuous assessment of the furnace exist gas temperatures. The acoustic pyrometer sends a sound pulse across the furnace; the transit time for the pulse is measured; thus, the mean speed of sound across the furnace is determined. The average temperature along the path can then be determined from the speed of the sound pulse. The acoustic temperature measurement technique requires a clear line of sight across the furnace at the measurement location. Since the boiler has a division wall running the length of the furnace, the first available location with acceptable access for the acoustic instrument was through a pair of ports just downstream of the first set of screen tubes (Location G in Figure 2-5).

5

RESULTS: NOELL ARIL LANCE TESTS

The original test plan for the ARIL lance tests comprised approximately eight weeks of parametric testing, with another two weeks of continuous 24-hour load-following operation in the automatic control mode. After the resolution of some minor start-up difficulties, testing began on April 20, 1995. More serious concerns arose when the lances were seen to bend significantly when inserted into the boiler. It was hypothesized that the bending was due to thermal stresses, and testing was postponed on two occasions while the lances were modified in attempts to correct the problem. The postponements delayed the test program such that there was insufficient time to complete the parametric testing before Arapahoe Unit 4 was taken off-line for a major turbine outage on July 29. Testing resumed on October 25, but was again postponed form October 30 to November 14 in order to accommodate a planned test burn of a Powder River Basin coal. The parametric tests resumed after the Thanksgiving holiday on November 27, and were completed on December 16. The urea injection system was operated in the automatic control mode from December 18 through December 21 in order to troubleshoot and fine tune the automatic control mode. The two weeks of 24-hour load-following tests were postponed until March 1996, and the results of these tests will be presented in the report describing the results of the integrated system tests.

The majority of the ARIL lance tests consisted of parametric variations aimed at defining the optimum injection location (Level 1, lances, or both), lance injection angle, and chemical injection rate as a function of boiler load. A limited number of tests were also run where detailed measurements were made to define the mixing and exactly where the NO removal was occurring. The new multipoint gas analyzer described in Section 4 was used for these measurements. The results of the parametric and detailed test efforts are discussed separately in the following sub-sections.

However, before the results are presented, it is worthwhile to discuss how the tests were actually conducted and, in particular, how the chemical injection rate and NO removal were defined. The relative chemical feedrate for a particular test is indicated by the N/NO molar ratio (i.e., the molar ratio of the amount of nitrogen injected as urea to the amount of NO in the untreated flue gas). Before each test, a target N/NO ratio was selected, and a baseline NO level measured at the economizer exit. From these two values, a chemical feedrate was calculated and the injection pump speed and urea control valve settings determined. At the conclusion of the test, the N/NO ratio was calculated from the average urea flow and baseline NO level. Since the urea flow may vary slightly over the duration of a test, and the baseline NO level may vary over the course of the day (baseline NO levels were not checked after each individual test, but periodically throughout each day), the calculated N/NO ratio was often slightly different than the target value. Throughout the text of this report, the target (or nominal) N/NO ratios will be utilized in the discussion of test conditions (i.e., a nominal N/NO ratio of 1.0 will indicate a calculated N/NO ratio in the region of 0.9 to 1.1). Appendix B contains a complete data summary which includes the actual calculated N/NO ratio for all tests.

From the preceding discussion, it is apparent that the N/NO ratio for each test was based on the boiler NO emission level existing after the low-NO_x combustion system retrofit. The amount of NO removal for each test was also calculated relative to this post-retrofit baseline. Although an individual test may result in a calculated NO removal of 40%, it must be realized that this is in addition to the 63 to 69% achieved with the low-NO_x combustion system. For this example, the overall NO removal due to the cumulative effect of the low-NO_x combustion system and SNCR would be approximately 80%.

5.1 Parametric Tests

During the previous (post-retrofit) SNCR test phase (Smith, et al., 1994b), tests were run at loads of 60, 80, 100 and 111 MWe. Installation of the lances allowed the range of effective SNCR NO_x removal to be extended down to the minimum operating load for Arapahoe Unit 4. During the current test phase, tests were run at 43, 50, 60, 70, 80, 90 and 100 MWe. The "mid-range" 70 and 90 MWe tests were run to aid in defining the load at which the injection location would transition from the ARIL lances to the Level 1 location on the back wall of the boiler. Since the primary goal of installing the ARIL lance system was to improve the SNCR NO_x removals at low boiler loads, no tests were run at the high load condition of 111 MWe during the current test phase. The results of the parametric tests will be presented as a function of load, with the low load results being discussed first.

A. 43 MWe Results

Arapahoe Unit 4 is taken off-line only to address maintenance or repair issues. If the unit is not needed for system regulation, it is "parked" at minimum load (approximately 43 MWe). At this condition, only two coal mills are in operation, and a single boiler feed pump and condensate pump are in service. This condition was not tested during the pre- and post-retrofit test phases, as the results indicated that the flue gas temperatures at the Level 1 injection location were already too low for efficient NO_x removal at 60 MWe. The addition of the lances to a higher temperature region of the boiler provided the opportunity to extend the operating range of the SNCR system to the minimum load condition.

Prior to the low-NO_x combustion system retrofit, minimum load for Arapahoe Unit 4 was approximately 43 MWe. As mentioned in Section 3.0, the retrofit resulted in a substantial decrease in furnace exit gas temperature. This temperature reduction not only affected the performance of the SNCR system at low loads, but also impacted the ability to maintain steam temperature at loads below 50 MWe. When load is reduced to 43 MWe, the steam temperature drops to 40 to 60°F below the control setpoint of 1000°F, even with the excess O_2 bias control at maximum. The Unit 4 minimum operating load was unchanged until the turbine outage in July 1995. When the unit came back on-line in October, the minimum operating load was increased to 50 MWe to reduce the chance of condensed water drops entering the low pressure turbine.

The 43 MWe tests reported in this sub-section were completed before the turbine outage, over a period of two days with a different coal mill in service pattern run on each day. On the first day, mills A and D were out of service (OOS), and on the second, A and B were OOS. (Refer to Figure 2-2 for a description of the mill/burner arrangement.) All tests were run with a total liquid flowrate of 4 gpm and an atomizing air pressure of 10 psig. During the ARIL lance shakedown tests, it was found that at total liquid flowrates of less than 4 gpm (i.e., 1 gpm per injection quadrant) the velocities in the liquid lines were too low to prevent "flashing" the water component into steam before reaching the individual nozzles. This process left crystalline urea deposits in the lines which would quickly plug the liquid orifices. Consequently, all subsequent testing was conducted with total liquid flowrates of 4 gpm or greater.

The centrifugal compressor which provides the atomizing air is controlled by setting a discharge pressure on the SNCR system PLC. Although any setpoint from 3 to 12 psig may be entered, there are minimum and maximum limits on the air flow which can be provided by the compressor. These limits are imposed by the configuration of the compressor diffuser assembly and inlet guide vanes. With air flow to the lances only, the minimum flowrate condition corresponds to a pressure of 10 psig. The minimum air and total liquid flowrates were used during the 43 MWe tests to minimize local cooling of the flue gas.

The effect of lance injection angle on NO removal and NH_3 slip at injection rates corresponding to a nominal N/NO ratio of 1.0 is shown in Figure 5-1. The injection angle is defined as shown in Figure 2-5, namely, 0° is down, 90° is horizontal toward the front wall of the furnace, and 180° is up. The injection angle is limited to the range of 22° to 135° by limit switches on each lance. The lower limit prevents the injection jets from impinging on the screen tubes located directly below the lances.

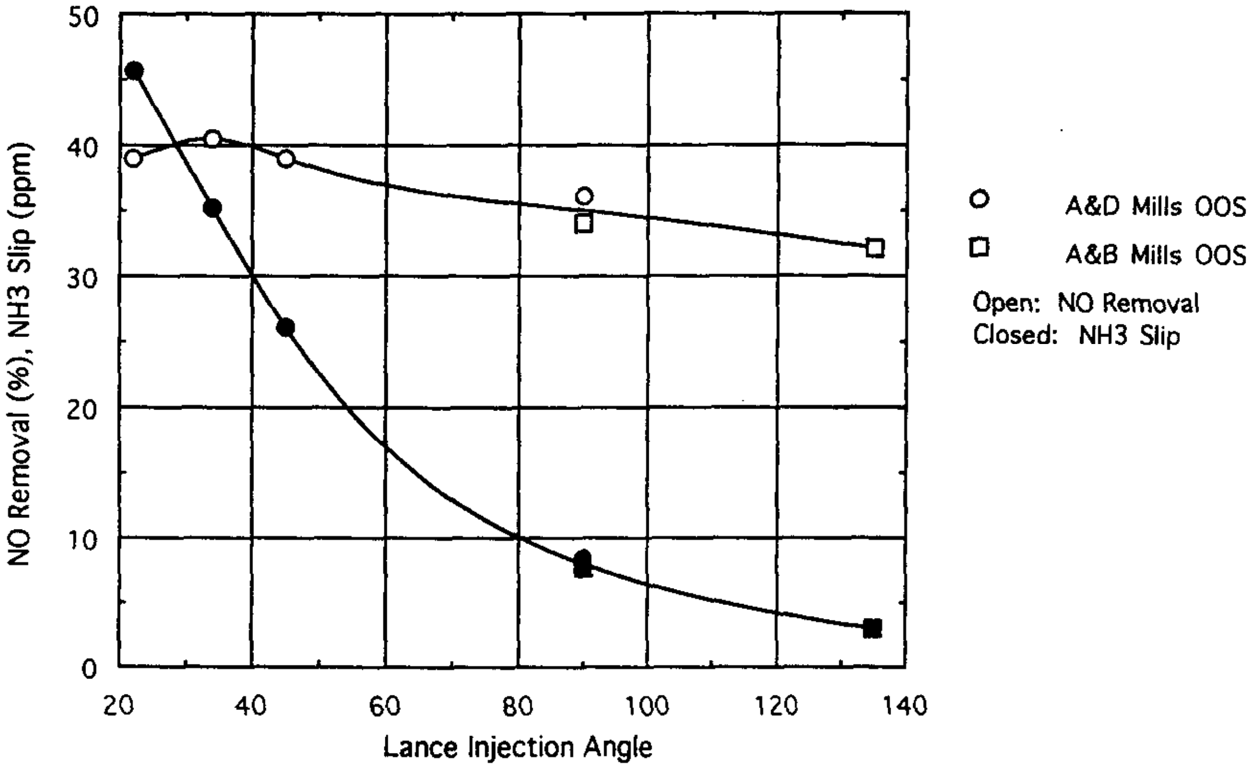


Figure 5-1. Effect of Lance Injection Angle at 43 MWe
(N/NO = 1.0, 4 gpm Liquid, 10 psig Air)

(Recall Figure 2-5.) Rotation in the upward direction is limited by the thermocouple and liquid line connections on the side of each lance.

The trends in NO removal and NH_3 slip shown in Figure 5-1 confirm that various flue gas temperature regimes are accessed by rotating the lances. The NH_3 slip shows a strong dependance on injection angle (i.e., flue gas temperature), while the NO removals are more modestly dependent on injection angle. This behavior is believed to be due to operating the boiler without all four coal mills in service. If all four mills are in service, the temperature profile at a particular elevation in the furnace would be fairly uniform. With one or two mills OOS, there will be relatively hot and relatively cool regions across the furnace at the same elevation. Thus, for a given injection angle, there will be regions of relatively high and relatively low NO removal. As the lance angle is changed, increased for example, the hot regions may become too hot and the NO removals decrease, while the NO removals in the cooler regions may increase. This "averaging" will tend to smooth-out the effect of injection angle on the overall NO removal. The overall NH_3 slip, on the other hand, will be driven by the low temperature regions. Thus, if the relatively cool regions were eliminated, the NH_3 slip at a particular injection angle would be reduced, and the entire NH_3 slip curve shown in Figure 5-1 would shift to the left. One approach to compensate for this effect would be to control each lance angle separately based on the mills in service. This concept was tested at a load of 70 MWe and the results discussed in a later part of this section.

Based on the results of the parametric angle variation tests (Figure 5-1), 90° was chosen as the optimum injection angle for operation at 43 MWe. At this angle, NO removals in the range of 37% were achievable with an NH_3 slip of less than 10 ppm. Figure 5-2 shows the effect of N/NO ratio on NO removal and NH_3 slip with the lances set at an angle of 90°. In this figure, the data at N/NO = 1.0 indicate that the NO removals and NH_3 slips are relatively insensitive to the coal mill OOS pattern. These results are based on composite or average measurements at the economizer exit duct. There was not adequate time for point-by-point measurements during the two days of

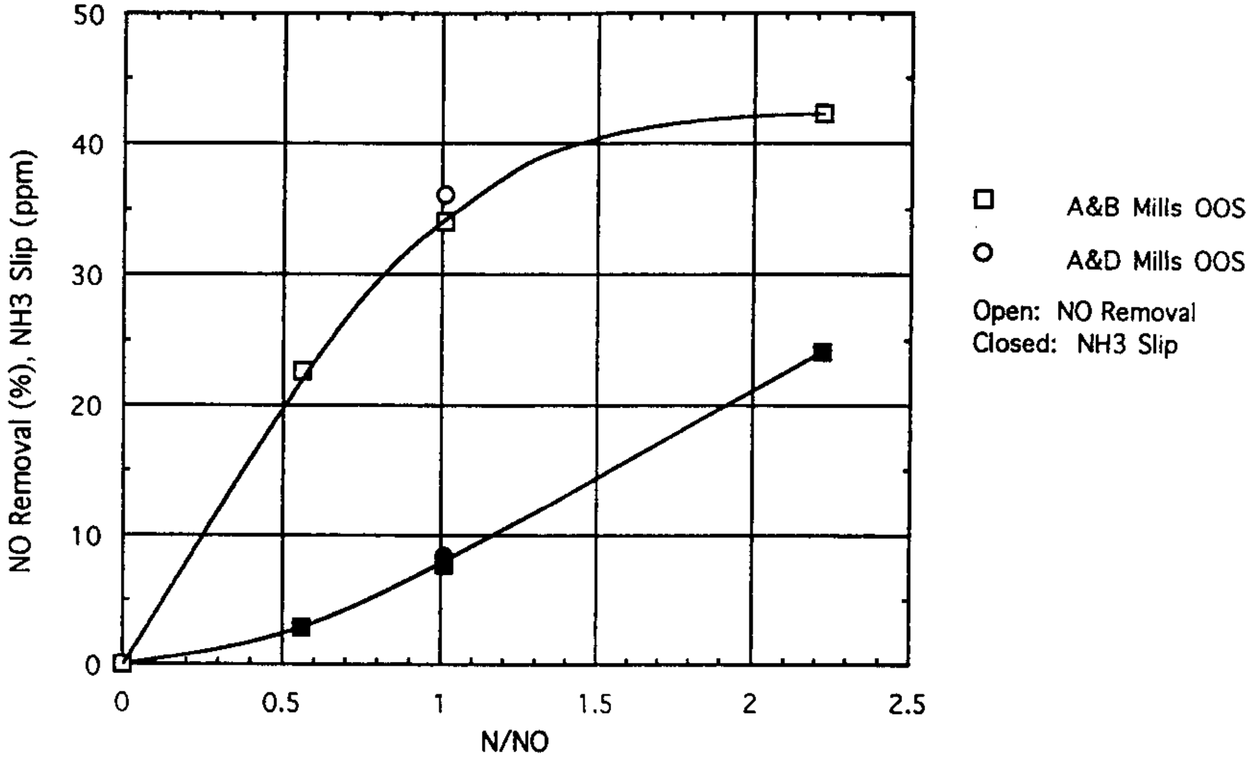


Figure 5-2. Effect of N/NO Ratio for Lance Injection at 43 MWe (90° Injection Angle, 4 gpm Liquid, 10 psig Air)

43 MWe testing, so the effect of mill OOS pattern on the local NO removals and NH_3 slips was not assessed.

B. 50 MWe Results

The 50 MWe testing reported in this subsection was completed after the turbine outage in order to establish the performance of the ARIL lance system at the "new" minimum load condition. Normally, operation at 50 MWe is similar to that at 43 MWe, with only two coal mills in service, with a single boiler feed pump and condensate pump. However, during the two consecutive days when the 50 MWe tests were run, C mill was OOS due to a vibration problem, and both B and D mills could be loaded only lightly as a result of problems in each mill's hammer section. Due to the feedrate limitations on B and D mills, it was necessary to run the 50 MWe tests with three mills in service rather than two. All of the 50 MWe tests were run with a total liquid flowrate of 4 gpm and at an atomizing pressure of 10 psig.

The effect of lance injection angle on NO removal and NH_3 slip for a nominal N/NO ratio of 1.0 is shown in Figure 5-3. In general, the trends are similar to those shown in Figure 5-1, where an increase in the injection angle results in a decrease in both NO removal and NH_3 slip. However, as a result of the increased average flue gas temperature, injection angle has a much greater effect on NO removal, and a much smaller effect on NH_3 slip. As the angle increases from 22°, the chemical is injected further away from the relatively cool zone above the screen tubes, and the NO removal decreases from over 45% down to 20% at an angle of 135°. The NH_3 slip levels shown in Figure 5-3 are less than 5 ppm, indicating that for all injection angles, the average flue gas temperature in the injection zone was hotter than that for the 43 MWe tests.

The results of the first day of testing at 50 MWe showed that a 22° injection angle yielded the best overall SNCR performance, so on the following day, a N/NO ratio curve was run at this angle. Although the NO removal at a nominal N/NO ratio of 1.0 was similar to that from the previous day, the NH_3 slip on the second day was 11 ppm (over

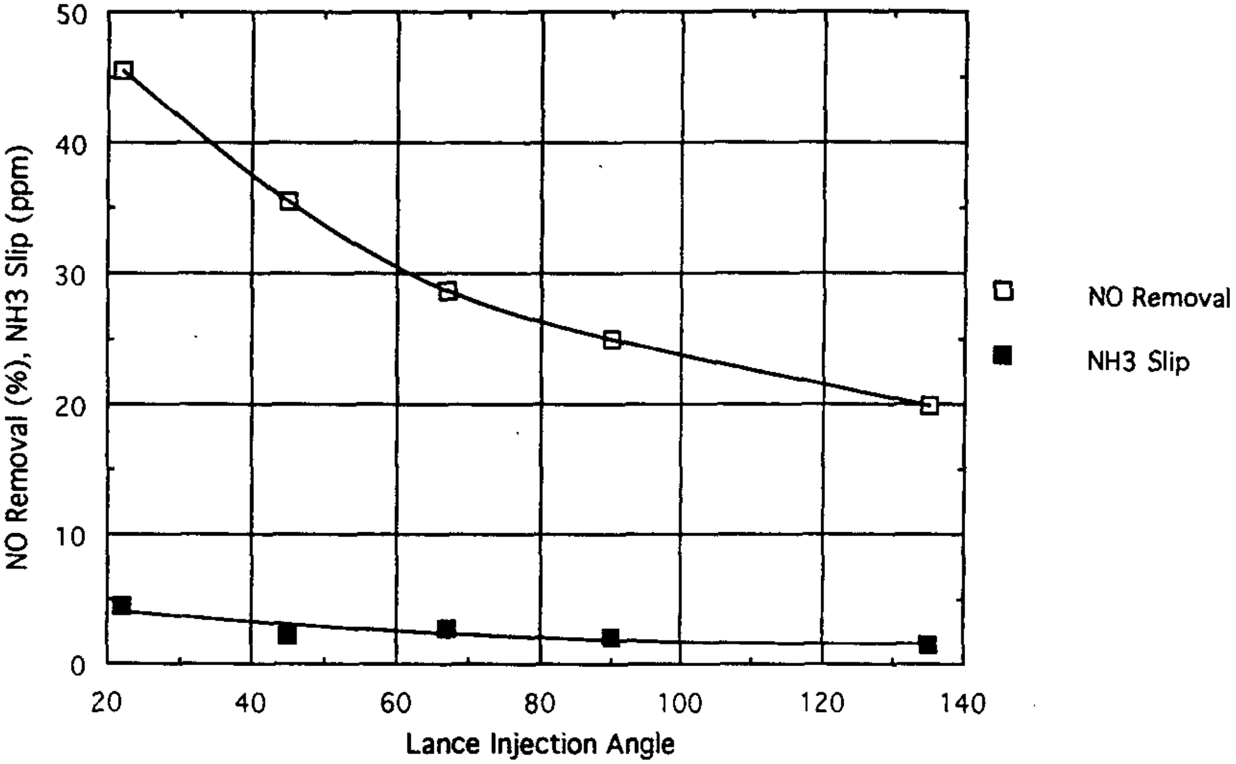


Figure 5-3. Effect of Lance Injection Angle at 50 MWe
(C Mill OOS, N/NO = 1.0, 4 gpm Liquid, 10 psig Air)

twice that from the previous day). Another N/NO ratio curve was run at an angle of 45° to assess if the slip could be reduced without adversely affecting the NO removal. This indeed was the case, and both of these sets of data are shown in Figure 5-4. At an NH_3 slip limit of 10 ppm, injection at 22° yielded 42% NO removal, while removals in excess of 50% were achieved at an angle of 45°.

In contrast to Figure 5-3, Figure 5-4 shows that injection angle had little effect on NO removal, and more of an effect on NH_3 slip. As these trends are similar to those seen at 43 MWe (Figure 5-1), the results indicate that the average injection-zone flue gas temperature were lower on the second day of 50 MWe tests than on the first. This hypothesis is supported by comparing the boiler O_2, steam temperature and attemperator valve data from the two days. On the first day, the attemperator valves were open and the steam temperature averaged 996°F. Although the average O_2 was only 0.25% (absolute) lower on the second day, the attemperator valves were closed and the average steam temperature fell to 963°F, indicating lower flue gas temperatures.

A second factor which may have also affected the results on each day was the operation of the coal mills. Although C mill was OOS on both days, the biasing of coal among the three mills in service was different on each day. On the first day, A mill was run with a bias of +5% to move some coal away from B and D mills, as B and D were having problems handling the coal feed rates. In addition, the west feeder on B mill was biased -10% (the west side of the mill was the problem side), and the west feeder on D mill was biased +12% (here, the east side was the problem). This bias pattern allowed B and D mills to run throughout the day without plugging or tripping off-line. On the second day, these mill and feeder biases were not sufficient to avoid mill problems, and it was necessary to also bias B mill -10% and D mill -15%. It is likely that the large change in mill bias on the second day resulted in a significant change in the flue gas temperature profile at the injection location, which in turn affected the SNCR results.

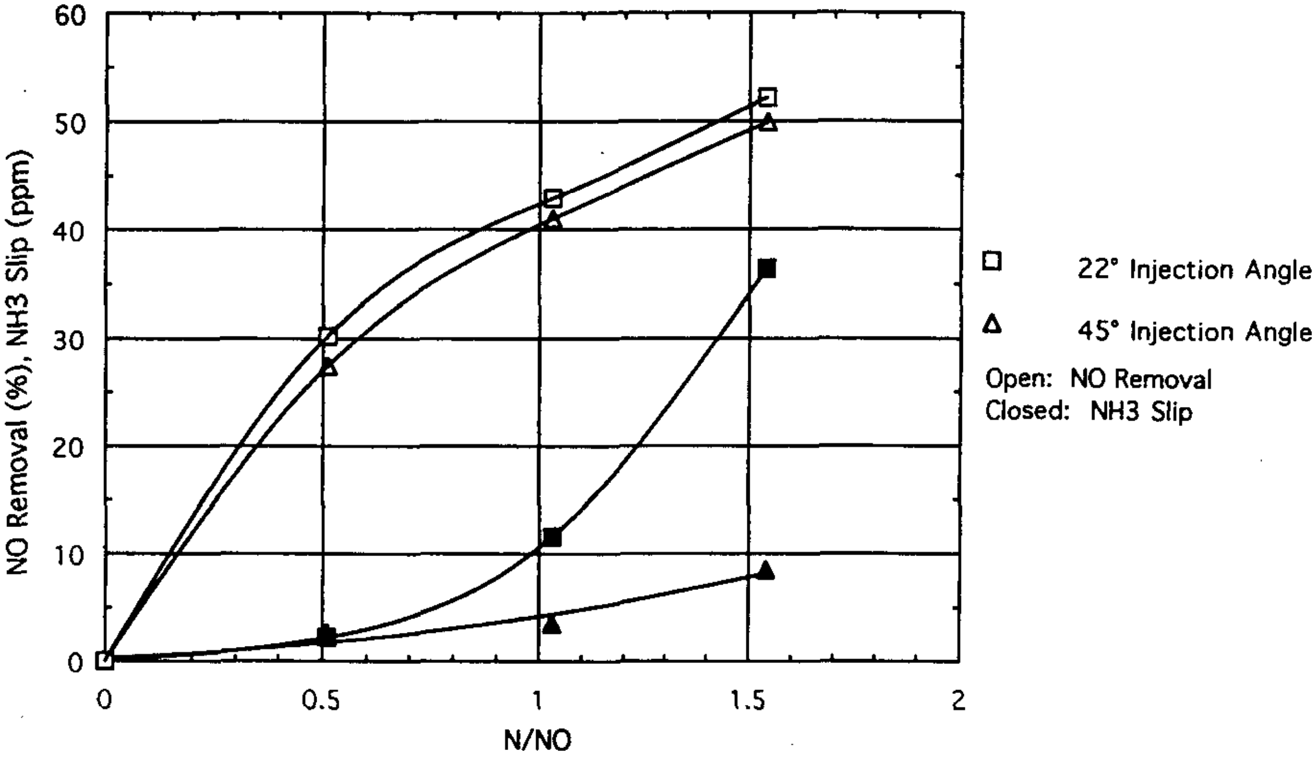


Figure 5-4. Effect of N/NO Ratio for Lance Injection at 50 MWe (C Mill OOS, 4 gpm Liquid, 10 psig Air)

C. 60 MWe Results

For Arapahoe Unit 4, 60 MWe is the upper limit for operation with only two coal mills in service. In fact, when running at this load with only two mills, the coal feeders are running at nearly 100% capacity. Consequently, any small upset in coal feed, coal quality or pulverizer performance can result in a boiler upset. For these reasons, most control operators prefer to run 60 MWe with three mills in service, and only go to two mill operation at loads below 55 to 56 MWe. However, with dry coal and two good pulverizers, 60 MWe can be achieved with two mills. During the ARIL lance optimization, tests were run at 60 MWe with both two and three mill-in-service conditions. All of the two-mill tests were run before the turbine outage during April and May of 1995, and the majority of the three-mill tests were run after the outage during the October to December time period.

The effect of lance injection angle on NO removal and NH_3 slip with two mills in service is shown in Figure 5-5. All of the two-mill tests were run with a total liquid flowrate of 4 gpm and at an atomizing air pressure of 12 psig. Both sets of two-mill tests were run early in the test phase, with the maximum amount of atomizing air pressure. It was later determined that for injection with the lances only, the difference in the minimum and maximum air pressures (10 and 12 psig, respectively) was insignificant with respect to both NO removal and NH_3 slip. The shape of the NO removal and NH_3 slip curves (i.e., monotonically decreasing NO removal and NH_3 slip with increasing angle) indicate that at 60 MWe, the flue gas regimes accessible by rotating the lances are on the high side of the optimal temperature window (recall Figure 2-3). Again, this is the most desirable area in which to operate a SNCR system, because although chemical utilization decreases at the higher temperatures, NH_3 slip is much less sensitive to changes in chemical flowrate or flue gas temperature.

In Figure 5-5, the limited data at N/NO = 2.2 show, as expected, that higher chemical flowrates result in increased NO removals and NH_3 slips for a fixed angle of injection. The data for an injection angle of 34° is replotted as a function of N/NO ratio in Figure 5-6. Included in Figure 5-6 is the data from the only test run with Level 1 injection at

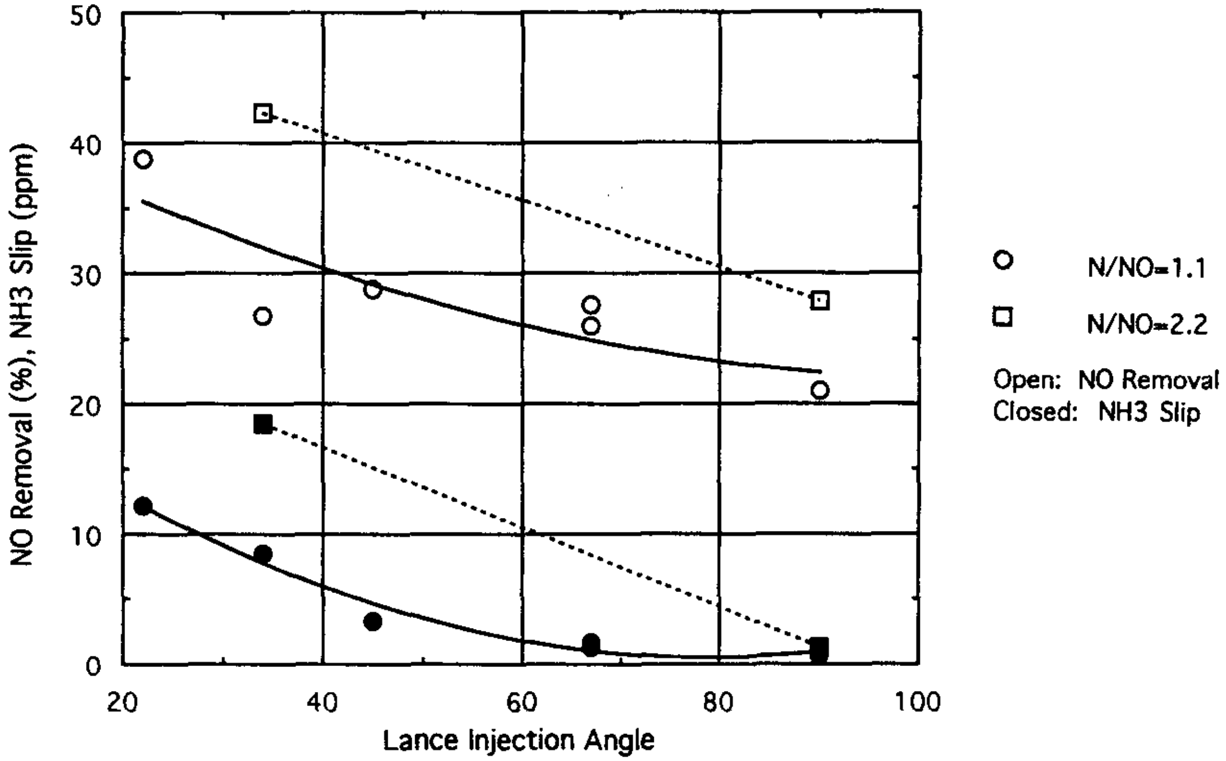


Figure 5-5. Effect of Lance Injection Angle with Two Mills in Service at 60 MWe (A & D Mills OOS, 4 gpm Liquid, 12 psig Air)

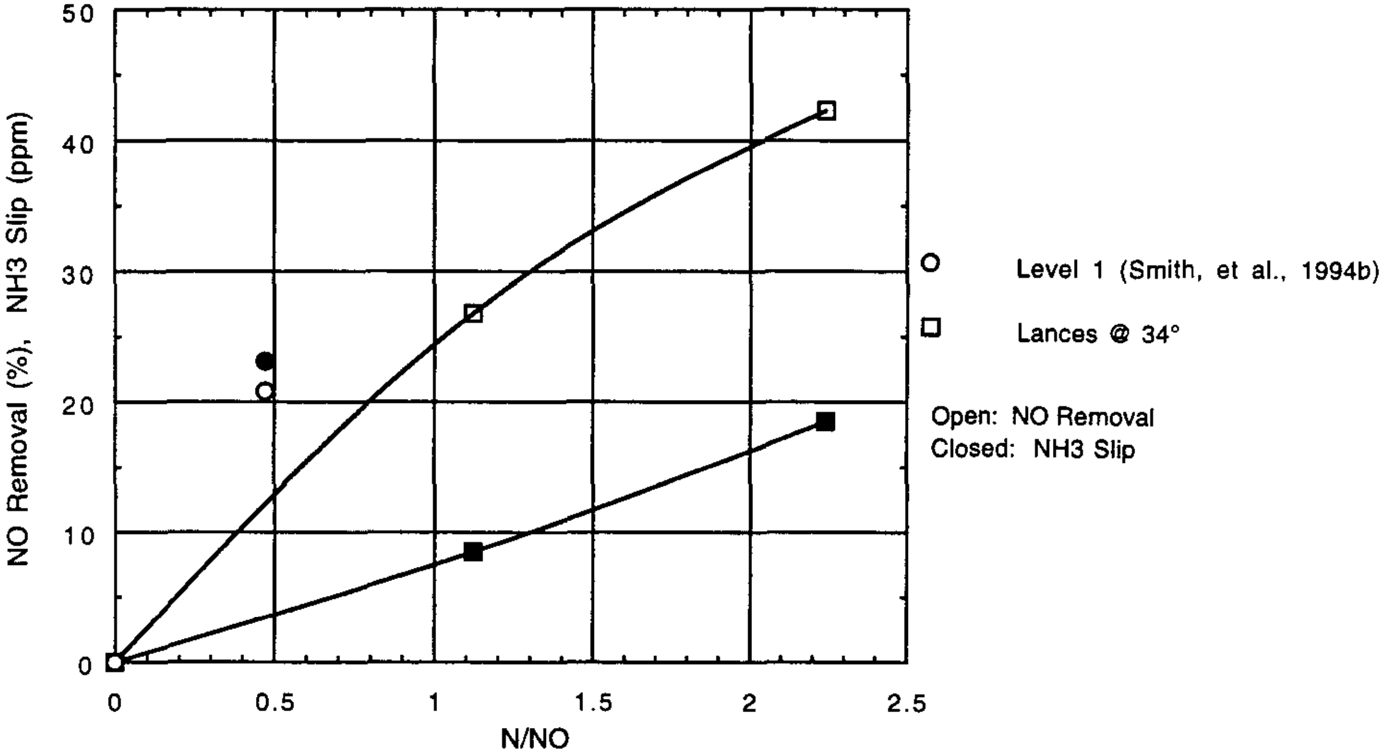


Figure 5-6. Comparison of Lance and Level 1 Injection with Two Mills in Service at 60 MWe (A & D Mills OOS, Lances @ 4 gpm Liquid and 12 psig Air, Level 1 @ 2 gpm Liquid and 8 psig Air)

60 MWe and two mills in service (A and D mills OOS). These results are from the post-retrofit tests (Smith, et al., 1994b). The Level 1 tests were run with a total liquid flowrate of 2 gpm and an atomizing air pressure of 8 psig. Although the Level 1 NO removal appears to be slightly better than that for the lances, the two results are comparable considering normal variation due to slight variations in boiler operating conditions. The NH_3 slip, on the other hand, is much higher for the Level 1 case (25 vs. 3 ppm). This is not surprising as the Level 1 injection location is in a lower temperature region of the boiler.

The majority of tests at 60 MWe were run with three mills in service, as this is the most common mode of operation for Arapahoe Unit 4 at this load. Only a few three-mill tests were completed before the turbine outage, and all of these were conducted with an injection angle of 34° and A mill OOS. Figure 5-7 shows the effect of N/NO ratio on NO removal and NH_3 slip for total liquid flowrates of 4 and 6 gpm. As the solution flowrate is increased, the NO removals decrease and NH_3 slip increases, indicating that the average flue gas temperature in the area in which the chemical is reacting is on the low temperature side of the optimal range. This trend seems to be inconsistent with that shown previously in Figure 5-5, where the angle variations with two mills in service suggested that the lances were operating on the high side of the SNCR temperature window. However, since the temperature profile in the furnace with three mills in service is likely different than that for two mill operation, the trends with temperature would not be expected to be identical. At an NH_3 slip limit of 10 ppm, NO removals of 35 and 21% can be achieved at 4 and 6 gpm, respectively. A total liquid flowrate of 4 gpm is clearly the better operating condition.

The 60 MWe tests with three mills in service continued when the boiler came back on-line after the turbine outage, and the first tests were run with B mill OOS. All of the 60 MWe tests after the outage were run with a total liquid flow of 4 gpm and an atomizing air pressure of 10 psig. Figure 5-8 shows NO removal and NH_3 slip as a function of N/NO ratio for injection angles of 22° and 34°; the results show that both NO removal and NH_3 slip are higher with the lances at 22°. However, the increase in NO removal is

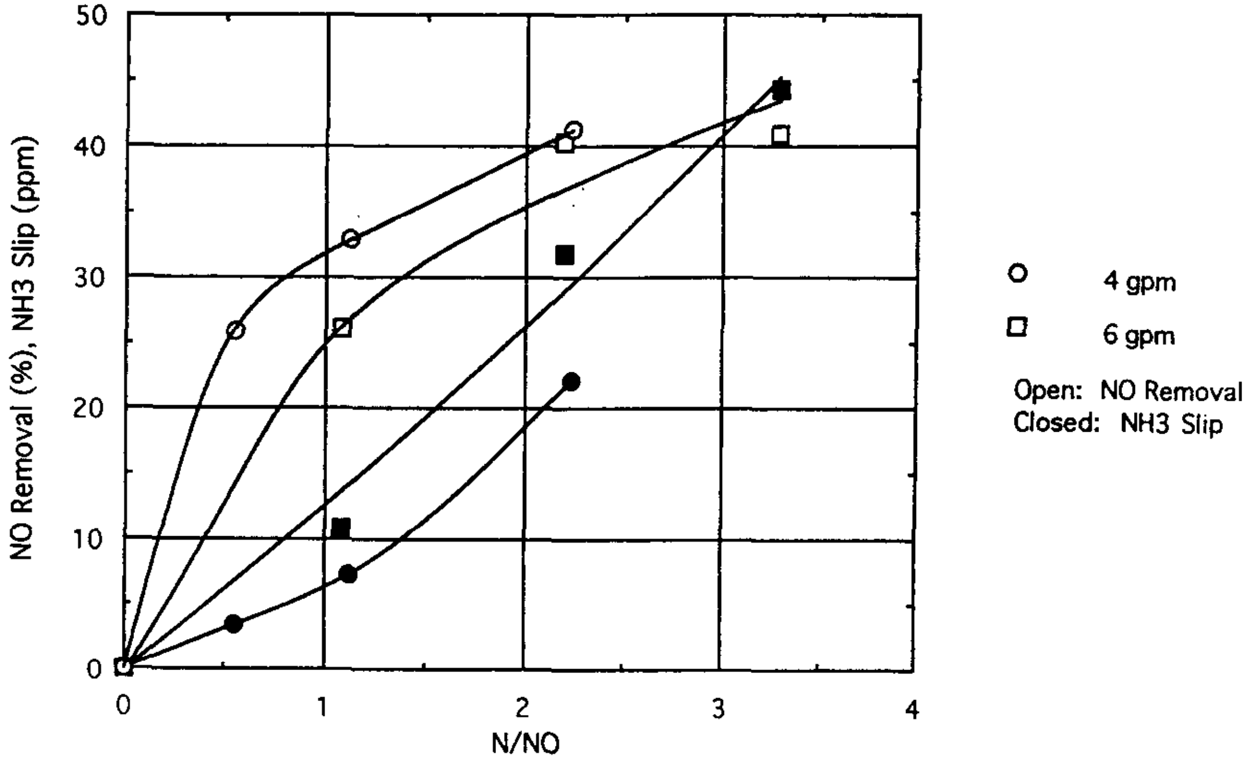


Figure 5-7. Effect of Total Liquid Flowrate for Lance Injection with Three Mills in Service at 60 MWe (A Mill OOS, 34° Injection Angle, 4 gpm Tests @ 10 psig Air, 6 gpm Tests @ 12 psig Air)

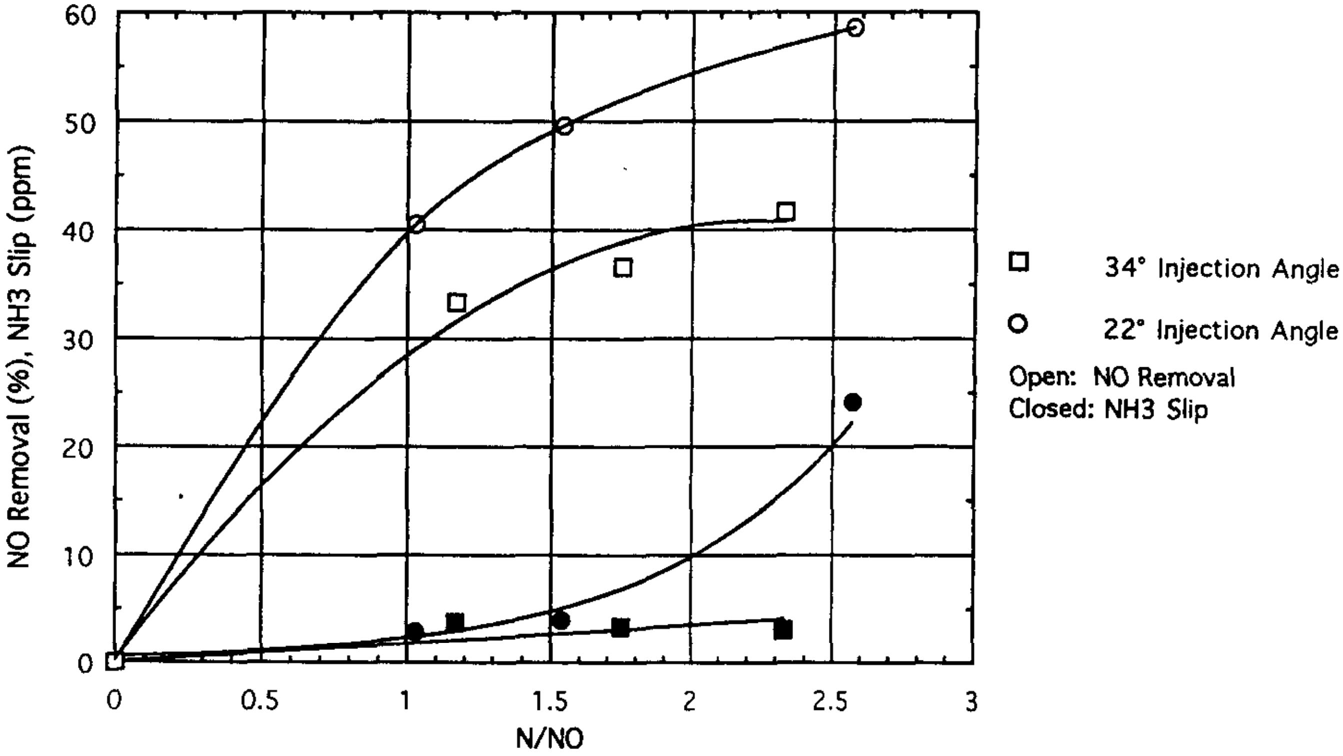


Figure 5-8. Effect of Lance Injection Angle with Three Mills in Service at 60 MWe (B Mill OOS, 4 gpm Liquid, 10 psig Air)

larger than that for NH_3 slip. Therefore, 22° is the better operating condition, as NO removals of nearly 55% can be achieved at the NH_3 slip limit of 10 ppm.

The results in Figures 5-7 and 5-8 show that for an injection angle of 34° with 4 gpm total liquid flow, the NO removals with A and B mills OOS are similar at N/NO=2.3 (about 41%), but the NH_3 slips are much lower with B mill OOS (4 vs. 22 ppm). It was hypothesized that the difference in NH_3 slip levels was due to localized variations in the flue gas temperature profiles resulting from the two different mill-in-service patterns. However, as the two sets of data were collected nearly five months apart, it was also possible that the effect may have been due to some other difference in boiler operation or condition. Figure 5-9 compares the results of tests run both before and after the turbine outage with A mill OOS and an injection angle of 34°. Although there is some scatter in the latter set of data (10/28/95), the NO removal and NH_3 slip results are in reasonable agreement. Therefore, the variation in NH_3 slip seen in Figure 5-7 and 5-8 is not likely a result of a change in boiler operation or condition between 5/31 and 10/28, but rather due to the difference in the mill-in-service pattern.

The ARIL parametric tests were suspended briefly in November to accommodate a two week test burn of a sub-bituminous Powder River Basin (PRB) coal. The ash characteristics of this coal resulted in decreased heat absorption in the radiant furnace and, thus, higher furnace exit gas temperatures during the test burn. Following the PRB test burn, and prior to resuming the parametric tests, the unit was operated on the baseline coal until the furnace exit gas temperature returned to normal. At this time, the effect of mill-in-service pattern at 60 MWe was investigated in more detail. A N/NO curve was run with each three mill-in-service condition over a period of four consecutive days. The results (Figure 5-10) show that mill-in-service pattern has a large effect on both NO removal and NH_3 slip. The NO removal at the NH_3 slip limit of 10 ppm ranges from 28 to 52%, depending on which mill is OOS. Table 5-1 shows the N/NO ratio and NO removal at the 10 ppm slip limit for each mill OOS condition. The average N/NO ratio and NO removal were 1.6 and 37%, respectively. The average N/NO ratio was

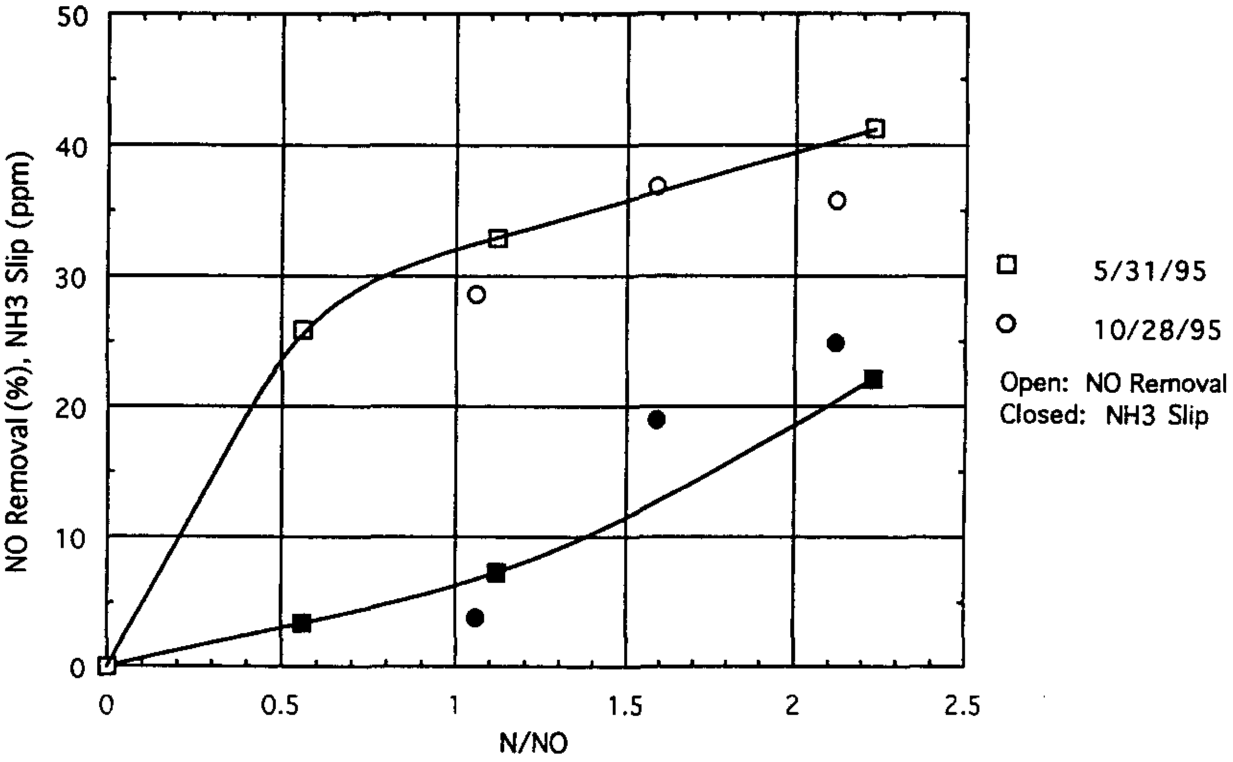


Figure 5-9. Comparison of Lance Injection Results Before and After Turbine Retrofit with Three Mills in Service at 60 MWe (A Mill OOS, 34° Injection Angle, 4 gpm Liquid, 10 psig Air)

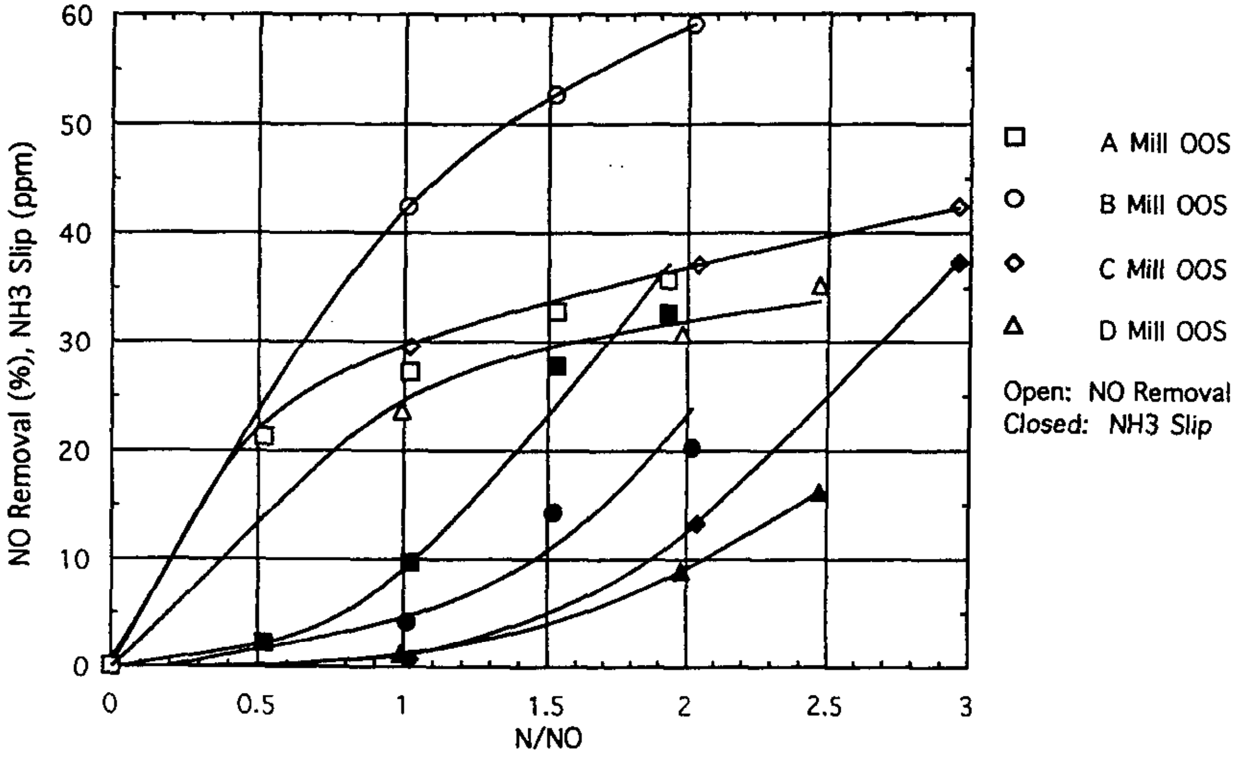


Figure 5-10. Effect of Mill-in-Service Pattern for Lance Injection at 60 MWe (22° Injection Angle, 4 gpm Liquid, 10 psig Air)

used as the initial set point for automatic control at 60 MWe. Although this flow rate will result in an NH_3 slip in excess of the 10 ppm limit when A mill is OOS, the automatic trim control will reduce the chemical flow until the NH_3 slip is below the limit.

Table 5-1

N/NO Ratio and NO Removal at 10 ppm NH_3 Slip for Three Mill Operation at 60 MWe

Mill OOS	N/NO Ratio	NO Removal (%)
A	1.05	28
B	1.45	52
C	1.85	37
D	2.05	32
Average	1.60	37

Composite flue gas measurements on the east and west sides of the economizer exit duct showed that in some cases, three mill operation at 60 MWe resulted in a large difference in the NO removals on each side of the boiler. In many cases, the east and west NH_3 slip levels were also very different. Figure 5-11 shows the baseline O_2 and NO measurements (east and west) for the N/NO = 2.0 tests shown previously in Figure 5-10. Also shown are the furnace exit gas temperatures measured for each test, as well as simplified plan views of the furnace indicating which burners were OOS. With either A or C mill OOS, two burners on the west side are not firing and only one on the east side is OOS. Therefore, there is a "net" shift in coal flow from the west to the east side of the furnace. As expected, both cases result in higher O_2 levels on the west side of the boiler. Conversely, with either B or D mill OOS the coal flow is shifted from east to west. However, with B mill OOS there was no difference between the east and west O_2 levels. With D mill OOS, there is an O_2 bias to the east, but the magnitude of the bias is less than one-half that measured with A mill OOS (1.4 vs. 3.2%). The O_2 results

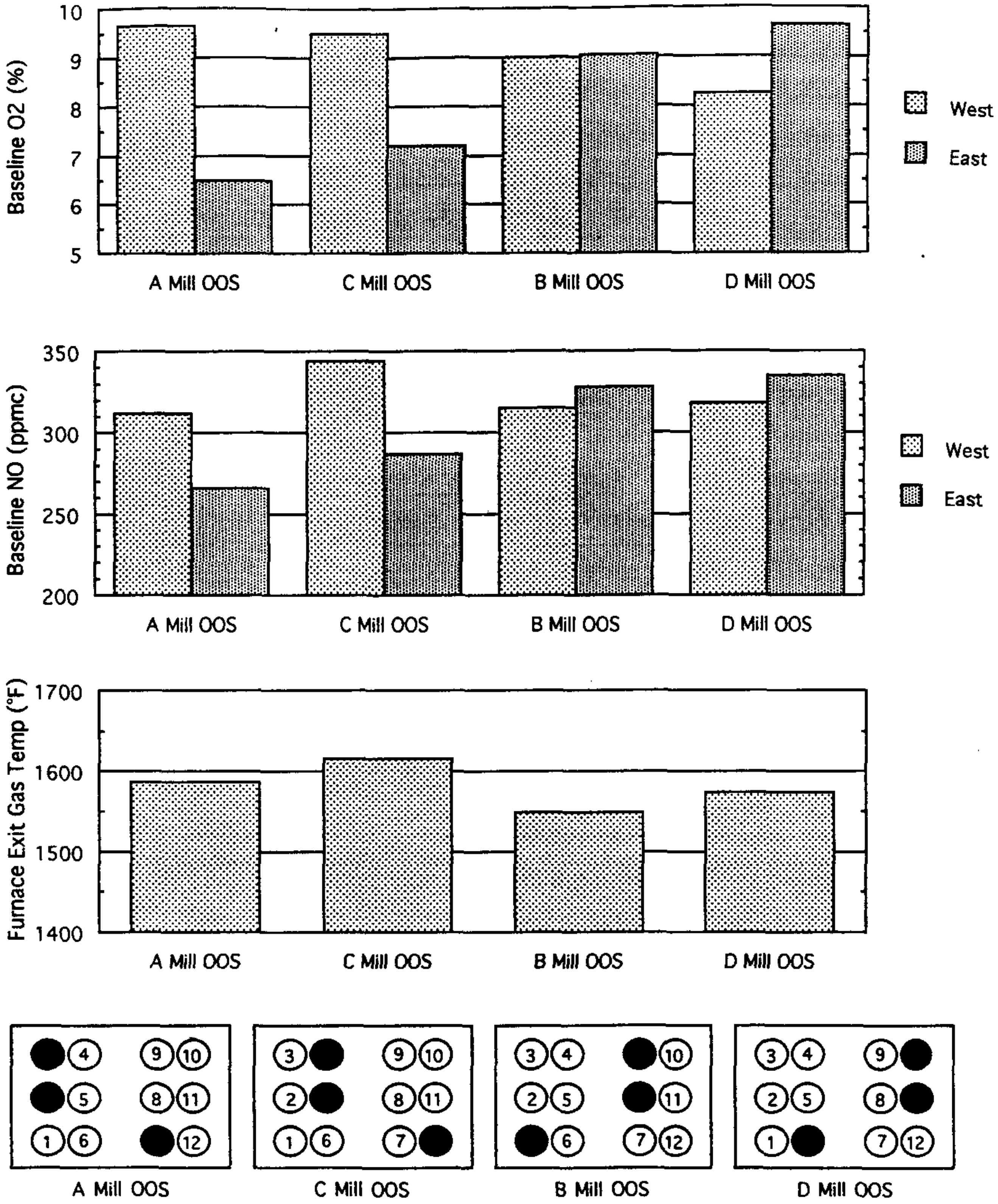


Figure 5-11. East-West Baseline O_2 and NO Distributions and Average Furnace Exit Gas Temperature as a Function of Mill-in-Service Pattern at 60 MWe (Note: In the burner diagrams above, west is on the left side and east on the right, and black circles indicate the burners OOS.)

indicate that there was an underlying maldistribution of fuel and/or air at the burner level during these tests. The tests were conducted near the end of the test program when both B and D mills were running poorly, and it is hypothesized that feedrate problems with these two mills may have resulted in a coal bias toward the east side of the furnace. Visual observations through view ports at the furnace exit seemed to confirm this, as for nearly every one of these tests, the east side of the furnace appeared to be much hotter than the west irrespective of the mill-in-service pattern.

Figure 5-11 also shows, as expected, that the baseline NO levels are highest in the areas of high O_2. Even with these sometimes large differences in fuel and O_2 levels east-to-west, the acoustic temperature measurements show that mill-in-service pattern had a relatively small effect (a maximum of 50°F) on the average temperature at the furnace exit. However, it must be noted that the acoustic measurement is a line-of-sight average, and thus does not provide any insight into how the actual temperature profile changes.

Figure 5-12 shows the east and west NO removal measurements, NH_3 slip levels, and lance metal temperatures for the four tests discussed above. Although the lance thermocouples do not provide a direct measurement of flue gas temperature, they do provide an indication of the trends on either side of the furnace, as well as the temperature difference between the two sides. The metal temperature indicate that the flue gas temperatures on the east side of the furnace are highest in each mill OOS configuration, and the NH_3 slip measurements confirm this observation. The simplified plan views at the bottom of the figure show that as the page is traversed from left to right (from A mill OOS to D mill OOS), coal is moved from the east side of the furnace to the west (i.e., with A or C mill OOS, there are more burners firing on the east side of the unit, and with B or D mill OOS, the opposite is true). As this occurs, the difference between the east and west NO removals decrease. The difference in the lance metal temperatures decrease, and the average NH_3 slip level generally decreases.

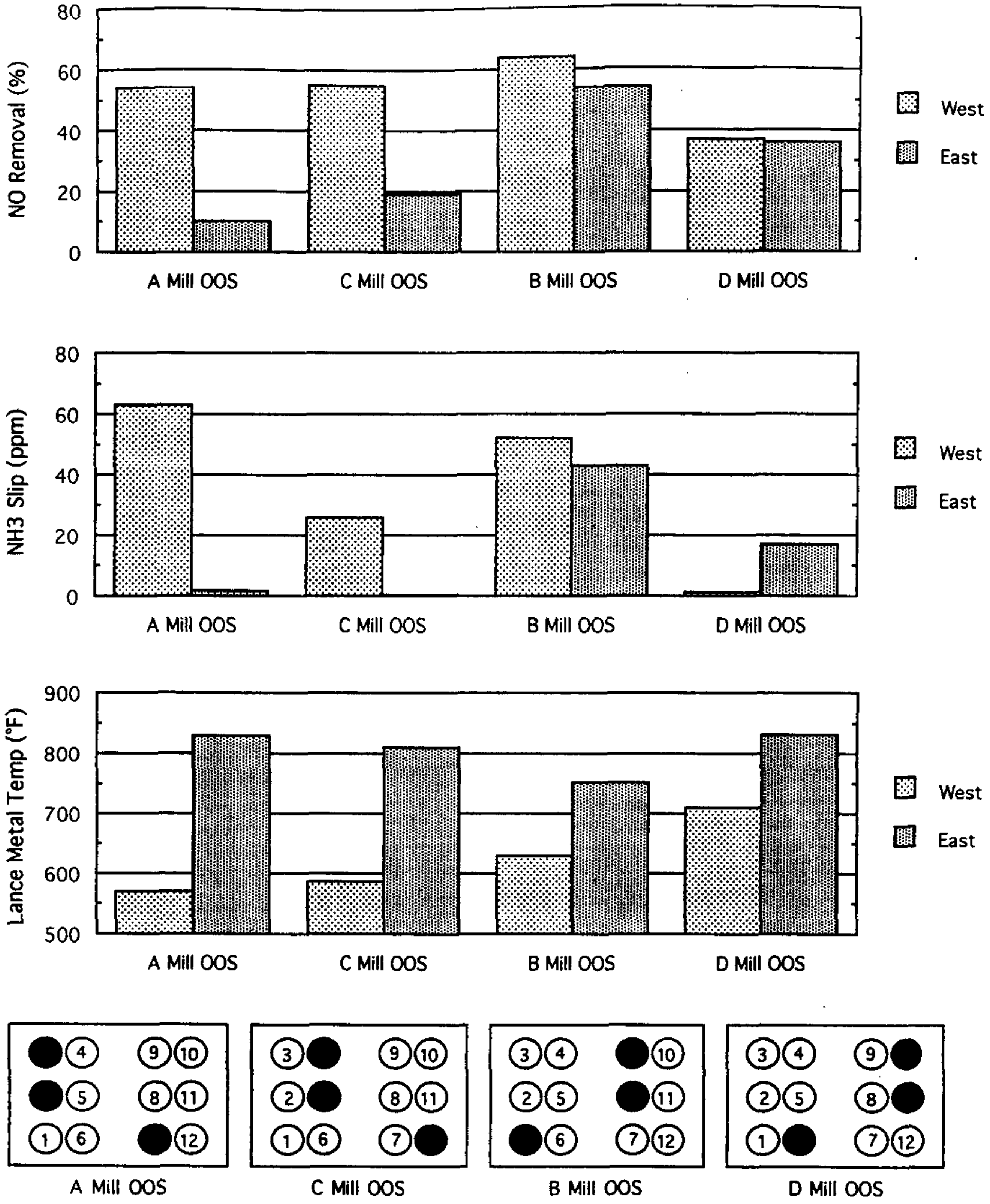


Figure 5-12. East-West NO Removal, NH_3 Slip and Lance Metal Temperature Distributions as a Function of Mill-in-Service Pattern at 60 MWe (N/NO = 2.0, 22° Injection Angle, 4 gpm Liquid, 10 psig Air)

All of the tests shown in Figure 5-10 were conducted without any bias in the coal mill controls. A series of tests was run to investigate the possibility of increasing SNCR performance with A mill OOS by biasing the three mills remaining in service. The mills were biased by the control operator, with the goal of making the O_2 distribution shown by the four PSCo probes (recall Figure 4-2) as uniform as possible. This was accomplished by biasing the coal to the west side of the furnace. Table 5-2 shows the bias settings used during these tests. A three-point N/NO curve was run with these biased mill settings, and at the end of the third test (N/NO=1.5), the mill biases were reset to zero and a fourth "no bias" test run at N/NO=1.5). Figure 5-13 shows the results of these tests, along with the A mill OOS curves from Figure 5-10 (no mill bias, 12/1/95), for comparison. The "no bias" results from the two separate days are in good agreement. The data from the second day show that when the bias was removed at N/NO=1.5, the NO removal decreased from 45 to 35%, and the NH_3 slip increased by over 15 ppm.

Table 5-2

Mill Bias Settings for 60 MWe Lance Injection

Mill	Mill Master Bias	West Feeder Bias
A	OOS	OOS
B	-10%	+11%
C	+10%	+5%
D	-10%	0

Figure 5-14 shows the east and west O_2 levels, NO removals, NH_3 slip emissions, and lance temperatures for the two back-to-back tests at N/NO = 1.5. These results indicate that the mill bias pattern in Table 5-2 reduced, but did not eliminate, the east-to-west imbalance with A mill OOS. Unfortunately, there was not sufficient time during the current test phase to rerun this test with higher levels of bias, or with other mill-in-service patterns. However, this single test does show that it is possible to increase the

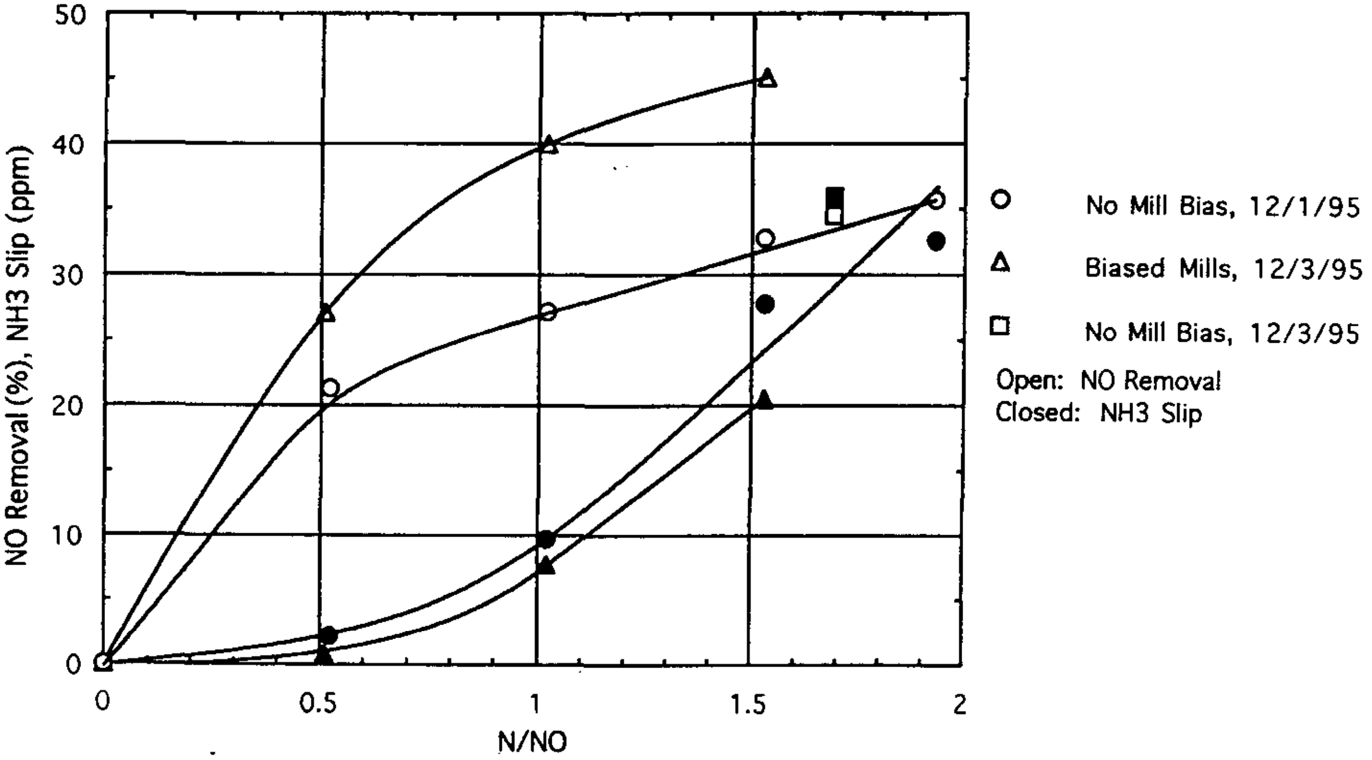


Figure 5-13. Effect of Coal Mill Bias for Lance Injection at 60 MWe (A Mill OOS, 22° Injection Angle, 4 gpm Liquid, 10 psig Air)

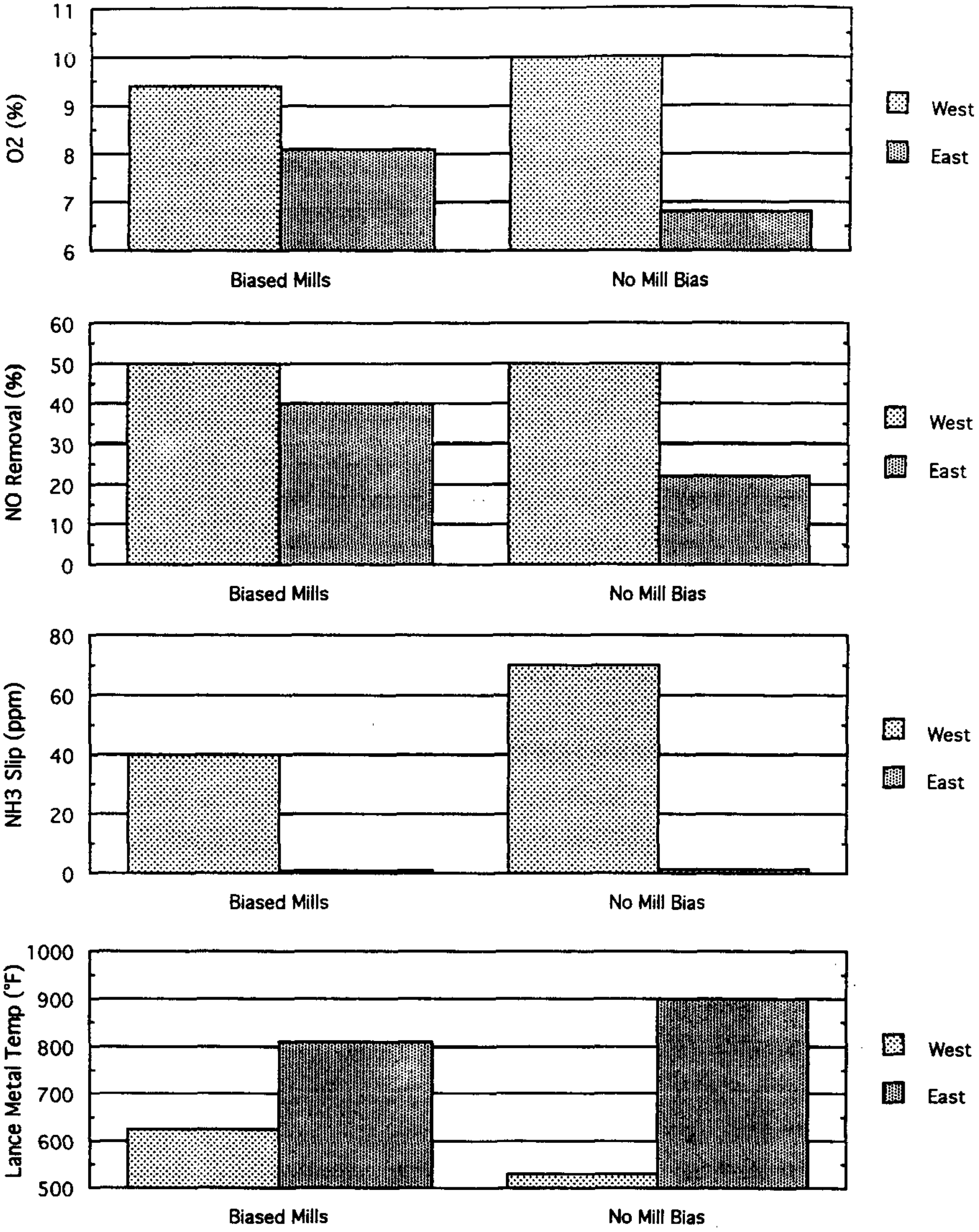


Figure 5-14. East-West O_2, NO Removal, NH_3 Slip and Lance Metal Temperature Distributions as a Function of Mill Bias at 60 MWe (A Mill OOS, 22° Injection Angle, 4 gpm Liquid, 10 psig Air)

SNCR system performance by providing more uniform combustion conditions across the width of the furnace.

Previous Level 1 testing with three mills in service (Smith, et al., 1994b) showed that the particular mill OOS had little effect on NO removal and only a slight effect on NH_3 slip. However, the lance results from the current phase of testing (Figure 5-10), show that mill-in-service pattern has a large effect on both NO removal and NH_3 slip. This difference in behavior is attributed to the location of each set of injectors. The Level 1 injectors are located on the back wall of the boiler, downstream of the first set of screen tubes. Although, the screen tubes are not as tightly packed as a superheater or reheater tube section, they will tend to smooth out the flue gas temperature profile, and to a lesser extent the velocity profile, at the Level 1 injection location. On the other hand, the lances are located at the furnace exit ahead of the screen tubes. At this location, there is no smoothing or moderation of the temperature profile, and the performance of the SNCR system will be more sensitive to the low temperature zones resulting from the various mill-in-service patterns.

Level 1 injection tests at 60 MWe were not completed during the current test phase, so any lance/Level 1 comparisons are based on the Level 1 results from the previous SNCR test phase (Smith, et al., 1994b). A comparison of the lance and Level 1 performance for three-mill operation with D mill OOS is shown in Figure 5-15. Although the lances require a higher chemical injection rate to achieve a given level of NO removal, this disadvantage is far outweighed by the reduction in NH_3 slip levels. At an NH_3 slip limit of 10 ppm, the NO removal is only 10% for injection at Level 1. The NO removal with the lances is 32% at the same NH_3 slip limit.

D. 70 MWe Results

As mentioned earlier, although there were no tests run at 70 MWe during either of the two previous SNCR test phases, 70 MWe tests were run during the current phase in order to help locate the optimal transition point between the two injection locations. All 70 MWe tests were run with three mills in service, and both Level 1 and lance injection

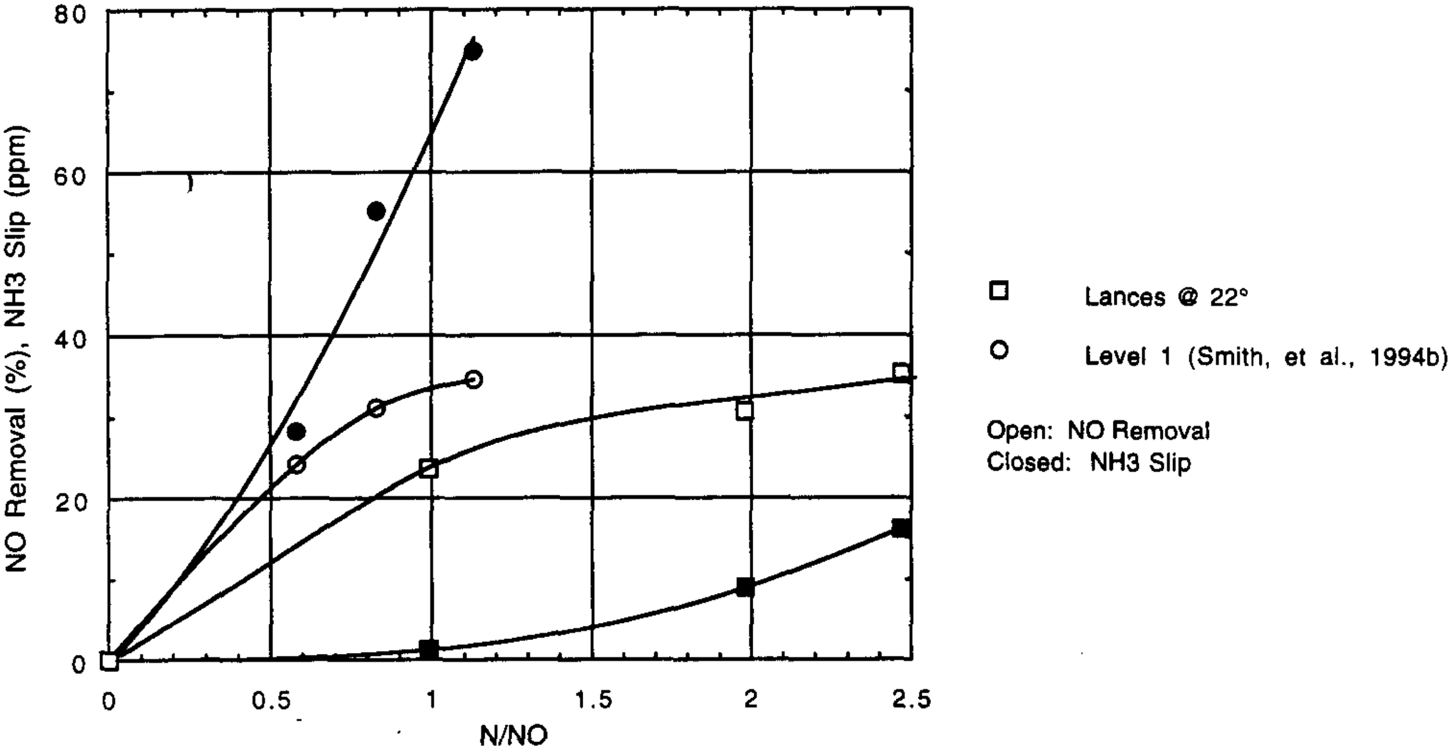


Figure 5-15. Comparison of Lance and Level 1 Injection with Three Mills in Service at 60 MWe (D Mill OOS, Lances @ 4 gpm Liquid and 10 psig Air, Level 1 @ 2 gpm Liquid and 8 psig Air)

configurations were tested. Unfortunately, it was not possible to run the two injection configurations with the same mill in service pattern. Figure 5-16 compares the results for lance injection at 22° with C mill OOS to the results for Level 1 injection with B mill OOS. The lance tests were run with a total liquid flow of 4 gpm and an atomizing air flow of 10 psig, while the Level 1 tests were run at 2 gpm and 8 psig, respectively.

If the results in Figure 5-16 are viewed strictly from the perspective of the maximum level of NO removal attainable at an NH_3 slip limit of 10 ppm, the lances would appear to be the better choice. At Level 1 the NO removal is 38%, while 44% removal is possible with the lances. However, the chemical flowrate required by the lances to achieve this level of NO removal is over four times the flow required by the Level 1 injectors (N/NO = 2.6 vs. N/NO = 0.6). At this load, although the NO removal/NH_3 slip performance of the lances is better, Level 1 injection is by far the most economical of the two locations.

The results shown in Figure 5-16 indicate that the average flue gas temperature at the lance injection location is well on the high side of the optimal window, as there is very little NH_3 slip even at high rates of chemical injection. However, since one mill is OOS at 70 MWe, it is likely that one side of the furnace will be cooler than the other. A series of tests were run to see if the performance of the system could be increased by running the two lances at different injection angles.

A parametric variation of injection angle was run at 72 MWe with A mill OOS. The effect of injection angle on NO removal and NH_3 slip is shown in Figures 5-17a and 5-17b, respectively. The four tests shown were run consecutively in a single day, at a nominal N/NO ratio of 0.9, with a total liquid flow of 6 gpm and an atomizing air pressure of 10 psig. With A mill OOS, three of the 12 burners are not firing -- two on the west side of the boiler, and one on the east side (recall Figure 2-2). It would, therefore, be reasonable to expect that the flue gas temperatures on the west side

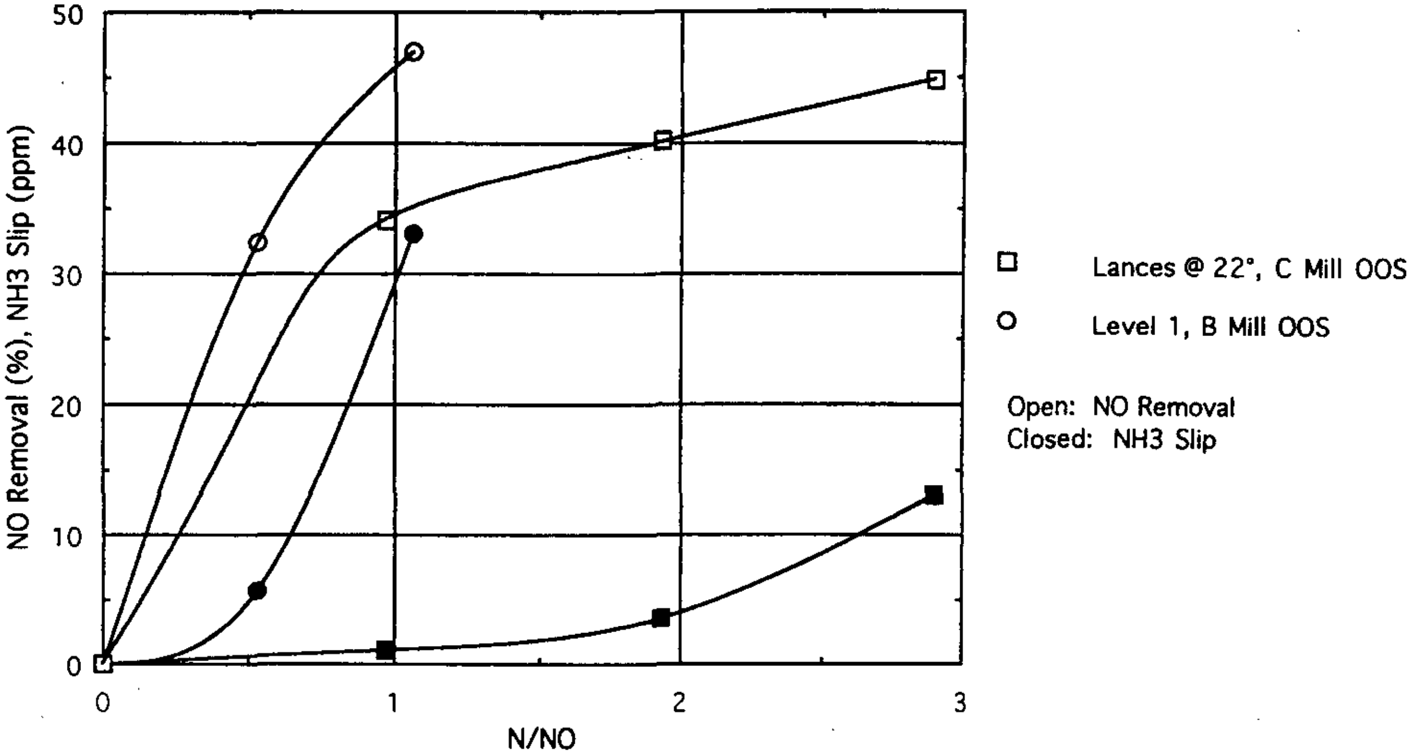


Figure 5-16. Comparison of Lance and Level 1 Injection at 70 MWe (Lances @ 4 gpm Liquid and 10 psig Air, Level 1 @ 2 gpm Liquid and 8 psig Air)

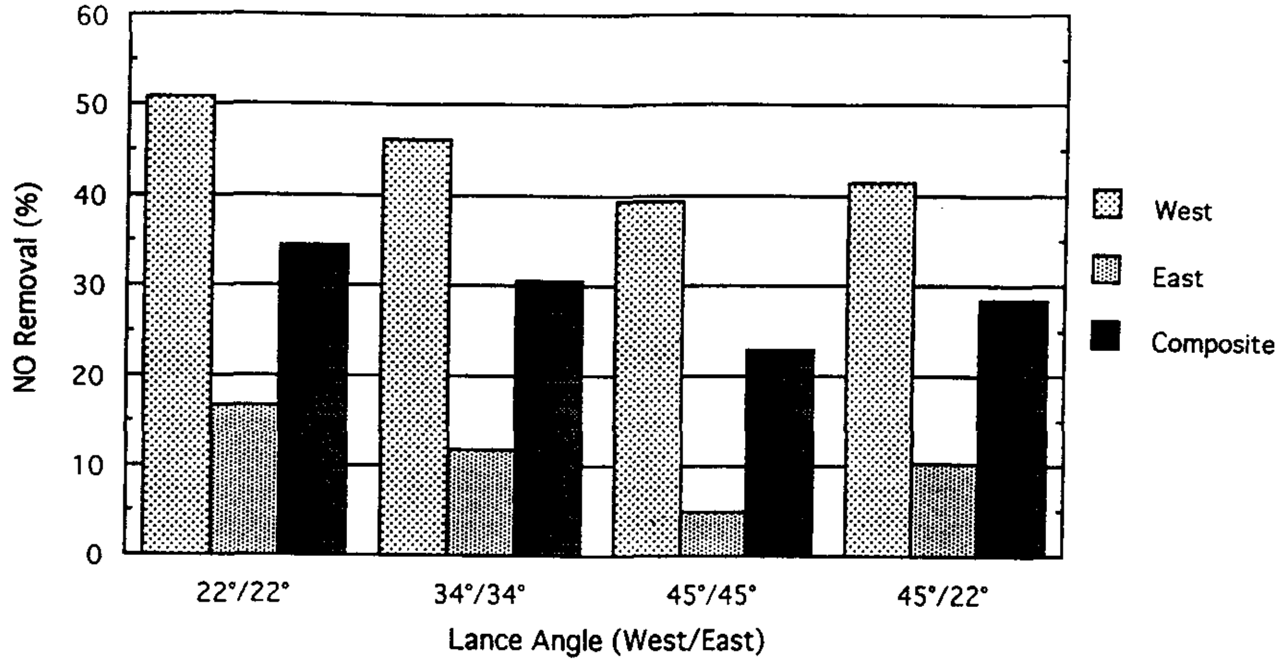


Figure 5-17a. NO Removal as a Function of Lance Injection Angle at 72 MWe (A Mill OOS, N/NO = 0.9, 6 gpm Liquid, 10 psig Air)

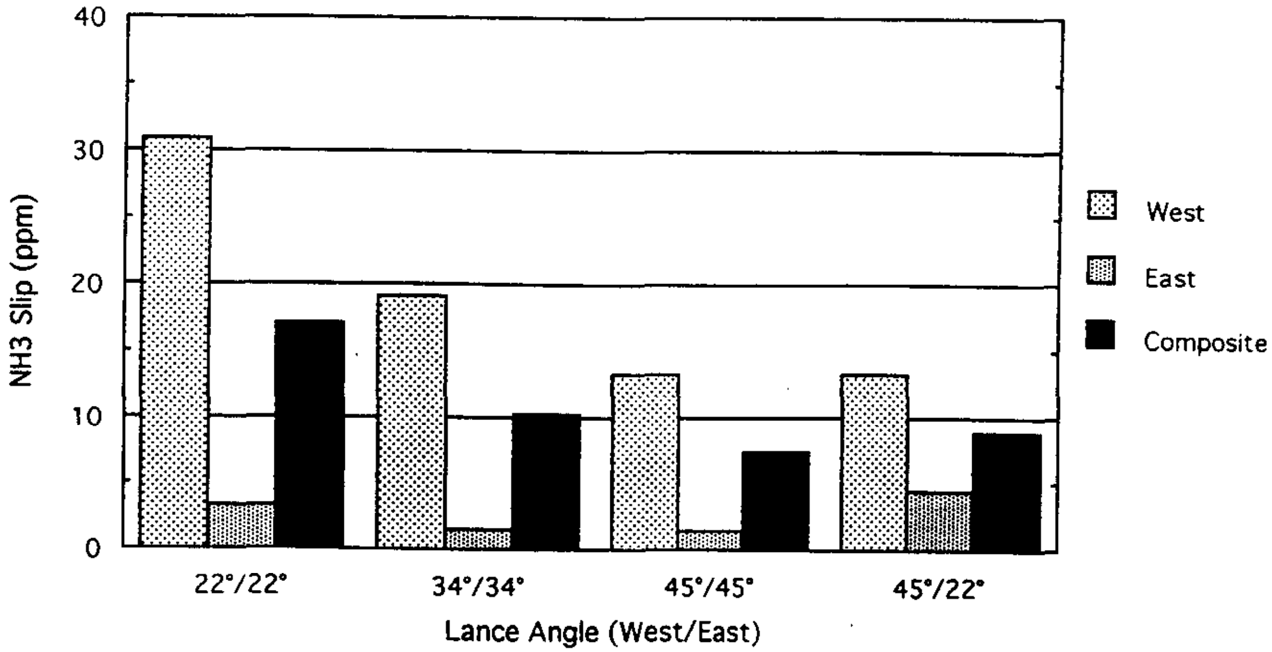


Figure 5-17b. NH_3 Slip as a Function of Lance Injection Angle at 72 MWe (A Mill OOS, N/NO = 0.9, 6 gpm Liquid, 10 psig Air)

would be cooler than on the east. The results in Figure 5-17b confirm that this is true, as the NH_3 slip is highest on the west side irrespective of the injection angle.

The results in Figure 5-17a show that as the injection angle is increased, NO removals on both sides of the boiler decrease, indicating that the removals are occurring on the high side of the optimal temperature window. Although on both sides, the maximum NO removals occurred at an injection angle of 22°, the angle on the west side was increased to 45° in order to minimize the overall NH_3 slip. Compared to the 22°/22° case, this adjustment resulted in a 50% reduction in the NH_3 slip (from nominally 18 to 9 ppm), with only a small decrease in NO removal (from 34 to 29%).

The results in Figure 5-17b show that even with an injection angle of 45°, the NH_3 slip on the west side of the boiler was still over twice as high as that on the east side. It was believed that the majority of the NH_3 slip on the west side was formed in the region near the outside wall where two burners (Numbers 1 and 2) were OOS. In an attempt to further reduce the overall NH_3 slip, a series of tests was run where the chemical flow was biased away from the area adjacent to the west wall of the boiler. Three tests were run, each at a nominal N/NO ratio of 2.0. In the first test, the liquid flow to all four lance quadrants was equal. In the second test, the flow to the quadrant adjacent to the west wall was reduced by 50%, and in the third test, the flow to the west quadrant was shut off completely. The total liquid flow to both lances was maintained at 6 gpm during all three tests. Thus, as the flow to the west quadrant was progressively reduced, the flow to the other three increased accordingly. Atomizing air flow to each quadrant was unchanged during these tests.

The NO removal and NH_3 slip results for the flow biasing tests are shown in Figures 5-18a and 5-18b, respectively. Reducing the flow to the west quadrant by 50% markedly decreased the NH_3 slip in that region, resulting in a decrease in the overall NH_3 slip from nominally 14 to 4 ppm. Biasing of the chemical to the higher temperature regions of the boiler resulted in a reduction of overall NO removal from approximately 34 to 29%. Further reductions in both NH_3 slip and NO removal were seen when the

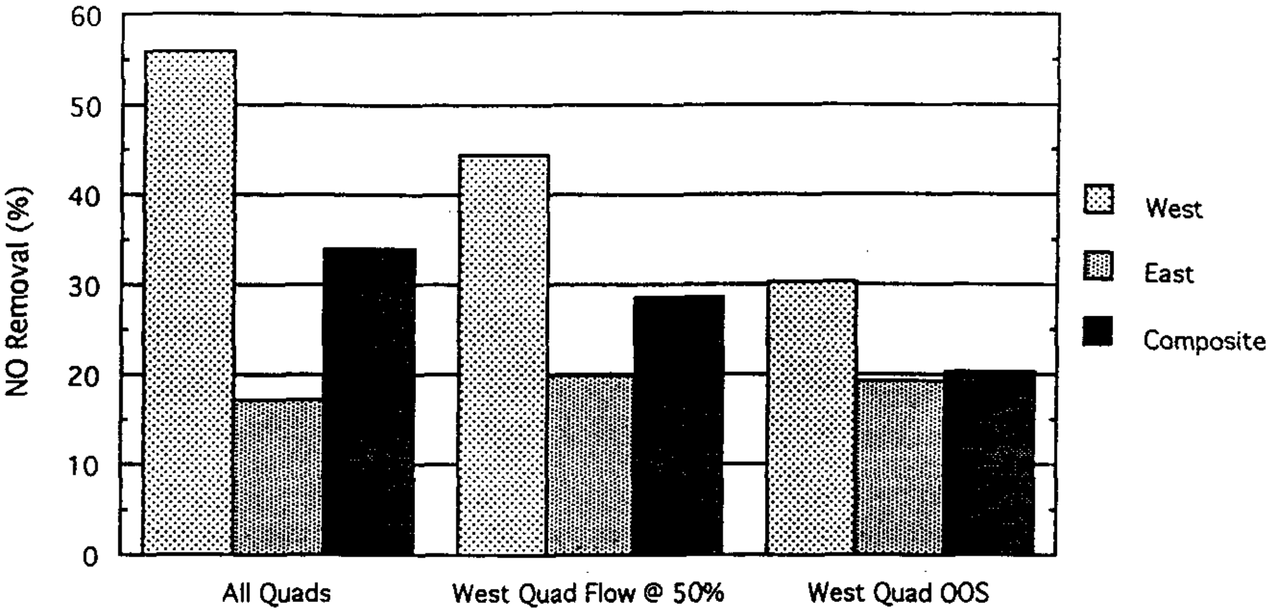


Figure 5-18a. Effect of Lance Liquid Biasing on NO Removal at 70 MWe
(A Mill OOS, N/NO = 2.0, 45°/22° Injection Angles (W/E), 6 gpm Liquid, 10 psig Air)

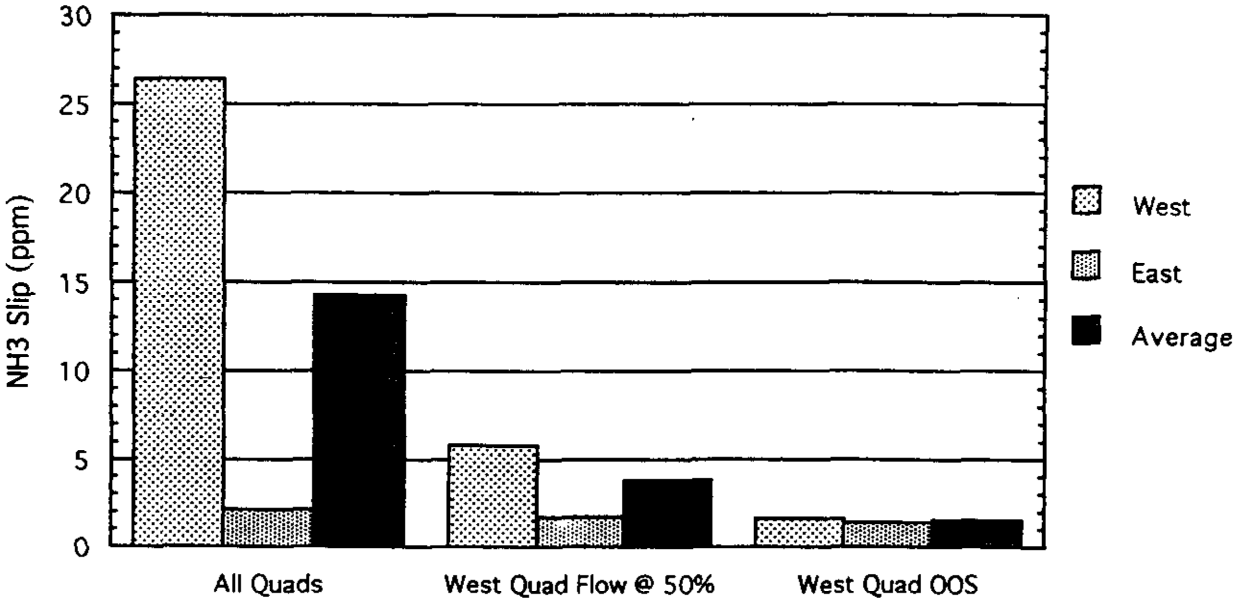


Figure 5-18b. Effect of Lance Liquid Biasing on NH_3 Slip at 70 MWe
(A Mill OOS, N/NO = 2.0, 45°/22° Injection Angles (W/E), 6 gpm Liquid, 10 psig Air)

flow to the west quadrant was completely shut off. However, in comparison to the decrease in NO removal, the reduction in NH_3 slip was far too small for the third injection configuration to be considered practical.

Figure 5-19 shows NO removal and NH_3 slip as a function of N/NO ratio for the 45°/22° configuration with all four injection quadrants in service, and with the west quadrant flow reduced by 50%. As was seen in Figure 5-18b, when compared on the basis of minimum NH_3 slip at a fixed N/NO ratio, operation with reduced flow to the west quadrant seems to be the preferable configuration. The same is true when the two configurations are compared on the basis of maximum achievable NO removal at a fixed NH_3 slip limit. With reduced flow to the west quadrant, nominally 31% NO removal can be achieved at an NH_3 slip limit of 4 ppm. With equal flow to all four quadrants, a NO removal of nominally 27% is achievable at the same limit. Although the NO removal is slightly less, operation with equal flow to all quadrants is actually the preferred configuration from a practical standpoint, because the N/NO ratio is less than one-half of that required when running with flow to the west quadrant cut by 50%. Although the chemical utilization is best with equal flow to all quadrants, the results also showed that biasing the flow can provide a means of controlling NH_3 slip. Further optimization of this approach would be practical only if the ability to bias the flow could be incorporated into the control system.

The results in Figures 5-17a and 5-17b showed that the SNCR performance with three mills in service could be improved by adjusting each lance angle independently. Unfortunately, this approach cannot be applied to the automatic control system since the PLC is not configured to "know" when or where a coal mill is OOS. These inputs could be provided from the Unit 4 DCS, but incorporating them into the SNCR control scheme would add another layer of complexity to the system. With the current control system, a better approach to improving SNCR performance would be to instruct the boiler control operators to adjust the mill bias settings to provide a uniform O_2 profile across the furnace, as was done during the 60 MWe tests shown in Figure 5-13.

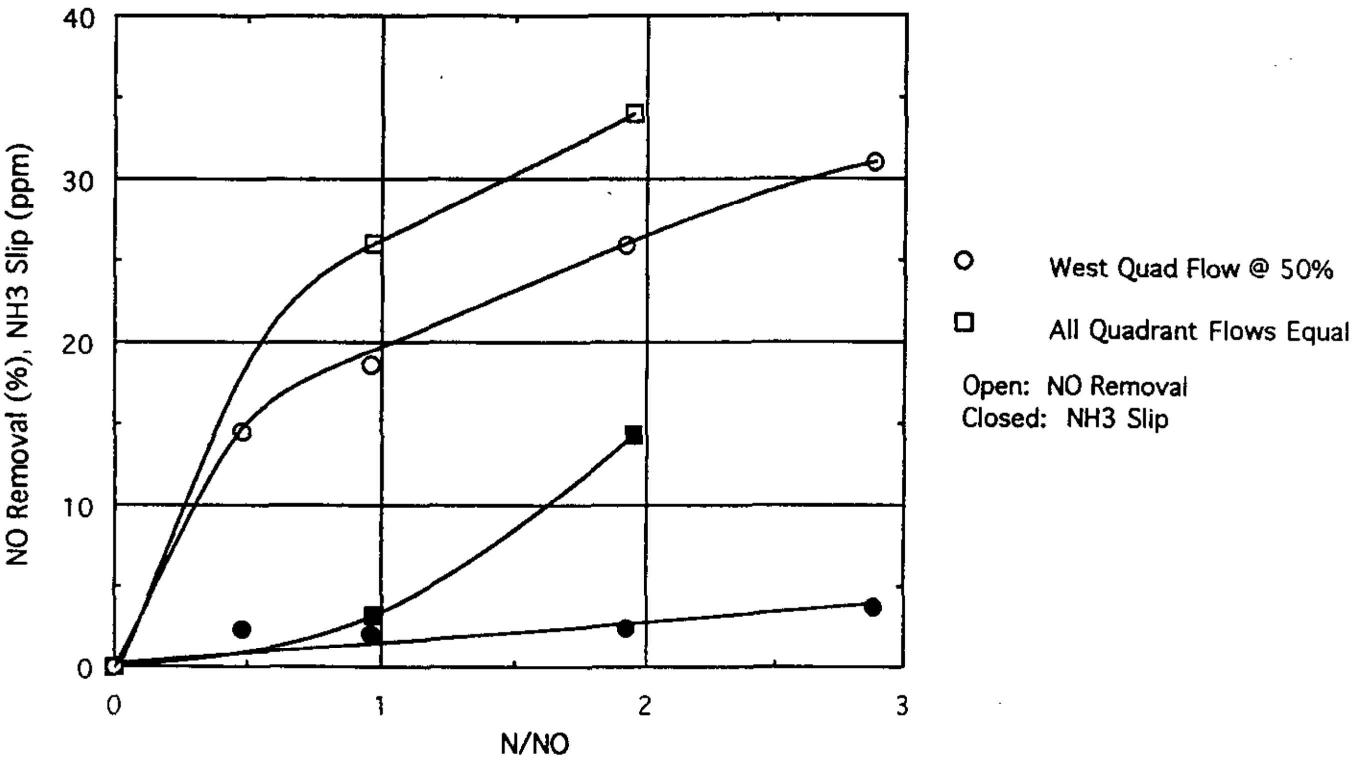


Figure 5-19. Effect of N/NO Ratio for Lance Injection at 70 MWe
(A Mill OOS, 45°/22° Injection Angles (W/E), 6 gpm Liquid, 10 psig Air)

E. 80 MWe Results

During the previous phase of SNCR testing, Level 1 injection tests were run at 80 MWe with both three and four coal mills in service. During the current test phase, three-mill tests were run with Level 1 injection alone, with lance injection alone, and with the two levels operating simultaneously. The NO removals and NH_3 slips for these three injection configurations are shown in Figure 5-20. The lance results were obtained at an injection angle of 22°, with a total liquid flowrate of 6 gpm, and an atomizing air pressure of 10 psig. For Level 1 injection alone, the liquid and air flowrates were 2 gpm and 8 psig, respectively. These values were established as the optimal settings for Level 1 injection at 80 MWe during the previous test phase, and were therefore used during the current test phase. For the simultaneous injection test, the total liquid flowrate was 8 gpm, where 6 gpm went to the lances, and the remaining 2 gpm to Level 1. Air pressure for this test was maintained at 8 psig.

The difference in the flue gas temperatures at the two injection locations is quite apparent in Figure 5-20. NO removals of greater than 50% are achievable with Level 1 injection, but the resulting NH_3 slips are in excess of 60 ppm. At the higher temperature lance location, the NH_3 slips are considerably lower, as are the NO removals. For an NH_3 slip limit of 10 ppm, the achievable NO removals at each location are similar with 25% for Level 1, and 27% for the lances. However, the N/NO ratios indicate that the amount of chemical necessary to achieve this NO removal with the lances is five times that required at the Level 1 injection location. Based on this comparison, Level 1 is the better location for SNCR at 80 MWe.

The simultaneous injection test was run at the end of the day of the Level 1 tests. It was believed that the combination of the two locations would result in a higher NO removal for a fixed NH_3 slip level. Although there was time for only a single test, the results were encouraging when compared to the results of the Level 1 tests from earlier in the day. The dashed lines in Figure 5-20 are estimates of the NO removal and NH_3 slip behavior for the simultaneous injection case, based upon the single data point at a nominal N/NO ratio of 2.0, and the shape of the curves for the other two injection

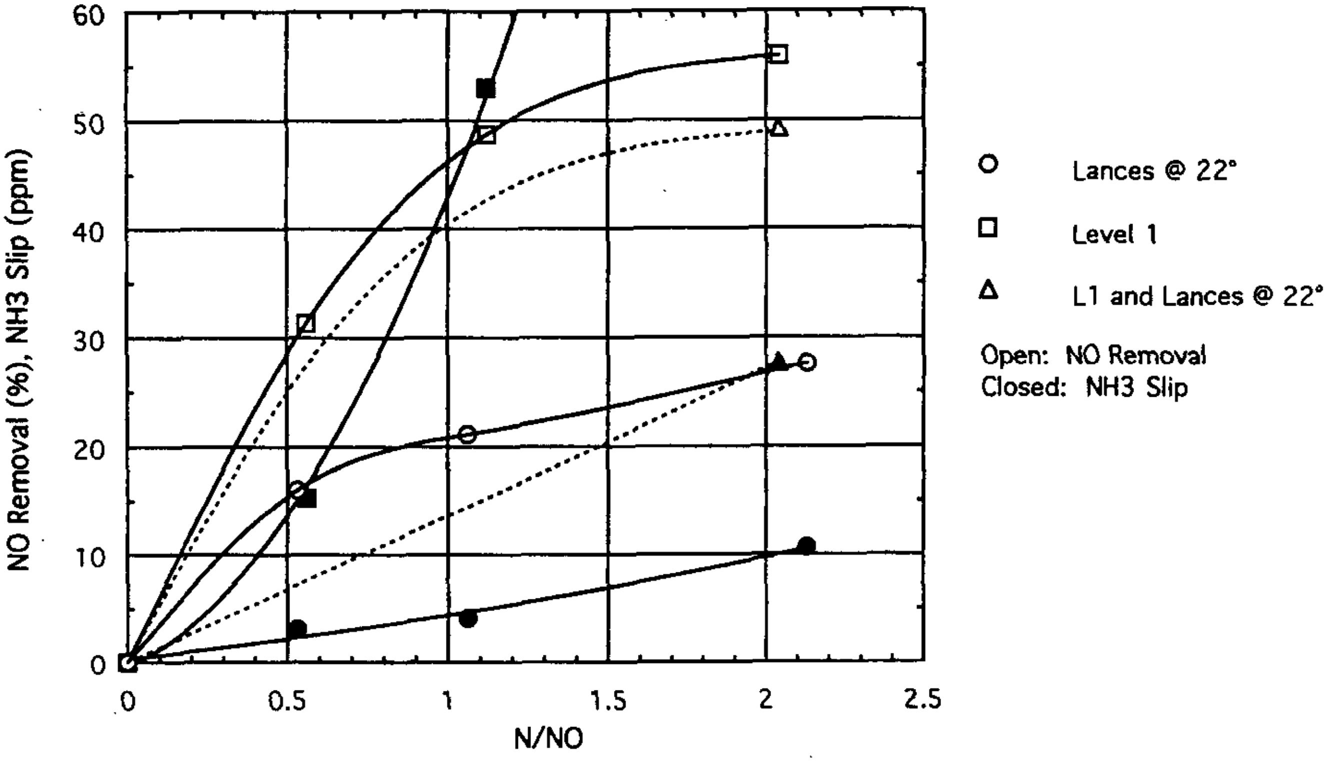


Figure 5-20. Comparison of Lance, Level 1, and Simultaneous Lance/Level 1 Injection at 80 MWe (A Mill OOS, Lances @ 6 gpm Liquid and 10 psig Air, Level 1 @ 2 gpm Liquid and 8 psig Air, Simultaneous @ 8 gpm Liquid and 8 psig Air)

configurations. Based on these predictions, 10 ppm NH_3 slip should occur at a N/NO ratio of approximately 0.75, with a corresponding NO removal in the range of 30 to 35%.

The results of the single simultaneous injection test warranted additional testing of this configuration. Therefore, a N/NO curve was run on the next day that 80 MWe was available. The results of these tests are shown in Figure 5-21, along with the single test point from Figure 5-20. Although the NO removals at the high N/NO ratio repeated well, the NH_3 slip was nearly 25 ppm higher on the second day. Two factors are believed to have at least partially contributed to the differences in NH_3 slip behavior seen between the two days. First, the boiler load on the second day drifted down slightly (from 80 to 77 MWe) during the time between the morning baseline test and first injection test. The reduced flue gas temperatures at the lower load will result in a slightly higher NH_3 slip for a fixed N/NO ratio. However, it is believed that this increase would be on the order of only 5 ppm, not 25 ppm as seen in Figure 5-21. The control operator was also experiencing difficulties with the B coal mill on the second day of tests. The east side of the mill was not pulverizing the coal as efficiently as the west, and had a tendency to occasionally "plug-up" throughout the day. Although the problem was not so severe as to cause the east feeder to trip off-line, or to require the operator to manually take the feeder OOS temporarily to allow the mill to clear itself out, the coal fineness or the distribution of the coal to the burners may have been affected. Either of these factors could have resulted in changes to the temperature profile near the injector locations. Again, whether or not the changes would be sufficient to cause a 25 ppm increase in NH_3 slip is open to speculation.

The advantages of the simultaneous injection configuration are shown more clearly in Figure 5-22. In this figure, NH_3 slip is plotted as a function of NO removal for each of the three injection configurations. Although the results for lance injection alone and Level 1 injection alone do not overlap (in terms of either NO removal or NH_3 slip), the two sets of results fall along the same basic curve. The results of both sets of

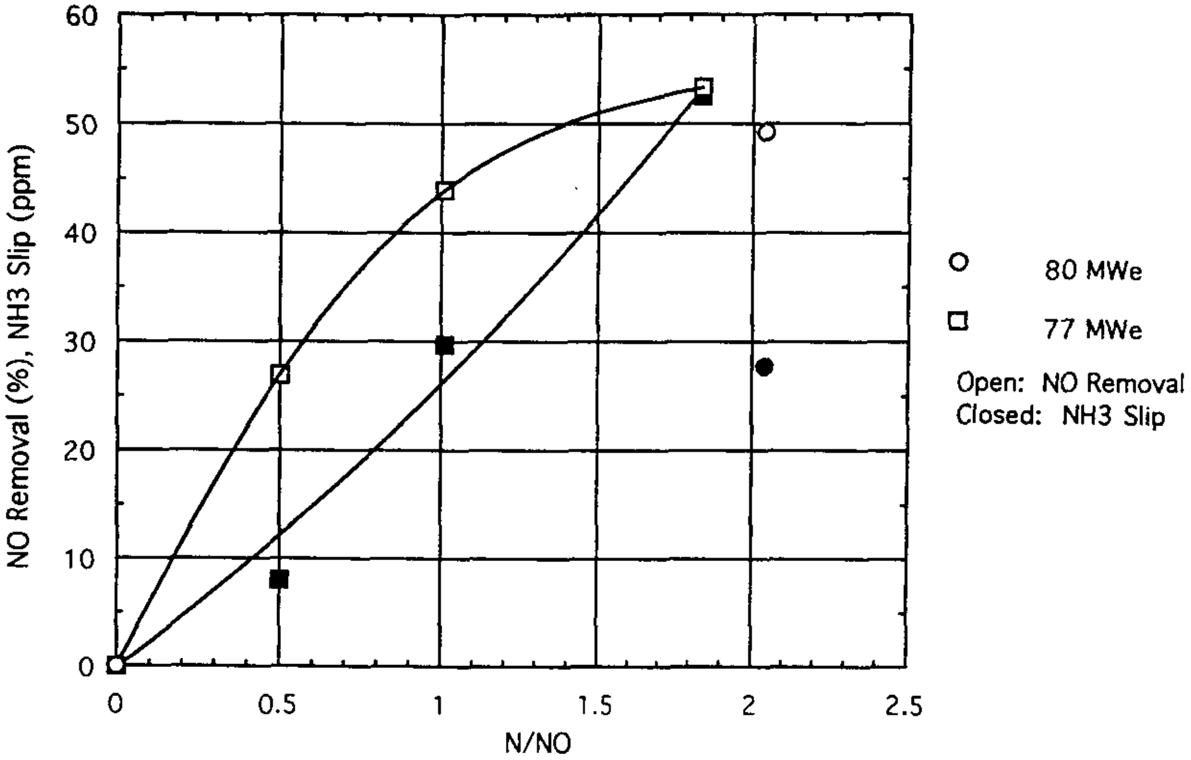


Figure 5-21. Effect of N/NO Ratio for Simultaneous Lance/Level 1 Injection at 80 MWe (A Mill OOS, 22° Injection Angle, 8 gpm Liquid, 10 psig Air)

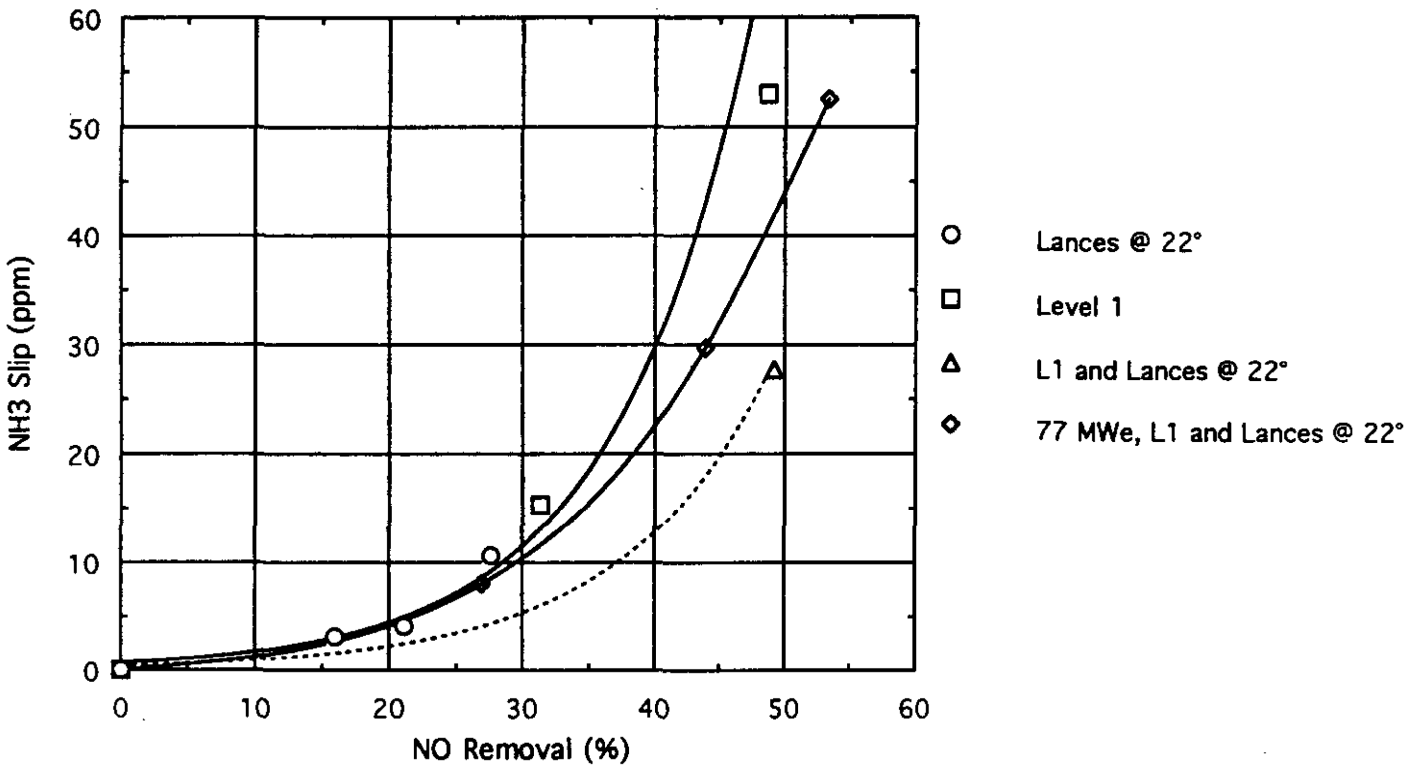


Figure 5-22. NH_3 Slip as a Function of NO Removal for Lance, Level 1, and Simultaneous Lance/Level 1 Injection at 80 MWe (A Mill OOS, Lances @ 6 gpm Liquid and 10 psig Air, Level 1 @ 2 gpm Liquid and 8 psig Air, Simultaneous @ 8 gpm Liquid and 8 psig Air)

simultaneous injection test falls to the right of this curve, indicating that higher NO removals are achieved at a fixed NH_3 slip level with this injection configuration.

Unfortunately, there was not sufficient time available during the current phase of testing to rerun the simultaneous injection tests. While there are questions raised by the difference in NH_3 slip behavior between the two days, it is most important to recall the effect seen on the first day when both the Level 1 and simultaneous injection tests were run sequentially (Figure 5-20). This data indicates that there is an increase in SNCR performance when the two injection levels are run simultaneously at 80 MWe. However, running with both injection levels in service also presents a problem due to the volume of atomization air injected into the boiler. When running either injection location alone, enough air is injected that the steam attemperation valves usually close, and the steam temperature drops to nominally 990°F (when open, the valves control the temperature to 1000°F). When both SNCR levels are in service, roughly twice as much air is injected, and the steam temperatures drop to the 950 top 960°F range. For operation with both injection levels in service to be feasible, the benefits of increased SNCR performance must be carefully weighed against the efficiency impacts of operating the turbine at reduced steam temperatures for long periods of time.

The effect of total liquid flowrate on NO removal and NH_3 slip for lance injection at 22° is shown in Figure 5-23. The first two sets of data show that as the total liquid flow is increased from 6 to 10 gpm, both NO removal and NH_3 slip increase, indicating that the SNCR process is occurring on the high side of the optimal temperature window. Both of these sets of data were collected when the boiler was burning the normal Colorado bituminous coal. The third set of data shown in the figure was collected during a trial burn of a high-volatile coal from the Colorado-Wyoming border. This coal was burned for a period of approximately four days during the current test series. Visual observations of the fire in the furnace and the steam attemperation valve controls indicated that the "Colo-Wyo" coal resulted in higher furnace exit gas temperatures than the normal coal. The SNCR results for the two coals at a total liquid flowrate of 6 gpm

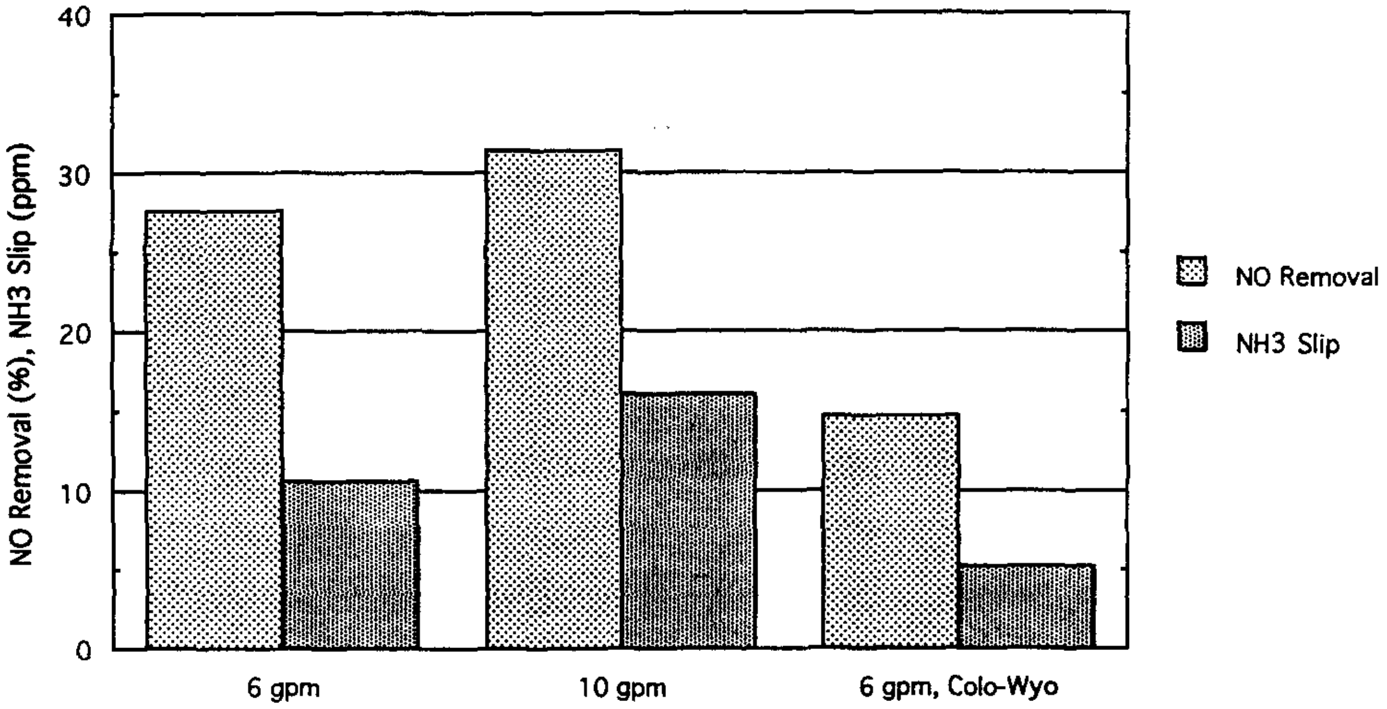


Figure 5-23. Effect of Total Liquid Flow for Lance Injection at 80 MWe
(A Mill OOS, 22° Injection Angle, 10 psig Air)

(Figure 5-23) show that both NO removal and NH_3 slip are lower with Colo-Wyo coal, confirming that the flue gas temperature at the furnace exit is higher with this fuel.

During the current phase of testing, Level 1 injection tests were run at 80 MWe with both three and four coal mills in service. These tests provided the opportunity to compare the current performance of the SNCR system to that documented during the previous test phase (Smith, et al., 1994b). Figure 5-24 compares the results of the two sets of tests with three mills in service. Both sets of tests were run with D mill OOS, and considering the length of time separating the two test phases (over two and one-half years), the agreement is very good. Figure 5-25 compares the results of the two sets of tests with all four mills in service, and once again, the agreement is quite good. Comparing the three and four mill results against one another further demonstrates that for Level 1 injection, the number of mills in service at a particular load has only a small effect on NO removal, but a significant effect on NH_3 slip. The sensitivity of NH_3 slip is believed to be due to the nonuniformities in the temperature profile caused by operating with one or more mills OOS.

F. 90 MWe Results

Initially, testing at 90 MWe focused on Level 1 injection alone, as it was believed that the furnace exit temperatures would be too hot for the lances to be useful. However, with the three mill-in-service configuration (A mill OOS), visual observations of the east and west sides of the furnace indicated that the west side was considerably cooler. Therefore, a short test series was run with Level 1 and the west lance operating simultaneously. The results of these tests are compared to the results for Level 1 injection alone in Figure 5-26. The five tests shown were run consecutively over the course of a single day. The Level 1 tests were run first, with a total liquid flowrate of 4 gpm and an atomizing air pressure of 8 psig. When the west lance was inserted for the two final tests (lance angle of 22°), the total liquid flow was increased to 7 gpm (4 gpm to Level 1 and 3 gpm to the lance), while the air pressure was maintained at 8 psig. Figure 5-26 shows that the NO removal characteristics of the two injection configurations are nearly identical, while lower NH_3 slip levels are achieved with

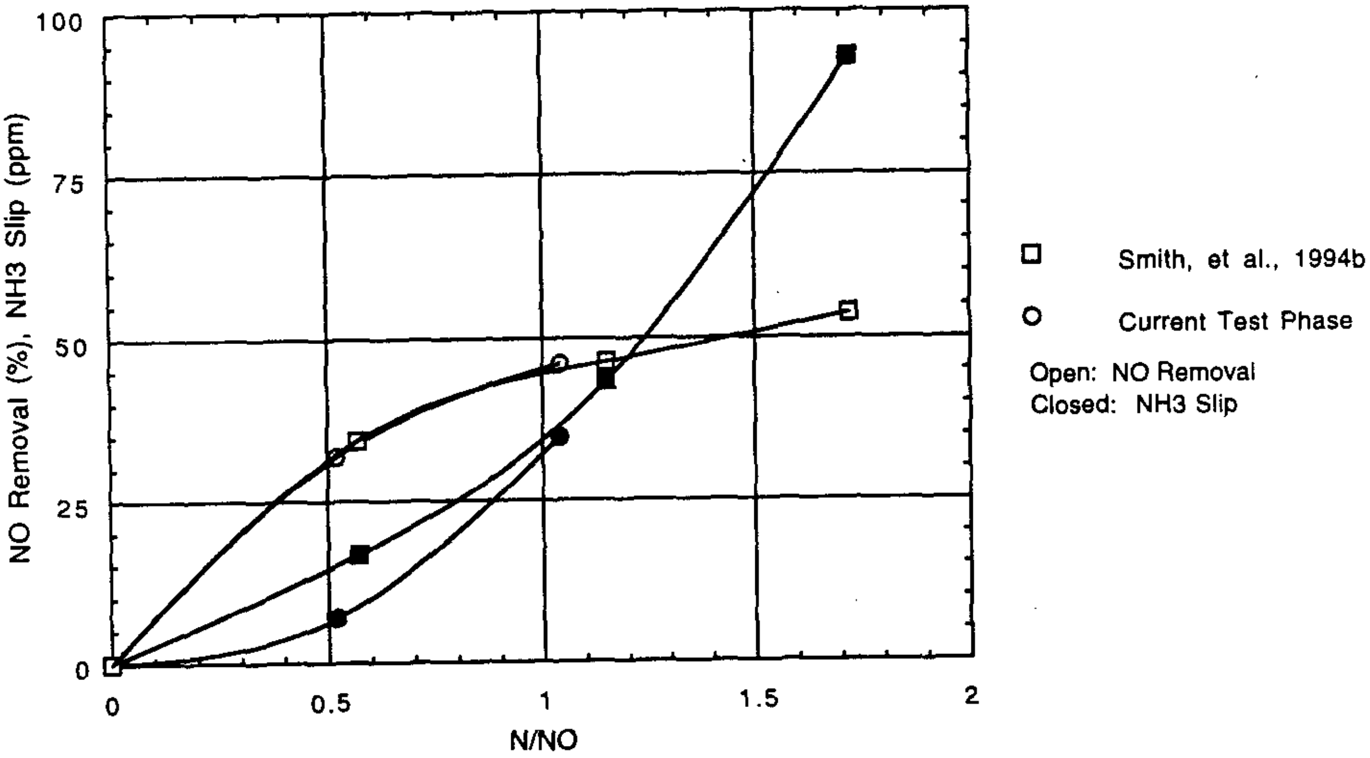


Figure 5-24. Effect of N/NO Ratio for Level 1 Injection with Three Mills in Service at 80 MWe (D Mill OOS, 2 gpm Liquid, 8 psig Air)

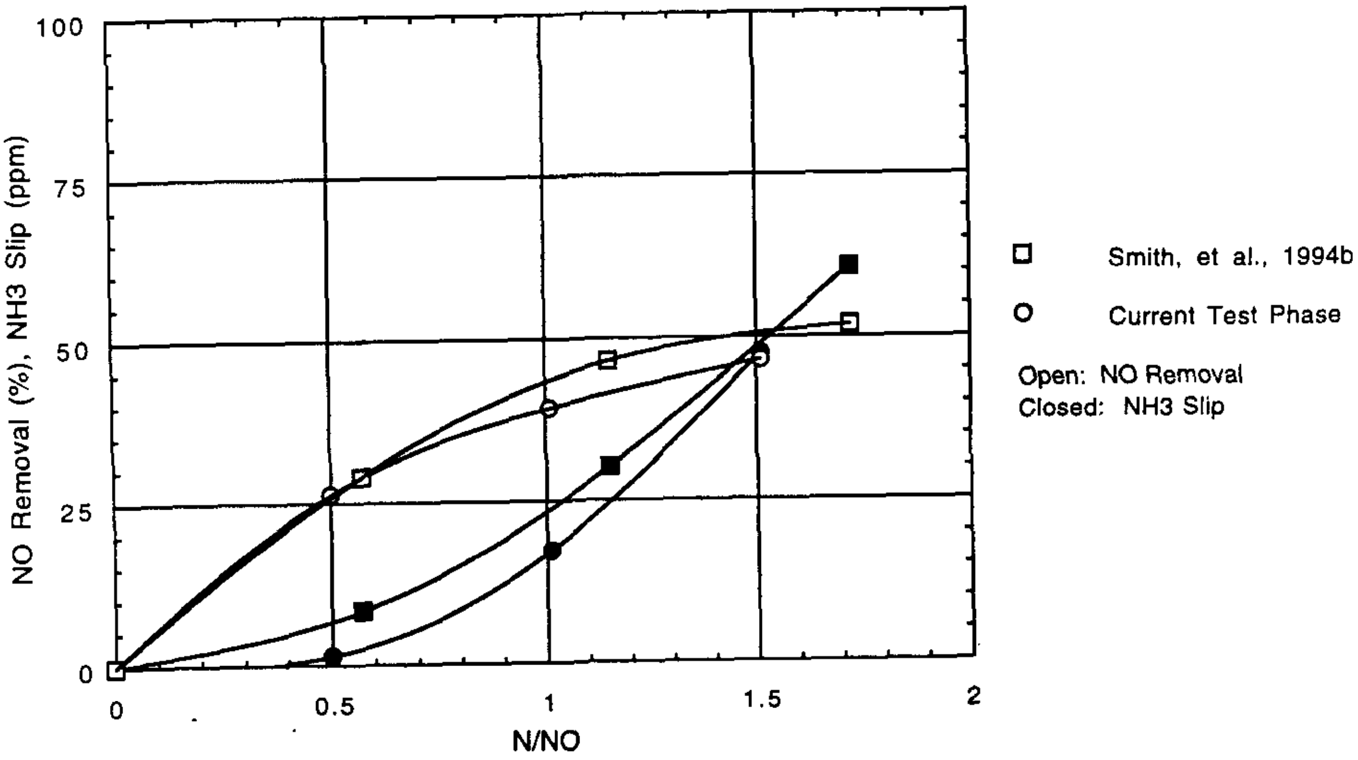


Figure 5-25. Effect of N/NO Ratio for Level 1 Injection with Four Mills in Service at 80 MWe (2 gpm Liquid, 8 psig Air)

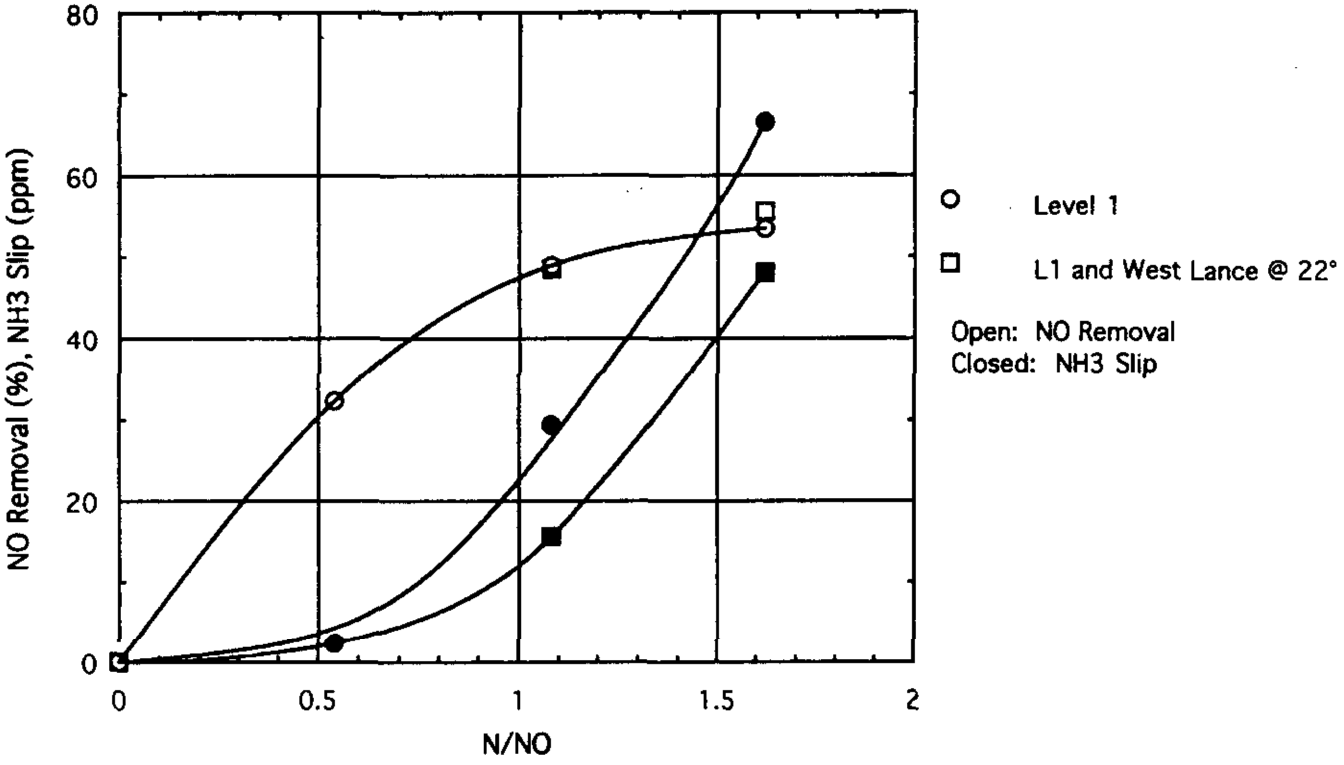


Figure 5-26. Comparison of Level 1 Injection to Level 1 and the West Lance Combined at 90 MWe (A Mill OOS, Level 1 @ 4 gpm Liquid and 8 psig Air, Combined @ 7 gpm Liquid and 8 psig Air)

simultaneous injection. At an NH_3 slip limit of 10 ppm, 41% NO removal is achievable with Level 1 alone, and 46% when the west lance is run concurrently.

Although the results shown in Figure 5-26 indicate that SNCR performance at 90 MWe (and A mill OOS) can be improved by operating the west lance in concert with the Level 1 injectors, the effect of this injection configuration on steam temperature also needs to be addressed. As was seen previously at 80 MWe, when the Level 1 injectors were placed in service, the steam attemperation valves closed and the temperature leveled out at 990 to 995°F. The steam temperature held constant at this level throughout the first three tests until the west lance was inserted, at which time it dropped again, eventually settling out in the range of 955 to 965°F. Once again, the benefits of increased SNCR performance must be carefully weighed against the long term efficiency impacts of operating the turbine at reduced steam temperatures.

Nearly one-half of the testing at 90 MWe took place during the test burn of the high-volatile Colo-Wyo coal. The results shown in Figure 5-26 were for operation with the coal normally burned at the station. The NO removal and NH_3 slip curves (Level 1 injection only) for operation with both the normal and Colo-Wyo coals are compared in Figure 5-27. All of the Colo-Wyo tests were run with a total liquid flowrate of 4 gpm. The first test was run with an atomizing air pressure of 8 psig, and the remaining three tests at 12 psig. The results indicate that the increase in atomizing air pressure from 8 to 12 psig has an insignificant effect on NO removal, as well as NH_3 slip. This insensitivity was also seen during the post-retrofit tests (Smith, et al., 1994b). A comparison of the SNCR performance with the two different coals confirms that flue gas temperatures are higher with the Colo-Wyo coal, as both the NO removals and NH_3 slips are lower for a fixed N/NO ratio.

G. 100 MWe Results

During the current test phase, Level 1 injection tests at 100 MWe were run in order to compare the current performance of the SNCR system to that recorded previously

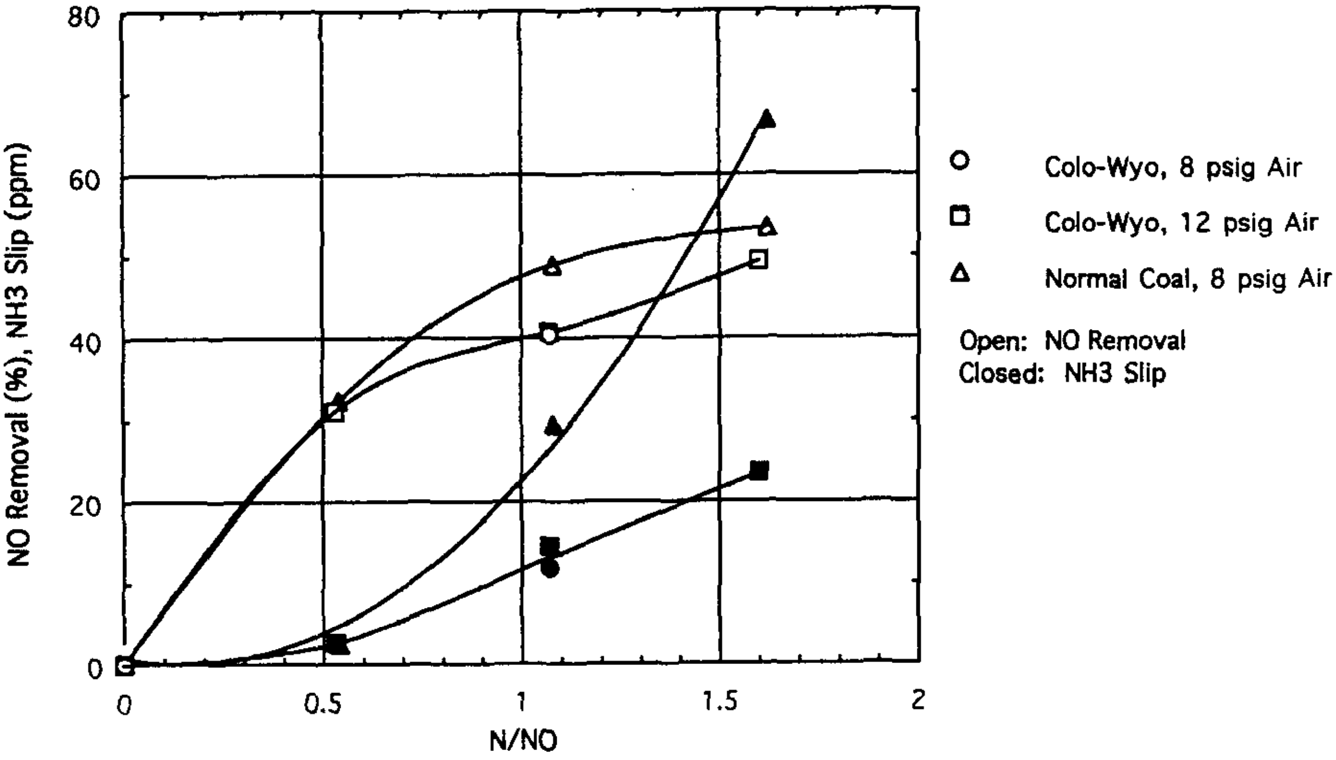


Figure 5-27. Effect of Coal Type for Level 1 Injection at 90 MWe (A Mill OOS, 4 gpm Liquid)

during the post-retrofit tests. While the post-retrofit tests were run with all four mills in service, tests were run with both three and four mills in service during the current series of tests. The NO removal and NH_3 slip results for the three sets of tests are shown in Figure 5-28. All of the tests were run with a total liquid flowrate of 6 gpm, and an atomizing air pressure of 8 psig, as these were the values determined as optimal during the post-retrofit tests. The NO removals for the three sets of tests agree well with each other, as do the NH_3 slip data for the four-mill tests. As expected, the NH_3 slip levels are lowest with all four mills in service. At the NH_3 slip limit of 10 ppm, 36 and 41% NO removal is achievable with three and four mills in service, respectively.

5.2 Detailed Tests

Detailed measurements of the NO removal profile at the economizer exit were made on a limited basis during the test program. Initially, these point-by-point measurements were made manually. This approach was time consuming with each 12-point traverse requiring 1-1/2 to 2 hours to complete. To expedite the testing, the multipoint gas analyzer discussed in Section 4.4 was used for a brief series of tests. This analyzer was used to simultaneously monitor the NO and O_2 levels at all twelve economizer exit sample points. Thus, once a baseline measurement was taken, the NO removal profile for a specific injection configuration could be characterized in a manner of minutes, rather than hours.

Figures 5-29 and 5-30 show the contour plots of the percentage NO removal for two tests at 90 MWe. The left and bottom axes correspond to the west and bottom walls of the economizer exit duct, respectively. Assuming that little mixing of the flue gas occurs between the injectors and economizer exit, the bottom of the economizer exit duct corresponds to flue gas passing near the injectors, while the top of the duct corresponds to flue gas on the wall opposite the injectors (recall Figures 2-1 and 2-5). The two tests were run sequentially at a nominal N/NO ratio of 1.5. In Figure 5-29 only the Level 1 injectors were in service, and the results clearly show higher NO removal at the bottom of the duct, and the NO removal was fairly uniform across the width of the duct. The higher NO reduction toward the bottom of the duct (i.e., region near the

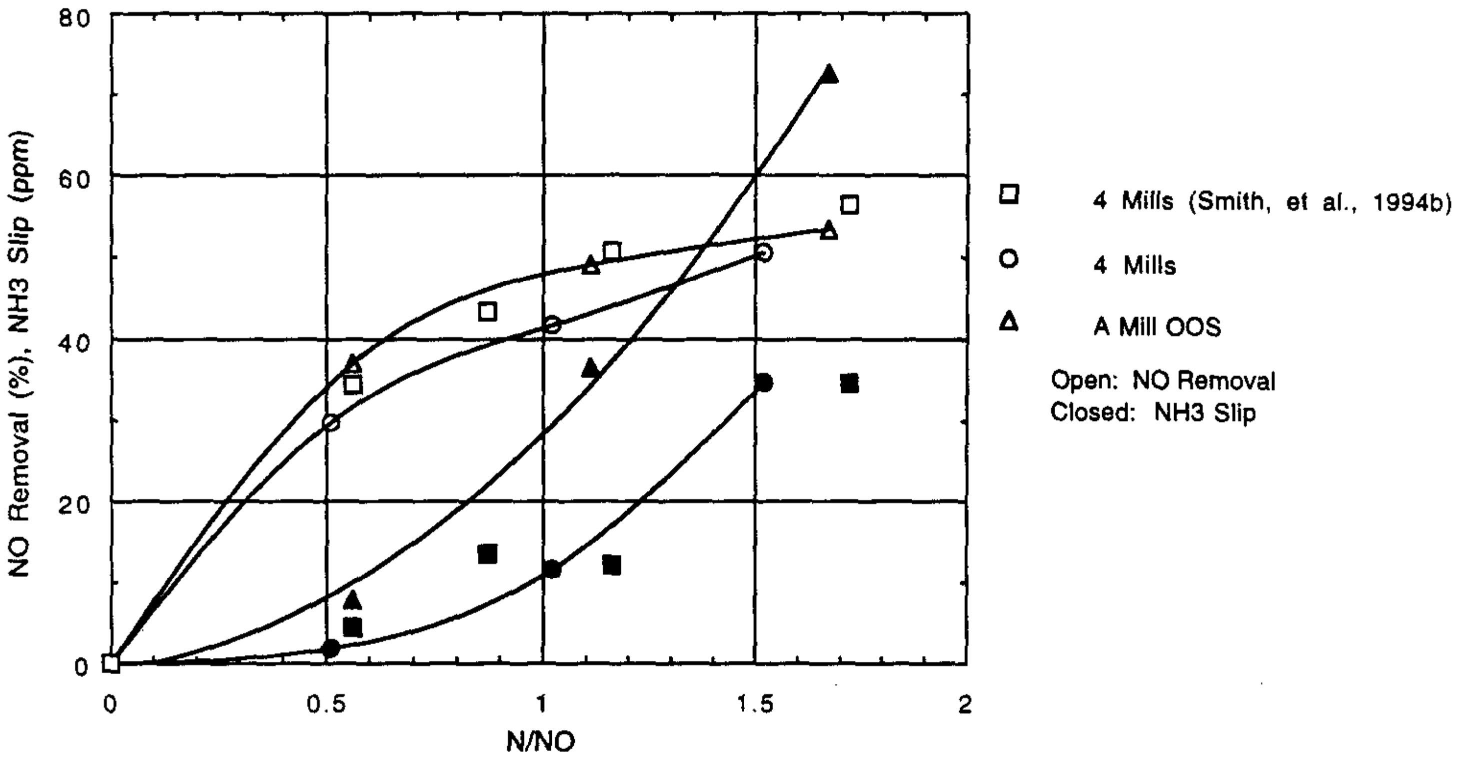


Figure 5-28. Effect of Mill-in-Service Pattern for Level 1 Injection at 100 MWe (6 gpm Liquid, 8 psig Air)

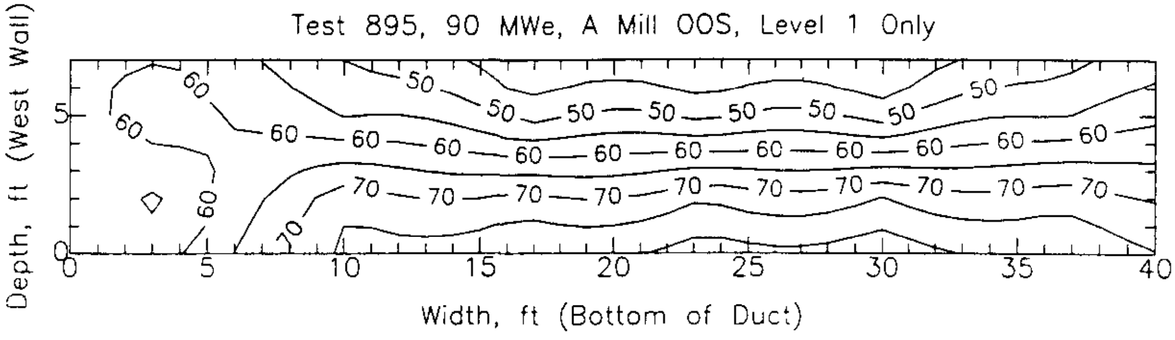


Figure 5-29. NO Removal Contour Plot for Level 1 Injection at 90 MWe (measurements made with the multipoint gas analyzer)

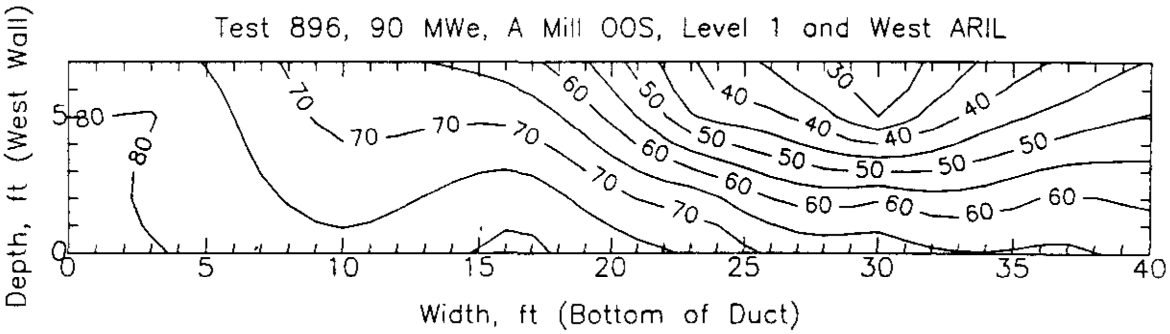


Figure 5-30. NO Removal Contour Plot for Level 1 and West ARIL Injection at 90 MWe (measurements made with the multipoint gas analyzer)

injectors) suggests that the Level 1 injectors may not provide sufficient momentum to fully penetrate the flue gas at 90 MWe.

In Figure 5-30, the west lance and Level 1 injectors were operating simultaneously. The contour plot shows that this configuration resulted in a much more even distribution of NO removal on the west side of the duct, indicating that the ARIL lance provides a better distribution of chemical across the depth of the furnace. Figure 5-30 also shows that the overall levels of NO removal on the west side increased, while the levels on the east side decreased (relative to Figure 5-29). This shift was due to the imbalance in the total liquid/chemical flows from west to east. With both the lance and Level 1 in operation, the total liquid flow to the west side was 5 gpm. On the east side (with Level 1 alone) the flow was only 2 gpm. Since the concentration of the urea/water mixture was the same throughout the injection system, the N/NO ratio was higher on the west side compared to the east (i.e., 2.1 compared to 0.9, respectively). This shift from east to west essentially moved the chemical, on average, into a higher temperature region, because it was now being injected through the lance rather than Level 1.

Recall that the 90 MWe results presented previously in Figure 5-26 showed that, while the overall NO removals were unaffected, the average NH_3 slip was reduced when the west lance and Level 1 injectors were run simultaneously. The results presented above indicate that the combination of the improved distribution of chemical on the west side, and the increase in the average injection temperature were responsible for the reduction in the NH_3 slip.

5.3 N_2O Emissions

N_2O emissions were also monitored during the ARIL lance tests as well as the prior SNCR test phases at Arapahoe Unit 4 (Smith, et al., 1993, Smith, et al., 1994b). While not a regulated species, there is interest in N_2O emissions due to potential impacts on stratospheric ozone chemistry and potential contributions to the greenhouse effect. Prior full-scale and pilot-scale studies have shown N_2O to be a product of the urea injection process (Smith, et al., 1994b). Since the N_2O is formed through a reaction between NO and an intermediate decomposition product of urea, the results are presented as a ratio of the amount of N_2O emitted divided by the amount of NO reduced. This is, in effect, the amount of NO converted to N_2O. The SNCR tests with the original combustion system and initial NO levels of about 850 ppmc, showed that the amount of N_2O produced was 7 to 17 percent of the NO reduced. The baseline results also indicated that the highest levels of N_2O were produced at reduced loads (Smith, et al., 1993).

With the retrofit combustion system and the Level 1 injectors, the N_2O conversion ranged from 20 to 35 percent, with the lowest levels occurring at reduced loads (Smith, et al., 1994b). The differences between the baseline and retrofit characteristics were attributed to differences in temperature and temperature-time characteristics in the boiler (Smith, et al., 1994b).

N_2O exhibits a temperature window similar to the SNCR temperature window for NO reduction. This window results from a competition between N_2O formation and reduction reactions (Smith, et al., 1994b). As such, the amount of N_2O emitted will depend primarily on parameters that affect temperatures. The major parameters being boiler load and lance injection angle, along with a modest dependence on the amount of chemical injected (N/NO_x).

Figure 5-31 shows the effect of lance injection angle on N_2O emissions for the 43 MWe and 50 MWe tests reported in Figures 5-1 and 5-3. Comparing the N_2O results in Figure 5-31 to the NO reduction results in Figures 5-1 and 5-3 it is observed that N_2O formation parallels the NO reduction. At a load of 43 MWe, NO reduction and N_2O formation were weakly dependent on lance angle, maximum NO reduction occurred at an angle of 35 degrees and maximum N_2O levels at an angle of 45 degrees. At 43 MWe, the NO to N_2O conversion varied from 26 to 32%. At a load of 50 MWe, the amount of N_2O decreased monotonically with increasing injection angle. With increasing angle, the flue gas temperature into which the urea is injected,

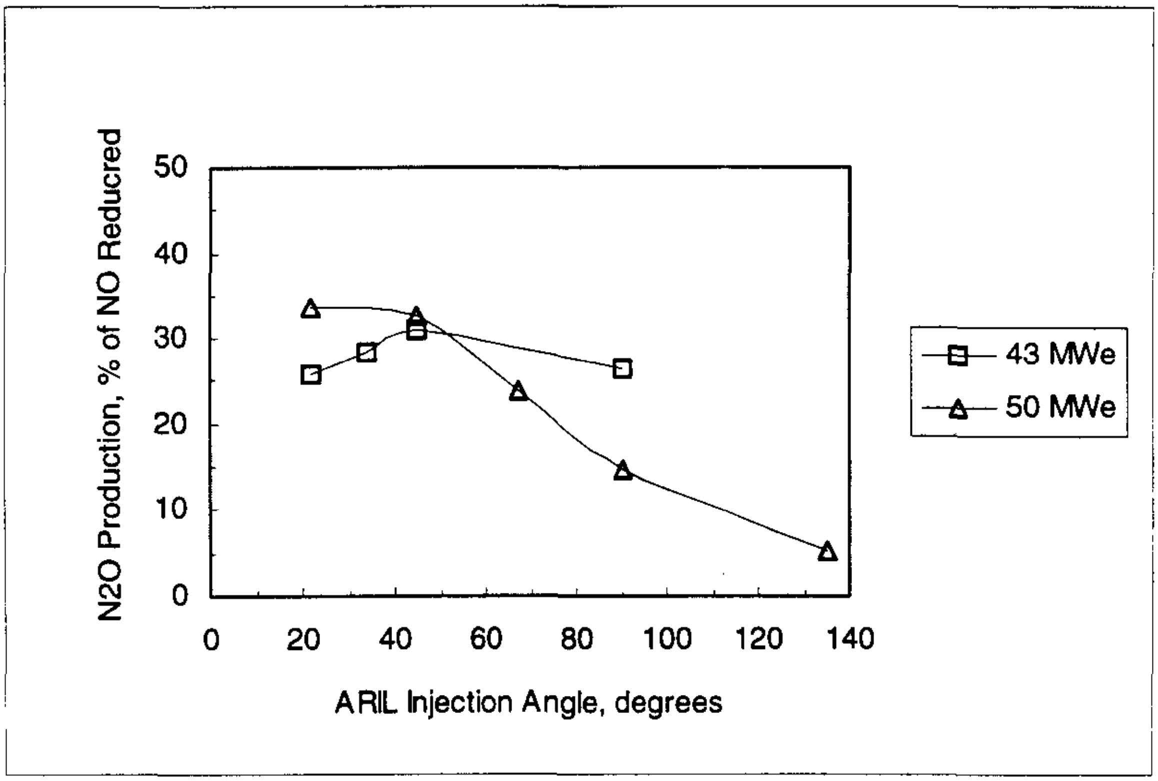


Figure 5-31. Effect of ARIL Injection Angle on N_2O Emissions at 43 MWe and 50 MWe (C Mill OOS, N/NO_x=1.0, Liquid: 4 gpm, Air: 10 psig)

increases, and the NO to N_2O conversion decreases from 33% at angles less than 45%, to 5% at an angle of 135 degrees.

The temperature distribution across the furnace also affected N_2O production. This is illustrated in Figure 5-32, which shows the effect of mill out of service pattern and N/NO ratio on N_2O at a boiler load of 60 MWe. As with the prior reported results with the retrofit combustion system and Level 1 injectors (Smith, et al., 1994b), the N_2O production with the ARIL lances exhibits a slight dependence on the N/NO ratio. The amount of N_2O also depended on which mill was out of service. With D mill out of service, the amount of N_2O was much higher than with any of the other mills taken out of service.

Figure 5-33 compares the N_2O production from the ARIL lances and Level 1 injectors at a load of 80 MWe. For these tests, the ARIL lance injection angle was fixed at 22 degrees. For these test conditions, the Level 1 injectors showed no effect of N/NO ratio on N_2O , while the N_2O production with the ARIL lances increased with increasing N/NO ratio. Operating both the Level 1 and ARIL lances simultaneously yielded N_2O levels between the Level 1 and ARIL lances operated alone.

Depending on the specific operating condition, N_2O production with the ARIL lances varied from 5% to over 50% of the NO_x reduced. With ARIL lance parameters anticipated for long term automatic operation, the N_2O conversion should be in the range of 20% to 45%; comparable to the Level 1 injectors.

5.4 Operational Experience with the ARIL Lance System

A number of start-up problems with the ARIL lance system delayed the start of the test program by approximately one week. Communications between the local IBM computer and the PLC on the west lance drive were established by the end of the week, although problems with the PLC program for automatic operation persisted beyond that time. When the lances were finally inserted, it was found that both lances

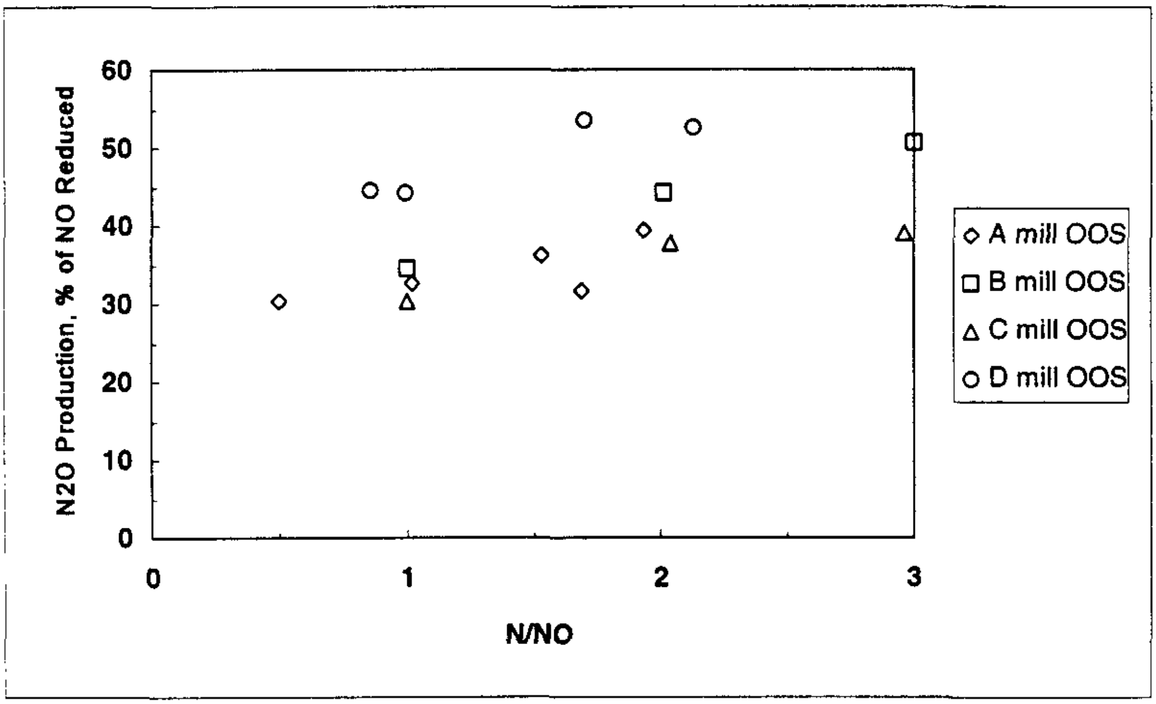


Figure 5-32. Effect of Mill Pattern and N/NO Ratio on N_2O
(Load: 60 MWe, Liquid: 4 gpm, Air: 10 psig)

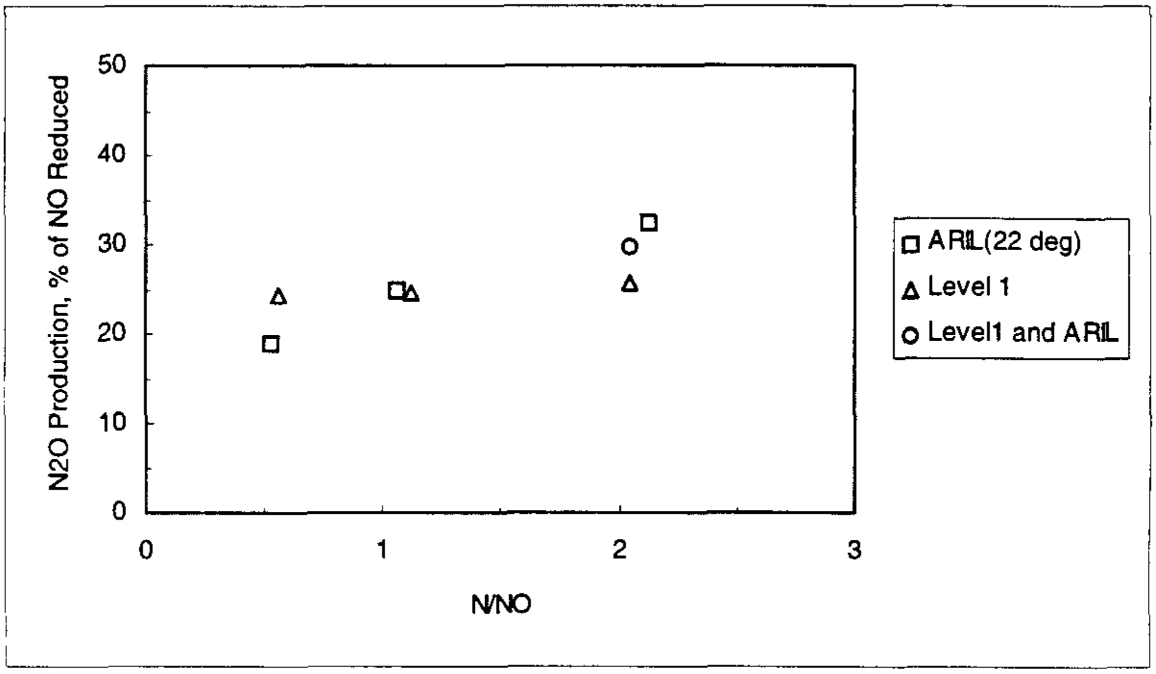


Figure 5-33. Comparison of N_2O Production Between the ARIL Lances and Level 1 Injectors (Load: 80 MWe; ARIL: 22 degrees, 6 gpm Liquid, 10 psig Air; Level 1: 2 gpm Liquid, 8 psig Air)

bent dramatically downward. It is believed that the bending was due to uneven heating on the upper and lower lance surfaces. The top of the lances receive a large radiant load from the roof-mounted burners, while the lower surface stays relatively cool due to the proximity of the screen tubes immediately below. This uneven heating pattern causes a greater expansion along the upper surface, and the lances bend downward toward the screen tubes. Within 30 minutes of insertion, the tip of each lance would droop by approximately 16 to 20 inches.

A second thermal expansion problem was found during the first week of tests. The large temperature difference between the lance and the two liquid tubes which carry the urea solution down the center of the lance resulted in a substantial difference in the thermal expansion. Although the liquid tubes were fabricated with expansion bends, the force of the greater expansion of the lance moved the liquid injection nozzles off-center from the air orifices. In one case, the force was so great as to break the weld on one of the internal tube supports. Each time the lances were removed from the boiler, it was necessary to re-center the liquid nozzles. In one case, the differential expansion had moved one of the liquid nozzles completely out of the air orifice, and the liquid was sprayed on the inside of the lance.

At the end of the first week of testing, it was decided to remove and repair the lances by modifying the internal piping and adding cooling holes to the upper surface of each lance. Forty-nine 1/4-inch diameter holes were drilled across the top of each lance approximately 40° up from the air injection nozzles. The holes were drilled at an angle of 30° relative to the centerline of the lance, in order to provide a cooling flow over the part of the lance exposed to the radiant heat. It was anticipated that the increased cooling would decrease the difference in thermal expansion, and reduce the bending. The liquid internals of each lance were also removed and new piping with an improved expansion loop between each nozzle installed. This modification allowed differential thermal expansion between the lance and liquid lines, while keeping the liquid nozzles fixed relative to the air orifices.

Testing was delayed for two weeks in order to complete the above repairs. During that time, work continued on the problems with the automatic control sequence. When testing resumed, it was found that the cooling holes did not solve the bending problem, and both lances continued to droop by up to 20 inches at the tip. However, the modifications to the liquid lines were successful. Parametric testing resumed, and it was soon discovered that the east lance was becoming permanently bent. Testing continued for 4-1/2 weeks until the east lance rotation motor failed. An investigation showed that the lance was so severely bent that it could not be rotated manually when in the retracted position. At this point, testing was again suspended until the lance could be straightened. This time period also coincided with a scheduled turbine outage.

During the turbine outage, both lances were removed and shipped back to the manufacturer for repair and modification. NOELL, Inc., indicated that the permanent bend of the east lance was the result of overheating due to insufficient cooling air at high temperatures. At a point in the test program, the east lance had been operated for approximately 10 minutes with essentially no cooling air flow. During installation, a pipe sling had inadvertently been left in the air supply piping. The sling plugged the lance restricting air flow but the lance did not automatically retract as air pressure was present. This short period without cooling may have contributed to the permanent bending. Modifications to each lance included adding an adjustable slot to the tip to increase airflow by approximately 35%, plugging the cooling holes drilled in the first attempt to improve lance cooling, and adding a metal/ceramic coating to the outside surface. NOELL, Inc., believed that the increase in cooling airflow along the entire length of the lance would reduce the chance of any future permanent deformation. The metal/ceramic coating was expected to slightly decrease the lance metal temperature by reducing lance emissivity and reduce radiant heating; as well as a minor decrease in thermal conductivity. When the lances were removed from the boiler, it was found that the west lance also had a slight bend, so both lances were straightened during the repair and modification process.

The modification, repair and reinstallation of the lances was complete shortly after the unit came back on-line from the turbine retrofit. The increase in airflow reduced the lance metal temperatures by approximately 500°F, but both lances still bent temporarily when inserted into the boiler. There was no indication of any permanent bending when the lances were retracted from the boiler, so the parametric testing resumed. After approximately one month of testing, the metal/ceramic coating began to show signs of wear and had partially flaked off in some areas near the tip of each lance. By the end of the parametric tests, large areas of the coating were missing, although there was still no sign of any permanent lance deformation. It is believed that the increase in cooling air provided the majority of the temperature reduction and the coating provided only minimal benefit.

5.5 Recommendations for SNCR Operation

The performance of an ammonia or urea-based post-combustion technology must be assessed in terms of achievable NO_x removal for a given level of NH_3 slip. There are four factors that must be considered when determining an "acceptable" NH_3 slip operating level:

1. NH_3/SO_3 reactions forming ammonia bisulfate and/or ammonia sulfate can foul air preheater surfaces;
2. plume reactions between NH_3 and HCl or SO_2 which can lead to plume visibility through the formation of solid ammonium chloride or ammonium sulfite;
3. absorption of NH_3 on the fly ash can lead to ash disposal or handling concerns; and/or
4. a regulatory limit on NH_3 emissions.

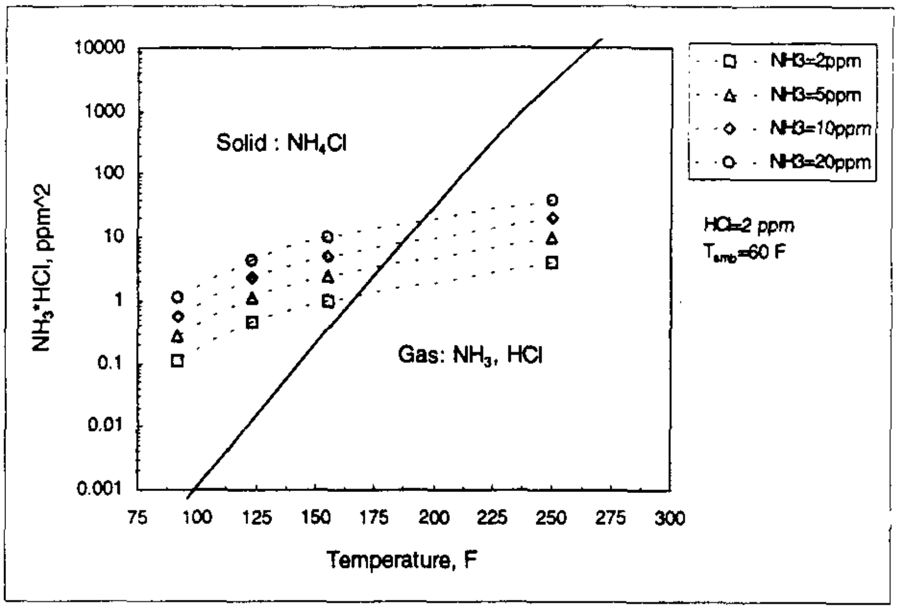
Arapahoe Unit 4 uses a low sulfur Colorado coal that leads to SO_3 emissions of less than 1 ppm. The unit also uses a tubular air heater that is not as sensitive to plugging by solid particles as regenerative air heaters.

NH_3 slip can react with HCl in the flue gas forming solid ammonium chloride (NH_4Cl). These reactions occur in the plume as the plume entrains ambient air and cools. If the amount of NH_4Cl formed is large, a detached visible plume can form. The chlorine content of the coal burned at Arapahoe is less than 0.01% leading to flue gas HCl concentrations on the order of 1-2 ppm. At these low HCl levels plume visibility is not likely due to NH_3/HCl reactions. Thermodynamic chemical equilibrium calculations were performed to assess the temperature region at which the NH_3/HCl reactions take place. The thermodynamic data was obtained from the JANAF tables (Chase, et al., 1985). The results are shown in Figure 5-34a. In this figure the solid line separates the regions between gaseous HCl and NH_3 from solid NH_4Cl. The dotted lines show the thermodynamic path of flue gas containing 2 ppm HCl as it exits the stack and entrains ambient air at a temperature of 60°F. As the plume entrains air the concentrations of NH_3 and HCl decrease due to dilution, and the temperature decreases. Depending on the amount of NH_3 in the flue gas, the solid NH_4Cl will form when sufficient air is entrained to reduce the plume temperature to 165-190°F. Again, with less than 2 ppm of HCl in the flue gas, even if the solid NH_4Cl forms, it should not result in plume visibility.

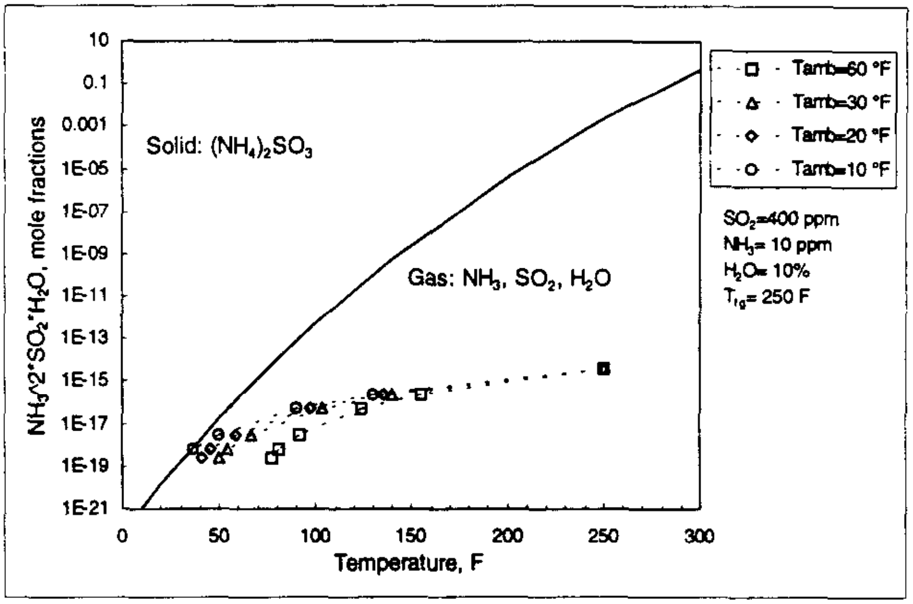
NH_3 slip can also react with SO_2 in the flue gas, forming compounds like ammonium sulfite, $(NH_4)_2SO_3$

$$2NH_3 + SO_2 + H_2O \rightarrow (NH_4)_2SO_3$$

This reaction occurs at much lower temperatures than the NH_3/HCl reactions discussed above. Thermodynamic chemical equilibrium calculations were performed to investigate the temperature region at which the above NH_3/SO_2 reaction will take place. Thermodynamic data for the above reaction was obtained from Hjuler (1991) and the calculations assumed $SO_2 = 400$ ppm, $NH_3 = 10$ ppm, $H_2O = 10\%$ and a flue gas temperature of 250°F. The results of these calculations are shown in Figure 5-34b. This figure is similar to Figure 5-34a. The solid line separates the region of gaseous NH_3, SO_2, H_2O and solid $(NH_4)_2SO_3$. The dotted lines show the thermodynamic path as



(a) Plume Formation of NH_4Cl



(b) Plume Formation of $(NH_4)_2SO_3$

Figure 5-34. Thermodynamic Calculations of NH_4Cl and $(NH_4)_2SO_3$ Formation in Plumes the plume entrains ambient air at varying temperatures. As can be seen in Figure 5-34b, for the assumed concentrations and thermodynamic data, the NH_3/SO_2 reactions will not take place unless the ambient temperature is below 20°F. This would explain the occasional detached visible plumes experienced during the SNCR testing during the winter months at Arapahoe (Smith, et al., 1994b). Testing at Arapahoe found that at ambient temperatures below 32°F , a visible plume would form at NH_3 concentrations of about 10 ppm. The severity of the plume increased as the ambient temperature was decreased.

NH_3 can also absorb on the fly ash. The amount of absorption varies with different ash composition. NH_3 absorption on ash may affect ash sales and may cause ash handling concerns. Finally, NH_3 slip emissions are not currently regulated in Colorado.

Lacking any regulatory limit on NH_3 slip and due to the low SO_3 and HCl emissions, the project team selected 10 ppm as the target NH_3 slip for tuning Arapahoe Unit 4's SNCR system. For a high sulfur/high chlorine coal, 10 ppm NH_3 slip may be the maximum that could be tolerated due to plume and air heater concerns. At Arapahoe it was believe this limit would provide a conservative limit that would minimize operational problems. While there are no formal federal or state NH_3 emissions limits, some site specific local permits have limited NH_3 emission to 10 to 25 ppm.

Based on the parametric tests, Figure 5-35 shows the nominal NO removal expected over the load range for a 10 ppm NH_3 slip limit. The figure includes the performance of the Level 1 injectors over the entire load range as well as the improvement expected at boiler loads less than 80 MWe by using the ARIL lances. It should be noted that the lines in Figure 5-35 represent average performance at a given load with either the Level 1 injectors or the ARIL lances. Varying boiler operating conditions, such as having different coal mills out of service can result in either higher, or lower NO removals than shown in Figure 5-35. Figure 5-35 clearly shows that the lances have markedly increased low load performance of the SNCR system. With the Level 1

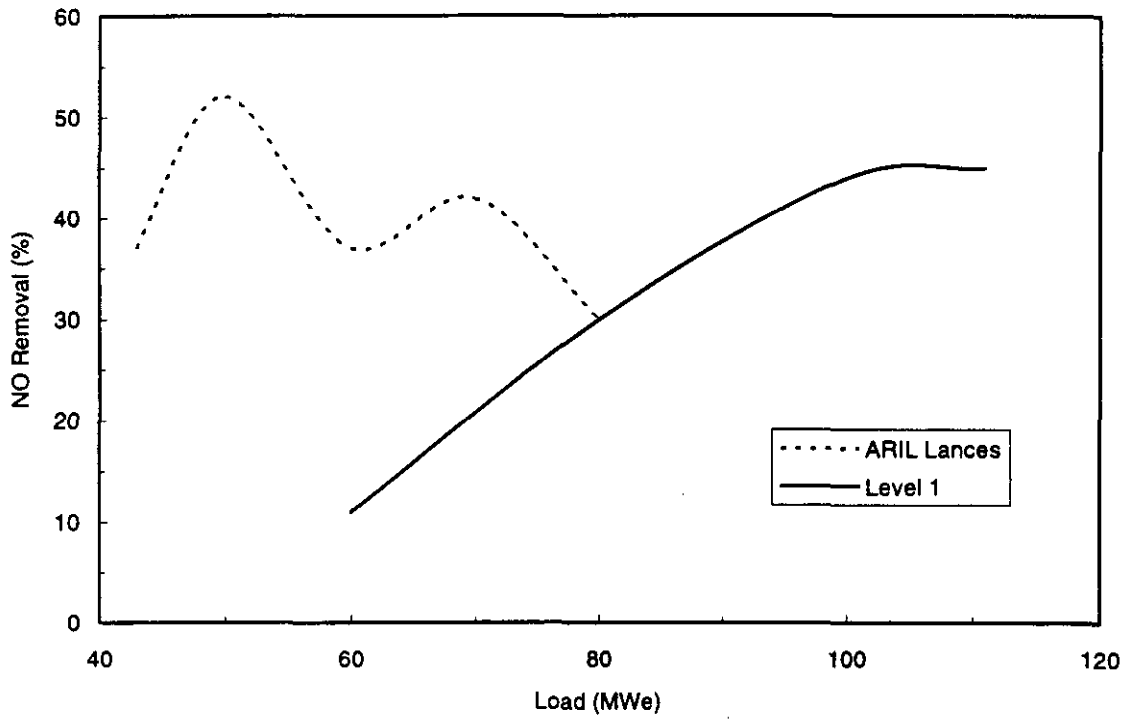


Figure 5-35. NO Removal as a Function of load for an NH_3 Slip Limit of 10 ppm

injectors alone, NO_x removal was limited to only 11% at 60 MWe. With the lances, NO removals in excess of 35% are achievable at 60 MWe.

Table 5-3 summarizes the recommended settings for the SNCR automatic control system. As noted previously, the test parametric results indicated that simultaneous operation of the lances and the Level 1 injectors could improve SNCR performance at selected loads. However, because of potential steam temperature control issues, simultaneous injection is not considered a viable long term option. These settings assume operation with four mills in service at loads of 80 MWe or greater, three mill operation from 55 to 80 MWe, and two mill operation at loads below 55 MWe. Although, the recommended N/NO ratio setting for 50 MWe is based on tests conducted with three (rather than two) mills in service, the feedback trim control system

Table 5-3

Recommended SNCR Settings for Automatic Control with the ARIL Lances

Load (MWe)	Injection Location	Lance Angle	N/NO Ratio	Total Liquid Flow (gpm)	Atomizing Air Pressure (psig)	Expected NO Reduction (%)
43	Lances	90°	1.15	4	10	37
50	Lances	45°	1.55	4	10	52
60	Lances	22°	1.60	4	10	37
70	Level 1	Retracted	0.65	2	8	42
80	Level 1	Retracted	0.85	2	8	30
90	Level 1	Retracted	0.75	4	8	37
100	Level 1	Retracted	0.95	6	8	43
111	Level 1	Retracted	1.55	6	8	45

will reduce the chemical flow rate if the stack NH_3 levels exceed 10 ppm. Conversely, the recommended N/NO ratio for 90 MWe is based on tests with three (rather than four) mills in service. In this case, the trim control will increase the chemical flow if the NH_3 slip is well below the 10 ppm limit.

Tests with three mills in service at 60 and 70 MWe showed that the distributions of O_2, NO and, most importantly, flue gas temperature varied greatly across the width of the furnace, depending on the particular mill OOS pattern. At 70 MWe test results showed that operating the lances at different angles on each side of the furnace and biasing liquid flow along the length of the lance, were both approaches which could be used to move the chemical away from the lower temperature regions, and thus increase the NO removal and NH_3 slip performance. However, the SNCR control system is not currently configured to use flue gas temperature as a trim control, nor is it capable of automatically biasing liquid flow. Thus, neither of these approaches can be utilized in the automatic control mode. On the other hand, the 60 MWe test results showed that

SNCR system performance could be improved by biasing the coal mills to provide more uniform combustion conditions at the furnace exit. With the current SNCR control system, the best approach to improve NO removal and NH_3 slip performance with mills out of service is to have the boiler control operator bias the appropriate coal mill(s). In fact, the Arapahoe Unit 4 DCS could be programmed to perform the mill biasing automatically by looking at the excess O_2 distribution shown by the four PSCo O_2 probes at the economizer exit. providing more uniform combustion conditions at the furnace exit would not only improve the performance of the SNCR system, but also reduce CO and LOI emissions.

Following the parametric tests, the SNCR system incorporating the ARIL lances was operated in automatic load following operation. This included some limited operating time with the SNCR alone. However, most of the long term operation was with integrated system (i.e., SNCR and sodium-based dry sorbent operated simultaneously). As such, the long term test results are presented in the integrated test report.

6

RESULTS: ALTERNATE DPSC LANCE TESTS

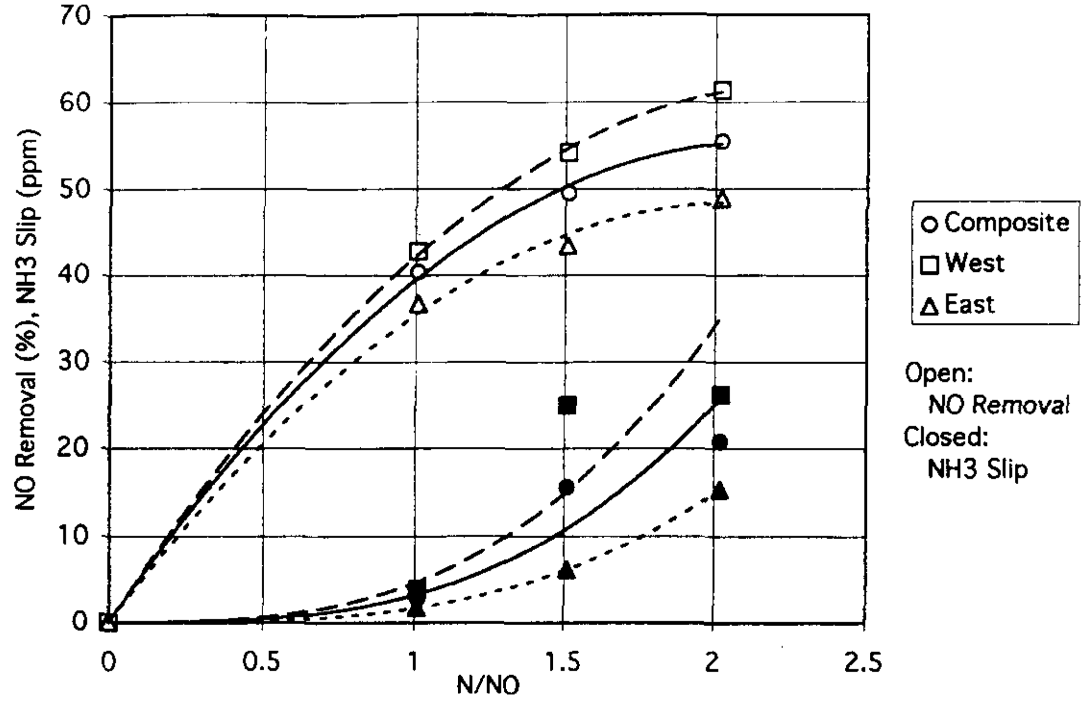
In February 1996, Diamond Power Specialty Company (DPSC) approached PSCo and DOE with a proposal to test a different lance design which they believed would significantly reduce the bending problem experienced with the ARIL lances. As discussed in Section 3, the new lance design was a substantial simplification of the original ARIL design.

A two-week, four-phase, test program was scheduled to evaluate the relative performance of the new lance to the original ARIL lances. The initial phase entailed collecting a baseline set of data with the ARIL lances. In the second phase, the DPSC lance would replace one of the existing ARIL lances, and the liquid atomizer would be installed in the air supply pipe immediately upstream of the NOELL, Inc. telescope assembly. Thus, the urea solution would be atomized into the air stream within the telescope. In the third phase, the telescope would be removed, and a 2-3/4-inch diameter "feed tube" installed in its place. In this configuration, the lance assembly would resemble a standard, single-sleeve soot blower, and prevent air and liquid being sprayed outside of the boiler. The liquid atomizer would be relocated to the rear of the *feed tube in this configuration. Finally, the fourth phase would entail removing the heat* shield.

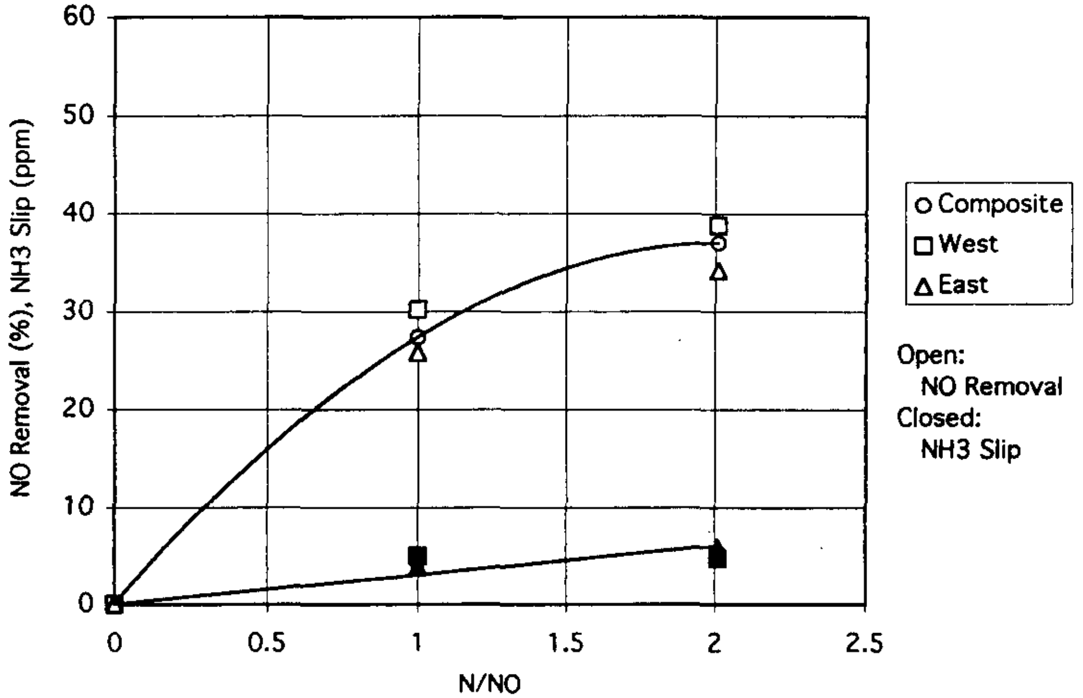
The test program began on August 16, 1996, and all tests were conducted at a boiler load of 60 MWe. Additionally, nearly all of the tests were run with B Mill OOS, as it was providing the poorest performance of the four coal mills at the time testing began. Prior to installing the DPSC lance, baseline data was obtained with the ARIL lances. The tests varied the chemical injection rate (N/NO ratio) at a total liquid and atomizing air flow of 4 gpm and 10 psig, respectively, at two injection angles -- 22° and 34°. Figures 6-1a and b show the results of the "ARIL-only" tests at the two angles. Each figure shows the results of the NO measurements made separately on the east and west sides of the economizer exit duct, as well as the composite measurement made across the entire cross-section of the duct. NH_3 slip measurements were also made separately on the east and west sides of the duct at the air heater exit location and averaged to arrive at a composite value. Even with the B Mill out-of-service, the temperatures on the west side appear lower than on the east. The NO_x reduction results agreed well with the previous ARIL lance results discussed in Section 5, even though there was a significant time difference between the testing.

The new DPSC lance was installed on the west side of the boiler which in general exhibits lower temperature than the east; based on previous temperature measurements and the ARIL test results. The lower temperature west side was selected as it was believed the DPSC lance would provide for faster evaporation and reaction of the urea with NO_x since much of the liquid would evaporate as it traveled through the lance. After the installation was complete, the new lance was run outside the boiler (in the "retracted" position) with air and water so that the degree of liquid atomization could be observed. The lance provided a finely atomized spray (similar to that seen with the ARIL lances) from each nozzle. However, the "jet" from each nozzle was angled slightly toward the tip of the lance at an angle of approximately 15 to 20°. It was hypothesized that since the nozzles in the DPSC lance were just holes (without any type of throat), there was an insufficient length-to-diameter ratio to force the air/liquid mixture out of the nozzle at a 90° angle (relative to the lance axis). Thus, each jet had a slight "axial" velocity component as it left the nozzle.

The second phase of the DPSC lance tests were preformed with the DPSC lance alone with the atomizer located at the entrance to the original ARIL air telescope. These tests were performed at the conditions summarized in Table 6-1.



a) *22° Injection Angle*



b) 34° Injection Angle

Figure 6-1. NO Removal and NH_3 Slip for ARIL Injection at 60 MWe (B Mill OOS, 4 gpm Liquid, 10 psig Air)

Table 6-1

DPSC Lance Tests; Atomizer Ahead of ARIL Telescope

Mill OOS	P_{Air} psi	Liquid Flow gpm	Injection Angle degree	N/NO molar
C*	10	4	22	1.0
C*	10	4	45	1.0
B	10	4	22	1.0, 2.0
B	10	4	34	1.0, 2.0

* A&D Mills heavily biased

During the first two tests with the new DPSC lance, C Mill was OOS for maintenance. Thus, it was necessary to heavily bias A and D Mills to allow operation with B Mill, which was not performing well. The heavy mill biasing resulted in an O_2 distribution (and presumably, a flue gas temperature profile) which was extremely non-uniform across the furnace from east to west. The results of tests run under these conditions should not be compared with those from the previous baseline ARIL lance tests with B Mill OOS. Also, they should not be directly compared to the C Mill OOS results discussed in Section 5 due to the heavy mill biases required during the current tests.

Both tests were run at a N/NO ratio of 1.0, with the DPSC lance in service on the west side of the boiler, and the ARIL lance on the east. The first test was run at an injection angle of 22° (for both lances), and while the NO removal measured on the west side of the duct was nominally 40 percent, the NH_3 slip on the west was nearly 25 ppm. The injection angles were increased to 45°for the second test, and the NO removal and NH_3 slip on the west side were reduced to nominally 35 percent and 2 ppm, respectively.

An important observation from these first two tests was that on the side with the new DPSC lance (west), a substantial amount of the urea/water solution was leaking from the seals at the joints of the telescope sections. Apparently, the new liquid atomizer was spraying a significant amount of the solution on the walls of the telescope. The solution then collected in the bottom of the telescope, and was forced out through the seals by the air pressure in the lance. During the previous ARIL-only tests, the telescope seals frequently leaked a small amount of air, and occasionally a very small amount of liquid (condensed water picked up by the air flowing through the quench tank). However, since the liquid leak under these circumstances was small, and did not involve urea, it was not considered to be a problem. With the DPSC lance, on the other hand, the leak rate was large enough to necessitate the use of 5-gallon buckets to catch it. When the liquid flow to the lance was first started, the leak rate was estimated to be as high as 0.5 gpm (one-quarter of the total liquid flow to the lance). By the end of the test, the leaks appeared to be slowed by the crystallization of urea within the seals, and the leak rate was reduced to approximately 0.25 gpm.

When inserted in the boiler, visual observations of the DPSC lance could be made through an inspection door which was just below the lance location. Visually, the jets from the DPSC lance looked quite different than that seen earlier in the day when the lance was run outside of the boiler with only air and water. With the DPSC lance inserted, a finely atomized spray was visible from all but the last two nozzles (opacity in the furnace made it difficult to see the nozzles near the tip). However, there was also a steady "stream" of liquid from each nozzle, which seemed to come from the far edge of the nozzle opening (i.e., the edge closest to the tip of the lance). Although a definitive reason for this difference in behavior cannot be offered, it appears that with a single liquid atomizer, a significant quantity of the urea/water solution impinges on the inside surfaces of the telescope and lance tube. This liquid collects in the bottom of the lance tube, until it reaches a level where it is carried out of the nozzle openings by the air flow. The test run with the DPSC lance in the retracted position was relatively short in duration, and was run with an injection angle of approximately 90°. It is possible that the test duration was too short to collect enough liquid in the lance tube for the "streaming" phenomena to occur. Also, when the lance is retracted, the distance between the atomizing nozzle and the lance nozzles is much shorter than when the lance is inserted. Throughout the short test program with the DPSC lance, this streaming phenomena was seen each time the lance was inserted.

Additional tests with the DPSC lance and original telescope were conducted with B Mill OOS. At N/NO = 1 with an injection angle of 22°, the NO removal measured on the west side was over 42 percent, but the NH_3 slip on the west was nearly 30 ppm. Two more tests were run, both at injection angles of 34°. The results of these tests (Figure 6-2) show that there was a large reduction in NH_3 slip when the injection angle was increased from 22° to 34°, but only a slight reduction in NO removal. The results also indicate that at 60 MWe with B Mill OOS, the optimal injection angle for the new DPSC lance (on the west side) was 34°.

Detailed measurements of the NO removal profiles (made with the multipoint multigas analyzer discussed in Section 4.4) indicated that, with the DPSC lance, the urea injection was biased toward the tip of the lance. Figure 6-3 shows a NO removal contour plot for the test at N/NO = 2 with a 34° injection angle (recall that the left-hand side of the figure corresponds to the west side of the economizer exit duct). For comparison, the contour plot for the ARIL-only injection test at the same conditions (60 MWe, B Mill OOS, 34° injection angle, and N/NO = 2) is shown in Figure 6-4. With the ARIL lances, the distribution of NO removal on the west side is fairly uniform. With the DPSC lance on the west side, however, the NO removal is skewed toward the middle of the duct (i.e., toward the division wall separating the two halves of the furnace). Although it was not apparent during the test outside the boiler (with air and water only), the NO removal contours for the DPSC lance indicated that the flow of the water/urea solution was biased toward the nozzles near the tip of the lance.

Figure 6-3 also indicates that, on the west side, the NO removal is generally biased toward the bottom of the economizer duct. The flue gas at the bottom of the economizer exit duct generally corresponds to the region of flue gas passing "far away" from the lance at the injection location (recall Figures 2-1 and 2-5). Compared to the ARIL lance on the west side (Figure 6-4), the NO removal contours in Figure 6-3 indicate that the urea "penetrated" farther across the furnace with the DPSC lance. If the atomized urea/water solution drops are larger, the time necessary to evaporate the

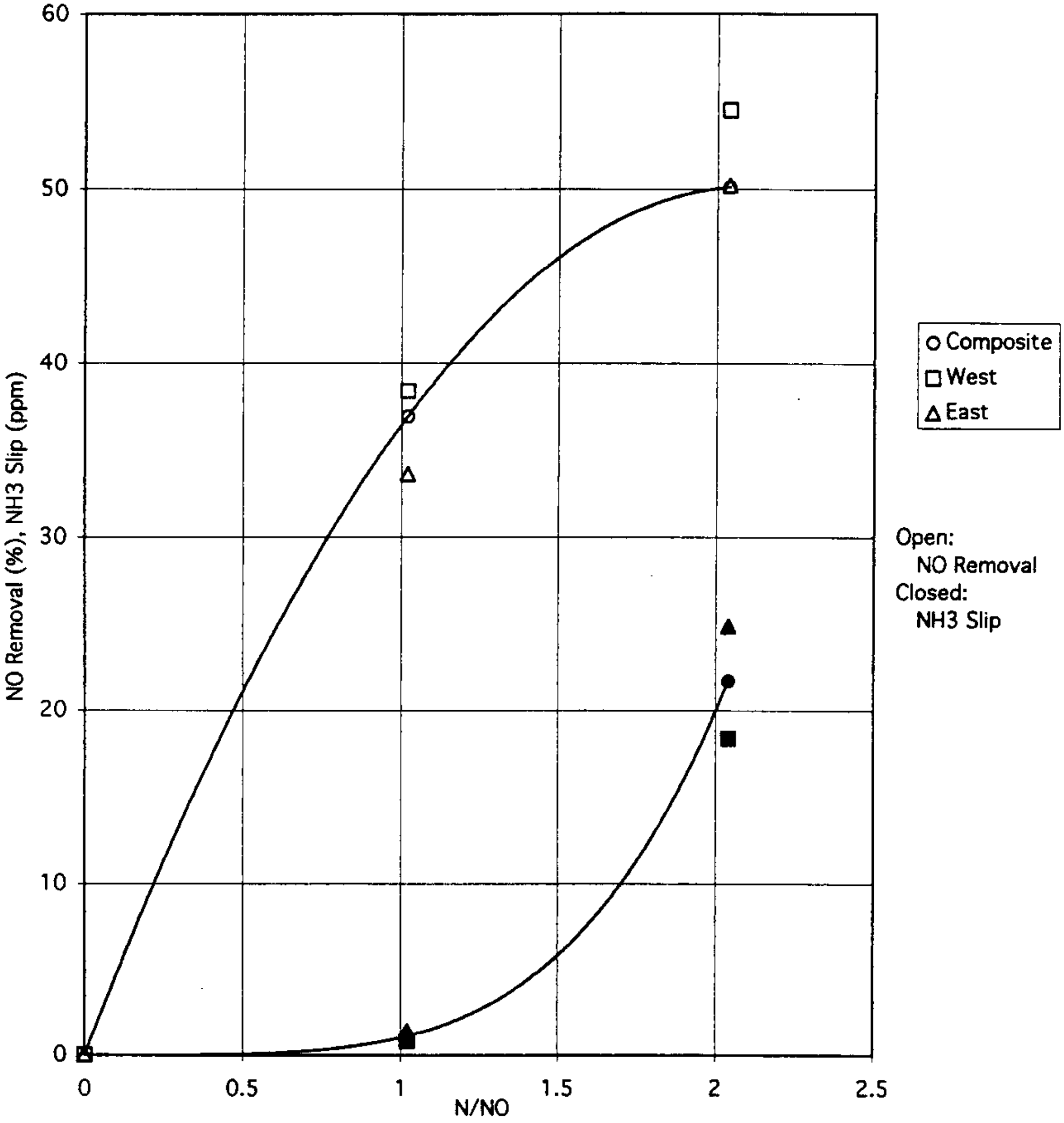


Figure 6-2. NO Removal and NH_3 Slip for West DPSC (without Feed Tube) and East ARIL Injection at 60 MWe (B Mill OOS, Injection Angle = 34°, 4 gpm Liquid, 10 psig Air)

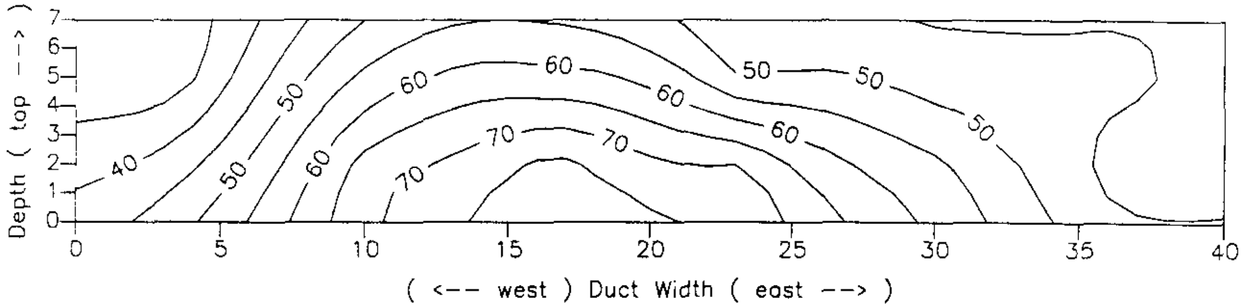


Figure 6-3. NO Removal Contour Plot for West DPSC (without Feed Tube) and East ARIL Injection at 60 MWe (B Mill OOS, 34° Injection Angles, N/NO = 2, 4 gpm Liquid, 10 psig Air)

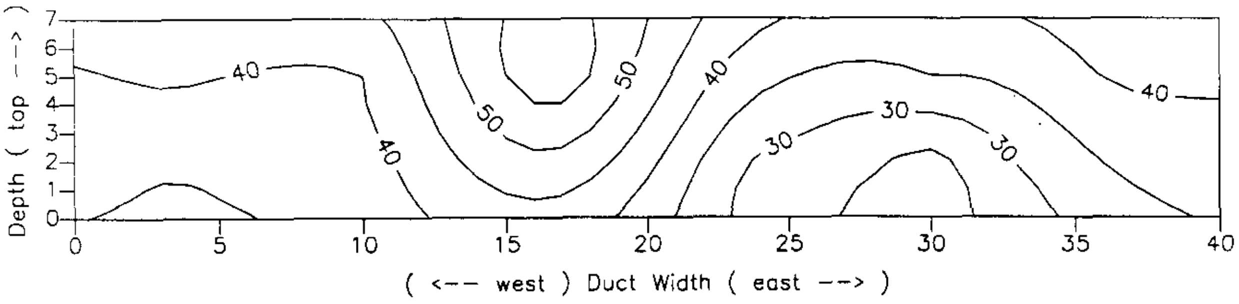


Figure 6-4. NO Removal Contour Plot for West and East ARIL Injection at 60 MWe (B Mill OOS, 34° Injection Angle, N/NO = 2, 4 gpm Liquid, 10 psig Air)

excess water, and bring the solution to a saturated state, will increase. This results in the urea being "released" in a region of flue gas farther away from the lance, as shown in Figure 6-3. This indicates that the original assumption that partial evaporation of the fluid in the DPSC lance would provide for a faster reaction was incorrect. While the amount of urea in liquid form injected by the DPSC lance is less, it is believed the average drop size is larger than with the ARIL lance. As such, the liquid carries further into the boiler.

Next, the telescope was removed and the feed tube installed on the west DPSC lance. Figure 6-5 shows the results of testing with both lances at injection angles of 34°. With the DPSC lance, nominally 43 percent NO removal was achievable on the west side, at an NH_3 slip limit of 10 ppm (N/NO ≈ 1.3). This level of NO removal is higher than that achievable with the ARIL lance on the west side at 34°, where only 39 percent NO removal was measured at the higher N/NO ratio of 2.0. However, recall that previous testing at 60 MWe showed that the optimal injection angle for the ARILs was 22° (see Section 5). The ARIL-only results at 22° (Figure 6-1a) showed nominally 50 percent NO removal on the west side at the 10 ppm NH_3 slip limit. Thus, although the performance of the new DPSC lance on the west side of the boiler was quite good, it did not perform as well as the ARIL lance (at 60 MWe with B Mill OOS).

The installation of the feed tube on the west side of the boiler eliminated the problem of liquid leaking through the telescope seals. However, the relatively small diameter of the feed tube increased the overall pressure drop through the injection system on the west side. During the two week assessment of the new lance, all tests were run with an atomizing air pressure set point of 10 psig. This pressure is measured upstream of the telescope or feed tube. Calculations performed by DPSC indicated that there would be a pressure drop of approximately 3 psig across the feed tube at the design air flow rate of nominally 1450 scfm per lance. This additional pressure drop resulted in a lower air flow through the new lance, since the pressure drop across the nozzles was reduced from nominally 10 to 7 psig. During the tests with the telescope in place, there was no discernable bending of the DPSC lance with 10 psig air pressure and 2 gpm liquid flow.

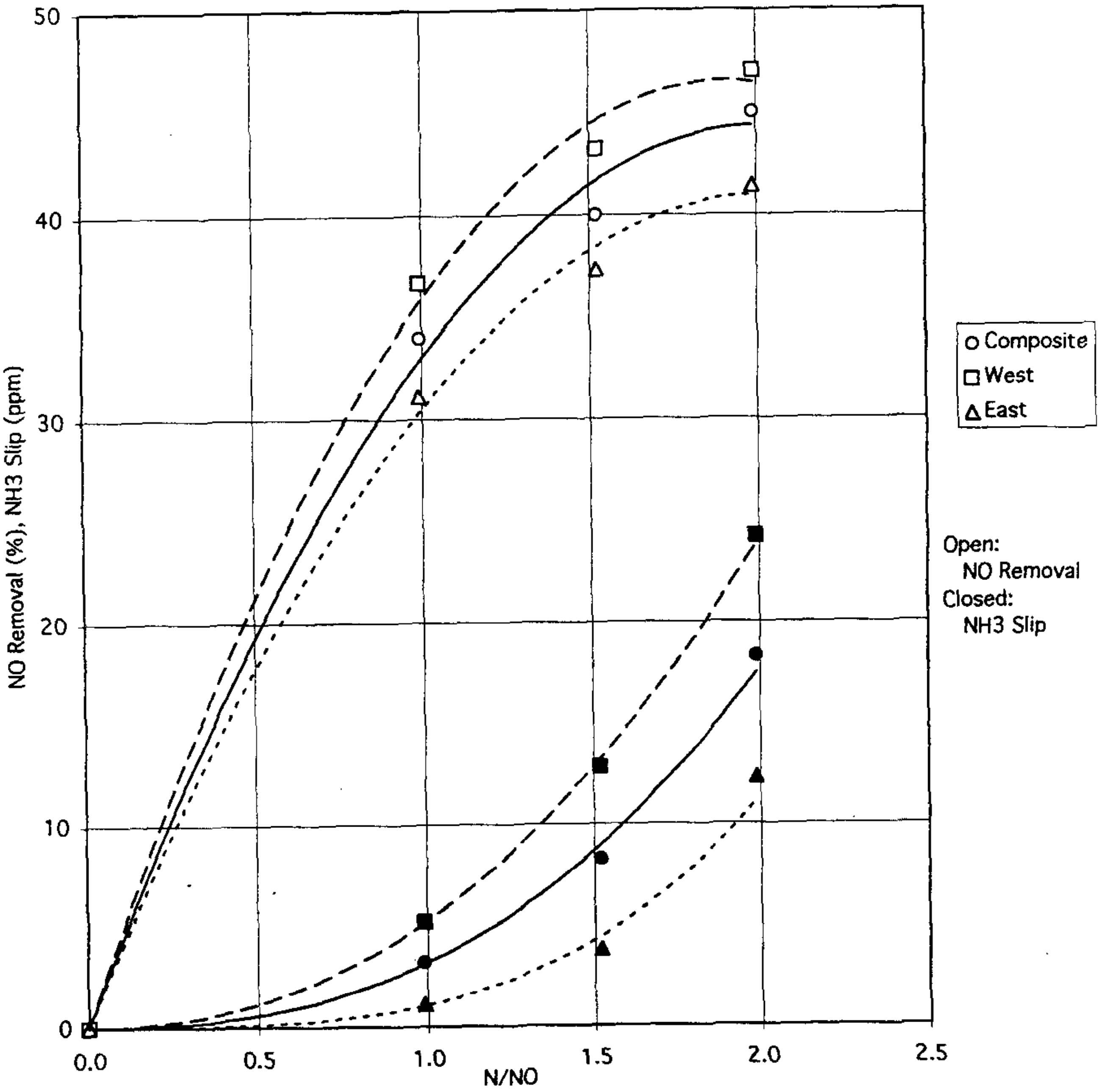


Figure 6-5. NO Removal and NH_3 Slip for West DPSC (with Feed Tube) and East ARIL Injection at 60 MWe (B Mill OOS, Injection Angle = 34°, 4 gpm Liquid, 10 psig Air)

After the feed tube was installed, the lance was seen to bend slightly (2-4 inches) when inserted with the reduced air flow. As with the ARIL lance, the bending was temporary and the lance was straight when retracted.

After the feed tube was installed, visual observations of the DPSC lance (made though the inspection door) indicated that there were still "streams' of liquid coming from each injection nozzle. However, there were also significant amounts of liquid "dripping" from the bottom of the lance at the "joints" between the individual heat shield sections. It is believed that the reduction in the pressure drop across the nozzles (the driving force to push the air and liquid out in a direction perpendicular to the lance axis), may have resulted in an increase in the "axial" component of the jet leaving the nozzle. The angle of the jets (toward the tip of the lance) may have increased to the point where a portion of the liquid "stream" was caught in the annular space between the heat shield and the lance tube. This liquid would then flow toward the tip of the lance, and drip out through the joints between the heat shield sections. This was confirmed when the lance was retracted and crystallized urea was found in the spaces between the heat shield and lance tube. Subsequently, the opening between the heat shield and the lance tube at each nozzle location was "seal" welded. While this prevented the liquid from entering the annular space, it did not solve the "dripping" problem, as the dripping now occurred at each individual nozzle location, rather than at the joints between the heat shield sections.

The reduction in air flow through the DPSC injection nozzles resulted in a reduction in the "penetration" of the jets into the flue gas stream. Recall that the contour plot shown in Figure 6-3 indicated that the urea was released in an area "far away" from the lance. Figure 6-6 shows the NO removal contour plot for a test run at the same conditions, but with the feed tube in place on the west side. The results show that the NO removal is no longer biased toward the bottom of the duct (i.e., the urea was released in a region "closer" to the lance). However, the DPSC lance still obtains more penetration than the ARIL lance. As previously discussed, it is believed the DPSC lance has a larger average drop size, with the larger drops penetrating further and evaporating slower.

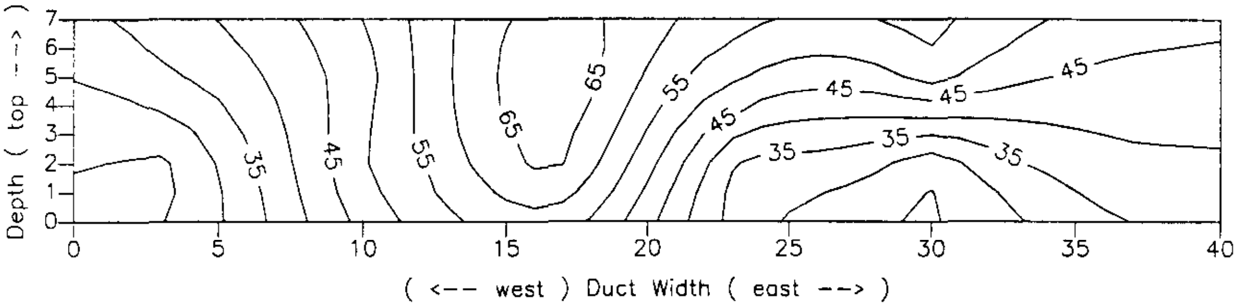


Figure 6-6. NO Removal Contour Plot for West DPSC and East ARIL Injection at 60 MWe (B Mill OOS, 34° Injection Angle, N/NO = 2, 4 gpm Liquid, 10 psig Air)

The difference in performance is attributable to the urea distribution along the DPSC lance and the finer atomization of the ARIL lance. The ARIL lance uses a separate liquid circuit with individual liquid orifices at each air nozzle. This results in a uniform liquid distribution along the length of the lance. The DPSC lance, on the other hand, sprays the urea solution into the cooling air stream at the inlet to the lance with some impingement on the walls. This provides a less uniform distribution with more liquid tending to be carried toward the far end of the lance. It is also believed that the DPSC lance generates slightly large drops which are carried further in the boiler. In addition, the feed tube geometry of the DPSC lance created an additional pressure drop, restricting the amount of cooling air flow and caused some minor temporary bending.

While the DPSC lance has caused some additional concerns, it has solved the mechanical problems experienced with the ARIL lance. The current results show that both lance designs have advantages and the "best" lance depends on site-specific considerations.

Overall, the results of the short test program of the DPSC lance were sufficiently positive that a second DPSC lance has been ordered. An additional test period of up to three weeks is planned, the results of which will be included in the final report.

REFERENCES

Chase, M.W., et al., *JANAF Thermochemical Tables Third Edition, Parts 1 and 2*, Journal of Physical and Chemical Reference Data, Volume 14, Supplement No. 1, 1985.

Hjuler, K., *The Reaction Between Sulphur Dioxide and Ammonia in Flue Gas*, Ph.D. Dissertation, Technical University of Denmark, 1991.

Shiomoto, G.H., et al., *Integrated Dry* NO_x/SO_2 *Emissions Control System Baseline Test Report*, DOE Contract Number DE-FCC22-91PC90550, NTIS: DE92040528, March 1992.

Smith, R.A., et al., *Integrated Dry* NO_x/SO_2 *Emissions Control System: Baseline SNCR Test Report*, DOE Contract Number DE-FCC22-91PC90550, NTIS: DE94005035, September 1993.

Smith, R.A., et al., *Integrated Dry* NO_x/SO_2 *Emissions Control System: Low-*NO_x *Combustion System Retrofit Test Report*, DOE Contract Number DE-FCC22-91PC90550, NTIS: DE94014532, October 1994a.

Smith, R.A., et al., *Integrated Dry* NO_x/SO_2 *Emissions Control System: Low-*NO_x *Combustion System SNCR Test Report*, DOE Contract Number DE-FCC22-91PC90550, NTIS: DE94017370, November 1994b.

TRC Environmental Corp., *Performance Test Final Report, Continuous Emissions Monitoring System Evaluation, Public Service Company of Colorado, Arapahoe Generating Station, Unit 4, Denver Colorado*, August 1993.

U. S. Environmental Protection Agency, Draft Method 206 - *Procedure for Collection and Analysis of Ammonia in Stationary Sources*, January 16, 1996.

APPENDICES

A

SUMMARY OF PROOF-OF-CONCEPT LANCE TESTS

Before actually proceeding with the design and fabrication of the ARIL lance system, two options for proof-of-concept tests were explored by PSCo. The first was a cold flow modeling study similar to the one performed early in the test program for the Level 1 and Level 2 injectors, where jet penetration and mixing characteristics could be assessed as a function of injection angle. Since the 1:10 scale model of the Arapahoe Unit 4 boiler was already in existence, a cold flow study could be conducted quickly and at a minimal cost. The disadvantage of this option is that it was not capable of assessing how NO removal would be affected by injection angle (i.e., flue gas temperature in the region of chemical reaction). The second option was to run full-scale urea injection tests, treating only a limited portion of the flue gas with a short lance. With this option, "real-world" NO removal data could be generated at a low cost, since the full-scale liquid metering and air transport systems were already on-site. The only additional equipment necessary would be the lance itself. PSCo decided to pursue the second option, as it would provide an indication of the actual NO removals achievable.

A short lance was designed with general characteristics similar to those proposed for the full-length ARIL lances. The stub-lance was air-cooled, nominally four inches in diameter, and was fitted with three injection nozzles spaced on two-foot centers. The lance was inserted through the unused sootblower opening on the west side of the furnace where it protruded approximately six feet into the flue gas flow. Thus, nominally *one-third of the gas in the west side of the furnace (i.e., nominally one-sixth of the total* flue gas flow) was treated. The proof-of-concept tests were conducted to provide an indication of the level of NO removal attainable at the new injection location, as well as assess the magnitude of the injection angle effect. All tests were run at a boiler load of 60 MWe with A Mill OOS. Figure A-1 shows the local NO removal (measured in the area of treatment only) as a function of injection angle for a fixed urea injection rate. The results indicate that injection angle has a large effect on process performance.

The results of the proof-of-concept tests are compared to the Level 1 injection results (from the previous test phase) in Figure A-2. With the exception of the single point for injection at 22°, the performance of the stub-lance was better than any of the Level 1 results, when compared on the basis of NH_3 slip as a function of NO removal. As only a portion of the flue gas was treated with the stub-lance, it is difficult to accurately quantify the N/NO ratios for these tests. The proof-of-concept tests were run at two different chemical flowrates. Assuming roughly one-half of the flue gas is treated, the nominal "local" N/NO ratios corresponding to the two chemical flowrates were 1.0 and 2.0. The results shown in Figure A-2 were sufficient to warrant proceeding with the design and fabrication of the full-length lances.

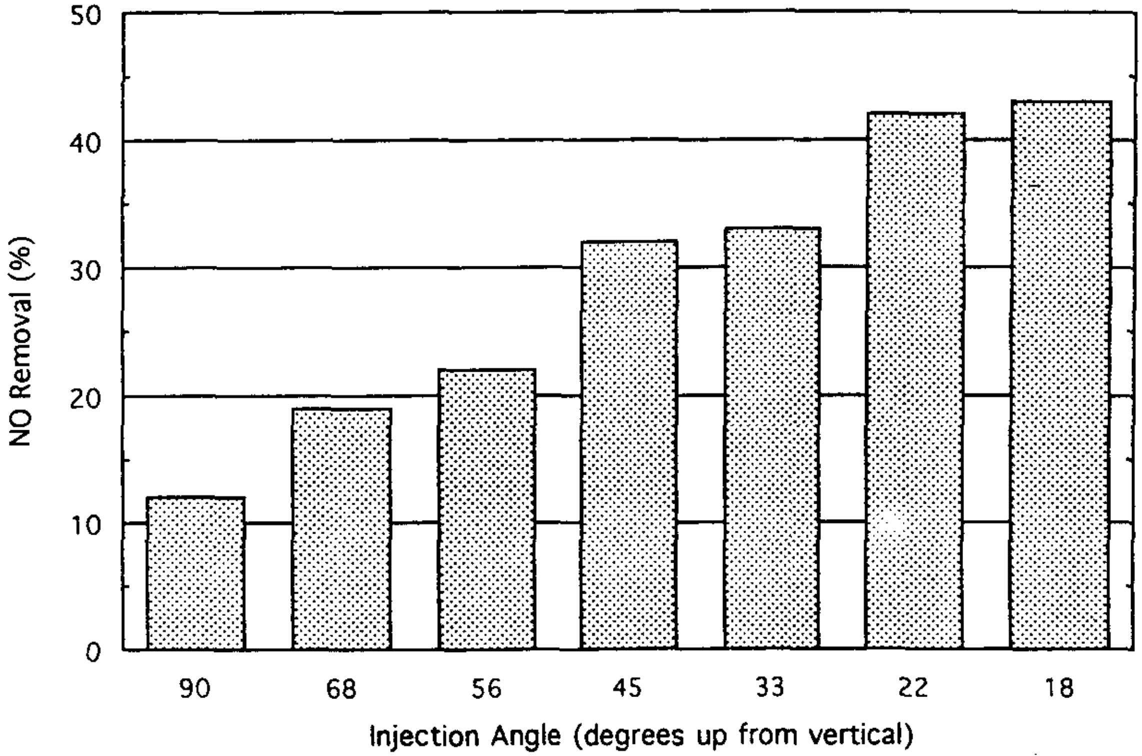


Figure A-1. Effect of Injection Angle for Proof-of-Concept Stub-Lance Tests

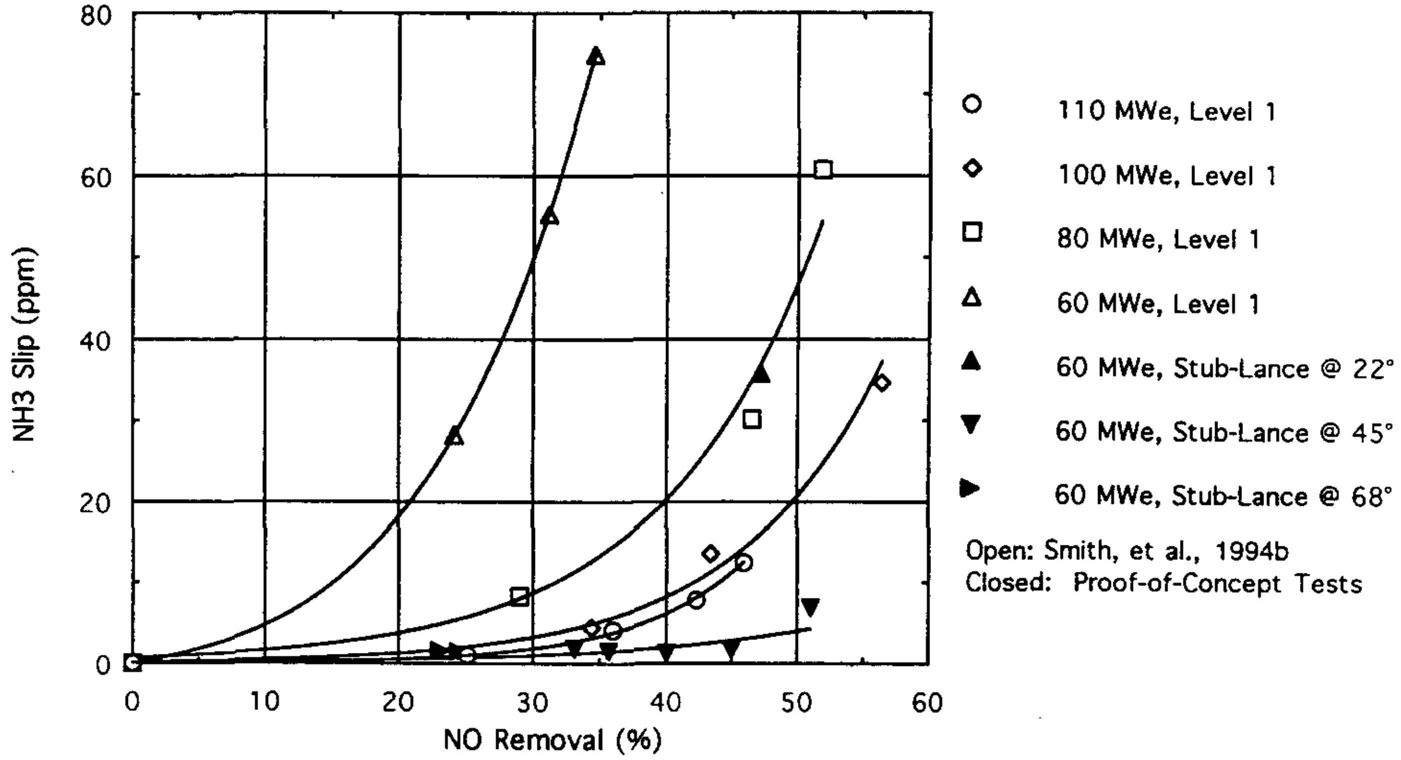


Figure A-2. Comparison of Proof-of-Concept Stub-Lance Results to Level 1 Results from Previous Test Phase

B

DATA SUMMARY: ARIL LANCE TESTS

PSCC Arapahoe Unit 4 Urea Lance Injection Summary

					Urea Injection--------								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load	Mills	O2cr	Level	ARIL	Quads	Urea	Total	Inj air	Conc	N/NO	base	base	SNCR	econ	ΔNO	econ	O2	SO2	NO	CO	NO2	CO2	N2O	O2	SO2	NO	CO	NO2	CO2	N2O	AHO comp	Comments
		MWe	OOS	%wet		Angle	OOS	gpm	gpm	psi	wt%		ppmc	ppmc	%	ppmc	%	ppmc	%dry	ppm	ppm	ppm	ppm	%	ppm	%dry	ppm	ppm	ppm	ppm	%	ppm	ppm	
UREA LANCE TESTS																																		
842	4/20/95 11:06	80	A	5.90	ARIL						41.6	--	322	359	--	--	--	--	6.95	280	251	16	1	11.60	-0.2									Morning Baseline
843	4/20/95 14:16	80	A	5.90	ARIL	22.5		1.00	6.0	8.5	41.6	0.93	328	360	32.8	--	--	1	7.00	280	255	16	1	11.49	-0.7	6.95	280	172	30					West Lance Only
844	4/20/95 15:12	80	A	5.90	ARIL						41.6	--	328	360	--	--	--	--	7.00	280	255	16	1	11.49	-0.7									Afternoon Baseline Check
845	4/24/95 11:55	60	A&D	7.10	ARIL						41.6	--	333	347	--	--	--	--	8.30	245	235	34	1	10.78	3.8									Morning Baseline
846	4/24/95 15:20	60	A&D	7.10	ARIL	45.0		0.90	2.0	9.0	41.6	1.11	329	350	26.4	31	36.2	3	8.30	247	232	36	1	10.75	4.4	8.50	241	168	52	0	10.44	26.2		Both Lances @ 45°
847	4/24/95 15:49	60	A&D	7.10	ARIL	22.5		0.90	2.0	9.0	41.6	1.11	329	350	26.0	30	34.7	20	8.30	247	232	36	1	10.75	4.4	8.50	229	169	53	0	10.51	24.9		Both Lances @ 22.5°
848	4/24/95 16:36	60	A&D	7.10	ARIL	22.5		1.80	4.0	9.0	41.6	2.22	329	350	38.4	50	39.7	88	8.30	247	232	36	1	10.75	4.4	8.55	181	140	63	0	10.50	39.0		Both Lances @ 22.5°
849	4/24/95 17:02	60	A&D	7.10	ARIL						41.6	--	329	350	--	--	--	--	8.30	247	232	36	1	10.75	4.4									Afternoon Baseline Check
850	4/25/95 9:30	60	A&D	7.20	ARIL						41.6	--	322	357	--	--	--	--	8.55	247	223	28	1	10.43	2.7									Morning Baseline
851	4/25/95 14:30	60	A&D	7.40	ARIL	22.5		0.90	2.0	12.0	41.6	1.21	303	356	27.2	34	41.0	44	8.45	248	211	35	1	10.43	2.8	8.75	212	150	56	0	10.23	25.7	45.2 avg	Both Lances @ 22.5°
											41.6	--	0	0	--	--	--	--															AHO1=72.1	
											41.6	--	0	0	--	--	--	--															AHO2=39.4	
											41.6	--	0	0	--	--	--	--															AHO3=10.6	
											41.6	--	0	0	--	--	--	--															AHO4=21.1	
											41.6	--	0	0	--	--	--	--															AHO5=49.6	
											41.6	--	0	0	--	--	--	--															AHO6=78.3	
852	4/25/95 16:20	60	A&D	7.40	ARIL	22.5	1&4	0.90	2.0	12.0	41.6	1.21	303	356	12.7	27	70.4	0	8.45	248	211	35	1	10.43	2.8	8.60	245	182	33	0	10.25	21.4		Outside Lance Quadrants OOS
853	4/25/95 16:55	60	A&D	7.40	ARIL						41.6	--	303	356	--	--	--	--	8.45	248	211	35	1	10.43	2.8									Afternoon Baseline Check
854	4/26/95 8:15	60	A&D	7.40	ARIL						41.6	--	324	360	--	--	--	--	8.55	249	224	29	2	10.67	2.9									Morning Baseline
855	4/27/95 7:45	60	A&D	7.40	ARIL						41.6	--	336	357	--	--	--	--	8.75	243	230	30	2	10.30	2.7									Morning Baseline
856	4/27/95 12:15	60	A&D	7.40	ARIL	67.5		0.90	4.0	12.0	41.6	1.06	336	357	27.6	22	23.6	3	8.75	243	230	30	2	10.30	2.7	8.50	246	170	30	1	10.55	16.0	1.65 avg	Both Lances @ 67.5°, N/NO = 1
											41.6	--	0	0	--	--	--	--															AHO1=6.2	
											41.6	--	0	0	--	--	--	--															AHO2=1.9	
											41.6	--	0	0	--	--	--	--															AHO3=0.5	
											41.6	--	0	0	--	--	--	--															AHO4=0.5	
											41.6	--	0	0	--	--	--	--															AHO5=0.3	
											41.6	--	0	0	--	--	--	--															AHO6=0.5	
857	4/27/95 14:15	60	A&D	7.40	ARIL	90.0		0.90	4.0	12.0	41.6	1.06	336	357	21.0	11	15.5	4	8.75	243	230	30	2	10.30	2.7	8.25	250	169	24	1	10.76	10.6	0.7	Both Lances @ 90°, N/NO = 1
											41.6	--	0	0	--	--	--	--															AHO1=0.9	
858	4/27/95 16:02	60	A&D	7.40	ARIL	90.0		1.80	4.0	12.0	41.6	2.16	336	357	27.9	21	22.4	7	8.75	243	230	30	2	10.30	2.7	8.15	250	174	27	1	10.64	17.9	1.3	Both Lances @ 90°, N/NO = 2
859	4/27/95 17:00	60	A&D	7.40	ARIL						41.6	--	325	361	--	--	--	--	8.70	240	222	35	1	10.32	3.5									Afternoon Baseline Check
860	4/28/95 11:26	80	A	6.00	ARIL						41.6	--	310	370	--	--	--	--	6.95	269	242	17	1	11.69	-1.4									Morning Baseline
1/4" COOLING HOLES AND LIQUID LINE EXPANSION LOOPS ADDED																																		
861	5/15/95 23:30	60	A&D	7.30	ARIL						41.6	--	335	391	--	--	--	--	8.80	265	227	31	0	10.37	-0.6									Baseline, unit not real steady
											41.6	--	377	410	--	--	--	--	11.2	223	205	23	-1	8.50	-0.6									EE 1&2
											41.6	--	368	394	--	--	--	--	8.20	280	262	55	2	11.18	-1.1									EE 3&4
											41.6	--	344	396	--	--	--	--	7.15	305	265	36	0	12.27	-0.9									EE 5&6
											41.6	--	323	390	--	--	--	--	6.70	310	257	17	0	11.93	-0.6									EE 7&8
											41.6	--	296	396	--	--	--	--	8.35	278	208	27	0	10.82	0.0									EE 9&10
											41.6	--	329	403	--	--	--	--	11.7	208	170	25	0	8.30	0.4									EE 11&12
862	5/16/95 2:30	60	A&D	7.50	ARIL	22.5		0.90	4.0	12.0	41.6	1.09	335	391	36.8	35	27.2	4	8.80	265	227	31	0	10.37	-0.6	8.45	270	143	46	-2	10.90	24.0	12.2 avg	O2 not steady
											41.6	--	377	410	46.2	49	28.4	12	11.2	223	205	23	-1	8.50	-0.6	10.6	230	117	37	-2	8.75	27.9	AHO1=0.8	EE 1&2
											41.6	--	368	394	36.9	32	23.5	2	8.20	280	262	55	2	11.18	-1.1	7.45	295	175	47	-1	11.71	22.9	AHO2=1.9	EE 3&4
											41.6	--	344	396	31.8	32	29.1	1	7.15	305	265	36	0	12.27	-0.9	7.20	303	180	26	-1	11.76	23.6	AHO3=0.0	EE 5&6
											41.6	--	323	390	31.5	35	33.9	-1	6.70	310	257	17	0	11.93	-0.6	7.20	300	170	29	-1	12.27	25.9	AHO4=6.9	EE 7&8
											41.6	--	296	396	46.2	36	26.4	-1	8.35	278	208	27	0	10.82	0.0	7.85	290	112	54	-2	11.16	27.5	AHO5=17.8	EE 9&10
											41.6	--	329	403	43.1	24	16.6	82	11.7	208	170	25	0	8.30	0.4	10.9	180	105	60	-2	8.76	13.6	AHO6=48.2	EE 11&12
863	5/16/95 4:45	60	A&D	7.30	ARIL	45.0		0.90	4.0	12.1	41.6	1.09	335	391	26.8	26	26.6	-4	8.80	265	227	31	0	10.37	-0.6	8.55	273	165	36	-1	10.83	18.6	3.3	O2 not steady
											41.6	--	377	410	36.1	41	30.3	12	11.2	223	205	23	-1	8.50	-0.6	10.9	223	135	26	-2	8.54	22.5		EE 1&2
											41.6	--	368	394	29.4	21	19.5	-3	8.20	280	262	55	2	11.18	-1.1	7.85	290	190	49	1	11.27	14.3		EE 3&4
											41.6	--	344	396	25.3	16	18.3	-5	7.15	305	265	36	0	12.27	-0.9	7.00	312	200	25	-1	11.53	11.5		EE 5&6
											41.6	--	323	390	19.9	18	27.7	-6	6.70	310	257	17	0	11.93	-0.6	6.55	318	208	19	-1	12.71	13.7		EE 7&8
											41.6	--	296	396	26.8	27	34.2	-1	8.35	278	208	27	0	10.82	0.0	7.70	293	160	36	-1	11.46	20.1		EE 9&10
											41.6	--	329	403	46.9	46	30.0	9	11.7	208	170	25	0	8.30	0.4	10.7	225	100	63	-1	8.97	26.9	AHO6=14.4	EE 11&12
864	5/16/95 5:40	60	A&D	7.30	ARIL	67.0		0.90	4.0	12.0	41.6	1.09	335	391	26.0	20	23.4	-11	8.80	265	227	31	0	10.37	-0.6	8.15	267	177	26	0	10.84	13.9	1.3	O2 not steady
											41.6	--	377	410	34.1	30	23.2	11	11.2	223	205	23	-1	8.50	-0.6	10.7	228	142	26	-2	8.87	16.4		EE 1&2
											41.6	--	368	394	33.1	16	14.7	-2	8.20	280	262	55	2	11.18	-1.1	7.35	300	187	34	1	11.89	12.4		EE 3&4
											41.6	--	344	396	16.9	7	10.3	-1	7.15	305	265	36	0	12.27	-0.9	6.95	310	218	21	0	11.87	4.3		EE 5&6
											41.6	--	323	390	17.5	16	28.7	0	6.70	310	257	17	0	11.93	-0.6	6.70	310	212	17	-1	12.29	12.3		EE 7&8
											41.6	--	296	396	31.5	26	27.4	0	8.35	278	208	27	0	10.82	0.0	7.50	297	152	28	-1	11.59	19.2		EE 9&10
											41.6	--	329	403	38.3	35	27.6	-2	11.7	208	170	25	0	8.30	0.4	10.1	245	123	39	-1	9.30	21.5	AHO6=5.3	EE 11&12
865	5/16/95 6:40	60	A&D	7.20	ARIL						41.6	--	323	397	--	--	--	--	8.75	270	220	34	0	10.56	0.6									Baseline Check

					Urea Injection------								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	base ppmc	base ppmc	SNCR %	econ ppmc	ΔNO %	econ ppmc	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	AHO comp ppm	Comments
											41.6	--	366	403	--	--	--	--	11.3	217	197	24	-1	8.37	0.0									EE 1&2
											41.6	--	345	401	--	--	--	--	8.20	265	245	49	2	10 60	-0.1									EE 3&4
											41.6	--	336	396	--	--	--	--	7.35	300	255	35	1	11.72	0.2									EE 5&6
											41.6	--	309	392	--	--	--	--	6.75	310	245	24	0	12.30	0.4									EE 7&8
											41.6	--	259	395	--	--	--	--	7.10	305	200	29	0	12.13	1.6									EE 9&10
											41.6	--	273	400	--	--	--	--	11.1	220	150	36	-1	8.54	2.0									EE 11&12
866	5/17/95 0:00	60	A&D	7.00	ARIL						41.6	--	327	446	--	--	--	--	8.60	307	225	28	2	10.68	0.2									Baseline, unit not real steady
											41.6	--	410	455	--	--	--	--	11.7	235	212	21	2	8.03	-0.1									EE 1&2
											41.6	--	380	446	--	--	--	--	8.30	315	268	35	2	11 02	0.4									EE 3&4
											41.6	--	367	443	--	--	--	--	7.50	332	275	57	3	11.52	0.7									EE 5&6
											41.6	--	335	442	--	--	--	--	6.75	350	265	17	1	12.57	-0.1									EE 7&8
											41.6	--	333	439	--	--	--	--	8.30	310	235	23	2	11.14	0.3									EE 9&10
											41.6	--	299	446	--	--	--	--	11.2	243	163	23	1	8.57	1.6									EE 11&12
867	5/17/95 4:40	60	A&D	7.20	ARIL	34.0		0.90	4.0	12.0	41.6	1.12	327	446	26.8	29	33.2	3	8.60	307	225	28	2	10.68	0.2	8.60	300	162	39	0	10.49	19.9	8.5	Both lances @ 34 deg, N/NO = 1
											41.6	--	410	455	50.9	52	25.0	10	11.7	235	212	21	2	8.03	-0.1	11.0	247	112	30	-1	8.74	28.9		EE 1&2
											41.6	--	380	446	43.9	31	18.6	7	8.30	315	268	35	2	11.02	0.4	7.90	320	155	43	0	11.25	23.0		EE 3&4
											41.6	--	367	443	29.9	21	19.2	-10	7.50	332	275	57	3	11.52	0.7	7.20	347	197	22	0	11.75	16.9		EE 5&6
											41.6	--	335	442	27.9	20	21.7	-5	6.75	350	265	17	1	12.57	-0.1	6.30	365	197	21	0	12.67	16.5		EE 7&8
											41.6	--	333	439	36.9	25	20.2	-11	8.30	310	235	23	2	11.14	0.3	7.30	343	160	40	0	11 80	19.2		EE 9&10
											41.6	--	299	446	36.2	27	23.6	43	11.2	243	163	23	1	8.57	1.6	10.3	240	110	70	-1	8.61	17.8		EE 11&12
868	5/17/95 5:55	60	A&D	7.10	ARIL	34.0		1.80	4.0	12.0	41.6	2.24	327	446	42.3	44	32.0	13	8 60	307	225	28	2	10.68	0.2	8.30	305	133	48	0	11.01	31.4	16.5	Both lances @ 34 deg, N/NO = 2
											41.6	--	410	455	64.6	75	28.3	42	11.7	235	212	21	2	8.03	-0.1	11.1	227	80	45	-1	8.80	41.1		EE 1&2
											41.6	--	380	446	47.0	40	22.3	-5	8.30	315	268	35	2	11.02	0.4	7.15	347	155	41	0	11.75	31.0		EE 3&4
											41.6	--	367	443	42.6	39	24.7	-3	7.50	332	275	57	3	11.52	0.7	7.15	343	162	23	-1	11.70	30.4		EE 5&6
											41.6	--	335	442	38.4	33	25.9	2	6.75	350	265	17	1	12.57	-0.1	6.15	363	170	23	0	12.51	27.4		EE 7&8
											41.6	--	333	439	48.5	36	22.5	-6	8.30	310	235	23	2	11.14	0.3	7.35	338	130	46	0	11.73	27.9		EE 9&10
											41.6	--	299	446	43.4	44	33.6	123	11.2	243	163	23	1	8.57	1.6	10.7	165	97	61	-1	9.02	26.8		EE 11&12
869	5/17/95 6:30	60	A&D	7.20	ARIL						41.6	--	307	458	--	--	--	--	8.70	313	210	26	1	10.57	0.5									Baseline Check
											41.6	--	262	463	--	--	--	--	10.5	270	153	24	0	9.06	0.9									EE 11&12
											41.6	--	360	464	--	--	--	--	11.5	245	190	23	1	8.23	0.9									EE 1&2
870	5/18/95 0:45	62	A	6.20	ARIL						41.6	--	257	429	--	--	--	--	7.50	322	193	35	0	11.64	1.0									Baseline
											41.6	--	310	423	--	--	--	--	12.4	202	148	10	0	7.39	2.1									EE 1&2
											41.6	--	257	429	--	--	--	--	8.20	305	183	64	1	11.16	2.5									EE 3&4
											41.6	--	210	420	--	--	--	--	5.80	355	177	100	0	13.49	4.3									EE 5&6
											41.6	--	239	422	--	--	--	--	4.80	380	215	40	1	13.93	0.4									EE 7&8
											41.6	--	251	427	--	--	--	--	5.80	365	215	17	1	13.26	-0.2									EE 9&10
											41.6	--	241	425	--	--	--	--	8.30	300	170	36	0	11.02	-0.9									EE 11&12
871	5/18/95 2:50	65	A	5.70	ARIL	34.0		0.72	4.0	12.0	41.6	1.05	257	429	27.1	14	19.7	26	7.50	322	193	35	0	11.64	1.0	6.60	323	150	42	-1	12.41	12.1	3.6 avg	Both lances @ 34 deg, N/NO = 1
											41.6	--	279	427	35.5	30	29.7	38	10.3	254	186	37	0	9.28	2.3	9.30	253	117	57	-1	10.27	21.7	AHO1/2=8.4	EE 1-4
											41.6	--	225	422	17.4	9	24.0	19	5.30	368	196	70	0	13.71	2.4	4.80	363	167	36	0	13.73	10.9	AHO3/4=1.4	EE 5-8
											41.6	--	247	427	17.4	7	16.8	18	6.95	333	193	27	1	12.14	-0.6	6.45	330	165	23	0	12.80	5.3	AHO5/6=1.1	EE 9-12
872	5/18/95 3:30	65	A	5.90	ARIL	34.0		0.72	4.0	12.0	41.6	1.06	257	429	26.6	15	22.3	23	7.50	322	193	35	0	11.64	1.0	6.90	318	148	43	0	12.33	13.0	33.0 avg	Both lances @ 34 deg, N/NO = 1
											41.6	--	310	423	40.6	41	32.2	43	12.4	202	148	10	0	7.39	2.1	11.9	192	93	47	-1	7.98	22.7	AHO1/2=6.6	EE 1&2
											41.6	--	257	429	32.7	19	22.1	39	8.20	305	183	64	1	11.16	2.5	6.45	315	140	57	-1	12.57	17.9		EE 3&4
											41.6	--	210	420	16.9	10	29.1	28	5.80	355	177	100	0	13.49	4.3	5.30	342	152	55	0	13.63	13.4	AHO3/4=1.3	EE 5&6
											41.6	--	239	422	11.9	4	14.0	9	4.80	380	215	40	1	13.93	0.4	3.90	393	200	23	0	14.58	4.2		EE 7&8
											41.6	--	251	427	16.8	5	10.9	21	5.80	365	215	17	1	13.26	-0.2	5.25	355	163	19	0	13.48	3.8	AHO5/6=1.0	EE 9&10
											41.6	--	241	425	23 2	10	16.5	6	8.30	300	170	36	0	11.02	-0.9	6.90	327	145	20	0	12.17	7.1		EE 11&12
873	5/18/95 4:50	66	A	6.00	ARIL	34.0		1.12	4.0	12.0	41.6	1.61	257	429	30.5	20	25.1	27	7.50	322	193	35	0	11.64	1.0	6.90	315	140	43	0	12.26	16.5	6.8 avg	Both lances @ 34 deg, N/NO = 1 5
											41.6	--	293	380	49.6	55	37.6	26	12.7	175	135	24	0	7.40	4.2	12.1	175	73	52	-2	7.66	31.5	AHO1/2=16.2	EE 1
											41.6	--	290	392	43.7	47	37.1	45	11.5	207	153	23	0	8.21	4.7	11.4	185	67	46	-1	8.35	29.8		EE 2
											41.6	--	257	429	36.1	27	29 3	39	8.20	305	183	64	1	11.16	2.5	6.55	313	132	78	0	12.60	24.7		EE 3&4
											41.6	--	210	420	15.7	11	33.7	23	5.80	355	177	100	0	13.49	4.3	5.00	353	157	84	0	13.63	14.4	AHO3/4=2.5	EE 5&6
											41.6	--	239	422	13.7	5	15.3	16	4.80	380	215	40	1	13.93	0.4	4.15	380	193	23	0	14.63	5.1		EE 7&8
											41.6	--	251	427	18.5	7	16.1	26	5.80	365	215	17	1	13.26	-0.2	5.35	348	178	16	0	13.39	6.3	AHO5/6=1.6	EE 9&10
											41.6	--	241	425	23.1	12	21.8	17	8.30	300	170	36	0	11.02	-0.9	7.10	315	143	19	0	11.96	8.4		EE 11&12
874	5/18/95 5:55	67	A	5.70	ARIL	34.0		1.50	4.0	12.0	41.6	2.12	257	429	30.8	23	28.5	35	7.50	322	193	35	0	11.64	1.0	6.85	310	140	47	-1	12.28	16.8	12.8 avg	Both lances @ 34 deg, N/NO = 2 0
											41.6	--	293	380	55.5	62	38.5	94	12.7	175	135	24	0	7.40	4.2	12.3	138	63	62	-1	7.31	34.6	AHO1/2=33.5	EE 1
											41.6	--	290	392	45.8	53	40.0	93	11.5	207	153	23	0	8.21	4.7	11.5	158	83	60	-1	8.00	32.7		EE 2
											41.6	--	257	429	38.1	37	38.1	53	8.20	305	183	64	1	11.16	2.5	7.45	283	120	80	1	11.57	30.7		EE 3&4
											41.6	--	210	420	23.7	21	41.5	24	5.80	355	177	100	0	13.49	4.3	4.90	355	143	74	0	13.79	23.0	AHO3/4=3.0	EE 5&6
											41.6	--	239	422	14.1	6	16.6	20	4.80	380	215	40	1	13.93	0.4	3 45	392	200	26	1	15.26	5 9		EE 7&8
											41.6	--	251	427	17.5	11	25.5	25	5.80	365	215	17	1	13.26	-0 2	5.55	345	178	20	0	13.06	9.4	AHO5/6=1.9	EE 9&10
											41.6	--	241	425	22 1	14	25 4	20	8 30	300	170	36	0	11 02	-0.9	6.80	320	148	32	0	12 43	9.7		EE 11&12

					Urea injection------								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	base ppmc	base ppmc	SNCR %	econ ppmc	ΔNO %	econ ppmc	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	AHO comp ppm	Comments
875	5/18/95 6:50	65	A	5.90	ARIL						41.6	--	236	402	--	--	--	--	6.90	315	185	55	0	12.37	2.1									Baseline, unit not steady
											41.6	--	293	380	--	--	--	--	12.7	175	135	24	0	7.40	4.2									EE 1
											41.6	--	290	392	--	--	--	--	11.5	207	153	23	0	8.21	4.7									EE 2
											41.6	--	247	400	--	--	--	--	7.50	300	185	65	1	11.61	3.6									EE 3&4
											41.6	--	218	389	--	--	--	--	5.05	345	193	75	0	13.84	5.2									EE 5&6
											41.6	--	266	401	--	--	--	--	4.40	370	245	33	1	15.01	0.4									EE 7&8
											41.6	--	229	387	--	--	--	--	4.25	360	213	36	1	14.70	3.3									EE 9&10
											41.6	--	235	395	--	--	--	--	6.20	325	193	49	1	12.80	-0.9									EE 11&12
876	*5/19/95 1:40*	*60*	*A*	*7.00*	*ARIL*						*41.6*	--	*278*	383	--	--	--	--	*7.75*	282	205	28	-1	*11.44*	2.1									*Baseline*
											41.6	--	345	385	--	--	--	--	12.5	182	163	22	0	7.53	0.3									EE 1&2
											41.6	--	250	383	--	--	--	--	7.65	280	183	87	0	11.63	1.1									EE 3&4
											41.6	--	247	371	--	--	--	--	5.70	315	210	49	0	13.24	0.8									EE 5&6
											41.6	--	261	387	--	--	--	--	5.75	328	238	20	1	13.05	0.2									EE 7&8
											41.6	--	251	394	--	--	--	--	5.70	335	213	40	0	13.42	-0.3									EE 9&10
											41.6	--	265	394	--	--	--	--	8.20	280	203	19	0	10.90	-2.6									EE 11&12
877	5/19/95 3:30	61	A	6.80	ARIL	34.0		0.75	6.0	12.0	41.6	1.08	278	383	26.2	25	34.1	3	7.75	282	205	28	-1	11.44	-1.2	8.30	268	145	28	-1	11.15	16.4	10.6 avg	Both lances @ 34 deg, N/NO = 1
											41.6	--	345	385	33.2	24	21.1	56	12.5	182	163	22	0	7.53	0.3	12.8	150	105	41	-1	7.31	11.3	AHO1/2=24.6	EE 1&2
											41.6	--	250	383	24.2	26	42.7	6	7.65	280	183	87	0	11.63	1.1	8.20	268	135	44	-1	11.08	19.5		EE 3&4
											41.6	--	247	371	26.6	30	45.0	-6	5.70	315	210	49	0	13.24	0.8	6.80	297	143	33	-1	12.28	24.1	AHO3/4=4 5	EE 5&6
											41.6	--	261	387	23.1	17	26.0	6	5.75	328	238	20	1	13.05	0.2	5.75	323	183	18	0	13.16	14.5		EE 7&8
											41.6	--	251	394	16.1	15	37.7	-3	5.70	335	213	40	0	13.42	-0.3	7.05	308	163	10	-1	11.97	11.5	AHO5/6=3 3	EE 9&10
											41.6	--	265	394	32.4	30	32.1	-16	8.20	280	203	19	0	10.90	-2.6	8.60	282	133	16	-1	10.77	17.9		EE 11&12
878	5/19/95 5:00	60	A	6.90	ARIL	34.0		1.50	6.0	12.0	41.6	2.19	278	383	40.4	43	37.8	25	7.75	282	205	28	-1	11.44	-1.2	8.20	255	118	42	-1	11.31	29.1	31.8 avg	Both lances @ 34 deg, N/NO = 2
											41.6	--	345	385	42.3	37	25.1	203	12.5	182	163	22	0	7.53	0.3	12.6	65	93	44	-2	7.17	17.4	AHO1/2=74.9	EE 1&2
											41.6	--	250	383	39.2	39	40.2	72	7.65	280	183	87	0	11.63	1.1	8.00	225	110	50	-1	11 24	29 6		EE 3&4
											41.6	--	247	371	43.2	49	45.7	-3	5 70	315	210	49	0	13.24	0.8	6.90	293	110	42	-1	12 25	38.9	AHO3/4=15.8	EE 5&6
											41.6	--	261	387	34.9	29	29.8	15	5.75	328	238	20	1	13.05	0.2	5.75	315	155	18	-1	13.03	24.9		EE 7&8
											41.6	--	251	394	24.7	33	53.5	21	5.70	335	213	40	0	13.42	-0.3	7.35	283	143	12	-1	11.76	24.9	AHO5/6=4.7	EE 9&10
											41.6	--	265	394	14.5	54	130.1	12	8.20	280	203	19	0	10.90	-2.6	9.20	250	160	15	-1	10.22	32.9		EE 11&12
879	5/19/95 6:08	60	A	6.90	ARIL	34 0		2.25	6.0	12.0	41.6	3.28	278	383	41.0	52	46.0	62	7.75	282	205	28	-1	11.44	-1.2	8.40	225	115	36	-1	10.97	35.6	44.3	Both lances @ 34 deg, N/NO = 3
											41.6	--	345	385	43.9	53	34.9	313	12.5	182	163	22	0	7.53	0.3	13.1	32	85	43	-2	6.93	23.5		EE 1&2
											41.6	--	250	383	42.3	57	53.5	143	7 65	280	183	87	0	11.63	1.1	8 80	163	98	61	-1	10.51	39 4		EE 3&4
											41.6	--	247	371	49.2	66	53.9	13	5.70	315	210	49	0	13.24	0.8	6.65	285	100	46	-1	12.28	53.0		EE 5&6
880	5/19/95 6 35	60	A	6.90	ARIL						41.6	--	278	377	--	--	--	--	8.50	282	193	20	0	10.72	0.0									Baseline
											41.6	--	335	387	--	--	--	--	13.1	170	147	12	-1	6.88	2.2									EE 1&2
											41.6	--	295	380	--	--	--	--	9.10	238	195	21	0	10.25	1.3									EE 3&4
											41.6	--	261	364	--	--	--	--	6.40	295	228	26	0	12.52	0.2									EE 5&6
											41.6	--	312	387	--	--	--	--	6.30	300	255	11	1	12.80	-2.0									EE 7&8
											41.6	--	298	369	--	--	--	--	6.20	303	243	9	1	12.91	-2.0									EE 9&10
											41.6	--	303	373	--	--	--	--	8.95	250	203	9	0	10.29	-1.3									EE 11&12
881	5/22/95 11:24	80	A	4.08	ARIL						41.6	--	220	457	--	--	--	--	5.45	395	190	75	0	13.60	0.0									Morning Baseline
882	5/22/95 13:38	80	A	4.10	ARIL	34.0		1.60	6.0	12.0	41.6	2.22	220	457	11.6	7	26.6	6	5.45	395	190	75	0	13.60	0.0	5.35	392	169	30	-1	13.50	5.9	5.3	34°, N/NO=2
883	5/22/95 15.13	80	A	4.02	ARIL	22.5		1.60	6.0	12.0	41.6	2.22	220	457	14.7	10	31.0	13	5.45	395	190	75	0	13.60	0.0	5.55	381	161	25	0	13.32	8.6	5.2	22.5°, N/NO=2
884	5/22/95 16:05	80	A	4.03	ARIL	22.5	1	1.60	6.0	12.0	41.6	2.22	220	457	7.1	5	35.1	10	5.45	395	190	75	0	13.60	0.0	5.50	385	176	30	-1	13.17	4.7	2.4	22.5°, N/NO=2, W.Outer quad OOS
885	5/22/95 16:55	80	A	4.02	ARIL						41.6	--	222	454	--	--	--	--	5.60	368	190	120	0	13.34	1.7									Afternoon Baseline Check
886	5/23/95 9:30	91	A	4.24	1						41.6	--	259	433	--	--	--	--	5.70	368	220	55	1	12.97	-1.0									Morning Baseline
887	5/23/95 11:30	91	A	4.22	1			1.00	4.0	8.0	41.6	1.04	259	433	42.2	26	23.6	10	5.70	368	220	55	1	12.97	-1.0	5.35	368	130	95	0	13.67	21.4	11.4 avg	Level 1 @ N/NO=1, 8 psi air
											41.6	--	0	0	--	--	--	--															AHO1-3=12 2	
											41.6	--	0	0	--	--	--	--															AHO4-6=10.5	
888	5/23/95 12:50	91	A	4.20	1			1.00	4.0	12.0	41.6	1.04	259	433	42.5	29	26.6	6	5.70	368	220	55	1	12.97	-1.0	5.40	368	129	90	0	13.46	24.3	14.5	Level 1 @ N/NO=1, 12 psi air
889	5/23/95 14:20	91	A	4.18	1			1.50	4.0	12.0	41.6	1.55	259	433	50.8	34	25.6	25	5.70	368	220	55	1	12.97	-1.0	5.30	356	111	90	0	13.65	26.4	23.6 avg	Level 1 @ N/NO=1.5, 12 psi air
											41.6	--	0	0	--	--	--	--															AHO1-3=21.5	
											41.6	--	0	0	--	--	--	--															AHO4-6=25.6	
890	5/23/95 15:25	91	A	4.18	1			0.50	4.0	12.0	41.6	0.52	259	433	33.1	19	22.5	5	5.70	368	220	55	1	12.97	-1.0	5.30	373	151	90	0	13.60	15.8	2.6	Level 1 @ N/NO=0.5, 12 psi air
891	5/23/95 16:12	91	A	4.18	1			0.00	4.0	12.0	41.6	0.00	259	433	9.7	-2	-8.8	6	5.70	368	220	55	1	12.97	-1.0	5.60	365	200	65	0	13.36	-2.9		Baseline w/ Air & Water On
892	5/23/95 16:34	91	A	4.19	1			0.00	0.0	12.0	41.6	0.00	259	433	12.5	-1	-3.0	8	5.70	368	220	55	1	12.97	-1.0	5.10	375	200	125	0	13.92	-1.9		Baseline w/ Air On
893	5/23/95 16:55	91	A	4.17	1						41.6	--	259	433	3.0	0	1.9	9	5.70	368	220	55	1	12.97	-1.0	5.30	370	219	105	0	13.36	-0.9		Afternoon Baseline Check
894	5/24/95 8:43	91	A	4 55	1						41.6	--	256	432	--	--	--	--	5.55	371	220	75	0	13.53	-0.4									Morning Baseline
895	5/24/95 10 50	90	A	4 66	1			1.50	4.0	12.0	41.6	1.59	256	432	49.6	37	29.1	24	5.55	371	220	75	0	13.53	-0.4	5.80	345	109	70	-1	13.38	30.9	41.9 avg	Level 1 @ N/NO=1 5, 12 psi air
											41.6	--	0	0	--	--	--	--															AHO1-3=51.2	
											41.6	--	0	0	--	--	--	--															AHO4-6=32.5	
896	5/24/95 12:30	90	A	4.65	Both	22.5		1.50	7 0	12 0	41.6	1.59	256	432	50.4	37	28.4	17	5.55	371	220	75	0	13.53	-0.4	6.00	346	106	55	-1	12 88	30.2	27.9 avg	Level 1 and West Lance Together
											41.6	--	0	0	--	--	--	--															AHO1-3=37 6	
											41.6	--	0	0	--	--	--	--															AHO4-6=18.1	

PSCC Arapahoe Unit 4 Urea Lance Injection Summary

Test	Date & Time	Load	Mills	O2cr	Urea Injection——								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	Comments
		MWe	OOS	%wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	base ppmc	base ppmc	SNCR %	econ ppmc	ΔNO %	econ ppmc	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	AHO comp ppm	
897	5/24/95 15:15	90	A	4.65	Both	22.5		1.50	5.0	12.0	41.6	1.59	256	432	34.0	25	29.1	12	5.55	371	220	75	0	13.53	-0.4	6.00	350	141	35	0	12.90	20.7	7.1 avg	East Level 1 and West Lance
											41.6	--	0	0	--	--	--	--															AHO1-3=3.0	
											41.6	--	0	0	--	--	--	--															AHO4-6=11.1	
898	5/24/95 16:50	90	A	4.68							41.6	--	256	432	-4.8	0	-2.9	11	5.55	371	220	75	0	13.53	-0.4	5.65	359	229	50	0	13.46	-0.1		Afternoon Baseline Check
899	5/25/95 8:14	90	A	4.58							41.6	--	294	369	--	--	--	--	5.40	320	255	62	1	13.59	-1.5									Morning Baseline
900	5/25/95 10:15	90	A	4.60	1			0.60	4.0	8.0	41.6	0.55	294	369	30.9	26	28.3	0	5.40	320	255	62	1	13.59	-1.5	5.95	309	170	36	0	13.02	20.1	2.3 avg	Level 1 @ N/NO=0.5, 8 psi air
											41.6	--	0	0	--	--	--	--															AHO1-3=2.5	
											41.6	--	0	0	--	--	--	--															AHO4-6=2.0	
901	5/25/95 11:30	90	A	4.62	1			1.20	4.0	8.0	41.6	1.10	294	369	47.9	39	27.9	18	5.40	320	255	62	1	13.59	-1.5	5.85	296	129	61	-1	13.00	31.6	29.4 avg	Level 1 @ N/NO=1.0, 8 psi air
											41.6	--	0	0	--	--	--	--															AHO1-3=29.1	
											41.6	--	0	0	--	--	--	--															AHO4-6=29.6	
902	5/25/95 12:38	90	A	4.60	1			1.80	4.0	8.0	41.6	1.66	294	369	52.4	46	30.0	49	5.40	320	255	62	1	13.59	-1.5	5.95	268	117	58	-1	13.09	37.2	66.5 avg	Level 1 @ N/NO=1.5, 8 psi air
											41.6	--	0	0	--	--	--	--															AHO1-3=59.5	
											41.6	--	0	0	--	--	--	--															AHO4-6=73.5	
903	5/25/95 14:42	90	A	4.62	Both	22.5		1.80	7.0	8.0	41.6	1.66	294	369	54.6	45	28.1	29	5.40	320	255	62	1	13.59	-1.5	5.90	265	112	62	-1	12.66	36.4	48.0 avg	Level 1 and West Lance, N/NO=1.5
											41.6	--	0	0	--	--	--	--															AHO1-3=59.4	
											41.6	--	0	0	--	--	--	--															AHO4-6=36.5	
904	5/25/95 15:44	90	A	4.66	Both	22.5		1.20	7.0	8.0	41.6	1.10	294	369	47.4	35	25.4	15	5.40	320	255	62	1	13.59	-1.5	5.75	300	131	70	-1	13.23	28.6	15.6 avg	Level 1 and West Lance, N/NO=1.0
											41.6	--	0	0	--	--	--	--															AHO1-3=17.2	
											41.6	--	0	0	--	--	--	--															AHO4-6=13.9	
905	5/25/95 17:10	90	A	4.67							41.6	--	294	369	-2.0	1	-23.0	3	5.40	320	255	62	1	13.59	-1.5	5.95	306	251	36	0	12.94	-0.3		Afternoon Baseline Check
906	5/26/95 10:50	100	A	4.35							41.6	--	328	364	--	--	--	--	5.65	310	280	37	0	13.15	-0.4									Morning Baseline
907	5/26/95 12:30	100	A	4.37	1			0.75	6.0	8.0	41.6	0.56	328	364	37.0	27	22.2	1	5.65	310	280	37	0	13.15	-0.4	5.60	310	177	67	-1	13.11	22.7	7.8	Level 1 @ N/NO=0.5, 8 psi air
908	5/26/95 13:25	100	A	4.37	1			1.50	6.0	8.0	41.6	1.11	328	364	49.1	37	22.8	13	5.65	310	280	37	0	13.15	-0.4	5.60	300	143	69	-1	13.20	31.0	36.5	Level 1 @ N/NO=1.0, 8 psi air
909	5/26/95 14:25	100	A	4.37	1			2.25	6.0	8.0	41.6	1.67	328	364	53.4	42	24.2	52	5.65	310	280	37	0	13.15	-0.4	5.70	265	130	100	-1	13.10	35.7	72.7	Level 1 @ N/NO=1.5, 8 psi air
910	5/30/95 8:20	80	A	5.49							41.6	--	300	371	--	--	--	--	6.70	295	238	30	1	12.13	-0.2									Morning Baseline
911	5/31/95 12:10	60	A	7.05							41.6	--	321	350	--	--	--	--	8.40	245	225	22	1	11.07	0.6									Morning Baseline
912	5/31/95 14:40	60	A	7.12	ARIL	34.0		0.85	4.0	9.5	41.6	1.12	309	364	32.9	27	27.0	4	8.60	251	213	26	0	10.70	0.6	8.50	250	144	81	0	10.96	19.7	7.3 avg	Lances Only, 34°, N/NO=1.0
											41.6	--	301	366	33.7	29	28.2	11	9.50	234	192	35	1	10.02	2.6	8.90	239	134	46	0	10.35	21.9	AHO1-3=11.5	EE 1-6 (West)
											41.6	--	298	360	32.4	31	31.9	1	7.60	268	222	20	1	11.47	-1.2	7.70	265	149	18	-1	11.28	21.6	AHO4-6=3.1	EE 7-12 (East)
913	5/31/95 15:50	60	A	7.01	ARIL	34.0		1.70	4.0	9.5	41.6	2.23	309	364	41.3	41	32.0	27	8.60	251	213	26	0	10.70	0.6	8.20	240	129	39	-1	11.04	30.0	22.1 avg	Lances Only, 34°, N/NO=2.0
											41.6	--	301	366	42.6	48	37.4	40	9.50	234	192	35	1	10.02	2.6	9.70	205	108	51	-1	9.67	32.7	AHO1-3=43.0	EE 1-6 (West)
											41.6	--	298	360	37.5	32	28.8	3	7.60	268	222	20	1	11.47	-1.2	7.00	278	145	21	-1	12.06	23.8	AHO4-6=1.1	EE 7-12 (East)
914	5/31/95 16:50	60	A	7.03	ARIL	34.0		0.42	4.0	9.5	41.6	0.55	309	364	25.9	15	19.3	-1	8.60	251	213	26	0	10.70	0.6	8.20	260	163	28	0	11.06	11.6	3.4 avg	Lances Only, 34°, N/NO=0.5
											41.6	--	301	366	22.0	20	29.7	-6	9.50	234	192	35	1	10.02	2.6	9.40	240	151	34	0	9.96	15.3	AHO1-3=4.9	EE 1-6 (West)
											41.6	--	298	360	21.0	15	24.1	3	7.60	268	222	20	1	11.47	-1.2	7.40	270	178	20	0	11.67	10.2	AHO4-6=1.8	EE 7-12 (East)
915	5/31/95 17:50	60	A	7.01							41.6	--	309	364	--	--	--	--	8.60	251	213	26	0	10.70	0.6									Afternoon Baseline Check
											41.6	--	301	366	--	--	--	--	9.50	234	192	35	1	10.02	2.6									EE 1-6 (West)
											41.6	--	298	360	--	--	--	--	7.60	268	222	20	1	11.47	-1.2									EE 7-12 (East)
916	6/1/95 7:40	80	A	5.53							41.6	--	315	355	--	--	--	--	6.90	278	247	25	1	12.06	-0.6									Morning Baseline
											41.6	--	315	359	--	--	--	--	8.50	249	219	35	1	10.72	0.7									EE 1-6 (West)
											41.6	--	321	354	--	--	--	--	5.60	303	275	19	1	13.40	-1.5									EE 7-12 (East)
917	6/1/95 11:15	80	A	5.49	ARIL	45.0		0.55	6.0	10.0	41.6	0.53	315	355	8.9	5	18.8	-1	6.90	278	247	25	1	12.06	-0.6	6.90	279	225	24	0	12.21	3.5	3.0 avg	Lances Only, 45°, N/NO=0.5
											41.6	--	315	359	13.0	10	24.3	6	8.50	249	219	35	1	10.72	0.7	8.40	247	192	26	0	10.94	7.7	AHO1-3=3.6	EE 1-6 (West)
											41.6	--	321	354	15.0	1	1.3	0	5.60	303	275	19	1	13.40	-1.5	5.05	314	242	26	1	14.04	-1.0	AHO4-6=2.4	EE 7-12 (East)
918	6/1/95 12:15	80	A	5.51	ARIL	22.5		0.55	6.0	10.0	41.6	0.53	315	365	16.0	10	18.9	4	6.90	278	247	25	1	12.06	-0.6	6.60	261	212	27	0	12.46	7.0	3.0 avg	Lances Only, 22.5°, N/NO=0.5
											41.6	--	315	359	18.9	19	32.3	6	8.50	249	219	35	1	10.72	0.7	8.40	247	179	28	0	10.92	14.2	AHO1-3=3.5	EE 1-6 (West)
											41.6	--	321	354	12.6	2	4.1	3	5.60	303	275	19	1	13.40	-1.5	5.05	311	249	26	0	13.78	-0.1	AHO4-6=2.6	EE 7-12 (East)
919	6/1/95 13:25	80	A	5.54	ARIL	22.5		1.10	6.0	10.0	41.6	1.06	315	355	21.1	17	25.2	0	6.90	278	247	25	1	12.06	-0.6	6.90	278	195	29	0	12.16	12.5	4.1 avg	Lances Only, 22.5°, N/NO=1.0
											41.6	--	315	359	35.4	34	30.7	9	8.50	249	219	35	1	10.72	0.7	8.65	242	141	33	-1	10.57	24.4	AHO1-3=4.7	EE 1-6 (West)
											41.6	--	321	354	13.0	5	11.5	3	5.60	303	275	19	1	13.40	-1.5	5.10	310	247	24	0	13.68	2.7	AHO4-6=3.4	EE 7-12 (East)
920	6/1/95 14:30	80	A	5.54	ARIL	22.5		2.20	6.0	10.0	41.6	2.13	315	355	27.6	28	32.4	0	6.90	278	247	25	1	12.06	-0.6	6.80	280	180	34	0	12.36	21.7	10.6 avg	Lances Only, 22.5°, N/NO=2.0
											41.6	--	315	359	44.7	54	38.2	4	8.50	249	219	35	1	10.72	0.7	8.50	248	121	41	-1	10.72	38.1	AHO1-3=18.4	EE 1-6 (West)
											41.6	--	321	354	14.7	8	16.1	1	5.60	303	275	19	1	13.40	-1.5	5.25	309	240	21	0	13.19	5.1	AHO4-6=2.7	EE 7-12 (East)
921	6/1/95 15:55	80	A	5.53	ARIL	22.5		2.20	10.0	9.5	41.6	2.13	315	355	31.4	33	33.0	0	6.90	278	247	25	1	12.06	-0.6	6.85	279	170	36	-1	12.26	25.1	16.1 avg	Increase Total Liquid to 10 gpm
											41.6	--	315	359	45.7	54	37.2	14	8.50	249	219	35	1	10.72	0.7	8.50	239	119	43	-1	10.79	37.9	AHO1-3=28.9	EE 1-6 (West)
											41.6	--	321	354	17.8	12	20.8	3	5.60	303	275	19	1	13.40	-1.5	5.40	304	229	21	0	13.37	8.8	AHO4-6=3.3	EE 7-12 (East)
922	6/1/95 17:10	80	A	5.58							41.6	--	315	355	-2.0	0	4.1	1	6.90	278	247	25	1	12.06	-0.6	6.95	278	251	26	0	12.13	-0.8		Afternoon Baseline Check
923	6/2/95 8:05	80	A	5.64							41.6	--	299	356	--	--	--	--	6.50	287	241	26	0	12.35	0.0									Morning Baseline
											41.6	--	319	356	--	--	--	--	8.30	251	225	30	0	11.02	0.6									EE 1-6 (West)
											41.6	--	298	354	--	--	--	--	5.20	311	262	20	0	13.46	-1.1									EE 7-12 (East)
924	6/2/95 9:55	80	A	5.64	1			0.55	2.0	8.0	41.6	0.56	299	356	31.3	23	24.4	3	6.50	287	241	26	0	12.35	0.0	6.90	277	161	47	-1	12.14	17.9	15.3 avg	Level 1, N/NO=0.5
											41.6	--	319	356	32.9	23	22.3	0	8.30	251	225	30	0	11.02	0.6	8.30	251	151	50	-1	10.75	17.1	AHO1-3=12.5	EE 1-6 (West)
											41.6	--	298	354	35.8	26	23.9	7	5.20	311	262	20	0	13.46	-1.1	5.40	301	166	38	-1	13.22	21.1	AHO4-6=18.0	EE 7-12 (East)

					Urea Injection------														Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	NO base ppmc	SO2 base ppmc	ΔNO SNCR %	ΔN2O econ ppmc	ΔN2O ΔNO %	ΔSO2 econ ppmc	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	AHO comp ppm	Comments
925	6/2/95 11:25	80	A	5.64	1			1.10	2.0	8.0	41.6	1.12	299	356	48.7	36	24.5	33	6.50	287	241	26	0	12.35	0.0	6.80	255	121	58	-1	12.17	28.2	53.0 avg	Level 1, N/NO=1.0
											41.6	--	319	356	46.6	34	22.7	21	8.30	251	225	30	0	11.02	0.6	6.20	238	121	60	-1	10.61	24.6	AHO1-3=52.6	EE 1-6 (West)
											41.6	--	298	354	53.0	34	21.7	32	5.20	311	262	20	0	13.46	-1.1	5.35	280	122	55	-1	13.03	28.8	AHO4-6=53.3	EE 7-12 (East)
926	6/2/95 12:50	80	A	5.64	1			2.00	2.0	8.0	41.6	2.04	299	356	55.9	43	25.8	132	6.50	287	241	26	0	12.35	0.0	6.95	175	103	69	-1	12.09	33.7	152.2 avg	Level 1, N/NO=2 0
											41.6	--	319	356	53.9	38	22.2	144	8.30	251	225	30	0	11.02	0.6	8.50	147	102	72	-2	10.48	27.1	AHO1-3=135	EE 1-6 (West)
											41.6	--	298	354	60.6	43	23.6	130	5.20	311	262	20	0	13.46	-1.1	5.10	198	104	63	-1	13.37	36.5	AHO4-6=170	EE 7-12 (East)
927	6/2/95 14:45	80	A	5.65	Both	22.5		2.00	8.0	8.0	41.6	2.04	299	356	49.2	44	29.7	5	6.50	287	241	26	0	12.35	0.0	6.90	275	119	53	-1	11.92	34.3	27.7 avg	Level 1 @ 2 gpm, Lances @ 6 gpm
											41.6	--	319	356	60.7	60	30.9	9	8.30	251	225	30	0	11.02	0.6	8.50	241	87	62	-2	10.57	42.2	AHO1-3=32.2	EE 1-6 (West)
											41.6	--	298	354	42.6	32	24.9	4	5.20	311	262	20	0	13.46	-1.1	5.70	298	145	39	-1	13.18	26.0	AHO4-6=23.1	EE 7-12 (East)
928	6/2/95 16:35	80	A	5.68							41.6	--	299	356	-2.8	0	-4.6	-4	6.50	287	241	26	0	12.35	0.0	6.95	281	240	23	0	11.88	0.3		Afternoon Baseline Check
929	6/4/95 2:50	48	A	8.25							36.7	--	323	357	--	--	--	--	9.90	220	199	21	0	9.46	2.3									Baseline
											36.7	--	286	360	--	--	--	--	10.6	206	165	36	-1	9.09	5.4									EE 1-6 (West)
											36.7	--	355	355	--	--	--	--	9.10	235	235	11	1	10.34	-1.0									EE 7-12 (East)
930	6/6/95 10:30	80	A	5.83							36.7	--	313	368	--	--	--	--	6.60	293	250	23	0	11.95	1.0									Morning Baseline
											36.7	--	347	372	--	--	--	--	8.50	258	241	22	0	10.55	1.1									EE 1-6 (West)
											36.7	--	291	368	--	--	--	--	4.75	332	263	25	-1	13.53	1.0									EE 7-12 (East)
931	6/6/95 14:55	77	A	5.82	Both	22.5		0.60	8.0	8.0	36.7	0.50	333	383	26.9	18	19.7	9	6.90	300	261	20	-1	11.79	-0.3	6.95	292	190	35	-2	11.98	13.5	8.0 avg	Level 1 @ 2 gpm, Lances @ 6 gpm
											36.7	--	361	390	39.8	29	20.4	16	8.60	269	249	17	0	10.66	-0.6	8.35	263	153	44	-2	10.64	20.0	AHO1-3=11.7	EE 1-6 (West)
											36.7	--	308	374	19.9	10	16.4	2	5.20	328	270	26	-1	13.12	-1.5	5.00	330	219	37	-1	13.47	7.4	AHO4-6=4.3	EE 7-12 (East)
932	6/6/95 15:50	77	A	5.80	Both	22.5		1.20	8.0	8.0	36.7	1.01	333	383	43.9	29	19.9	10	6.90	300	261	20	-1	11.79	-0.3	6.95	291	146	43	-2	11.74	22.4	29.7 avg	Level 1 @ 2 gpm, Lances @ 6 gpm
											36.7	--	361	390	50.6	42	23.2	30	8.60	269	249	17	0	10.66	-0.6	8.60	250	124	42	-2	10.36	28.8	AHO1-3=39.4	EE 1-6 (West)
											36.7	--	308	374	32.5	21	21.4	0	5.20	328	270	26	-1	13.12	-1.5	5.30	328	181	36	-1	13.36	17.2	AHO4-6=20.0	EE 7-12 (East)
933	6/6/95 16:50	77	A	5.82	Both	22.5		2.20	8.0	8.0	36.7	1.84	333	383	53.3	41	23.3	45	6.90	300	261	20	-1	11.79	-0.3	6.90	265	122	50	-2	11.83	32.1	52.5 avg	Level 1 @ 2 gpm, Lances @ 6 gpm
											36.7	--	361	390	61.7	54	24.4	105	8.60	269	249	17	0	10.66	-0.6	8.40	200	97	54	-2	10.56	37.4	AHO1-3=84.7	EE 1-6 (West)
											36.7	--	308	374	44.1	31	22.8	-5	5.20	328	270	26	-1	13.12	-1.5	5.30	330	150	44	-2	13.11	25.5	AHO4-6=20.3	EE 7-12 (East)
934	6/6/95 17:50	77	A	5.81							36.7	--	333	383	--	--	--	--	6.90	300	261	20	-1	11.79	-0.3									Baseline Check
											36.7	--	361	390	--	--	--	--	8.60	269	249	17	0	10.66	-0.6									EE 1-6 (West)
											36.7	--	308	374	--	--	--	--	5.20	328	270	26	-1	13.12	-1.5									EE 7-12 (East)
935	6/7/95 7:50	70	A	6.51							36.7	--	304	396	--	--	--	--	7.40	299	230	39	1	11.68	-0.7									Morning Baseline
											36.7	--	326	402	--	--	--	--	8.90	270	219	23	1	10.38	0.0									EE 1-6 (West)
											36.7	--	302	395	--	--	--	--	6.05	328	251	29	1	12.83	-0.4									EE 7-12 (East)
936	6/7/95 11:10	72	A	6.42	ARIL	22.5		1.00	6.0	9.5	36.7	0.91	327	400	34.4	24	21.2	12	7.50	300	245	38	0	11.76	0.6	7.30	295	163	53	-1	11.72	18.8	17.1 avg	Lances@22.5°, N/NO=1.0
											36.7	--	351	403	50.8	39	21.8	18	8.75	274	239	20	1	10.36	0.3	8.60	265	119	49	-1	10.57	27.1	AHO1-3=30.9	EE 1-6 (West)
											36.7	--	296	394	16.7	6	12.4	6	5.75	334	251	42	0	12.98	2.0	5.75	329	209	64	0	12.99	7.2	AHO4-6=3.3	EE 7-12 (East)
937	6/7/95 12:45	72	A	6.39	ARIL	34.0		1.00	6.0	8.0	36.7	0.91	327	400	30.5	21	21.3	10	7.50	300	245	38	0	11.76	0.6	7.20	299	174	42	-1	11.78	16.9	10.3 avg	Lances@34°, N/NO=1.0
										9.6	36.7	--	351	403	46.1	40	24.9	14	8.75	274	239	20	1	10.36	0.3	8.55	269	131	44	-1	10.58	28.2	AHO1-3=19.1	EE 1-6 (West)
											36.7	--	296	394	11.6	5	13.7	3	5.75	334	251	42	0	12.98	2.0	5.85	329	220	36	0	12.95	6.0	AHO4-6=1.5	EE 7-12 (East)
938	6/7/95 13:45	72	A	6.38	ARIL	45.0		1.00	6.0	9.5	36.7	0.91	327	400	22.9	20	26.3	9	7.50	300	245	38	0	11.76	0.6	7.50	293	189	31	0	11.50	15.3	7.4 avg	Lances@45°, N/NO=1.0
											36.7	--	351	403	39.4	38	27.6	11	8.75	274	239	20	1	10.36	0.3	8.90	263	143	30	-1	10.34	26.0	AHO1-3=13.3	EE 1-6 (West)
											36.7	--	296	394	4.9	4	28.2	5	5.75	334	251	42	0	12.98	2.0	6.30	318	230	28	0	12.23	5.3	AHO4-6=1.4	EE 7-12 (East)
939	6/7/95 14:50	72	A	6.39	ARIL	45/22		1.00	6.0	9.5	36.7	0.91	327	400	28.4	22	23.2	6	7.50	300	245	38	0	11.76	0.6	7.30	300	178	40	0	11.77	17.0	8.9 avg	West@45°, East@22.5°, N/NO=1
											36.7	--	351	403	41.4	39	27.0	7	8.75	274	239	20	1	10.36	0.3	8.65	267	139	33	-1	10.50	26.6	AHO1-3=13.3	EE 1-6 (West)
											36.7	--	296	394	10.3	6	20.4	4	5.75	334	251	42	0	12.98	2.0	6.10	323	220	39	0	12.61	7.1	AHO4-6=4.4	EE 7-12 (East)
940	6/7/95 15:45	72	A	6.38	ARIL	45/22		2.00	6.0	9.5	36.7	1.83	327	400	35.1	34	29.8	19	7.50	300	245	38	0	11.76	0.6	7.50	286	159	40	-1	11.45	26.2	23.8 avg	West@45°, East@22.5°, N/NO=2
											36.7	--	351	403	55.2	60	30.8	38	8.75	274	239	20	1	10.36	0.3	9.00	243	105	41	-1	10.13	40.1	AHO1-3=45.4	EE 1-6 (West)
											36.7	--	296	394	12.3	12	33.2	2	5.75	334	251	42	0	12.98	2.0	6.10	325	215	35	0	12.66	12.0	AHO4-6=2.1	EE 7-12 (East)
941	6/7/95 16:50	72	A	6.39							36.7	--	327	400	--	--	--	--	7.50	300	245	38	0	11.76	0.6									Baseline Check
											36.7	--	351	403	--	--	--	--	8.75	274	239	20	1	10.36	0.3									EE 1-6 (West)
											36.7	--	296	394	--	--	--	--	5.75	334	251	42	0	12.98	2.0									EE 7-12 (East)
942	6/8/95 8:10	70	A	6.48							36.7	--	311	398	--	--	--	--	7.15	308	239	27	0	12.08	-0.5									Baseline
											36.7	--	342	403	--	--	--	--	8.95	270	229	17	1	10.32	-0.4									EE 1-6 (West)
											36.7	--	283	398	--	--	--	--	5.50	341	244	30	0	13.14	0.7									EE 7-12 (East)
943	6/8/95 12:45	70	A	6.49	ARIL	45/22		1.00	6.0	9.5	36.7	0.97	315	394	28.0	21	25.5	1	7.30	300	240	24	0	11.60	-0.1	7.50	295	175	26	-1	11.54	15.6	3.2 avg	West@45°, East@22.5°, N/NO=1
											36.7	--	348	398	42.7	39	26.1	-1	8.95	265	233	17	0	10.38	0.4	8.90	267	134	27	-1	10.34	26.5	AHO1-3=4.0	EE 1-6 (West)
											36.7	--	310	393	12.0	8	22.4	2	6.20	323	255	22	0	12.45	0.4	6.55	314	219	23	0	12.27	7.1	AHO4-6=2.3	EE 7-12 (East)
944	6/8/95 14:30	70	A	6.48	ARIL	45/22		2.00	6.0	9.5	36.7	1.95	315	394	34.0	35	32.2	7	7.30	300	240	24	0	11.60	-0.1	7.60	268	155	31	0	11.45	25.6	14.3 avg	West@45°, East@22.5°, N/NO=2
											36.7	--	348	398	55.9	58	29.7	20	8.95	265	233	17	0	10.38	0.4	8.70	257	105	42	-2	10.44	39.9	AHO1-3=26.4	EE 1-6 (West)
											36.7	--	310	393	17.2	13	24.8	2	6.20	323	255	22	0	12.45	0.4	6.35	318	209	24	-1	12.47	11.2	AHO4-6=2.1	EE 7-12 (East)
945	6/8/95 15:30	70	A	6.49	ARIL	45/22		2.00	6.0	9.5	36.7	1.95	315	394	28.8	33	36.5	0	7.30	300	240	24	0	11.60	-0.1	7.65	292	167	24	-1	11.31	24.3	3.8 avg	Cut West Outside Quad Flow 50%
											36.7	--	348	398	44.4	48	31.4	0	8.95	265	233	17	0	10.38	0.4	8.90	266	130	27	-1	10.46	33.0	AHO1-3=5.8	EE 1-6 (West)
											36.7	--	310	393	19.9	17	28.0	1	6.20	323	255	22	0	12.45	0.4	6.30	320	203	25	-1	12.49	14.5	AHO4-6=1.7	EE 7-12 (East)
946	6/8/95 16:30	70	A	6.49	ARIL	45/22	1	2.00	6.0	9.5	36.7	1.95	315	394	20.3	24	37.3	-3	7.30	300	240	24	0	11.60	-0.1	7.40	300	190	22	-1	11.69	17.9	1.5 avg	West Outside Quad OOS
											36.7	--	348	398	30.3	36	33.7	-1	8.95	265	233	17	0	10.38	0.4	8.75	270	165	19	-1	10.38	24.6	AHO1-3=1.6	EE 1-6 (West)
											36.7	--	310	393	19.3	18	30.7	4	6.20	323	255	22	0	12.45	0.4	6.25	319	205	26	-1	12.65	15.5	AHO4-6=1.4	EE 7-12 (East)

					Urea injection-------								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	base ppmc	base ppmc	SNCR %	econ ppmc	ΔNO %	econ ppmc	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	AHO comp ppm	Comments
947	6/8/95 17:50	70	A	6.50							36.7	--	315	394	--	--	--	--	7.30	300	240	24	0	11.60	-0.1									Baseline Check
											36.7	--	348	396	--	--	--	--	8.95	265	233	17	0	10.38	0.4									EE 1-6 (West)
											36.7	--	310	393	--	--	--	--	6.20	323	255	22	0	12.45	0.4									EE 7-12 (East)
948	6/9/95 7:50	70	A	6.50							36.7	--	320	396	--	--	--	--	7.40	299	242	18	1	11.67	-0.6									Baseline
											36.7	--	332	399	--	--	--	--	8.65	274	228	17	0	10.58	-0.7									EE 1-6 (West)
											36.7	--	296	394	--	--	--	--	5.85	332	249	27	0	13.09	-0.2									EE 7-12 (East)
949	6/9/95 12:40	70	A	6.43	ARIL	45/22		0.50	6.0	9.5	36.7	0.48	320	396	14.5	10	20.6	4	7.40	299	242	18	1	11.67	-0.6	7.20	300	210	28	-1	11.72	6.7	2.3 avg	W Out Quad Flow @ 50%, N/NO=.5
											36.7	--	332	399	22.7	17	22.7	5	8.65	274	228	17	0	10.58	-0.7	8.60	272	177	30	-1	10.58	11.1	AHO1-3=2.8	EE 1-6 (West)
											36.7	--	296	394	5.2	4	25.4	4	5.85	332	249	27	0	13.09	-0.2	5.85	329	236	25	-1	12.80	3.1	AHO4-6=1.8	EE 7-12 (East)
950	6/9/95 13:45	70	A	6.36	ARIL	45/22		1.00	6.0	9.5	36.7	0.96	320	396	18.6	14	23.5	2	7.40	299	242	18	1	11.67	-0.6	7.20	302	200	26	-1	11.90	10.1	2.0 avg	W Out Quad Flow @ 50%, N/NO=1
											36.7	--	332	399	27.5	26	28.1	3	8.65	274	228	17	0	10.58	-0.7	8.75	270	164	22	-1	10.43	16.8	AHO1-3=1.6	EE 1-6 (West)
											36.7	--	296	394	6.9	6	21.8	4	5.85	332	249	27	0	13.08	-0.2	5.70	332	229	26	0	13.13	4.7	AHO4-6=2.4	EE 7-12 (East)
951	6/9/95 14:45	70	A	6.39	ARIL	45/22		2.00	6.0	9.5	36.7	1.92	320	396	25.9	26	31.2	2	7.40	299	242	18	1	11.67	-0.6	7.20	302	162	24	-1	11.68	19.2	2.4 avg	W Out Quad Flow @ 50%, N/NO=2
											36.7	--	332	399	39.1	43	32.7	8	8.65	274	228	17	0	10.58	-0.7	8.55	271	140	27	-1	10.68	28.7	AHO1-3=2.1	EE 1-6 (West)
											36.7	--	296	394	8.8	13	48.3	1	5.85	332	249	27	0	13.09	-0.2	6.05	327	224	23	0	12.60	10.3	AHO4-6=2.7	EE 7-12 (East)
952	6/9/95 15:45	70	A	6.43	ARIL	45/22		3.00	6.0	9.5	36.7	2.88	320	396	31.0	35	35.7	5	7.40	299	242	18	1	11.67	-0.6	7.15	301	170	28	-1	11.67	26.7	3.7 avg	W Out Quad Flow @ 50%, N/NO=3
											36.7	--	332	399	45.2	56	37.2	8	8.65	274	228	17	0	10.58	-0.7	8.55	271	126	28	-2	10.48	37.9	AHO1-3=5.1	EE 1-6 (West)
											36.7	--	296	394	11.4	14	40.9	5	5.85	332	249	27	0	13.09	-0.2	5.75	330	222	25	-1	13.11	11.5	AHO4-6=2.3	EE 7-12 (East)
953	6/9/95 16:50	70	A	6.40							36.7	--	312	396	--	--	--	--	7.00	306	243	21	-1	11.82	0.5									Baseline Check
954	6/12/95 23:40	43	A,D	8.90							36.7	--	348	442	--	--	--	--	10.4	260	205	30	-1	9.60	2.3									Baseline
											36.7	--	377	439	--	--	--	--	11.2	239	205	20	0	8.99	0.4									EE 1-6 (West)
											36.7	--	316	441	--	--	--	--	9.60	279	200	37	0	9.86	4.0									EE 7-12 (East)
955	6/13/95 1:25	43	A,D	8.76	ARIL	22.5		0.70	6.0	9.5	36.7	1.01	348	442	39.6	34	24.5	21	10.4	260	205	30	-1	9.60	2.3	10.3	250	125	49	-2	9.31	22.4	40.1 avg	Lances @ 22°, 6 gpm, N/NO=1.0
											36.7	--	377	439	40.2	36	23.9	39	11.2	239	205	20	0	8.99	0.4	11.0	222	125	46	-2	9.24	20.5	AHO1-3=50.9	EE 1-6 (West)
											36.7	--	316	441	34.3	38	34.8	21	9.60	279	200	37	0	9.86	4.0	9.90	259	128	55	-2	9.66	27.1	AHO4-6=29.2	EE 7-12 (East)
956	6/13/95 2:40	43	A,D	8.76	ARIL	22.5		0.70	4.0	9.5	36.7	1.01	348	442	39.0	35	25.9	34	10.4	260	205	30	-1	9.60	2.3	10.4	240	125	49	-2	9.32	23.0	45.7 avg	Lances @ 22°, 4 gpm, N/NO=1.0
											36.7	--	377	439	39.3	35	24.0	45	11.2	239	205	20	0	8.99	0.4	11.0	219	127	43	-1	9.14	20.1	AHO1-3=58.0	EE 1-6 (West)
											36.7	--	316	441	35.8	38	33.6	21	9.60	279	200	37	0	9.86	4.0	9.90	259	125	58	-1	9.86	27.3	AHO4-6=33.3	EE 7-12 (East)
957	6/13/95 3:45	43	A,D	8.77	ARIL	34.0		0.70	4.0	9.5	36.7	1.01	348	442	40.5	40	28.4	25	10.4	260	206	30	-1	9.60	2.3	10.4	245	122	50	-2	9.30	25.9	35.2 avg	Lances @ 34°, 4 gpm, N/NO=1.0
											36.7	--	377	439	44.7	49	29.3	35	11.2	239	205	20	0	8.99	0.4	10.8	229	118	39	-2	9.11	28.4	AHO1-3=44.3	EE 1-6 (West)
											36.7	--	316	441	36.4	37	32.4	25	9.60	279	200	37	0	9.86	4.0	9.70	261	126	64	-1	9.92	27.4	AHO4-6=26.1	EE 7-12 (East)
958	6/13/95 5:00	43	A,D	8.76	ARIL	45.0		0.70	4.0	9.5	36.7	1.01	348	442	39.0	42	30.9	19	10.4	260	205	30	-1	9.60	2.3	10.4	249	125	50	-1	9.56	27.0	26.1 avg	Lances @ 45°, 4 gpm, N/NO=1.0
											36.7	--	377	439	43.1	46	26.6	23	11.2	239	205	20	0	8.99	0.4	11.0	231	119	34	-1	8.89	26.2	AHO1-3=32.3	EE 1-6 (West)
											36.7	--	316	441	34.3	38	34.9	15	9.60	279	200	37	0	9.86	4.0	9.80	265	129	56	-1	9.79	27.5	AHO4-6=19.6	EE 7-12 (East)
959	6/13/95 6:00	43	A,D	8.76	ARIL	90.0		0.70	4.0	9.5	36.7	1.01	348	442	36.1	33	26.4	2	10.4	260	205	30	-1	9.60	2.3	10.4	259	131	30	-1	9.36	21.8	6.4 avg	Lances @ 90°, 4 gpm, N/NO=1.0
											36.7	--	377	439	43.7	42	25.8	6	11.2	239	205	20	0	8.99	0.4	10.9	242	119	30	-2	8.95	24.2	AHO1-3=15.2	EE 1-6 (West)
											36.7	--	316	441	31.6	24	24.1	1	9.60	279	200	37	0	9.86	4.0	9.50	261	136	31	-2	10.13	19.4	AHO4-6=1.6	EE 7-12 (East)
960	6/13/95 6:50	43	A,D	8.77							36.7	--	325	442	--	--	--	--	10.2	265	195	33	-1	9.75	5.2									Baseline Check
961	6/13/95 23:00	43	A,B	8.75							36.7	--	347	440	--	--	--	--	10.0	269	212	22	-1	9.57	2.8									Baseline
											36.7	--	311	436	--	--	--	--	11.1	240	171	26	-1	8.63	5.0									EE 1-6 (West)
											36.7	--	377	435	--	--	--	--	9.00	290	251	19	0	10.58	0.4									EE 7-12 (East)
962	6/14/95 1:55	43	A,B	8.78	ARIL	90.0		0.70	4.0	9.5	36.7	1.01	347	440	34.0	24	20.6	-3	10.0	269	212	22	-1	9.57	2.8	10.0	271	140	30	-2	9.82	17.6	7.7 avg	Lances @ 90°, 4 gpm, N/NO=1.0
											36.7	--	311	436	39.3	34	27.5	4	11.1	240	171	26	-1	8.63	5.0	10.8	245	107	36	-2	8.74	24.2	AHO1-3=14.2	EE 1-6 (West)
											36.7	--	377	435	32.4	15	12.4	-2	9.00	290	251	19	0	10.58	0.4	9.05	290	169	20	-1	10.66	10.4	AHO4-6=1.1	EE 7-12 (East)
963	6/14/95 3:00	43	A,B	8.85	ARIL	135.0		0.70	4.0	9.5	36.7	1.01	347	440	32.1	22	19.7	-10	10.0	269	212	22	-1	9.57	2.8	10.0	275	144	27	-2	9.72	16.2	3.0 avg	Lances @ 135°, 4 gpm, N/NO=1.0
											36.7	--	311	436	41.5	36	27.9	-5	11.1	240	171	26	-1	8.63	5.0	10.8	250	103	32	-2	8.82	25.6	AHO1-3=4.5	EE 1-6 (West)
											36.7	--	377	435	25.7	6	6.4	2	9.00	290	251	19	0	10.58	0.4	8.90	291	186	19	-1	10.55	4.6	AHO4-6=1.4	EE 7-12 (East)
964	6/14/95 4:05	43	A,B	8.78	ARIL	90.0		0.35	4.0	9.5	36.7	0.50	347	440	28.7	13	13.0	-6	10.0	269	212	22	-1	9.57	2.8	9.70	280	153	26	-1	9.96	11.3	2.8 avg	Lances @ 90°, 4 gpm, N/NO=0.5
											36.7	--	311	436	26.6	23	27.6	-13	11.1	240	171	26	-1	8.63	5.0	10.9	252	128	32	-2	8.78	17.9	AHO1-3=4.2	EE 1-6 (West)
											36.7	--	377	435	29.2	9	8.1	-9	9.00	290	251	19	0	10.58	0.4	8.50	306	185	19	-1	10.83	6.6	AHO4-6=1.3	EE 7-12 (East)
965	6/14/95 5:10	43	A,B	8.81	ARIL	90.0		1.40	4.0	9.5	36.7	2.02	347	440	47.7	38	23.0	15	10.0	269	212	22	-1	9.57	2.8	9.70	267	114	35	-2	9.73	26.7	24.1 avg	Lances @ 90°, 4 gpm, N/NO=2.0
											36.7	--	311	436	48.0	55	37.0	38	11.1	240	171	26	-1	8.63	5.0	11.1	219	89	49	-2	8.71	35.3	AHO1-3=46.2	EE 1-6 (West)
											36.7	--	377	435	46.5	24	13.9	-6	9.00	290	251	19	0	10.58	0.4	8.50	306	140	21	-1	10.61	17.3	AHO4-6=2.0	EE 7-12 (East)
966	6/14/95 6:10	43	A,B	8.78							36.7	--	315	466	--	--	--	--	9.65	290	195	26	-1	9.76	4.7									Baseline Check
											36.7	--	299	463	--	--	--	--	10.9	260	168	33	-1	8.78	7.2									EE 1-6 (West)
											36.7	--	352	437	--	--	--	--	8.20	311	250	26	0	10.92	2.5									EE 7-12 (East)
967	6/14/95 22:50	43	A,D	8.75							36.7	--	344	398	--	--	--	--	10.6	230	199	26	0	9.37	2.9									Baseline
											36.7	--	344	406	--	--	--	--	10.6	230	195	22	-1	9.06	1.5									EE 1-6 (West)
											36.7	--	331	411	--	--	--	--	10.5	240	193	32	-1	9.54	4.7									EE 7-12 (East)
BACK AFTER 10-WEEK TURBINE OUTAGE, LANCES STRAIGHTENED AND COATED, AND COOLING SLOTS ADDED																																		
968	10/25/95 23 12	60	B	6.72							36.7	--	331	390	--	--	--	--	9.10	258	219	17	1	11.19	-1.6									Baseline
											36.7	--	332	400	--	--	--	--	9.25	261	217	14	0	10.96	-1.7									EE 1-6 (West)
											36.7	--	321	390	--	--	--	--	8.90	262	216	19	0	11.20	-0.9									EE 7-12 (East)

					Urea injection--------								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load	Mills	O2cr	Level	ARIL	Quads	Urea	Total	Inj air	Conc	N/NO	base	base	SNCR	econ	ΔNO	econ	O2	SO2	NO	CO	NO2	CO2	N2O	O2	SO2	NO	CO	NO2	CO2	N2O	AHO comp	Comments
		MWe	OOS	%wet		Angle	OOS	gpm	gpm	psi	wt%		ppmc	ppmc	%	ppmc	%	ppmc	%dry	ppm	ppm	ppm	ppm	%	ppm	%dry	ppm	ppm	ppm	ppm	%	ppm	ppm	
969	10/26/95 1:55	60	B	6.96	ARIL	34.0		1.10	4.0	10.0	36.7	1.17	338	393	33.3	33	28.9	0	9.50	251	216	14	0	10.58	-0.1	9.10	260	149	17	-1	11.18	21.4	3.6	Lances @ 34°, 4 gpm, N/NO=1.2
											36.7	--	339	395	38.9	40	30.5	-2	9.60	250	215	13	0	10.60	-0.5	9.20	260	136	16	-1	10.93	25.9		EE 1-6 (West)
											36.7	--	326	388	28.1	31	33.6	-5	9.40	250	210	15	0	10.53	0.0	9.10	260	155	17	-1	10.98	20.3		EE 7-12 (East)
970	10/26/95 3:10	60	B	6.96	ARIL	34.0		1.65	4.0	10.0	36.7	1.75	338	393	36.6	40	32.1	2	9.50	251	216	14	0	10.58	-0.1	9.25	255	140	16	-1	11.12	25.6	3.4	Lances @ 34°, 4 gpm, N/NO=1.8
											36.7	--	339	395	41.2	50	35.4	5	9.60	250	215	13	0	10.60	-0.5	9.00	260	133	16	-1	10.98	32.5		EE 1-6 (West)
											36.7	--	326	388	33.4	46	42.3	-5	9.40	250	210	15	0	10.53	0.0	9.55	250	138	16	-1	10.75	29.3		EE 7-12 (East)
971	10/26/95 4:30	60	B	6.96	ARIL	34.0		2.20	4.0	10.0	36.7	2.33	200	390	41.6	54	38.5	-1	9.50	251	216	14	0	10.58	-0.1	9.15	259	130	19	-1	11.02	35.5	3.1	Lances @ 34°, 4 gpm, N/NO=2.3
											36.7	--	339	395	43.4	60	40.9	3	9.60	250	215	13	0	10.60	-0.5	9.20	257	126	16	-2	10.80	39.0		EE 1-6 (West)
											36.7	--	326	388	35.6	48	41.6	-2	9.40	250	210	15	0	10.53	0.0	9.00	260	140	20	-1	10.96	32.1		EE 7-12 (East)
972	10/26/95 5:46	60	B	6.97							36.7	--	338	393	--	--	--	--	9.50	251	216	14	0	10.58	-0.1									Baseline Check
											36.7	--	339	395	--	--	--	--	9.60	250	215	13	0	10.60	-0.5									EE 1-6 (West)
											36.7	--	326	388	--	--	--	--	9.40	250	210	15	0	10.53	0.0									EE 7-12 (East)
973	10/26/95 23:10	60	B	7.20							36.7	--	349	411	--	--	--	--	9.40	265	225	10	0	10.90	-1.5									Baseline
											36.7	--	352	408	--	--	--	--	9.45	262	226	10	1	10.65	-1.4									EE 1-6 (West)
											36.7	--	363	411	--	--	--	--	9.60	260	230	10	0	10.61	-1.3									EE 7-12 (East)
974	10/27/95 1:25	60	B	7.21	ARIL	22.0		1.00	4.0	10.2	36.7	1.03	349	411	40.5	51	36.2	5	9.40	265	225	10	0	10.90	-1.5	9.30	264	135	1	-1	10.83	31.8	2.9 avg	Lances @ 22°, 4 gpm, N/NO=1.0
											36.7	--	352	408	41.2	56	38.8	-6	9.45	262	226	10	1	10.65	-1.4	9.70	260	130	14	-1	10.72	34.0	AHO1-3=3.0	EE 1-6 (West)
											36.7	--	363	411	40.9	45	30.0	5	9.60	260	230	10	0	10.61	-1.3	9.25	265	140	17	-1	11.16	27.6	AHO4-6=2.7	EE 7-12 (East)
975	10/27/95 2:45	60	B	7.21	ARIL	22.0		1.50	4.0	10.2	36.7	1.54	349	411	49.6	68	39.5	4	9.40	265	225	10	0	10.90	-1.5	9.55	259	112	21	-1	10.91	42.0	4.0 avg	Lances @ 22°, 4 gpm, N/NO=1.5
											36.7	--	352	408	52.9	75	40.3	-3	9.45	262	226	10	1	10.65	-1.4	9.40	265	107	21	-1	10.69	46.9	AHO1-3=3.3	EE 1-6 (West)
											36.7	--	363	411	49.1	62	35.0	18	9.60	260	230	10	0	10.61	-1.3	9.50	251	118	20	-1	10.86	38.6	AHO4-6=4.6	EE 7-12 (East)
976	10/27/95 4:05	60	B	7.22	ARIL	22.0		2.50	4.0	10.0	36.7	2.57	349	411	58.6	93	45.3	28	9.40	265	225	10	0	10.90	-1.5	9.55	244	92	26	-2	10.64	57.4	24.1 avg	Lances @ 22°, 4 gpm, N/NO=2.5
											36.7	--	352	408	57.3	99	49.0	14	9.45	262	226	10	1	10.65	-1.4	9.50	252	96	23	-1	10.97	61.6	AHO1-3=9.5	EE 1-6 (West)
											36.7	--	363	411	61.6	84	37.5	62	9.60	260	230	10	0	10.61	-1.3	9.65	207	88	32	-1	10.42	51.6	AHO4-6=38.7	EE 7-12 (East)
977	10/27/95 23:30	60	A	7.22							36.7	--	338	417	--	--	--	--	9.40	269	218	14	1	10.94	-2.0									Baseline
											36.7	--	341	422	--	--	--	--	10.5	246	199	15	1	10.00	-1.1									EE 1-6 (West)
											36.7	--	326	412	--	--	--	--	8.25	292	232	11	1	11.87	-2.8									EE 7-12 (East)
978	10/28/95 1:15	60	A	7.25	ARIL	34.0		1.00	4.0	10.5	36.7	1.06	336	417	26.6	29	30.3	9	9.40	269	218	14	1	10.94	-2.0	9.45	262	155	16	0	10.65	16.6	3.6 avg	Lances @ 34°, 4 gpm, N/NO=1.0
											36.7	--	341	422	38.4	64	41.0	16	10.5	246	199	15	1	10.00	-1.1	10.6	230	119	27	-1	9.78	29.4	AHO1-3=5.3	EE 1-6 (West)
											36.7	--	326	412	17.8	10	16.5	6	8.25	292	232	11	1	11.87	-2.8	7.90	298	196	11	0	12.20	4.1	AHO4-6=2.2	EE 7-12 (East)
979	10/28/95 2:35	60	A	7.26	ARIL	34.0		2.00	4.0	10.5	36.7	2.12	336	417	35.8	46	36.1	34	9.40	269	218	14	1	10.94	-2.0	9.40	247	140	27	-1	11.02	27.7	24.9 avg	Lances @ 34°, 4 gpm, N/NO=2.0
											36.7	--	341	422	55.8	84	44.3	87	10.5	246	199	15	1	10.00	-1.1	10.5	195	88	36	-1	10.09	48.1	AHO1-3=47.2	EE 1-6 (West)
											36.7	--	326	412	21.4	19	27.2	7	8.25	292	232	11	1	11.87	-2.8	8.00	293	186	14	0	11.98	10.9	AHO4-6=2.5	EE 7-12 (East)
980	10/28/95 3:45	60	A	7.26	ARIL	34.0		1.50	4.0	10.5	36.7	1.59	336	417	36.9	41	32.6	21	9.40	269	218	14	1	10.94	-2.0	9.20	260	140	22	0	11.15	24.6	19.0 avg	Lances @ 34°, 4 gpm, N/NO=1.5
											36.7	--	341	422	50.8	72	41.5	39	10.5	246	199	15	1	10.00	-1.1	10.6	221	97	34	-1	10.04	40.5	AHO1-3=35.6	EE 1-6 (West)
											36.7	--	326	412	22.8	14	19.1	3	8.25	292	232	11	1	11.87	-2.8	7.90	298	184	13	0	12.21	7.5	AHO4-6=2.4	EE 7-12 (East)
BACK AFTER POWDER RIVER BASIN TEST BURN																																		
1017	11/13/95 8:15	80		4.33							36.7	--	241	354	--	--	--	--	6.15	292	199	26	-1	13.20	-2.3									Baseline on Normal Coal
											36.7	--	249	358	--	--	--	--	6.60	286	199	21	-1	12.87	-1.6									EE 1-6 (West)
											36.7	--	236	348	--	--	--	--	5.90	292	200	22	-1	13.36	0.9									EE 7-12 (East)
1018	11/13/95 10:10	80		4.33	1			0.45	2.0	8.0	36.7	0.50	241	354	29.9	22	30.0	0	6.15	292	199	26	-1	13.20	-2.3	6.10	293	140	31	-1	13.46	15.6	2.4 avg	80MW, Level 1, N/NO=0.5
											36.7	--	249	358	32.1	22	27.5	2	6.60	286	199	21	-1	12.87	-1.6	6.40	288	137	26	-2	12.98	16.2	AHO1-3=2.0	EE 1-6 (West)
											36.7	--	236	348	29.8	20	28.0	-1	5.90	292	200	22	-1	13.36	-1.6	5.95	292	140	37	-2	13.39	15.0	AHO4-6=2.8	EE 7-12 (East)
1019	11/13/95 12:00	80		4.33	1			0.90	2.0	8.0	36.7	1.00	241	354	43.5	32	30.9	11	6.15	292	199	26	-1	13.20	-2.3	6.20	282	112	34	-2	13.28	24.4	13.1 avg	80MW, Level 1, N/NO=1.0
											36.7	--	249	358	45.4	33	29.3	13	6.60	286	199	21	-1	12.87	-1.6	6.30	281	111	28	-2	12.68	26.4	AHO1-3=10.9	EE 1-6 (West)
											36.7	--	236	348	42.6	33	32.5	14	5.90	292	200	22	-1	13.36	-1.6	6.35	272	111	40	-2	13.11	25.4	AHO4-6=15.3	EE 7-12 (East)
1020	11/13/95 13:45	80		4.41	1			1.35	2.0	8.0	36.7	1.50	241	354	51.2	40	32.5	20	6.15	292	199	26	-1	13.20	-2.3	6.00	278	98	42	-2	13.19	31.2	32.0 avg	80MW, Level 1, N/NO=1.5
											36.7	--	249	358	54.6	42	31.1	37	6.60	286	199	21	-1	12.87	-1.6	6.50	258	91	36	-2	12.79	32.4	AHO1-3=27.6	EE 1-6 (West)
											36.7	--	236	348	47.6	39	34.4	7	5.90	292	200	22	-1	13.36	-1.6	5.80	266	106	47	-2	13.43	31.5	AHO4-6=36.4	EE 7-12 (East)
1021	11/13/95 15:10	80		4.43							36.7	--	241	354	-1.4	2	-54.6	-11	6.15	292	199	26	-1	13.20	-2.3	6.35	297	199	15	-2	12.81	-0.6		Baseline Check
											36.7	--	249	358	-5.8	0	-2.5	-13	6.60	286	199	21	-1	12.87	-1.6	6.70	294	209	10	-1	12.21	-1.3		EE 1-6 (West)
											36.7	--	236	348	1.2	1	33.1	-24	5.90	292	200	22	-1	13.36	-1.6	6.10	306	195	22	-1	13.00	-0.6		EE 7-12 (East)
1022	11/14/95 8:10	100		3.70							36.7	--	265	384	--	--	--	--	5.40	333	230	110	1	13.76	0.4									Baseline, BWldr-5%, DWldr+5%
											36.7	--	267	380	--	--	--	--	6.00	317	239	19	-1	13.03	-1.9									EE 1-6 (West)
											36.7	--	241	370	--	--	--	--	4.30	343	224	325	-1	14.42	-1.3									EE 7-12 (East)
1023	11/14/95 9:55	100		3.70	1			0.60	6.0	8.0	36.7	0.50	256	380	18.4	13	27.1	-21	5.25	315	224	117	-1	13.73	-0.8	5.40	330	181	60	-1	13.84	10.3	1.8 avg	Lvl1, N/NO=0.5, Bmaster-5%
											36.7	--	263	386	25.0	20	27.6	-13	5.65	312	241	19	-1	13.41	-0.9	5.80	320	179	23	-1	13.45	15.6	AHO1-3=1.6	EE 1-6 (West)
											36.7	--	257	380	19.3	9	17.2	-15	5.10	318	227	145	-1	13.75	0.5	5.20	329	182	84	-1	13.99	8.0	AHO4-6=2.0	EE 7-12 (East)
1024	11/14/95 12:00	100		3.70	1			0.90	6.0	8.0	36.7	0.76	256	380	24.7	22	34.9	-10	5.25	315	224	117	-1	13.73	-0.8	5.50	319	166	60	-2	13.53	18.2	1.6 avg	Lvl1, N/NO=1.0, Bmaster-5%
											36.7	--	263	386	32.8	26	28.2	-9	5.65	312	241	19	-1	13.41	-0.9	5.75	318	161	27	-2	13.21	21.2	AHO1-3=1.5	EE 1-6 (West)
											36.7	--	257	380	23.9	16	25.8	-6	5.10	318	227	145	-1	13.75	0.5	5.35	318	170	34	-2	13.63	14.3	AHO4-6=1.6	EE 7-12 (East)
1025	11/14/95 14:30	100		3.70	1			1.80	6.0	8.0	36.7	1.51	256	380	42.4	37	33.7	6	5.25	315	224	117	-1	13.73	-0.8	5.25	310	129	56	-2	13.71	31.2	18.0 avg	Lvl1, N/NO=1.5, Bmaster-5%
											36.7	--	263	386	51.6	43	29.5	6	5.65	312	241	19	-1	13.41	-0.9	5.60	308	117	44	-2	13.41	35.9	AHO1-3=18.4	EE 1-6 (West)

Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Urea Injection------- Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	NO base ppmc	SO2 base ppmc	ΔNO SNCR %	ΔN2O econ ppmc	ΔN2O ΔNO %	ΔSO2 econ ppmc	Economizer Exit, dry (1-12): Base O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	Economizer Exit, dry (1-12): w/Urea O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	NH3 Slip AHO comp ppm	Comments
											36.7	--	257	360	36.5	34	36.2	11	5.10	316	227	145	-1	13.75	0.5	5.00	310	145	92	-2	13.96	30.7	AHO4-6=17.5	EE 7-12 (East)
1026	11/14/95 15:55	100		3.70							36.7	--	256	360	--	--	--	--	5.25	315	224	117	-1	13.73	-0.8									Base, BWldr-5%, DWldr+5%, B-5%
											36.7	--	283	366	--	--	--	--	5.65	312	241	19	-1	13.41	-0.9									EE 1-6 (West)
											36.7	--	257	360	--	--	--	--	5.10	316	227	145	-1	13.75	0.5									EE 7-12 (East)
1027	11/27/95 23:45	60	B	7.29							36.7	--	324	381	--	--	--	--	9.00	254	216	8	2	10.23	-0.1									Baseline, Norm Coal, B Mill OOS
											36.7	--	310	389	--	--	--	--	8.50	270	215	9	2	10.63	-0.4									EE 1-6 (West)
											36.7	--	316	392	--	--	--	--	8.70	268	216	11	1	10.99	-0.7									EE 7-12 (East)
1028	11/28/95 2:30	60	B	7.26	ARIL	23.0		0.90	4.0	10.5	36.7	1.00	321	397	34.6	39	34.6	0	8.90	267	216	9	0	10.47	-1.6	8.80	269	142	12	-1	10.55	24.6	1.3 avg	Lances @ 23°, 4 gpm, N/NO=1.0
											36.7	--	318	390	37.2	41	34.7	-4	8.90	262	214	9	0	10.54	-1.2	8.75	268	136	12	-1	10.62	26.8	AHO1-3=1.4	EE 1-6 (West)
											36.7	--	320	389	27.8	32	36.1	-6	9.20	255	210	11	0	10.04	-1.2	9.10	261	153	13	-1	10.35	20.0	AHO4-6=1.1	EE 7-12 (East)
1029	11/28/95 3:40	60	B	7.30	ARIL	23.0		1.80	4.0	10.5	36.7	2.01	321	397	44.0	63	44.3	3	8.90	267	216	9	0	10.47	-1.6	8.90	265	121	15	-2	10.45	40.5	1.3 avg	Lances @ 23°, 4 gpm, N/NO=2.0
											36.7	--	318	390	49.7	70	44.2	-6	8.90	262	214	9	0	10.54	-1.2	8.75	269	109	15	-2	10.82	46.4	AHO1-3=1.2	EE 1-6 (West)
											36.7	--	320	389	36.7	50	42.9	-5	9.20	255	210	11	0	10.04	-1.2	9.20	258	133	16	-1	10.25	31.8	AHO4-6=1.4	EE 7-12 (East)
1030	11/28/95 5:00	60	B	7.26	ARIL	23.0		2.70	4.0	10.5	36.7	3.01	321	397	47.9	78	50.8	11	8.90	267	216	9	0	10.47	-1.6	8.85	261	113	17	-2	10.69	51.2	2.5 avg	Lances @ 23°, 4 gpm, N/NO=3 0
											36.7	--	318	390	51.7	88	52.3	-4	8.90	262	214	9	0	10.54	-1.2	8.60	271	106	18	-2	10.63	58.0	AHO1-3=2.1	EE 1-6 (West)
											36.7	--	320	389	44.0	68	48.5	4	9.20	255	210	11	0	10.04	-1.2	8.95	258	120	23	-2	10.40	44.6	AHO4-6=2.8	EE 7-12 (East)
1031	11/28/95 6:30	60	B	7.29							36.7	--	321	397	--	--	--	--	8.90	267	216	9	0	10.47	-1.6									Baseline Check
											36.7	--	318	390	--	--	--	--	8.90	262	214	9	0	10.54	-1.2									EE 1-6 (West)
											36.7	--	320	389	--	--	--	--	9.20	255	210	11	0	10.04	-1.2									EE 7-12 (East)
1032	11/28/95 23:20	60	C	7.00							36.7	--	317	396	--	--	--	--	8.50	275	220	13	0	10.97	-1.3									Baseline, Norm Coal, C Mill OOS
											36.7	--	344	401	--	--	--	--	9.50	256	220	10	0	10.06	-0.8									EE 1-6 (West)
											36.7	--	287	391	--	--	--	--	7.20	300	220	12	0	11.60	-1.3									EE 7-12 (East)
1033	11/29/95 1:30	60	C	6.98	ARIL	23.0		0.90	4.0	10.5	36.7	1.02	317	396	29.5	28	30.3	0	8.50	275	220	13	0	10.97	-1.3	8.50	275	155	14	-1	10.80	18.4	0.7 avg	Lances @ 23°, 4 gpm, N/NO=1.0
											36.7	--	344	401	43.2	52	35.2	9	9.50	256	220	10	0	10.06	-0.8	9.50	250	125	20	-2	10.06	32.6	AHO1-3=0.9	EE 1-6 (West)
											36.7	--	287	391	11.1	9	27.8	-1	7.20	300	220	12	0	11.60	-1.3	7.60	292	190	9	-1	11.47	5.3	AHO4-6=0.5	EE 7-12 (East)
1034	11/29/95 2:45	60	C	6.97	ARIL	23.0		1.80	4.0	10.5	36.7	2.04	317	396	37.1	44	37.6	13	8.50	275	220	13	0	10.97	-1.3	8.45	267	139	21	-1	10.71	29.5	13.3 avg	Lances @ 23°, 4 gpm, N/NO=2.0
											36.7	--	344	401	54.9	71	37.6	39	9.50	256	220	10	0	10.06	-0.8	9.40	233	100	30	-2	10.00	45.0	AHO1-3=26.2	EE 1-6 (West)
											36.7	--	287	391	18.7	15	28.0	-2	7.20	300	220	12	0	11.60	-1.3	7.35	298	177	11	-1	11.71	10.1	AHO4-6=0.4	EE 7-12 (East)
1035	11/29/95 4:10	60	C	6.96	ARIL	23.0		2.70	4.0	10.5	36.7	2.98	328	398	42.4	54	39.1	47	8.60	270	222	12	-1	10.84	-0.8	8.70	240	129	27	-2	11.07	36.5	37.3 avg	Lances @ 23°, 4 gpm, N/NO=3.0
											36.7	--	352	399	62.6	90	41.1	93	9.80	248	219	9	0	9.60	0.0	9.80	190	82	38	-2	9.78	56.3	AHO1-3=73.3	EE 1-6 (West)
											36.7	--	293	391	14.8	19	45.1	4	7.65	290	217	13	0	11.55	-1.2	7.50	290	167	11	-1	11.46	13.4	AHO4-6=1.2	EE 7-12 (East)
1036	11/29/95 5:35	60	C	6.99							36.7	--	328	398	--	--	--	--	8.60	270	222	12	-1	10.84	-0.8									Baseline Check
											36.7	--	352	399	--	--	--	--	9.80	248	219	9	0	9.60	0.0									EE 1-6 (West)
											36.7	--	293	391	--	--	--	--	7.65	290	217	13	0	11.55	-1.2									EE 7-12 (East)
1037	11/29/95 23:10	60	D	7.06							36.7	--	309	397	--	--	--	--	8.75	270	210	13	-1	10.62	-1.2									Baseline, Norm Coal, D Mill OOS
											36.7	--	318	395	--	--	--	--	8.25	280	225	12	0	11.31	-2.0									EE 1-6 (West)
											36.7	--	335	395	--	--	--	--	9.65	249	211	14	0	9.88	-1.1									EE 7-12 (East)
1038	11/30/95 1:10	60	D	7.06	ARIL	23.0		0.85	4.0	10.5	36.7	0.99	309	397	23.6	32	44.3	3	8.75	270	210	13	-1	10.62	-1.2	8.70	269	161	16	-2	10.76	20.9	1.2 avg	Lances @ 23°, 4 gpm, N/NO=1.0
											36.7	--	318	395	25.3	30	37.2	1	8.25	280	225	12	0	11.31	-2.0	8.25	279	168	10	-1	10.99	19.2	AHO1-3=1.2	EE 1-6 (West)
											36.7	--	335	395	26.9	33	37.1	6	9.65	249	211	14	0	9.88	-1.1	9.30	253	159	22	-1	10.02	20.6	AHO4-6=1.2	EE 7-12 (East)
1039	11/30/95 2:15	60	D	7.01	ARIL	23.0		1.70	4.0	10.5	36.7	1.98	309	397	30.7	51	53.5	0	8.75	270	210	13	-1	10.62	-1.2	8.80	269	145	19	-2	10.48	33.1	8.9 avg	Lances @ 23°, 4 gpm, N/NO=2.0
											36.7	--	318	395	37.1	50	42.8	9	8.25	280	225	12	0	11.31	-2.0	8.20	275	142	11	-1	10.78	33.9	AHO1-3=1.2	EE 1-6 (West)
											36.7	--	335	395	35.7	50	42.0	26	9.65	249	211	14	0	9.88	-1.1	9.20	242	141	30	-1	10.45	31.8	AHO4-6=16.5	EE 7-12 (East)
1040	11/30/95 3:35	60	D	7.06	ARIL	23.0		2.13	4.0	10.5	36.7	2.47	309	397	35.2	57	52.7	26	8.75	270	210	13	-1	10.62	-1.2	8.75	252	136	23	-2	10.69	37.8	16.2 avg	Lances @ 23°, 4 gpm, N/NO=2.5
											36.7	--	318	395	37.8	61	50.5	6	8.25	280	225	12	0	11.31	-2.0	8.25	278	140	11	-2	10.91	40.9	AHO1-3=1.4	EE 1-6 (West)
											36.7	--	335	395	37.8	56	44.4	44	9.65	249	211	14	0	9.88	-1.1	9.15	231	137	30	-1	10.17	35.6	AHO4-6=31.0	EE 7-12 (East)
1041	11/30/95 4:55	60	D	7.06	ARIL	23.0		0.85	6.0	10.5	36.7	0.99	309	397	25.7	35	44.6	7	8.75	270	210	13	-1	10.62	-1.2	8.75	265	156	19	-1	10.77	22.9	6.8 avg	Lances @ 23°, 6 gpm, N/NO=1.0
											36.7	--	318	395	30.3	32	33.8	6	8.25	280	225	12	0	11.31	-2.0	8.00	261	160	11	-1	11.26	21.4	AHO1-3=1.4	EE 1-6 (West)
											36.7	--	335	395	30.7	35	34.5	7	9.65	249	211	14	0	9.88	-1.1	9.20	254	152	23	-1	10.16	22.1	AHO4-6=11.1	EE 7-12 (East)
1042	11/30/95 6:00	60	D	7.02							36.7	--	322	385	--	--	--	--	8.60	261	218	13	-1	10.65	-0.9									Quick Baseline Check
1043	11/30/95 23:10	60	A	7.02							36.7	--	298	397	--	--	--	--	8.30	280	210	18	-1	11.20	-0.6									Baseline, Norm Coal, A Mill OOS
											36.7	--	312	395	--	--	--	--	9.65	249	197	16	-1	9.80	0.2									EE 1-6 (West)
											36.7	--	266	395	--	--	--	--	6.50	318	214	23	0	12.50	-1.6									EE 7-12 (East)
1044	12/1/95 1:20	60	A	7.03	ARIL	22.0		0.85	4.0	10.5	36.7	1.02	298	397	27.2	27	32.7	10	8.30	280	210	18	-1	11.20	-0.6	8.45	270	151	21	-2	10.74	17.9	9.7 avg	Lances @ 22°, 4 gpm, N/NO=1 0
											36.7	--	312	395	38.0	48	40.1	12	9.65	249	197	16	-1	9.80	0.2	9.65	237	120	32	-2	9.74	29.7	AHO1-3=17.8	EE 1-6 (West)
											36.7	--	266	395	7.5	10	50.8	5	6.50	318	214	23	0	12.50	-1.6	7.15	300	189	13	0	11.96	6.3	AHO4-6=1.5	EE 7-12 (East)
1045	12/1/95 2:40	60	A	7.04	ARIL	22.0		1.60	4.0	10.5	36.7	1.93	298	397	35.7	42	39.3	43	8.30	280	210	18	-1	11.20	-0.6	8.30	250	135	30	-1	10.82	28.9	32.6 avg	Lances @ 22°, 4 gpm, N/NO=2 0
											36.7	--	312	395	53.7	67	40.1	80	9.65	249	197	16	-1	9.80	0.2	9.60	196	90	44	-2	9.60	42.1	AHO1-3=63.4	EE 1-6 (West)
											36.7	--	266	395	9.5	16	63.5	6	6.50	318	214	23	0	12.50	-1.6	7.15	299	185	14	-1	11.82	10.6	AHO4-6=1.7	EE 7-12 (East)
1046	12/1/95 3:50	60	A	7.02	ARIL	22.0		1.27	4.0	10.5	36.7	1.53	298	397	32.8	35	36.1	28	8.30	280	210	18	-1	11.20	-0.6	8.40	258	140	28	-2	10.82	24.1	27.8 avg	Lances @ 22°, 4 gpm, N/NO=1 5
											36.7	--	312	395	48.1	54	36.2	46	9.65	249	197	16	-1	9.80	0.2	9.90	215	100	37	-2	9.58	33.7	AHO1-3=53.8	EE 1-6 (West)
											36.7	--	266	395	13.9	12	32.0	3	6.50	318	214	23	0	12.50	-1.6	6.75	310	181	14	-1	12.33	7.8	AHO4-6=1.7	EE 7-12 (East)
1047	12/1/95 5:05	60	A	7.05	ARIL	22.0		0.43	4.0	10.5	36.7	0.52	298	397	21.3	19	30.2	3	8.30	280	210	18	-1	11.20	-0.6	8.40	276	164	21	-1	10.84	12.8	2.2 avg	Lances @ 22°, 4 gpm, N/NO=0.5
											36.7	--	312	395	28.6	31	34.6	-5	9.65	249	197	16	-1	9.80	0.2	9.70	251	140	23	-1	9.70	19.6	AHO1-3=2.3	EE 1-6 (West)

					Urea Injection———								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load	Mills	O2cr	Level	ARIL	Quads	Urea	Total	Inj air	Conc	N/NO	base	base	SNCR	econ	ΔNO	econ	O2	SO2	NO	CO	NO2	CO2	N2O	O2	SO2	NO	CO	NO2	CO2	N2O	AHO comp	Comments
		MWe	OOS	%wet		Angle	OOS	gpm	gpm	psi	wt%		ppmc	ppmc	%	ppmc	%	ppmc	%dry	ppm	ppm	ppm	ppm	%	ppm	%dry	ppm	ppm	ppm	ppm	%	ppm	ppm	
											36.7	--	266	395	6.2	7	41.2	5	6.50	318	214	23	0	12.50	-1.6	7.20	299	191	14	-1	11.77	3.7	AHO4-6=2.0	EE 7-12 (East)
1048	12/1/95 6:15	60	A	7.02							36.7	--	292	397	--	--	--	--	8.30	280	206	18	-1	10.97	0.6									Baseline Check
											36.7	--	298	399	--	--	--	--	9.35	258	193	18	0	9.92	1.9									EE 1-6 (West)
											36.7	--	289	390	--	--	--	--	6.75	309	213	21	0	12.17	-0.1									EE 7-12 (East)
1049	12/1/95 23:20	60	B	7.29							36.7	--	331	393	--	--	--	--	9.10	260	219	15	-1	10.40	-1.3									Baseline, Norm Coal, B Mill OOS
											36.7	--	318	389	--	--	--	--	9.05	258	210	15	0	10.15	-0.7									EE 1-6 (West)
											36.7	--	340	387	--	--	--	--	9.15	255	224	10	0	10.16	-1.5									EE 7-12 (East)
1050	12/2/95 1:20	60	B	7.35	ARIL	22.0		0.90	4.0	10.5	36.7	1.01	319	393	42.4	45	33.6	4	9.10	260	211	14	0	10.25	-0.3	9.25	254	120	20	-2	10.16	29.4	4.2 avg	Lances @ 22°, 4 gpm, N/NO=1.0
											36.7	--	315	395	47.6	55	36.2	8	9.00	263	210	14	-1	10.17	-0.1	8.95	259	110	20	-2	10.09	36.4	AHO1-3=4.5	EE 1-6 (West)
											36.7	--	328	387	38.2	40	31.7	2	9.05	257	218	11	0	10.10	-0.1	9.30	250	132	18	-1	9.99	25.7	AHO4-6=3.9	EE 7-12 (East)
1051	12/2/95 2:40	60	B	7.35	ARIL	22.0		1.80	4.0	10.5	36.7	2.02	319	393	59.1	71	37.7	32	9.10	260	211	14	0	10.25	-0.3	9.00	241	87	30	-2	10.49	47.1	20.3 avg	Lances @ 22°, 4 gpm, N/NO=2.0
											36.7	--	315	395	64.3	78	38.3	42	9.00	263	210	14	-1	10.17	-0.1	9.00	235	75	32	-2	10.12	51.6	AHO1-3=22.9	EE 1-6 (West)
											36.7	--	328	387	54.0	63	35.6	20	9.05	257	218	11	0	10.10	-0.1	8.65	248	102	27	-2	10.22	42.5	AHO4-6=17.7	EE 7-12 (East)
1052	12/2/95 4:10	60	B	7.36	ARIL	22.0		1.35	4.0	10.5	36.7	1.52	319	393	52.7	58	34.5	15	9.10	260	211	14	0	10.25	-0.3	8.95	253	101	25	-2	10.15	38.6	14.3 avg	Lances @ 22°, 4 gpm, N/NO=1.5
											36.7	--	315	395	55.7	66	36.7	18	9.00	263	210	14	-1	10.17	-0.1	9.25	246	91	25	-2	10.07	44.3	AHO1-3=15.6	EE 1-6 (West)
											36.7	--	328	387	49.3	52	32.3	10	9.05	257	218	11	0	10.10	-0.1	9.10	249	110	25	-2	10.10	34.5	AHO4-6=12.9	EE 7-12 (East)
1053	12/2/95 5:30	60	B	7.36							36.7	--	319	393	--	--	--	--	9.10	260	211	14	0	10.25	-0.3									Baseline Check
											36.7	--	315	395	--	--	--	--	9.00	263	210	14	-1	10.17	-0.1									EE 1-6 (West)
											36.7	--	328	387	--	--	--	--	9.05	257	218	11	0	10.10	-0.1									EE 7-12 (East)
1054	12/2/95 23:55	60	A	7.16							36.7	--	316	398	--	--	--	--	8.75	271	215	15	0	10.62	-1.6									Baseline, A Mill OOS, Biased B,C,D
											36.7	--	308	394	--	--	--	--	9.30	256	200	24	0	10.23	-0.3									EE 1-6 (West)
											36.7	--	305	389	--	--	--	--	8.00	281	220	8	0	11.57	-1.7									EE 7-12 (East)
1055	12/3/95 1.20	60	A	7.17	ARIL	22.0		0.45	4.0	10.5	36.7	0.51	316	398	27.1	23	27.0	3	8.75	271	215	15	0	10.62	-1.6	8.80	268	156	22	-1	10.82	14.1	0.8 avg	Lances @ 22°, 4 gpm, N/NO=0.5
											36.7	--	308	394	23.9	29	39.4	-1	9.30	256	200	24	0	10.23	-0.3	9.70	248	147	30	-1	10.07	17.9	AHO1-3=1.0	EE 1-6 (West)
											36.7	--	305	389	26.2	15	17.6	-2	8.00	281	220	8	0	11.57	-1.7	7.75	268	161	15	-1	11.43	9.4	AHO4-6=0.6	EE 7-12 (East)
1056	12/3/95 2:35	60	A	7.18	ARIL	22.0		0.90	4.0	10.5	36.7	1.02	316	398	40.0	39	30.6	18	8.75	271	215	15	0	10.62	-1.6	8.75	259	129	25	-1	10.82	24.7	7.7 avg	Lances @ 22°, 4 gpm, N/NO=1.0
											36.7	--	308	394	40.0	47	38.5	16	9.30	256	200	24	0	10.23	-0.3	9.60	239	117	36	-1	10.03	29.7	AHO1-3=14.7	EE 1-6 (West)
											36.7	--	305	389	36.4	32	28.9	-5	8.00	281	220	8	0	11.57	-1.7	7.90	287	141	16	-1	11.37	21.6	AHO4-6=0.6	EE 7-12 (East)
1057	12/3/95 3:55	60	A	7.18	ARIL	22.0		1.35	4.0	10.5	36.7	1.53	316	398	45.1	51	35.9	28	8.75	271	215	15	0	10.62	-1.6	8.65	250	117	30	-1	10.78	33.0	20.5 avg	Lances @ 22°, 4 gpm, N/NO=1.5
											36.7	--	308	394	49.6	62	40.8	48	9.30	256	200	24	0	10.23	-0.3	9.40	224	100	44	-2	10.03	39.8	AHO1-3=40.0	EE 1-6 (West)
											36.7	--	305	389	39.8	40	33.4	-3	8.00	281	220	8	0	11.57	-1.7	8.05	282	132	17	-1	11.30	27.4	AHO4-6=0.9	EE 7-12 (East)
1058	12/3/95 5:10	60	A	7.19	ARIL	22.0		1.35	4.0	10.5	36.7	1.69	286	404	34.5	31	31.6	47	8.40	283	200	20	0	11.16	-0.2	8.50	248	130	32	-1	10.84	21.4	35.9 avg	Same as previous, but no mill bias
											36.7	--	301	411	49.5	51	34.0	111	10.0	251	184	18	0	9.73	0.9	10.0	183	93	45	-1	9.69	31.8	AHO1-3=70.4	EE 1-6 (West)
											36.7	--	264	397	22.4	13	21.2	5	7.20	304	218	14	0	12.01	-1.6	6.80	309	174	20	-1	12.16	9.0	AHO4-6=1.3	EE 7-12 (East)
1059	12/3/95 6:23	60	A	7.19							36.7	--	286	404	--	--	--	--	8.40	283	200	20	0	11.16	-0.2									Baseline with no Mill Bias
											36.7	--	301	411	--	--	--	--	10.0	251	184	18	0	9.73	0.9									EE 1-6 (West)
											36.7	--	264	397	--	--	--	--	7.20	304	218	14	0	12.01	-1.6									EE 7-12 (East)
1060	12/4/95 9:25	70	B	5.72							36.7	--	307	392	--	--	--	--	7.40	296	232	21	0	11.66	-0.3									Baseline, B OOS, +5% D West Fdr
											36.7	--	299	390	--	--	--	--	7.20	299	229	22	0	11.77	-0.5									EE 1-6 (West)
											36.7	--	316	387	--	--	--	--	7.90	282	230	24	0	11.20	0.3									EE 7-12 (East)
1061	12/4/95 14:13	70	B	5.69	1			0.50	2.0	8.0	36.7	0.50	307	392	37.5	23	20.2	20	7.40	296	232	21	0	11.66	-0.3	7.30	283	146	36	-1	11.61	17.4		D slugging badly, Ignitors on
											36.7	--	299	390	34.0	23	22.2	9	7.20	299	229	22	0	11.77	-0.5	7.30	290	150	29	-1	11.49	16.7		EE 1-6 (West)
											36.7	--	316	387	37.5	20	17.2	6	7.90	282	230	24	0	11.20	0.3	7.60	284	147	41	-1	11.43	15.5		EE 7-12 (East)
1062	12/5/95 7:50	70	B	5.75							36.7	--	289	399	--	--	--	--	7.50	299	217	27	0	12.10	-0.8									Baseline, B OOS, -10% D mill,
											36.7	--	274	393	--	--	--	--	6.90	308	215	27	1	12.33	-0.4									EE 1-6 (West) +5% D West Fdr
											36.7	--	296	396	--	--	--	--	7.60	295	220	24	1	11.54	-0.6									EE 7-12 (East)
1063	12/5/95 9:50	70	B	5.74	1			0.50	2.0	8.0	36.7	0.53	289	399	32.4	26	27.6	9	7.50	299	217	27	0	12.10	-0.8	7.65	269	145	49	-1	11.69	18.4	5.7 avg	Level 1, N/NO=0.5
											36.7	--	274	393	34.4	26	27.2	1	6.90	308	215	27	1	12.33	-0.4	7.00	305	140	43	-1	12.11	19.6	AHO1-3=1.0	EE 1-6 (West)
											36.7	--	296	396	26.4	25	29.6	12	7.60	295	220	24	1	11.54	-0.6	7.90	280	154	42	-1	11.49	17.5	AHO4-6=10.4	EE 7-12 (East)
1064	12/5/95 11:45	70	B	5.76	1			1.00	2.0	8.0	36.7	1.06	289	399	47.0	37	27.0	47	7.50	299	217	27	0	12.10	-0.8	7.50	264	115	54	-1	11.65	26.7	33.1 avg	Level 1, N/NO=1.0
											36.7	--	274	393	47.6	41	31.4	20	6.90	308	215	27	1	12.33	-0.4	7.10	288	111	55	-2	12.14	31.3	AHO1-3=21.9	EE 1-6 (West)
											36.7	--	296	396	40.5	12	9.6	43	7.60	295	220	24	1	11.54	-0.6	8.00	255	127	51	-1	11.31	7.9	AHO4-6=44.2	EE 7-12 (East)
1065	12/6/95 10:00	100		4.42							36.7	--	277	391	--	--	--	--	5.90	326	232	86	0	13.03	-0.7									Baseline, D mill-10%, DW Fdr+10%,
											36.7	--	275	391	--	--	--	--	5.90	326	231	40	1	13.06	-0.4									EE 1-6 (West) BW Fdr-5%
											36.7	--	275	389	--	--	--	--	5.90	326	231	140	0	13.12	0.0									EE 7-12 (East)
1066	12/6/95 11:30	100		4.42							36.7	--	281	386	--	--	--	--	5.60	330	223	144	0	13.29	0.1									Baseline, D mill-10%, DW Fdr+10%,
											36.7	--	284	389	--	--	--	--	5.65	332	225	63	0	13.23	-0.5									EE 1-6 (West) BW Fdr-10%
											36.7	--	285	378	--	--	--	--	5.60	323	227	157	0	13.06	0.9									EE 7-12 (East)
1067	12/7/95 8:00	80		5.26							36.7	--	240	361	--	--	--	--	6.30	311	196	49	0	12.64	0.8									Baseline, C mill +10%
											36.7	--	251	361	--	--	--	--	6.65	304	200	19	0	12.37	-1.1									EE 1-6 (West)
											36.7	--	232	377	--	--	--	--	6.10	312	192	59	0	12.71	-1.0									EE 7-12 (East)
1068	12/7/95 9:35	80		5.23	1			0.45	2.0	8.0	36.7	0.50	240	361	28.3	19	29.4	-2	6.30	311	196	49	0	12.64	0.8	6.55	307	142	43	-1	12.59	15.7	1.4 avg	Level 1, N/NO=0.5
											36.7	--	251	361	28.3	24	34.0	1	6.65	304	200	19	0	12.37	-1.1	6.90	298	141	26	-1	12.04	17.6	AHO1-3=1.4	EE 1-6 (West)
											36.7	--	232	377	23.7	20	35.9	1	6.10	312	192	59	0	12.71	-1.0	6.15	310	146	44	-1	12.55	15.3	AHO4-6=1.4	EE 7-12 (East)

Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Urea Injection------- Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	NO base ppmc	SO2 base ppmc	ΔNO SNCR %	ΔN2O econ ppmc	ΔN2O ΔNO %	ΔSO2 econ ppmc	Economizer Exit, dry (1-12): Base O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	Economizer Exit, dry (1-12): w/Urea O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	NH3 Slip AHO comp ppm	Comments
1069	12/7/95 10:45	80		5.23	1			0.90	2.0	8.0	36.7	1.01	240	381	39.3	30	31.6	8	6.30	311	196	49	0	12.64	0.8	6.55	299	117	50	-1	12.43	24.7	17.3 avg	Level 1, N/NO=1.0
											36.7	--	251	381	45.2	36	32.1	11	6.65	304	200	19	0	12.37	-1.1	7.00	288	107	37	-1	11.92	27.2	AHO1-3=16.0	EE 1-6 (West)
											36.7	--	232	377	36.3	30	35.6	11	6.10	312	192	59	0	12.71	-1.0	6.25	300	121	54	-1	12.49	23.6	AHO4-6=18.5	EE 7-12 (East)
1070	12/7/95 12:10	80		5.25	1			1.35	2.0	8.0	36.7	1.51	240	381	46.5	39	35.1	41	6.30	311	196	49	0	12.64	0.8	6.70	270	102	54	-1	12.29	31.9	47.5 avg	Level 1, N/NO=1.5
											36.7	--	251	381	52.8	45	33.8	57	6.65	304	200	19	0	12.37	-1.1	6.85	255	93	45	-2	12.17	34.1	AHO1-3=48.2	EE 1-6 (West)
											36.7	--	232	377	42.1	39	39.7	34	6.10	312	192	59	0	12.71	-1.0	6.40	276	109	51	-1	12.36	30.4	AHO4-6=46.9	EE 7-12 (East)
1071	12/7/95 13:30	80	D	5.20							36.7	--	292	362	--	--	--	--	7.00	297	227	47	0	11.72	3.9									Baseline, D OOS, C +10%, B -10%,
											36.7	--	316	378	--	--	--	--	5.75	320	268	80	0	12.64	3.4									EE 1-6 (West) B west fdr -10%
											36.7	--	268	383	--	--	--	--	7.80	261	211	45	0	11.33	0.4									EE 7-12 (East)
1072	12/7/95 14:25	80	D	5.21	1			0.55	2.0	8.0	36.7	0.52	284	386	31.9	28	30.6	10	7.00	300	221	115	0	11.84	-1.6	7.05	291	150	51	-1	12.00	19.9	7.0	Level 1, N/NO=0 5
1073	12/7/95 16:10	80	D	5.22	1			1.10	2.0	8.0	36.7	1.04	284	386	46.0	38	29.1	31	7.00	300	221	115	0	11.84	-1.6	7.05	275	119	100	-1	11.90	27.9	34.8	Level 1, N/NO=1.0
1074	12/7/95 16:35	80	D	5.20							36.7	--	284	386	--	--	--	--	7.00	300	221	115	0	11.84	-1.6									Baseline Check
1075	12/8/95 8:40	100		4.53							36.7	--	254	387	--	--	--	--	5.90	325	213	100	0	13.09	3.1									Baseline, B-10%, C +15%, D -10%
											36.7	--	248	385	--	--	--	--	5.70	327	211	125	1	13.22	1.7									EE 1-6 (West)
											36.7	--	254	383	--	--	--	--	5.95	320	212	33	1	13.01	-0.6									EE 7-12 (East)
1076	12/8/95 10:20	100		4.52	1			0.60	6.0	8.0	36.7	0.51	254	387	29.6	21	27.1	7	5.90	325	213	100	0	13.09	3.1	5.75	322	151	181	0	13.18	20.5	1.6 avg	Level 1, N/NO=0.5, bias as above,
											36.7	--	248	385	35.6	26	26.6	10	5.70	327	211	125	1	13.22	1.7	5.30	327	139	247	0	13.34	24.1	AHO1-3=1.7	EE 1-6 (West) w/ D west fdr +5%
											36.7	--	254	383	24.6	22	35.4	6	5.95	320	212	33	1	13.01	-0.6	6.00	314	159	38	0	12.92	17.9	AHO4-6=1.8	EE 7-12 (East)
1077	12/8/95 11:50	100		4.52	1			1.20	6.0	8.0	36.7	1.02	254	387	41.7	39	36.6	13	5.90	325	213	100	0	13.09	3.1	5.55	321	127	150	0	13.41	36.6	11.6 avg	Level 1, N/NO=1.0, bias as above,
											36.7	--	248	385	49.5	44	35.9	13	5.70	327	211	125	1	13.22	1.7	5.20	326	110	275	-1	13.52	40.5	AHO1-3=6.7	EE 1-6 (West) w/ D west fdr +5%
											36.7	--	254	383	37.5	34	35.6	23	5.95	320	212	33	1	13.01	-0.6	5.90	302	133	52	0	13.04	27.9	AHO4-6=16.5	EE 7-12 (East)
1078	12/8/95 13:25	100		4.52	1			1.80	6.0	8.0	36.7	1.52	254	387	50.6	45	35.0	30	5.90	325	213	100	0	13.09	3.1	5.50	306	106	75	-1	13.34	41.9	34.7 avg	Level 1, N/NO=1.5, bias as above,
											36.7	--	248	385	55.0	47	34.5	22	5.70	327	211	125	1	13.22	1.7	5.60	310	96	84	-1	13.14	42.0	AHO1-3=30.0	EE 1-6 (West) w/ D west fdr +5%
											36.7	--	254	383	43.6	39	35.5	43	5.95	320	212	33	1	13.01	-0.6	5.65	290	122	65	0	13.19	32.6	AHO4-6=39.4	EE 7-12 (East)
1079	12/8/95 14:50	100		4.52							36.7	--	263	382	--	--	--	--	5.75	324	223	82	1	13.35	-2.5									Baseline Check
											36.7	--	258	383	--	--	--	--	5.60	326	221	129	0	13.27	0.1									EE 1-6 (West)
											36.7	--	262	378	--	--	--	--	5.80	319	221	36	1	13.24	0.2									EE 7-12 (East)
1080	12/11/95 23:50	70	C	6.51							36.7	--	350	393	--	--	--	--	8.40	275	245	15	1	10.78	-1.1									Baseline, C OOS, A+5%, B-10%,
											36.7	--	351	392	--	--	--	--	8.60	270	242	16	1	10.92	-0.6									EE 1-6 (West) BW fdr -5%, D-11%,
											36.7	--	335	388	--	--	--	--	8.00	280	242	20	0	11.46	-1.1									EE 7-12 (East) DW fdr +10%
1081	12/12/95 2:00	70	C	6.48	ARIL	22.0		1.10	4.0	10.5	36.7	0.97	350	393	34.1	37	30.6	5	8.40	275	245	15	1	10.78	-1.1	8.20	276	164	17	-1	11.00	24.9	1.1 avg	ARIL @ 22°, N/NO=1.0
											36.7	--	351	392	34.4	45	37.4	5	8.60	270	242	16	1	10.92	-0.6	8.50	269	160	16	-1	10.71	30.6	AHO1-3=0.9	EE 1-6 (West)
											36.7	--	335	388	26.4	24	25.6	-2	8.00	280	242	20	0	11.46	-1.1	7.80	286	176	16	0	11.53	16.7	AHO4-6=1.3	EE 7-12 (East)
1082	12/12/95 3:50	70	C	6.47	ARIL	22.0		2.20	4.0	10.5	36.7	1.93	350	393	40.2	51	36.5	4	8.40	275	245	15	1	10.78	-1.1	8.10	279	150	22	-1	11.27	35.7	3 6 avg	ARIL @ 22°, N/NO=2.0
											36.7	--	351	392	44.3	69	44.2	1	8.60	270	242	16	1	10.92	-0.6	8.30	276	138	25	-1	10.98	47.7	AHO1-3=6.1	EE 1-6 (West)
											36.7	--	335	386	31.9	40	37.6	3	8.00	280	242	20	0	11.46	-1.1	7.90	280	166	15	-1	11.16	28.2	AHO4-6=1.1	EE 7-12 (East)
1083	12/12/95 5:00	70	C	6.48	ARIL	22.0		3.30	4.0	10.5	36.7	2.90	350	393	44.6	72	46.1	12	8.40	275	245	15	1	10.78	-1.1	8.15	272	138	26	-1	11.04	60.5	13.1 avg	ARIL @ 22°, N/NO=3 0
											36.7	--	351	392	50.6	92	51.7	26	8.60	270	242	16	1	10.92	-0.6	8.75	249	116	36	-1	10.79	61.8	AHO1-3=25.8	EE 1-6 (West)
											36.7	--	335	388	36.4	63	51.6	6	8.00	280	242	20	0	11.46	-1.1	8.00	276	154	16	-1	11.09	44.3	AHO4-6=0.4	EE 7-12 (East)
1084	12/12/95 23:10	70	C	6.46							36.7	--	330	378	--	--	--	--	8.25	268	234	16	4	10.57	0.9									Baseline, C OOS, A+5%, B-10%,
											36.7	--	351	379	--	--	--	--	8.65	260	241	11	4	10.09	1.0									EE 1-6 (West) BWfdr-10%, D-15%,
											36.7	--	312	375	--	--	--	--	7.90	273	227	28	4	10.90	1.5									EE 7-12 (East) DWfdr+10%
1085	12/13/95 2:45	70	C	6.41	ARIL	22.0		1.05	6.0	10.5	36.7	0.95	340	381	33.2	35	31.0	16	8.30	269	240	16	0	10.90	-0.9	8.00	284	164	16	3	10.71	24.4	4.1 avg	ARIL @ 22°, N/NO=1.0, 6 gpm
											36.7	--	348	380	28.0	37	38.5	6	8.60	262	240	12	0	10.29	-0.8	8.45	261	175	16	3	10.27	25.3	AHO1-3=5.4	EE 1-6 (West)
											36.7	--	321	374	27.0	12	13.5	-2	8.00	270	232	19	0	11.02	-0.5	8.10	269	168	14	2	21.40	7.9	AHO4-6=2.7	EE 7-12 (East)
1086	12/13/95 4:25	70	C	6.41	ARIL	22.0		2.10	6.0	10.5	36.7	1.90	340	381	38.2	48	36.7	-10	8.30	269	240	16	0	10.90	-0.9	8.25	277	149	20	-1	11.21	32.8	5.5 avg	ARIL @ 22°, N/NO=2.0, 6 gpm
											36.7	--	348	380	36.0	62	47.2	-2	8.60	262	240	12	0	10.29	-0.8	8.75	260	147	22	-1	10.53	41.7	AHO1-3=6.2	EE 1-6 (West)
											36.7	--	321	374	33.3	47	43.6	-4	8.00	270	232	19	0	11.02	-0.5	7.90	275	156	15	-1	11.06	33.4	AHO4-6=4.6	EE 7-12 (East)
1087	12/13/95 5:40	70	C	6.41							36.7	--	340	381	--	--	--	--	8.30	269	240	16	0	10.90	-0.9									Baseline Check
											36.7	--	348	380	--	--	--	--	8.60	262	240	12	0	10.29	-0.8									EE 1-6 (West)
											36.7	--	321	374	--	--	--	--	8.00	270	232	19	0	11.02	-0.5									EE 7-12 (East)
1088	12/13/95 23:10	70	C	6.35							36.7	--	328	393	--	--	--	--	8.10	282	235	18	0	11.45	-1.1									Baseline, C OOS, A+5%, B-8%,
											36.7	--	348	393	--	--	--	--	8.60	271	240	11	1	10.66	-1.7									EE 1-6 (West) BWfdr-10%, D-15%,
											36.7	--	310	390	--	--	--	--	7.70	288	229	23	1	11.63	-1.5									EE 7-12 (East) DWfdr+10%
1089	12/14/95 0:45	70	C	6.32	ARIL	22.0		1.00	6.0	10.5	36.7	0.94	328	393	28.8	28	29.9	3	8.10	282	235	18	0	11.45	-1.1	7.90	284	170	17	-1	11.63	19.4	1.7 avg	ARIL @ 22°, N/NO=1 0, 6 gpm
											36.7	--	348	393	32.3	37	32 6	4	8.60	271	240	11	1	10.66	-1.7	8.10	279	169	16	0	11.16	24.5	AHO1-3=1.9	EE 1-6 (West)
											36.7	--	310	390	25.8	24	29.7	4	7.70	288	229	23	1	11.63	-1.5	7.70	285	170	12	0	11.37	16.0	AHO4-6=1.5	EE 7-12 (East)
1090	12/14/95 1:50	70	C	6.26	ARIL	22.0		2.10	6.0	10.5	36.7	1.97	328	393	37.6	46	37.2	5	8.10	282	235	18	0	11.45	-1.1	7.90	283	149	17	-1	11.23	32.2	2.0 avg	ARIL @ 22°, N/NO=2 0, 6 gpm
											36.7	--	348	393	45.2	60	37.9	5	8.60	271	240	11	1	10.66	-1.7	7.80	285	140	20	-1	11.33	42.0	AHO1-3=1.5	EE 1-6 (West)
											36.7	--	310	390	32.3	44	43.9	4	7.70	288	229	23	1	11.63	-1.5	7.70	285	155	15	0	11.55	31.0	AHO4-6=2.5	EE 7-12 (East)
1091	12/14/95 2:55	70	C	6.26	ARIL	22.0		3.15	6.0	10.5	36.7	2.95	328	393	41.6	62	45.6	9	8.10	282	235	18	0	11.45	-1.1	7.90	280	139	19	-1	11.17	44.3	5.4 avg	ARIL @ 22°, N/NO=3 0, 6 gpm
											36.7	--	348	393	46.7	74	43.4	10	8.60	271	240	11	1	10.66	-1.7	7.90	279	130	25	-1	11.18	51.8	AHO1-3=8.0	EE 1-6 (West)
											36.7	--	310	390	35.3	58	52.6	3	7.70	288	229	23	1	11.63	-1.5	7.80	284	147	17	-1	11.47	40.9	AHO4-6=2.6	EE 7-12 (East)
1092	12/14/95 4:05	70	C	6.26	ARIL	22.0		3.15	4.0	10.5	36.7	2.95	328	393	37.0	55	45.5	6	8.10	282	235	18	0	11.45	-1.1	7.75	285	152	16	-1	11.21	39.5	4.5 avg	ARIL @ 22°, N/NO=3 0, 4 gpm

					Urea Injection-------														Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load MWe	Mills OOS	O_2cr %wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	NO base ppmc	SO_2 base ppmc	ΔNO SNCR %	ΔN_2O econ ppmc	ΔN_2O/ΔNO %	ΔSO_2 econ ppmc	O_2 %dry	SO_2 ppm	NO ppm	CO ppm	NO_2 ppm	CO_2 %	N_2O ppm	O_2 %dry	SO_2 ppm	NO ppm	CO ppm	NO_2 ppm	CO_2 %	N_2O ppm	AHO comp ppm	Comments
											36.7	- -	348	393	44.8	64	40.8	9	8.60	271	240	11	1	10.66	-1.7	7.90	280	140	18	-1	11.18	44.5	AHO1-3=7.0	EE 1-6 (West)
											36.7	- -	310	390	30.3	48	51.2	3	7.70	268	229	23	1	11.63	-1.5	7.75	285	159	14	-1	11.30	33.9	AHO4-6=2.0	EE 7-12 (East)
1093	12/14/95 5:20	70	C	6.30	ARIL	22.0		3.15	6.0	10.5	36.7	2.95	328	393	46.4	72	47.7	12	8.10	282	235	16	0	11.45	-1.1	7.80	280	129	26	-1	11.41	52.0	11.1 avg	ARIL @ 22°, N/NO=3.0, 6 gpm
											36.7	- -	348	393	51.9	80	44.4	13	8.60	271	240	11	1	10.66	-1.7	8.00	275	121	28	-1	11.02	56.2	AHO1-3=18.6	EE 1-6 (West)
											36.7	- -	310	390	39.5	56	45.6	3	7.70	268	229	23	1	11.63	-1.5	7.55	269	140	21	-1	11.53	40.2	AHO4-6=3.6	EE 7-12 (East)
1094	12/14/95 23:20	50	C	8.18							36.7	- -	319	414	- -	- -	- -	- -	9.70	260	200	13	0	10.34	-1.1									Baseline, C OOS, A+5%,
											36.7	- -	325	408	- -	- -	- -	- -	9.70	256	204	11	0	9.74	-1.0									EE 1-6 (West) BWldr-10%,
											36.7	- -	293	409	- -	- -	- -	- -	9.20	268	192	13	0	10.53	-0.9									EE 7-12 (East) DWldr+12%
1095	12/15/95 0:55	50	C	8.21	ARIL	135.0		0.75	4.0	10.5	36.7	1.01	319	414	19.9	3	5.1	6	9.70	260	200	13	0	10.34	-1.1	10.0	248	156	7	-1	9.71	0.9	1.5 avg	ARIL @ 135°, N/NO=1.0, 4 gpm
											36.7	- -	325	408	24.0	6	7.1	2	9.70	256	204	11	0	9.74	-1.0	10.0	248	151	7	-1	9.55	2.4	AHO1-3=1.5	EE 1-6 (West)
											36.7	- -	293	409	12.4	2	4.3	9	9.20	268	192	13	0	10.53	-0.9	10.2	240	154	7	-1	9.55	0.1	AHO4-6=1.4	EE 7-12 (East)
1096	12/15/95 1:50	50	C	8.21	ARIL	90.0		0.75	4.0	10.5	36.7	1.01	319	414	25.0	12	14.6	8	9.70	260	200	13	0	10.34	-1.1	9.70	255	150	8	-1	9.86	6.2	2.1 avg	ARIL @ 90°, N/NO=1.0, 4 gpm
											36.7	- -	325	408	26.0	13	14.9	2	9.70	256	204	11	0	9.74	-1.0	9.70	255	151	9	-1	10.14	6.9	AHO1-3=1.9	EE 1-6 (West)
											36.7	- -	293	409	20.6	8	13.6	9	9.20	268	192	13	0	10.53	-0.9	9.70	251	146	7	-1	9.86	4.3	AHO4-6=2.2	EE 7-12 (East)
1097	12/15/95 2:50	50	C	8.20	ARIL	67.0		0.75	4.0	10.5	36.7	1.01	319	414	26.7	22	23.9	6	9.70	260	200	13	0	10.34	-1.1	9.90	252	140	10	-1	9.74	12.4	2.6 avg	ARIL @ 67°, N/NO=1.0, 4 gpm
											36.7	- -	325	408	30.4	24	24.2	2	9.70	256	204	11	0	9.74	-1.0	9.70	255	142	10	-1	10.00	14.0	AHO1-3=2.6	EE 1-6 (West)
											36.7	- -	293	409	23.6	22	31.8	12	9.20	268	192	13	0	10.53	-0.9	9.90	245	138	9	-1	9.57	12.7	AHO4-6=2.9	EE 7-12 (East)
1098	12/15/95 3:55	50	C	8.21	ARIL	45.0		0.75	4.0	10.5	36.7	1.01	319	414	35.5	37	32.7	13	9.70	260	200	13	0	10.34	-1.1	9.70	252	129	13	-1	9.71	22.1	2.2 avg	ARIL @ 45°, N/NO=1.0, 4 gpm
											36.7	- -	325	408	34.5	38	34.0	2	9.70	256	204	11	0	9.74	-1.0	9.50	259	136	15	-1	10.25	23.3	AHO1-3=2.0	EE 1-6 (West)
											36.7	- -	293	409	32.5	35	36.7	7	9.20	268	192	13	0	10.53	-0.9	9.80	250	123	10	-2	9.59	20.9	AHO4-6=2.3	EE 7-12 (East)
1099	12/15/95 4:55	50	C	8.19	ARIL	22.0		0.75	4.0	10.5	36.7	1.01	319	414	45.5	49	33.6	8	9.70	260	200	13	0	10.34	-1.1	9.70	255	109	26	-2	9.92	29.5	4.5 avg	ARIL @ 22°, N/NO=1.0, 4 gpm
											36.7	- -	325	408	49.0	53	33.2	0	9.70	256	204	11	0	9.74	-1.0	9.60	258	105	34	-1	10.10	32.5	AHO1-3=5.6	EE 1-6 (West)
											36.7	- -	293	409	42.3	45	36.6	6	9.20	268	192	13	0	10.53	-0.9	9.70	253	106	21	-2	9.75	27.6	AHO4-6=3.4	EE 7-12 (East)
1100	12/15/95 5:45	50	C	8.22							36.7	- -	303	401	- -	- -	- -	- -	9.60	254	192	15	0	9.93	-0.2									Baseline Check
											36.7	- -	326	399	- -	- -	- -	- -	10.0	244	199	15	0	9.52	0.1									EE 1-6 (West)
											36.7	- -	292	406	- -	- -	- -	- -	9.70	255	183	13	-1	9.99	-0.2									EE 7-12 (East)
1101	12/15/95 23:10	50	C	7.98							36.7	- -	334	407	- -	- -	- -	- -	9.80	253	206	9	0	9.91	-1.8									Baseline, C OOS, A+5%, B-10%,
											36.7	- -	357	409	- -	- -	- -	- -	10.3	243	212	8	0	9.29	-1.4									EE 1-6 (West) BWldr-10%, D-15%,
											36.7	- -	330	402	- -	- -	- -	- -	9.50	257	211	5	0	10.16	-1.6									EE 7-12 (East) DWldr+10%
1102	12/16/95 0:40	50	C	8.01	ARIL	22.0		0.40	4.0	10.5	36.7	0.51	334	407	30.2	32	32.1	3	9.80	253	206	9	0	9.91	-1.8	9.50	258	149	23	-1	10.10	16.9	2.2 avg	ARIL @ 22°, N/NO=0.5, 4 gpm
											36.7	- -	357	409	32.2	33	28.7	7	10.3	243	212	8	0	9.29	-1.4	9.90	248	149	35	-1	9.73	18.9	AHO1-3=2.5	EE 1-6 (West)
											36.7	- -	330	402	33.1	25	23.0	3	9.50	257	211	5	0	10.16	-1.6	9.10	264	146	11	-1	10.29	15.0	AHO4-6=1.8	EE 7-12 (East)
1103	12/16/95 1:40	50	C	8.06	ARIL	22.0		0.80	4.0	10.5	36.7	1.03	334	407	42.9	46	33.1	25	9.80	253	206	9	0	9.91	-1.8	9.50	244	122	34	-1	9.94	26.5	11.6 avg	ARIL @ 22°, N/NO=1.0, 4 gpm
											36.7	- -	357	409	43.6	47	30.1	39	10.3	243	212	8	0	9.29	-1.4	9.90	228	124	43	-1	9.66	27.4	AHO1-3=20.0	EE 1-6 (West)
											36.7	- -	330	402	45.5	44	29.5	4	9.50	257	211	5	0	10.16	-1.6	8.90	268	121	20	-1	10.36	28.1	AHO4-6=3.2	EE 7-12 (East)
1104	12/16/95 2:40	50	C	8.03	ARIL	22.0		1.20	4.0	10.5	36.7	1.54	334	407	52.2	60	34.6	64	9.80	253	206	9	0	9.91	-1.8	9.50	219	102	39	-1	10.05	36.7	36.4 avg	ARIL @ 22°, N/NO=1.5, 4 gpm
											36.7	- -	357	409	51.3	57	31.2	101	10.3	243	212	8	0	9.29	-1.4	9.90	190	107	49	-1	9.60	33.8	AHO1-3=61.9	EE 1-6 (West)
											36.7	- -	330	402	51.5	57	33.5	9	9.50	257	211	5	0	10.16	-1.6	9.10	260	106	26	-1	10.31	36.0	AHO4-6=10.9	EE 7-12 (East)
1105	12/16/95 3:40	50	C	8.04	ARIL	45.0		1.20	4.0	10.5	36.7	1.54	334	407	49.9	66	39.3	4	9.80	253	206	9	0	9.91	-1.8	9.50	257	107	22	-2	9.96	40.0	8.9 avg	ARIL @ 45°, N/NO=1.5, 4 gpm
											36.7	- -	357	409	53.2	75	39.4	18	10.3	243	212	8	0	9.29	-1.4	9.90	241	103	32	-1	9.57	44.6	AHO1-3=15.1	EE 1-6 (West)
											36.7	- -	330	402	50.7	59	35.1	0	9.50	257	211	5	0	10.16	-1.6	9.50	257	104	13	-1	9.97	36.0	AHO4-6=2.6	EE 7-12 (East)
1106	12/16/95 4:35	50	C	8.02	ARIL	45.0		0.80	4.0	10.5	36.7	1.03	334	407	41.0	50	36.4	-2	9.80	253	206	9	0	9.91	-1.8	9.60	259	125	15	-1	9.96	29.7	3.5 avg	ARIL @ 45°, N/NO=1.0, 4 gpm
											36.7	- -	357	409	43.3	58	37.7	-2	10.3	243	212	8	0	9.29	-1.4	9.70	258	127	20	-1	9.62	35.0	AHO1-3=4.5	EE 1-6 (West)
											36.7	- -	330	402	39.3	43	33.0	5	9.50	257	211	5	0	10.16	-1.6	9.50	254	126	10	-1	10.01	25.6	AHO4-6=2.5	EE 7-12 (East)
1107	12/16/95 5:30	50	C	8.03	ARIL	45.0		0.40	4.0	10.5	36.7	0.51	334	407	27.4	34	37.2	5	9.80	253	206	9	0	9.91	-1.8	9.80	250	151	13	-1	9.77	19.4	2.6 avg	ARIL @ 45°, N/NO=0.5, 4 gpm
											36.7	- -	357	409	32.3	34	29.9	9	10.3	243	212	8	0	9.29	-1.4	9.60	253	153	15	-1	9.96	20.3	AHO1-3=2.4	EE 1-6 (West)
											36.7	- -	330	402	29.9	27	27.1	6	9.50	257	211	5	0	10.16	-1.6	9.50	253	146	10	-1	9.84	15.5	AHO4-6=2.7	EE 7-12 (East)

C

DATA SUMMARY: DPSC LANCE TESTS

PSCC Arapahoe Unit 4 Urea Lance Injection Summary

DIAMOND POWER (DPSC) LANCE TESTS

					Urea Injection--------														Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	NO base ppmc	SO2 base ppmc	ΔNO SNCR %	ΔN2O econ ppmc	ΔN2O ΔNO %	ΔSO2 econ ppmc	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	AHO comp ppm	Comments
1115	8/16/96 23.28	60	B	6.16							35.9	--	348	424	--	--	--	--	9.10	280	230	21	-1	11.36	-0.5									Baseline, B Mill OOS
											35.9	--	339	428	--	--	--	--	8.80	290	230	18	-1	11.56	-0.8									West
											35.9	--	355	427	--	--	--	--	9.40	275	229	20	-2	11.27	-0.3									East
1116	8/17/96 2:51	60	B	6.38	ARIL	22.0		1.00	4.0	9.8	35.9	1.01	348	424	40.4	47	33.2	-3	9.10	280	230	21	-1	11.36	-0.5	8.85	288	140	36	-2	11.52	31.0	2.6 Avg	ARILs @ 22°, 4 gpm, N/NO=1.0
											35.9	--	339	428	42.8	53	36.4	0	8.80	290	230	18	-1	11.56	-0.8	8.85	289	131	35	-2	11.54	34.9	2.9	West
											35.9	--	355	427	36.7	41	31.2	7	9.40	275	229	20	-2	11.27	-0.3	9.00	280	150	33	-2	11.47	26.8	2.3	East
1117	8/17/96 4 20	60	B	6.41	ARIL	22.0		1.50	4.0	9.8	35.9	1.51	348	424	49.5	60	34.7	10	9.10	280	230	21	-1	11.36	-0.5	8.80	280	119	45	-3	11.62	40.0	14.8 Avg	ARILs @ 22°, 4 gpm, N/NO=1.5
											35.9	--	339	428	54.2	62	33.8	13	8.80	290	230	18	-1	11.56	-0.8	8.60	286	107	43	-3	11.83	42.0	22.5	West
											35.9	--	355	427	43.4	54	35.2	9	9.40	275	229	20	-2	11.27	-0.3	9.45	268	129	39	-2	11.25	34.6	7.1	East
1118	8/17/96 5:55	60	B	6.41	ARIL	22.0		2.00	4.0	9.8	35.9	2.02	348	424	55.5	70	36.2	25	9.10	280	230	21	-1	11.36	-0.5	8.80	270	105	48	-3	11.43	46.9	17.6 Avg	ARILs @ 22°, 4 gpm, N/NO=2.0
											35.9	--	339	428	61.4	73	34.9	22	8.80	290	230	18	-1	11.56	-0.8	8.50	282	91	50	-3	11.96	49.7	21.2	West
											35.9	--	355	427	48.9	67	38.5	26	9.40	275	229	20	-2	11.27	-0.3	9.50	256	116	42	-3	10.66	42.4	14.0	East
1119	8/17/96 8:00	60	B	6.40							35.9	--	335	431	--	--	--	--	8.90	290	225	33	-1	11.70	0.6									Baseline Check
1120	8/17/96 23:35	60	B	6.13							35.9	--	350	424	--	--	--	--	8.90	285	235	16	-2	11.25	0.1									Baseline, B Mill OOS
											35.9	--	334	429	--	--	--	--	8.40	300	234	23	-2	11.90	0.1									West
											35.9	--	357	421	--	--	--	--	9.40	271	230	16	-2	11.02	-0.3									East
1121	8/18/96 1:04	60	B	6.14	ARIL	34.0		1.00	4.0	9.7	35.9	1.00	350	424	27.4	36	37.6	3	8.90	285	235	16	-2	11.25	0.1	8.80	285	172	22	-3	11.28	24.5	4.4 Avg	ARILs @ 34°, 4 gpm, N/NO=1.0
											35.9	--	334	429	30.2	42	41.8	7	8.40	300	234	23	-2	11.90	0.1	8.65	289	160	19	-3	11.49	29.1	4.9	West
											35.9	--	357	421	25.8	32	34.6	2	9.40	271	230	16	-2	11.02	-0.3	9.10	277	175	22	-3	11.08	20.8	3.8	East
1122	8/18/96 2:22	60	B	6.11	ARIL	34.0		2.00	4.0	9.7	35.9	2.01	350	424	37.0	56	43.2	1	8.90	285	235	16	-2	11.25	0.1	8.75	288	150	25	-3	11.52	38.1	5.3 Avg	ARILs @ 34°, 4 gpm, N/NO=2.0
											35.9	--	334	429	38.8	59	45.4	5	8.40	300	234	23	-2	11.90	0.1	8.50	294	142	23	-3	11.81	41.0	4.7	West
											35.9	--	357	421	34.2	50	40.9	3	9.40	271	230	16	-2	11.02	-0.3	9.05	277	156	26	-3	11.12	32.8	5.8	East
1123	8/18/96 3.47	60	B	6.12	ARIL	22.0		2.00	4.0	9.7	35.9	2.01	350	424	46.6	67	41.4	10	8.90	285	235	16	-2	11.25	0.1	8.65	284	128	40	-3	11.70	46.4	24.4 Avg	ARILs @ 22°, 4 gpm, N/NO=2.0
											35.9	--	334	429	51.4	80	46.6	14	8.40	300	234	23	-2	11.90	0.1	8.70	283	111	41	-3	11.73	54.8	26.1	West
											35.9	--	357	421	40.6	51	35.4	22	9.40	271	230	16	-2	11.02	-0.3	8.95	267	142	36	-3	11.29	34.0	22.6	East
1124	8/18/96 5:17	60	B	6.15	ARIL	22.0		2.00	6.0	9.8	35.9	2.01	350	424	49.1	69	39.9	30	8.90	285	235	16	-2	11.25	0.1	8.75	268	121	43	-3	11.45	46.8	30.2 Avg	ARILs @ 22°, 6 gpm, N/NO=2.0
											35.9	--	334	429	53.5	80	44.7	18	8.40	300	234	23	-2	11.90	0.1	8.60	283	107	42	-3	11.83	55.2	33.3	West
											35.9	--	357	421	45.1	55	34.3	30	9.40	271	230	16	-2	11.02	-0.3	8.50	271	136	43	-3	11.54	38.0	27.1	East
1125	8/18/96 6:33	60	B	6.08	ARIL	22.0		1.00	6.0	9.8	35.9	1.00	350	424	32.8	42	36.5	11	8.90	285	235	16	-2	11.25	0.1	8.40	289	165	34	-3	11.73	29.2	3.4 Avg	ARILs @ 22°, 6 gpm, N/NO=1.0
											35.9	--	334	429	40.2	52	38.6	9	8.40	300	234	23	-2	11.90	0.1	8.30	296	141	33	-3	12.01	36.7	3.7	West
											35.9	--	357	421	31.8	37	32.8	3	9.40	271	230	16	-2	11.02	-0.3	9.10	276	161	25	-3	11.13	24.3	3.1	East
1126	8/18/96 7 40	60	B	6.14							35.9	--	346	419	--	--	--	--	8.50	291	240	23	-2	11.82	0.8									Baseline Check
1127	8/19/96 23:35	60	C	6.47							35.9	--	386	421	--	--	--	--	9.40	271	249	12	-2	10.74	-0.5									Baseline, C Mill OOS, A Mill +5%,
											35.9	--	392	414	--	--	--	--	9.65	261	247	15	-2	10.47	0.5									West B Mill -10%, B W Fdr +8%,
											35.9	--	378	410	--	--	--	--	9.10	271	250	8	-2	10.99	-1.3									East D Mill +8%
1128	8/20/96 1:43	60	C	6.47	AR/DP	22.0		1.10	4.0	9.8	35.9	1.00	386	421	43.5	47	28.1	28	9.40	271	249	12	-2	10.74	-0.5	9.30	255	142	34	-3	10.70	30.2	18.5 Avg	E.ARIL,W.DPSC,Both22°,N/NO=1
											35.9	--	392	414	40.1	48	30.3	38	9.65	261	247	15	-2	10.47	0.5	9.50	240	150	41	-3	10.60	30.9	23.9	West
											35.9	--	378	410	44.0	49	29.4	2	9.10	271	250	8	-2	10.99	-1.3	9.10	270	140	26	-3	10.94	31.0	13.1	East
1129	8/20/96 4:15	60	C	6.43	AR/DP	45.0		1.10	4.0	9.8	35.9	1.03	375	411	37.3	41	29.2	-3	8.95	275	251	12	-2	10.98	-0.2	9.05	275	156	17	-3	11.19	26.9	1.6 Avg	E.ARIL,W.DPSC,Both45°,N/NO=1
											35.9	--	380	412	34.7	43	32.3	1	9.30	268	247	16	-1	10.87	0.1	9.40	265	160	20	-3	10.84	27.5	2.3	West
											35.9	--	376	406	41.2	44	28.6	-4	8.95	272	252	8	-2	11.00	-1.4	8.80	278	150	14	-3	11.07	28.7	0.9	East
1130	8/20/96 5:30	60	C	6.46							35.9	--	375	411	--	--	--	--	8.95	275	251	12	-2	10.98	-0.2									Baseline Check
											35.9	--	380	412	--	--	--	--	9.30	268	247	16	-1	10.87	0.1									West
											35.9	--	376	406	--	--	--	--	8.95	272	252	8	-2	11.00	-1.4									East
1131	8/20/96 23:20	60	B	6.58							35.9	--	327	420	--	--	--	--	8.95	281	219	18	-1	11.24	-1.2									Baseline, B Mill OOS
											35.9	--	331	424	--	--	--	--	9.10	280	219	13	-1	10.95	-1.7									West
											35.9	--	319	417	--	--	--	--	8.70	285	218	14	0	11.39	-1.6									East
1132	8/21/96 1:10	60	B	6.58	AR/DP	22.0		0.95	4.0	9.8	35.9	1.02	327	420	41.7	40	29.6	0	8.95	281	219	18	-1	11.24	-1.2	9.20	275	125	30	-2	10.72	25.3	20.2 Avg	E.ARIL,W.DPSC,Both22°,N/NO=1
											35.9	--	331	424	42.7	40	28.4	9	9.10	280	219	13	-1	10.95	-1.7	9.05	275	126	38	-2	11.11	25.0	29.1	West
											35.9	--	319	417	41.7	42	31.5	1	8.70	285	218	14	0	11.39	-1.6	9.10	275	123	29	-2	10.78	26.1	11.3	East
1133	8/21/96 3.05	60	B	6.56	AR/DP	34.0		0.95	4.0	9.8	35.9	1.02	327	420	36.9	39	32.7	-1	8.95	281	219	18	-1	11.24	-1.2	9.15	277	136	18	-2	10.74	24.8	1.1 Avg	E.ARIL,W.DPSC,Both34°,N/NO=1
											35.9	--	331	424	38.4	40	31.1	2	9.10	280	219	13	-1	10.95	-1.7	9.00	281	136	19	-1	10.88	24.7	0.8	West
											35.9	--	319	417	33.6	42	38.9	-2	8.70	285	218	14	0	11.39	-1.6	9.35	271	137	20	-2	10.74	25.5	1.4	East
1134	8/21/96 4:25	60	B	6.53	AR/DP	34.0		1.90	4.0	9.8	35.9	2.04	327	420	50.1	60	36.8	20	8.95	281	219	18	-1	11.24	-1.2	9.20	262	107	29	-2	10.69	38.4	21.7 Avg	E.ARIL,W.DPSC,Both34°,N/NO=2
											35.9	--	331	424	54.5	62	34.5	22	9.10	280	219	13	-1	10.95	-1.7	8.95	269	101	33	-2	10.85	39.9	18.4	West
											35.9	--	319	417	50.2	65	40.7	3	8.70	285	218	14	0	11.39	-1.6	9.00	276	106	34	-2	11.12	41.9	24.9	East
1135	8/21/96 5 40	60	B	6.56							35.9	--	325	422	--	--	--	--	9.05	280	216	12	-1	10.86	-0.5									Baseline Check
											35.9	--	312	421	--	--	--	--	8.65	289	214	17	-1	11.34	-0.5									West
											35.9	--	327	410	--	--	--	--	9.15	270	215	11	-1	10.64	-0.8									East

DIAMOND POWER (DPSC) LANCE TESTS

					Urea injection--------								NO	SO2	ΔNO	ΔN2O	ΔN2O	ΔSO2	Economizer Exit, dry (1-12): Base							Economizer Exit, dry (1-12): w/Urea							NH3 Slip	
Test	Date & Time	Load MWe	Mills OOS	O2cr %wet	Level	ARIL Angle	Quads OOS	Urea gpm	Total gpm	Inj air psi	Conc wt%	N/NO	base ppmc	base ppmc	SNCR %	econ ppmc	ΔNO %	econ ppmc	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	O2 %dry	SO2 ppm	NO ppm	CO ppm	NO2 ppm	CO2 %	N2O ppm	AHO comp ppm	Comments
1136	8/21/96 23:05	60	B	6.65							35.9	--	335	415	--	--	--	--	9.25	271	219	15	0	10.87	-2.3									Baseline, B Mill OOS
											35.9	--	335	417	--	--	--	--	9.25	272	219	12	0	10.79	-2.1									West
											35.9	--	337	415	--	--	--	--	9.30	270	219	15	0	11.08	-2.1									East
1137	8/22/96 1:15	60	B	6.61	AR/DP	34.0		0.95	4.0	10.0	35.9	0.99	335	415	34.0	37	32.5	4	9.25	271	219	15	0	10.87	-2.3	9.30	267	144	20	-1	10.59	21.8	3.2 Avg	E. ARIL, W. DPSC w/ feed tube,
											35.9	--	335	417	36.7	40	32.6	0	9.25	272	219	12	0	10.79	-2.1	9.30	271	138	23	-1	10.88	24.0	5.2	West Both 34° ,N/NO=1
											35.9	--	337	415	31.1	35	33.1	2	9.30	270	219	15	0	11.08	-2.1	9.30	269	151	19	-1	10.92	20.4	1.1	East
1138	8/22/96 2:30	60	B	6.60	AR/DP	34.0		1.45	4.0	10.0	35.9	1.52	335	415	40.0	49	36.6	3	9.25	271	219	15	0	10.87	-2.3	9.20	270	132	23	-1	10.90	29.9	8.3 Avg	E. ARIL, W. DPSC w/ feed tube,
											35.9	--	335	417	43.2	52	35.5	12	9.25	272	219	12	0	10.79	-2.1	9.00	270	127	24	-1	10.82	32.2	12.8	West Both 34° ,N/NO=1.5
											35.9	--	337	415	37.3	46	37.0	8	9.30	270	219	15	0	11.08	-2.1	9.50	260	135	20	-1	10.54	27.6	3.8	East
1139	8/22/96 3:55	60	B	6.63	AR/DP	34.0		1.90	4.0	10.0	35.9	1.89	335	415	45.0	58	38.1	18	9.25	271	219	15	0	10.87	-2.3	9.30	258	120	24	-1	10.63	35.1	18.3 Avg	E. ARIL, W. DPSC w/ feed tube,
											35.9	--	335	417	47.0	61	38.9	19	9.25	272	219	12	0	10.79	-2.1	9.05	264	118	26	-2	10.99	38.6	24.2	West Both 34° ,N/NO=2
											35.9	--	337	415	41.4	53	37.7	10	9.30	270	219	15	0	11.08	-2.1	9.60	257	125	22	-2	10.58	31.3	12.3	East
1140	8/22/96 5:20	60	B	6.61							35.9	--	333	419	--	--	--	--	9.10	277	220	13	0	10.93	-1.7									Baseline Check
1141	8/22/96 23:15	60	B	6.60							35.9	--	333	426	--	--	--	--	9.50	272	213	11	-3	10.32	-0.1									Baseline, B Mill OOS
											35.9	--	335	430	--	--	--	--	9.70	270	210	8	-3	10.15	-0.1									West
											35.9	--	343	425	--	--	--	--	9.60	269	217	10	-3	10.02	-0.1									East
1142	8/2/96 23:30	60	B	6.43							35.9	--	346	416	--	--	--	--	9.35	269	224	11	0	10.90	-1.1									Baseline, B Mill OOS
											35.9	--	349	415	--	--	--	--	9.25	271	228	12	0	10.67	-0.6									West
											35.9	--	360	409	--	--	--	--	9.50	261	230	9	0	10.36	-1.7									East
1143	8/25/96 1:15	60	B	6.43	DP	34.0		0.75	2.2	10.0	35.9	0.80	329	412	16.0	22	42.3	-7	8.90	277	221	13	0	11.27	-1.8	9.40	270	178	13	-1	10.69	12.6	AHO1=0.0	W. DPSC w/ feed tube ONLY, 34°
											35.9	--	335	414	31.2	31	29.9	2	8.90	278	225	16	0	11.02	-1.4	9.20	270	151	18	-1	11.16	19.1	AHO2=0.2	West west N/NO = 1.5
											35.9	--	338	401	4.1	12	84.7	-4	9.00	267	225	8	0	11.08	-1.8	9.60	256	205	9	-1	10.39	5.7	AHO3=0.4	East east N/NO = 0
											35.9	--	0	0	--	--	--	--															AHO4=5.5	
											35.9	--	0	0	--	--	--	--															AHO5=0.4	
											35.9	--	0	0	--	--	--	--															AHO6=0.0	
1144	8/25/96 3:40	60	B	6.48	DP	22.0		1.00	2.2	10.0	35.9	1.07	329	412	25.1	35	42.5	15	8.90	277	221	13	0	11.27	-1.8	9.30	258	160	21	-2	10.70	21.1	AHO1=25.9	W. DPSC w/feed tube ONLY, 22°, w/
											35.9	--	335	414	46.7	58	37.4	18	8.90	278	225	16	0	11.02	-1.4	9.00	264	119	27	-2	10.94	37.6	AHO2=34.4	West lance retracted 18"
											35.9	--	338	401	4.6	6	50.4	1	9.00	267	225	8	0	11.08	-1.8	9.20	262	211	9	-1	10.37	3.4	AHO3=12.7	East west & east N/NO = 2.0 & 0.0
											35.9	--	0	0	--	--	--	--															AHO4=0.7	
											35.9	--	0	0	--	--	--	--															AHO5=0.0	
											35.9	--	0	0	--	--	--	--															AHO6=0.5	
1145	8/25/96 6:40	60	B	6.46	DP	22.0		1.00	2.2	10.0	35.9	1.07	329	412	27.3	36	40.0	3	8.90	277	221	13	0	11.27	-1.8	9.25	267	156	21	-1	10.78	21.7	AHO1=19.5	W. DPSC w/feed tube ONLY, 22°, w/
											35.9	--	335	414	42.4	52	36.5	13	8.90	278	225	16	0	11.02	-1.4	9.05	266	126	29	-2	11.11	33.0	AHO2=18.3	West lance @ norm position
											35.9	--	338	401	10.3	16	45.1	-5	9.00	267	225	8	0	11.08	-1.8	9.40	261	195	14	-1	10.63	8.4	AHO3=7.2	East west & east N/NO = 2.0 & 0.0
											35.9	--	0	0	--	--	--	--															AHO4=7.4	
											35.9	--	0	0	--	--	--	--															AHO5=0.5	
											35.9	--	0	0	--	--	--	--															AHO6=0.6	
1146	8/25/96 8:30	60	B	6.46							35.9	--	329	412	--	--	--	--	8.90	277	221	13	0	11.27	-1.8									Baseline Check
											35.9	--	335	414	--	--	--	--	8.90	278	225	16	0	11.02	-1.4									West
											35.9	--	338	401	--	--	--	--	9.00	267	225	8	0	11.08	-1.8									East
1147	8/25/96 23:05	60	C	5.97							35.9	--	348	415	--	--	--	--	8.85	280	235	10	-1	11.40	-1.5									Baseline, C Mill OOS
											35.9	--	386	410	--	--	--	--	9.80	255	240	10	-1	10.38	-0.9									West
											35.9	--	332	407	--	--	--	--	8.00	294	240	9	-1	11.67	-1.5									East
1148	8/26/96 1:30	60	C	5.97	AR/DP	22/34		1.00	4.5	10.0	35.9	1.01	348	415	26.6	24	26.4	3	8.85	280	235	10	-1	11.40	-1.5	8.75	280	174	15	-2	11.05	15.1	1.2 Avg	E. ARIL @ 22°, W. DPSC w/ feed
											35.9	--	386	410	33.9	29	22.6	-2	9.80	255	240	10	-1	10.38	-0.9	9.50	263	163	18	-2	10.40	17.9	0.4	West tube @ 34° ,N/NO=1
											35.9	--	332	407	23.8	18	22.9	-2	8.00	294	240	9	-1	11.67	-1.5	7.85	299	165	12	-2	12.06	11.7	2.0	East
1149	8/26/96 2:55	60	C	5.95	AR/DP	22/34		1.50	4.7	10.0	35.9	1.51	348	415	32.2	35	30.9	-1	8.85	280	235	10	-1	11.40	-1.5	8.80	282	160	18	-2	11.21	22.0	2.5 Avg	E. ARIL @ 22°, W. DPSC w/ feed
											35.9	--	386	410	39.3	48	31.4	-8	9.80	255	240	10	-1	10.38	-0.9	9.85	259	145	24	-3	10.22	28.6	3.9	West tube @ 34° ,N/NO=1.5
											35.9	--	332	407	26.8	24	26.9	-4	8.00	294	240	9	-1	11.67	-1.5	7.90	299	177	10	-2	11.78	15.9	1.1	East
1150	8/26/96 4:05	60	C	5.96	AR/DP	22/34		2.00	4.6	10.0	35.9	2.01	348	415	33.6	39	33.5	-3	8.85	280	235	10	-1	11.40	-1.5	8.85	282	156	20	-3	11.30	25.0	AHO1=9.5	E. ARIL @ 22°, W. DPSC w/ feed
											35.9	--	386	410	43.0	51	30.8	2	9.80	255	240	10	-1	10.38	-0.9	9.45	262	141	26	-3	10.63	31.9	AHO2=16.1	West tube @ 34° ,N/NO=2
											35.9	--	332	407	26.8	29	32.7	-4	8.00	294	240	9	-1	11.67	-1.5	7.90	299	177	13	-3	12.08	19.7	AHO3=12.8	East
											35.9	--	0	0	--	--	--	--															AHO4=1.5	
											35.9	--	0	0	--	--	--	--															AHO5=0.8	
											35.9	--	0	0	--	--	--	--															AHO6=0.4	
1151	8/26/96 5:40	60	C	5.97							35.9	--	347	422	--	--	--	--	8.60	291	239	12	-2	11.52	-0.5									Baseline Check