INTEGRATED DRY NO_x/SO_2 EMISSIONS CONTROL SYSTEM

SODIUM-BASED DRY SORBENT INJECTION TEST REPORT

(Test Period: August 4, 1993 to July 29, 1995)

DOE Contract Number DE-FC22-91PC90550

Prepared by

R. A. Smith
G. H. Shiomoto
L. J. Muzio
Fossil Energy Research Corp.
Laguna Hills, CA

T. Hunt
Public Service Company of Colorado
Denver, CO

Prepared for

Public Service Company of Colorado
Denver, CO

Draft: November 1994
Revised: January 1997
Final: April 1997

Patents Cleared by Chicago on MAY 2 3 1997

DISCLAIMER

ABSTRACT

The DOE sponsored Integrated Dry NO_x/SO_2 Emissions Control System program, is a Clean Coal Technology III demonstration, 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 emissions 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.

This report documents the sixth phase of the test program, where the performance of dry sorbent injection with sodium compounds was evaluated as a SO_2 removal technique. Dry sorbent injection was performed "in-duct" downstream of the air heater (ahead of the fabric filter), as well as at a higher temperature location between the economizer and air heater. Two sodium compounds were evaluated during this phase of testing: sodium sesquicarbonate and sodium bicarbonate. In-duct sodium injection with low levels of humidification was also investigated. This sixth test phase was primarily focused on a parametric investigation of sorbent type and feed rate, although boiler load and sorbent preparation parameters were also varied.

The in-duct injection of sodium sesquicarbonate achieved the target 70 percent SO_2 emission reduction at normalized stoichiometric ratios ranging from approximately 1.6 to 2.2. (The stoichiometric ratio is 2 moles of sodium per mole of sulfur). The data exhibit day-to-day variations which were attributable to the sorbent feed system which utilized volumetric screw feeders.

Sodium bicarbonate injection ahead of the fabric filter showed variable SO_2 removal characteristics which were attributed to the relatively low temperatures at the fabric filter inlet (i.e., on the order of 230 to 270°F). Injection of sodium bicarbonate at the air heater inlet, where the temperatures were on the order of 600°F, showed more consistent SO_2 removals. Under these conditions, sodium bicarbonate yielded a 70 percent SO_2 removal at a 2Na/S ratio of approximately 1.1.

A byproduct of the sodium/SO_2 chemistry is the oxidation of NO to NO_2, which may result in plume visibility. The NO_2 production with sodium sesquicarbonate was less than with sodium bicarbonate. However, on some occasions, a faint visible plume was observed. The test program showed that NO_2 levels were not only dependent on the type and amount of sodium compound injected, but also on the fabric filter cleaning cycle. After each cleaning cycle, the NO_2 emissions increased markedly.

A long-term test of nominally four months was conducted with sodium sesquicarbonate injection ahead of the fabric filter. A rolling average SO_2 removal of 40 percent was easily maintained for the duration of the test. Average NO_2 emissions during this test were 6.7 ppm and there were no occurrences of a brown plume at the stack.

A four-week 70 percent removal test with sodium sesquicarbonate injection ahead of the fabric filter fell just short of the goal, with an average SO_2 removal of 67.9 percent. System availability during this test was only 94 percent primarily due to a 32-hour period when neither of the two sorbent injection systems were in service. The average NO_2 emissions during this test were 15.2 ppm, and a faint brown plume was visible on several occasions.

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, Mr. Tom Arrigoni, and Mr. Tim McIlvried of PETC DOE, whose contributions are greatly appreciated. We are all saddened by Tom Arrigoni's and Tim McIlvried's deaths in the USAir accident. The advice and technical assistance provided by Mr. Jeff Stallings and Ms. Barbara Toole-O'Neil at EPRI have 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.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Section **Page**

Appendices

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF DEFINITIONS

B&W	Babcock & Wilcox
CEM	Continuous Emission Monitor
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
FERCo	Fossil Energy Research Corp.
FFDC	Fabric Filter Dust Collector
ID	Induced Draft (fan)
LNB	Low-NO_x Burner
MMD	Mass Mean Diameter
MWe	MegaWatts (electrical)
OFA	OverFire Air
ppm	Parts Per Million
ppmc	Parts Per Million Corrected to 3 percent O_2 level, dry
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
T_{app}	Approach to Saturation Temperature
2Na/S	Sodium-to-Sulfur Ratio

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

This report presents the results of the sodium injection tests performed after the combustion system retrofit on the Arapahoe Unit 4 boiler. The SO_2 removal performance of the sodium sorbents was evaluated with the in-duct dry injection system. The primary injection location was downstream of the air preheater, at the inlet of the fabric filter dust collector. Two sodium-based dry sorbents were tested, sodium sesquicarbonate and sodium bicarbonate. Unlike the previously tested calcium sorbents, the sodium compounds were processed through an attrition mill prior to injection, in order to reduce the particle size and increase the SO_2 removal effectiveness. Humidification was briefly tested with sodium sesquicarbonate by atomizing water into the flue gas, and cooling the average gas temperatures closer to the saturation point. Both sodium reagents were injected at two locations: in-duct (downstream of the air heater ahead of the fabric filter) and at a higher temperature location at the inlet to the air heater. Parametric testing of the sodium injection system was conducted during the period of August 4, 1993 to May 27, 1994.

The primary operating parameter for the sodium injection processes was the normalized stoichiometric ratio, which is the amount of sorbent injected relative to the mass flow of sulfur in the flue gas. The chemical reactions require two molecules of sodium to react with each molecule of sulfur (SO_2), therefore the normalized stoichiometric ratio is expressed as 2Na/S, where a unity value is equivalent to the stoichiometric concentration. Parametric variations of the 2Na/S ratio, sorbent type, and boiler load were performed for the sodium injection tests. In the cases when humidification was utilized, the primary operating variable was the approach to saturation temperature of the flue gas. Saturation temperatures of the flue gas ranged from 112 to 118°F, depending on boiler operating conditions. During these tests, the humidification system was used to vary the approach to saturation from 50 to 90°F.

With a nominal 2Na/S ratio of 2.0, the SO_2 removals with in-duct sodium sesquicarbonate injection ranged from 64 to 78 percent (Figure ES-1). Alternatively, the 2Na/S ratio required for 70 percent SO_2 removal ranged from 1.6 to 2.2. Sorbent utilization decreased with increasing sorbent injection rates, as shown by the tapering off of the SO_2 removals as the 2Na/S ratio was increased to higher levels. The scatter apparent in Figure ES-1 represents day-to-day variations that were seen in the process. It is believed that a large portion of these variations resulted from day-to-day changes in sorbent feed rate and not the effectiveness of the process at a given 2Na/S ratio. Since the sorbent feed was based on the calibration of a volumetric screw system, any loss in feed capacity could not be readily detected. This would cause the actual 2Na/S to be lower than the set point.

The in-duct injection of sodium bicarbonate showed erratic results which are attributed to the relatively low flue gas temperatures at the fabric filter inlet (i.e., approximately 230 to 270°F). Since the operating temperatures for the duct and baghouse at Arapahoe

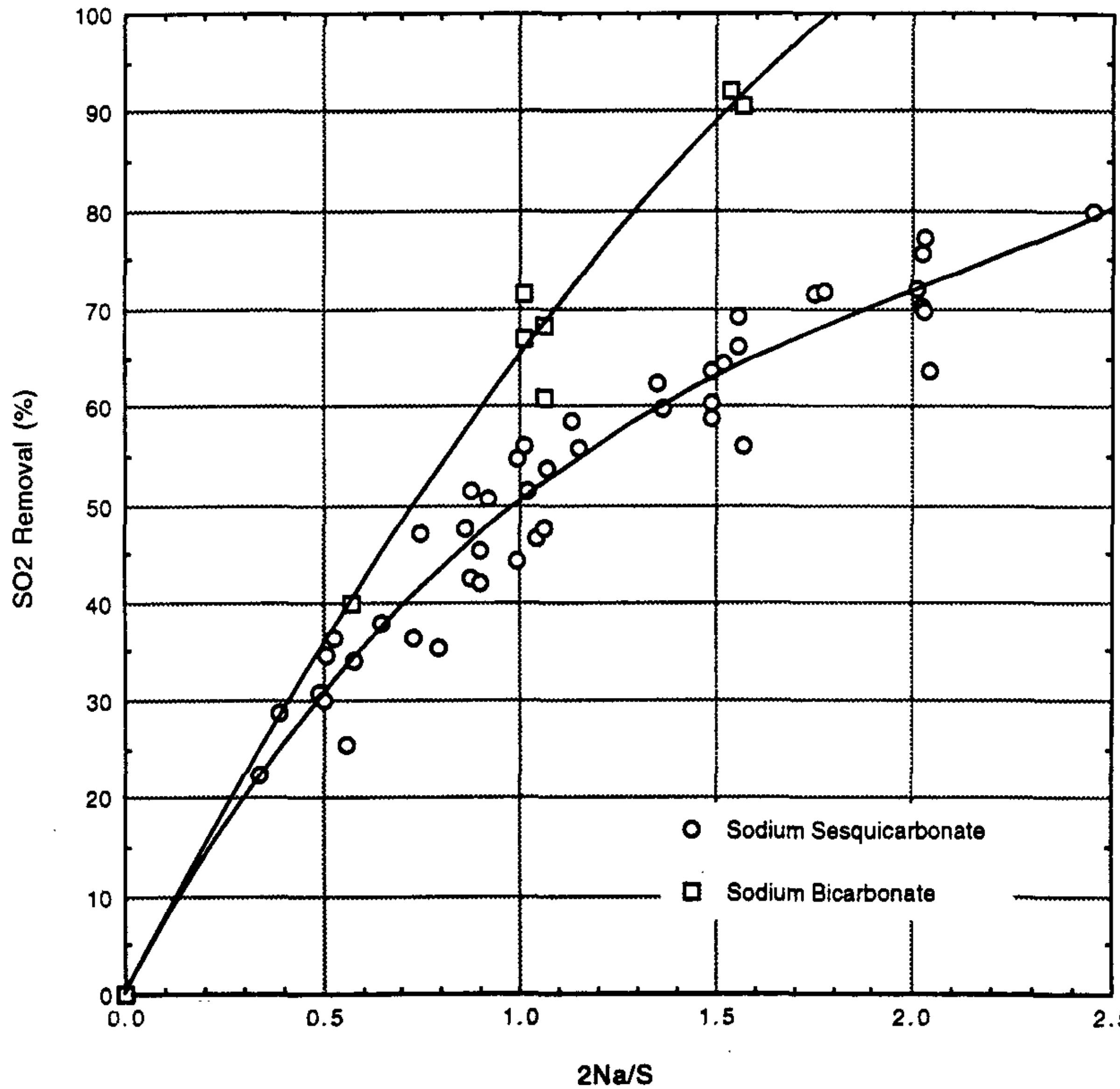


Figure ES-1. Comparison of SO_2 Removals for Injection of Sodium Sesquicarbonate (Fabric Filter Inlet) and Sodium Bicarbonate (Air Heater Inlet)

Unit 4 were on the low side for optimum use of sodium bicarbonate, modifications were made and additional testing was conducted with injection at the economizer exit (air heater inlet) during April and May 1994. These results were more consistent than those for duct injection and showed that a 2Na/S ratio of approximately 1.1 was required for a 70 percent SO_2 removal (Figure ES-1).

There were no apparent problems associated with the use of the sodium injection system with regard to the operation of the boiler or any cold-end equipment. Chronic problems with sorbent feed, injection system deposit formation and plugging, and sorbent pulverizer operation were encountered throughout the test program. However, all of these problems are deemed manageable by routine maintenance procedures.

In addition to determining the SO_2 removals achievable with the injection of sodium sesquicarbonate and sodium bicarbonate, the evaluation of the impact of the sodium compounds on NO_2 emissions and NO_x removal was also an important element of this test phase. One of the more interesting observations from the current test program was the process dynamics of NO_2 formation with sodium injection. Time-resolved measurements showed that the NO_2 emissions were not only dependent on the amount of sodium injected but also on the cleaning cycle of the Arapahoe Unit 4 fabric filter. With both sodium sesquicarbonate and sodium bicarbonate, the NO_2 emissions were found to increase markedly just after a cleaning cycle. This suggests that there is an interaction between the NO_2 and the fly ash. This was further confirmed by measurements made in each individual fabric filter compartment which showed that the NO_2 levels were not just a function of the SO_2 removal in each compartment, but also appeared to be related to the amount of fly ash collected in each compartment. This phenomena accounts for the high degree of variability in NO_2 emissions and NO_x reductions reported not only in this test program, but in previously reported full-scale sodium injection demonstrations (Fuchs, et al., 1989; Muzio, et al., 1984).

In terms of the levels of NO_2 produced, sodium sesquicarbonate produced NO_2 levels of nominally 10 ppm at a nominal 2Na/S ratio of 2.0 (although there were a few occasions where the NO_2 level reached almost 30 ppm). The NO_2 levels with sodium bicarbonate injection were generally higher. At a nominal 2Na/S ratio of 1.0, NO_2 levels with sodium bicarbonate injection were nominally 20 ppm with levels occasionally reaching 50 ppm. No plume coloration was noted with sodium sesquicarbonate injection, although some plume coloration was observed with sodium bicarbonate injection when NO_2 levels exceeded 35 ppm.

At injection rates providing 70% SO_2 removal, both sodium sorbents resulted in NO_x removals of nominally 10 percent. These levels are consistent with those reported in the previous full-scale demonstrations mentioned above (Fuchs, et al., 1989; Muzio, et al., 1984).

After completion of the parametric tests with both sorbents, a long-term test of nominally four months duration was conducted with sodium sesquicarbonate injection ahead of the fabric filter. During this test, the control system was set to achieve a 40 percent SO_2 removal. Daily average SO_2 removals of 40 percent were easily achievable during the four-month period, although there were brief periods when the sodium injection system was off-line due to minor problems with plugging the sorbent transport lines or system maintenance requirements.

Following completion of the four-month test, a second long-term test was run with a SO_2 removal setpoint of 70 percent. This test was run for four weeks and ended when Arapahoe Unit 4 was taken off-line for a scheduled 10-week outage. At the end of the test, the rolling average SO_2 removal was 67.9 percent, just short of the goal of 70 percent. A number of mechanical problems resulted in a system availability of only 94 percent for the four-week test. During this high SO_2 removal test period there were a few occasions when the NO_2 levels caused a slightly visible plume. This was the first time that a visible NO_2 plume was encountered during the test program.

1.0 INTRODUCTION

This report presents the results from one phase of the Public Service Company of Colorado (PSCo) and the Department of Energy (DOE) sponsored Integrated Dry NO_x/SO_2 Emissions Control System program. The DOE Clean Coal Technology III demonstration program is being conducted by Public Service Company of Colorado at PSCo's Arapahoe Generating Station Unit 4, located in Denver, Colorado. The intent of the demonstration program at Arapahoe Unit 4 is to achieve up to 70 percent reductions in NO_x and SO_2 emissions through the integration of existing and emerging technologies, while minimizing capital expenditures and limiting waste production to dry solids that are handled with conventional ash removal equipment. The technologies to be integrated are: 1) a down-fired low-NO_x burner system with overfire air; 2) Selective Non-Catalytic Reduction (SNCR) with urea and ammonia-based compounds for additional NO_x removal; and 3) dry sorbent injection (calcium- and sodium-based compounds) and duct humidification for SO_2 removal. Figure 1-1 shows a simplified schematic of the integrated system as implemented at Arapahoe Unit 4.

During the demonstration program, these emissions control systems are being optimized and integrated with the goal of achieving up to 70 percent reductions in NO_x and SO_2. It is anticipated that the emissions control system will achieve these reductions at costs lower than other currently available technologies. It is also anticipated that these technologies will integrate synergistically. For example, an undesirable side effect of sodium-based sorbent injection for SO_2 control has been oxidation of NO to NO_2, resulting in plume colorization. Pilot-scale testing, sponsored by the Electric Power Research Institute (EPRI), has shown that the presence of NH_3 can reduce the NO_2 emissions from sodium-based dry sorbent injection. In the integrated system, the byproduct NH_3 emissions from the urea injection system will serve to minimize NO_2 formation.

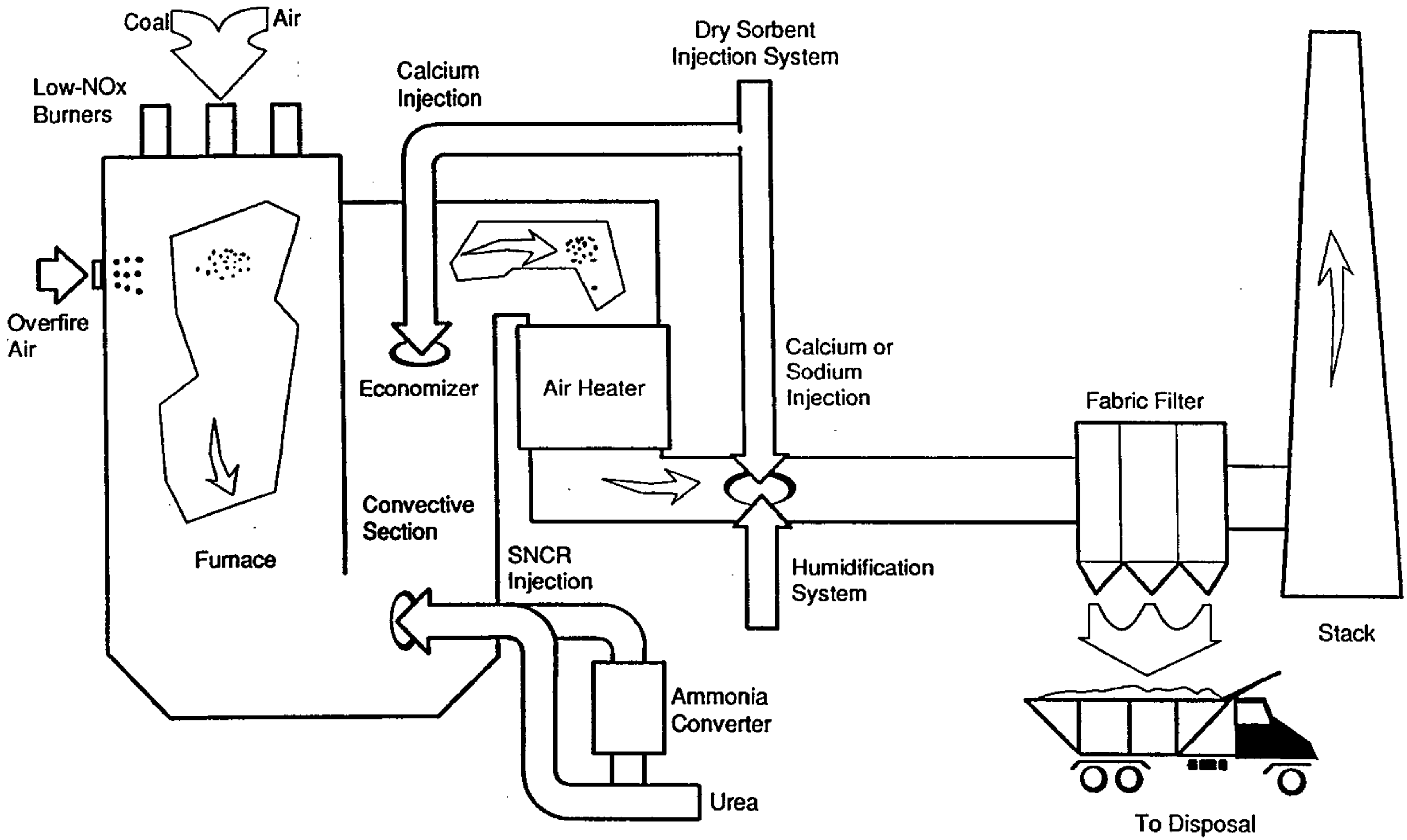


Figure 1-1. Arapahoe Unit 4 Integrated Dry NO_x/SO_2 Emissions Control System

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

- Baseline tests of the original combustion system. These results provide the basis for comparing the performance of the individual technologies as well as that of the integrated system. (completed, Shiomoto, et al., 1992)
- Baseline combustion system/SNCR tests. Performance of urea and aqueous ammonia injection with the original combustion system. (completed, Smith, et al., 1993)
- Low-NO_x burner (LNB)/overfire air (OFA) tests. (completed, Smith, et al., 1994a)
- LNB/OFA/SNCR tests. NO_x reduction potential of the combined low-NO_x combustion system and SNCR. (completed, Smith, et al., 1994b)
- LNB/OFA/calcium-based sorbent injection. Economizer injection and duct injection with humidification. (completed, Shiomoto, et al., 1994)
- LNB/OFA/sodium injection. SO_2 removal performance of sodium-based sorbents. (subject of this report)
- Integrated Systems test. NO_x and SO_2 reduction potential of the integrated system using LNB/OFA/SNCR/Dry Sorbent Injection (with calcium- or sodium-based reagents).

In addition to the investigation of NO_x and SO_2 emissions, the test program also investigated air toxic emissions. Air toxic emission levels were measured during the testing of the low-NO_x combustion system, and during the LNB/OFA/SNCR tests with urea. Air toxics emission levels were also measured during the calcium injection tests, and additional tests were conducted during the sodium injection tests to determine the potential air toxics removal of these two pollution control technologies. The air toxics test results will be documented in separate Environmental Monitoring Reports.

This report presents the results of the dry sorbent injection tests with sodium-based sorbents. These tests included the use of sodium sesquicarbonate and sodium bicarbonate injection both downstream and upstream of the air heater. A limited number of sodium sesquicarbonate injection tests were performed with the use of the humidification system to enhance SO_2 removal.

2.0 PROJECT DESCRIPTION

The following subsections will describe the key aspects of all the technologies being demonstrated as a part of the Integrated Dry NO_x/SO_2 Emissions control system program. The project participants and their relative roles are also reviewed.

2.1 Process Description

The Integrated Dry NO_x/SO_2 Emissions Control system consists of five major control technologies that are combined to form an integrated system to control both NO_x and SO_2 emissions. NO_x reduction is accomplished through the use of low-NO_x burners, overfire air, and SNCR, while dry sorbent injection (using either calcium- or sodium-based reagents) is used to control SO_2 emissions. Flue gas humidification will be used to enhance the SO_2 removal capabilities of the calcium-based sorbents. Each of these technologies is discussed briefly below.

2.1.1 Low-NO_x Burners

NO_x formed during the combustion of fossil fuels consists primarily of NO_x formed from fuel-bound nitrogen, and thermal NO_x. NO_x formed from fuel-bound nitrogen results from the oxidation of nitrogen which is organically bonded to the carbon in the fuel. Thermal NO_x forms when nitrogen in the combustion air dissociates and oxidizes at flame temperatures. Thermal NO_x is of primary importance at temperatures in excess of 2800°F.

To reduce the NO_x emissions formed during the combustion process, Babcock and Wilcox (B&W) Dual Register Burner-Axially Controlled Low-NO_x (DRB-XCL®) burners were retrofit to the Arapahoe Unit 4 boiler. Most low-NO_x burners reduce the formation of NO_x through the use of air staging, which is accomplished by limiting the availability of air during the early stages of combustion. This lowers the peak flame temperature and results in a reduction in the formation of thermal NO_x. In addition, by reducing the oxygen availability in the initial combustion zone, the fuel-bound nitrogen is less likely to be converted to NO_x, but rather to N_2 and other stable nitrogen compounds. The B&W DRB-XCL® burner achieves increased NO_x reduction effectiveness by incorporating fuel staging in addition to air staging. Fuel staging involves the introduction of fuel downstream of the flame under fuel-rich conditions. This results in the generation of hydrocarbon radicals which further reduce NO_x levels. The fuel staging is accomplished through the design of the coal nozzle/flame stabilization ring on the burner. Additionally, combustion air to each burner is accurately measured and regulated to provide a balanced fuel and air distribution for optimum NO_x reduction and combustion efficiency. Finally, the burner assembly is equipped with two sets of adjustable spin vanes which provide swirl for fuel/air mixing and flame stabilization.

2.1.2 Overfire Air

Low-NO_x burners and overfire air reduce the formation of NO_x by controlling the fuel/air mixing process. While low-NO_x burners control the mixing in the near-burner region, overfire air controls the mixing over a larger part of the furnace volume. By diverting part of the combustion air to a zone downstream of the burner, initial combustion takes place in a near stoichiometric or slightly fuel rich environment. The remaining air necessary to ensure complete combustion is introduced downstream of the primary combustion zone through a set of overfire air ports, sometimes referred to as NO_x ports. Conventional single-jet overfire air ports are not capable of providing adequate mixing across the entire furnace. The B&W dual-zone NO_x ports, however, incorporate a central zone which produces an air jet that penetrates across the furnace and a separate outer zone that diverts and disperses the air in the area of the furnace near the NO_x port. The central zone is provided with a manual air control disk for flow control, and the outer zone incorporates manually adjustable spin vanes for swirl control.

The combined use of the low-NO_x burners and overfire air ports was expected to reduce NO_x emissions by up to 70 percent.

2.1.3 Selective Non-Catalytic Reduction

NO_x reduction in utility boilers can also be accomplished by Selective Non-Catalytic Reduction (SNCR). This 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, NH_2 is released from the injected chemical which then selectively reacts with NO in the presence of oxygen, forming primarily N_2 and H_2O. An SNCR system is capable of removing 40 to 50 percent of the NO from the flue gas stream.

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 2-1. At temperatures above the optimum, the injected chemical will react with 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 NH_3 emissions (referred to as ammonia slip). Chemical additives can be injected with the urea to widen the optimum temperature range and minimize NH_3 emissions.

The SNCR chemical of primary interest for the present program is urea. The urea is generally injected into the boiler as a liquid solution through atomizers. The atomizing medium can be either air or steam, although air is used in the current installation. The urea and any additives are stored as a liquid and pumped through the injection atomizers. At Arapahoe Unit 4, a system has also been installed to catalytically convert the urea solution to ammonium compounds. The urea solution can be either injected directly into the furnace or processed through the catalytic system prior to injection.

2.1.4 Dry Sorbent Injection System

The dry sorbent injection (DSI) system consists of equipment for storing, conveying, pulverizing and injecting calcium- or sodium-based reagents into the flue gas between the

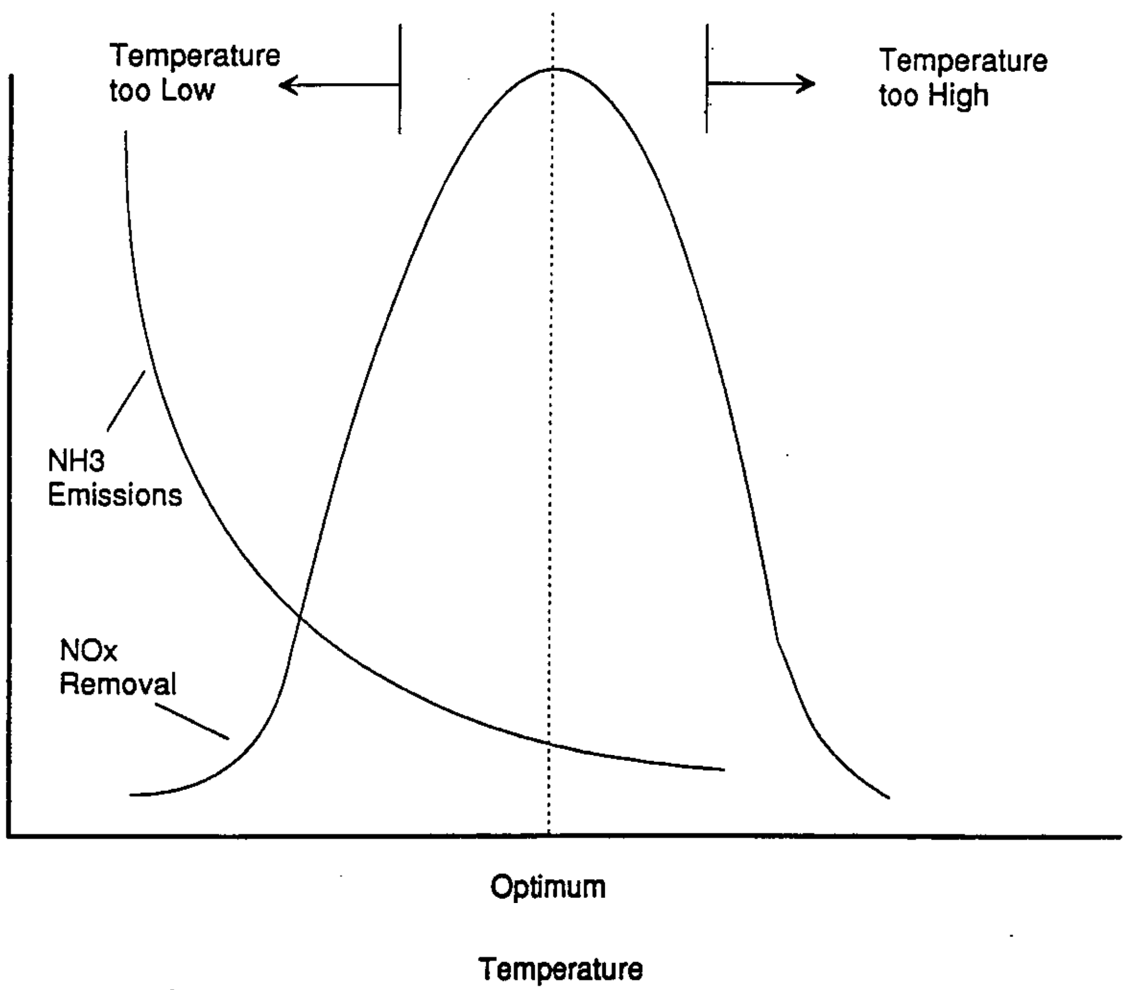


Figure 2-1. Conceptual Temperature Window for the SNCR Process

air heater and the particulate removal equipment, or calcium-based reagents upstream of economizer. The SO_2 formed during the combustion process reacts with the sodium- or calcium-based reagents to form solid sulfites and sulfates. These reaction products are collected in the particulate removal equipment together with the flyash and any unreacted reagent, and then removed for disposal. The system is expected to remove up to 70 percent of the SO_2 when using sodium-based products while maintaining high sorbent utilization.

Although sodium-based DSI systems reduce SO_2 emissions, NO_2 formation has been observed in some applications. NO_2 is a red/brown gas; therefore, a visible plume may form as NO_2 in flue gas exits the stack. Previous pilot-scale tests have shown that ammonia slip from urea injection reduces the formation of NO_2 while removing the ammonia which would otherwise exit the stack.

In certain areas of the country, it may be more economically advantageous to use calcium-based reagents, rather than sodium-based reagents, for SO_2 removal. SO_2 removal using calcium hydroxide ($Ca(OH)_2$) involves dry injection of the reagent into the furnace at a point where the flue gas temperature is approximately 1000°F. $Ca(OH)_2$ materials can also be injected into the flue gas ductwork downstream of the air heater, but at reduced SO_2 removal effectiveness.

2.1.5 Humidification

The effectiveness of calcium hydroxide in reducing SO_2 emissions when injected downstream of the air heater can be increased by flue gas humidification. Flue gas conditioning by humidification involves injecting water into the flue gas downstream of the air heater and upstream of any particulate removal equipment. The water is injected into the duct by dual-fluid atomizers which produce a fine spray that can be directed downstream and away from the duct walls. The subsequent evaporation causes the flue gas to cool, thereby decreasing its volumetric flowrate and increasing its relative and absolute humidity. It is important that the water be injected in such a way as to prevent it from wetting the duct walls and to ensure complete evaporation before the gas enters the particulate removal equipment or contacts the duct turning vanes. Since calcium hydroxide is not as reactive as the sodium-based reagents, the presence of water in the flue gas, which contains unreacted reagent, provides for additional SO_2 removal. Up to 50 percent SO_2 removal is expected when $Ca(OH)_2$ is used in conjunction with flue gas humidification.

2.2 Project Participants

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. (Appendix A contains a synopsis of their work.) 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.

3.0 DRY SORBENT INJECTION AND HUMIDIFICATION SYSTEM DESCRIPTION

The dry sorbent injection (DSI) system consists of a redundant system designed for the delivery of calcium- or sodium-based materials into the duct work between the air heater and the fabric filter. The redundant system includes two separate systems, including storage silos, feeders, pulverizers, and delivery systems. In addition to the fabric filter inlet injection location, temporary injectors were also installed at the air heater inlet to inject sodium bicarbonate at higher flue gas temperatures.

The DSI and the duct humidification systems were added to the existing Arapahoe Unit 4 boiler and flue gas duct work, and required no major modifications beyond adding access into the existing flow system. The original Unit 4 electrostatic precipitators had been removed and a new reverse-gas fabric filter and induced draft (ID) fans were installed in 1985. A retrofit fabric filter dust collector (FFDC) was relocated in back of the common stack for Units 3 and 4 and required a long duct that connected the fabric filter inlet with the existing air heater exit. This air heater exit duct provided the site for both duct sorbent injection and humidification.

3.1 Process Chemistry

Details of the chemical and physical processes which occur between sodium-based sorbents and SO_2 are currently not well understood. In terms of the chemical processes, it is generally thought that SO_2 reacts directly with sodium carbonate (Na_2CO_3). Previous work (Muzio, et al., 1984), proposed that the overall chemical mechanisms for the two sorbents investigated during the current phase of testing are as follows:

Sodium Bicarbonate

$$2NaHCO_3 \text{ ----> } Na_2CO_3 + H_2O + CO_2 \quad \text{(Eqn. 3-1)}$$

$$Na_2CO_3 + SO_2 + 1/2O_2 \text{ ----> } Na_2SO_4 + CO_2 \quad \text{(Eqn. 3-2)}$$

Sodium Sesquicarbonate

$NaHCO_3 \cdot Na_2CO3 \cdot 2H_2O \text{ ----> } NaHCO3 \cdot Na_2CO_3 + 2H_2O$ (Eqn. 3-3)

$2(NaHCO_3 \cdot Na_2CO_3) \text{ ----> } 3Na_2CO_3 + H_2O + CO_2$ (Eqn. 3-4)

$Na_2CO_3 + SO_2 + 1/2O_2 \text{ ----> } Na_2SO_4 + CO_2$ (Eqn. 3-2)

The sodium bicarbonate mechanism consists of two steps. In the first, a high surface area Na_2CO_3 particle is created through the release of H_2O and CO_2. This decomposition is followed by the sulfation reaction, with the final product being sodium sulfate (Na_2SO_4). There has also been speculation that overall utilization is enhanced by having the decomposition step and sulfation step occur simultaneously in the duct. During the current test series, it was found (consistent with previous studies) that the overall reaction between sodium bicarbonate and SO_2 was highly sensitive to flue gas temperature. As will be addressed in more depth below, it is believed that the endothermic decomposition step (Eqn. 3-1) is likely responsible for this temperature sensitivity.

The mechanism for sodium sesquicarbonate consists of three steps, where the last two are very similar to the two discussed above for the sodium bicarbonate mechanism. It is speculated that the initial release of the two water molecules (Eqn. 3-3) "opens-up" the pore structure of the particle, thereby allowing reaction to occur between SO_2 and the Na_2CO_3 component. This initial dehydration reaction is thought to occur at relatively low temperatures (on the order of 120°F). Results of the current series of tests seem to confirm this hypothesis, as they have shown that the overall reaction between sodium sesquicarbonate and SO_2 occurs rapidly and is relatively insensitive to flue gas temperature.

As the sodium compounds react with SO_2, there are parallel reactions that result in the oxidation of NO to NO_2 with some NO_x removal. While the NO_x removal is an added benefit of the dry sorbent injection process, the oxidation of NO to NO_2 can pose operational problems. NO is a colorless gas which has no impact on plume visibility.

However, NO_2 is a brown gas that, depending on the concentration, can result in plume visibility. In the case of particulate matter, a plume becomes visible due to light scattering from the particulate matter in the plume. The mechanism is different for the coloration due to NO_2. NO_2 in the plume tends to absorb all visible wavelengths of light except the red wavelengths. The transmitted red wavelengths then give the plume its brownish appearance. The amount absorbed depends on the product of the NO_2 concentration times the diameter of the plume. Lindau (1991) proposed the following equation to calculate the effect of NO_2 on opacity:

$$\text{Opacity (\%)} = 100[1-\exp(-0.000101 \times NO_2 \times D)]$$

NO_2 = NO_2 concentration, ppm

D = stack diameter, feet

For a utility boiler stack diameter of 20 feet, an NO_2 concentration of 25 ppm, the above equation predicts an opacity of 5%. This is only an approximate value, as plume visibility is extremely complex and depends not only on the stack diameter and NO_2 concentration, but also on the background conditions, view angle relative to the sun, etc.

The detailed chemistry resulting in NO to NO_2 oxidation and NO_x removal is not well understood. The most comprehensive study of the $Na/SO_2/NO_x$ interaction was performed by Verlaetent et al., 1993. They proposed the following reaction sequence to explain the removal of SO_2 and NO_x with sodium bicarbonate.

$$NaHCO_3 + SO_2 \text{ ----> } NaHSO_3 + CO_2 \quad \text{(Eqn. 3-5)}$$

$$2NaHSO_3 \text{ ----> } Na_2S_2O_5 + H_2O \quad \text{(Eqn. 3-6)}$$

$$Na_2S_2O_5 + 2NO + O_2 \text{ ----> } NaNO_2 + NaNO_3 + 2SO_2 \quad \text{(Eqn. 3-7)}$$

$$2NaHSO_3 + 2NO + O_2 \text{ ----> } NaNO_2 + NaNO_3 + 2SO_2 + H_2O \quad \text{(Eqn. 3-8)}$$

In this mechanism, SO_2 behaves as a catalyst by helping the formation of sodium-nitrogen compounds. It is believed that the product $NaNO_2$ is unstable, and is therefore rapidly converted to carbonate and nitrate via the following reactions:

$$NaNO_2 + 1/2CO_2 + 1/2O_2 \text{ ----> } \tfrac{1}{2}(Na_2CO_3) + NO_2 \quad \text{(Eqn. 3-9)}$$

$$NaNO_2 + 1/2O_2 \text{ ----> } NaNO_3 \quad \text{(Eqn. 3-10)}$$

It must be emphasized that the above mechanisms are only speculation and must be more completely evaluated prior to acceptance. However, these mechanisms provide a preliminary framework on which to structure explanations regarding differences in SO_2 and NO removal, as well as NO_2 production, characteristics of the two sodium-based sorbents.

In a parallel effort to the full-scale tests at Arapahoe Unit 4, a fundamental study of the sodium/SO_2/NO_x chemistry was conducted by the Colorado School of Mines (Lai, et al., 1994). The goal of the study was to gain a better understanding of the detailed chemistry in terms of SO_2 and NO_x removal, as well as NO_2 formation. The study involved both bench-scale experiments and chemical kinetic modeling. The results of this study support Verlaetent, et al.'s (1991) mechanism involving $Na_2S_2O_5$ as the key intermediate (Eqn. 3-7). A synopsis of this study is provided in Appendix A of this report.

As mentioned above, the overall temperature dependence of the sodium bicarbonate-SO_2 reactions are thought to be due to the thermal decomposition of sodium bicarbonate. This decomposition was studied by Keener, et al., 1985, using a shrinking core model. Using this model the decomposition time is given by:

$$t = \frac{\rho_A M_c d_s}{2kM_A} \qquad \text{(Eqn. 3-11)}$$

ρ_a = density of sodium bicarbonate
M_c = molecular weight of CO_2
d_s = initial diameter of sodium bicarbonate particle, cm
M_A = molecular weight of sodium bicarbonate
k = reaction rate constant
= $Ae^{-E/RT}$
$A = 4.91\times10^4$ g/cm^2 sec
E = 20,500 cal/g-mole
T = temperature, °K

Using this model, the decomposition time for sodium bicarbonate is shown as a function of particle size and temperature in Figure 3-1. The figure shows that below 300°F, decomposition time increases dramatically as the temperature decreases. For instance, at 250°F, a 20 micron sodium bicarbonate particle will require 45 minutes to completely decompose.

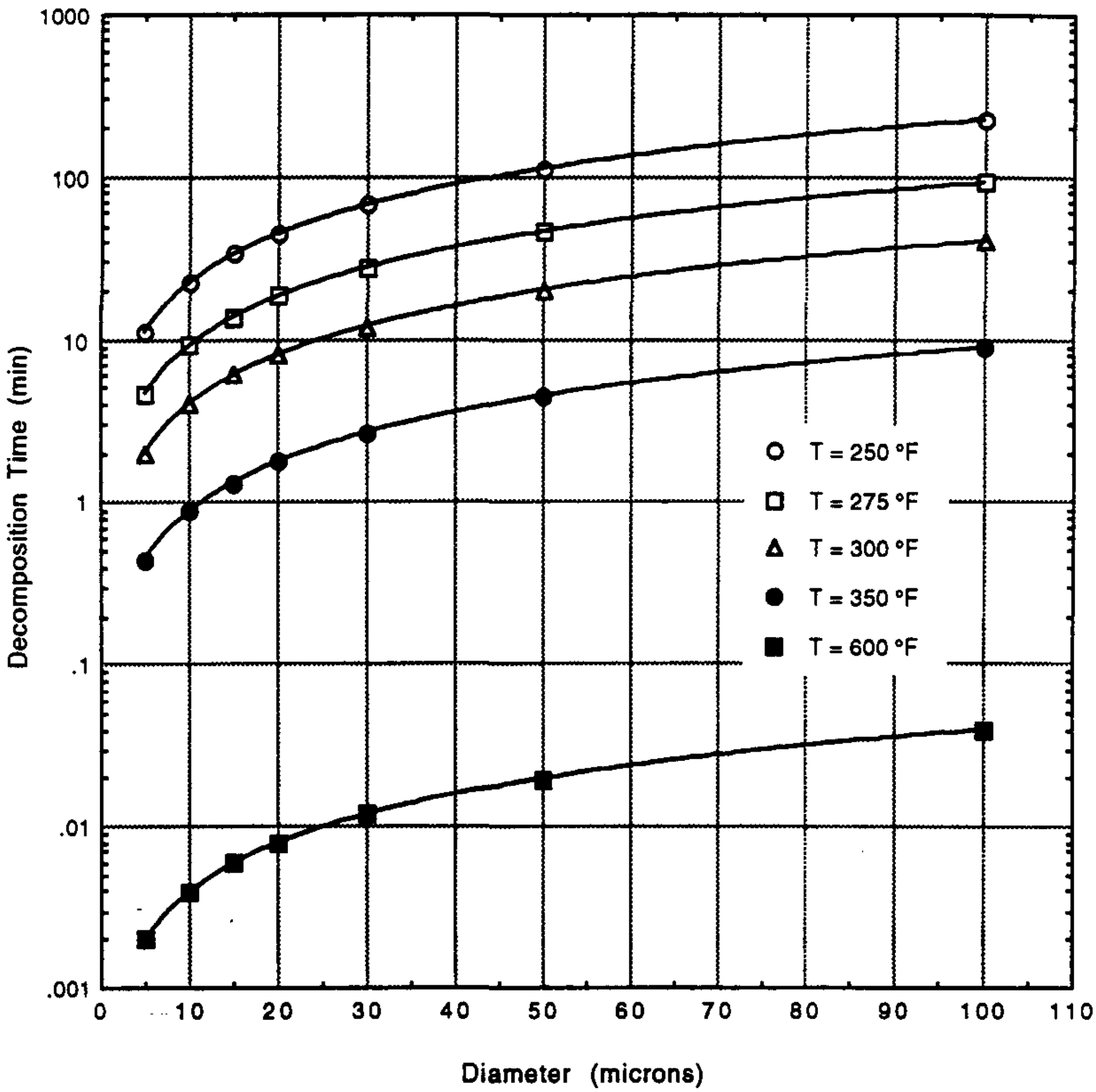


Figure 3-1. Calculated Decomposition Times for Sodium Bicarbonate

3.2 Existing Boiler Equipment

Arapahoe Unit 4 utilizes a single tubular air heater for heating the secondary air. The boiler flue gases exit the air heater in a single, short and very wide duct. The air heater exit duct work immediately transitions into a narrower and taller duct. Figures 3-2 and 3-3 show the side and top views of duct/FFDC/stack arrangement for Unit 4. The air heater exit is approximately 150 feet from the inlet of the fabric filter, while the transition duct accounts for 36 feet of the total. Flow diverting vanes are used in the transition duct, while flow straighteners are used in the duct immediately downstream of the transition point. The balance of the duct is 114 feet long and has moderate changes in profile and elevation into the fabric filter. The location of the duct sorbent and humidification injection is just downstream of the flow straighteners, approximately 103 feet from the fabric filter inlet, where the duct is 17' 3" wide by 9' 9" tall. Approximately halfway to the fabric filter, the duct work transitions into a 15' wide by 11' 6" tall duct. In this second transition duct, a single, vertical air foil is installed near the center of the duct, to divert gas from the west to the east side of the duct. According to plant personnel, this air foil is intended to eliminate ash drop-out or deposition on the bottom of the duct on the east side. This air foil is part of the existing boiler equipment and was not installed as part of the test program. The air foil assembly also includes a horizontal stiffener that connects the center of the foil with the west wall. After this second transition point and the air foil location, the duct starts to rise up to the fabric filter inlet elevation. As the duct rises in elevation, it also gradually changes to conform with the 12' wide by 14' tall fabric filter inlet dimensions.

The Arapahoe Unit 4 FFDC is an Ecolaire Environmental Company reverse gas fabric filter with 12 compartments and is designed for a gas flow of 600,000 acfm at 290°F. These compartments are arranged in a 2 wide by 6 long pattern around the centrally located inlet duct. Each compartment consists of 252 woven fiberglass bags that are 12 inches in diameter and 34 feet long. The original operating pressure drop was specified as 6.6 inches of H_2O at the design conditions, although the operating practice at the plant initiates

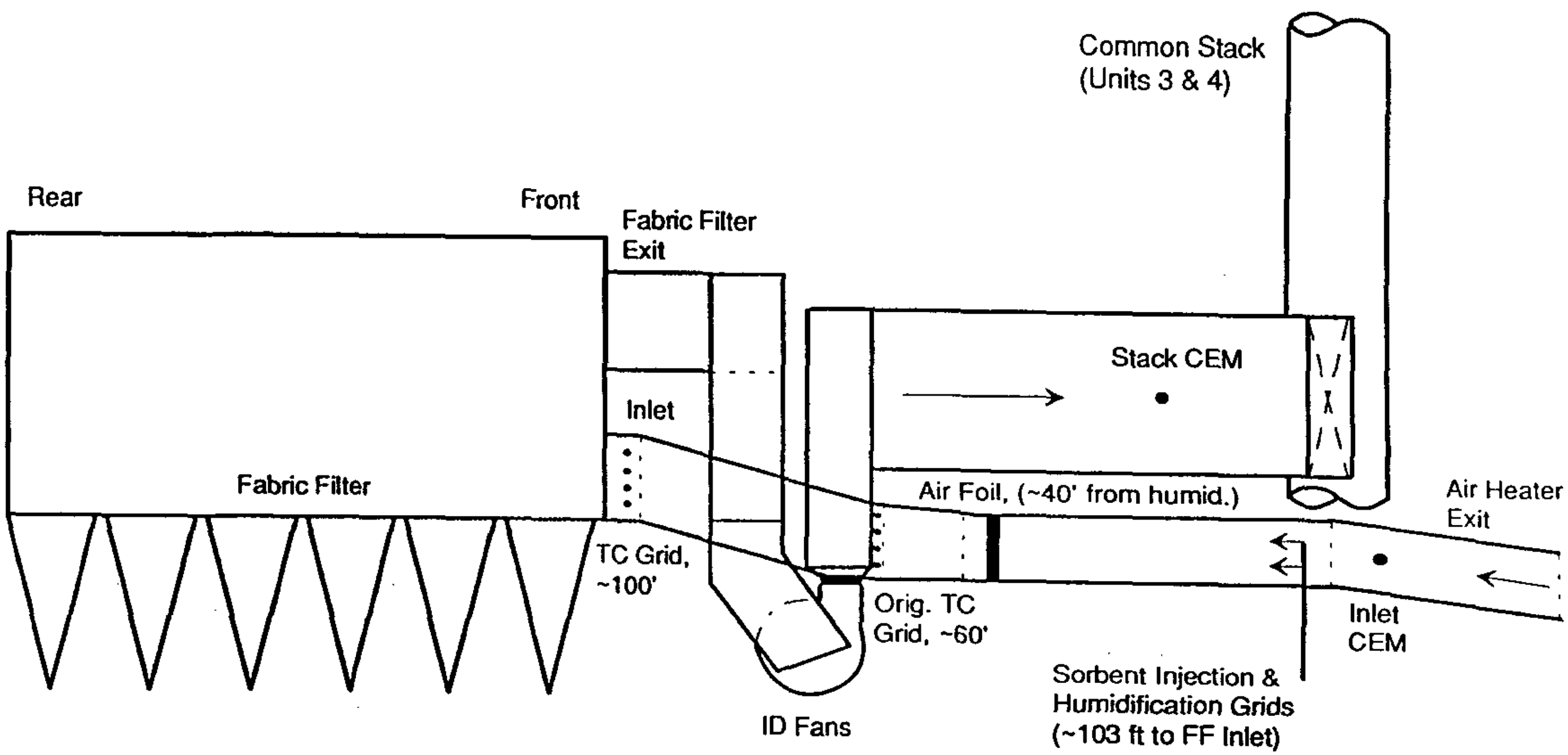


Figure 3-2. Side View of Equipment Downstream of the Arapahoe Unit 4 Air Heater

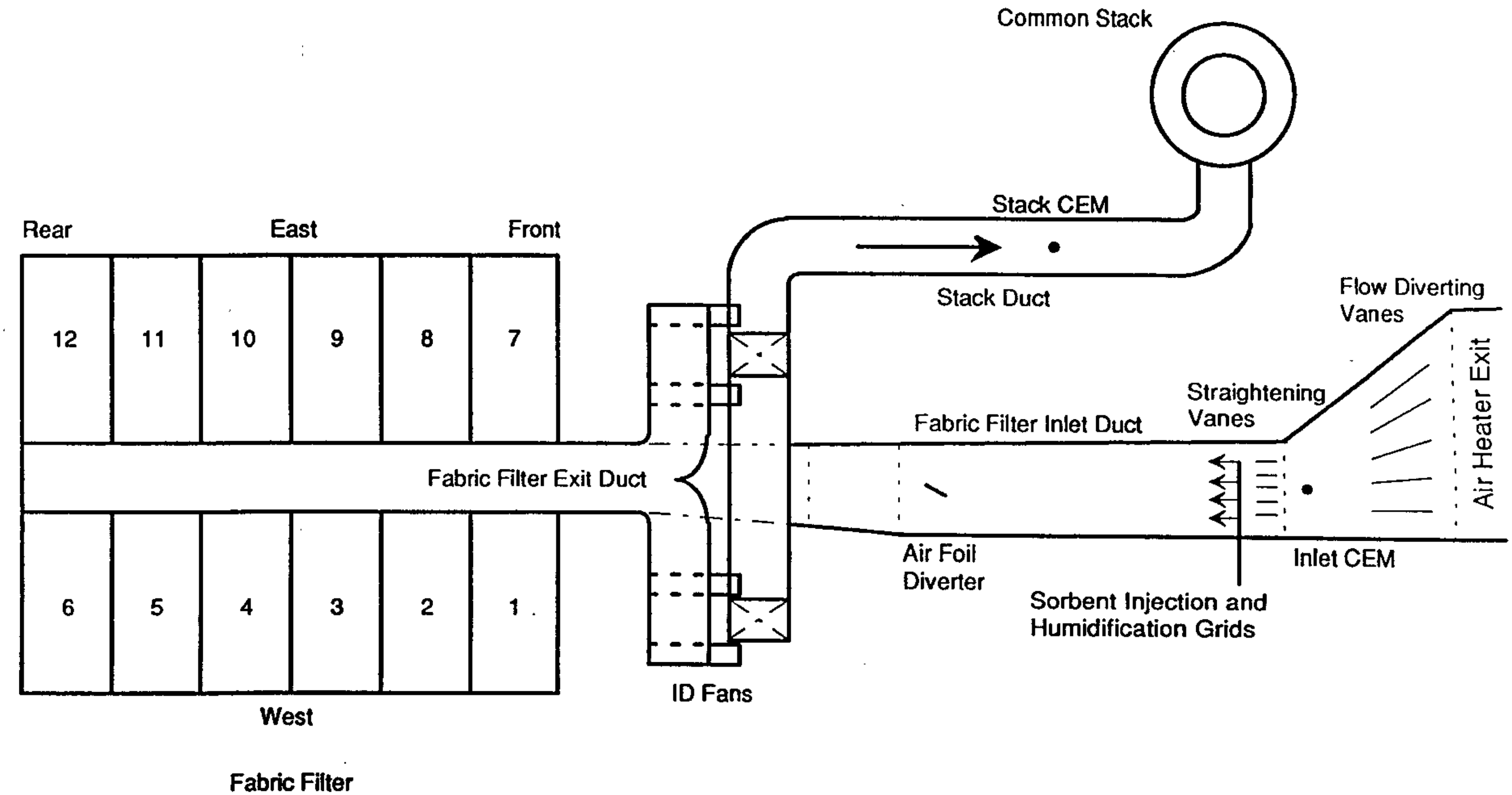


Figure 3-3. Top View of Equipment Downstream of the Arapahoe Unit 4 Air Heater

a cleaning cycle when the pressure drop reaches 4.0 inches of H_2O. At full load, normal O_2 levels, and with all compartments in service, the fabric filter pressure drop decreases to approximately 2 inches of H_2O immediately after a cleaning cycle. Each compartment gas inlet pulls flue gas from the bottom of the fabric filter inlet duct into the upper level of the ash hoppers, just below the tube sheet. The flue gases flow up into the bags and the clean gas exits into a common duct located near the top of the compartments. Poppet valves and dampers control the gas flow and cleaning for each compartment.

After the cleaned flue gases exit the fabric filter, the duct splits for the two ID fans, then recombines into a single duct to return back to the common stack for Units 3 and 4. The single duct between the ID fans and the stack was used for all gas sampling at the fabric filter exit or "stack" location, since the common stack was not suitable for monitoring Unit 4.

3.3 Humidification System

The humidification system was used primarily for the tests with calcium-based sorbents (Shiomoto, et al., 1994), although a number of tests were conducted with sodium sesquicarbonate injection as well. Humidification lowers the flue gas temperature by spraying a finely atomized water spray from an array of atomizers. The humidification system installed at Arapahoe Unit 4 includes a set of atomizer lances installed in the duct, a variable speed water pump, two large atomizing air compressors, a thermocouple grid to monitor the gas temperatures, and a humidification process control system (Figure 3-4). The humidification grid is located in the air heater exit duct, just downstream of the flow straighteners and near the beginning of a long straight run of duct (Figure 3-2). This location is also the site of the sorbent injectors for the duct injection system.

The humidification atomizers are a dual-fluid design, utilizing high pressure air. Six atomizers are arranged on each lance, with air and water supplied from a common lance header. Each lance incorporates an aerodynamic shell around the atomizers that is

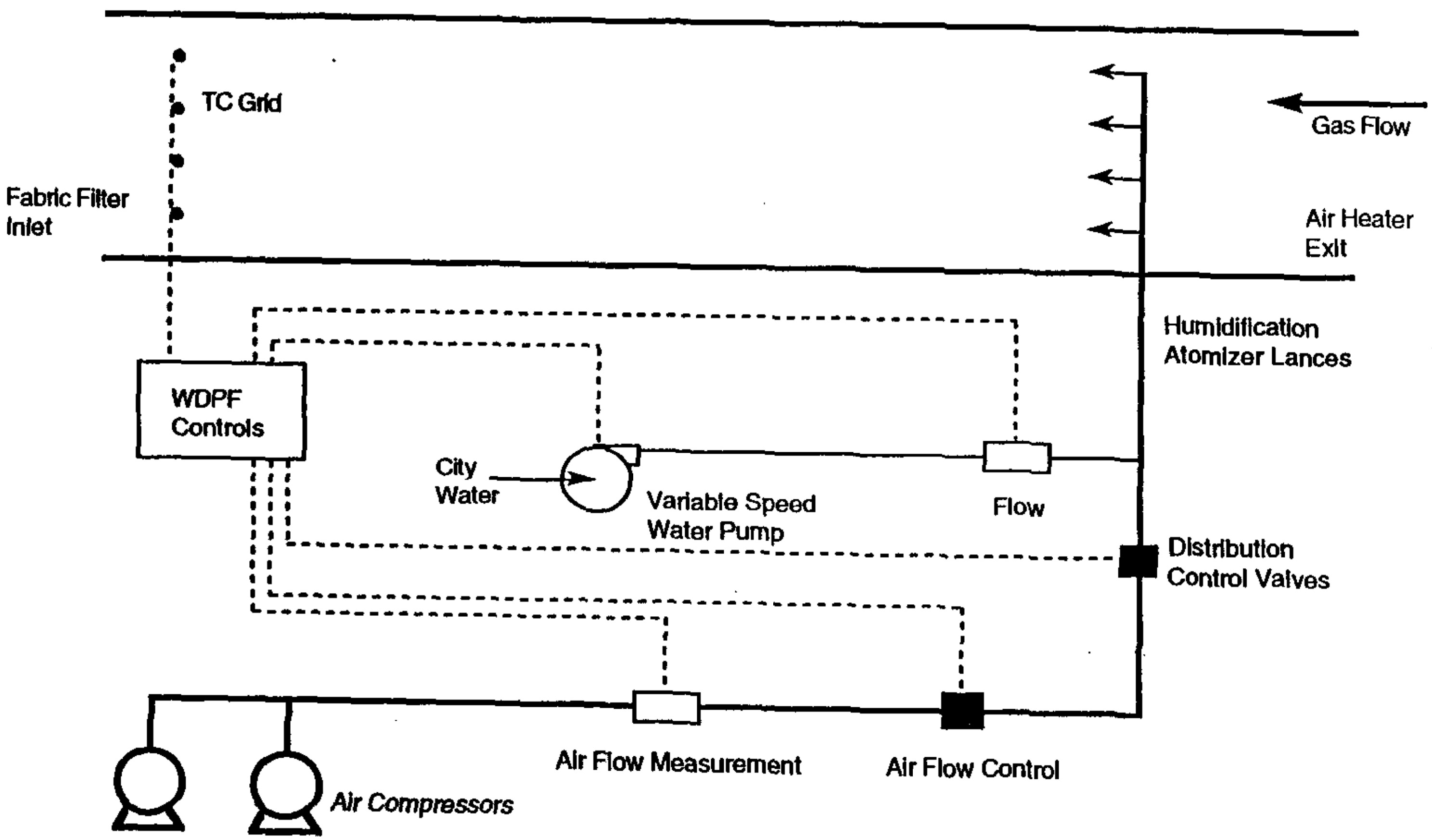


Figure 3-4. *Simplified Diagram of the Humidification Injection and Control System*

purged with clean gas (fabric filter outlet gas is used at Arapahoe Unit 4) to prevent ash deposition when the humidification system is not in use. A set of seven lances is installed into both the east and west side walls of the duct, for a total of 84 atomizers arranged in a 12 wide by 7 high grid (Figures 3-5 and 3-6). City water is supplied to common headers and controlled with a variable speed pump. A magnetic flow meter and temperature indicator provide the signals supplied to the system controls. The water is filtered to prevent plugging of the atomizers. A detailed description of the system is contained in a prior test report (Shiomoto, et al., 1994).

A grid of 12 flue gas thermocouples located downstream of the lances and just upstream of the fabric filter inlet monitors the effects of the humidification system. Although the average gas temperature is used for control, each individual thermocouple is monitored. Alarms and water shut off controls are provided for both the individual and average temperatures. The humidified fabric filter inlet gas temperature is controlled by modulating the water flow rate with the variable speed pump.

3.4 Dry Sorbent Injection (DSI) System

The DSI system at Arapahoe Unit 4 utilizes two identical preparation and injection systems to provide the required capacity at high sorbent flow rates and redundancy at lower flow rates. These two systems are entirely separate up to and including the sorbent injectors in the duct. This system initially allowed sorbent injection at either the fabric filter inlet or the economizer inlet by manual piping changes. The economizer injection location was utilized during the calcium-based sorbent injection tests. As will be discussed in the presentation of the results, it became apparent during the current phase of testing that it would be desirable to inject the sodium compounds ahead of the air heater, at the economizer exit. This modification used the existing economizer injection piping.

Figure 3-7 shows one of the two sorbent preparation and injection systems. Each system includes a storage silo, variable speed screw feeder, rotary air lock, blower for conveying air, pulverizer to grind the sorbent, distributor to split the sorbent stream, and injectors.

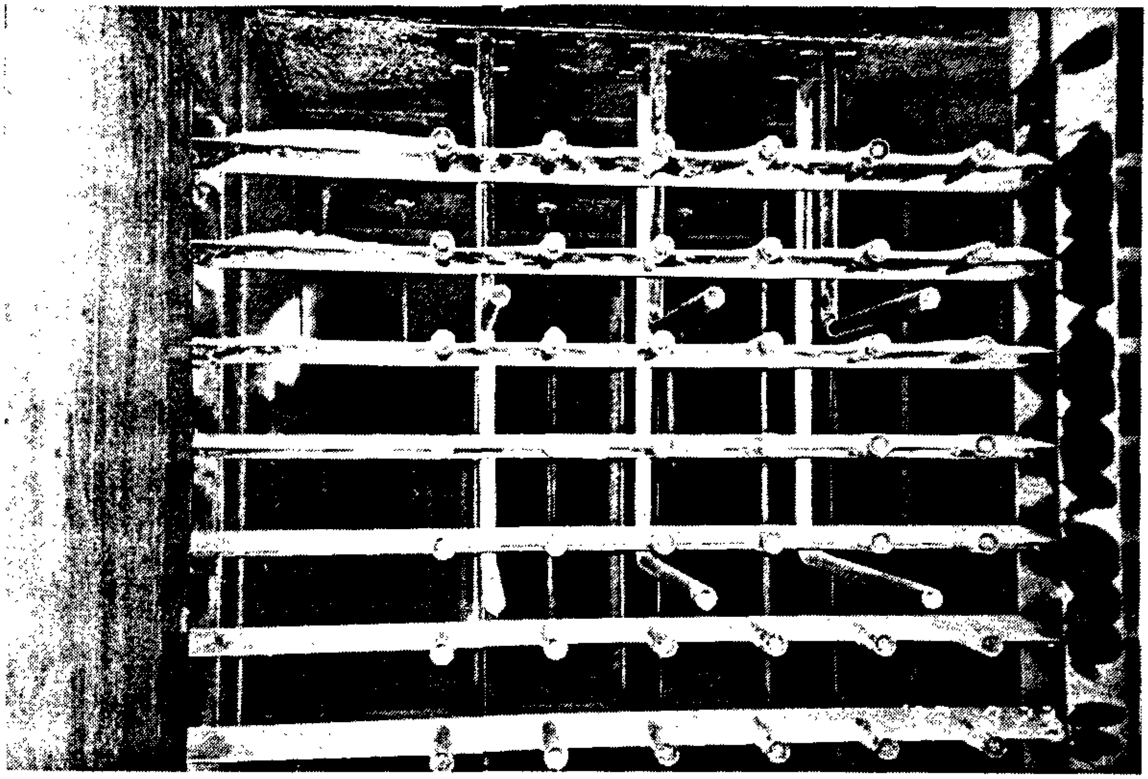


Figure 3-5. Humidification and Sorbent Injection Grids (East Half)

Figure 3-6. Humidification Nozzles and Sorbent Injector

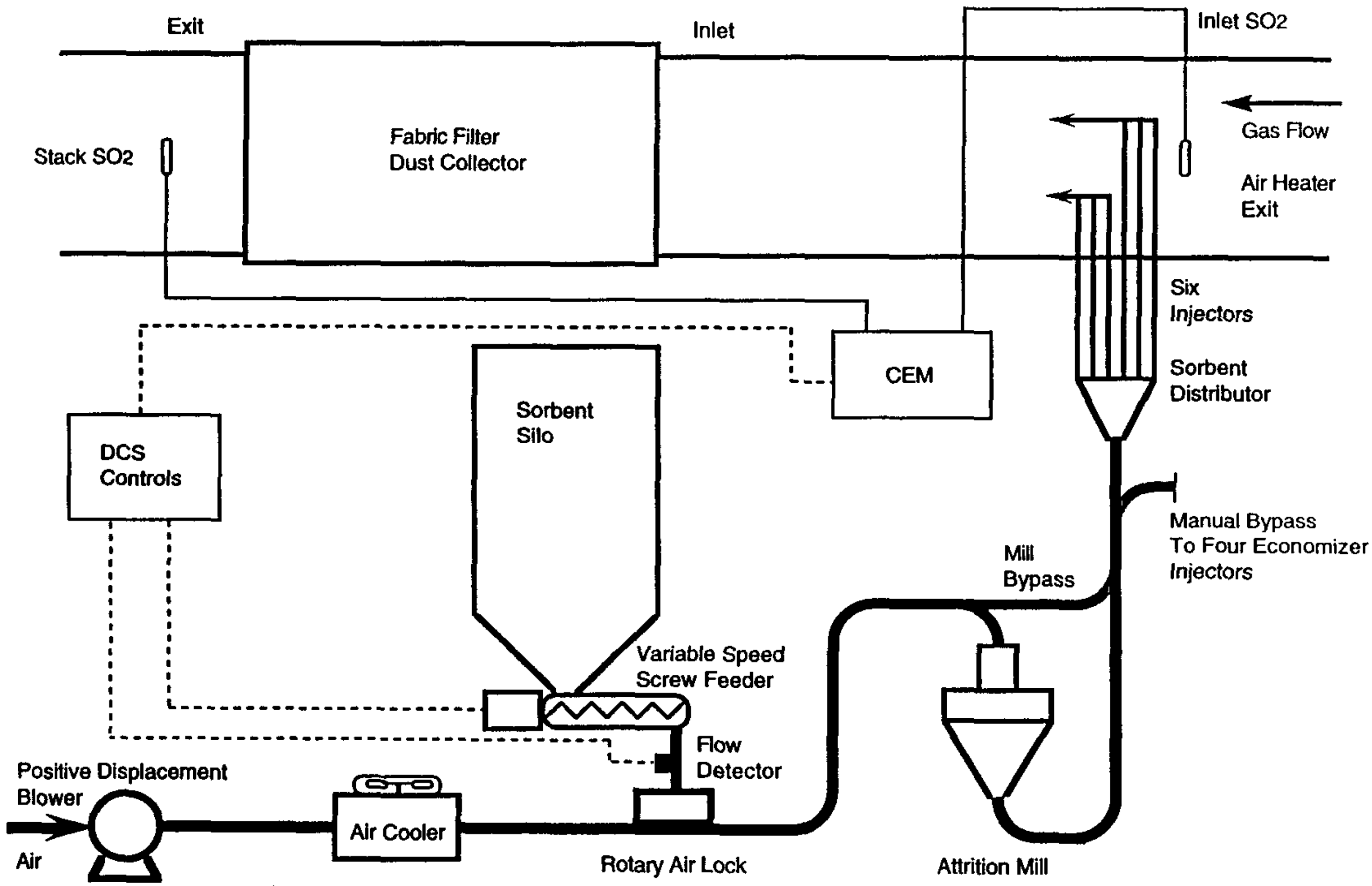


Figure 3-7. Simplified Diagram of One Sorbent Handling System and the Process Controls

3.4.1 Dry Sorbent Storage and Handling

The two sorbent preparation and injection systems (labeled A and B for the testing) are identical in capacity and operation. Each has separate controls and can be independently operated from a control screen on the Arapahoe Unit 4 Distributed Control System (DCS). The following paragraphs describe one of the two identical systems.

Sorbent is stored in a silo with a capacity of approximately 6100 cubic feet. Dry sorbents are transported by truck and pneumatically loaded into the top of the silo. The silo is vented at the top through a small fabric filter system which prevents fugitive dust emissions. An ultrasonic level indicator provides continuous silo level measurements.

A slide gate is installed at the bottom of the silo hopper to allow isolation from the feeder when necessary. Directly below the slide gate is a variable speed screw feeder. The volumetric screw feeder provides the sorbent flow control for the system and can be operated with local controllers in the sorbent preparation building or from a screen on the DCS. The feeder can be operated in either a manual or automatic mode. In the manual mode, the operator sets a constant screw speed. In the automatic mode, an SO_2 removal setpoint is input and the control system varies the feed rate to maintain the setpoint SO_2 removal. The automatic control system also incorporates a trim control to limit NO_2 emission levels to less than a user defined setpoint. For the majority of the current test phase, the feeder speed was manually set to obtain the desired stoichiometric ratio.

The screw feeder delivers sorbent directly into the top of a rotary air lock which provides the necessary isolation between the sorbent feed and the conveying air systems. The air lock is used for isolation, not feed rate control, and therefore is operated at a constant rotational speed. The air lock is vented to relieve the higher pressure from the conveying air and help prevent pressurization of the bottom of the silo and screw feeder. The vent line extends up to the top of the silo and into the fabric filter venting system. A flow detection probe installed between the exit of the screw feeder and the inlet of the air lock is used to detect the loss of sorbent flow. When properly calibrated for sorbent type, this probe determines loss of flow and displays an alarm on the DSI control screen.

The conveying air piping passes just below the rotary air lock, which allows the sorbent to drop into and be dispersed within the air. The air is supplied from a positive displacement blower that operates at a constant speed and air flow rate (nominally 660 cfm at 9 psig). Blower air pressure is monitored to determine if plugging occurs or if sorbent flow is abnormal. The air supply pressure is limited to 10 psig by a relief valve installed downstream of the blower. An air-to-air heat exchanger installed downstream of the blower cools the conveying air whenever the sorbent pulverizers are in use. This heat exchanger cools the air to reduce the mill exit air temperature and prevent sorbent overheating. After the air cooler, the air flows under the rotary air lock and picks up the sorbent flow. After the sorbent and air are mixed, the flow can be directed either into or around the Entoleter attrition mill via manual piping changes. The attrition mill was bypassed during the previous series of tests with calcium-based sorbents (Shiomoto, et al., 1994). During the current series of tests, the mill was placed in service in order to increase the fineness of the sodium-based sorbent.

After exiting the mill, the sorbent and carrier air are piped to one of the injection locations at either the fabric filter inlet or the air heater inlet. The piping at each injection location is very similar, although the number of injectors differs. Most of the testing was performed at the fabric filter inlet location. A distributor is installed on the top of the air heater exit duct to split the sorbent flow to each injector. A single pipe supplies the sorbent from the preparation system and the flow is evenly split into six injection streams. At the outlet of the distributor is a separate ball valve on each line that is used to isolate each injector from the system. The piping for injection at the air heater inlet is identical, except that a distributor divides the flow into four streams instead of six.

3.4.2 Fabric Filter Inlet Sorbent Injection

The duct injection location at the fabric filter inlet was utilized for the majority of the tests with sodium-based sorbents. This location (shown in Figure 3-2) is located at the air heater exit just downstream of the flow straighteners. Injection at this location provides approximately 103 feet of duct work prior to entry into the fabric filter. Immediately after the sorbent and humidification injection location, the duct remains relatively constant in cross section for roughly one-half of the distance to the fabric filter.

The sodium-based sorbents are injected into the flue gas stream at the same plane as the humidification system through a grid of 12 nozzles arranged in a 2 high by 6 wide array. Injection nozzles from each of the two systems (A and B) are interspersed within the grid, so that operation with only a single system provides sorbent injection across the entire duct. The A and B systems alternate injectors in a checkerboard fashion within the 12 point grid. Each system comprises six injectors, three on each side of the duct (Figure 3-8).

Each injector is fabricated from a two-inch pipe, which enters the air heater exit duct from the top and turns 90 degrees within the duct. The exit of each injector is oriented downstream such that the sorbent-conveying air flow and flue gas flow are in the same direction. The injection nozzles are located at the exit plane of the humidification atomizers, and between two adjacent humidification lances in the vertical direction (Figures 3-5 and 3-6).

3.4.3 Air Heater Inlet/Economizer Exit Sorbent Injection

Early tests showed that the flue gas temperatures at the fabric filter inlet were too low (i.e., <290°F) for good performance with sodium bicarbonate injection. In an effort to enhance performance, the injection location was temporarily moved to the air heater inlet where the flue gas temperatures are nominally 650°F. The piping utilized to inject calcium hydroxide at the economizer during the previous phase of testing (Shiomoto, et al., 1994), was modified to supply the temporary injectors at the air heater inlet.

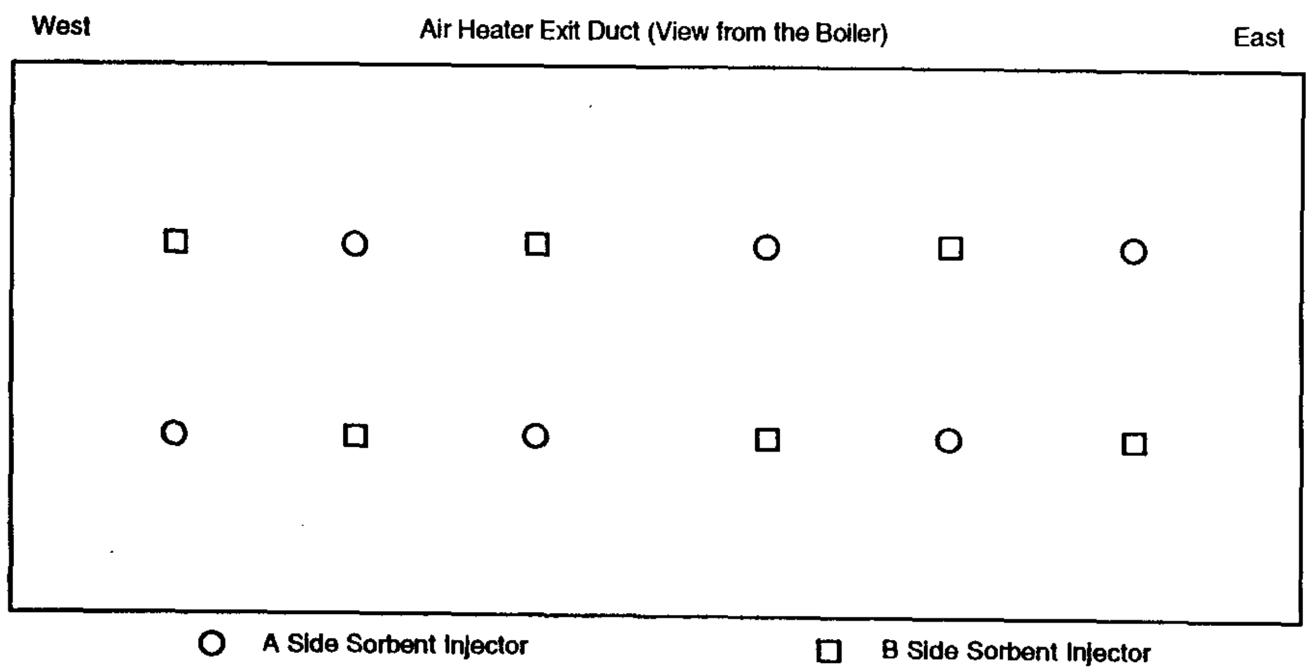


Figure 3-8. Approximate Locations of Duct Injectors from the A and B Side Sorbent Systems

Changing the injection location from the fabric filter inlet to the economizer required plant maintenance personnel to remove and reinstall different piping connections to redirect the sorbent flow. In the economizer injection configuration, distributors for the A and B sorbent systems are located on opposite sides of the boiler, with the A system being on the west and the B system on the east. This configuration required that both systems be in operation in order to inject $Ca(OH)_2$ into the east and west halves of the boiler. During the current phase of testing, the economizer injection piping for the B system was utilized to supply the temporary injectors at the air heater inlet. The flow distributor remained in its original location, on the east side of the boiler, and two-inch diameter flexible hoses transported the sorbent up nearly one-half the height of the boiler, and across the width of the air heater inlet/economizer exit duct to the four new injectors.

Existing two-inch pipe ports were utilized for the temporary injectors. These ports are normally used for the economizer exit gas sample probes (described in the following section), and required removal of the probes when the injectors were in use. A total of six ports are available at the economizer exit sample location (Figure 3-9) and of these, the four center ports were used for the temporary injectors. With this injection pattern, only the center portion of the short and wide (7 feet tall by 40 feet wide) economizer exit/air heater inlet duct would be treated by the sorbent. However, it would provide the most optimum coverage available for this temporary injection system. The four injectors were fabricated from 1-1/2-inch diameter pipe and were built to fit inside the existing ports (Figure 3-10). Sorbent flowed through the 1-inch diameter probe tip as well as through 3/4-inch orifices on the probe side walls.

3.5 Operational Problems

Operational problems encountered during the sodium-based sorbent injection program are described briefly in this section. This experience is documented in order to avoid these problems in the future system designs. The problems to be discussed may be characteristic of this specific system design that could be improved with modifications.

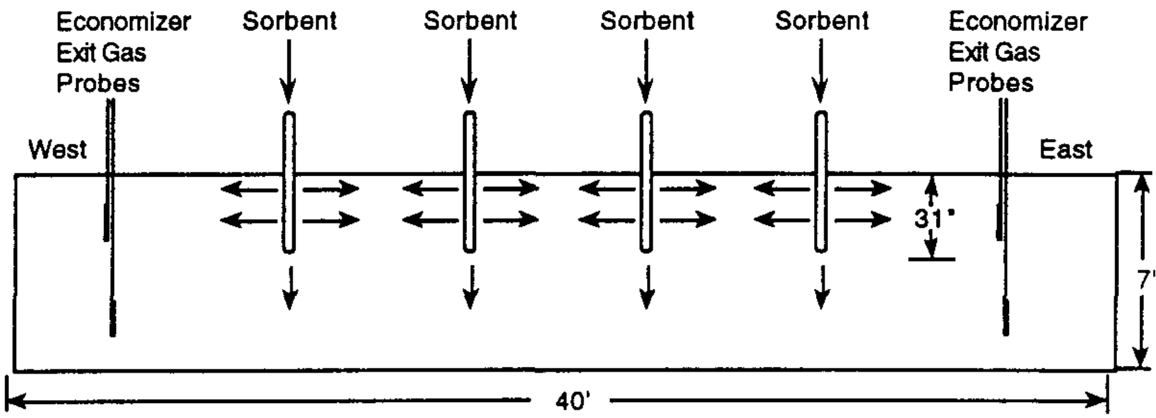


Figure 3-9. Air Heater Inlet Sodium Injection Locations

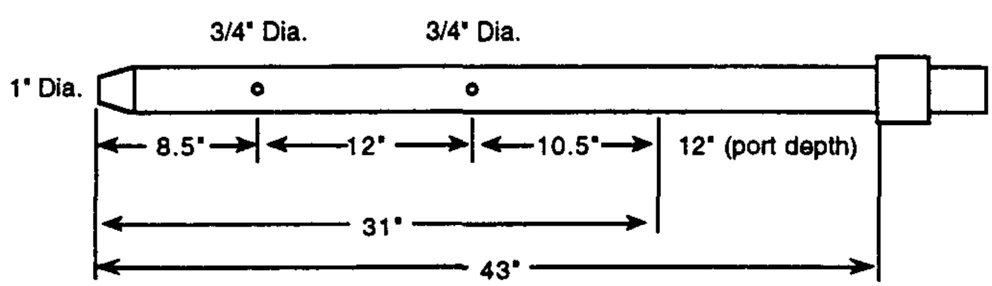


Figure 3-10. Air Heater Inlet Sodium Injector Design

Other problems encountered with the use or limitations of sorbent injection will be covered in later sections with the test results.

3.5.1 Sorbent Storage and Handling Problems

A number of problems, which resulted in erratic or loss of sorbent flow, were encountered with the sorbent handling. Problems of this nature were observed with both calcium- and sodium-based sorbents. Storage problems in the silo which prevented smooth flow into the screw feeder were encountered periodically. Rat holes down the center of the silo would impede flow by allowing the feeder to run dry, despite a considerable amount of sorbent collecting on the hopper slopes. Vibrators on the silo hopper were only moderately successful at improving the sorbent flow, as was an "air cannon" installed on one silo hopper. Beating the hopper walls with a sledgehammer was frequently employed with some success. The majority of these problems were related to product contamination from moisture or other chemicals that occurred during transport. Some problems were simply due to the difficulty in flowing these bulk materials and were a consequence of the specific material handling properties.

Air leakage through the rotary air lock is suspected as a significant problem which can cause erratic feed rates. Air leakage from the carrier air can pressurize the outlet of the screw feeder and the bottom of the silo. Sufficient sorbent levels in the silo may reduce the problem; however, pressurizing the feeder and sorbent bed can disrupt the material flow and cause erratic or significantly reduced flow rates. A different air lock and/or improved venting system may reduce these problems. One additional problem suspected with the air lock venting concerns the loss of sorbent carried away with vent air. With very fine materials, a significant portion of feed material may be lost to the vent system before the sorbent is added to the carrier air. This leads to feed rate calibration errors whenever screw feeder calibrations are performed at atmospheric pressure without the air lock in service. During the current program, revised feeder calibration procedures were instituted to resolve these difficulties, although the root cause is the rotary air lock leakage. This *problem was primarily encountered with the fairly fine sodium sesquicarbonate (and* calcium hydroxide) and was not a major issue with the sodium bicarbonate.

3.5.2 Sorbent Injection Problems

Plugging of individual injectors or the distributor has been a recurring problem with all sorbents. Hard deposits within the piping may be the result of aerodynamic impaction on turns or flow irregularities, or may perhaps be formed by contact with moisture in the flue gas or other ambient sources. In most cases, disassembly and removal of the hard deposits by hand was required. Injection transport lines were also periodically filled or flushed with water to soften and remove the deposits. A few deposits have been noted at the sorbent injector tips located in the fabric filter inlet, although none of the injector tips have been entirely closed off. Water was not used to clean the sorbent injector lines entering the duct. Additional problems were encountered with plugging of the long hoses running to the air heater inlet injectors. However, these problems may have been due to the temporary nature of this injector location design. In addition, sorbent types were changed quite frequently during the current phase of testing, and it is not certain to what extent this may have contributed to the plugging problems.

3.5.3 Determining Sorbent Feed Rate

One other issue of interest is the ability to accurately determine the sorbent feed rate during the short-term parametric tests. The project is intended as a full-scale commercial demonstration, with the equipment design reflecting a commercial configuration. In actual long-term operation, the control system would be set at a percent SO_2 removal efficiency, and the feed rate adjusted automatically. Overall sorbent utilization would then be determined on an integrated basis over a relatively long time period. As such, a commercial system would not necessarily require gravimetric feeders to determine the instantaneous sorbent feed rate.

The lack of an instantaneous gravimetric sorbent feed rate posed some problems in determining the stoichiometric ratio (2Na/S) for the short-term tests. In order to determine the feed rate, calibration of the screw feeder was done two ways. As mentioned previously, a calibration was performed by shutting off the rotary air lock, and opening up an access port above the rotary air lock. The feeder was then calibrated with the discharge at atmospheric pressure. This raised a concern that when operating in the normal mode, the back pressure from leakage past the rotary air lock, or the sorbent loss through the vent line, could affect the feed rate relative to the atmospheric calibration. To check this, a second calibration was performed while the system was on-line. For this calibration procedure, the ball valve for an individual injector downstream of the sorbent distributor was turned off. A fabric filter bag was attached to the flexible hose downstream of the valve, and then a sorbent sample was collected and weighed from each injector line. Typically, this procedure yielded a feed rate approximately 10 to 20 percent less than the atmospheric calibration of the screw feeder for the sodium sesquicarbonate. For sodium bicarbonate, there was no measurable difference in the calibrations. All data presented in this report are based on the injector calibration procedure.

3.5.4 Sorbent Pulverizer Problems

The injection of sodium-based sorbents requires the use of the high-speed attrition mills in the sorbent feed system. The mills are installed downstream of the rotary air lock in the transport line prior to being conveyed to the fabric filter inlet or air heater inlet injection locations. These mills operate by impacting the sorbent particles on stationary and rotating pins as the sorbent flows through the mill. The rotating pins are mounted on a 200 pound disk operating at high speed. As a result of the high rotational speeds and the physical characteristics of the sorbents, mill vibration problems were often encountered.

Initially, the mills were operated at a speed of 5700 rpm. However, this proved to be too close to a second resonant frequency which caused significant vibrational problems that could not be resolved. The mill speeds were temporarily reduced to 4000 rpm, while awaiting parts that would eventually allow operation at 5000 rpm. During this period, rebalancing of each mill was also performed to reduce the vibration to reasonable levels.

The majority of the sodium injection tests were conducted with the 5000 rpm speed. Unless otherwise noted, all results presented in this report are from operation at 5000 rpm.

While lowering the mill speed reduced the problems, vibration remains a chronic, but manageable problem of the sorbent preparation and feed systems. By passing sorbents through the mills, deposits on the rotating parts would accumulate, and typically the mill vibration levels would gradually increase throughout a test day. When the vibration limits were exceeded, the mill and sorbent feed systems would trip off. Generally, a mill shut down and restart sequence was the only action required to dislodge the material and restore the mill vibration to acceptable levels. In some cases however, a water wash of the mill was necessary to remove soluble sodium deposits.

During one period of extended 24-hour operation, a catastrophic failure of the "B" mill occurred while injecting sodium bicarbonate. The failure was caused by tramp stainless steel delivered with the reagent. The non-magnetic stainless steel was not captured by the magnetic separator installed to protect the pulverizer. The net effect of the failure included a bent shaft, a broken mill case, shattered grinding element pins, uprooted anchor bolts, and numerous electrical and plumbing components that were apparently broken by excessive vibration. To prevent non-magnetic metal from entering the mill, a screen was installed downstream of the rotary air lock and upstream of the mill.

4.0 MEASUREMENT METHODS

This section describes the measurement methods used to determine the system operating conditions and the SO_2 reductions resulting from the sorbent injection processes.

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 either gas filter correlation or 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	0-400 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	0-100 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 programmable logic controller. The measured gas concentration data is displayed on a dedicated 486-based computer, which also provides data logging, manipulation and reporting capabilities.

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 (Smith, et al., 1994a), 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 is configured to measure NH_3. Although this feature was not utilized during the current series of tests, this capability imposes some special requirements upon the design of the CEM sampling system. In order to maintain the sample integrity, 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 is configured to sample from only two different single-point locations. The first location is at the exit of the air heater in the duct leading to the fabric filter. The second location is in the duct leading to the common stack for Units 3 and 4. The air heater exit location is at a point just upstream of the flow straightening vanes and the sorbent injection/humidification lances (see Figure 3-2). The air heater exit location is used to determine the initial boiler exit gas conditions, while the stack or fabric filter outlet sample location is used for the determination of effects after the humidification and/or sorbent injection. Calculation of the SO_2 removal between the air heater exit and the stack locations includes correction for dilution from ambient air inleakage, as well as the additional dilution effects resulting from the vaporization of the humidification water, if used.

In order to obtain a representative composite gas sample from the boiler, 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 was utilized as the gas analysis instrumentation, the measurement of NH_3 at the additional sampling locations was 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. Down-stream 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.

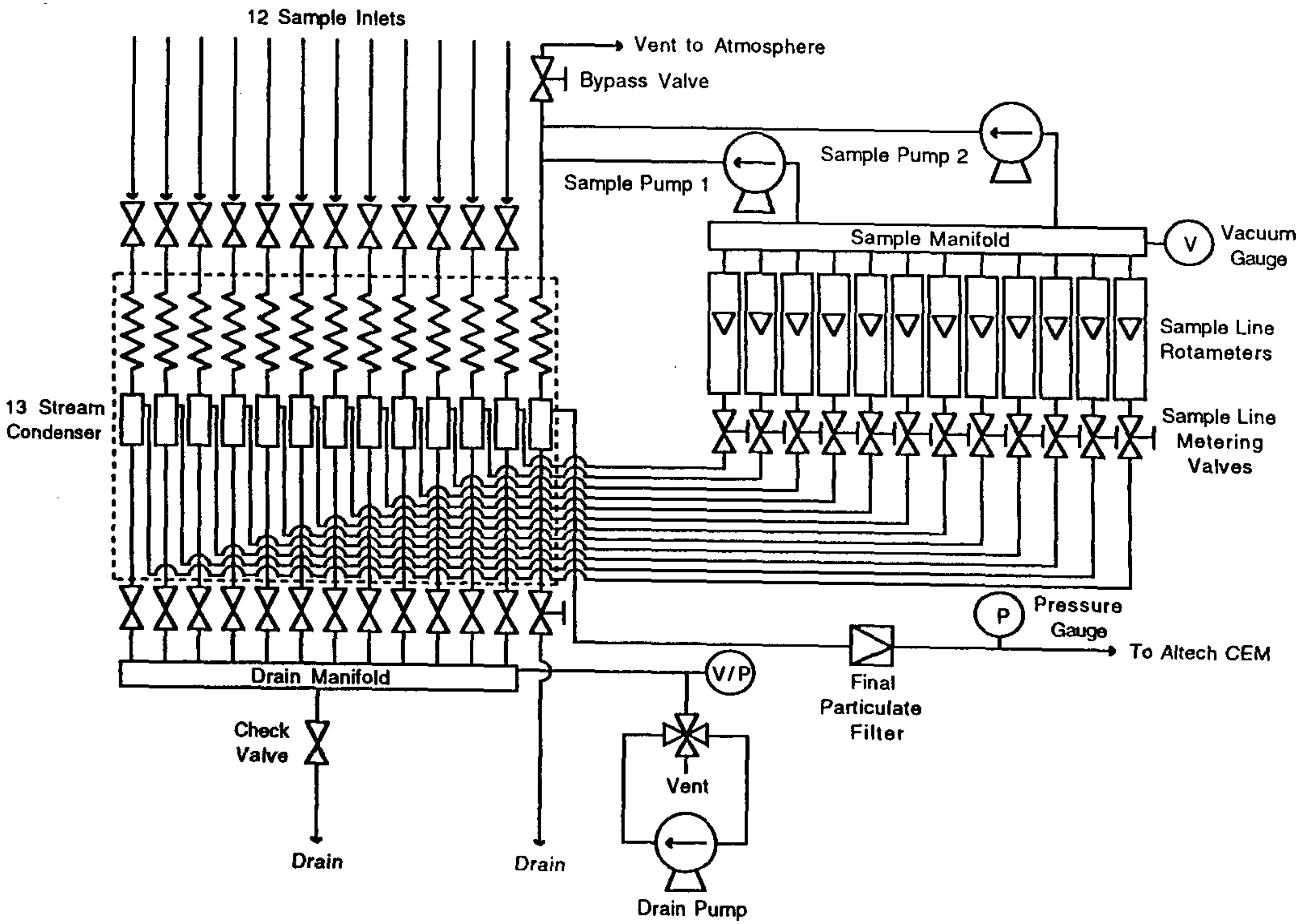


Figure 4-1. Sample Gas Conditioning System

The locations of the unheated sample probes during the current phase of testing were identical to those used for the previous phases of the test program, namely: twelve at the exit of the economizer, six at the exit of the air heater, and one in the fabric filter outlet duct leading to the stack. Additional sample locations were provided for the individual fabric filter compartment outlet gas and the fabric filter inlet gas measurements that were performed manually.

The sample probe grid in the horizontal duct at the economizer exit is shown in Figure 4-2. Although this duct is 40 feet wide, it is only 7 feet deep, so an array of 12 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 PSCo O_2 probes at the economizer exit which are used for boiler trim control. The PSCo equipment uses *in situ* probes that determine the O_2 concentration on a wet basis. These probes (numbered A, B, C and D) were located approximately three feet upstream of the Fossil Energy Research Corp. (FERCo) grid, and very near probe numbers 3, 5, 7 and 9. Two additional sampling ports were available at the economizer exit which were used for limited SO_3 measurements during the baseline burner and LNB/OFA tests.

The importance of the position of the 12-point grid relative to the four PSCo O_2 probes was realized during the baseline burner tests when it was found that the average O_2 measured from the grid was nominally one percent higher than the average indicated in

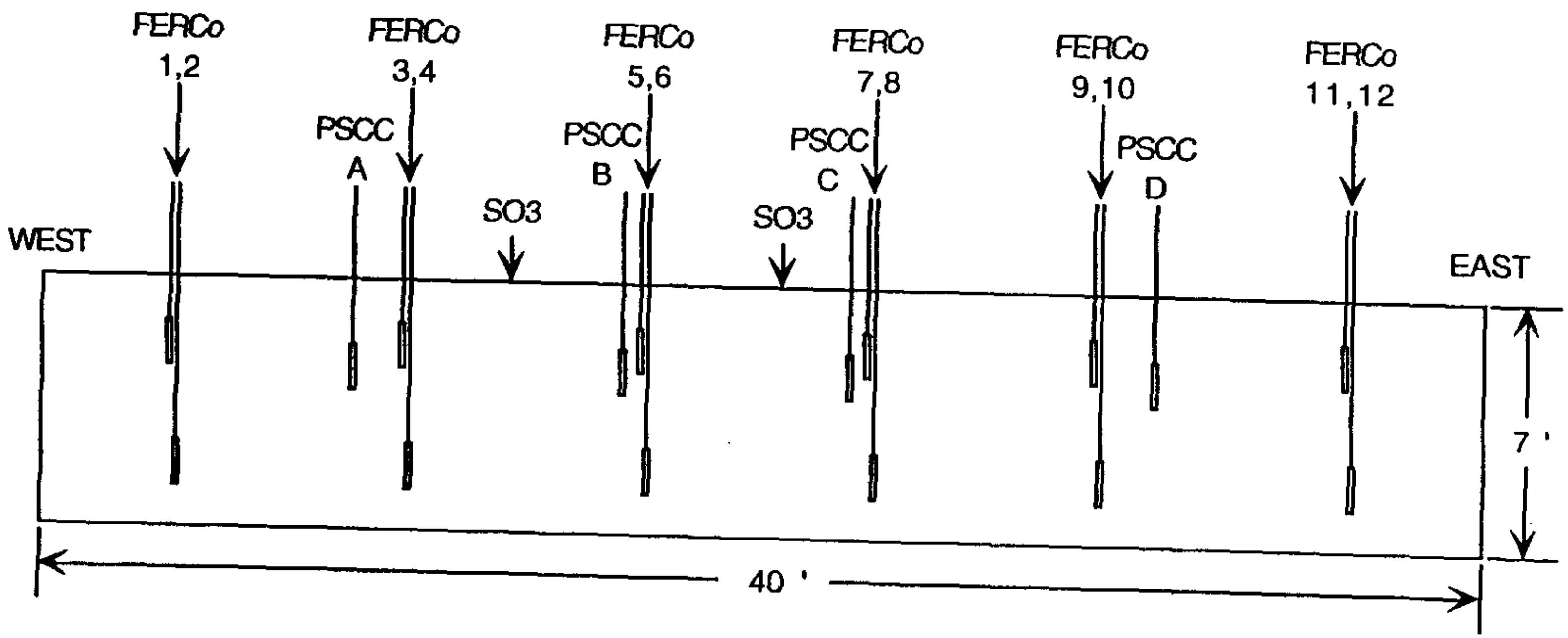


Figure 4-2. Economizer Exit Sampling Locations

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 resulted from air in-leakage.

The economizer grid probes were not used to determine the SO_2 emissions reductions from the sorbent injection or humidification processes; however, the grid was used to determine the actual boiler O_2 levels and used in the calculations for total flue gas flow. This measurement point was also used for accurate determination of average boiler NO_x emissions. Additional gas sample probes were installed at the air heater exit and the stack (fabric filter outlet duct) locations. The probes with unheated sample lines at the air heater exit were used during the tests with sodium bicarbonate injection at the air heater inlet, in order to provide an indication of the SO_2 removal occurring upstream of the fabric filter. Only six probes were utilized at this test 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 air heater exit. This probe was 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 was approximately 20 feet upstream of the unheated probe installed during the baseline burner tests. Only a single probe was used for both the CEM and the unheated probe locations since both were downstream of the fabric filter and induced draft fans where little stratification of the flue gas stream was expected. Figure 4-4 shows the installation of the heated CEM probe in the fabric filter outlet duct.

Along with the gas sample locations for the Altech and the FERCo systems, additional gas measurements were obtained from the individual fabric filter compartments. A separate fabric filter gas sample stream was added to the FERCo sample system and subsequently analyzed with the Altech CEM. Since accurate SO_2 emissions would be required from the

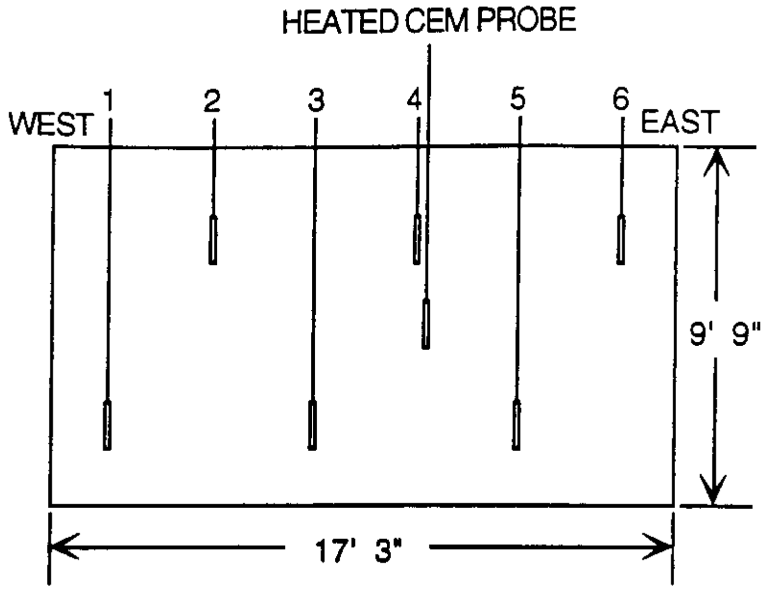


Figure 4-3. Air Heater Exit Sampling Locations

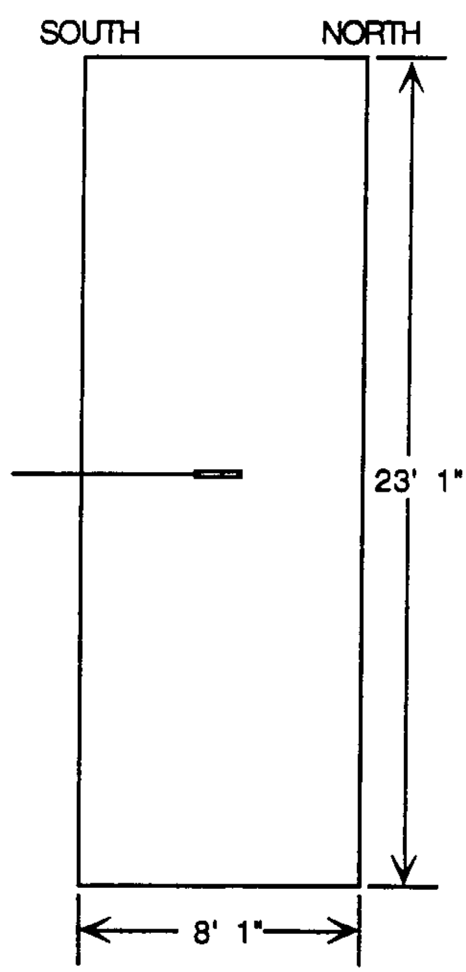


Figure 4-4. Fabric Filter Outlet Duct Sampling Location

fabric filter compartment samples, a non-bubbling condenser and water dropout were added to the sample line just outside of the compartment sample location. Initially, existing pressure taps installed for monitoring compartment pressure drop were used to obtain a compartment gas sample from the top of the tube sheet on the clean gas side. During a boiler outage, a Teflon line was installed in the top of each compartment that was used to pull a sample from the center of the compartment clean gas outlet opening. A fitting was installed on the door of each compartment to access this compartment gas sample. The compartment gas samples were acquired manually and required that the sample line and water dropout be moved and reconnected for each compartment during this measurement. This data was utilized to analyze the SO_2 removals and indirectly determine the sorbent distribution on a compartment-by-compartment basis. A comparison between the CEM stack sampling location and the average of the compartment samples showed very good agreement, and indicated that the compartment gas sampling technique was valid.

4.3 Approach To Saturation

The measurement of flue gas temperature and approach to saturation is a key variable in characterizing the humidification and SO_2 removal process with calcium- or sodium-based sorbents. The use of a thermocouple grid should have permitted an accurate gas temperature measurement, given sufficient residence time for evaporation and an even distribution of water, and uniform flue gas and flow temperature. However, problems with partially wet thermocouples resulted in low gas temperature indications that affected the evaluation of the actual operating conditions. Correctly evaluating the actual flue gas and approach temperatures was considered a high priority item for evaluating the test results. While modifications to the measurement system improved performance, the grid could not accurately indicate the dry bulb temperatures with high humidification rates.

Several means of verifying the actual flue gas temperature and the amount of humidification were used: 1) monitoring the steady state baghouse outlet temperature, 2) measuring the flue gas wet bulb temperatures, and 3) adiabatic energy calculations of the humidification process. All of these verifications indicated that the equilibrium fabric filter exit temperatures were higher than the average measurement by the thermocouples at the inlet grid during steady state tests at high humidification rates (Shiomoto, et al., 1994). Four additional thermocouples were installed in the ID fan inlet ducts to provide a better means of monitoring fabric filter outlet temperature. While the fabric filter outlet temperature would be sufficient for steady state tests, it is not adequate for load following or short term tests and cannot be used to adjust or control the humidification process.

Psychometric calculations were performed to model the humidification process and verify the water flow rate and the average fabric filter inlet grid temperature measurements. These are described in the report documenting the testing with calcium-based sorbents (Shiomoto, et al., 1994). During the test program, the psychometric calculations were relied upon to determine the humidification system operation point and to determine the flue gas approach temperature. Errors from the fabric filter inlet grid were unavoidable at high water flow rates, but the set point temperatures could be biased to provide the desired test conditions while maintaining automatic controls for the water injection. In this report, the calculated approach temperatures were utilized for determining the humidification process operation and for all data interpretation. However, the humidification data summary in the appendix includes the calculated dry bulb temperature as well as the measured values throughout the system.

5.0 RESULTS

This section presents the results of the short-term parametric sorbent injection tests. In presenting these results, the chemical and physical properties are presented first (Subsection 5.1). This is followed by a discussion of the results with sodium sesquicarbonate at both the FFDC inlet and air heater inlet (Subsection 5.2) and a similar discussion of the sodium bicarbonate results (Subsection 5.3). Subsection 5.4 presents the results of the solids analyses performed on fly ash/sorbent samples collected from the FFDC hoppers during injection tests with both sorbents. Finally, Subsection 5.5 presents the results of two parametric tests with sodium sesquicarbonate which were performed during an alternate coal test burn on Arapahoe Unit 4 in November, 1995. A detailed data summary for the short-term parametric tests is contained in Appendix B.

5.1 Sorbent Characteristics

The sodium sesquicarbonate used during the test program was obtained from Solvay Minerals, Inc., Green River, WY. The sodium bicarbonate was obtained from NaTec Resources, Inc., Houston, TX (solution-mined in Western Colorado). The chemical composition and physical characteristics of the two materials are shown in Table 5-1.

Table 5-1

Sorbent Characteristics

Material	Sodium Sesquicarbonate	Sodium Bicarbonate
Chemical Formula	$NaHCO_3 \cdot Na_2CO_3 \cdot 2H_2O$	$NaHCO_3$
Supplier	Solvay Minerals, Inc.	NaTec Resources, Inc.
Composition: Na_2CO_3 $NaHCO_3$	 45.8% 36.3%	 -- 99.5%
Percent Na by Weight	29.8%	27.2%
Bulk Density	49 lb/ft^3	64 lb/ft^3

Samples of the raw (unpulverized) and pulverized materials were submitted to Leeds & Northrup Co. for particle size analysis (Microtrac). The mass mean diameter (MMD) particle size for the raw and pulverized sodium sesquicarbonate samples were 27.8, 17.0, and 15 microns, respectively. The particle size distributions for the three samples are shown in Figure 5-1. The pulverized samples were collected when the mill was operating at speeds of 4000 and 5000 rpm. It should be noted that the particle sizes are determined after the sample is ultrasonically dispersed in a liquid medium. Thus, there may be some differences between the measurements and the actual particle size from the pulverizer.

Pulverized sodium bicarbonate samples were analyzed for mill speeds of both 4000 and 5000 rpm. The results (Figure 5-2) showed that the MMD's for the raw, 4000 rpm, and 5000 rpm samples were 61.5, 24.3, and 18.8 microns, respectively. The data indicate that the reduced pulverized speed resulted in a slightly larger particle size distribution.

In addition to pulverizer speed, the particle size is dependent on the mass flowrate through the mill. Early in the test program, there was a concern that the grinding efficiency of one of the mills was degraded at higher sorbent feed rates. Table 5-2 shows the MMD's measured for samples collected at four different sodium sesquicarbonate feed rates while operating the mill at 4000 rpm. The results indicate that at a pulverizer speed of 4000 rpm, particle size was not adversely affected over the range of sorbent feed rates investigated.

Table 5-2

Effect of Sodium Sesquicarbonate Feed Rate on Pulverizer Performance (Pulverizer Speed: 4000 rpm)

Feed Rate (lb/min)	2Na/S Ratio (nom. @ full load)	MMD (microns)
16.1	0.43	15.1
25.5	0.65	19.6
49.0	1.26	19.8
58.4	1.91	17.0

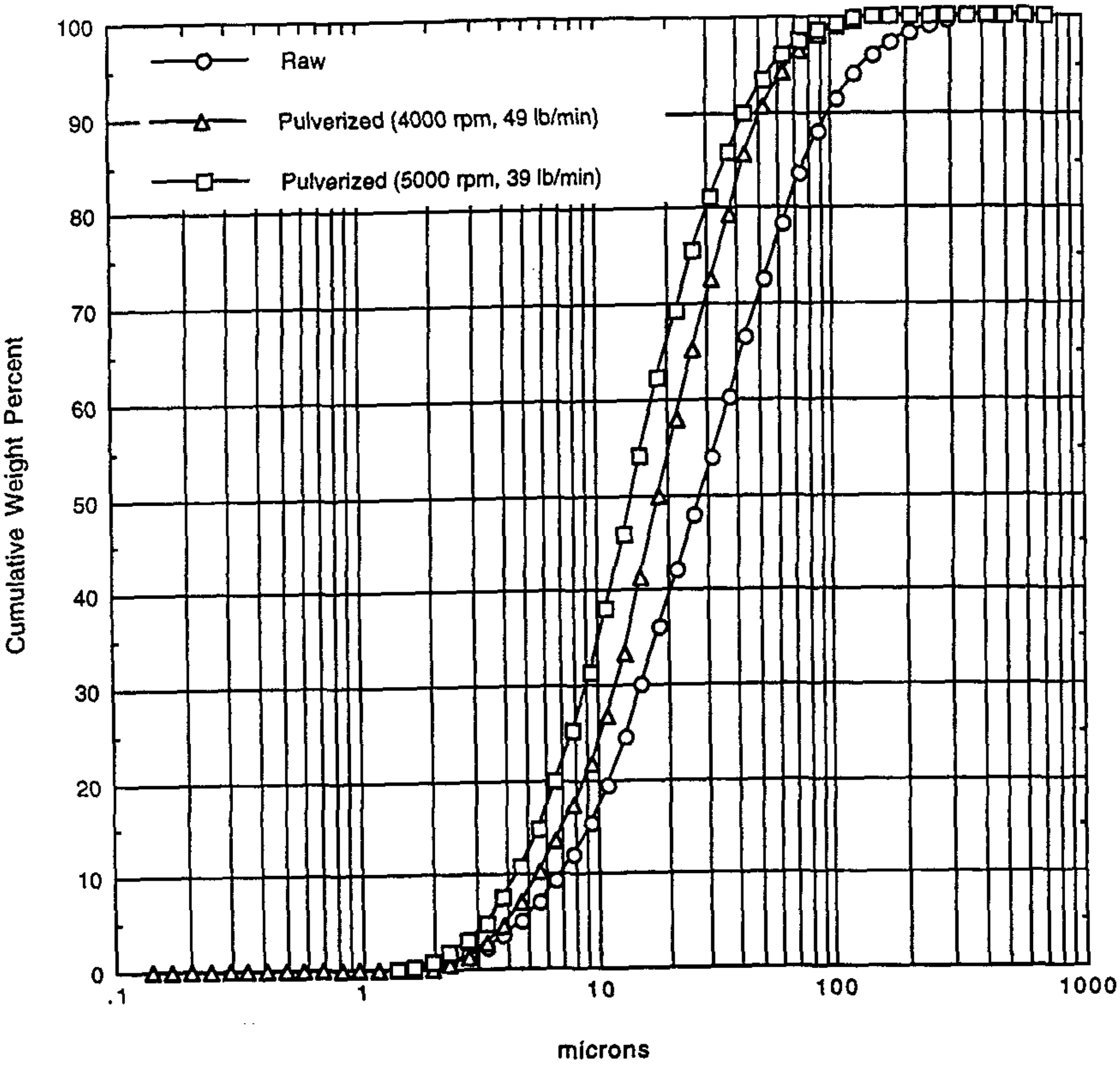


Figure 5-1. Sodium Sesquicarbonate Particle Size Distribution for Raw and Pulverized Samples

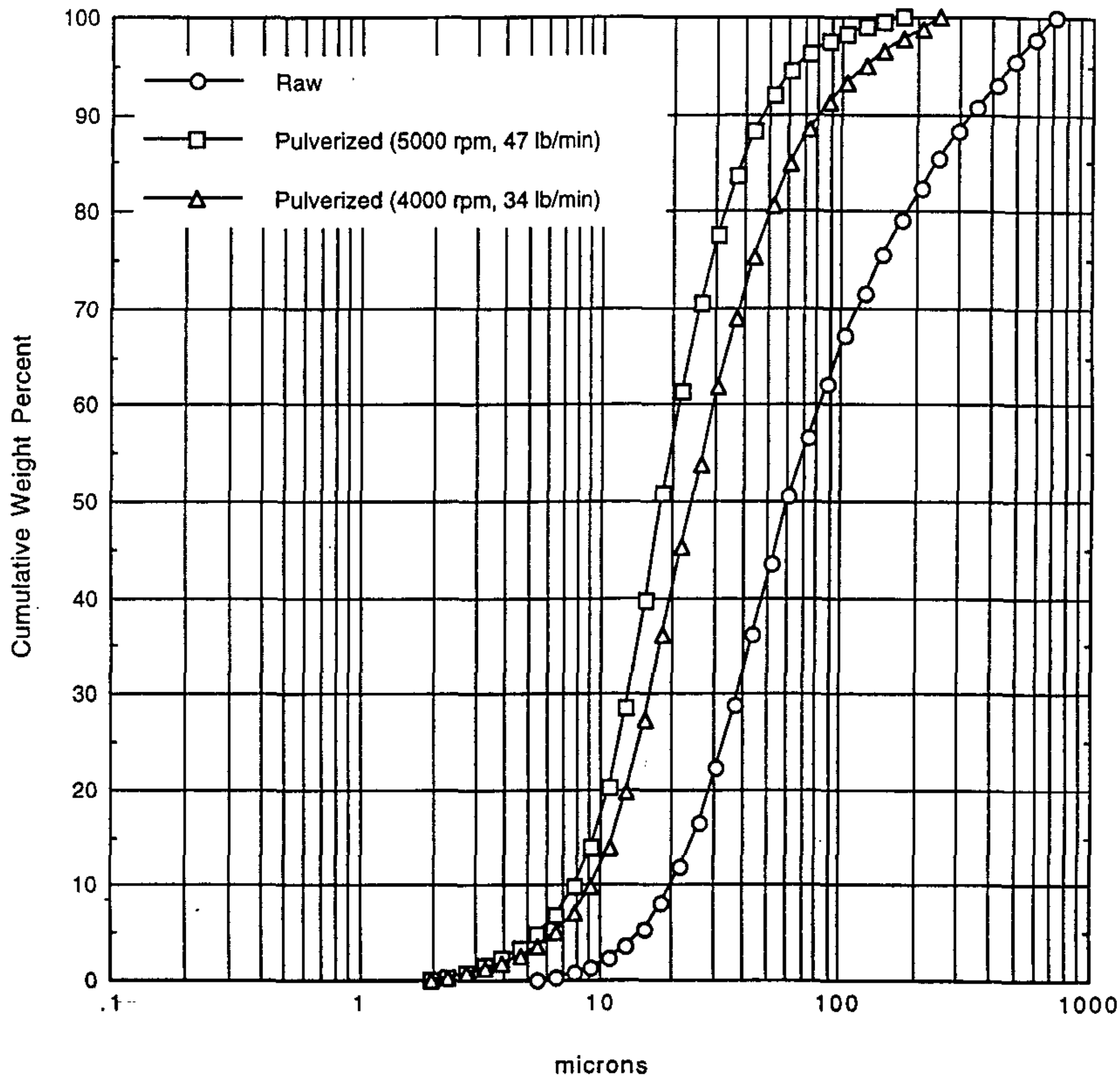


Figure 5-2. Sodium Bicarbonate Particle Size Distribution for Raw and Pulverized Samples

5.2 Sodium Sesquicarbonate

The sodium sesquicarbonate tests were performed at two different injection locations. A majority of the tests were run with sorbent injection ahead of the FFDC, and without humidification. Although little effect was expected, a few tests were also run with humidification, since the equipment was already in place from the previous phase of testing with calcium-based sorbents (Shiomoto, et al., 1994). After the testing with sodium sesquicarbonate was complete, tests began with sodium bicarbonate at the same location. These tests showed that the flue gas temperatures at the FFDC inlet were too low for good SO_2 removal performance with this sorbent. The injection location was then moved to a hotter region at the air heater inlet. After completion of the sodium bicarbonate tests at the new injection location, a short series of tests were also run with sodium sesquicarbonate in order to assess the effect of the higher injection temperature with this sorbent. The results of the sodium sesquicarbonate tests at the two injection locations are discussed separately in the following subsections.

5.2.1 Injection of Sodium Sesquicarbonate at the FFDC Inlet

A. SO_2 Removal. The tests with sodium sesquicarbonate injection ahead of the FFDC showed the SO_2 removal process to be very well-behaved with good day-to-day repeatability. Figure 5-3 shows the SO_2 removal measured at the exit of the FFDC over a seven-hour time period, where a single injection condition was maintained throughout the duration of the test. The nominal 2Na/S ratio for this particular test was 1.5, and the boiler load was 107 MWe. Previous tests at PSCo's Cameo Station (Muzio, et al., 1984) and at City of Colorado Springs' Nixon Station (Fuchs, et al., 1989), have shown that the reactions between the sodium sesquicarbonate and SO_2 are relatively rapid. Even during a fabric filter cleaning cycle there is only a temporary drop in SO_2 removal. Therefore, an effort was made during the current series of tests to measure the SO_2 removal immediately before and after each FFDC cleaning cycle in order to fully characterize this behavior. The SO_2 removals measured "before cleaning" are shown in Figure 5-3 as dark symbols. In general, the results with sodium sesquicarbonate showed that once injection had begun,

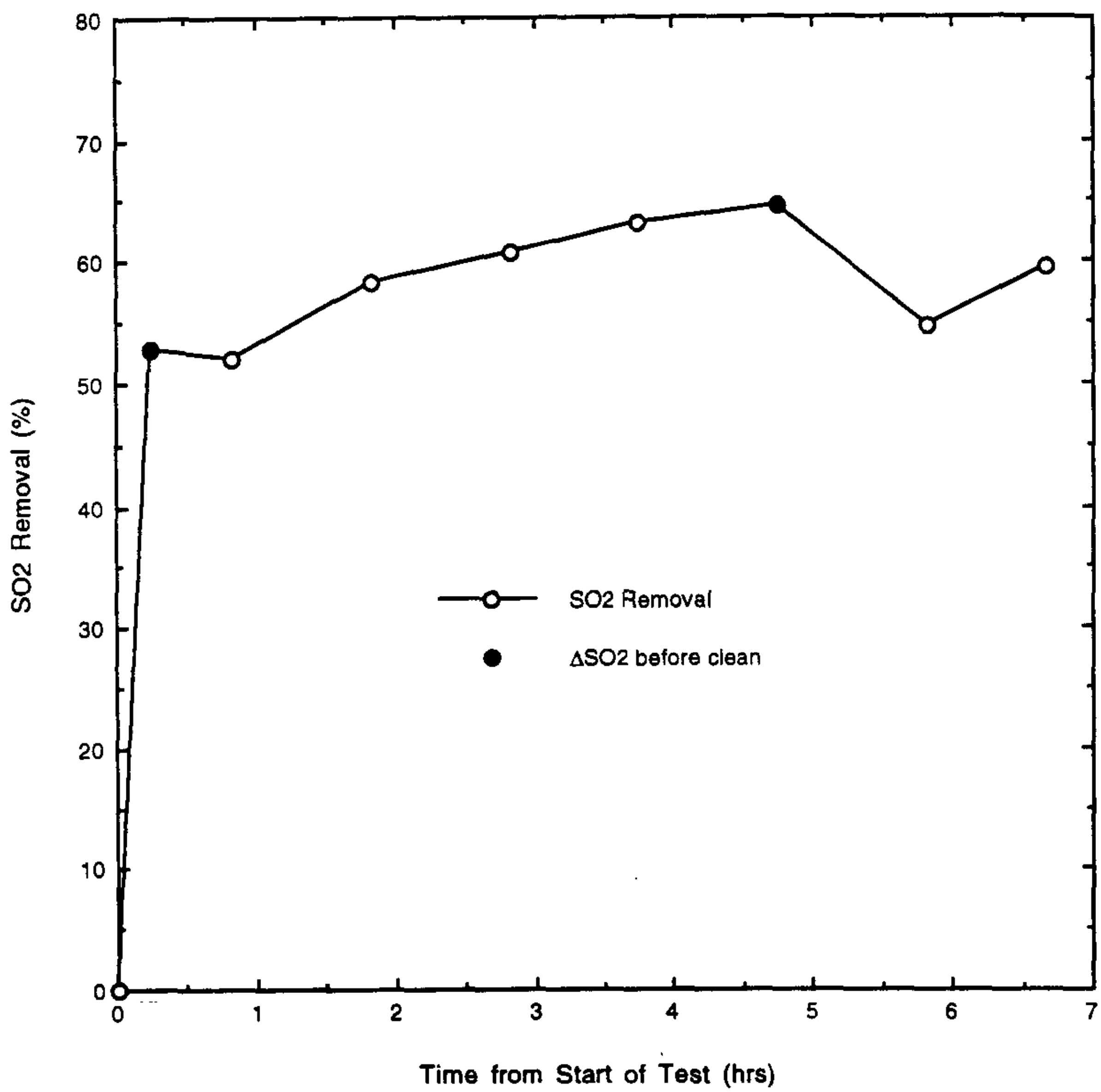


Figure 5-3. SO_2 Removal Versus Time for Sodium Sesquicarbonate Injection Ahead of the FFDC (Test 818)

SO_2 removals increased rapidly and leveled-out in a relatively short amount of time. For the test shown in Figure 5-3, a cleaning cycle began only 15 minutes after sorbent injection was initiated. In that short amount of time, the SO_2 removal had already reached 53 percent. There was no appreciable decrease in removal after this first cleaning cycle, and then a slow increase up to nominally 65 percent removal before the second cleaning. The decrease in SO_2 removal at the six-hour mark (nominally 10 percent) is typical of the response that was seen after each cleaning cycle with sodium sesquicarbonate injection at the FFDC inlet.

The steady-state SO_2 removal and utilization results of many tests like the one shown in Figure 5-3 are presented as a function of sorbent injection rate (expressed in terms of 2Na/S ratio) in Figures 5-4a and 5-4b. Variations in boiler load were expected to have little effect on SO_2 removal, and the data confirm this expectation. At nominal 2Na/S ratios of 1.0 and 2.0, SO_2 removals range from 44 to 56 percent and 64 to 78 percent, respectively. Alternatively, the 2Na/S ratios required to achieve the target SO_2 removal of 70 percent ranged from 1.6 to 2.2.

Along with boiler load, flue gas temperature was expected to have little effect on SO_2 removal for sesquicarbonate injection ahead of the FFDC. As will be discussed in the presentation of the sodium bicarbonate results, the FFDC outlet temperature at Arapahoe Unit 4 routinely varies from 230 to 280°F depending on load, time of day, and ambient temperature. There was no effect seen over this temperature range during the current series of sesquicarbonate tests.

The SO_2 removals shown in Figure 5-4a for 2Na/S ratios up to 1.0 are comparable to those reported in the previous studies performed at Cameo and Nixon. As the 2Na/S ratio is increased further, the results from the current study begin to fall below those of the earlier work. Figure 5-5 shows a comparison of the two sets of results. It was thought that the difference may have been due to a deterioration of the grinding performance of the

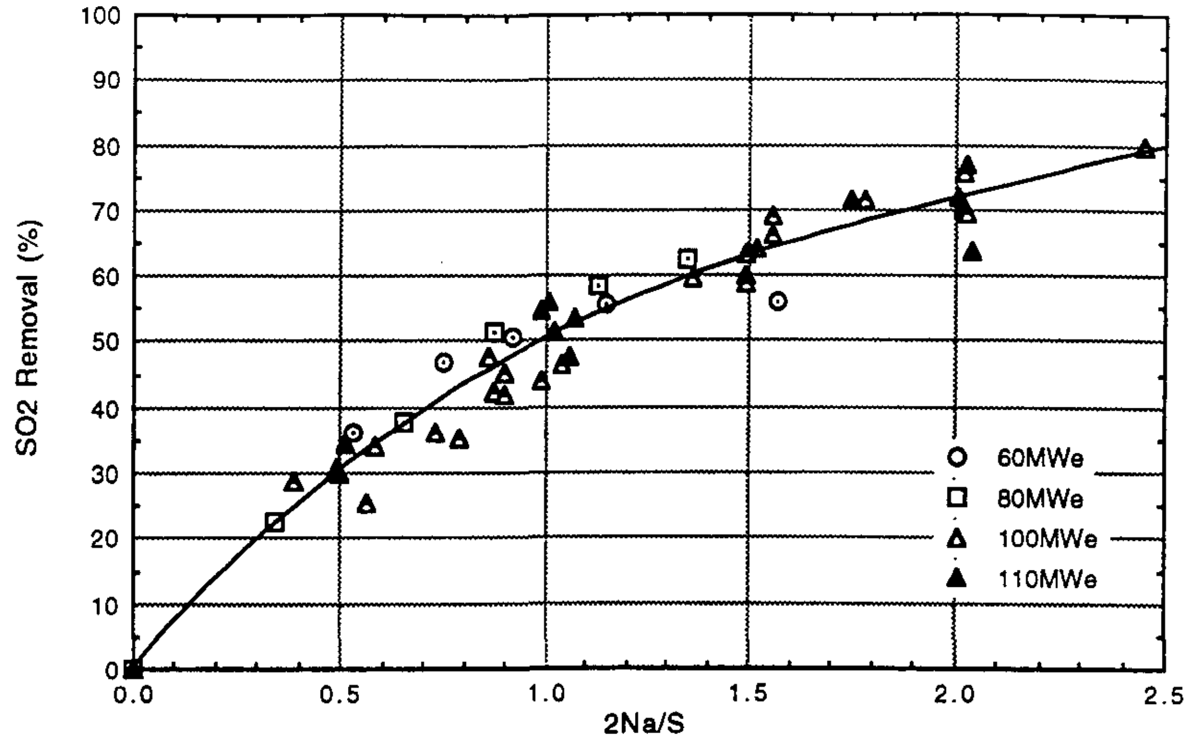


Figure 5-4a. SO_2 Removal as a Function of 2Na/S Ratio for Sodium Sesquicarbonate Injection Ahead of the FFDC

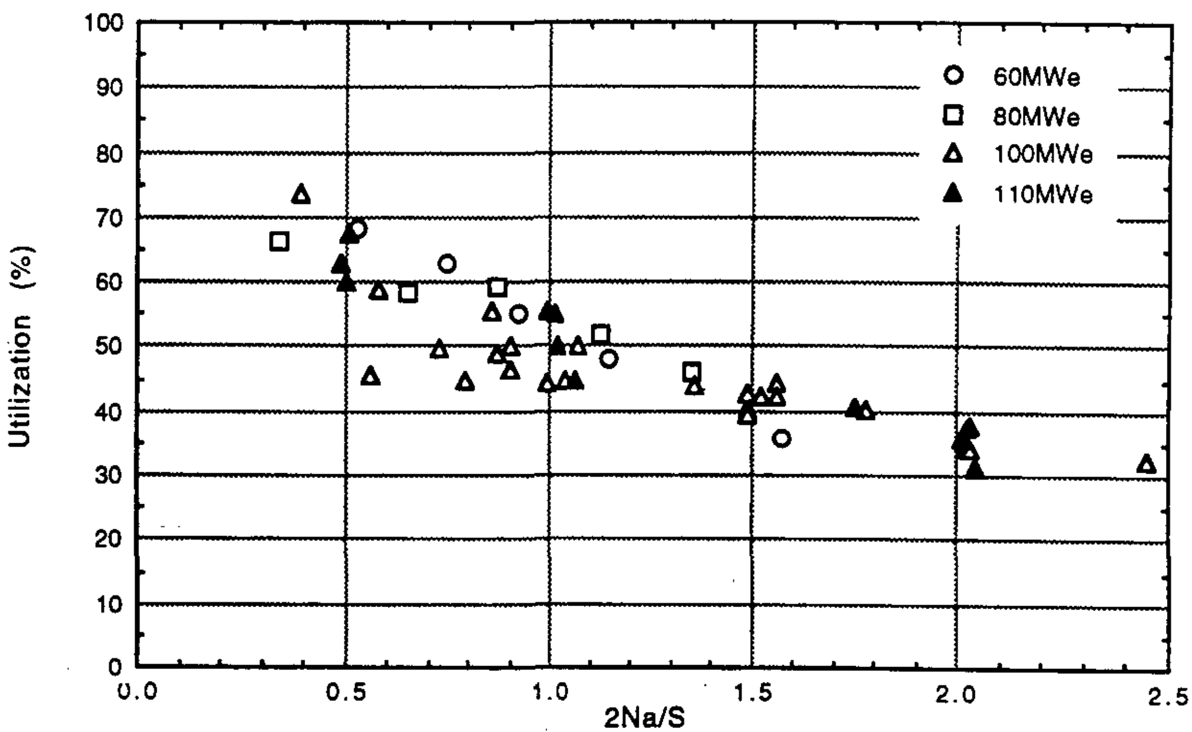


Figure 5-4b. Utilization as a Function of 2Na/S Ratio for Sodium Sesquicarbonate Injection Ahead of the FFDC

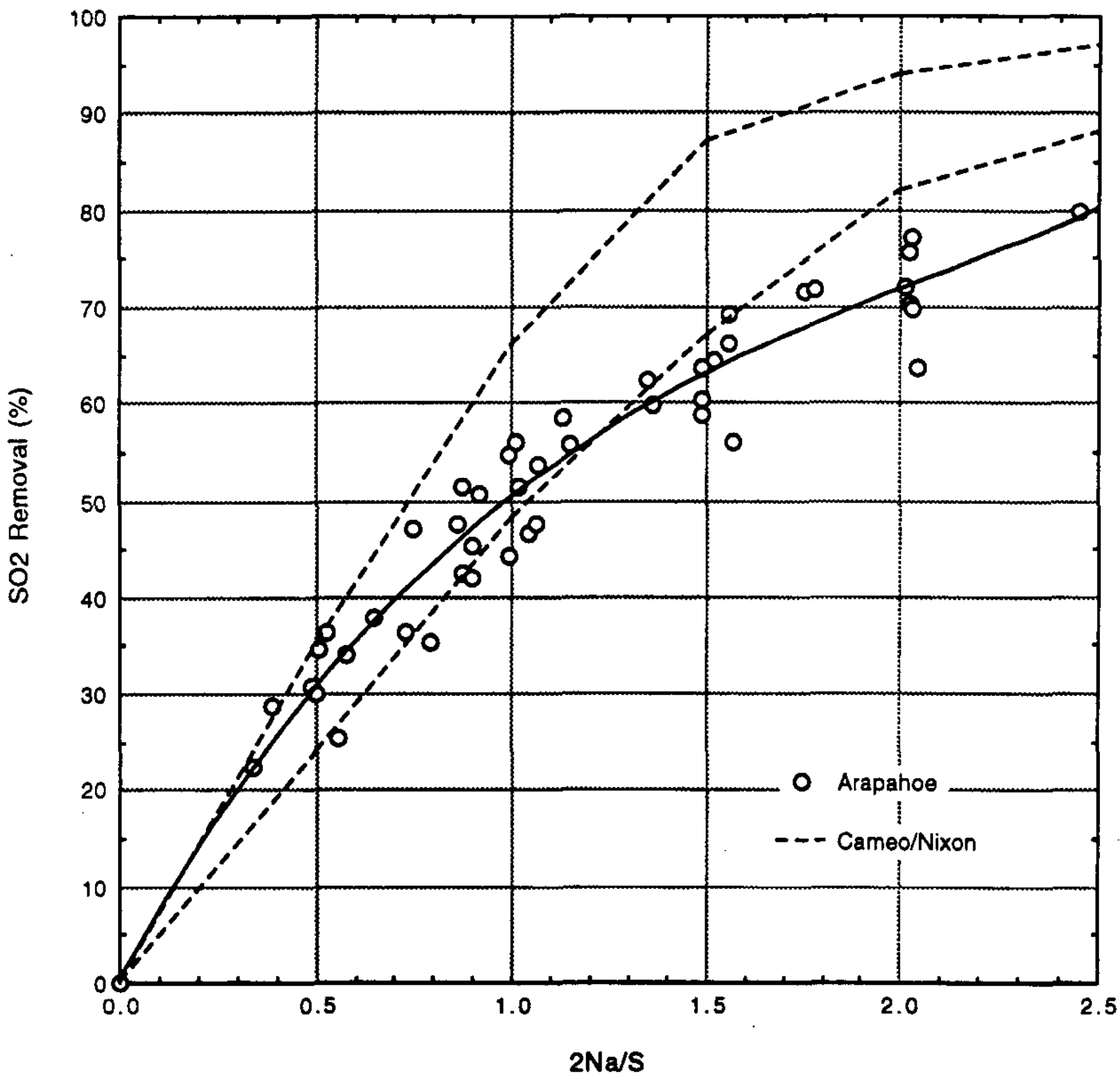


Figure 5-5. Comparison of SO_2 Removals for Sodium Sesquicarbonate Injection Ahead of the Arapahoe Unit 4 FFDC to Previous Full-Scale Demonstrations (Cameo and Nixon data from Muzio, et al., 1984 and Fuchs, et al., 1989)

Arapahoe DSI pulverizers at the higher sorbent feed rates; however, the test results shown in Table 5-2 do not support this hypothesis.

Further, tests were conducted using either one or both of the sorbent feed systems to achieve a given 2Na/S ratio. If particle size degraded with pulverizer throughput rate, then a test using both systems to achieve a given 2Na/S ratio should produce smaller sorbent particles and higher SO_2 removal. With two sorbent preparation systems, each mill would only have one half of the throughput. Also, the distribution within the duct should improve as the material would be injected through twelve pipes instead of six. Figure 5-6 shows the SO_2 removals obtained when one and two of the sorbent feed systems were used. As can be seen, the results in Figure 5-6 do not show any clear difference between using one or two sorbent preparation systems.

The data in Figures 5-4a and 5-4b show that SO_2 removals and utilizations are consistent over time, with the 60, 80 and 100 MWe collected in September 1993 being comparable to the 110 MWe data which was collected nearly eight months later in May 1994. The latter set of data was collected during the Integrated Systems (LNB/OFA/SNCR/sodium-based DSI) phase of tests which immediately followed the phase of testing described in this report. Since the results in Figures 5-4a and 5-4b are repeatable, it is not believed that the differences between the Cameo/Nixon and Arapahoe results at higher feed rates are due to process variability at the current installation.

One variable which was expected to have an effect on process performance was sorbent particle size. Figure 5-7 shows the effect of pulverizer speed on SO_2 removal for sesquicarbonate injection ahead of the FFDC. As discussed in Section 3, the sorbent pulverizers were installed with operating speeds of 5700 rpm. Before testing began, however, it was discovered that this speed was very near a critical frequency. Therefore, a decision was made to reduce the speed to 5000 rpm. Due to the 3-week lead time for the new drive sheaves, the pulverizers were run for a short time at 4000 rpm (these sheaves were readily available). The data in Figure 5-7 show that the higher pulverizer

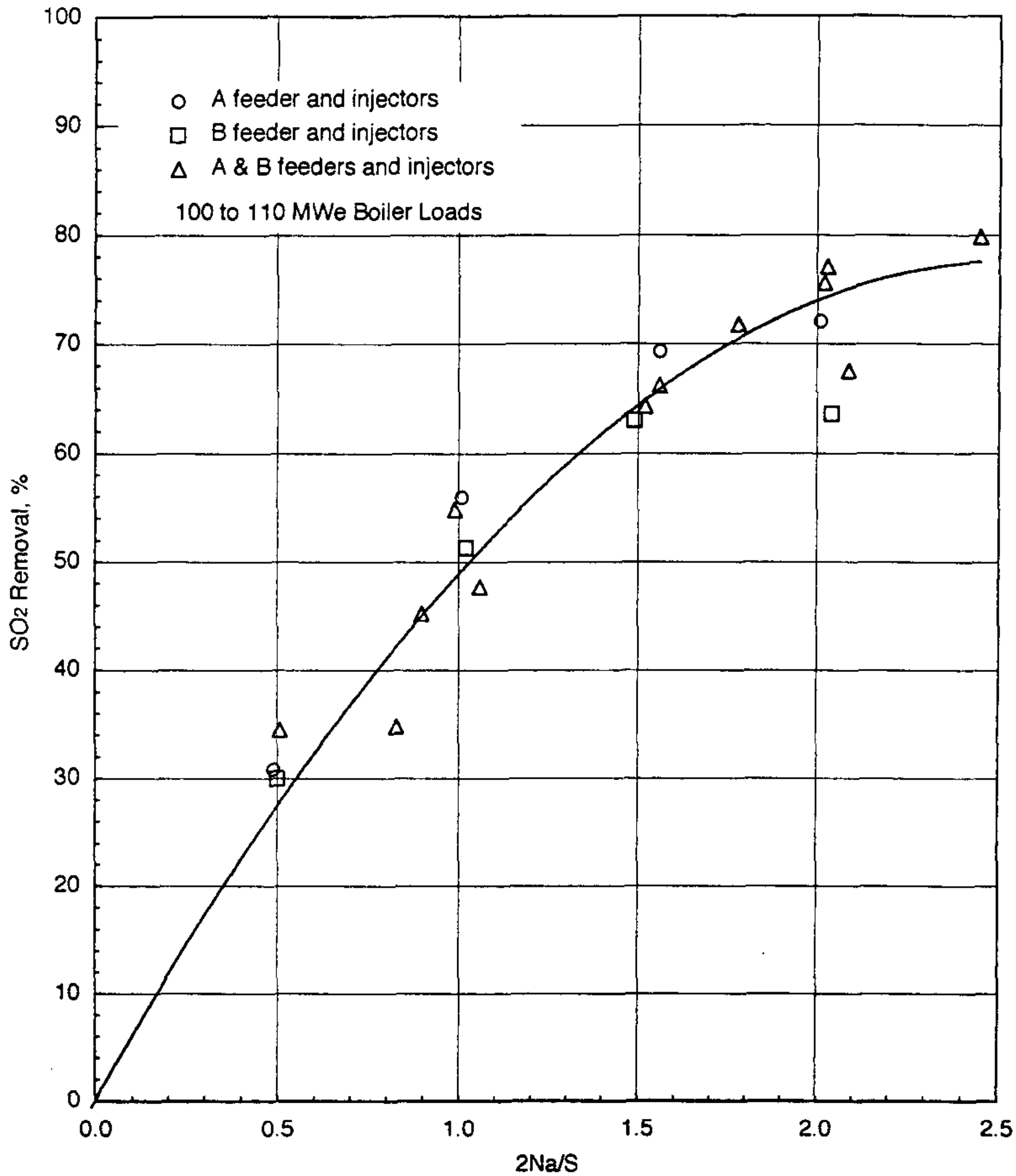


Figure 5-6. Effect of Using One and Two Sorbent Preparation Systems on SO_2 Removal (Sodium Sesquicarbonate Injection Ahead of the Fabric Filter)

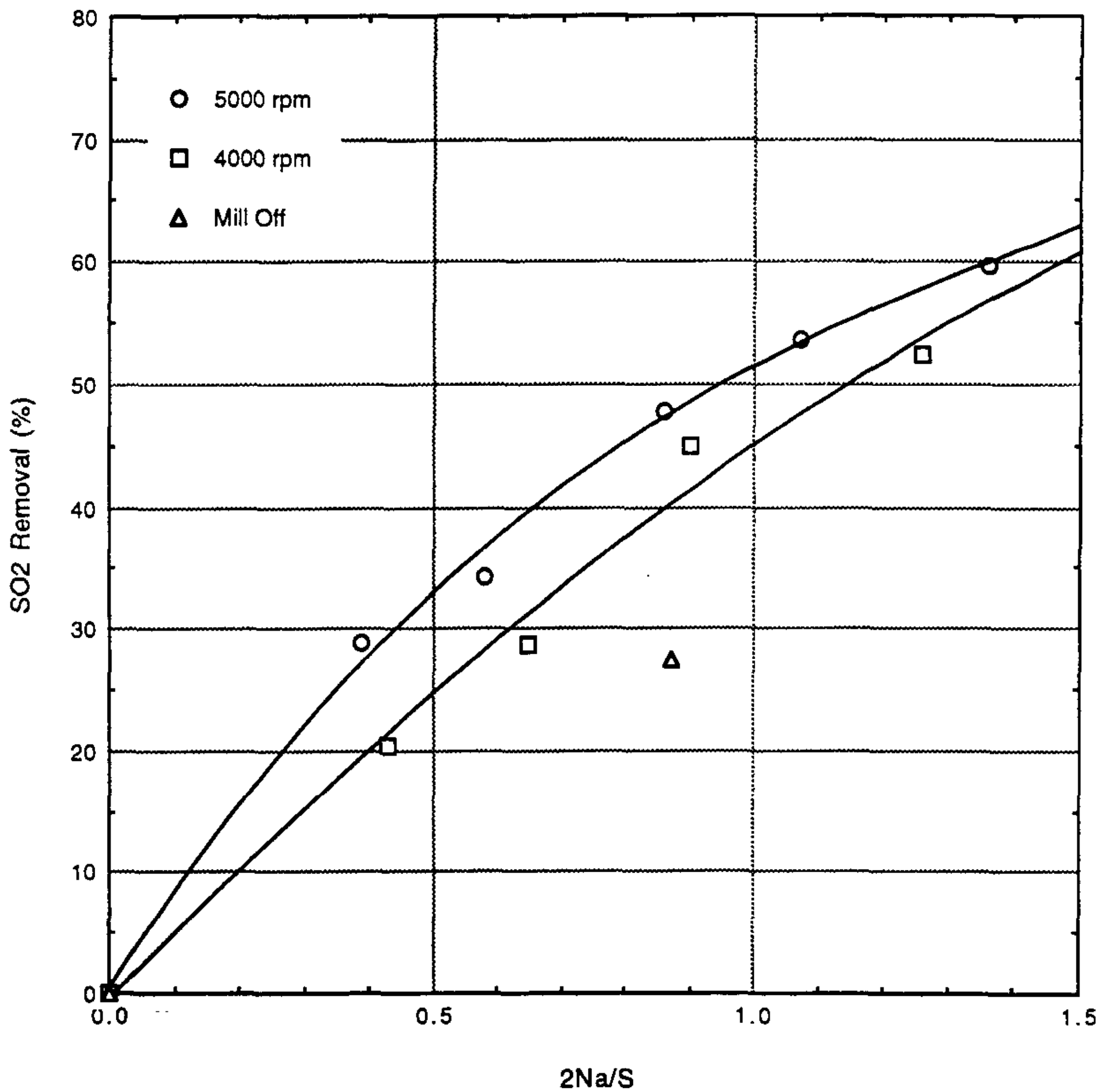


Figure 5-7. Effect of Pulverizer Speed on SO_2 Removal for Sodium Sesquicarbonate Injection Ahead of the FFDC

speed results in approximately a net seven percent increase in SO_2 removal at a nominal 2Na/S ratio of 1.0. The "mill off" point is a single test run at the end of a test day when the speed was 5000 rpm. After the final "mill on" test was finished, the mill was turned off while the sorbent feed continued. A data point was taken after the mill had stopped rotating (which can take 10 to 15 minutes due to the weight of the grinding disk). Recall that at 4000 rpm, the mill reduces the particle MMD from nominally 28 to 17 microns (Figure 5-1). The data in Figure 5-6 show that this size reduction results in an increase in SO_2 removal from approximately 27 to 48 percent at a nominal 2Na/S ratio of 0.9.

During the final test at 4000 rpm, gaseous emission measurements were made at the exit of each FFDC compartment in an effort to characterize the distribution of sorbent in the fabric filter. Figure 5-8 shows the results of the compartment-by-compartment measurements. The results indicate that the highest levels of SO_2 removal (45 to 58 percent) occur in the second and third compartments on each side of the baghouse, indicating that the majority of the sorbent is deposited in these areas. The peak on each side is followed by a rapid decrease down to 10 to 15 percent removal in the rear compartments. These results also show that, with the exception of the final two compartments, removals in the east compartments are nominally 10 to 15 percent higher than the removals in the corresponding west-side compartments. This difference is likely due to a bias in the injection system, which resulted from partial plugging of some of the east-side injectors. Also, note in Figure 5-8 that the average of the compartment-by-compartment SO_2 removals is in good agreement with the overall SO_2 removal across the FFDC (35.1 percent compared to 35.5 percent). This suggests that the gas flow rates through each compartment are relatively equal.

Another possible explanation for the differences between the current SO_2 removal results at Arapahoe and the prior demonstrations at Cameo and Nixon (Muzio, et al., 1984, and Fuchs, et al., 1989) is the compartment-by-compartment variations in SO_2 removal shown in Figure 5-8. However, reviewing the compartment-by-compartment SO_2 removals

Test 641, 2Na/S=0.88, NaSC, Mill Speed 4000 rpm
9/7/93

Compartment Gas Measurement

#	O2	SO2	NO	NOc	SO2c	SO2n	ΔSO2
___	%dry	ppm	ppm	ppmc	ppmc	___	%
1 sw	6.30	255	210	257	312	1.15	26.0
2 w	5.85	196	215	255	233	0.86	44.8
3 w	5.65	200	215	252	235	0.86	44.4
4 w	5.35	240	215	247	276	1.02	34.5
5 w	5.50	300	222	258	348	1.28	17.4
6 nw	5.20	320	215	245	365	1.34	13.6
7 se	5.50	213	204	237	247	0.91	41.3
8 e	5.20	155	190	216	177	0.65	58.1
9 e	5.40	156	192	222	180	0.66	57.3
10 e	5.10	190	195	221	215	0.79	49.0
11 e	5.20	260	210	239	296	1.09	29.8
12 ne	5.30	330	212	243	378	1.39	10.3
Ave	5.46			241	272	1.00	35.5
West	5.64			252	295	1.08	30.1
East	5.28			230	249	0.92	41.0

Average Inlet/Outlet Gas Measurements

Probe	O2	SO2	NO	H2O	NOc	SO2c	ΔSO2
___	%wet	ppm	ppm	%	ppmcd	ppmcd	%
Inlet	4.90	331	208	9.39	265	422	
Stack	5.40	208	189	9.15	249	274	35.1

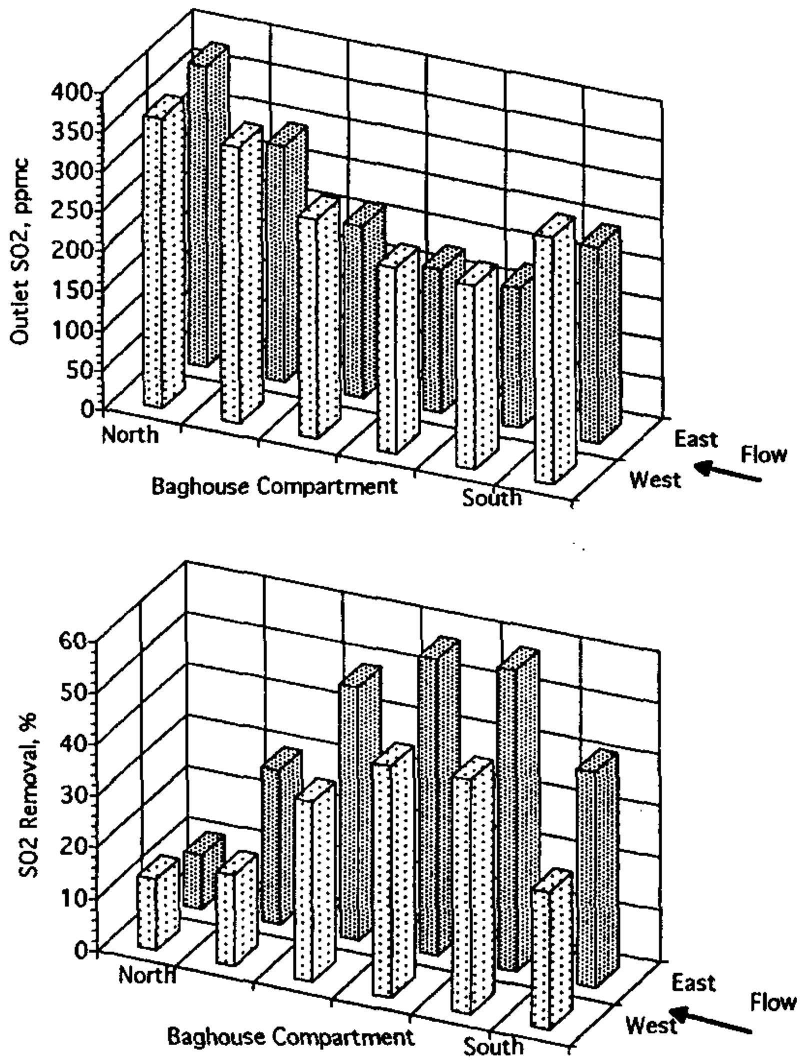
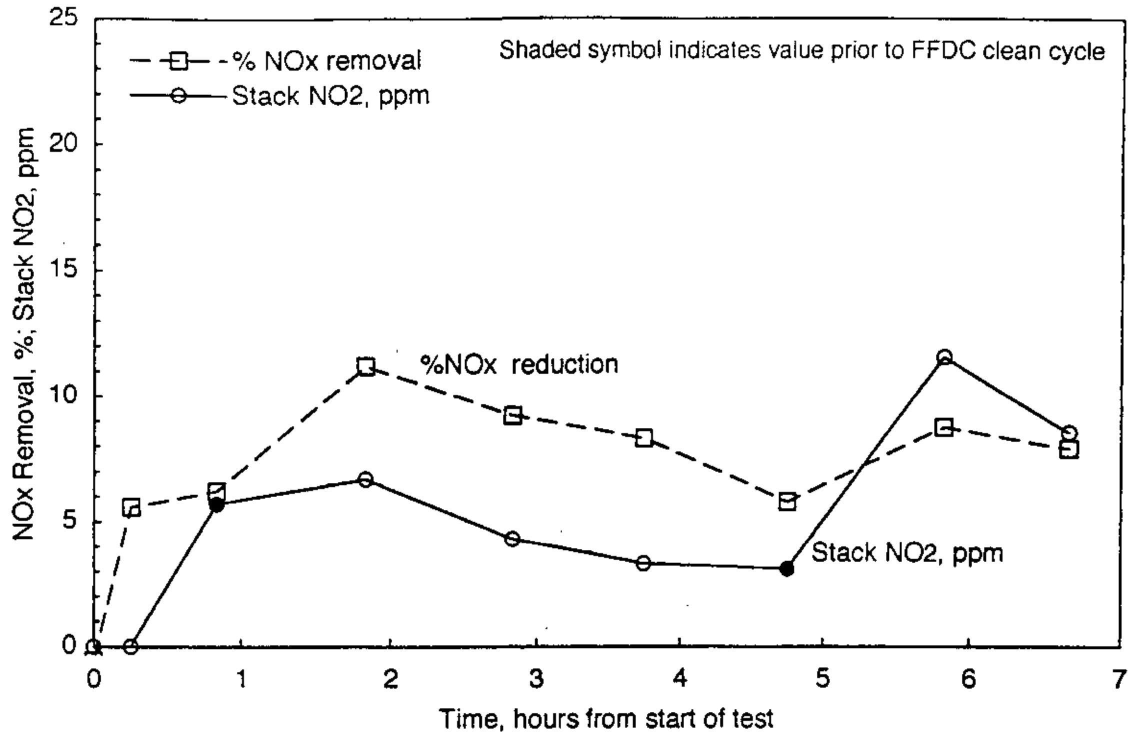


Figure 5-8. Compartment-by-Compartment Gaseous Measurements for Sodium Sesquicarbonate Injection Ahead of the FFDC (Test 641)

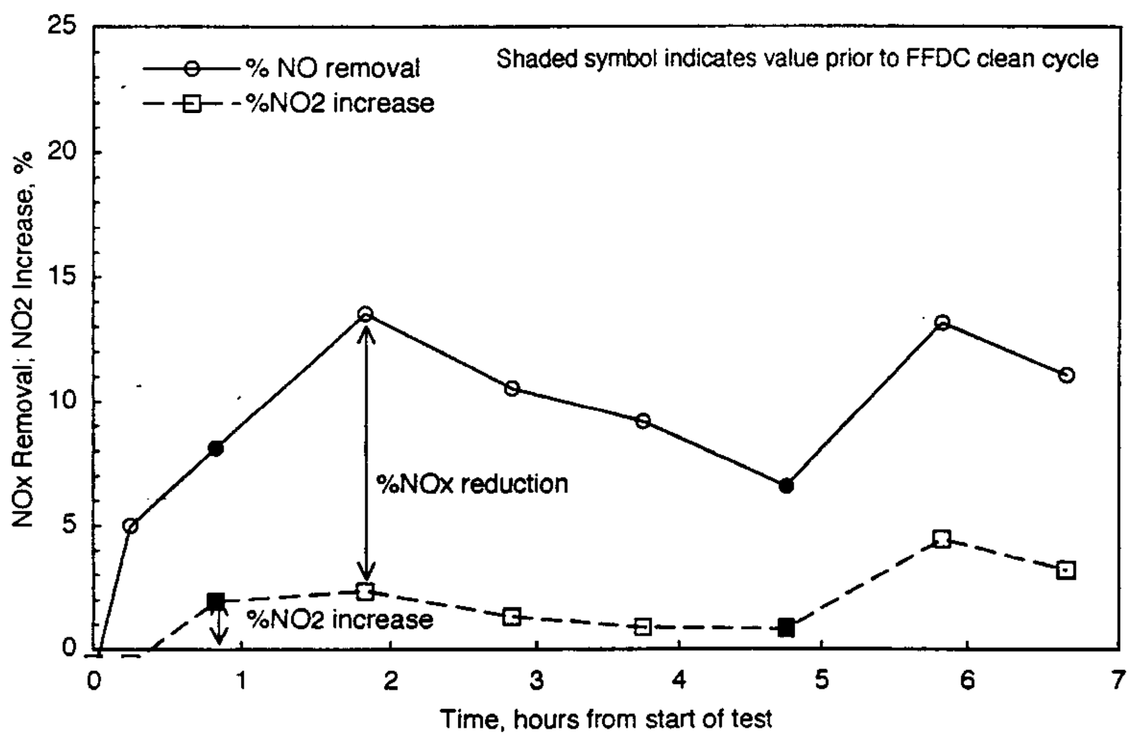
measured during the Cameo demonstration (Muzio, et al., 1984) show a higher degree of variability than seen in Figure 5-8. This suggests that compartment by compartment sorbent distribution does not explain the differences in the current Arapahoe results and prior Cameo/Nixon results.

B. NO_x Removals and NO_2 Emissions. The previous work at Cameo and Nixon (Muzio, et al., 1984, Fuchs, et al., 1989) showed that in addition to the removal of SO_2, sodium-based sorbents also remove a small amount of NO_x as well as oxidize a portion of the NO to NO_2. During the current test program, NO_x removals and NO_2 emissions were characterized with both sorbents. Before presenting the sodium sesquicarbonate results in terms of the overall NO_x removals and NO_2 emissions measured as a function of the sorbent injection rate, it is of interest to first look at some of the time-resolved data from a typical test.

Figure 5-9a shows both the NO_x removal and NO_2 emission traces recorded during the 7-hour test with sodium sesquicarbonate injection ahead of the FFDC shown in Figure 5-3. The NO_2 trace shows an interesting trend that was not reported previously, where NO_2 emissions increase sharply after each cleaning cycle. After the initial increase, there is a slow decrease in NO_2 emissions until the second cleaning cycle begins. This behavior was also seen during the long-term sodium bicarbonate injection tests, and will be discussed in more detail during the presentation of those results. It is currently thought that this behavior is due to an interaction between NO_2 and the fly ash on the bags. The peak NO_2 level achieved during the test shown in Figure 5-9a was 12 ppm. However, data points immediately after each cleaning indicate an increasing trend, and it is possible that the peak level would have been higher if the test had been run for a longer time period. The NO_x removals shown in Figure 5-9a also indicate an increasing trend with time, but unlike the NO_2 emissions, there does not appear to be an effect of FFDC cleaning cycle. The range of 10 to 15 percent NO_x removal shown in Figure 5-9a is consistent with the levels observed during the previous Cameo and Nixon studies.



(a) NO_2 and NO_x Removal



(b) Partitions of the Change in NO Between NO_2 and NO_x Removal

Figure 5-9. NO_x Removal and NO_2 Emissions Versus Time for Sodium Sesquicarbonate Injection Ahead of the FFDC (Test 818)

The increase in NO_2 levels following a fabric filter cleaning cycle is quite interesting and, as mentioned above, have not been reported in previous studies of dry sodium injection. The effect is due to an interaction between NO_2 and the fly ash on the bags. More specifically, it is currently thought that the interaction is with the carbon in the fly ash. Following the low NO_x combustion system retrofit, while the carbon content of the ash did not increase, it did appear to change physically. Even though the ash carbon contents were still at the pre-retrofit levels, the ash visually appeared black. This suggests the possibility that the low NO_x combustion system may form some small soot particles that coat the ash particles. This fine coating of carbon on the ash could be more reactive than an equivalent amount of carbon more uniformly distributed through an ash particle. How the fly ash, or fly ash carbon, interacts with the sodium generated NO_2 is currently not known. Possible mechanisms include physical absorption of the NO_2 by the carbon, catalytic oxidation of $NaNO_2$ to $NaNO_3$, or catalytic reduction of NO_2 to NO. The specific mechanism is currently not known; and the results indicate that the overall NO_x chemistry associated with dry sodium injection is even more complex than outlined in Section 3.

Figure 5-9a showed the NO_2 levels and NO_x removal that occurred during the 7-hour test with sodium sesquicarbonate. As discussed in Section 3.1, the chemical mechanism is thought to involve the formation of an unstable intermediate sodium compound, $NaNO_2$, which will further react to release NO_2, or oxidize to form solid $NaNO_3$. The latter resulting in NO_x removal. It is of value to look at how the NO that reacts is partitioned between NO_2 and NO_x removal. This is shown in Figure 5-9b for the data in Figure 5-9a. In Figure 5-9b, the total height of the line plotted with the "circles" represents the total change in NO due to the sodium reactions. The dotted line represents the conversion of NO to NO_2. For instance, for the data point just before 2 hours, the total change in NO was about 13%; the NO_x removal was 11%, and the increase NO_2 emissions represents only 2% of the initial NO_x. Even after the second cleaning cycle, which started just before 5 hours, when the NO_2 increased from 3 ppm to 11 ppm (2% to 5%), the majority of the change in NO resulted in NO_x removal.

Figure 5-10 shows the compartment-by-compartment NO_x removals and NO_2 levels for the same test shown in Figure 5-8. As with the SO_2 removals shown in Figure 5-8, the NO_x removal and NO_2 levels are higher on the east side of the fabric filter. In fact, the NO_2 levels are less than 1 ppm exiting the compartments on the west side. As with Figure 5-9b, Figure 5-11 shows the partitioning of the NO that reacts between NO_2 and NO_x removal. For all compartments, the vast majority that reacts results in NO_x removal, rather than NO_2 emissions.

Figure 5-12 summarizes the NO_2 emission measurements as a function of injection rate (2Na/S) for all of the sodium sesquicarbonate tests performed during the current study. The figure includes data for injection ahead of the FFDC as well as ahead of the air heater. (The air heater data will be discussed in a later section.) Although the data exhibit an increasing trend with injection rate, there is a large amount of scatter where the NO_2 emissions range from approximately 5 to 25 ppm at a nominal 2Na/S ratio of 2.0. As discussed above, the NO_2 emissions depend not only on the injection rate, but also on the FFDC cleaning cycle (i.e., the amount of flyash on the bags). It should be noted that there has been no attempt to either filter or correlate the data in Figure 5-12 with respect to cleaning cycle timing.

Figure 5-13 summarizes the NO_x removals with sodium sesquicarbonate injection ahead of the FFDC. As was seen for NO_2 emissions, there is a significant amount of scatter in the data, with a very slightly increasing trend with injection rate. NO_x removals range from 2 to 18 percent at a nominal 2Na/S ratio of 2.0.

C. Sodium Sesquicarbonate Injection with Humidification. A limited number of sodium sesquicarbonate tests were run with humidification in order to see if the SO_2 removals would increase. Five tests were run with an approach to saturation temperature of approximately 60°F, and one each with approaches of 50 and 90°F. The results of these tests are compared to the SO_2 removals without humidification in Figure 5-14. It should

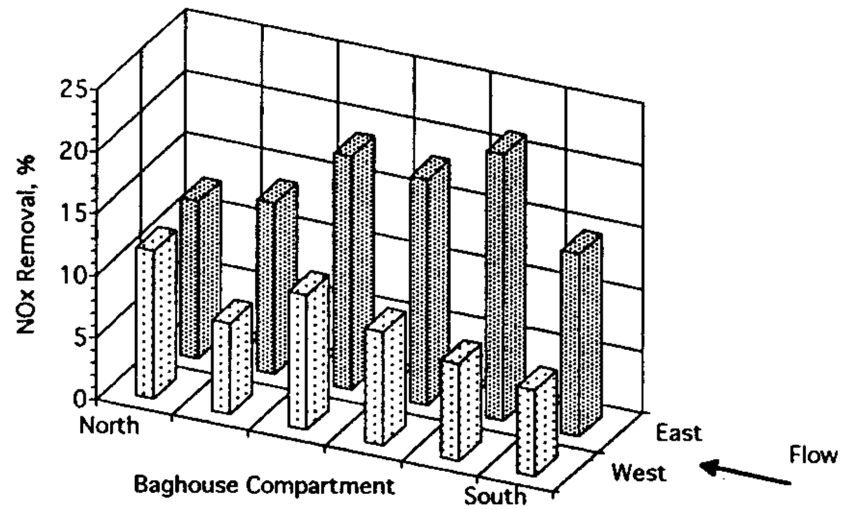
Test 641, 2Na/S=0.88, NaSC, Mill Speed 4000 rpm
9/7/93

Compartment Gas Measurement

#	O2	NO	NO2	NOx	NOxc	NOxn	Δ%NOx	Δ%NO2
___	%dry	ppm	ppm	ppm	ppmc	___	%	%
1 sw	6.30	210	1.0	211	258	1.07	7.1	0.4
2 w	5.85	215	0.4	215	256	1.06	8.0	0.2
3 w	5.65	215	0.2	215	252	1.04	9.2	0.1
4 w	5.35	215	0.3	215	248	1.02	10.9	0.1
5 w	5.50	222	-0.2	222	258	1.06	7.4	-0.1
6 nw	5.20	215	-0.1	215	245	1.01	11.9	0.0
7 se	5.50	204	0.0	204	237	0.98	14.8	0.0
8 e	5.20	190	1.5	192	218	0.90	21.5	0.6
9 e	5.40	192	5.1	197	227	0.94	18.2	2.1
10 e	5.10	195	4.4	199	226	0.93	18.8	1.8
11 e	5.20	210	0.5	211	240	0.99	13.7	0.2
12 ne	5.30	212	-0.1	212	243	1.00	12.6	0.0
Ave	5.48	208	1.1	209	242	1.00	12.8	0.4
West	5.64	215	0.3	216	253	1.04	9.1	0.1
East	5.28	201	1.9	202	232	0.96	16.6	0.8

Average Inlet/Outlet Gas Measurements

Probe	O2	NO	NO2	H2O	NOx	NOxc	ΔNOx
___	%wet	ppm	ppm	%	ppm	ppmcd	%
Econ	5.60	235	0.4	0.78	235	278	
Stack	5.40	189	0.0	9.15	189	249	10.5



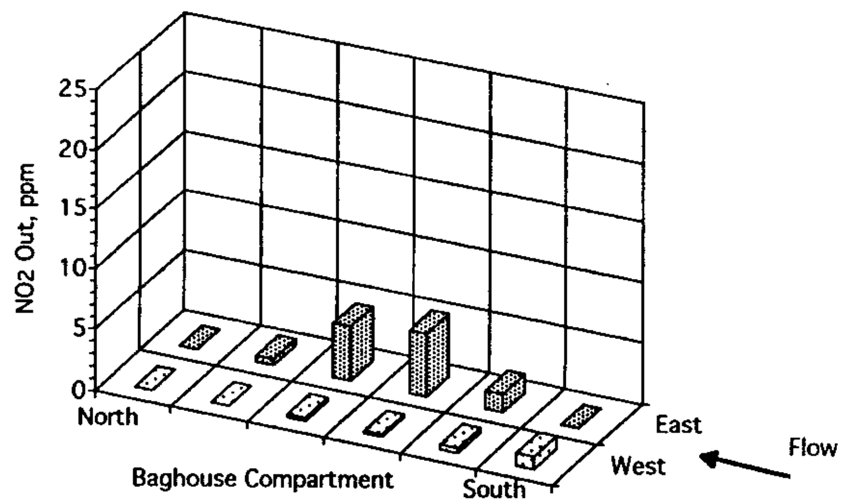
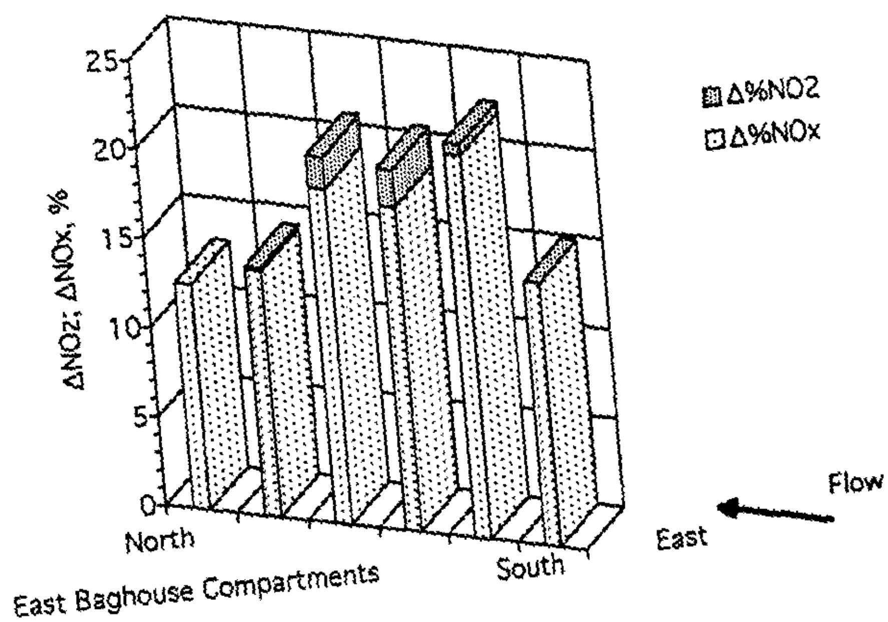


Figure 5-10. Compartment-by-Compartment NO and NO_2 for Sodium Sesquicarbonate Injection Ahead of the FFDC (Test 641)



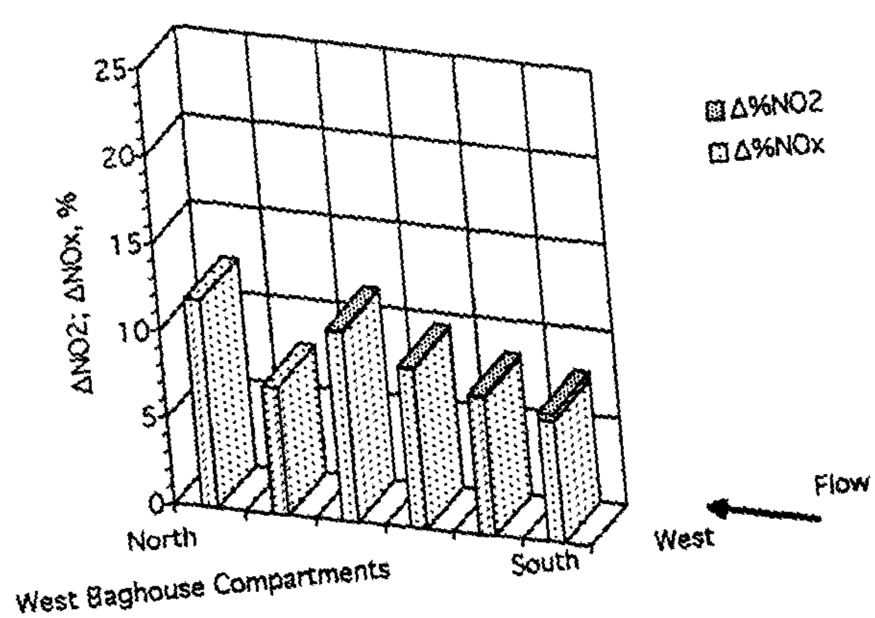


Figure 5-11. Change in NO_x and NO_2 for Sodium Sesquicarbonate for FFDC Inlet Injection (Test 641)

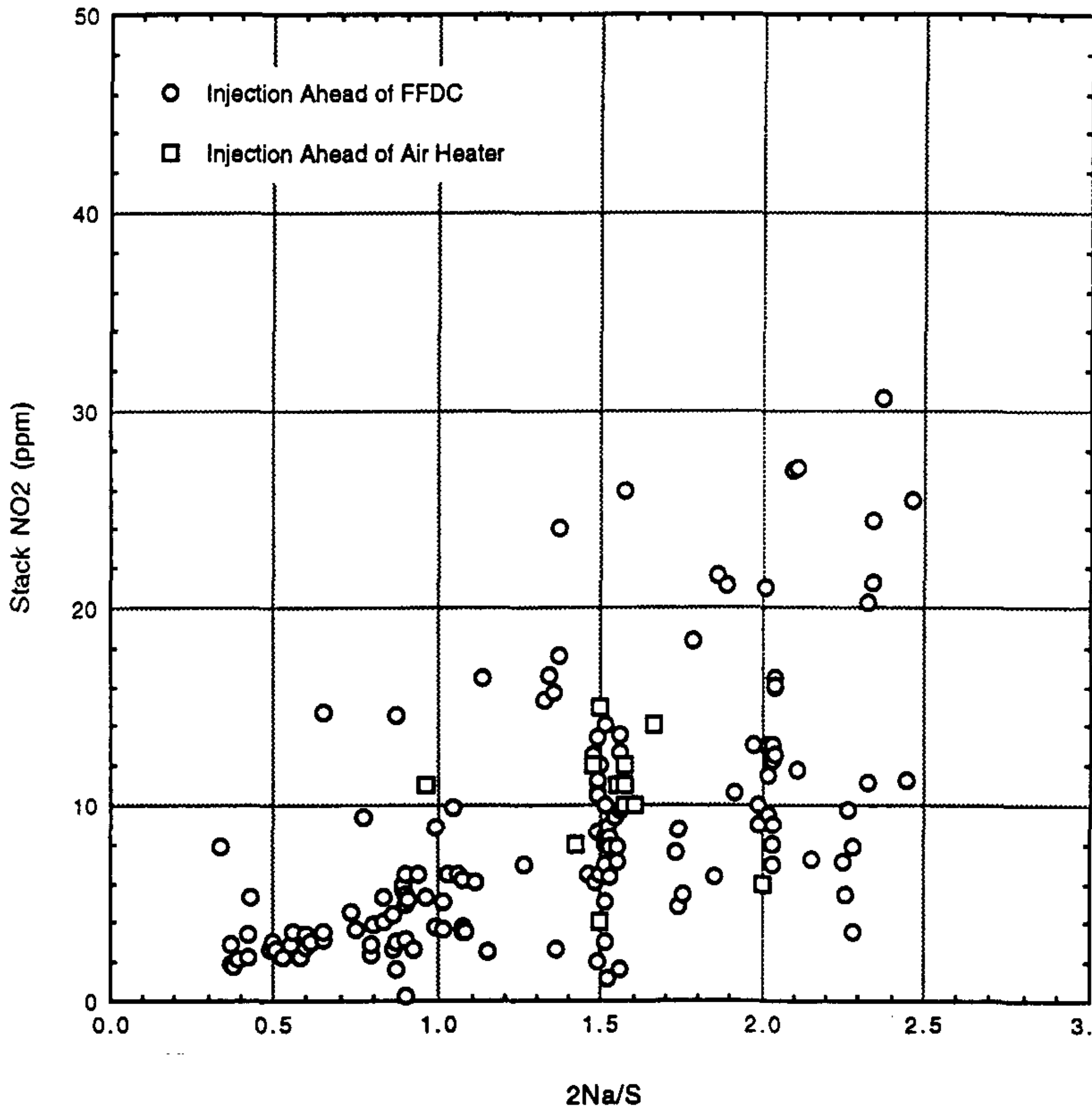


Figure 5-12. Summary of NO_2 Emissions with Sodium Sesquicarbonate Injection

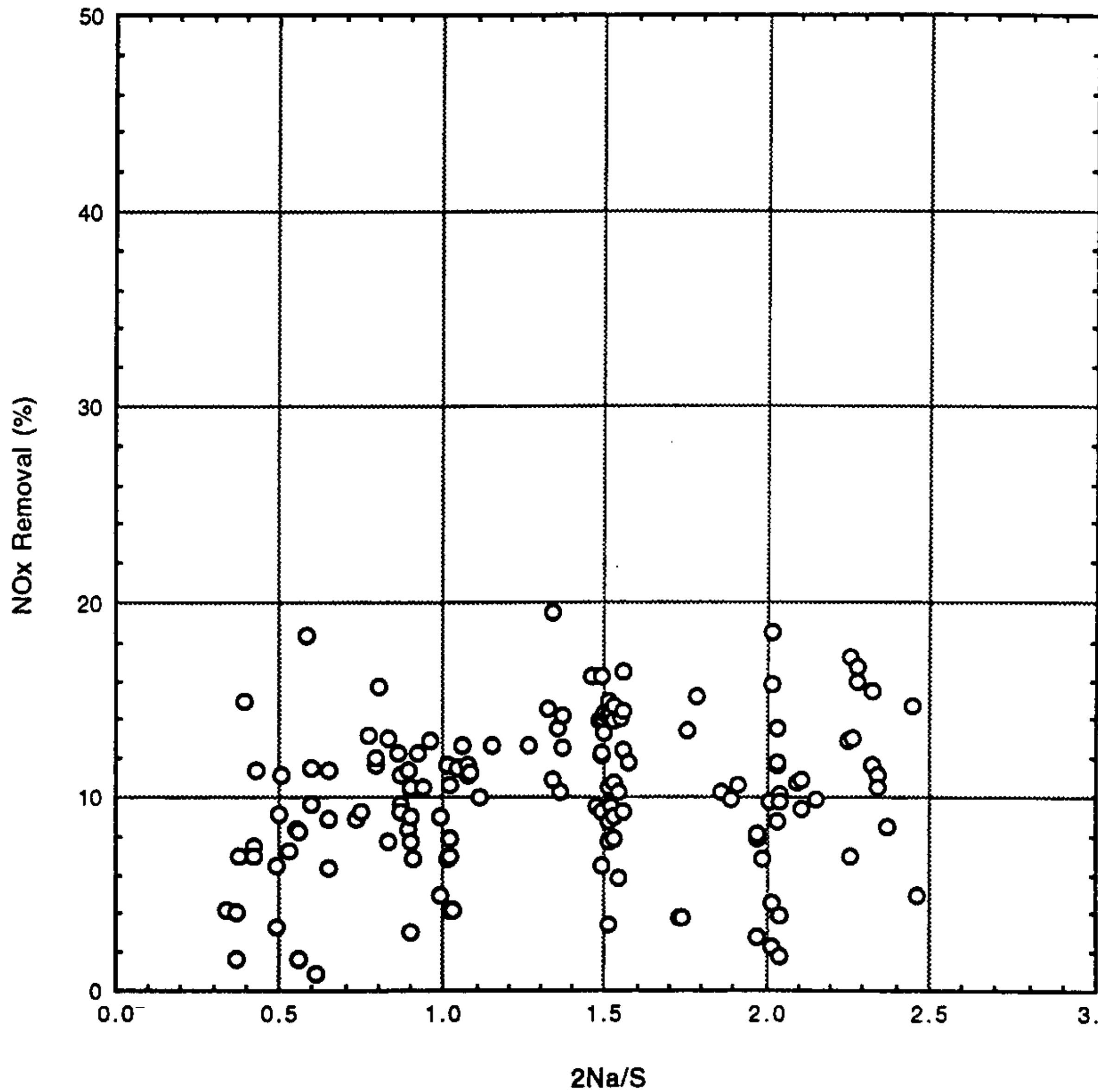


Figure 5-13. Summary of NO_x Removals with Sodium Sesquicarbonate Injection Ahead of the FFDC

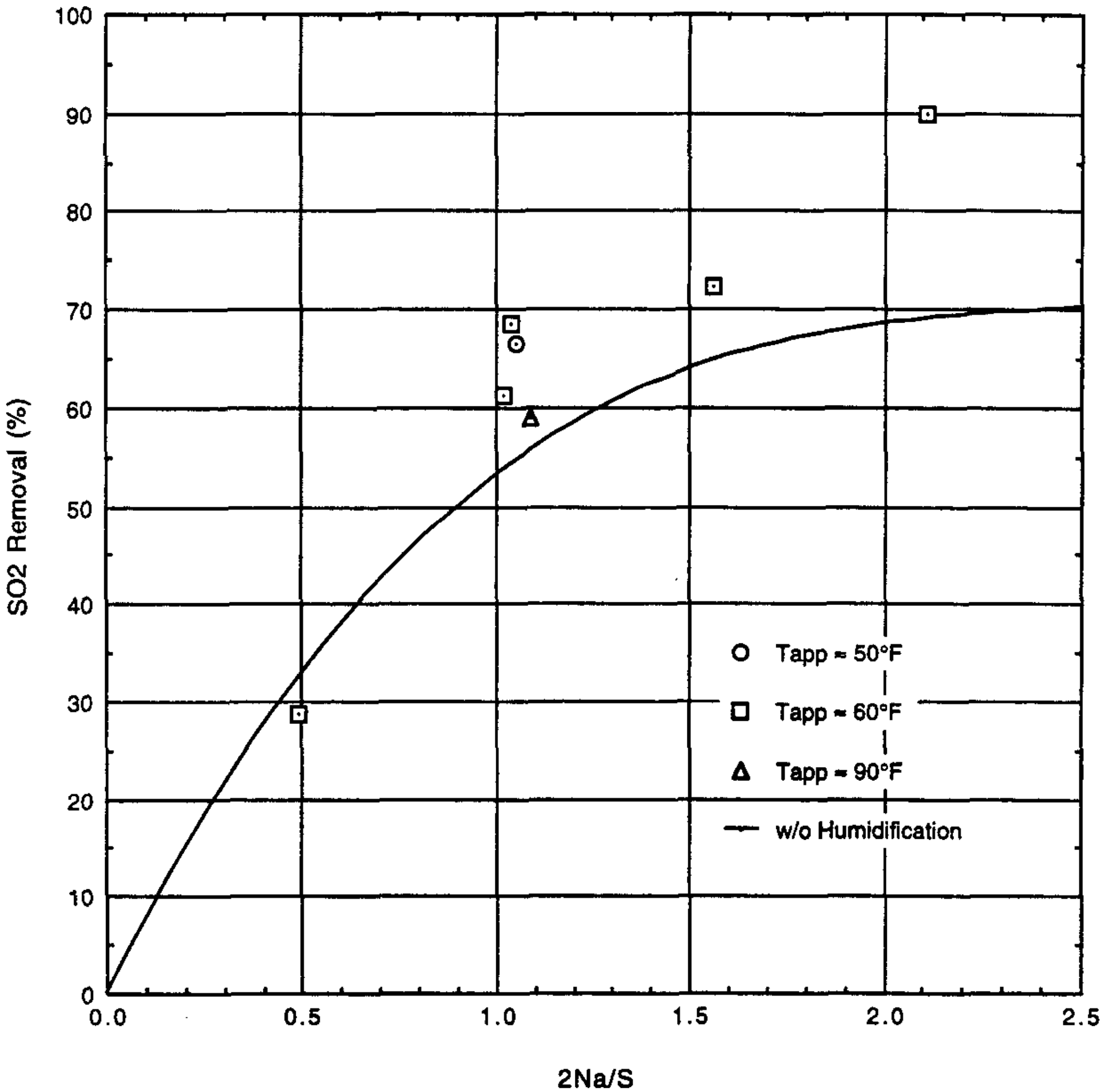


Figure 5-14. Effect of Humidification Approach to Saturation Temperature on SO_2 Removal for Sodium Sesquicarbonate Injection Ahead of the FFDC

be noted that the "without" points shown in the figure are not actual tests, but rather interpolated points from the curve fit in Figure 5-4a. The data show that humidification results in increased SO_2 removals at higher sorbent feed rates (2Na/S ratios in excess of 1.0). At a nominal 2Na/S ratio of 2.0, the removals are increased from approximately 70 to 90 percent with an approach to saturation temperature of nominally 60°F. Data obtained at a lower 2Na/S ratio of 1.0 indicate that humidification had a smaller effect on SO_2 removal with increases that ranged from 5 to 15%. As normal data scatter is in the range of 5 to 10% net SO_2 removal at a given 2Na/S ratio, the data indicate that humidification has an increasing improvement as injection rate increases.

Figure 5-15 shows the compartment-by-compartment gaseous emissions measurements made during one of the humidification tests at an approach temperature of approximately 60°F with a nominal 2Na/S ratio of 1.0. The distribution of SO_2 removal within the FFDC is quite different than that for the no humidification case shown in Figure 5-8. With humidification, the removals in each compartment are relatively equal. In contrast, there was a marked difference in the SO_2 removals among the compartments when operating without humidification. The non-humidification data indicate that each compartment collected varying amounts of the sodium sorbent. With humidification, the SO_2 removals are relatively equal among the compartments suggesting that more of the SO_2 removal occurred in the duct upstream of the FFDC. Moisture becoming associated with the sodium particles during the humidification process would be expected to increase the overall reactivity with SO_2, thus allowing more of the SO_2 removal process to occur ahead of the FFDC.

5.2.2 Sodium Sesquicarbonate Injection at the Air Heater Inlet

Although injection at the FFDC inlet was the main focus of the sodium sesquicarbonate tests, two days of tests were also run at the hotter air heater inlet location. Figure 5-16 presents the results of the first day of testing, where SO_2 removal was determined as a function of 2Na/S ratio. The average results from tests at the FFDC inlet are also shown for comparison. Although the two sets of data indicate that there is little difference in the

Test 665, Bag comp, 60°F approach, 2Na/S=1.0 NaSC
9/20/93

Compartment Gas Measurement

#	O2	SO2	NO	NOc	SO2c	SO2n	ΔSO2
___	%dry	ppm	ppm	ppmc	ppmc	___	%
1 sw	5.50	119	219	254	138	0.81	67.5
2 w	5.40	109	224	258	126	0.73	70.4
3 w	5.20	148	222	253	169	0.98	60.4
4 w	5.25	157	219	250	179	1.05	57.8
5 w	5.20	185	222	253	211	1.23	50.5
6 nw	5.44	172	225	260	199	1.16	53.2
7 se	5.18	112	211	240	127	0.74	70.0
8 e	5.15	133	214	243	151	0.88	64.5
9 e	5.20	158	218	248	180	1.05	57.7
10 e	5.50	177	223	259	206	1.20	51.7
11 e	5.35	162	217	250	186	1.09	56.2
12 ne	5.32	162	217	249	186	1.08	56.3
Ave	5.31			252	172	1.00	59.7
West	5.33			255	170	0.99	60.0
East	5.28			248	173	1.01	59.4

Average Inlet/Outlet Gas Measurements

	O2	SO2	NO	H2O	NOc	SO2c	ΔSO2
___	%wet	ppm	ppm	%	ppmcd	ppmcd	%
Inlet	4.30	350	208	9.00	253	425	
Stack	4.82	133	185	12.1	244	176	56.7

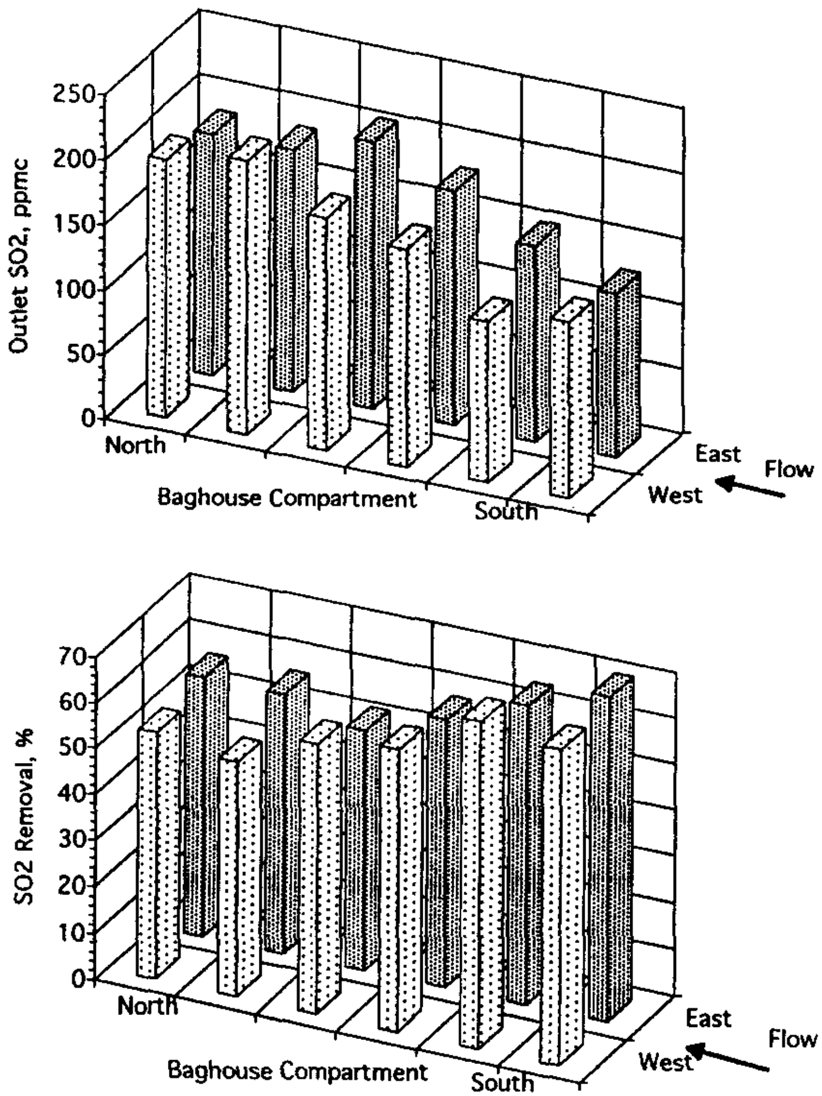


Figure 5-15. Compartment-by-Compartment Gaseous Measurements for Sodium Sesquicarbonate Injection with Humidification Ahead of the FFDC (Test 665)

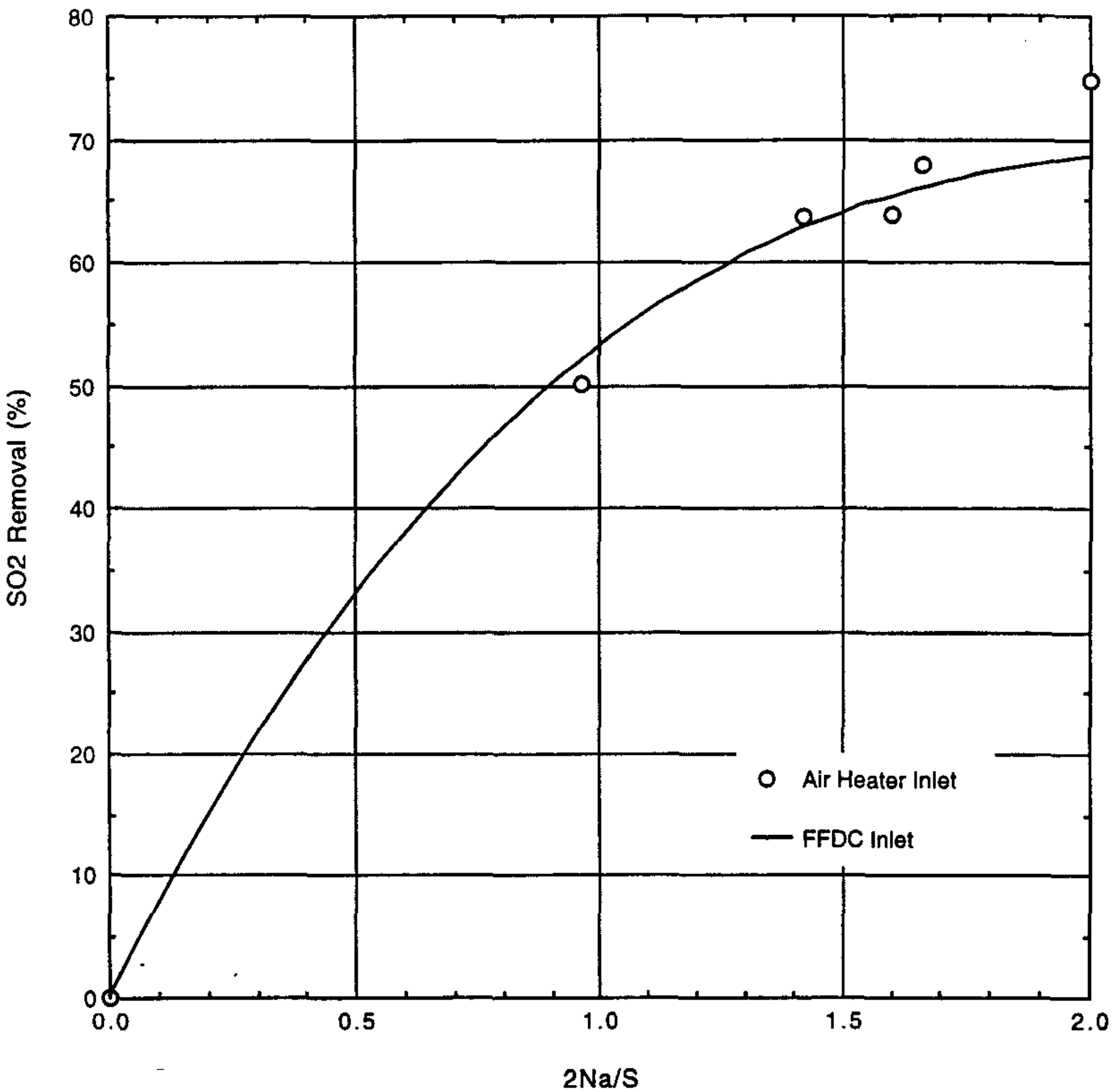


Figure 5-16. Comparison of SO_2 Removals for Sodium Sesquicarbonate Injection at Air Heater Inlet and FFDC Inlet Locations

steady-state SO_2 removals, the removals as a function of time for the two injection locations were found to be quite different. Figure 5-17 compares the SO_2 removal versus time traces for a test run at each injection location at a nominal 2Na/S ratio of 1.5. The data show that the initial response time at the air heater location is much longer, and the level to which the SO_2 removal drops after a cleaning cycle is much lower. These observations indicate that the response time of the overall SO_2 removal process is slower when injecting at the air heater inlet. Although the steady-state removals are comparable (roughly 65 percent), the slower response time will result in a lower time-averaged SO_2 removal when injecting at the air-heater inlet.

The NO_2 emissions resulting from sodium sesquicarbonate injection ahead of the air heater were presented along with the results for injection ahead of the FFDC in Figure 5-12. There does not appear to be any major difference in the NO_2 levels produced between these two injection locations.

5.3 Sodium Bicarbonate

The sodium bicarbonate tests were performed at two different injection locations. The original test plan called for injection ahead of the FFDC, at the same location utilized for the sodium sesquicarbonate tests. In addition, a series of tests were also run with a second set of injectors located ahead of the air heater. The results of the tests at the two locations are discussed separately in the following subsections.

5.3.1 Injection of Sodium Bicarbonate at the FFDC Inlet

A. SO_2 Removal. The previous work at Cameo (Muzio, et al., 1984) showed that the SO_2 removal process with sodium bicarbonate injection upstream of a fabric filter was highly temperature dependent. At temperatures below approximately 290°F, the reaction kinetics are slowed significantly, which results in an overall decrease in SO_2 removal. Figure 5-18 shows the SO_2 removal versus time trace for one of the first tests run with sodium bicarbonate injection upstream of the Arapahoe Unit 4 FFDC. The decrease in SO_2 removal seen mid-way through the test is due to a FFDC cleaning cycle which started

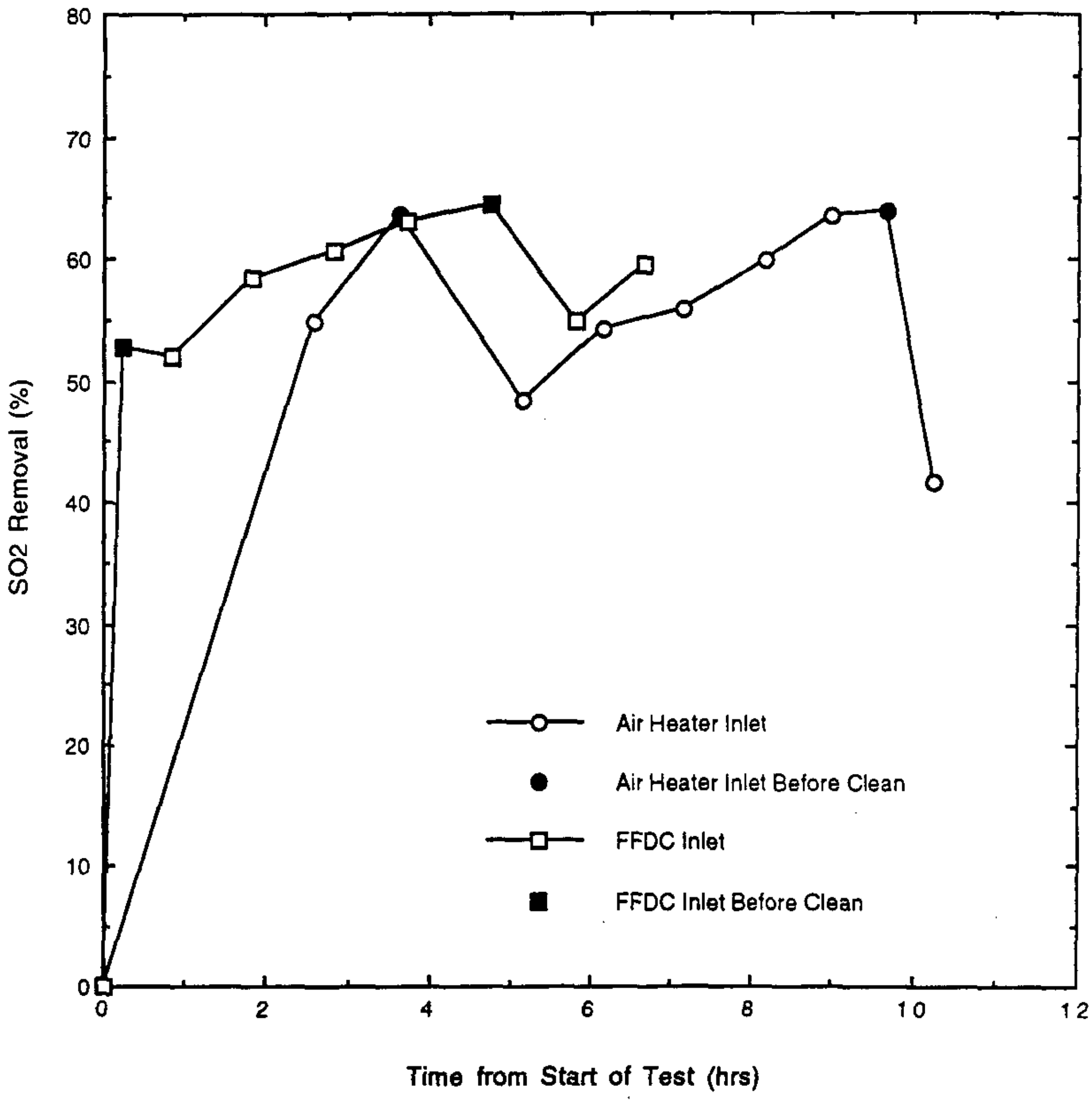


Figure 5-17. Comparison of Response Time Characteristics for Sodium Sesquicarbonate Injection at Air Heater Inlet and FFDC Inlet Locations (2Na/S=1.5)

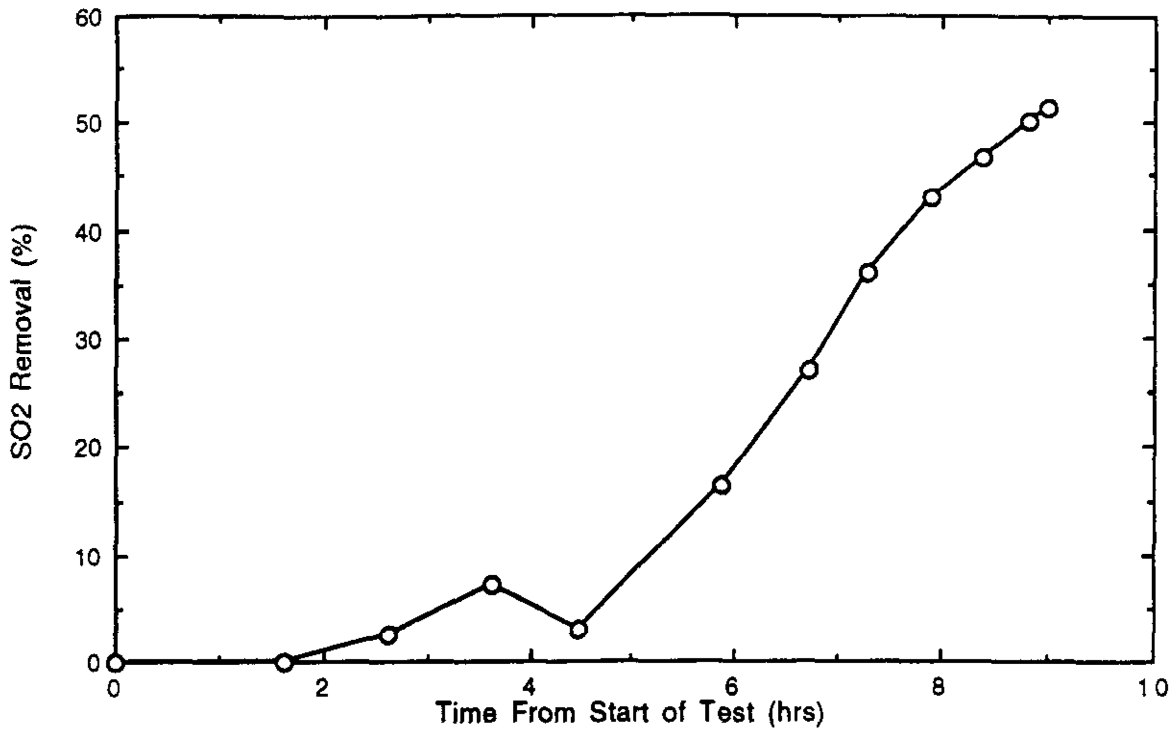


Figure 5-18. SO_2 Removal Versus Time for Sodium Bicarbonate Injection Ahead of the FFDC (Test 640)

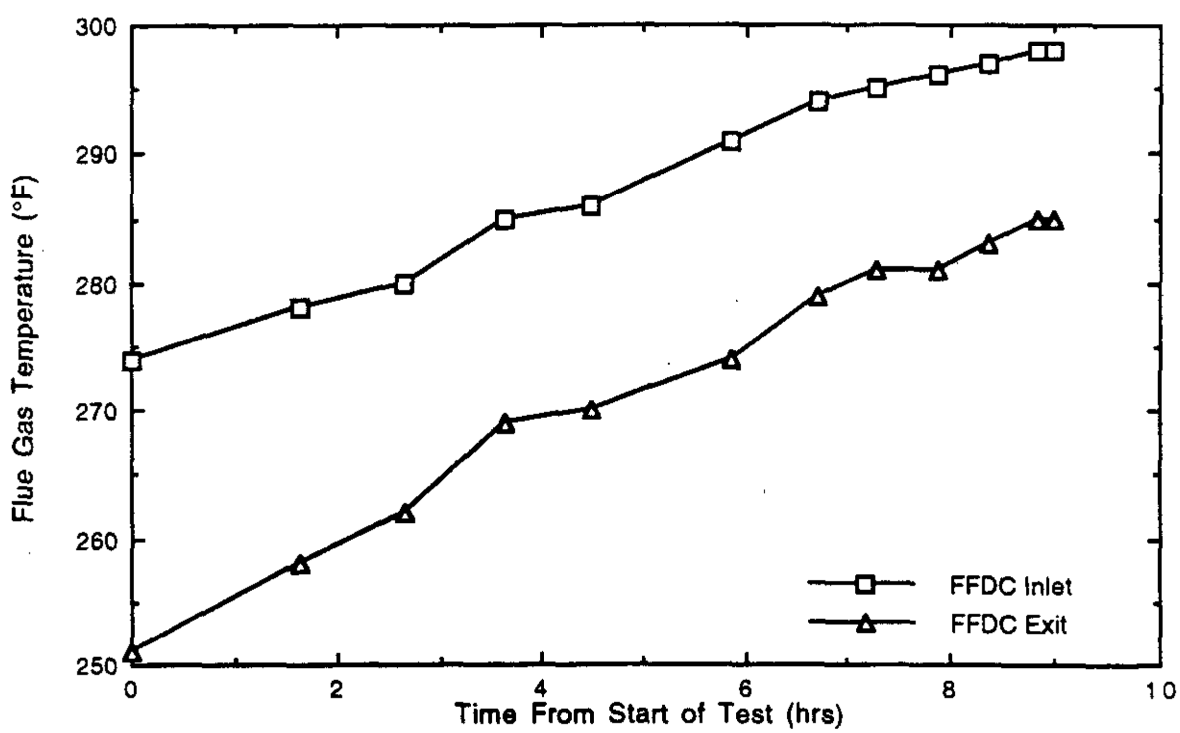


Figure 5-19. Inlet and Exit FFDC Temperatures Versus Time for Sodium Bicarbonate Injection Ahead of the FFDC (Test 640)

approximately 3-1/2 hours into the test. The data show that nearly nine hours were required for the SO_2 removal to reach 50 percent, and at the point when the sorbent feed was shut down at the end of the day, the removals had still not reached a steady-state level. Flue gas temperatures entering and exiting the FFDC slowly climbed throughout the day as shown in Figure 5-19, but the exit gas temperature never exceeded 285°F. The slowly increasing trend in SO_2 removal seen during this test was likely due to a combination of the slow increase in FFDC temperature throughout the day and the accumulation of unreacted sodium on the bags.

The FFDC exit temperature at Arapahoe Unit 4 normally ranges from 230 to 270°F, and seldom reaches 290°F. In order to better understand the dynamics of the SO_2 removal process at these lower temperatures, the sorbent injection system was run 24 hours a day for a period of five days. Arapahoe Unit 4 is normally used by the PSCo dispatch center for system regulation; therefore, boiler load normally changes suddenly and frequently. During these five days of testing, the boiler was used for regulation, but with the agreement that when load was changed, it would be left constant for a period of three to four hours. Gaseous emission data was collected on an hourly basis during this test, so at least three to four sets of data could be collected at each new load point before another change was made. The sorbent injection rate was manually controlled throughout the duration of the test to maintain a nominal 2Na/S ratio of 1.0. Figure 5-20 shows the SO_2 removal, 2Na/S ratio, and FFDC exit temperature trends for the duration of the test. The FFDC was allowed to clean on its normal cycle during the test (automatically when reaching a pressure drop of 4.0 inches of H_2O), and a set of data was collected immediately before and after each cleaning cycle in order to accurately characterize the time required for the SO_2 removal to recover. The dark symbols on the SO_2 removal trace denote the removals recorded just before each cleaning cycle. The results show that the SO_2 removals drop dramatically after each cleaning cycle. Although, there were some initial problems encountered in maintaining a constant 2Na/S ratio, the first ten hours showed a slow increase in SO_2 removal similar to that seen in Figure 5-18. However, after the FFDC had been "conditioned" through a few cleaning cycles, the recovery time after a cleaning was

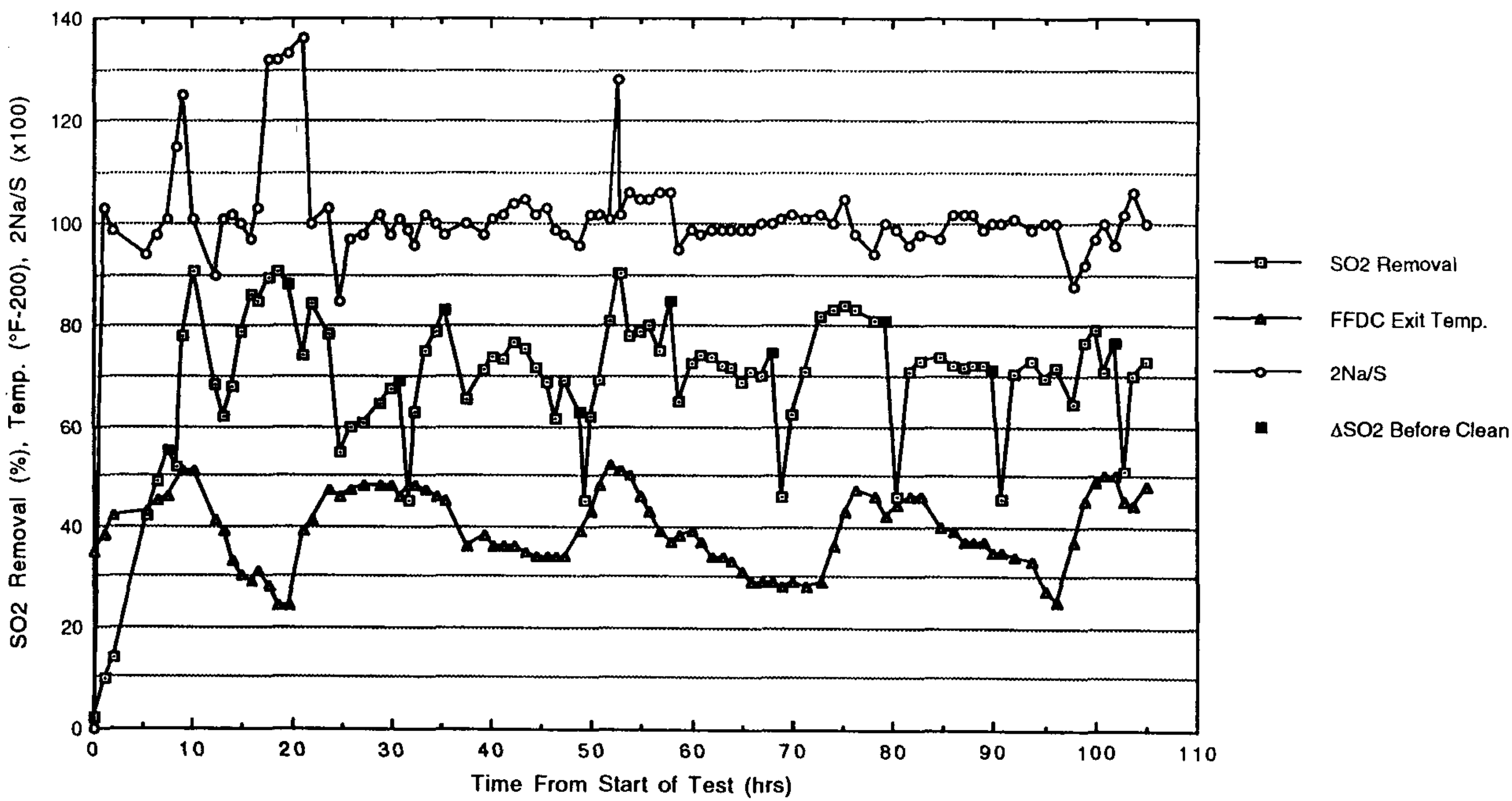


Figure 5-20. SO_2 Removal, FFDC Exit Temperature, and 2Na/S Ratio Versus Time for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

significantly reduced, and the SO_2 removals often reached a relatively steady state after only a couple of hours.

Although the 2Na/S ratio varied over only a narrow range during the five-day test, the "steady-state" data collected before each cleaning cycle provide an indication of the effect of 2Na/S ratio on SO_2 removal (Figure 5-21). At a nominal 2Na/S ratio of 1.0, SO_2 removals ranged from 65 to 85 percent. These results are slightly below, but comparable to, those seen in the earlier demonstrations at Cameo and Nixon (Muzio, et al., 1984; Fuchs et al., 1989) where removals ranged from 70 to 90 percent at a nominal 2Na/S ratio of 1.0. The sorbent utilizations computed for the data from the current series of tests (Figure 5-22) range from 65 to 85 percent.

In the automatic control mode, the DSI system is set to maintain a specified level of SO_2 removal, and the feed rate is constantly varied in order to achieve that goal. The combination of the time required for the SO_2 removal to respond to a change in feed rate, the time required to recover after a cleaning cycle, and the variability of the steady-state removals made trying to control the DSI system with bicarbonate injection in this manner impractical. An attempt was made to "tune" the DSI control system to compensate for the slow response of the SO_2 removal, but it was unsuccessful.

On the final day of the five-day test, gaseous emission measurements were made at the exit of each FFDC compartment in order to characterize the distribution of sorbent in the baghouse. The results of the compartment-by-compartment measurements are shown in Figure 5-23. At the time that the measurements were performed, compartment Number 11 was out of service for maintenance. The results show high levels of SO_2 removal (80 to 90 percent) in the first three compartments on each side of the baghouse. This is followed by a rapid decrease down to levels of only 10 to 20 percent in the rear compartments. Clearly, the majority of the sorbent is deposited in the front half of the FFDC. This compartment-by-compartment distribution of SO_2 removal is similar to that seen for sodium

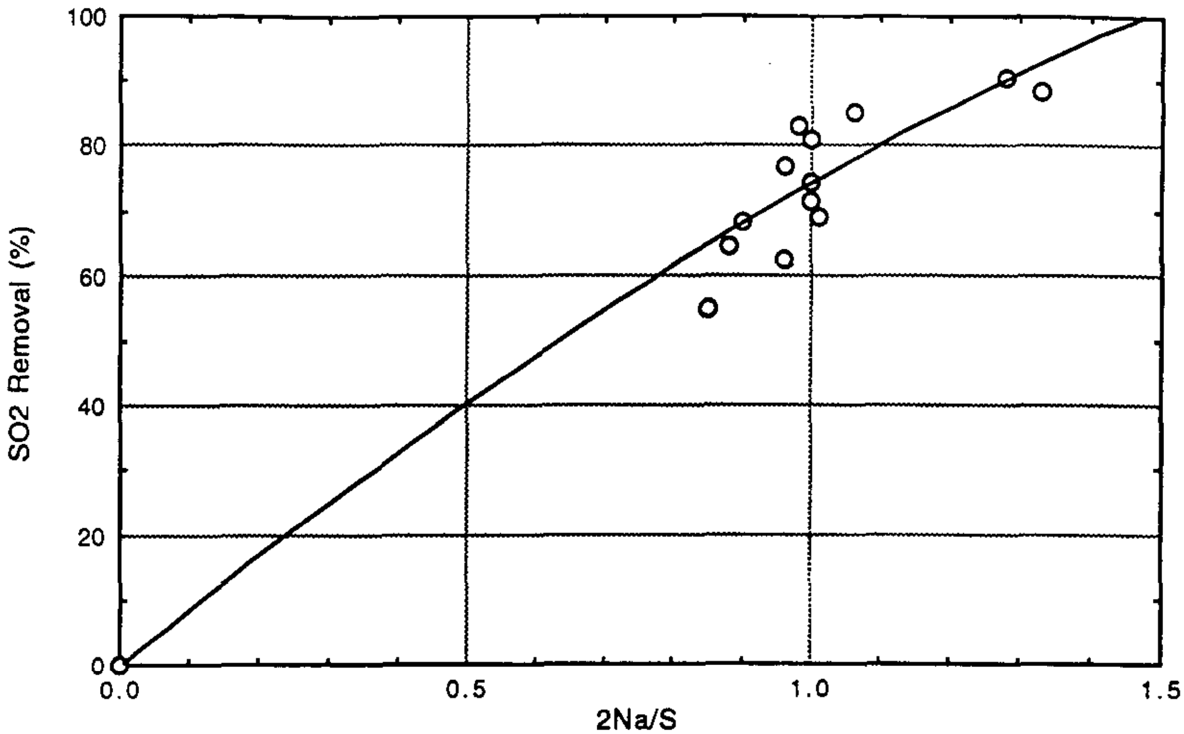


Figure 5-21. SO_2 Removal as a Function of 2Na/S Ratio for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

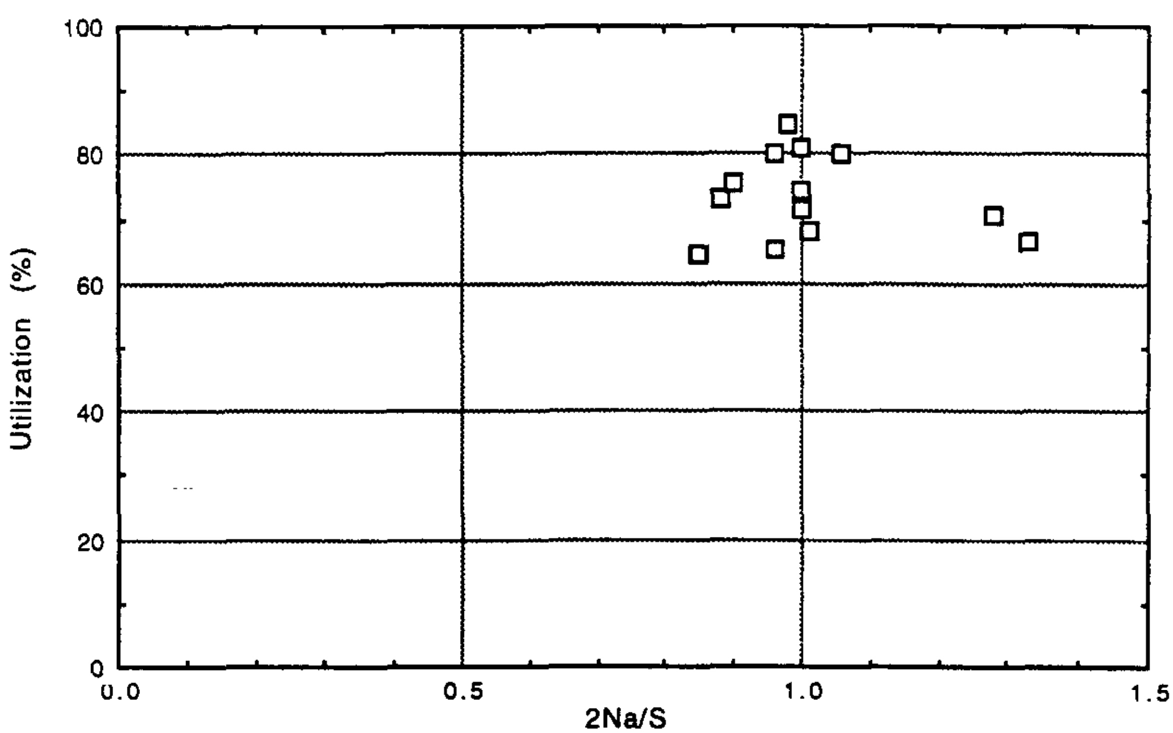


Figure 5-22. Utilization as a Function of 2Na/S Ratio for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

Test 763, 2/4/93, 2Na/S=1.0 NaBicarb

Bag Compartment Gas Profile

Compartment Gas Measurement

#	O2	SO2	NO	NOc	SO2c	SO2n	ΔSO2
___	%dry	ppm	ppm	ppmc	ppmc	___	%
1 sw	6.80	43	193	245	55	0.35	88.3
2 w	6.90	36	185	236	46	0.29	90.1
3 w	6.95	46	190	243	59	0.37	87.4
4 w	6.65	104	211	265	130	0.83	72.0
5 w	7.40	175	219	290	232	1.47	50.3
6 nw	9.55	235	190	299	369	2.35	20.8
7 se	5.40	85	210	242	98	0.62	79.0
8 e	5.50	55	190	221	64	0.41	86.3
9 e	5.70	79	200	235	93	0.59	80.1
10 e	6.00	137	215	258	164	1.04	64.8
11 e							
12 ne	7.75	310	219	298	421	2.68	9.7
Ave	6.78			257	157	1.00	66.3
West	7.38			263	148	0.94	68.2
East	6.07			251	168	1.07	64.0

Average Inlet/Outlet Gas Measurements

	O2	SO2	NO	H2O	NOc	SO2c	ΔSO2
___	%wet	ppm	ppm	%	ppmcd	ppmcd	%
Inlet	4.90	370	230	8.67	290	466	
Stack	6.30	120	180	7.81	248	165	64.5

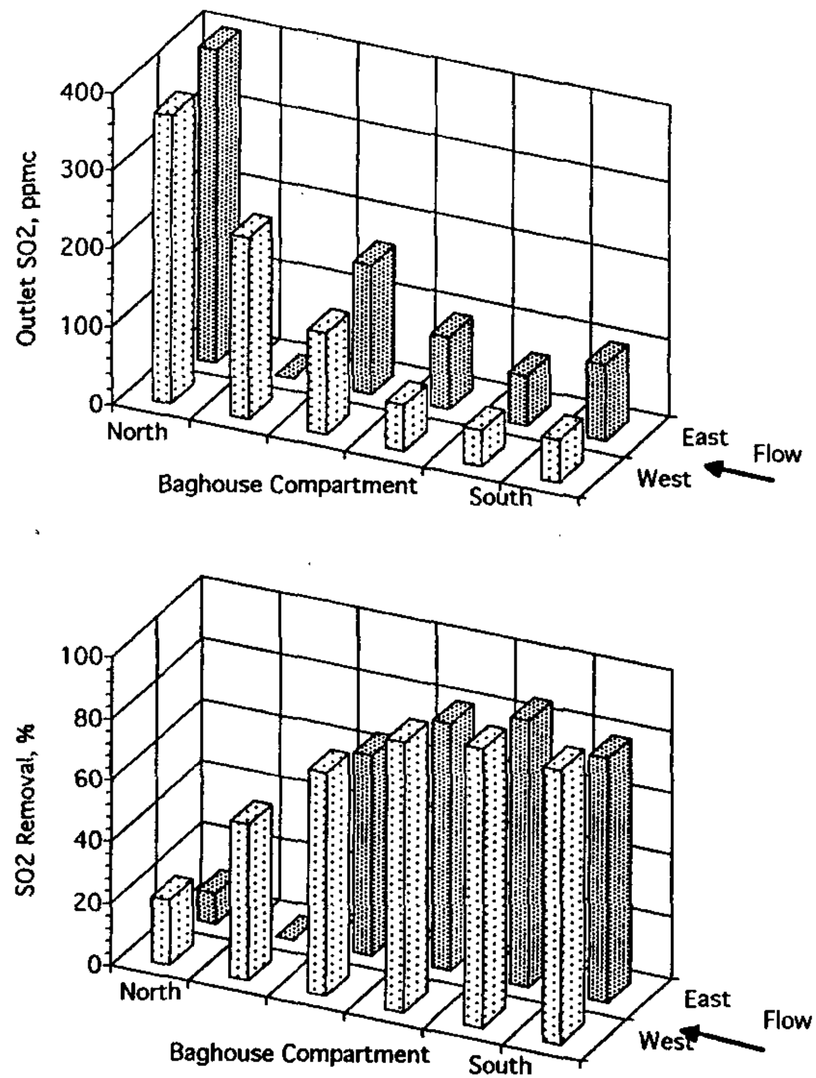


Figure 5-23. Compartment-by-Compartment SO_2 Removals for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

sesquicarbonate injection (Figure 5-8), although the peak removals are greater with sodium bicarbonate. The results in Figure 5-23 also show that the removals in the east compartments are nominally ten percent lower than the removals in the corresponding compartments on the west side. This difference is likely due to a bias in the injection system which resulted from a partial plugging of some of the east side injectors.

B. NO_x Removal and NO_2 Emissions. Figure 5-24 shows the NO_x removal and NO_2 emission traces recorded over the five-day test period. The average NO_x removal for the test was 10 percent. Although this result is consistent with the levels reported in the earlier work at Cameo (Muzio, et al., 1984), the individual measurements varied widely (from 0 to 25 percent) with no discernable correlation with either FFDC cleaning cycle or temperature. The NO_2 emissions also varied widely during the test, ranging from 6 to 33 ppm, with an average of 16 ppm. Two trends can be seen in the NO_2 data shown in Figure 5-24. First, in all instances but one, there is a sharp increase in NO_2 emissions after a FFDC cleaning cycle, followed by a slow decrease in emissions until the next cleaning. This is currently thought to be again due to an interaction between NO_2 and the carbon in the fly ash on the bags. When the FFDC is cleaned, there is less fly ash on the bags and, therefore, less absorption. As the cake builds back up after a cleaning cycle, the absorption of NO_2 increases. Secondly, the data indicate that there was a general increasing trend in NO_2 emissions throughout the duration of the five-day test. The NO_2 emissions for the first 40 hours were quite variable. This was partially due to variations in load and 2Na/S ratio. However, after 40 hours a continuously increasing trend in NO_2 can be seen. Again, no explanation can be offered for this observation.

5.3.2 Sodium Bicarbonate Injection at the Air Heater Inlet

A. SO_2 Removal. The previous demonstration at PSCo's Cameo station (Muzio et al., 1984) showed that the reduced reactivity of sodium bicarbonate at low baghouse temperatures, can be compensated for by injecting the material at higher temperatures, such as those encountered at the air heater inlet. After it became apparent that flue gas temperatures at the Arapahoe Unit 4 FFDC inlet were limiting the process performance

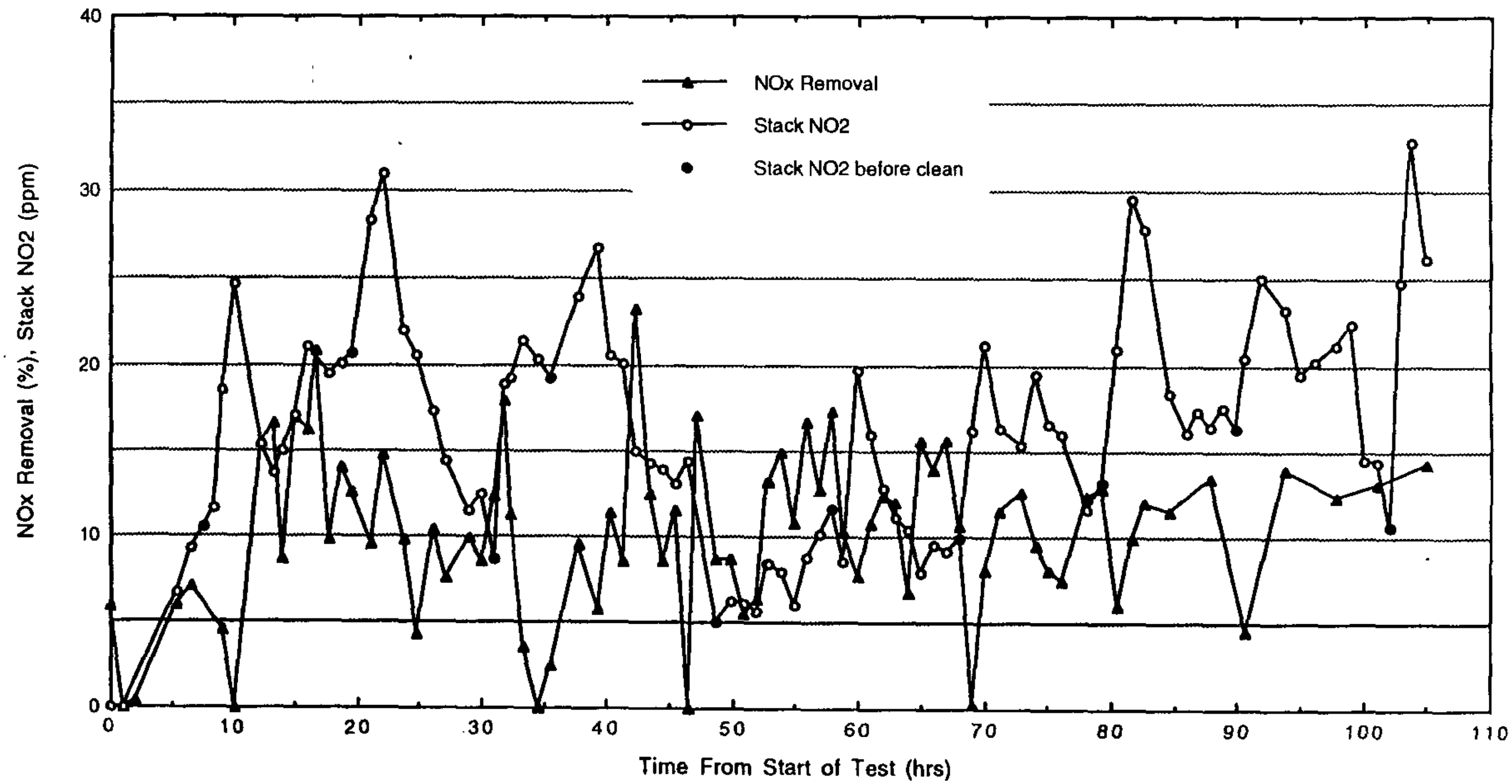


Figure 5-24. NO_x Removal and NO_2 Emissions Versus Time for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

with sodium bicarbonate, the sorbent injection location was moved to a higher temperature zone ahead of the air heater. Four injectors were installed in the top of the duct between the economizer and air heater, as described previously (Section 3.4.3).

Figure 5-25 shows SO_2 removals measured at both the baghouse inlet and stack for a test run with the new injection location and a nominal 2Na/S ratio of 1.0. The stack data show that the SO_2 removal response time is much improved over that seen previously for injection at the FFDC inlet (Figures 5-18 and 5-20). The initial response time was reduced to approximately 1-1/2 hours, and the recovery time after subsequent cleaning cycles was reduced to less than 30 minutes. These results indicate that the endothermic decomposition of sodium bicarbonate (recall Equation 3-1 in Section 3.1) is likely responsible for the temperature sensitivity discussed previously for sorbent injection at the FFDC inlet.

Gaseous measurements at the baghouse inlet show that SO_2 removals of nominally 20 percent occur in the "entrained" phase before the sorbent is deposited on the bags. However, it must be noted that these measurements were made through sampling probes with in-duct filters, and although the filters were "blown-back" with compressed air before each measurement, the sorbent which collects on the filters during sampling could scrub SO_2 from the sample stream. Therefore, it is possible that the SO_2 removals measured at this location are biased slightly on the high side. Irrespective of whether the entrained removals are 20 percent, or less, the results indicate that the majority of the sulfation reaction occurs within the baghouse.

Figures 5-26 and 5-27 show the effect of 2Na/S ratio on SO_2 removal and sorbent utilization for injection ahead of the air heater. Data for both the 4000 and 5000 rpm pulverizer speeds are plotted in each figure. The data in Figure 5-26 show that at 2Na/S ratios up to approximately 1.0, pulverizer speed has little effect on SO_2 removal. However, at 2Na/S ratios in excess of 1.5, the SO_2 removals at 5000 rpm continue to increase, while the 4000 rpm data begins to level out. If the pulverized reagent size increased as the feed rate decreased from 5000 to 4000 rpm, an explanation of this data would be possible;

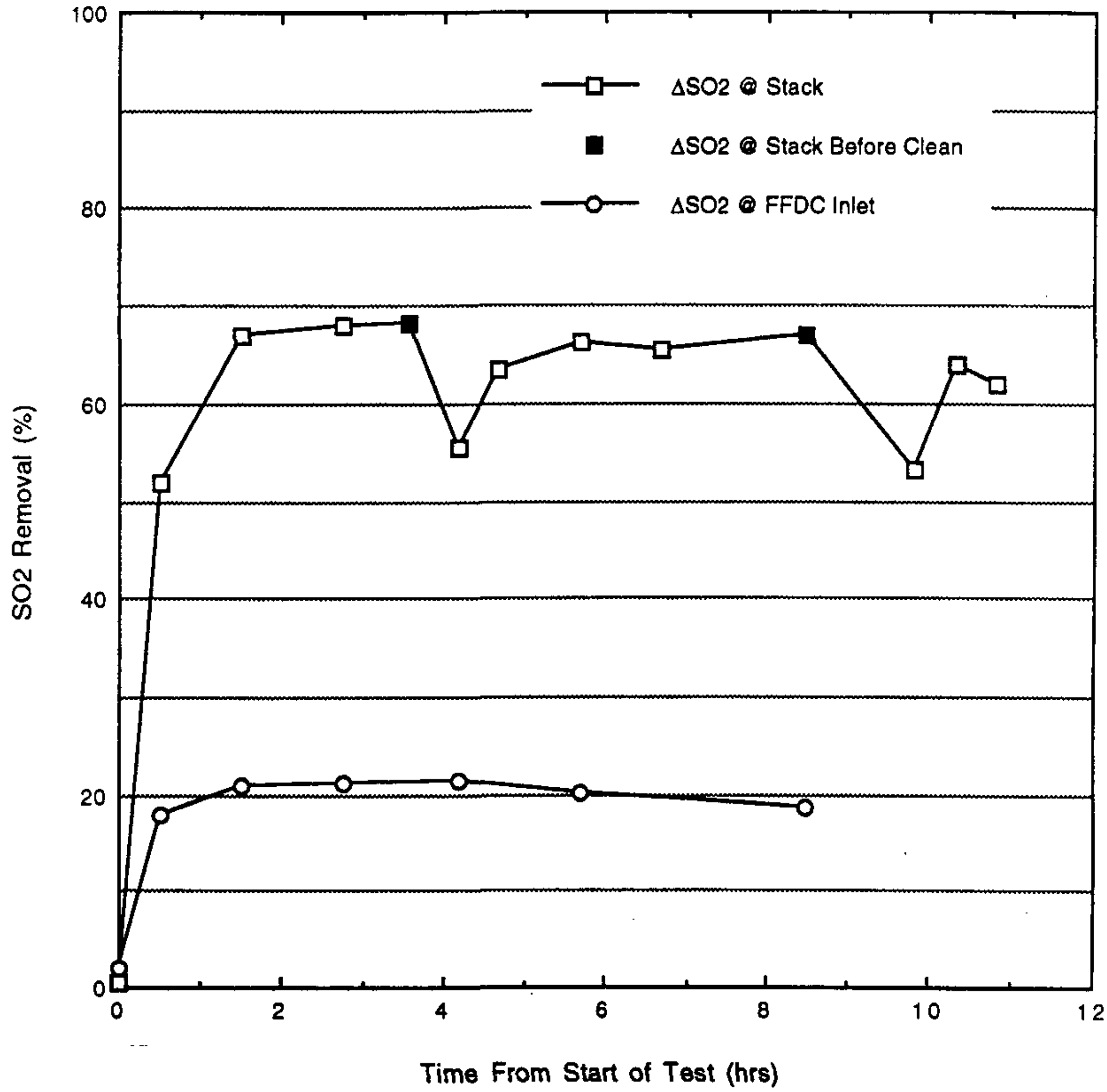


Figure 5-25. SO_2 Removal Versus Time for Sodium Bicarbonate Injection Ahead of the Air Heater (Test 792, 2Na/S=1.0)

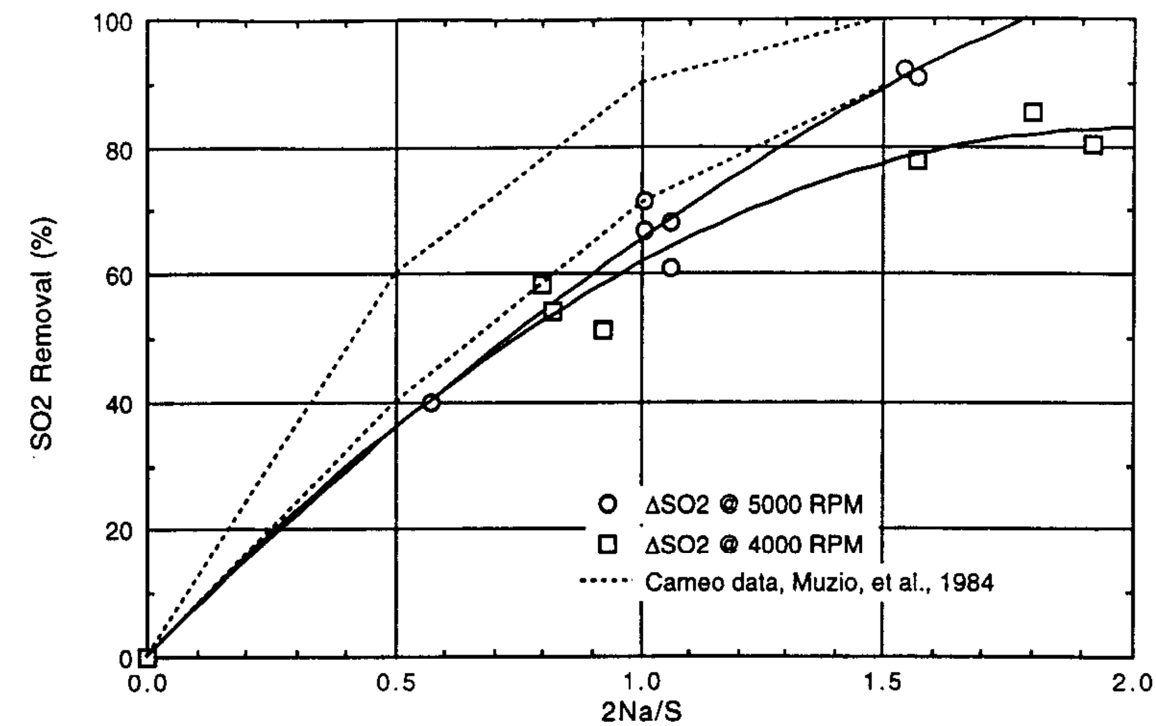


Figure 5-26. SO_2 Removal as a Function of 2Na/S Ratio for Sodium Bicarbonate Injection Ahead of the Air Heater

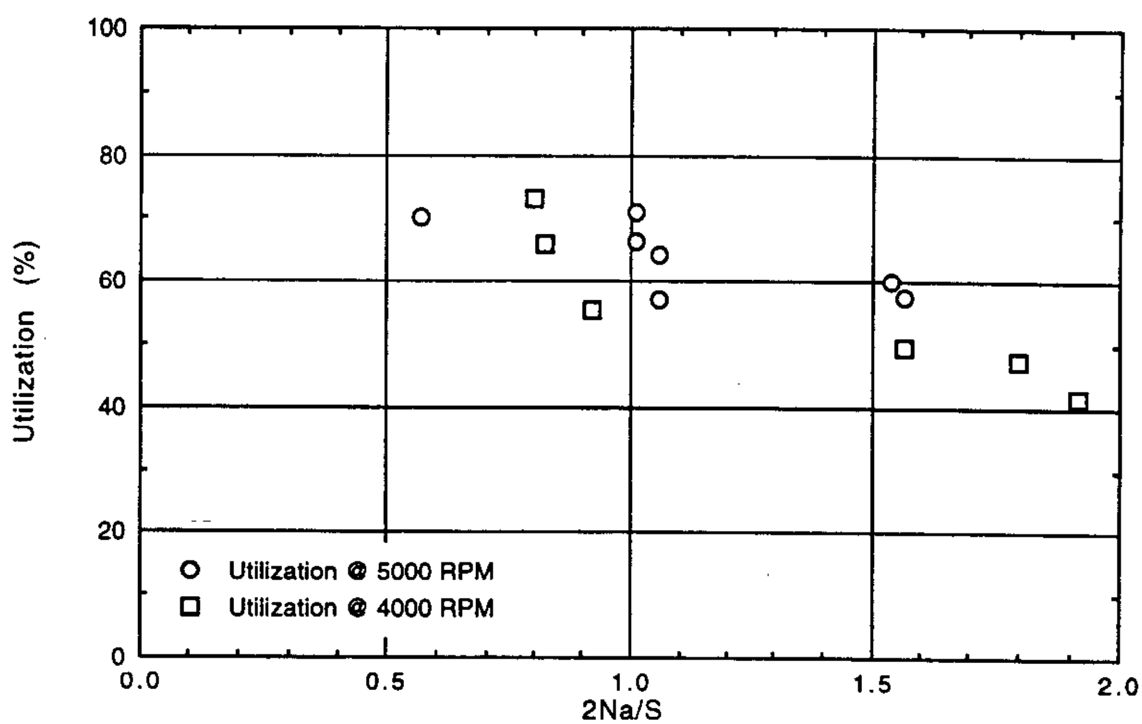


Figure 5-27. Utilization as a Function of 2Na/S Ratio for Sodium Bicarbonate Injection Ahead of the Air Heater

since larger particles are less reactive. However, the data presented previously in Table 5-2 for sodium sesquicarbonate indicated only a minor change in particle size with increased loading at 4000 rpm. It is possible that the large raw product size of sodium bicarbonate (60μ for sodium bicarbonate versus 28μ for sodium sesquicarbonate) would exhibit a larger feed rate effect, but this was not tested.

The SO_2 removal data shown previously for sodium bicarbonate injection at the FFDC inlet (Figure 5-21) were collected at the 5000 rpm pulverizer speed. Comparison of this data to the 5000 rpm data in Figure 5-26 shows that the SO_2 removals for injection at the FFDC inlet are slightly higher than those for injection ahead of the air heater (approximately 75 percent versus 66 percent at a nominal 2Na/S ratio of 1.0). It is believed that the higher removals are due to the difference in the rate of endothermic decomposition of sodium bicarbonate. During decomposition, the evolution of H_2O and CO_2 creates a high surface area Na_2CO_3 particle. When injecting ahead of the air heater, the decomposition reaction occurs quickly at the higher temperatures, and the sorbent is more decomposed by the time it reaches the bags. As the sulfation reaction progresses, it becomes limited by the diffusion rate of SO_2 through the Na_2SO_4 product layer which forms on the particle surface. Without further decomposition to expose additional unreacted sorbent, utilization is decreased. When the sorbent is injected at the inlet of the FFDC, however, the decomposition and sulfation reactions occur simultaneously. It is hypothesized that the release of H_2O and CO_2 from the interior of the particle provides a means of maintaining an open pore structure during the sulfation process, which allows the SO_2 to reach the unreacted Na_2CO_3 more readily. Thus, the sulfation process is less limited by diffusion across the solid Na_2SO_4 product layer.

Figure 5-28 shows the compartment-by-compartment gaseous emission measurements for sodium bicarbonate injection ahead of the air heater measured during the test depicted in Figure 5-25. These compartment-by-compartment data were collected between hours 7 and 8 of the test (i.e., just before the second fabric filter cleaning cycle). The front-to-back distribution of SO_2 removal is similar, but somewhat improved, to that seen for injection at the FFDC inlet (Figure 5-23), indicating that the majority of the sorbent is

Test 792, 4/18/94 15:45, 2Na/S=1.0 NaBicarb at AHI
Bag Compartment Gas Profile, ~ 7 hours from start

Compartment Gas Measurement

#	O2	SO2	NO	NOc	SO2c	SO2n	ΔSO2
___	%dry	ppm	ppm	ppmc	ppmc	___	%
1 sw	6.00	101	208	250	121	0.64	76.8
2 w	5.60	134	210	245	157	0.83	70.0
3 w	5.40	190	221	255	219	1.16	58.1
4 w	5.30	257	233	267	295	1.55	43.8
5 w	5.40	295	239	276	340	1.79	34.9
6 nw	5.30	293	239	274	336	1.77	35.7
7 se	4.95	6	145	163	7	0.04	98.7
8 e	5.05	13	147	166	15	0.08	97.2
9 e	5.20	64	167	190	73	0.38	86.1
10 e	5.10	135	187	212	153	0.81	70.8
11 e	5.20	219	210	239	249	1.31	52.3
12 ne	5.35	272	229	263	313	1.65	40.2
Ave	5.32			233	190	1.00	63.7
West	5.50			261	245	1.29	53.2
East	5.14			206	135	0.71	74.2

Average Inlet/Outlet Gas Measurements

	O2	SO2	NO	H2O	NOc	SO2c	ΔSO2
___	%wet	ppm	ppm	%	ppmcd	ppmcd	%
Inlet	7.40	395		0.00	0	523	
Stack	5.30	139	179	7.81	229	178	65.4

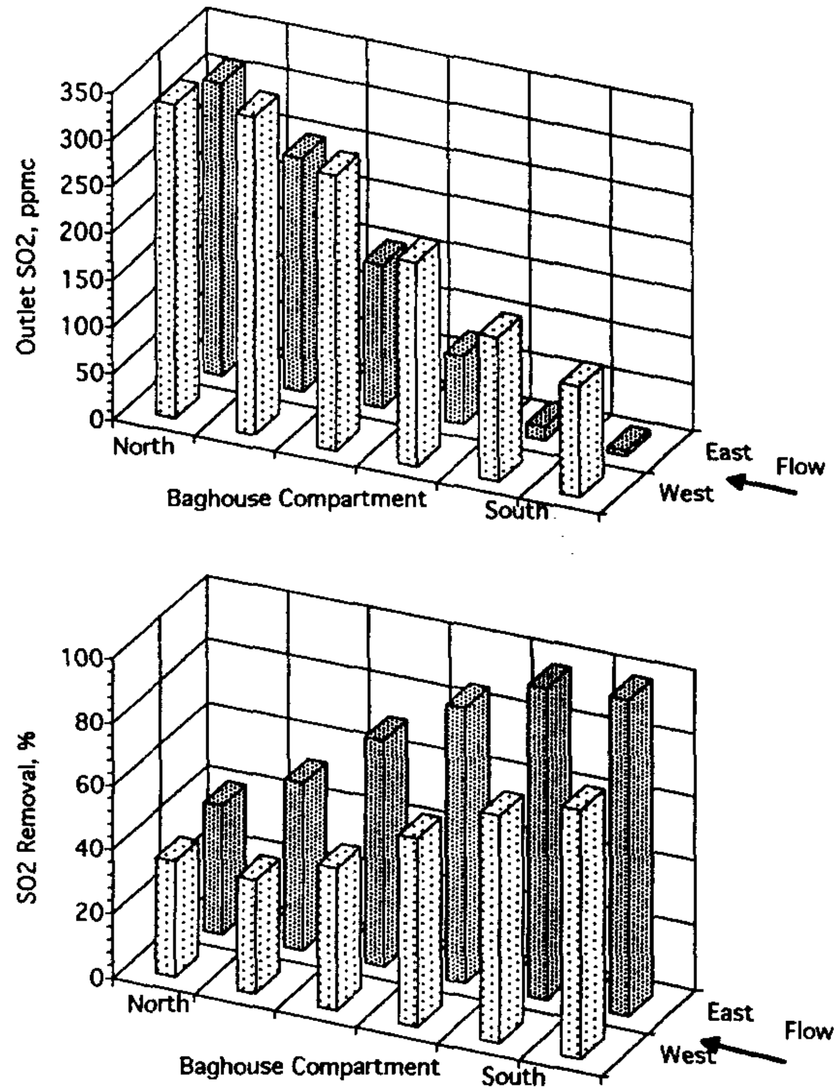


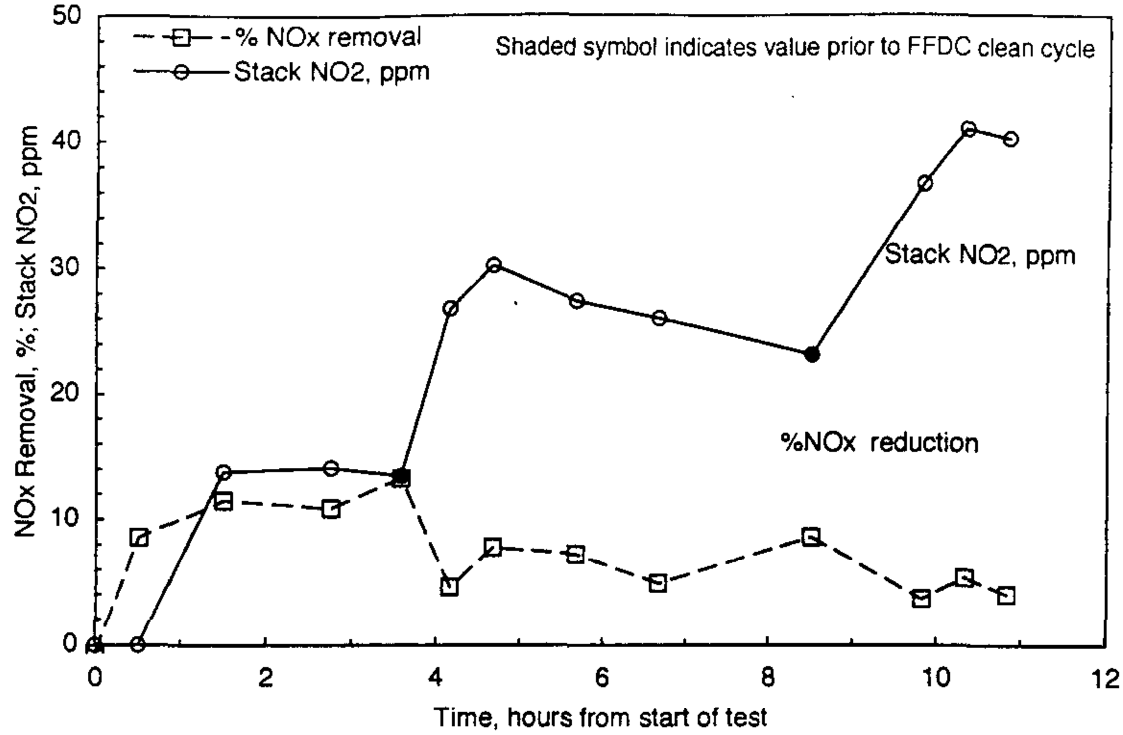
Figure 5-28. Compartment-by-Compartment SO_2 Removals for Sodium Bicarbonate Injection Ahead of the Air Heater (Test 792)

deposited in the forward compartments. The improvement in SO_2 removal in the back compartments is due to the additional SO_2 removal that occurred in the duct due to the higher temperature and longer residence time. The differences in SO_2 removal on the east and west sides are again likely due to an imbalance in the sorbent distribution between individual injectors. All four injectors were supplied by a single distributor located on the east side of the boiler. Four individual hoses ran from the distributor, up the side of the boiler, and across the top of the horizontal duct between the economizer and air heater. Thus, the hoses feeding the two injectors on the west side had long horizontal runs from the east edge of the duct and high pressure drop. This created an imbalance in flow that would also affect reagent distribution.

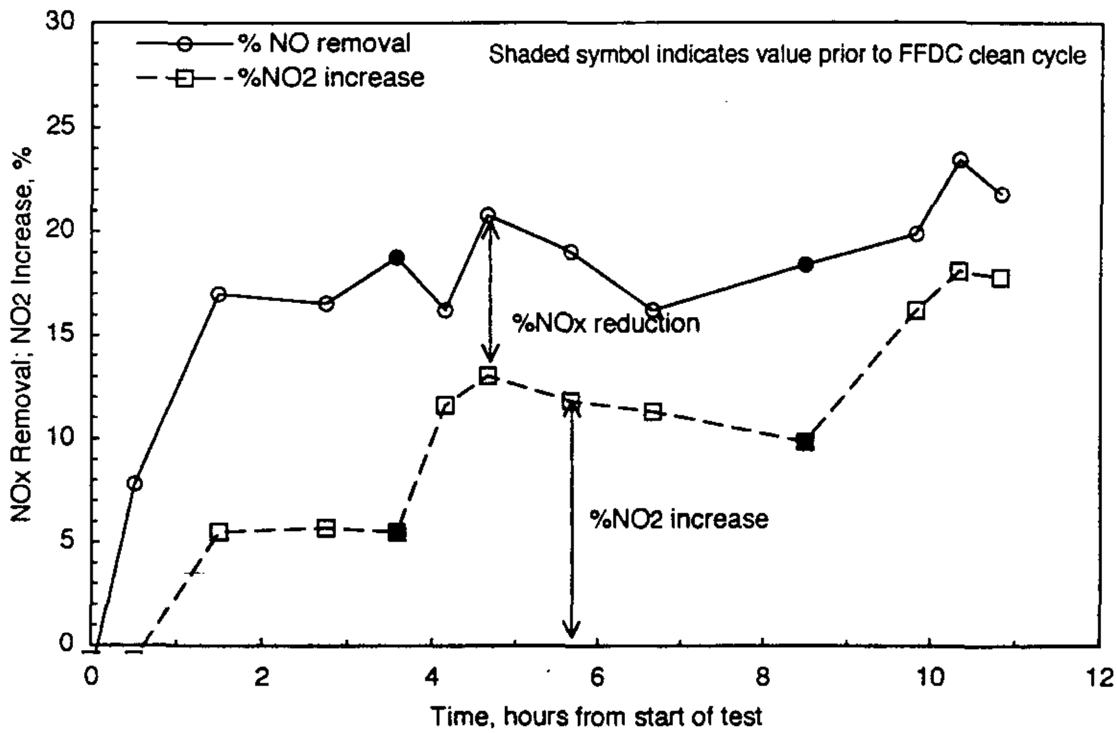
As discussed previously, it can be noted that the arithmetic average of the compartment-by-compartment SO_2 removals is in good agreement with the overall SO_2 removal measured across the fabric filter. This indicates that the gas flow rates to each compartment were approximately equal.

B. $\underline{NO_x \text{ Removals and } NO_2 \text{ Emissions.}}$ Figure 5-29a shows the NO_x removal and NO_2 emission traces for the 11-hour test depicted in Figure 5-25. As was seen with sorbent injection ahead of the FFDC, the NO_2 emissions increase after each cleaning cycle. However, unlike the behavior seen at the low-temperature injection location, the NO_2 levels were relatively constant between cleaning cycles. Again, on the average, the NO_2 emission level continued to increase throughout the duration of the test. The average NO_x removal for the entire test is 8 percent, but the removals decrease with time in accordance with the increases in NO_2 emissions. Initially, the NO_x removal was relatively constant at 12 percent, with NO_2 emissions averaging 14 ppm. After the first cleaning cycle, the average NO_x removal decreased to 7 percent, and NO_2 emissions increased to nominally 27 ppm. After the second cleaning cycle, average NO_x removals and NO_2 emissions were 4 percent and 39 ppm, respectively.

Figure 5-29b shows how the change in NO due to the reactions with sodium is partitioned between NO_2 and NO_x removal. The trend seen for this test with sodium bicarbonate is somewhat different than the data shown in Figure 5-9b.



(a) NO_2, ppm; ΔNO_x %



(b) Partitioning of ΔNO between NO_2 and ΔNO_x

Figure 5-29. NO_x Removal and NO_2 Emissions Versus Time for Sodium Bicarbonate Injection Ahead of the Air Heater (Test 792)

With sodium sesquicarbonate, the majority of the change in NO showed up as NO_x removal and this trend remained fairly constant with time. However, with sodium bicarbonate, injection ahead of the air preheaters, Figure 5-29b shows that early in the test, NO_x removal is favored over NO_2 emissions. As the test proceeded through two fabric cleaning cycles, the trend shifted and the majority of the NO that reacted showed up as NO_2 with a much lesser fraction as NO_x removal.

Further insight into the NO_x removal and NO_2 formation processes can be gained by looking at the compartment-by-compartment measurements. Figure 5-28 showed the SO_2 removals occurring in the individual compartments for sodium bicarbonate injection ahead of the air heater. Figure 5-30 shows the compartment-by-compartment NO_x removals and NO_2 emissions for the same test. In general, the NO_x removal and NO_2 levels were higher on the east side of the fabric filter where the SO_2 removals were also higher. However, there are some observations that are noteworthy. For instance, the NO_x removal and NO_2 emissions do not necessarily directly correlate with the SO_2 removals. This can be illustrated by looking at the compartment-by-compartment data in terms of what fraction of the NO that reacts appears as NO_2, or results in NO_x removal. The data in Figure 5-30 have been replotted on this basis in Figure 5-31 where the total height of the bars represent the percentage of the NO that has reacted in each compartment. The dark shading represents the NO_2 and the lighter shading represents the NO_x removal. On the west side, the majority of the NO that reacted showed up as NO_2 with little NO_x removal. On the east side, the compartments near the entrance exhibited more NO_2 than NO_x removal. It is interesting to compare compartments that exhibited similar levels of SO_2 removal. For instance, compartments 2 (west) and 10 (east) both had SO_2 removals of 70%. Yet, the NO_2 level and NO_x removals in compartment 10 were almost double that of 44 and 40%, respectively. For compartment 4, there was essentially no NO_x removal and the NO_2 levels were 16 ppm, whereas for compartment 12, there was 14% NO_x removal and NO_2 levels of 32 ppm.

It has been observed that the two compartments at the entrance to the fabric filter (Numbers 1 and 7) collect the largest amount of ash. These compartments also capture

Test 792, 4/18/94 15:45, 2Na/S=1.0 NaBicarb at AHi

Bag Compartment Gas Profile, ~ 7 hours from start

Compartment Gas Measurement

#	O2	NO	NO2	NOx	NOxc	NOxn	Δ%NOx	Δ%NO2
___	%dry	ppm	ppm	ppm	ppmc	___	%	%
1 sw	6.00	208	22.7	231	277	1.1	1.2	9.7
2 w	5.60	210	17.5	228	266	1.0	5.1	7.3
3 w	5.40	221	12.4	233	269	1.0	3.9	5.1
4 w	5.30	233	10.6	244	279	1.1	0.3	4.3
5 w	5.40	239	9.3	248	287	1.1	-2.3	3.8
6 nw	5.30	239	6.8	246	282	1.1	-0.6	2.8
7 se	4.95	145	30.4	175	197	0.8	29.8	12.2
8 e	5.05	147	39.8	187	211	0.8	24.8	16.0
9 e	5.20	167	44.0	211	240	0.9	14.2	17.9
10 e	5.10	187	38.8	226	256	1.0	8.8	15.7
11 e	5.20	210	25.4	235	268	1.0	4.3	10.3
12 ne	5.35	229	12.2	241	277	1.1	1.0	5.0
Ave	5.32	203	22.5	225	259	1.0	7.5	9.2
West	5.50	225	13.2	238	277	1.1	1.3	5.5
East	5.14	181	31.8	213	242	0.9	13.8	12.9

Average Inlet/Outlet Gas Measurements

	O2	NO	NO2	H2O	NOx	NOxc	ΔNOx
___	%wet	ppm	ppm	%	ppm	ppmcd	%
Inlet	5.40	241	1.8	0.00	243	280.2	
Stack	5.30	179	26.0	8.81	205	266.4	4.9

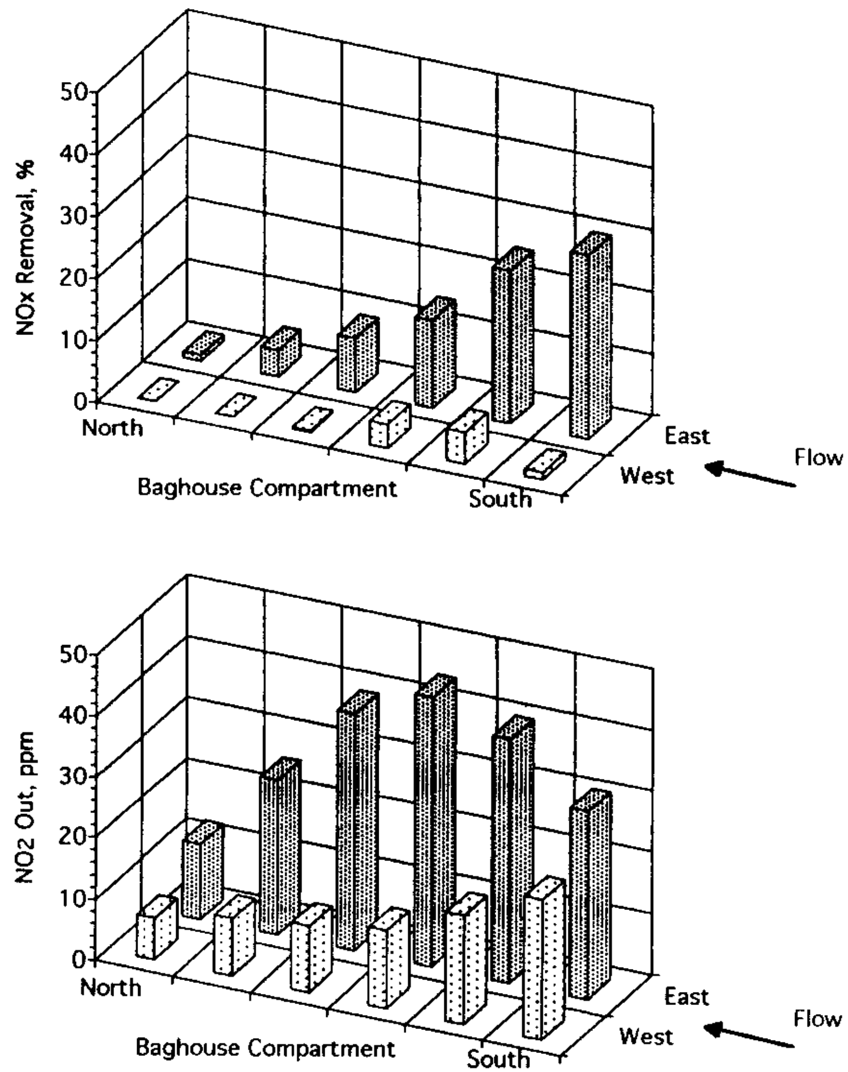


Figure 5-30. Compartment-by-Compartment NO Removals for Sodium Bicarbonate Injection Ahead of the Air Heater (Test 792)

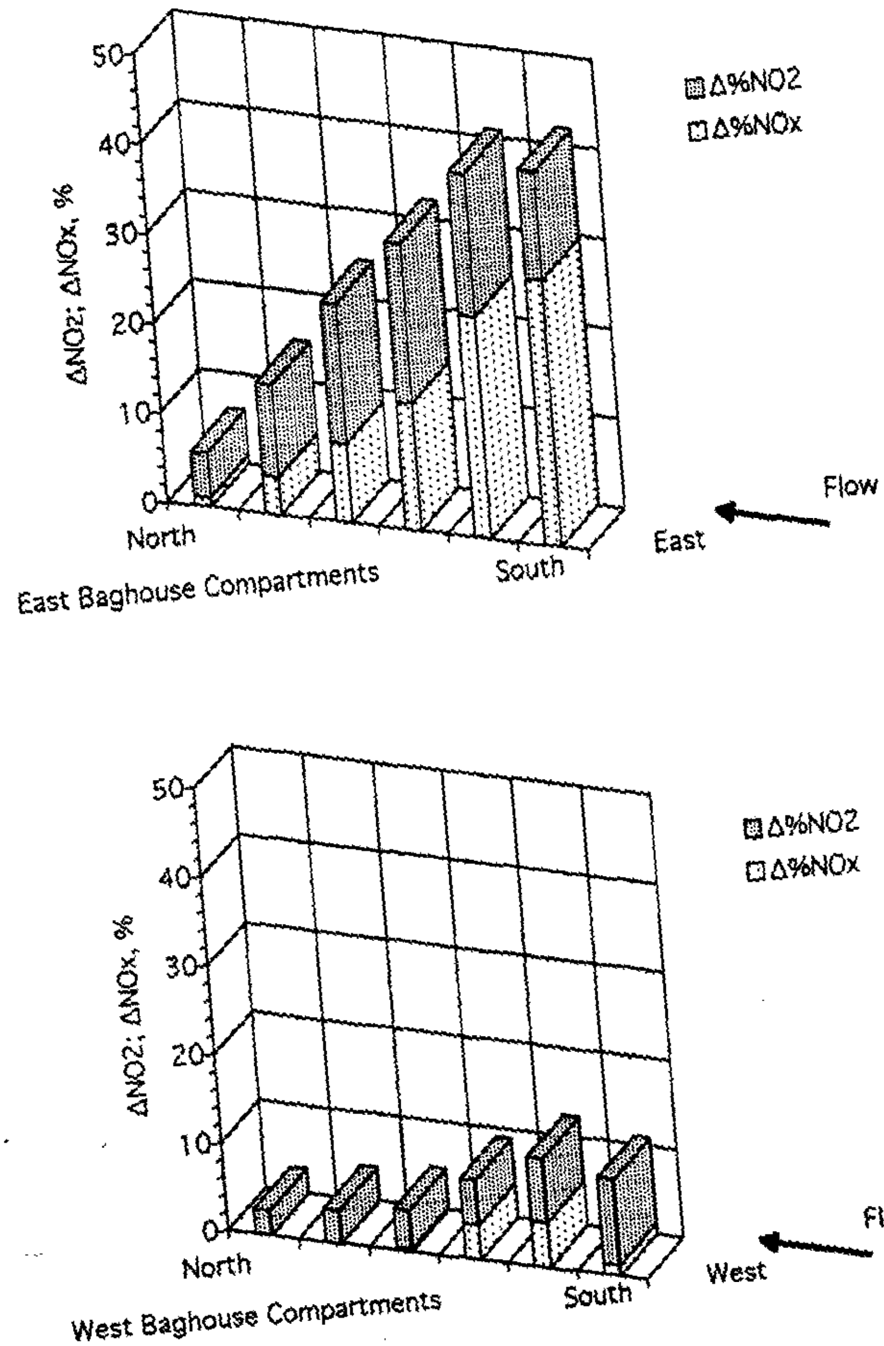


Figure 5-31. Compartment-by-Compartment NO_2 Emissions for Sodium Bicarbonate Injection Ahead of the Air Heater (Test 792)

the largest particles, which will also tend to have the highest carbon content. This could account for the lower NO_2 emissions even though the SO_2 and NO_x removals are highest in these two compartments.

The differences in the trends between Figure 5-9b and Figure 5-29b, the differences in compartment-by-compartment in Figures 5-30 and 5-31 coupled with the increases in NO_2 following a fabric filter cleaning cycle illustrate the complexity of the sodium/SO_2/NO_x chemistry. The reader is referred to Appendix A which reports on the laboratory work completed to better understand the chemistry of NO_2 generation and NO_x reduction that is obtained during sodium injections. However, in addition to the detailed chemistry between sodium, SO_2, and NO, there appears to be an interaction with fly ash carbon that is currently not well understood.

The NO_2 emissions for all of the sodium bicarbonate tests at both injection locations (ahead of the FFDC and ahead of the air heater) are summarized in Figure 5-32. Again, the scatter in the data is attributable to the dependence of NO_2 emissions not only on the amount of sodium injected, but also on the fly ash and FFDC cleaning cycle. As seen with sodium sesquicarbonate, there is no clear difference in the amount of NO_2 produced at each injection location. The data in the 2Na/S range of 0.9 to 1.1 have been replotted in Figure 5-33 as a function of the time from the end of a fabric filter cleaning cycle. This presentation of the data shows that the large variations in NO_2 shown in Figure 5-32 occur just after a cleaning cycle. At longer time periods after a cleaning cycle, the NO_2 levels trend toward a steady state level of 10-20 ppm.

The NO_x removals with sodium bicarbonate are summarized in Figure 5-34 for both injection ahead of the FFDC and ahead of the air heater. Again, a fair amount of scatter in the data is seen, which is attributed to the process dynamics. Overall NO_x removals at a nominal 2Na/S ratio of 1.0 ranged from 0 to 20 percent, and averaged roughly 10 percent. These levels of NO_x removal are consistent with previously reported results from the Cameo and Nixon demonstrations (Muzio, et al., 1984; Fuchs, et al., 1989).

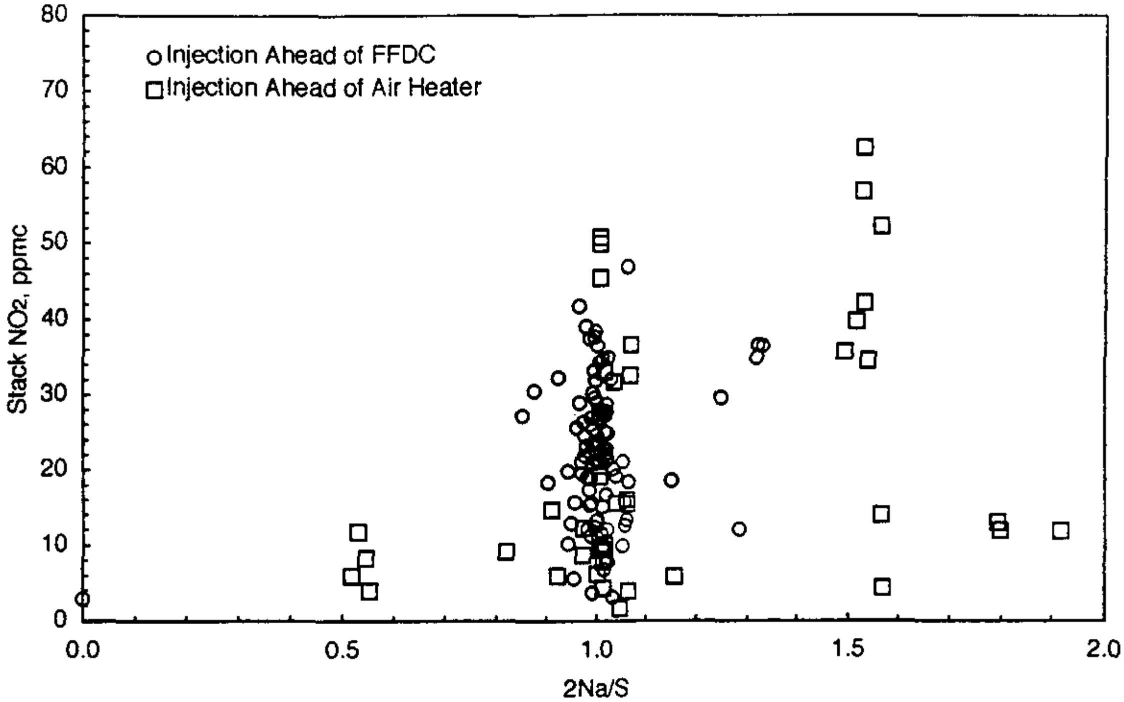


Figure 5-32. Summary of NO_2 Emissions with Sodium Bicarbonate Injection

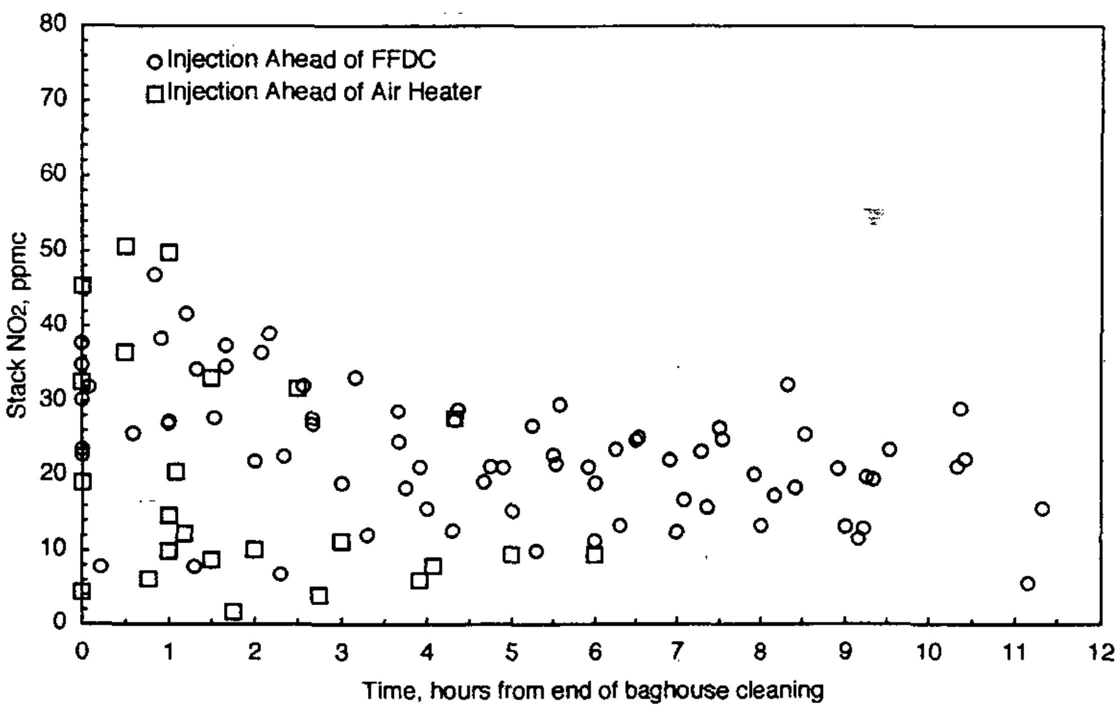


Figure 5-33. NO_2 Emissions and FFDC Cleaning with Sodium Bicarbonate (2Na/S 0.9 to 1.1)

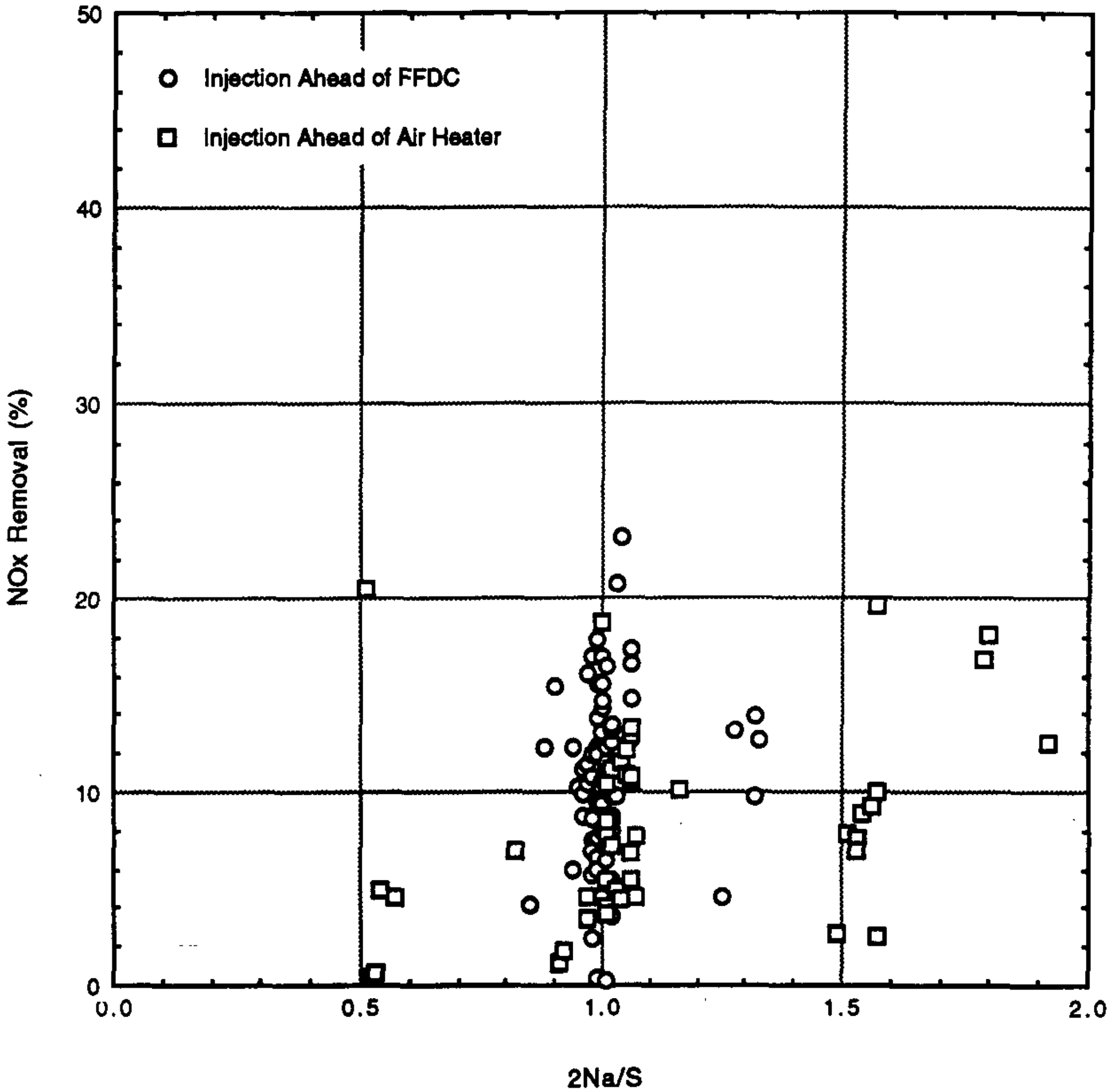


Figure 5-34. Summary of NO_x Reductions with Sodium Bicarbonate Injection

5.4 Solids Analysis

Samples of the sorbent and fly ash mixture were collected on a number of occasions during the current series of tests. The samples were collected separately from the individual FFDC compartments in an effort to assess any variation in sorbent distribution and utilization within the fabric filter. The solids analysis would also provide a means to check the 2Na/S ratio calculated from the sorbent feed rate. Samples were collected during both the sodium sesquicarbonate and sodium bicarbonate injection tests; these results are discussed separately in the following subsections.

In general, there are many concerns with the solid sample analysis. Solids analysis would be accurate if the ash and reagent products were equally distributed throughout the hoppers and sampling techniques were perfected. At Arapahoe, the FFDC has twelve compartments arranged in two rows of six (Figure 3-3) with the front compartments Number 1 on the west and 7 on the east. There is a good indication by observing an ash pull that the ash is severely non-uniform. The front compartments collect the greatest quantity of ash, while the last compartments collect the least, even though the gas flow through the FFDC is uniformly distributed. A similar problem occurs with the reagent distribution in the FFDC. The reagent may or may not be distributed in the same manner as the ash. If the reagent distribution is different than the ash distribution, then the solids analyses are difficult to interpret in terms of the dry sorbent process parameters. In addition to the distribution concerns, it is also very difficult to obtain a representative sample of such a large quantity of waste within an individual hopper. Thus, additional unknowns are introduced, although a number of different sampling techniques were tried to minimize the potential problems. Because of these problems, solids analysis should be used only for general observations and not absolute data analysis.

5.4.1 Sodium Sesquicarbonate

During the initial tests with sodium sesquicarbonate injection ahead of the FFDC, a set of solid samples was collected in order to determine if a significant amount of the sorbent was falling out of suspension and dropping into the hoppers before reaching the bags. The samples were analyzed to determine what difference, if any, in utilization occurred between the material on the bags and that in the hoppers. The samples were collected on a day when the injection system was running at a constant 2Na/S ratio of approximately 0.85. At the beginning of the day, sorbent injection was started, and a cleaning cycle was initiated manually in order to clean the fabric filter of the fly ash collected during the previous night. The hoppers were then evacuated after the cleaning cycle was complete. The injection condition was held constant until the pressure drop approached 4 inches (at which point a cleaning cycle would be initiated automatically). The FFDC control was put into manual in order to prevent the cleaning, and a sample was collected from all twelve compartments through a 4-inch port located near the bottom of each hopper. These samples should be biased toward the material that fell directly into the hopper before reaching the bags. The hoppers were then evacuated, and the FFDC allowed to clean automatically. Immediately after the cleaning, but before the hoppers were evacuated again, another set of single samples from each hopper were collected. These samples should be representative of the material that resided on the bags. Again, the "before clean" and "after clean" samples should be indicative of the material "in the hoppers" and "on the bags", respectively.

Portions of all 24 samples were sent to PSCo Applied Sciences Laboratory for analysis for sodium and sulfate. As very little of the captured sulfur was expected to be in the form of sulfite, only four of the samples were analyzed for this component. Sodium content was determined via an ICP (induced coupled plasma) analysis (EPA Method 200.7). Sulfate and sulfite were determined via ion chromatography (EPA Method 300.1) and titration (ASTM Method 4500), respectively. The sulfite analyses confirmed that only a small amount (generally less than 2 percent) of the sulfur was in the form of Na_2SO_3.

Figures 5-35a and 5-35b show the results of the sodium analyses for the samples taken before and after cleaning the FFDC, respectively. Recall that the fabric filter has twelve compartments arranged in two rows of six (Figure 3-3), and that compartment Number 1 is the first one on the west side, while Number 7 is the first one on the east side. The results indicate that the sodium concentration is lower in the first compartments on each

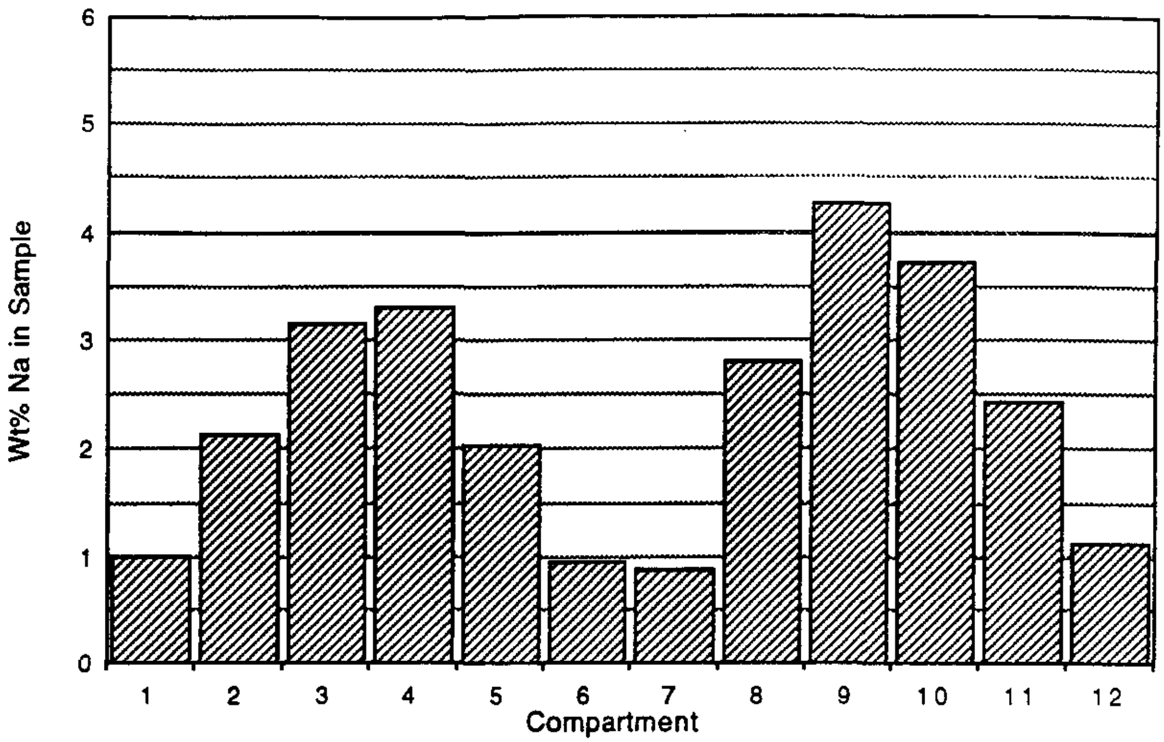


Figure 5-35a. Sodium Analysis Results for Sodium Sesquicarbonate Injection Samples Collected Before FFDC Cleaning (Test 641)

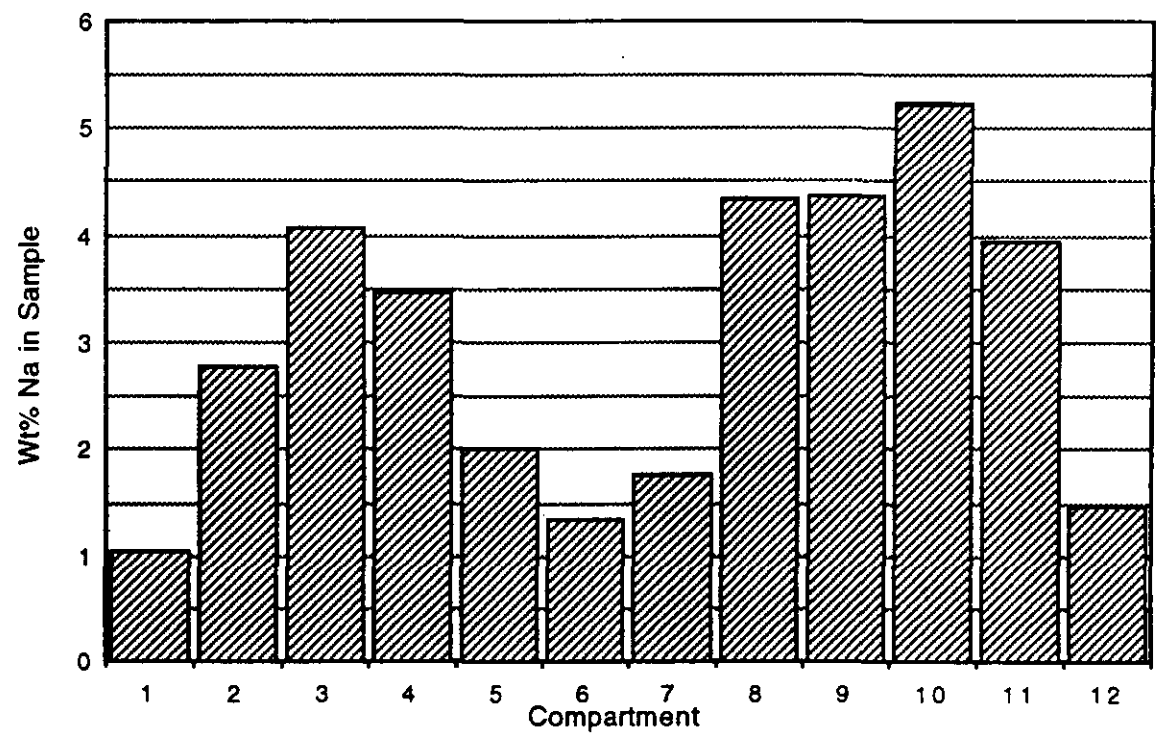


Figure 5-35b. Sodium Analysis Results for Sodium Sesquicarbonate Injection Samples Collected After FFDC Cleaning (Test 641)

side, *increases to a maximum in the central compartments, and then decreases in the rear* compartments.

The results of the sulfate analyses (Figures 5-36a and 5-36b) show a compartment-by-compartment distribution of sulfate which is similar to that seen for the sodium. However, there is substantially more sulfur in the material on the bags than in the material which is deposited in the hoppers. Cursory review of the data seem to indicate that the sodium is biased to the middle compartments of the FFDC. If the ash was uniformly distributed within the compartments, then this initial indication would be true. As discussed in the introduction to this section, ash and reagent are not uniformly distributed. In addition to these concerns related to distribution between the FFDC compartments, similar concerns also exist for the sample obtained before cleaning the FFDC. However, using the observation that higher ash collections occur in the front compartments, some observations can be made. The front compartments show low sodium, but the front compartments also contain higher quantities of ash. With more ash, the sodium concentration is "diluted". While no conclusion can be made, it appears that the sodium reagent is also preferentially deposited in the forward compartments, although not to the extent of the fly ash, and the back compartments have significantly less reagent. This is supported by the compartment SO_2 removal traverse data in Figure 5-8 which shows approximately equal SO_2 removal *in the first compartments with a gradual reduction in SO_2 removal toward the rear* compartments. Another observation is that both the pre- and post-cleaning samples have approximately the same sodium weight percentage in each hopper. This likely indicates that approximately the same amount of reagent and ash fall out in the hoppers. As the particle size for both reagent and ash are approximately equal, this is not unexpected.

A measure of the utilization of the sodium in each sample may be determined from the molar ratios of sodium and sulfur. Since two moles of sodium are required to completely react with a single mole of sulfur, a molar sulfur-to-sodium ratio of 0.5 would indicate complete sodium utilization. Thus, dividing the S/Na ratio found in each sample by 0.5, provides a measure of the sodium utilization in that sample. Figures 5-37a and 5-37b show these calculated utilizations for samples collected both before and after the FFDC

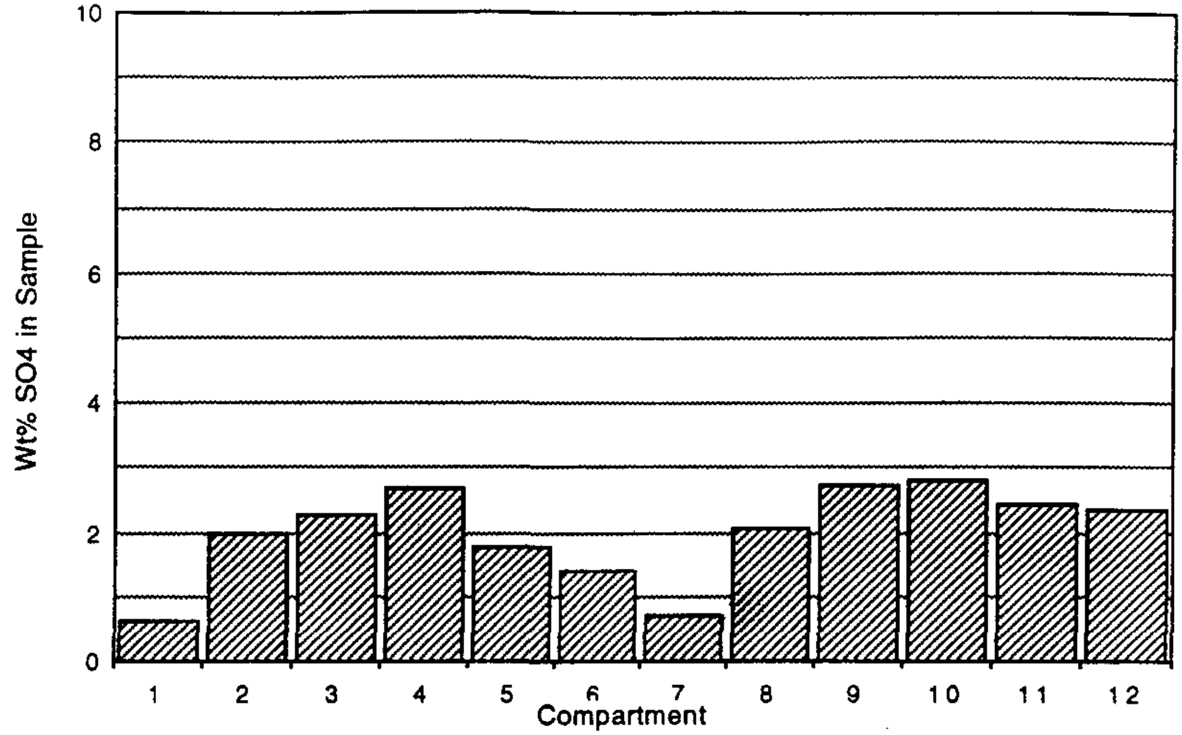


Figure 5-36a. Sulfate Analysis Results for Sodium Sesquicarbonate Injection Samples Collected Before FFDC Cleaning (Test 641)

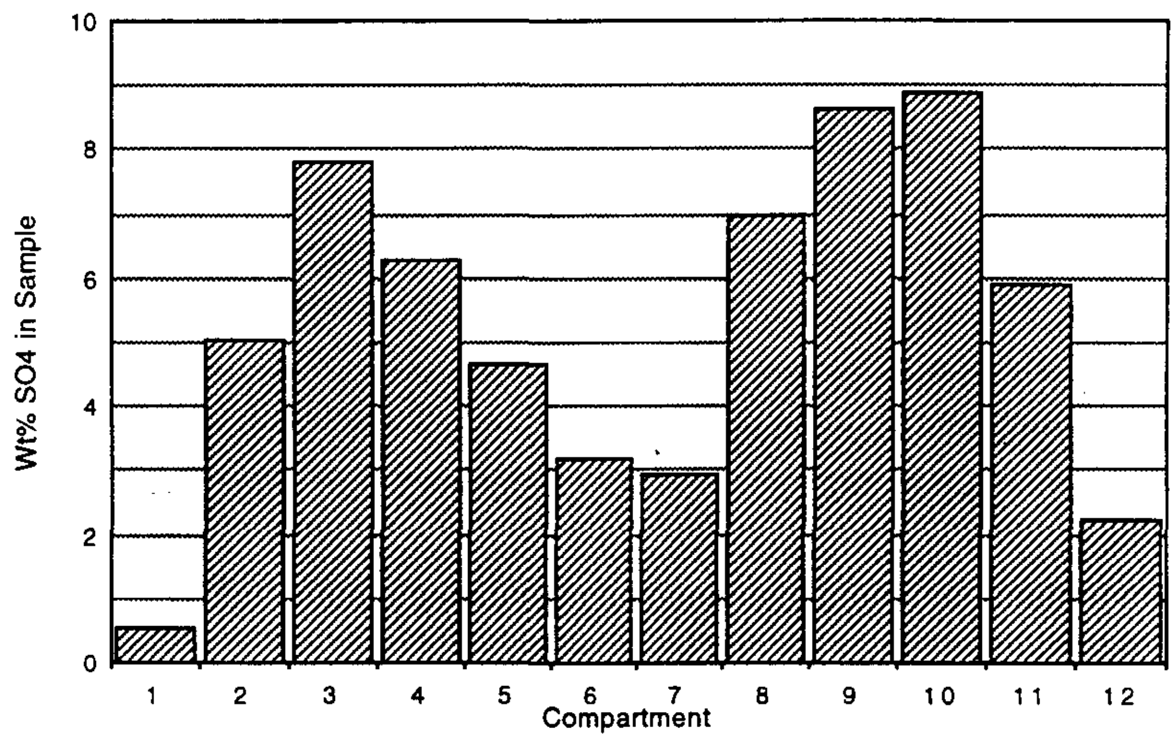


Figure 5-36b. Sulfate Analysis Results for Sodium Sesquicarbonate Injection Samples Collected After FFDC Cleaning (Test 641)

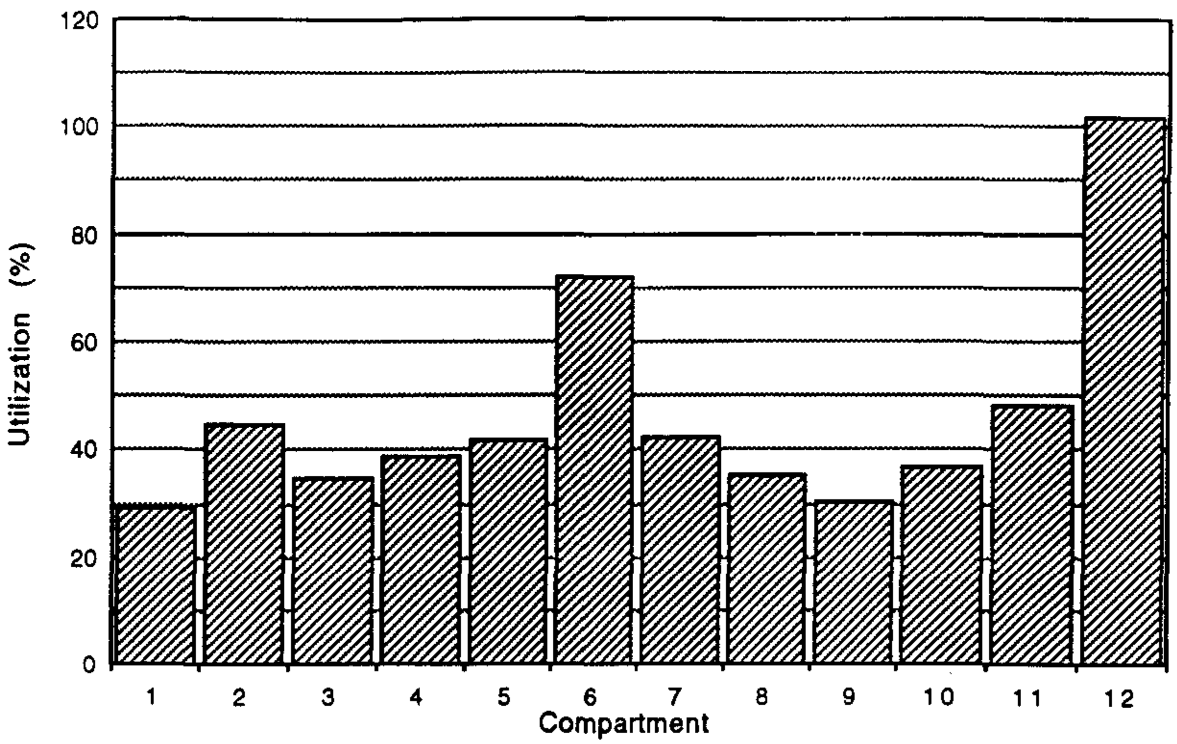


Figure 5-37a. Utilization Calculations for Sodium Sesquicarbonate Injection Samples Collected Before FFDC Cleaning (Test 641)

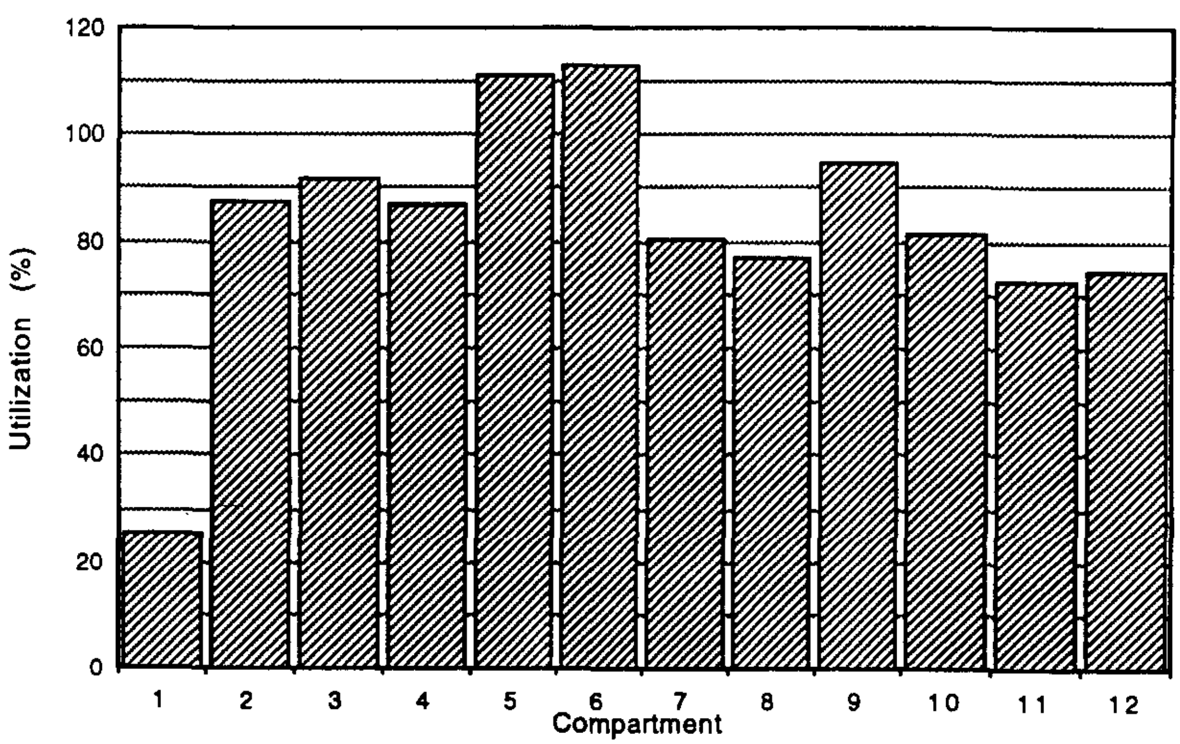


Figure 5-37b. Utilization Calculations for Sodium Sesquicarbonate Injection Samples Collected After FFDC Cleaning (Test 641)

cleaning. Although, utilizations in excess of 100 percent are unrealistic (and are likely due to small inaccuracies in the solids analyses), the results confirm that the material which collects on the bags is much more highly utilized than the material which falls out of suspension and into the hoppers. The very low utilization of the post-cleaning sample for compartment 1 was not expected and is likely due to a sampling inconsistency. As discussed above, only general observations can be made due to the non-uniform ash and reagent distribution. As the sodium percentages were approximately equal in the pre- and post-cleaning samples, it would be expected that the sulfate quantities would also be equal if the reagent reacted the same. As the post-cleaning sample has significantly more sulfate, it is more fully reacted. This shows that the reagent that drops out in the hoppers obtains less SO_2 capture. This is consistent with the gaseous SO_2 results which indicated that the majority of the SO_2 removal is obtained while the material is in the FFDC.

Another objective of performing the solids analyses was to confirm the 2Na/S ratio calculated from the sorbent feed rate and the gaseous SO_2 measurements. Since the results discussed above show a large difference in utilization between the material on the bags and that in the hoppers, and the relative quantities of waste before and after cleaning are not known, it was necessary to revise the sampling method. The new method consisted of collecting a single sample having average properties which were representative of the material deposited throughout each compartment. This was accomplished by allowing the baghouse to clean in a normal fashion, and then evacuating the hoppers one at a time while taking a sample from the bottom of the hopper at regular (one minute) intervals. This method provided a series of small samples which were representative of the vertical distribution of material in the hopper.

Once the hopper was completely evacuated, the individual samples were composited together into a single sample for that particular compartment. Samples were collected from all twelve compartments in a similar manner.

The new method was used to collect samples for three tests which were run with similar operating conditions during the final phase of air toxics testing performed in October, 1993.

The three tests were run at a boiler load of 100 MWe, with nominal 2Na/S ratios of 1.5. The overall SO_2 removals measured for each test were similar, ranging from 61 to 65 percent. This corresponds to overall utilizations of 40 to 43 percent based on the sorbent feed rate and SO_2 removal. The compartment-by-compartment utilizations calculated for all three tests are shown in Figure 5-38.

In general, all three sets of data indicate that the material deposited in the rear compartments is more highly utilized than that deposited in the front. However, the results also show that the utilization calculated for a single compartment can vary greatly, depending on the particular test. It is believed that this variability is due to test-to-test variations in how the sorbent is deposited in the FFDC, and in the ability to obtain a representative sample from each compartment hopper.

If the sorbent was evenly distributed among the twelve FFDC compartments, calculating an overall 2Na/S ratio from the compartment-by-compartment solids analyses would be a simple matter of dividing the overall SO_2 removal by the arithmetic average of the compartment utilizations. However, the data previously presented in Figures 5-35a and 5-35b indicate that more of the sorbent is deposited in the front compartments than in the rear. Therefore, the 2Na/S ratios must be calculated separately for each compartment, and then averaged, in order to provide an accurate overall value. To do so requires the measurement of the SO_2 removal in each compartment, in addition to the utilization calculation.

Compartment-by-compartment SO_2 removals were measured during the final air toxics test with sodium sesquicarbonate injection (Test 704). These results, as well as the calculated utilizations based on the solid samples for each compartment, are shown in Figure 5-39. The peak SO_2 removals occur in the central compartments of each side of the baghouse in a pattern which is similar to that seen for the sodium distribution (Figures 5-35a and 5-35b). The arithmetic average of the SO_2 removal data was 55.9 percent. This compares to an overall SO_2 removal of 60.8 percent measured across the fabric filter. Since the arithmetic average of the compartment-by-compartment SO_2 removal measurements is in

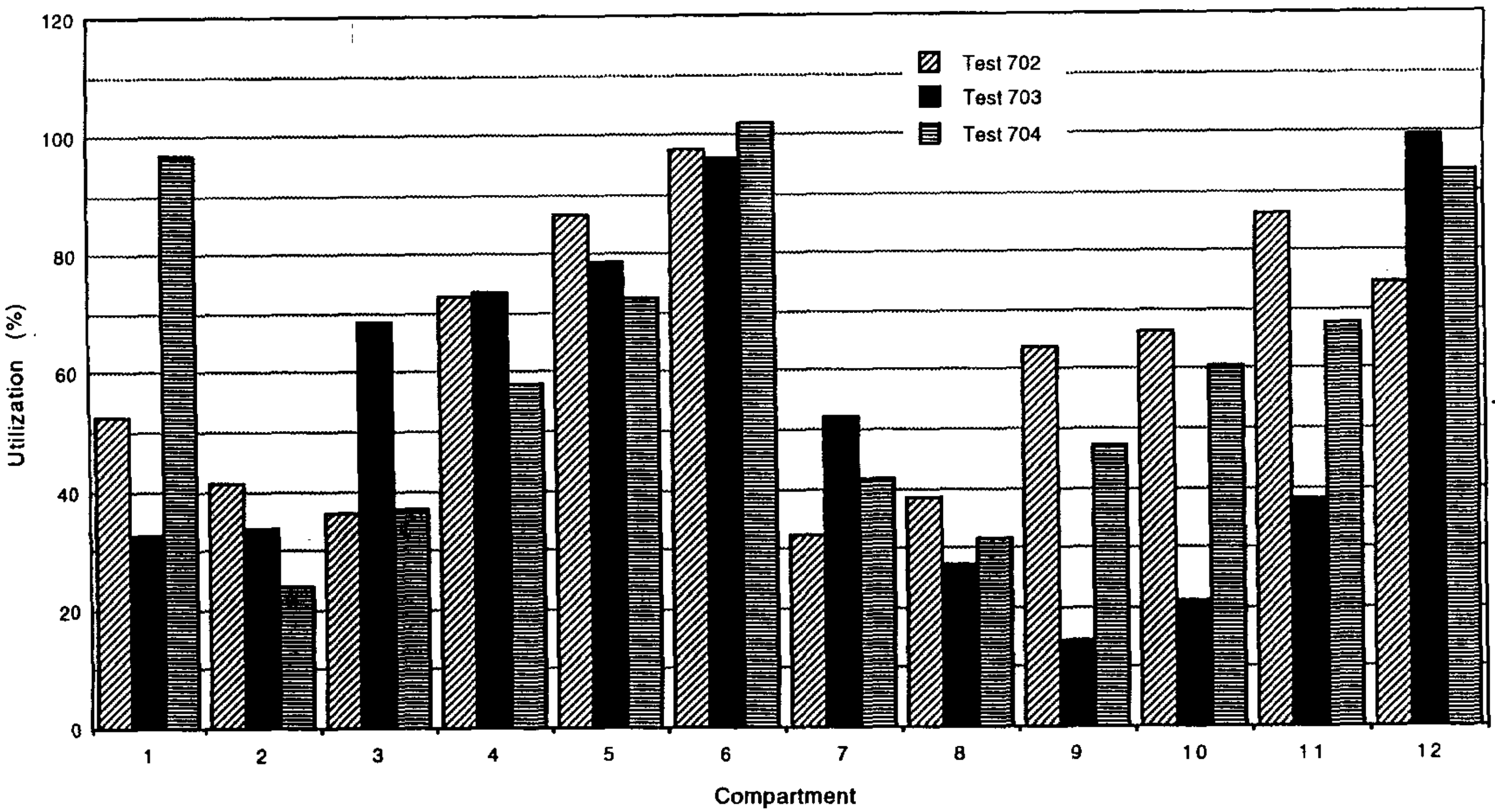


Figure 5-38. Utilization Calculations for Sodium Sesquicarbonate Injection Samples Collected During Air Toxics Tests (2Na/S=1.5)

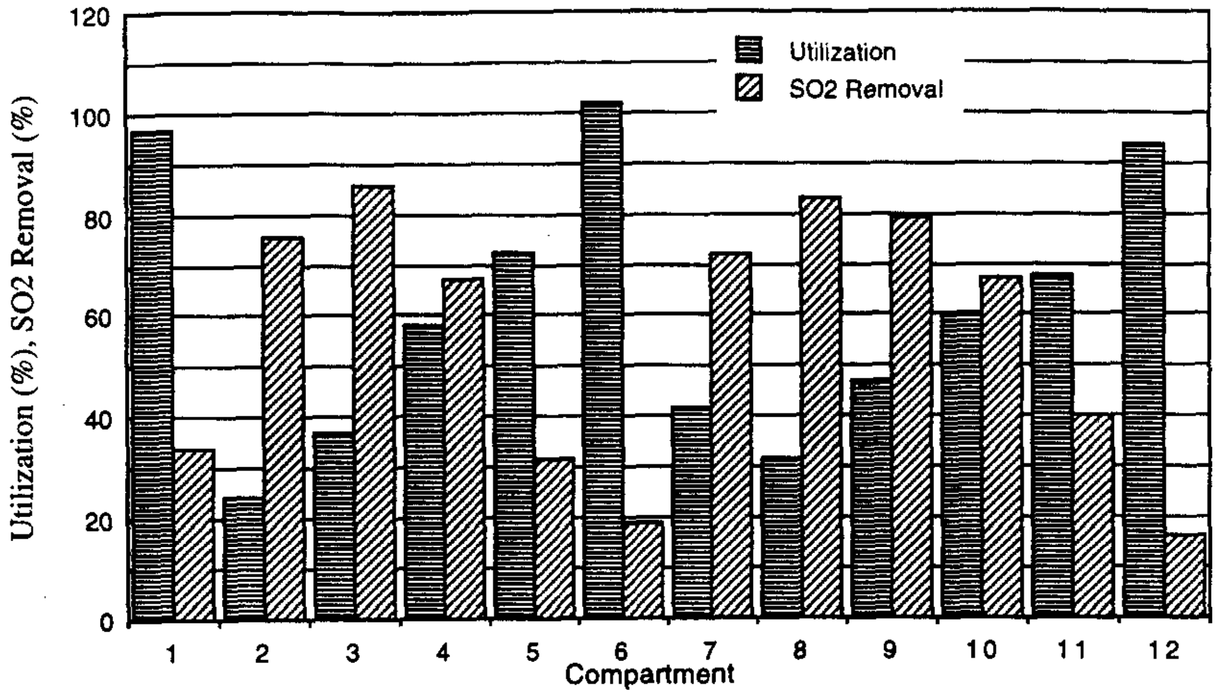


Figure 5-39. Compartment-by-Compartment Utilization Calculations and SO_2 Removals for Sodium Sesquicarbonate Injection (Test 704)

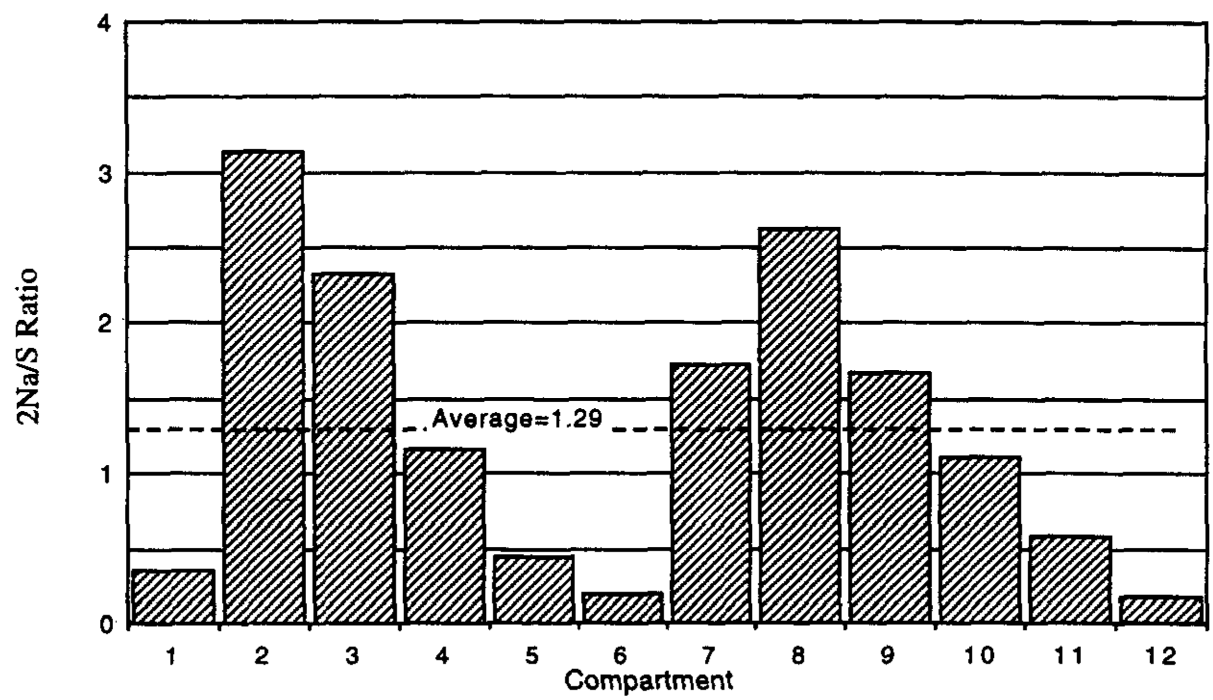


Figure 5-40. Compartment-by-Compartment 2Na/S Ratio Calculations for Sodium Sesquicarbonate Injection (Test 704)

good agreement with the overall measurement across the fabric filter, each compartment has essentially the same gas flow. Figure 5-40 shows the 2Na/S ratio calculated on a compartment-by-compartment basis. These results further support the previous observation that most of the sodium is deposited in the center compartments, and very little reaches the back compartments (Numbers 11 and 12). The arithmetic average of this data (2Na/S = 1.29) is in reasonable agreement with the feed rate calculation (2Na/S = 1.53).

At the conclusion of the air toxics testing performed during October 1993, a series of twelve fly ash/sorbent samples were collected from a location upstream of the FFDC in an effort to assess the sorbent distribution uniformity inside the duct. The samples were collected at a location approximately 60 feet downstream of the sorbent injection grid, through a set of four ports occupied by the original humidification thermocouple grid (recall Figure 3-2). Three separate samples were collected through each port at depths of 0.25, 0.50, and 0.75 of the total duct depth at that location. All sampling was performed in accordance with EPA Method 17 in order to assure a representative sample. Figures 5-41 and 5-42 show the flue gas velocity and total particulate concentration (fly ash and sorbent) results of these tests. Although the velocity profile is nearly uniform across the duct, the particulate concentration was skewed, with the lowest loading at the top west comer and an increasing trend across the diagonal to the highest concentration at the lower east comer. A sodium analysis of the filter catch from each test (Figure 5-43) also showed high levels of sodium in the samples from the lower east comer. The sodium concentration (mg/Nm^3) at each sample point was computed from the total particulate concentration and the sodium content of the sample. The normalized results (Figure 5-44) show a large maldistribution of sorbent, with most of the material being found in the lower east quadrant of the duct.

As discussed previously, sorbent injector plugging was a recurring problem during the program. Since the pulverizer added a significant amount of heat to the sorbent/air mixture, it was rather easy to locate an injector which was totally plugged by simply touching the pipe upstream of the injector. A warm pipe was flowing, while a cold pipe indicated that the injector was plugged. Unfortunately, this method would not locate a

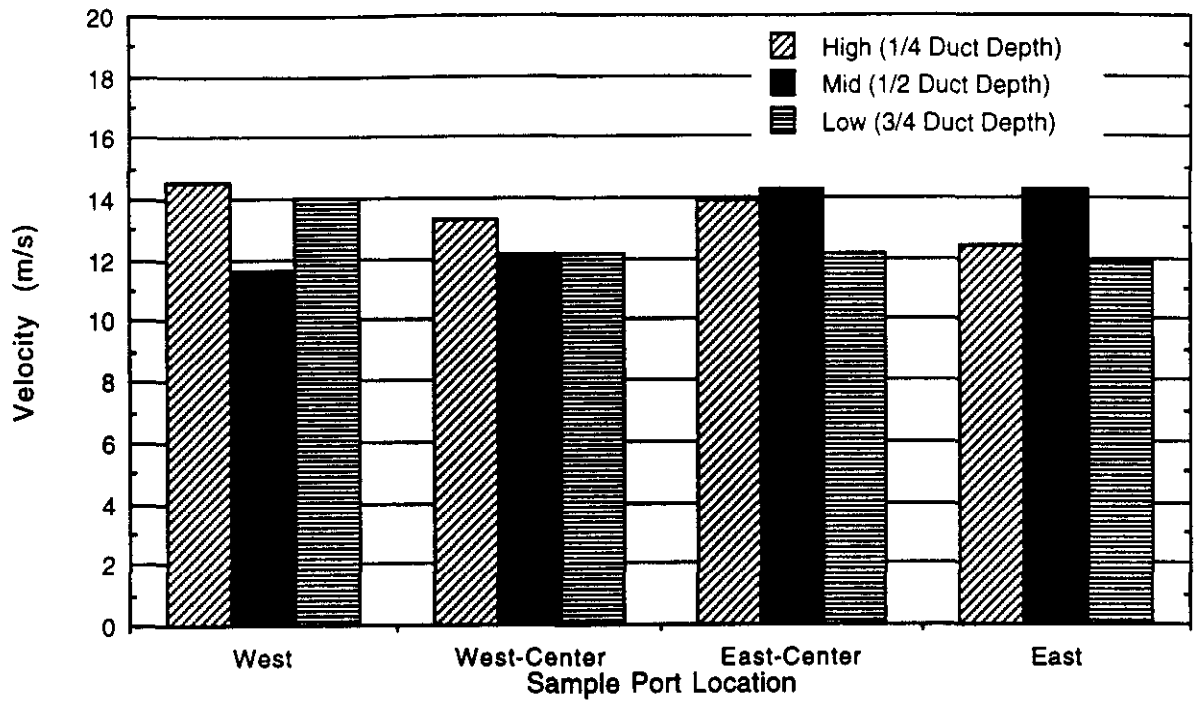


Figure 5-41. Flue Gas Velocity Distribution at FFDC Inlet for Sodium Sesquicarbonate Injection (Test 705)

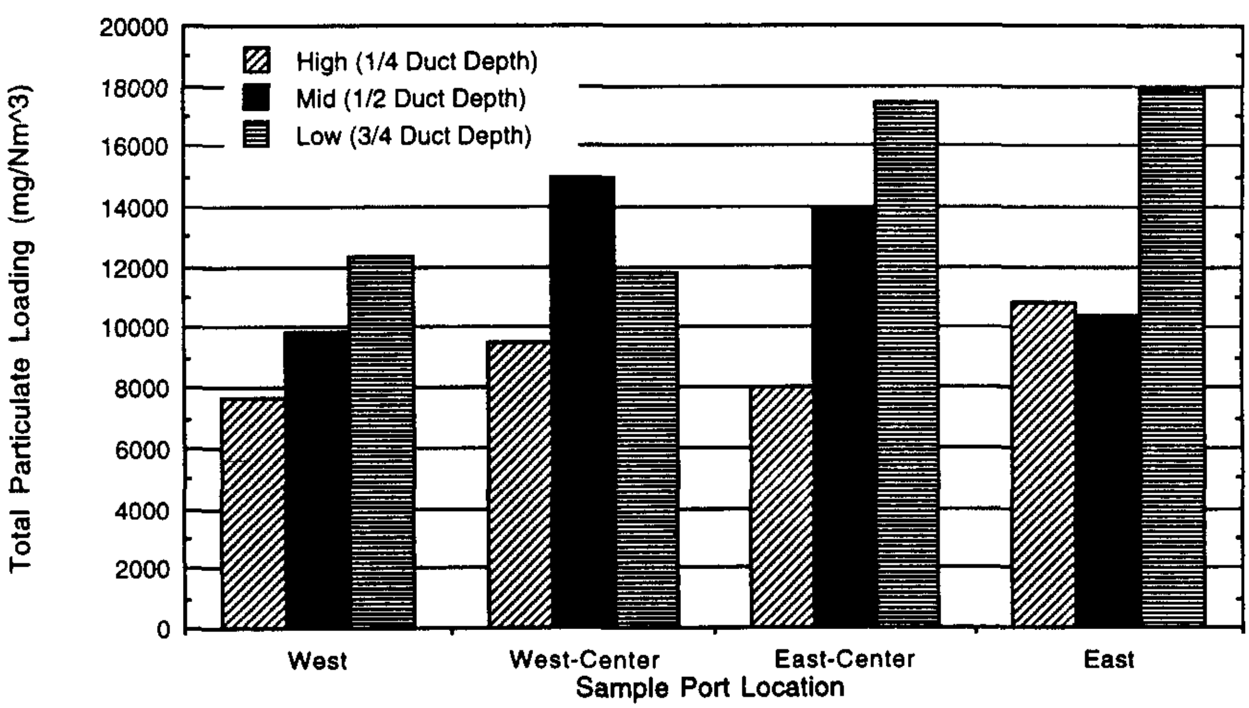


Figure 5-42. Total Particulate Loading (Flyash and Sorbent) at FFDC Inlet for Sodium Sesquicarbonate Injection (Test 705)

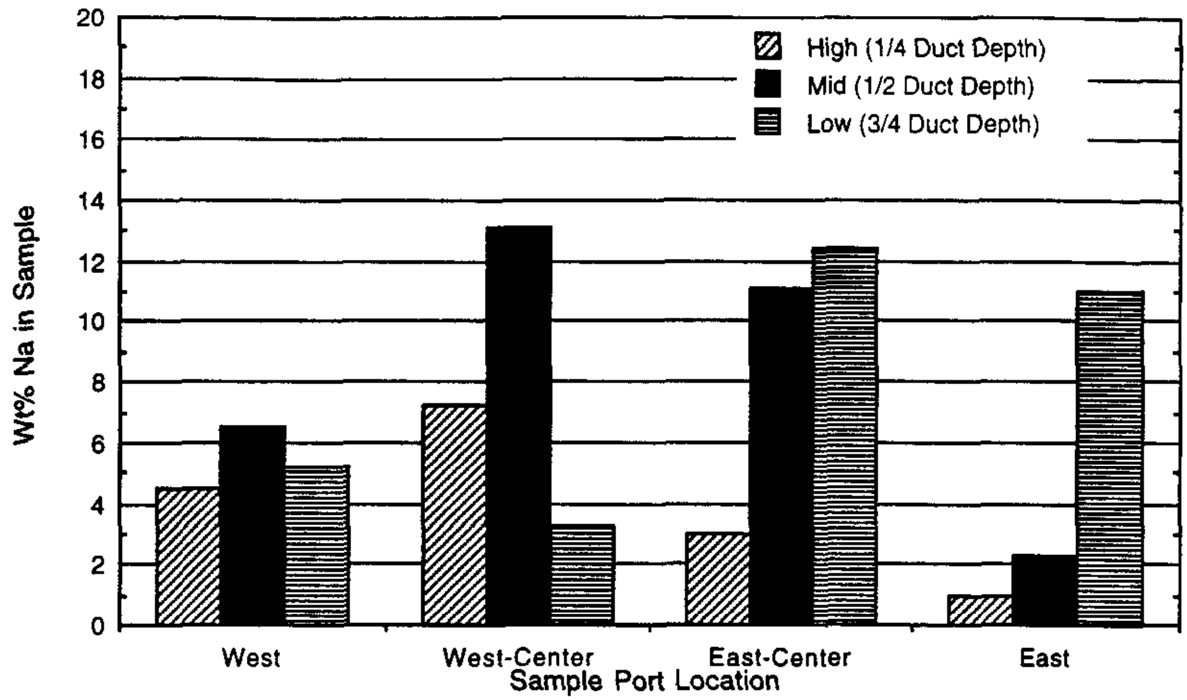


Figure 5-43. Sodium Analysis Results for Samples Collected at FFDC Inlet for Sodium Sesquicarbonate Injection (Test 705)

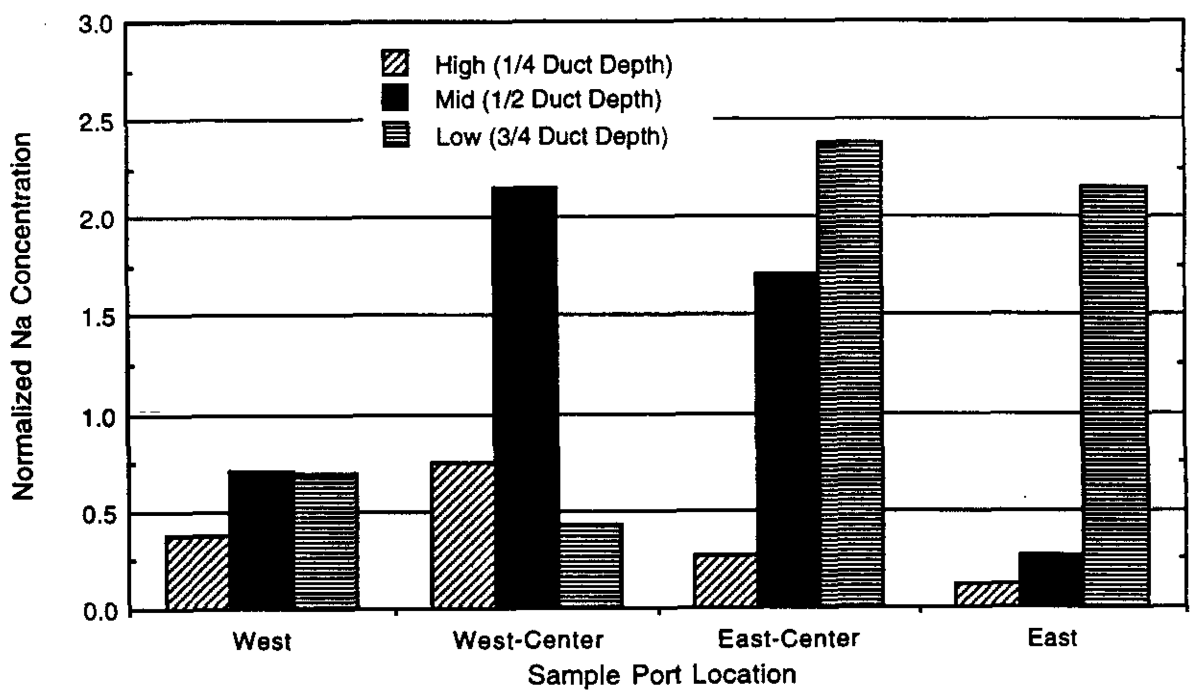


Figure 5-44. Calculated Sodium Distribution at FFDC Inlet for Sodium Sesquicarbonate Injection (Test 705)

partially blocked injector until it had become totally plugged. It is likely that the distribution of sorbent shown in Figure 5-44 is the result of a particular pattern of partially plugged injectors. It is also believed that the pattern, and therefore the distribution of sorbent in the duct as well as in the baghouse, could change on a day-to-day basis. The variability of the utilizations calculated for a single compartment shown in Figure 5-38 can at least be partially attributed to this behavior of the injection system. Fortunately, this variability does not seem to affect the overall process performance, as the SO_2 removals measured at the stack for these three tests were consistent, ranging from 61 to 65 percent.

5.4.2 Sodium Bicarbonate

As discussed previously, the SO_2 removal process with sodium bicarbonate injection ahead of the FFDC was found to be highly temperature dependent and difficult to control. Solid samples were collected at the end of the five-day test shown in Figure 5-20, in order to provide a set of samples which was representative of the "long-term" process performance. In order to evaluate the extent to which the sorbent was being utilized when deposited on the bags, individual compartment samples were collected. The procedure which collected multiple samples from each hopper at one minute intervals during ash pulling was used. The compartment hoppers were evacuated prior to cleaning the bags and collecting the samples, so that only material on the bags was collected.

Portions of the samples were sent to the PSCo Applied Sciences Laboratory and analyzed for sodium, sulfate and sulfite. As was seen for sodium sesquicarbonate injection, sulfite was found in only negligible amounts. However, the compartment-by-compartment utilizations calculated from the sodium and sulfate results ranged from 140 to 170 percent. Although a review of the laboratory procedures did not indicate any analytical problems, a second portion of each sample was submitted for analysis as a check.

The sodium and sulfate results for the two sets of analyses are compared in Figures 5-45a and 5-45b, respectively. Note that compartment 11 was out of service for maintenance on the day that the samples were collected. In each figure, there are compartments where

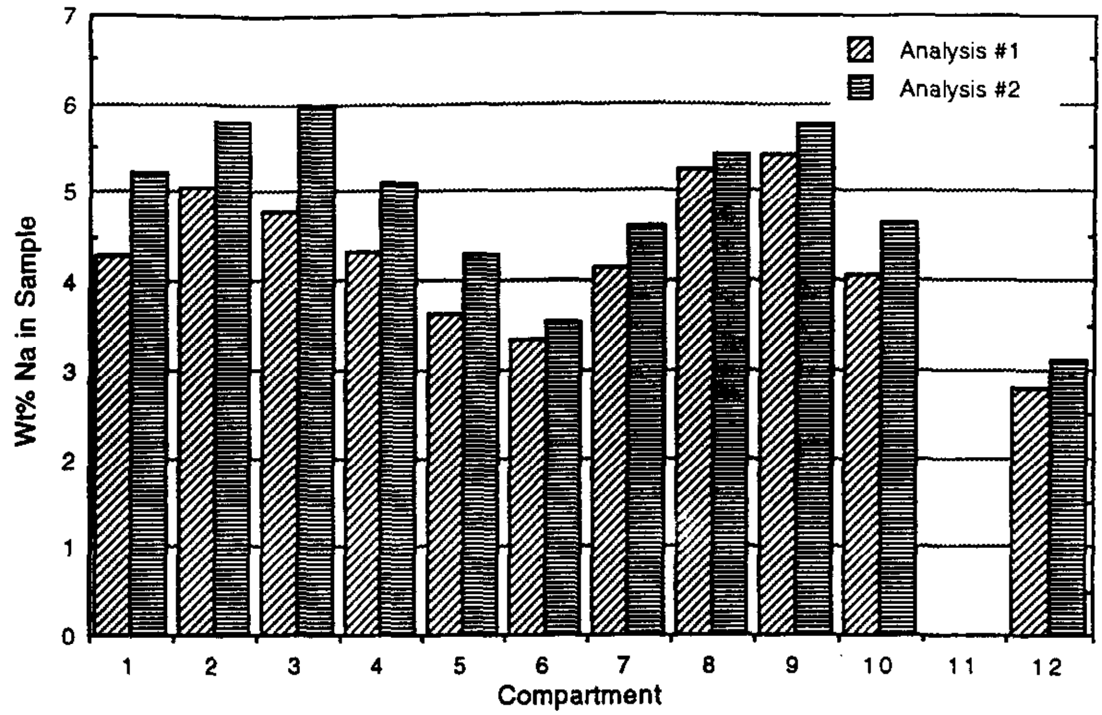


Figure 5-45a. Sodium Analysis Results for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

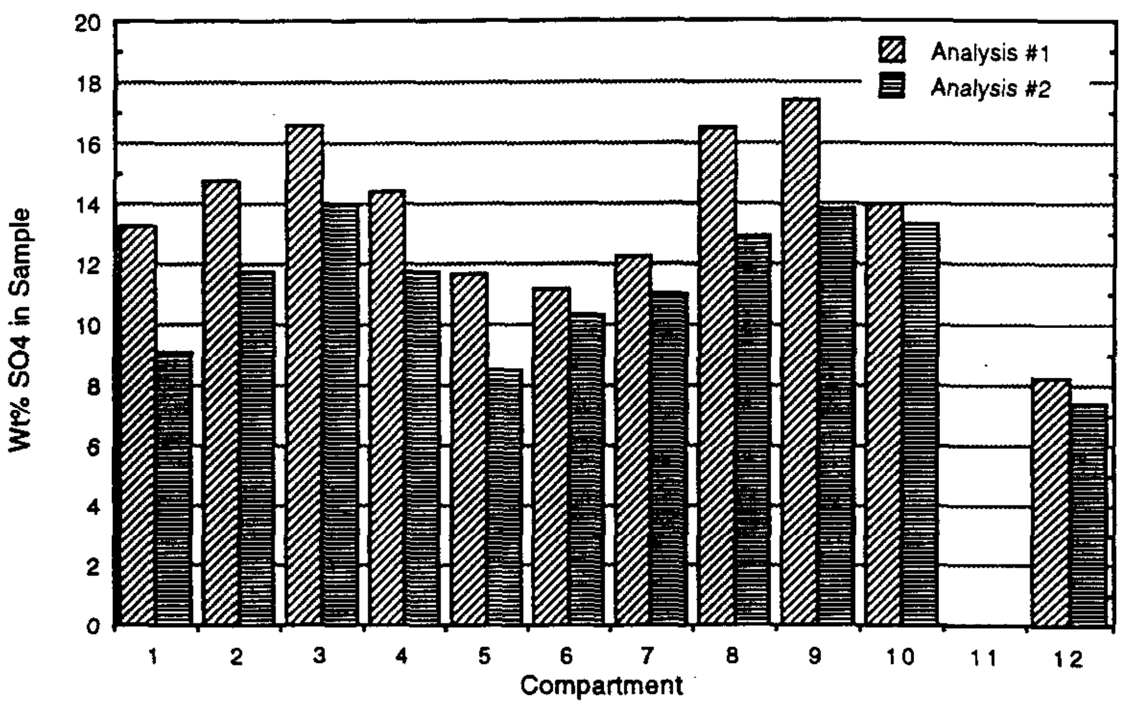


Figure 5-45b. Sulfate Analysis Results for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

the two sets of data are in good agreement, and then others where there are relatively large differences. It is notable, however, that in each compartment, the sodium results from the second analysis are higher than the first, while the sulfate results are lower. Although a small random variability in the results may be explained by the non-homogeneous nature of the large sample from which the two smaller samples were taken, the "shift" between the two sets of results may also indicate an analysis problem.

Figure 5-46 shows that, in general, the compartment-by-compartment utilizations calculated from the second set of analyses are lower than the first. However, there are still two compartment analyses which are questionable with utilizations of nearly 140 percent. These two notwithstanding, the second set of utilizations fall within the range of 85 to 115 percent, indicating that the sorbent becomes highly utilized when deposited on the bags. This compares to an average utilization of 72% calculated from the measured SO_2 removal and sorbent feed rate.

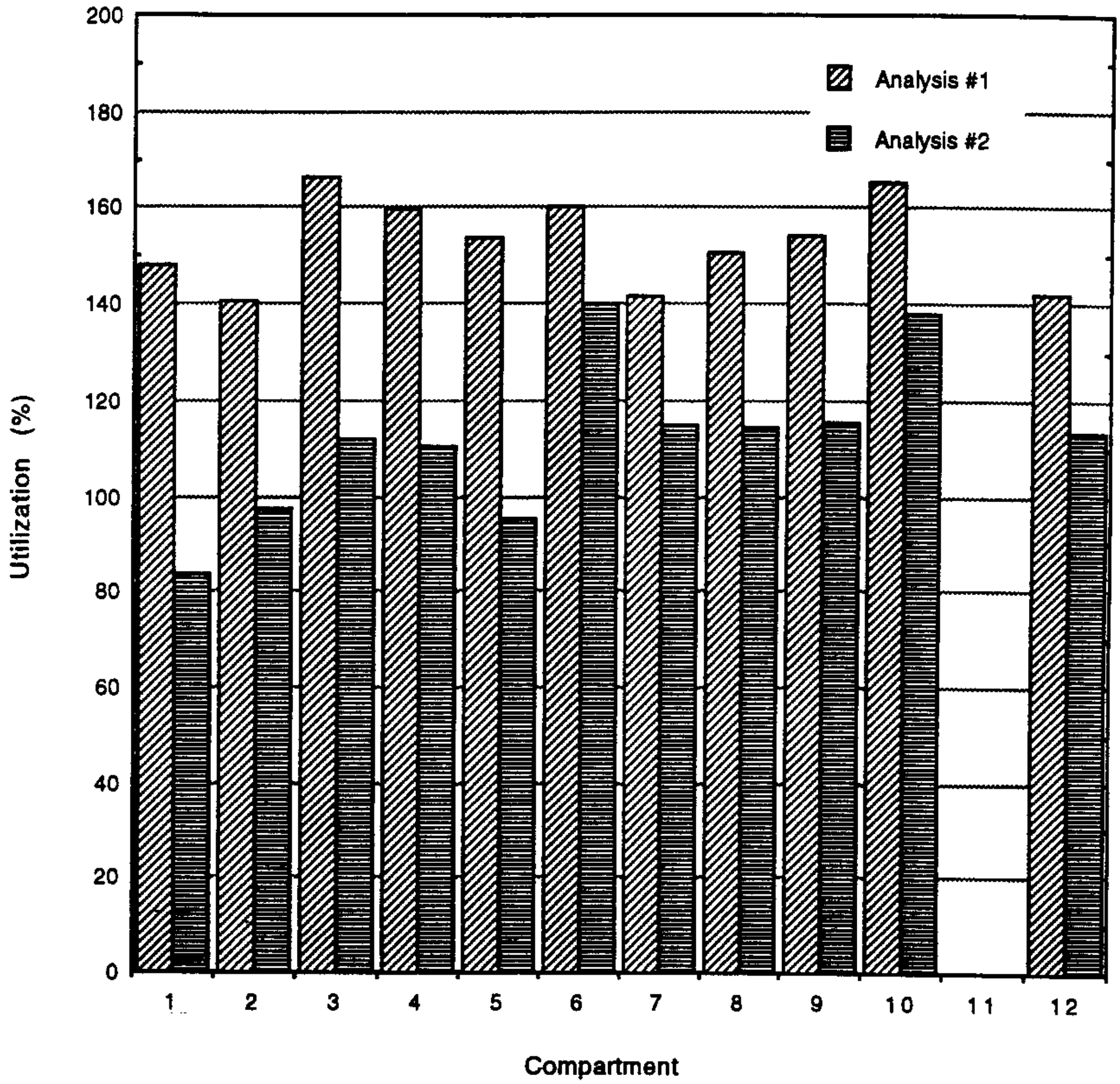


Figure 5-46. Utilization Calculations for Sodium Bicarbonate Injection Ahead of the FFDC (Test 763)

6.0 LONG TERM LOAD FOLLOWING TEST RESULTS

After completion of the short term parametric tests reported in the previous section, a long term test of nominally four months duration was begun with sodium sesquicarbonate injection ahead of the fabric filter. During this test, the boiler was run in the normal load following manner as dictated by the PSCo system dispatch center. The DSI system was run in the automatic control mode, with the goal of maintaining an average SO_2 removal of 40 percent for the first two months, and then 70 percent for the remaining two months.

The test began on November 14, 1994, and during the first month, both the "A" and "B" injection systems experienced repeated problems with plugging of the piping downstream of the splitter valves. The "A" system piping was redesigned in December, and all of the long radius elbows were replaced with five radius elbows. After the modifications to the piping external to the flue gas duct, the injectors still plugged at the 90° bend inside the duct every three to five days. To solve this problem, the in-duct elbows were removed, and the sorbent injected perpendicular to, rather than concurrent with, the flue gas flow. The "A" system was then run for two weeks in order to ensure that the modifications corrected the plugging problem, and then the "B" system was modified similarly. These modifications were completed in early February, 1995, at the time when it was planned to increase the target SO_2 removal from 40 to 70 percent.

In February, 1995, a number of equipment problems occurred such that only one injection system was available for much of the time. The two major problems were a screw feeder bearing failure, and a high vibration problem on the "A" pulverizer. The bearing failure resulted in the loss of one system for nearly a week due to problems in locating parts and scheduling a maintenance crew. Additionally, during an attempt to remove the "A" pulverizer rotor disk and investigate the vibration problem, the disk was damaged. Since the delivery time on a new rotor from the manufacturer was eight weeks, an attempt to repair the disk was made in-house by the PSCo machine shop. The repairs were not completed by the time the long-term test ended on March 14, 1995. Due to these equipment problems, 70 percent SO_2 removal testing was not possible for the entire two month planned period.

Figures 6-1 through 6-5 show the hourly averages of SO_2 removal and NO_2 emissions as a function of time for the months of November, 1994 through March, 1995, respectively. Throughout the four-month test, the rolling average SO_2 removal was easily maintained at, or above, 40 percent. However, the hourly average SO_2 removal data show that there were brief periods when the sodium injection system was off-line due to minor problems of line plugging or system maintenance requirements. Normally, when these occur, the backup pulverizer and injection system would be brought on-line. Unfortunately, as noted above, during much of this test period one of the two systems was down for either maintenance or repairs, and thus no back-up system was available.

In Figures 6-1 through 6-5, the timing of the fabric filter cleaning cycles is shown by the "FFDC clean time", which indicates the number of hours which have passed since the last cleaning cycle. As was seen previously during the short term tests (Figure 5-9), the NO_2 emissions during the long term test increased sharply after each cleaning cycle, and then slowly decreased until the next cleaning cycle. Although the NO_2 emissions are generally low (usually less than 10 ppm), it is difficult to visually assess an "average" level due to the large spikes after each cleaning cycle.

Figure 6-6 shows the daily average SO_2 removals and NO_2 emissions as a function of time for the entire duration of the four-month test. These results show that on a daily basis, the NO_2 emissions were usually below 10 ppm (the average for the duration of the test was 6.7 ppm). However, there were three periods of time when the levels approached or exceeded 20 ppm. All three of these cases correspond to times when the sodium sesquicarbonate feed rate was higher than normal. Figures 6-1 and 6-2 show that the first two cases (late November and late December) correspond to periods when the inlet SO_2 levels were higher than usual. The main fuel source for the Arapahoe Station is a Cyprus Yampa

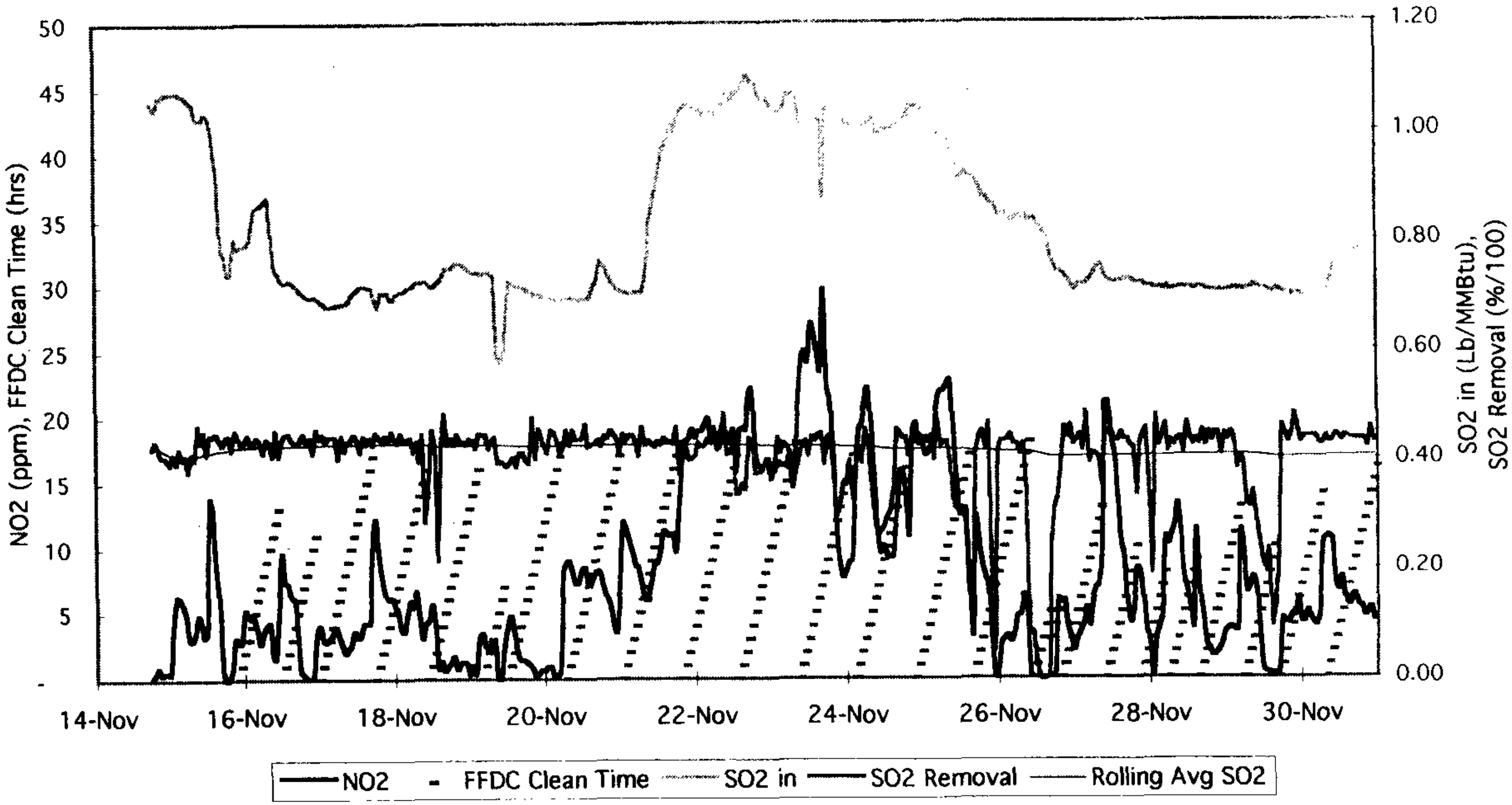


Figure 6-1. Long-Term Test with Sodium Sesquicarbonate Injection at 40% SO_2 Removal Hourly Averages for November, 1994

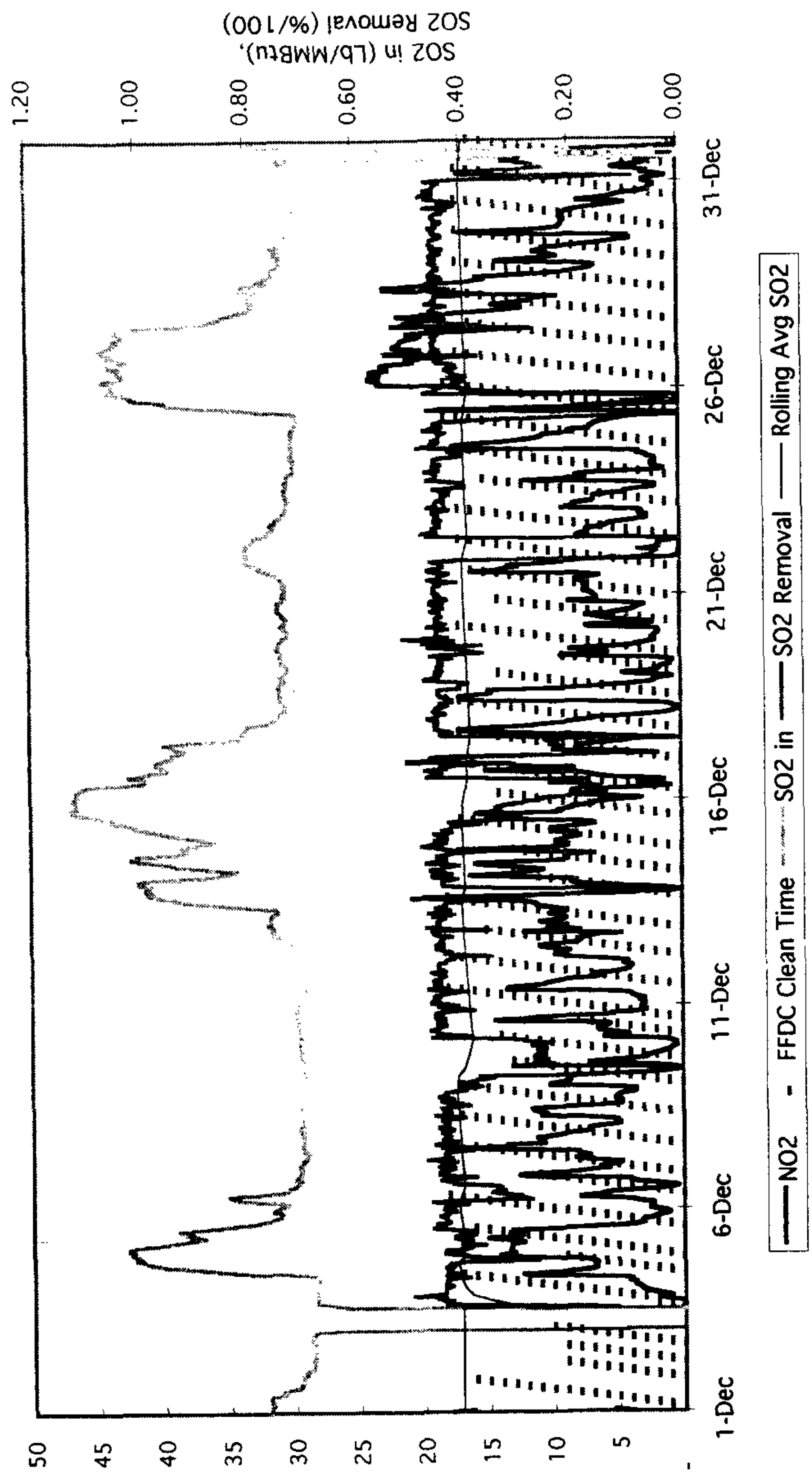


Figure 6-2. Long-Term Test with Sodium Sesquicarbonate Injection at 40% SO_2 Removal Hourly Averages for December, 1994

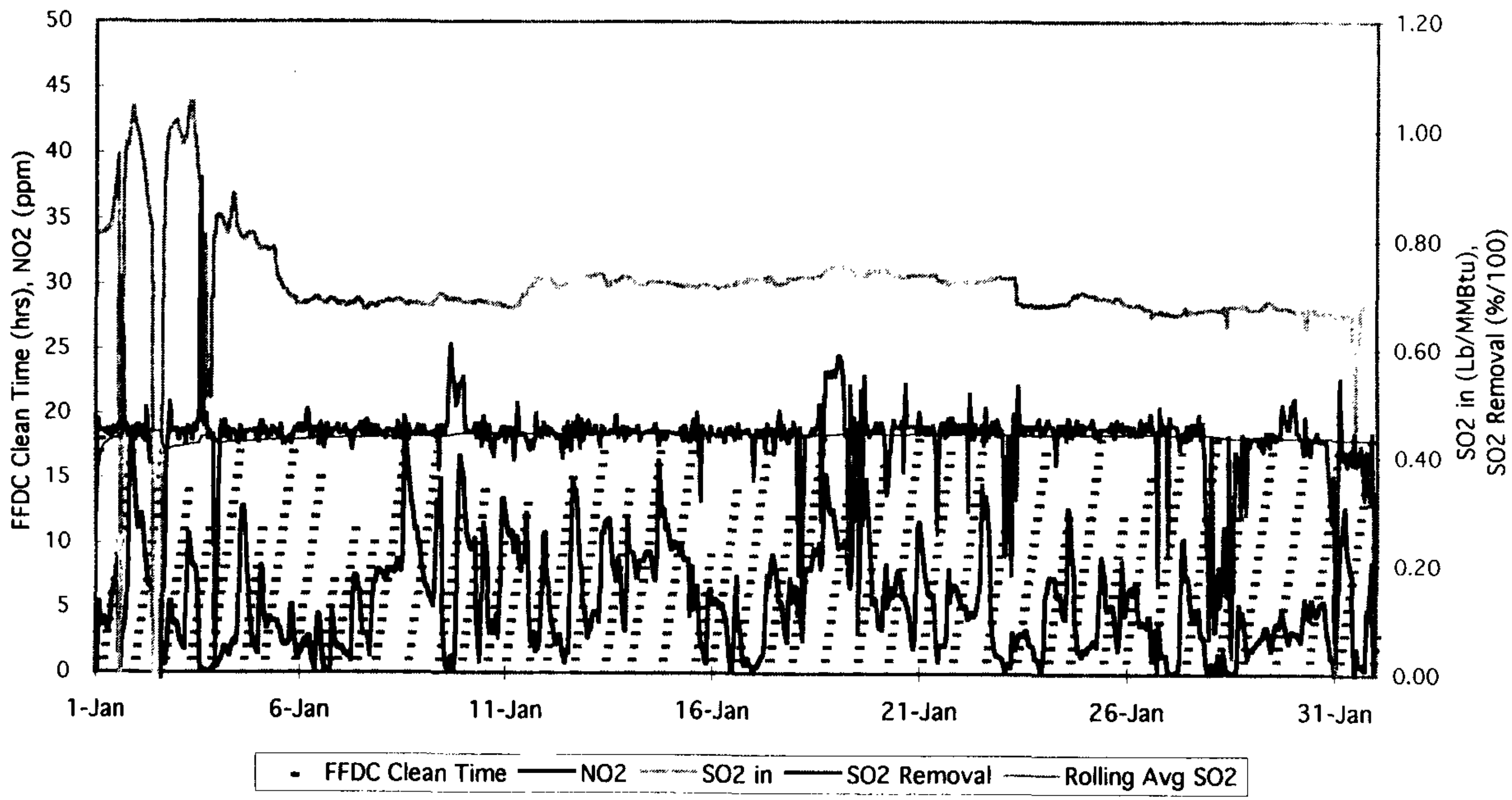


Figure 6-3. Long-Term Test with Sodium Sesquicarbonate Injection at 40% SO_2 Removal Hourly Averages for January, 1995

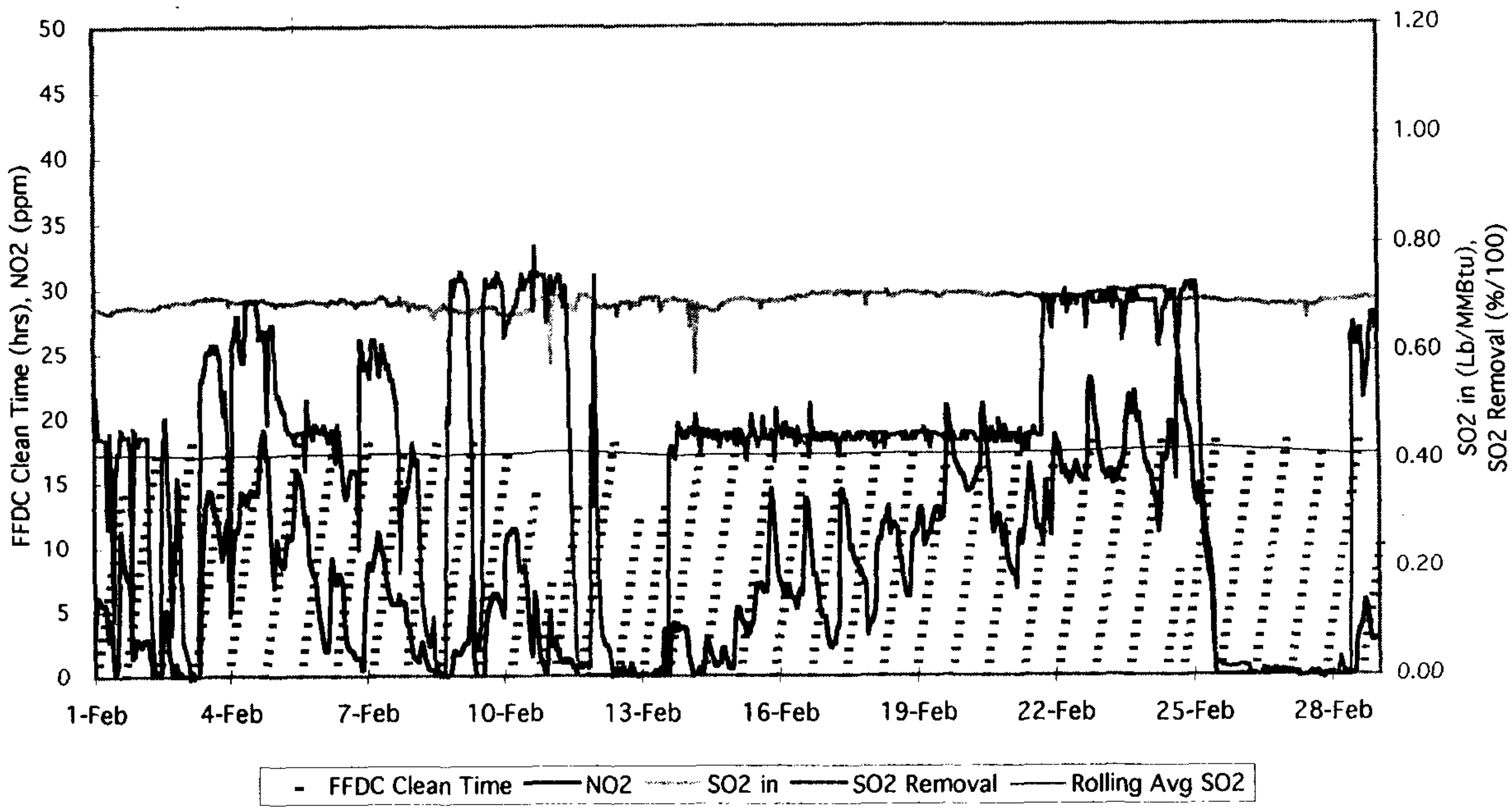


Figure 6-4. Long-Term Test with Sodium Sesquicarbonate Injection at 40% SO_2 Removal Hourly Averages for February, 1995

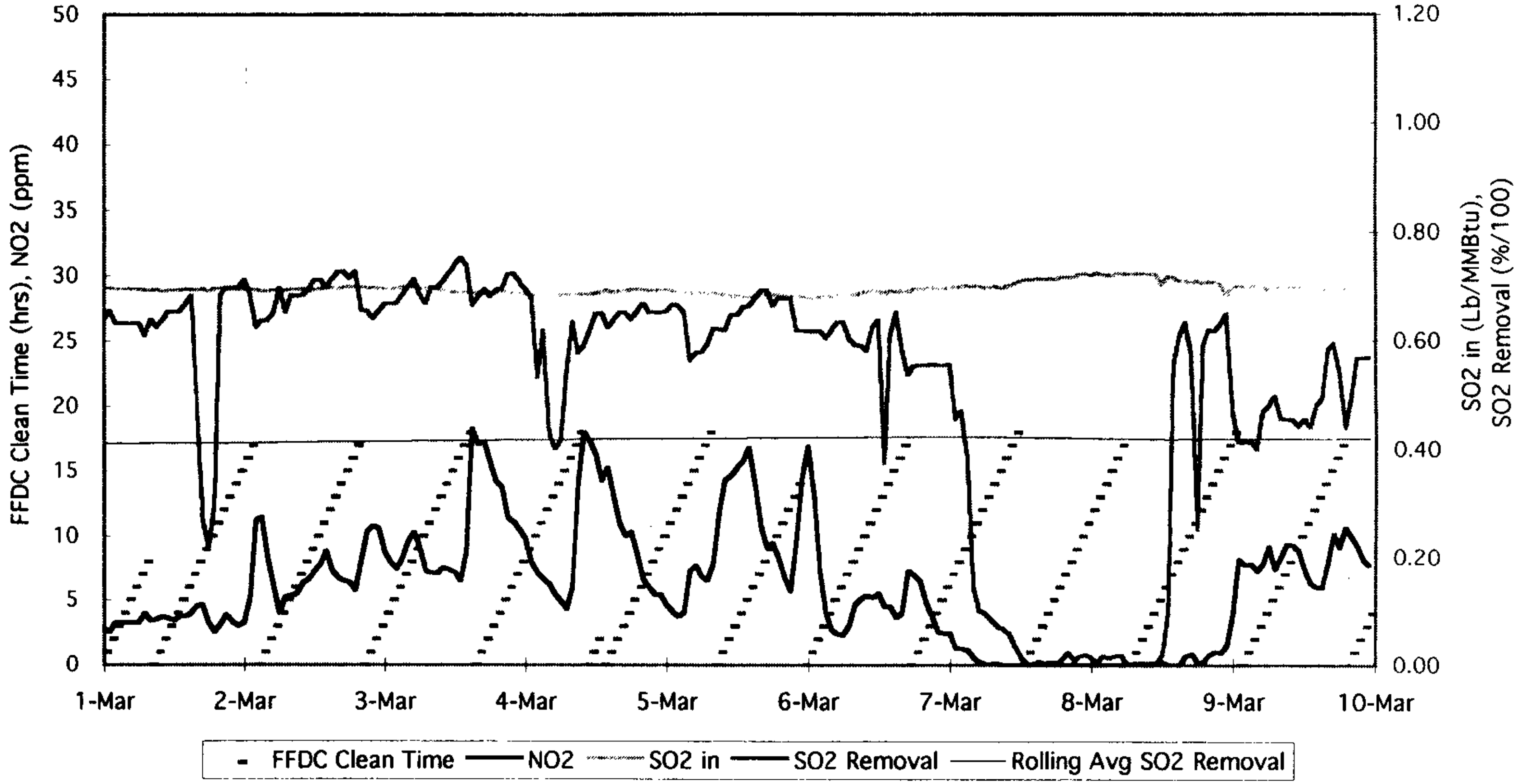


Figure 6-5. Long-Term Test with Sodium Sesquicarbonate Injection at 40% SO_2 Removal
Hourly Averages for March, 1995

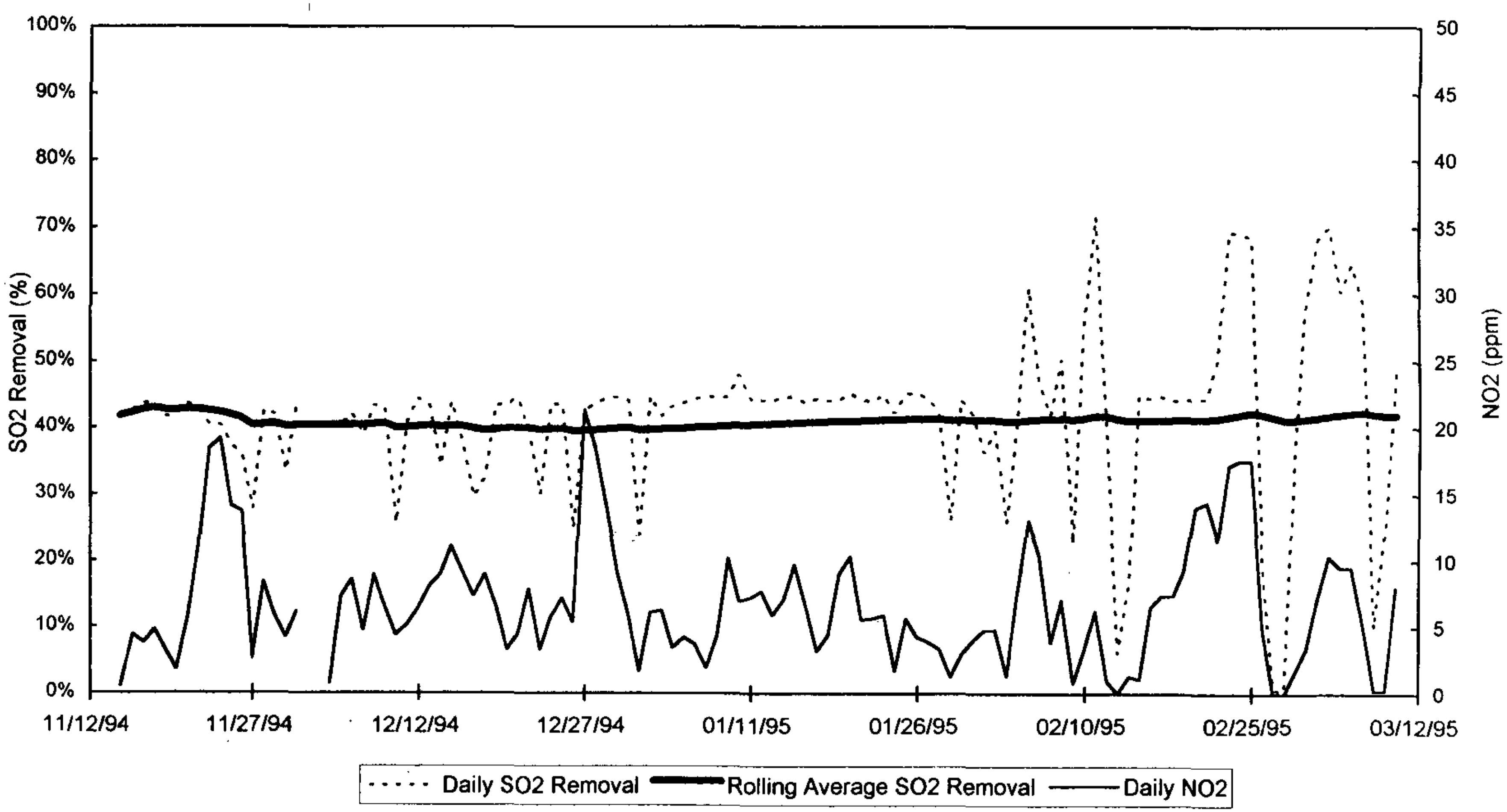


Figure 6-6. Daily Averages for Long-Term Test with Sodium Sesquicarbonate Injection at 40% SO_2 Removal

Valley coal. On occasion, coal from a different source (Edna mine) is utilized. The two coals are very similar, with the major difference being the sulfur content. When burning the Yampa coal, the baseline SO_2 emissions are usually in the range of 0.7 lb/MMBtu. With the Edna coal, the baseline levels can reach 1.1 lb/MMBtu as seen in Figures 6-1 to 6-3. These higher SO_2 levels require higher reagent feed rates to maintain the 40 percent removal setpoint, and thus the NO_2 levels into the fabric filter are also higher. These increased levels are seen at the stack immediately after each cleaning cycle when the bags are relatively clean and there is little fly ash (i.e., carbon) available to interact with the NO_2.

The third time when the daily average NO_2 emissions approached 20 ppm was near the end of the four-month test. This occurrence was in late February, 1995, during one of the aborted attempts to run the system at 70 percent SO_2 removal (Figure 6-4). The higher NO_2 emissions are again attributed to an increased reagent feed rate. There were three other occasions during the test when attempts were made to operate the system at 70 percent SO_2 removal for a short period of time (two in February and one in March, 1995). Figures 6-4 and 6-5 show that the NO_2 emissions tended to increase during these times as well. However, problems with maintaining a consistent reagent feed rate during these attempts precluded generating NO_2 emissions which approached or exceeded 20 ppm.

The repairs to the "A" pulverizer were completed on June 26, 1995. On June 30, 1995, a second long-term test was started with the goal of maintaining an average SO_2 removal of 70 percent. This test ended on July 29, 1995, when Arapahoe Unit 4 was taken off-line for a scheduled 10-week outage. Figure 6-7 shows the hourly averages of SO_2 removal and NO_2 emissions as a function of time for the duration of the four-week test. At the end of the test, the rolling average SO_2 removal was 67.9 percent, just short of the goal of 70 percent. A number of mechanical problems resulted in a system availability of only 94 percent for the four weeks. Bearing failures in both the "A" and "B" screw feeders

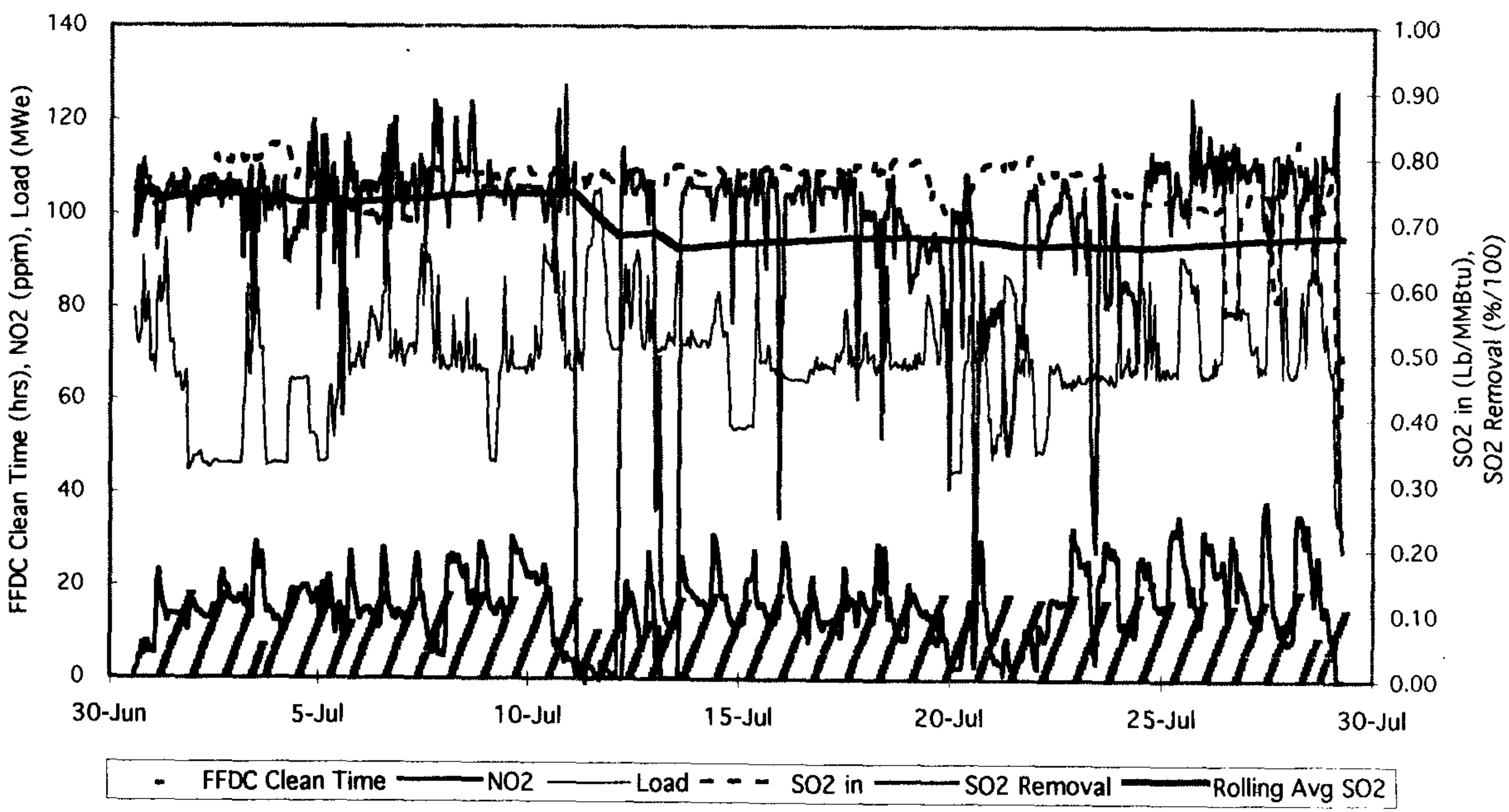


Figure 6-7. Hourly Averages for Long-Term Test with Sodium Sesquicarbonate Injection at 70% SO_2 Removal

occurred, and there were continued problems with maintaining consistent reagent feed rates. The "A" silo was not emptied after the pulverizer disk was damaged during the 40 percent SO_2 removal test. Four months of no material movement resulted in compaction of the reagent in the silo, and the material became very difficult to feed during the subsequent 70 percent SO_2 removal test. It was decided not to add any additional reagent to the "A" silo until it was empty to ensure that all of the compacted material was removed. The silo emptied on July 11, 1995, and the screw feeder bearing on the "B" system failed three hours later. Thirty-two of the total 33 hours of downtime during the four-week test were related to the bearing failure and the lack of reagent in the operating silo.

It is believed that all of the screw feeder bearing failures experienced during both the 40 and 70 percent removal tests were related to excessive air leakage through the rotary airlocks. The leakage from the transport line below the airlock pressurizes the screw feeder and forces reagent into the bearing lubrication material. Lack of proper lubrication then causes failure of the bearing. The possibility of replacing the airlocks before completion of the testing of the integrated system is currently under investigation.

During the long-term test at 40 percent SO_2 removal, NO_2 emissions averaged 6.7 ppm and there were no occurrences of a brown plume at the stack. The average NO_2 emissions during the 70 percent test increased to 15.2 ppm, and a faint NO_2 plume was visible on some occasions. The plume and NO_2 emissions were more prevalent during long periods of low load operation. This again may be related to an ash carbon effect with lower carbon levels at low loads.

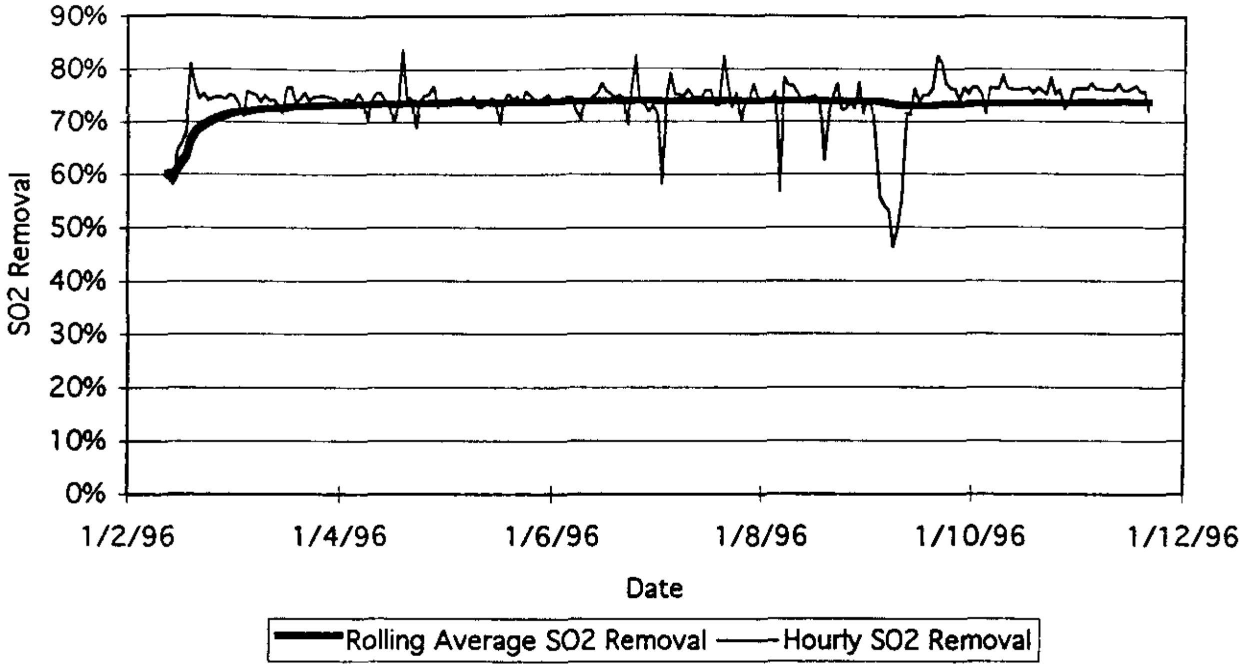
After the 10-week outage, further modifications were made to both DSI injection systems. These modifications primarily involved insulating the pipes which transported the material from the sorbent preparation area to the splitter valves at the FFDC injection location. Depending on the sorbent loading, the pulverizers can impart a significant amount of heat to the transport air stream (pulverizer exit temperatures can reach nearly 200°F without any sorbent flow). It was believed that some of the plugging problems experienced during the previous long-term tests were due to condensation forming in the transport lines as the carrier air/sorbent mixture cooled on the way to the injection location.

A third long-term test was begun on January 2, 1996, with the goal of maintaining a rolling-average SO_2 removal in excess of 70 percent until the long-term testing of the integrated system (simultaneous DSI and SNCR) was to begin in mid February. The SO_2 removal setpoint was actually set at 75 percent during this time. The long-term DSI-only test had been running for only 10 days when the new fly ash removal system plugged, and both DSI systems had to be shut down. The rolling-average SO_2 removal at the end of the 10-day period was 74 percent. The problem with the fly ash removal system was attributed to some residual effects of a Powder River Basin coal test burn run two months before. It was not believed that the plugging was a direct result of the sodium-injection test, although the increased solids loading may have accelerated the rate of plugging.

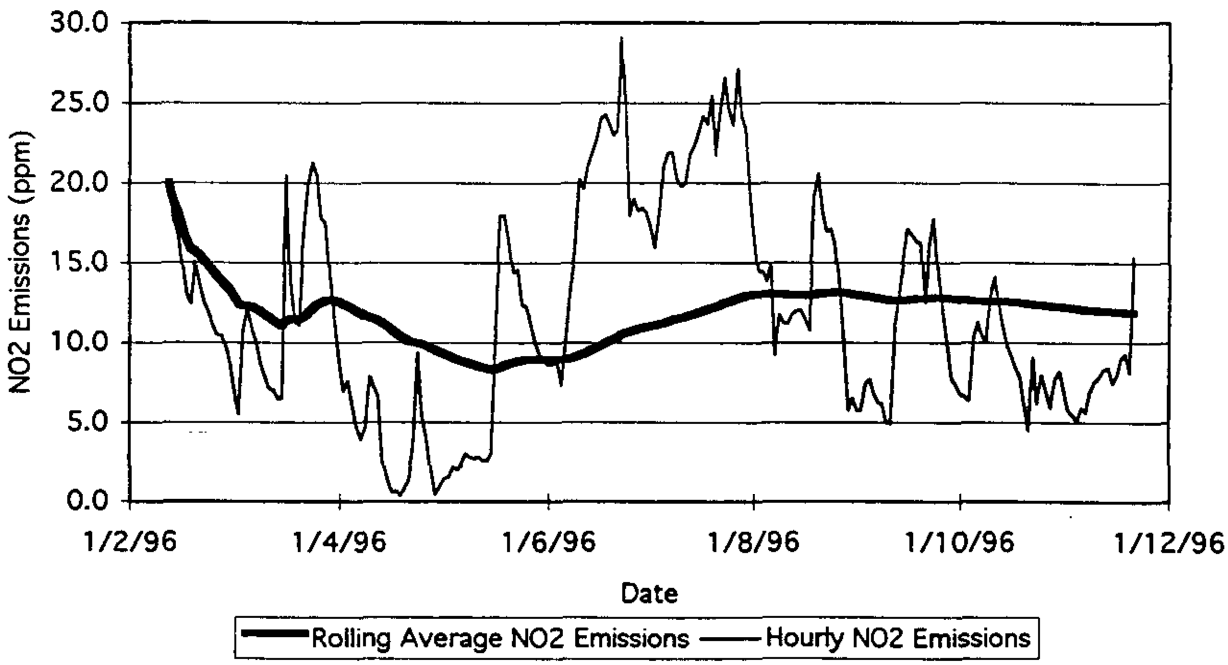
The fly ash removal system was brought back on-line on January 19, and both DSI systems were re-started. At this time, a problem with the "B" DSI system developed where the screw feeder would trip off-line randomly, for no apparent reason. This problem was resolved on January 28, with the installation of a new variable-speed drive controller. At higher boiler loads, both DSI systems are necessary to achieve 70 percent SO_2 removal. Since the "B" system was often off-line during the period of January 19 to 28, the rolling-average SO_2 removal fell well below 70 percent.

The long-term DSI-only test continued until February 12, when the new Unit 4 fly ash removal system again failed. At this time, the fluidizing stones at the base of the ash storage silo (which keep the ash in a fluidized state during the unloading process) had become so plugged with ash, that air could no longer pass through them, and the silo could not be emptied. Both DSI systems were taken off-line at this point in time, and the long-term test ended. During the period from January 28 to February 12, the combination of increasing air leakage rates through the rotary airlocks and minor plugging problems resulted in a rolling-average SO_2 removal of less than 70 percent.

Figures 6-8a and b show the hourly averages of SO_2 removal and NO_2 emissions, respectively, for the first 10 days of the long-term test begun on January 2, 1996. As *mentioned previously, the rolling-average SO_2 removal for this time period was 74 percent.* Figure 6-8b shows that, while the NO_2 emissions varied over the range of approximately 0 to 30 ppm, the rolling-average for the 10-day period was 11.9 ppm. This level is lower than that seen during the month-long 70 percent SO_2 removal test shown in Figure 6-7 (June 30 to July 29, 1995). Although the difference is believed to be due to the shorter duration of the test performed in January, 1996, there is no conclusive evidence to support this hypothesis. Another attempt to maintain a rolling-average SO_2 removal in excess of 70 percent with DSI alone (for a period of approximately four weeks) will be made after the conclusion of the integrated tests in late 1996. The results of this test will provide a better indication of the average long-term NO_2 emissions.



a) SO_2 Removal



b) NO_2 Emissions

Figure 6-8. Hourly Averages for Long-Term Test with Sodium Sesquicarbonate Injection at 75% SO_2 Removal (January 2-11, 1996)

7.0 DISCUSSIONS AND CONCLUSIONS

During this test phase, sodium sesquicarbonate and sodium bicarbonate were evaluated in terms of SO_2 removal, NO_2 production and NO_x removal. Of particular concern was the production of NO_2 and the possibility of plume coloration. In general, the results were consistent with those reported from previous full-scale dry sodium injection demonstrations (Fuchs, et al., 1989; Muzio, et al., 1984).

One of the more interesting observations from the current test program was the process dynamics of NO_2 formation with sodium injection. Time resolved measurements showed that NO_2 emissions were not only dependent on the amount of sodium injected, but also on the fabric filter cleaning cycle. With both sodium sesquicarbonate and sodium bicarbonate, NO_2 emissions were found to increase markedly just after a cleaning cycle. This suggests that there is an interaction between the NO_2 and the fly ash on the bags; and more specifically, the fly ash carbon. This was further confirmed by compartment-by-compartment measurements which showed that the NO_2 levels were not just a function of the SO_2 removal in each compartment, but also appear to be related to the amount of fly ash collected in each compartment. This phenomena accounts for the high degree of variability in NO_2 emissions and NO_x removals reported not only in this test program, but in the previous demonstrations.

Specific conclusions from the dry sodium injection tests are listed below.

1. Both sodium sesquicarbonate and sodium bicarbonate were able to achieve 70% SO_2 removal. Sodium bicarbonate exhibits a higher utilization of sodium than sodium sesquicarbonate. As such, sodium bicarbonate can achieve 70% SO_2 removal at a lower molar ratio of sodium to SO_2 than sodium sesquicarbonate. The primary factor controlling SO_2 removal was the sorbent injection rate, or normalized stoichiometric ratio (2Na/S). Seventy percent SO_2 removal was achieved at the following 2Na/S ratios for the two sorbents:

   Sodium Sesquicarbonate : 2Na/S = 1.9

   Sodium Bicarbonate : 2Na/S = 0.9

2. Boiler load had no effect on SO_2 removal, or sodium utilization over the load range investigated (60 to 100 MWe).

3. Flue gas temperature had some effect on the SO_2 removal process and was different for the two reagents. There was no effect on SO_2 removal, or utilization, over the investigated temperature range of 220°F to 280°F for sodium sesquicarbonate injection ahead of the FFDC. When sodium sesquicarbonate was injected ahead of the air heater at approximately 650°F, the SO_2 reaction rate was slower than injection at the FFDC inlet. This resulted in the same steady-state level of SO_2 removal but a slightly lower time-averaged SO_2 removal. Sodium bicarbonate injection at the FFDC provided a very slow SO_2 reaction and was not effective at the flue gas temperatures available at Arapahoe. Injection ahead of the air heater, at approximately 650°F, increased the reaction rate and allowed good process control and reactivity. Minor temperature changes at both locations did not significantly affect the process.

4. Particle size affected the SO_2 removal and utilization of both products. No significant change to SO_2 removal, or utilization, was noted when sodium sesquicarbonate was pulverized within the range of 15 to 20 microns MMD. Injection of non-pulverized sodium sesquicarbonate, with a 28 micron MMD, reduced SO_2 removal, at an equivalent reagent feed rate, by a significant 10 to 15%.

   No significant change to SO_2 removal, or utilization, was noted when sodium bicarbonate was pulverized to a range of 18 to 25 microns MMD and injected to yield SO_2 removals of 70% or less. At higher feed rates which provided up to 90% SO_2 removal, reagent in the size range of 25 microns degraded SO_2 removal by a net 10%. SO_2 removal and utilization were not affected by the feed rate through the mill with either reagent, when the mill was operated at a set speed.

5. Minor changes in the distribution of the reagent at the injection location, due to injector plugging, or modifications to the injection system, did not affect the overall SO_2 removal or utilization for either reagent. However, changes in distribution did change the distribution of SO_2 removal within the FFDC.

6. Humidification of the flue gas to a 60°F approach to saturation temperature increased SO_2 removal by up to 20% when injecting sodium sesquicarbonate (at the same 2Na/S ratios).

7. Both sodium sesquicarbonate and sodium bicarbonate also produce some NO_x reduction. At a 70% SO_2 removal approximately 10% NO_x reduction is obtained with both reagents. The NO_x reduction varies due to unexplainable conditions and cannot be controlled. However, over time, an average NO_x removal of 10% could be consistently achieved with both reagents at Arapahoe Unit 4 when obtaining 70% SO_2 removal.

8. Both sodium reagents oxidize NO to NO_2. While the total NO_x emissions are reduced, the NO_2 emission will increase. There is significant variation in NO_2 emissions, but the reagent feed rate, FFDC cleaning cycle, and the ash composition

are all important variables affecting NO_2. NO_2 is a visible gas and thus can create a visible plume. At Arapahoe Unit 4, a net NO_2 emission of approximately 35 ppm will create a visible stack plume.

9. Sodium sesquicarbonate creates less NO_2 than sodium bicarbonate at the same SO_2 removal level. NO_2 emissions increased up to 30 ppm with sodium sesquicarbonate and up to 50 ppm with sodium bicarbonate injection.

10. A four week test of sodium sesquicarbonate easily met the 40 percent SO_2 removal goal with an average NO_2 emission of 7 ppm. There were no occurrences of a visible brown plume.

11. A four week test of sodium sesquicarbonate fell just short of the 70% removal goal, with an average SO_2 removal of 68%. NO_2 emissions during this test averaged 15 ppm and a faint brown plume was visible on some occasions. The goal was not achieved due to equipment problems that prevented any sodium injection for a 32-hour period during the test.

8.0 REFERENCES

Fuchs, M.R., et al., *Full-Scale Demonstration of a Utility Dry Sodium Injection FGD Facility*, EPRI Final Report, Project RP-16826, December 1989.

Keener, T., et al., *Thermal Decomposition of Sodium Bicarbonate*, Chem. Eng. Commun., Vol. 33, pp. 93-105, 1985.

Lai, Y., et al., *Simultaneous Removal of SO_2 and NO_x By Selected Sodium-Based Dry Sorbents,* Final Technical Report to Public Service Co., Colorado School of Mines, 1994.

Lindau, L., *NO_2 Effect on Flue Gas Opacity*, J. Air Waste Management Assoc., Vol. 41, No. 8, August 1991.

Muzio, L.J., et al., *Dry SO_2 Particulate Removal for Coal-Fired Boilers,* Volume 2: 22-MW Demonstration Using Nacholite, Trona, and Soda Ash, EPRI Report CS-2894, June 1984.

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.

Shiomoto, G.H., et al., *Integrated Dry NO_x/SO_2 Emissions Control System: Calcium-Based Dry Sorbent Injection Test Report*, DOE Contract Number DE-FCC22-91PC90550, December 1994.

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.

Smith, R.A., et al., *Calcium Injection Upstream of an Electrostatic Precipitator and a Fabric Filter for Simultaneous SO_2 and Particulate Removal: Pilot- and Bench-Scale Results*, EPRI Report EPRI TR-100260, January 1992.

Verlaetent, J., et al., *Combined SO_2/NO_x Abatement by Sodium Bicarbonate Dry Injection,* 10 50 Brussels, Belgium, 1993.

APPENDICES

APPENDIX A

Synopsis of the
Colorado School of Mines
Bench-Scale Study of Sodium/SO_2/NO_x Chemistry Entitled:

"SIMULTANEOUS REMOVAL OF SO_2 AND NO_x BY SELECTED SODIUM-BASED DRY SORBENTS"

by
Y. Lai

and
V. F. Yesavage

A. FUNDAMENTAL STUDY OF SODIUM/SO_2/NO_X CHEMISTRY

A.1 Background

A fundamental study of sodium/SO_2/NO_x chemistry was conducted by Colorado School of Mines to support the full-scale integrated NO_x and SO_2 removal work at Arapahoe Unit 4 (Lai, et al., 1994). The goal of the study was to gain a better understanding of the detailed chemistry in terms of SO_2 and NO_x removal, as well as NO_2 formation. The study involved both bench-scale experiments and chemical kinetic modeling. Since little work was previously published on the fundamental chemistry associated with NO_x removal and NO_2 production with sodium compounds, the study emphasized this aspect of the chemistry.

Before discussing the specific experiments that were conducted, it is of value to briefly review the potential detailed mechanisms associated with NO_2 formation and NO_x removal. Two different mechanisms have been proposed for the production of NO_2 during the sodium/SO_2 reactions. One was developed by work supported by EPRI (EPRI, 1990) and the other is work done by Solvay (Verlaeten, et al., 1993). The mechanisms shown below are for sodium bicarbonate, although parallel mechanisms could be written for sodium sesquicarbonate.

A.2 EPRI Mechanism

Sodium Bicarbonate Decomposition

$$2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O \tag{1}$$

SO_2 Removal

$$Na_2CO_3 + SO_2 + 1/2\,O_2 \rightarrow Na_2SO_4 + CO_2 \tag{2}$$

NO Removal and NO_2 Formation

$$NO + 1/2\,O_2 \xrightarrow{Na/SO_2} NO_2 \tag{3}$$

$$Na_2CO_3 + 3NO_2 \rightarrow 2NaNO_3 + NO + CO_2 \tag{4}$$

The EPRI mechanism proposes sodium carbonate (Na_2CO_3) as the primary reactant leading to SO_2 removal. NO_2 is proposed to form via reaction (3) along with some undetermined intermediate steps. NO_x removal then occurs by a reaction between sodium carbonate and NO_2 forming sodium nitrate, reaction (4).

A.3 Solvay Mechanism

The Solvay mechanism incorporates a direct reaction between the undecomposed sodium materials and SO_2.

<u>SO_2 Removal</u>

$$NaHCO_3 + SO_2 \rightarrow NaHSO_3 + CO_2 \tag{5}$$

$$2NaHSO_3 \rightarrow Na_2S_2O_5 + H_2O \tag{6}$$

With the sodium sulfite ($NaHSO_3$) and sodium pyrosulfite ($Na_2S_2O_5$) intermediates, Solvay has an alternate interpretation of the NO_x removal mechanism which involves the intermediate sodium pyrosulfite compound.

<u>NO Removal</u>

$$Na_2S_2O_5 + 2NO + O_2 \rightarrow NaNO_2 + NaNO_3 + 2SO_2 \tag{7}$$

$$2NaHSO_3 + 2NO + O_2 \rightarrow NaNO_2 + NaNO_3 + 2SO_2 + 2H_2O \tag{8}$$

In the Solvay mechanism the NO_2 would be formed by decomposition of one of the products from reactions (7) and/or (8).

Both of the above mechanisms were investigated through a series of chemical kinetic models.

A.4 Experimental Approach

The experiments were conducted in a bench-scale batch-fed reactor. The apparatus consists of SO_2 and NO feed systems, a neutralization bottle containing 1M NaOH solution designed for trapping SO_2 and NO_x acid gases, a system for feeding background gas containing 3% oxygen and 97% nitrogen, a batch reactor with a heating control unit, and a gas analysis system.

A schematic of the bench-scale system is shown in Figure A-1. The basic components are a 12864 ml batch reactor which contains the reaction mixtures, the dry sorbent, a heating control unit which keeps the reaction temperature constant between 100 to 300°C, and a propeller-type mixer designed to eliminate temperature and mass transfer gradients surrounding the dry sorbent particles.

The batch reactor is made of stainless steel with four fittings on the top cover. The first fitting, V2, is a control valve with a 1/2" opening utilized for either gas or sorbent powder injection. The second fitting, V3, is a control valve with a 1/4" opening used for draining the unreacted acid gases to a neutralization bottle containing a 1M NaOH solution. The third fitting, P1, is a sampling port with a 1/2" opening which is a swagelock fitting equipped with a 9 millimeter diameter septum. The fourth fitting, P2, is an injection port with a 1/2" opening and septum, which is identical to the sampling port (P1). Both, sampling and injection ports, are used for withdrawing the reacting gas mixtures and for injecting acid gases, SO_2 and NO.

A Haake Buchler stirring motor, M1, is used to drive a propeller type mixing device with a variable speed ranging from 0 to 700 rpm. A teflon-type Conax sealant is used to seal the rotating rod at ambient pressure in the reactor.

The major components in the heating control unit are a 1800 Watt Watlow mica band heater, and an Omega Series 920 temperature controller.

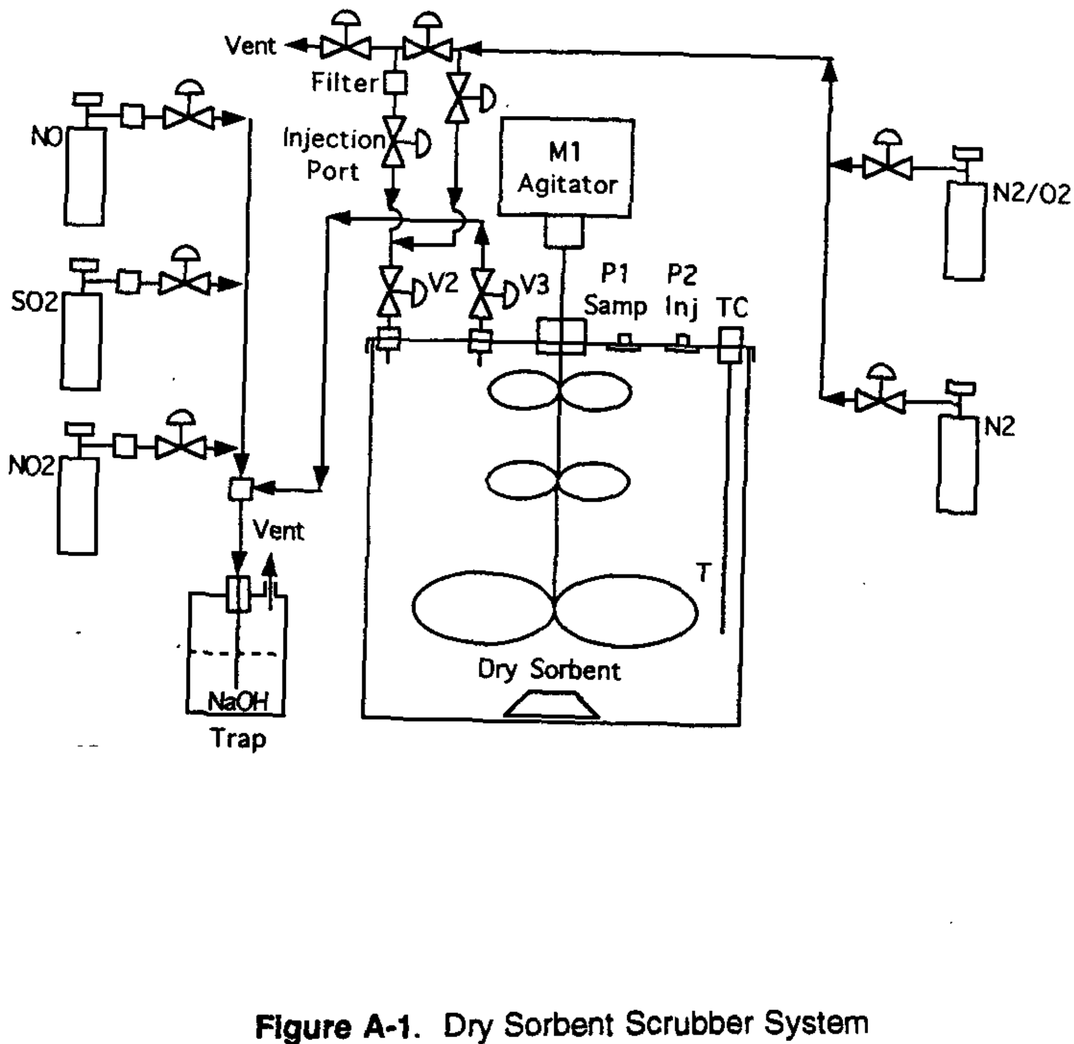


Figure A-1. Dry Sorbent Scrubber System
Bench-Scale Apparatus

Analytical techniques include the analysis of syringe samples for SO_2, NO_x and NO. SO_2 was measured using a Hewlett Packard model 5890 gas chromatograph equipped with a thermal conductivity detector, and a 8' x 1/4" Supelco Porapak Q glass column with particle size 80/100 at a temperature of 70°C. During the course of the study, it was shown that this gas chromatographic procedure lead to errors in the SO_2 concentration due to the presence of NO_x in the reaction mixture. This effect was thought to be due to a reaction sequence that forms N_2O (Muzio, et al., 1988). To eliminate the effect, it was necessary to perform the SO_2 analysis immediately upon obtaining a sample.

A chemiluminescent NO-NO_x analyzer (TECO model 44), was used to measure concentrations of NO and NO_x; NO_2 was determined by difference. The chemiluminescent instrument is normally used in a continuous sampling mode. For this study, a technique was developed to use the chemiluminescent analyzer to analyze batch syringe samples from the reactor tests (Lai, et al., 1994).

A.5 Experimental Results

Two basic types of experiments were conducted during the study. The first group of experiments were conducted to develop overall reaction rate data for SO_2 reactions with sodium bicarbonate and sodium sesquicarbonate. These experiments were conducted with the following range of parameters:

Sodium Sorbents	:	sodium bicarbonate, sodium sesquicarbonate
Particle Size	:	53 μm < d < 63 μm
Stoichiometric Ratio (2Na/S)	:	0, 0.85, 3.4, 13.5
Temperature	:	260°F, 300°F
SO_2	:	1800 ppm
NO	:	1800 ppm
H_2O, O_2	:	5%, 3%, (balance N_2)
Reaction Times	:	0 - 30 minutes

During these tests, time resolved histories of SO_2, NO, and NO_x were measured.

The next group of experiments sought to provide a better understanding of the detailed chemistry between SO_2, NO_x and the sodium compounds. These latter experiments involved varying the water content of the gas; as well as studying the reaction of potential intermediate compounds (i.e., $NaHSO_3$ and $Na_2S_2O_5$) with SO_2 and NO_x.

In this section, the basic experimental results with sodium bicarbonate and sodium sesquicarbonate will be presented. This will be followed by a discussion of the results of the experiments addressing the detailed chemistry.

A.6 Overall Reaction Rates

The SO_2 time histories for both sodium bicarbonate and sodium sesquicarbonate are shown in Figure A-2. As expected, SO_2 removals increase with increasing stoichiometric ratios (2Na/S) for both sorbents. The short time data (i.e., less than 5 minutes) are consistent with the full-scale data in that the sesquicarbonate reacts faster than the bicarbonate. At 2Na/S ratios of 0.85 and 3.4, the overall level of SO_2 removal are similar for both sorbents. This is quite surprising, particularly at the lower value of 0.85. The current full-scale tests at Arapahoe, as well as previous full-scale demonstrations (Fuchs, et al., 1989; Muzio, et al., 1984) show that sodium bicarbonate will yield higher overall SO_2 removal than sodium sesquicarbonate for a given amount of sodium. This may have been the case had the experiments shown in Figure A-2 been extended to longer time periods.

The NO_2 production as a function of reaction time is shown in Figure A-3 for both sodium bicarbonate (2Na/S=0.85, 3.4, 13.5) and sodium sesquicarbonate (2Na/S=0.85, 3.4). For both sorbents, there does not appear to be a strong effect of stoichiometric ratio on the amount of NO_2 produced, as the scatter in the data is as great as any perceptible 2Na/S effect. The NO_2 results do indicate that sodium bicarbonate (solid symbols) tends to produce higher levels of NO_2 than sodium sesquibicarbonate (open symbols) which is consistent with the full-scale test results at Arapahoe. With sodium sesquicarbonate the NO_2 levels were generally 200 ppm (11% of the initial NO levels).

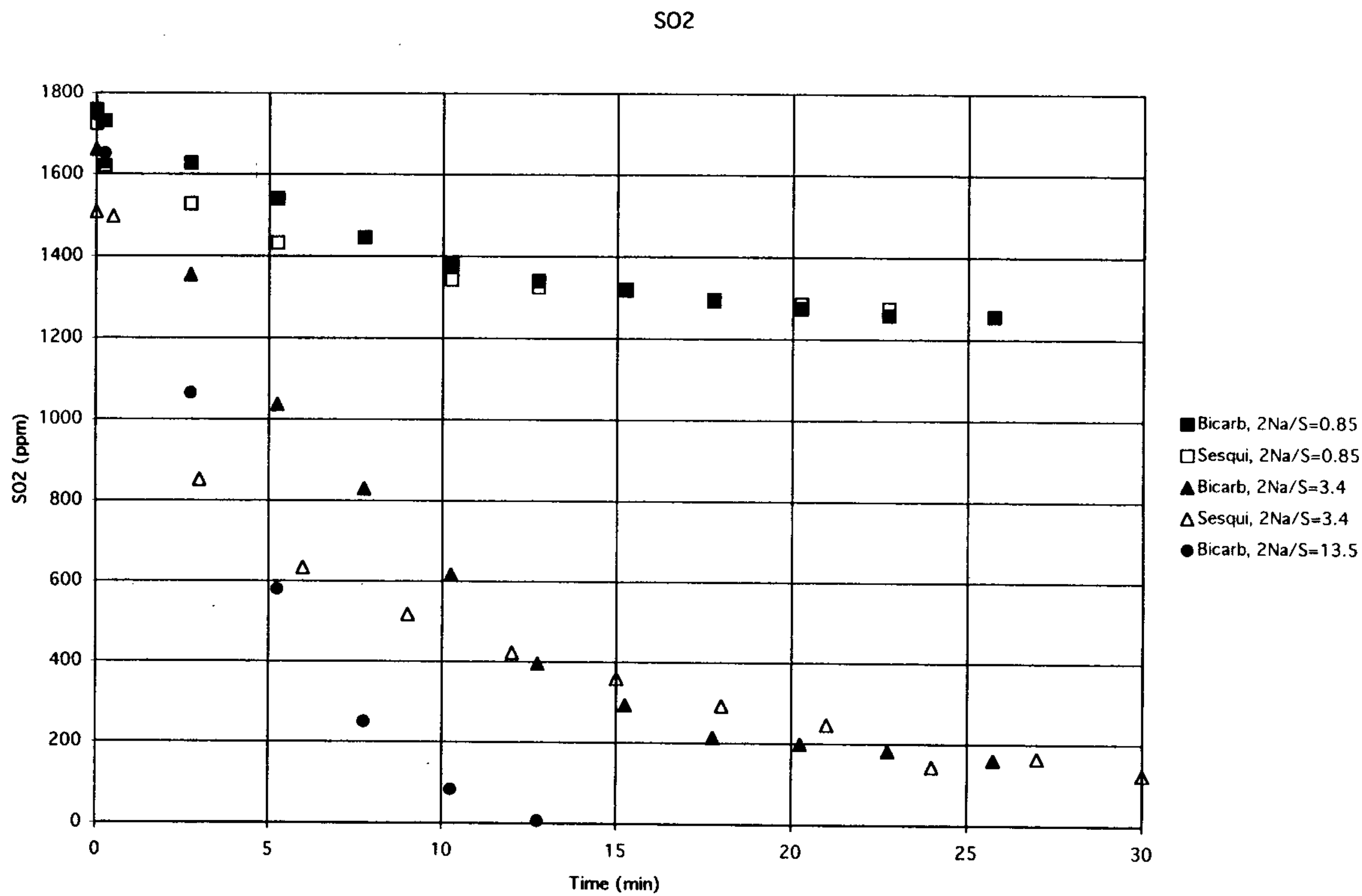


Figure A-2. SO_2 Time Histories in the Bench-Scale Apparatus

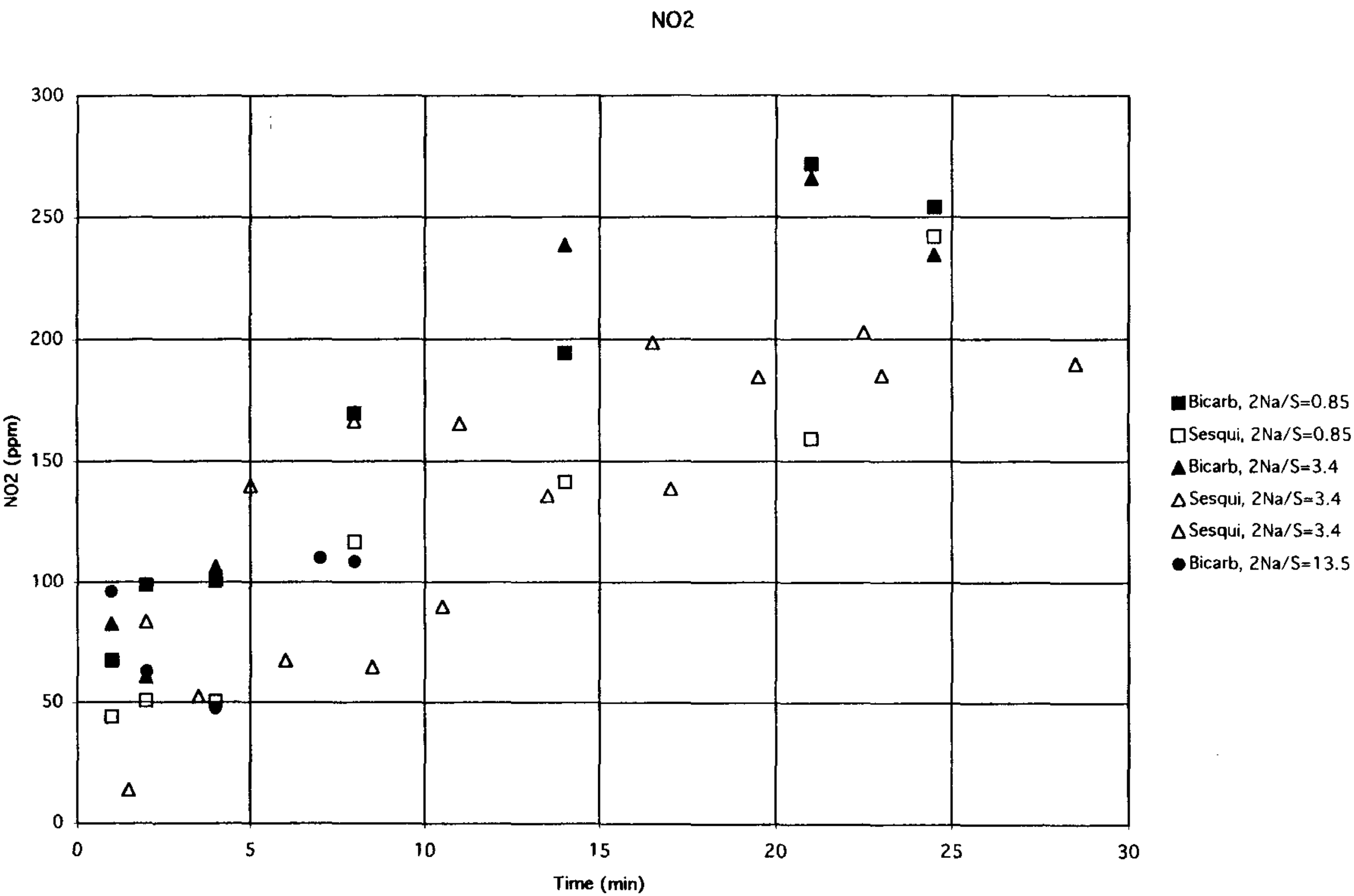


Figure A-3. NO_2 Time Histories in the Bench-Scale Apparatus

The effect of temperature on NO_2 formation with sodium sesquicarbonate is shown in Figure A-4, where the open symbols are tests conducted at 260°F, and the solid symbols are tests results for temperatures of 300°F. While there is quite a large amount of scatter in the data presented in Figure A-4, the results suggest that the level of NO_2 decreased, somewhat, as the temperature was increased from 260°F to 300°F.

The time histories of NO_x removal are shown in Figure A-5 for both sodium bicarbonate and sodium sesquicarbonate. The open symbols are data for sodium bicarbonate and the solid symbols for sodium sesquicarbonate. For both sorbents, the level of NO_x removal increases with increasing stoichiometric ratio. At 2Na/S ratios of 0.85 and 3.4, the ultimate level of NO_x removal was similar for both sorbents. Although consistent with the initially higher reaction rate of sodium sesquicarbonate, the rate of NO_x removal with sodium sesquicarbonate at 2Na/S=3.4 was faster than for sodium bicarbonate. The overall NO_x removal of 10% at 2Na/S=0.85 is also consistent with the NO_x removals achieved at full-scale.

The next group of tests were conducted to determine if the intermediate compounds proposed by Solvay (Verlaetent, et al., 1993); $NaHSO_3$ or $Na_2S_2O_5$ were important intermediates. Figure A-6 shows the results of the reaction between 3000 ppm sodium pyrosulfite ($Na_2S_2O_5$) and a gas mixture of 1500 ppm NO, 3% O_2 and 5% H_2O at a temperature of 260°F. The results show the NO_x removal is about equal to the amount of SO_2 produced; consistent with reaction (7). This would suggest that sodium pyrosulfite may indeed be an intermediate in the removal of NO_x by sodium-based sorbents.

A comparable test was conducted with sodium sulfite ($NaHSO_3$) at a stoichiometric ratio of 2 (i.e., 4 moles of $NaHSO_3$ per mole of NO, per reaction (8)) and a temperature of 260°F. During this test, there was no production of SO_2 and the change in NO_x was minimal. This would suggest that while $NaHSO_3$ may be an intermediate in the chemistry, it is the formation of NaS_2O_5 from the $NaHSO_3$ (i.e., reaction (6)) that is important, and not reaction (8) in terms of NO_x removal or NO_2 production.

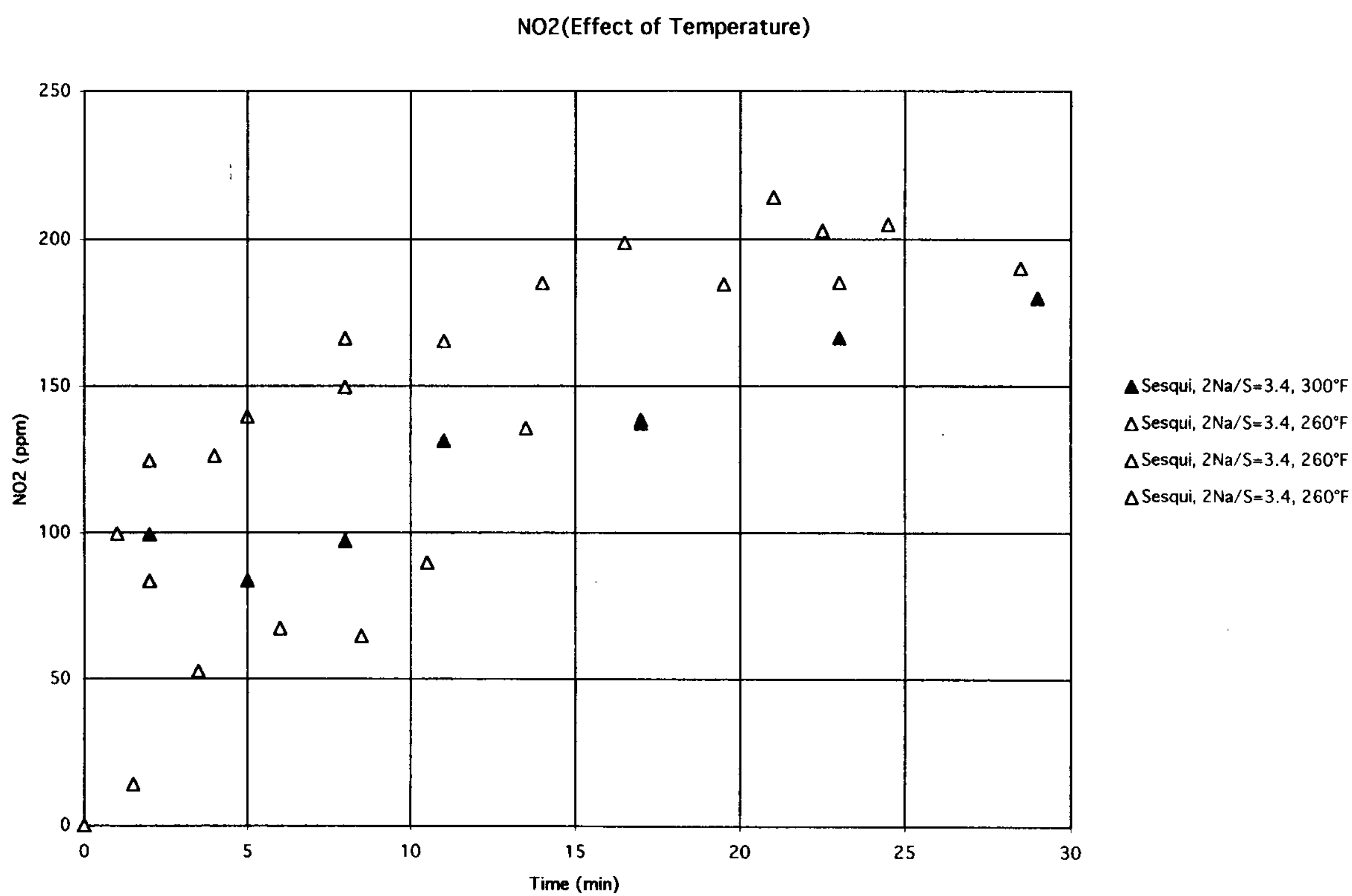


Figure A-4. Effect of Temperature on the NO_2 Time Histories with Sodium Sesquicarbonate in the Bench-Scale Apparatus

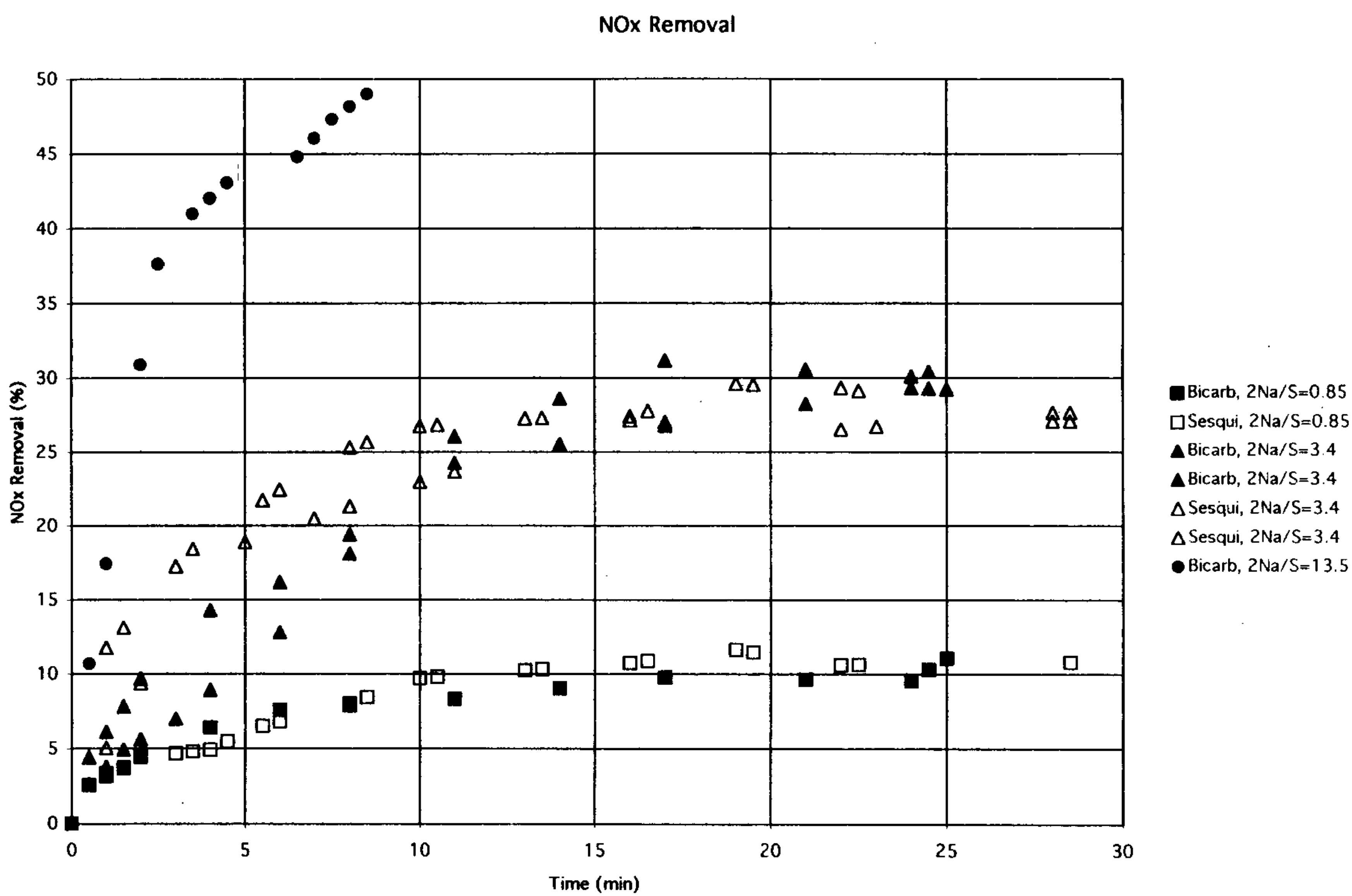


Figure A-5. NO_x Removal in the Bench-Scale Apparatus

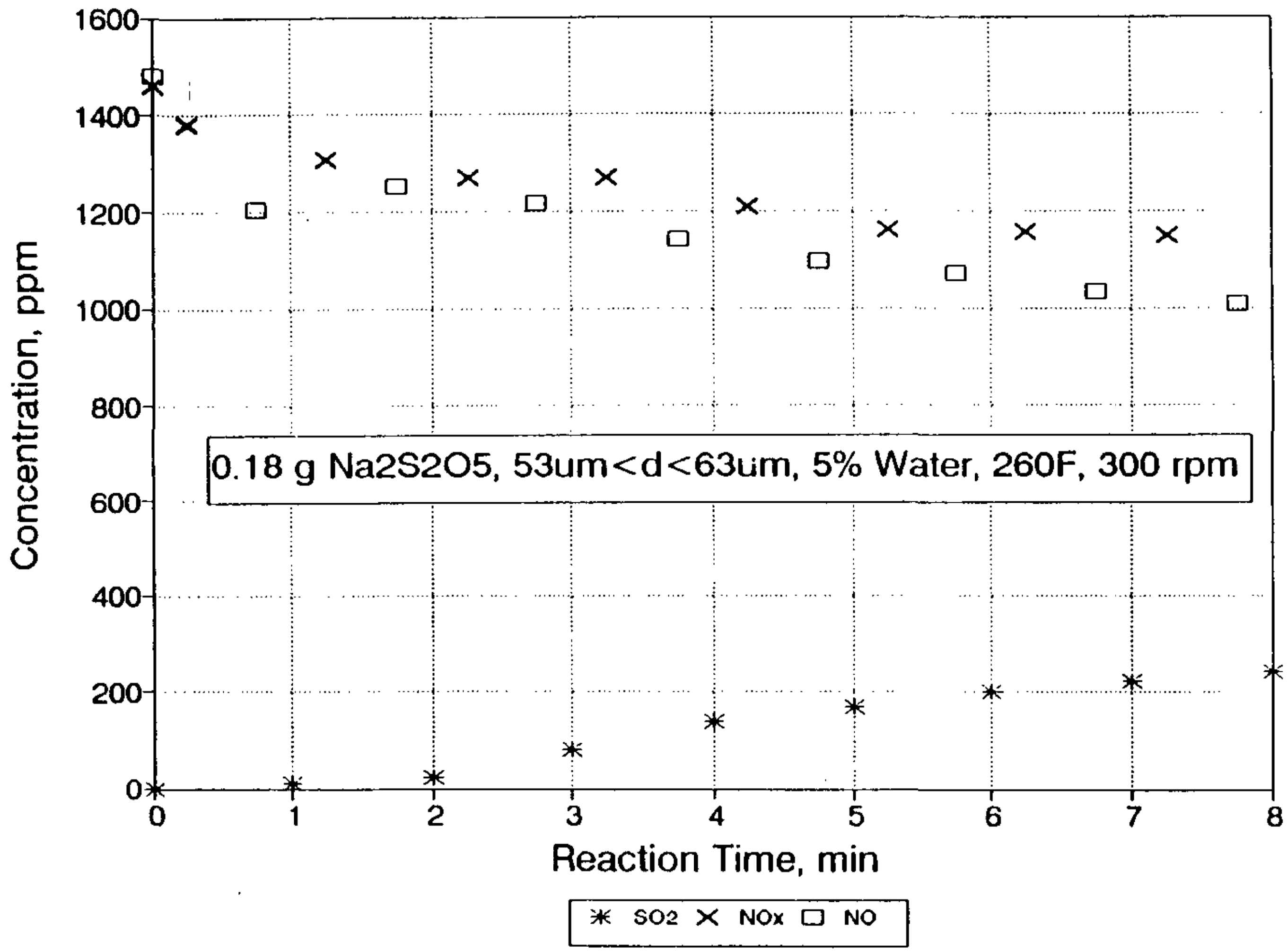


Figure A-6. NO_x Removal by Sodium Pyrosulfite in the Bench-Scale Apparatus

A.7 Chemical Kinetic Modeling

Chemical kinetic modeling was used to evaluate the two detailed mechanisms discussed previously. A shrinking core model was used and the rate constants for the individual reactions were extracted from the bench-scale data. The modeling effort suggested that the sodium/SO_2/NO_x chemistry is better predicted using the Solvay mechanism. This subsection will briefly summarize the detailed mechanism and average rate constants extracted from the data.

The detailed Solvay mechanism was simplified assuming that the intermediate compounds ($Na_2S_2O_5$ and $NaHSO_3$) have short lifetimes. With this assumption, the shrinking core model of the Solvay mechanism reduces to the following set of equations.

$$\frac{d[SO_2]}{dt} = -S\,k_A\,[SO_2] \tag{9}$$

$$\frac{d[NO]}{dt} = -S\,k_B\,[SO_2]\,[NO] \tag{10}$$

$$\frac{d[NO_2]}{dt} = -\frac{x}{2}\,S\,k_B\,[SO_2]\,[NO] \tag{11}$$

$$\frac{dR}{dt} = -\frac{1}{2}\,\frac{M}{D}\left\{k_A\,[SO_2] + \frac{1}{2}\left(1 - \frac{x}{2}\right)k_B\,[SO_2]\,[NO]\right\} \tag{12}$$

$$S = \frac{6(NSR)\,[SO_2]_0}{D\,R_0^3}\,M'\,R^2 \tag{13}$$

k_A, k_B = rate constants, (mole/cm^3 min)
M = molecular weight of the sodium compound
D = particle density
R_0 = mean initial radius of the sodium sorbent particle
x = empirical stoichiometric constant that varies between 0 and 1
S = reactive surface area per unit volume
NSR = normalized stoichiometric ratio (2Na/S)

$[SO_2]_0$ = initial concentration of SO_2

M' = mass of sodium sorbent per mole of sodium

Table A-1 summarizes the rate constants and parameter x obtained from the data.

Table A-1
Summary of the Model Parameters

Sorbent	k_A (cm/min)	k_B (cm^4/min mol)	x
Sodium Sesquicarbonate	8.77	1.24×10^8	0.55
Sodium Bicarbonate	7.65	1.06×10^8	0.70

Figure A-7 shows the model predictions (curves) relative to the bench-scale data (points) for sodium bicarbonate at 2Na/S=3.37 and temperature of 260°F.

A.8 References

Evaluation of Dry Sodium Sorbent Utilization in Combustion Gas SO_x/NO_x Reduction, Final Report, EPRI Project 1682-2, EPRI GS-6850, May 1990.

Fuchs, M.R., et al., *Full-Scale Demonstration of a Utility Dry Sodium Injection FGD Facility,* EPRI Final Report, Project RP-16826, December 1989.

Lai, Y, Yesavage V.F., *Simultaneous Removal of SO_2 and NO_x By Selected Sodium Based Dry Sorbents,* Final Technical Report to Public Service Company of Colorado, 1994.

Muzio, L.J., et al., *Dry SO_2 Particulate Removal for Coal-Fired Boilers,* Volume 2: 22-MW Demonstration Using Nacholite, Trona, and Soda Ash, EPRI Report CS-2894, June 1984.

Muzio, L.J., Kramlich, J.C., *An Artifact in The Measurement of N_2O from Combustion Systems,* Geophysical Research Letters, Vol. 15, No. 12, 1369-1372, November 1988.

Verlaeten, J., De Soele, G.C., Ninane, L., Blondel, J.M., *Combined SO_2/NO_2 Abatement by Sodium Bicarbonate Dry Injection* , 10 50 Brussels, Belgium, 1993.

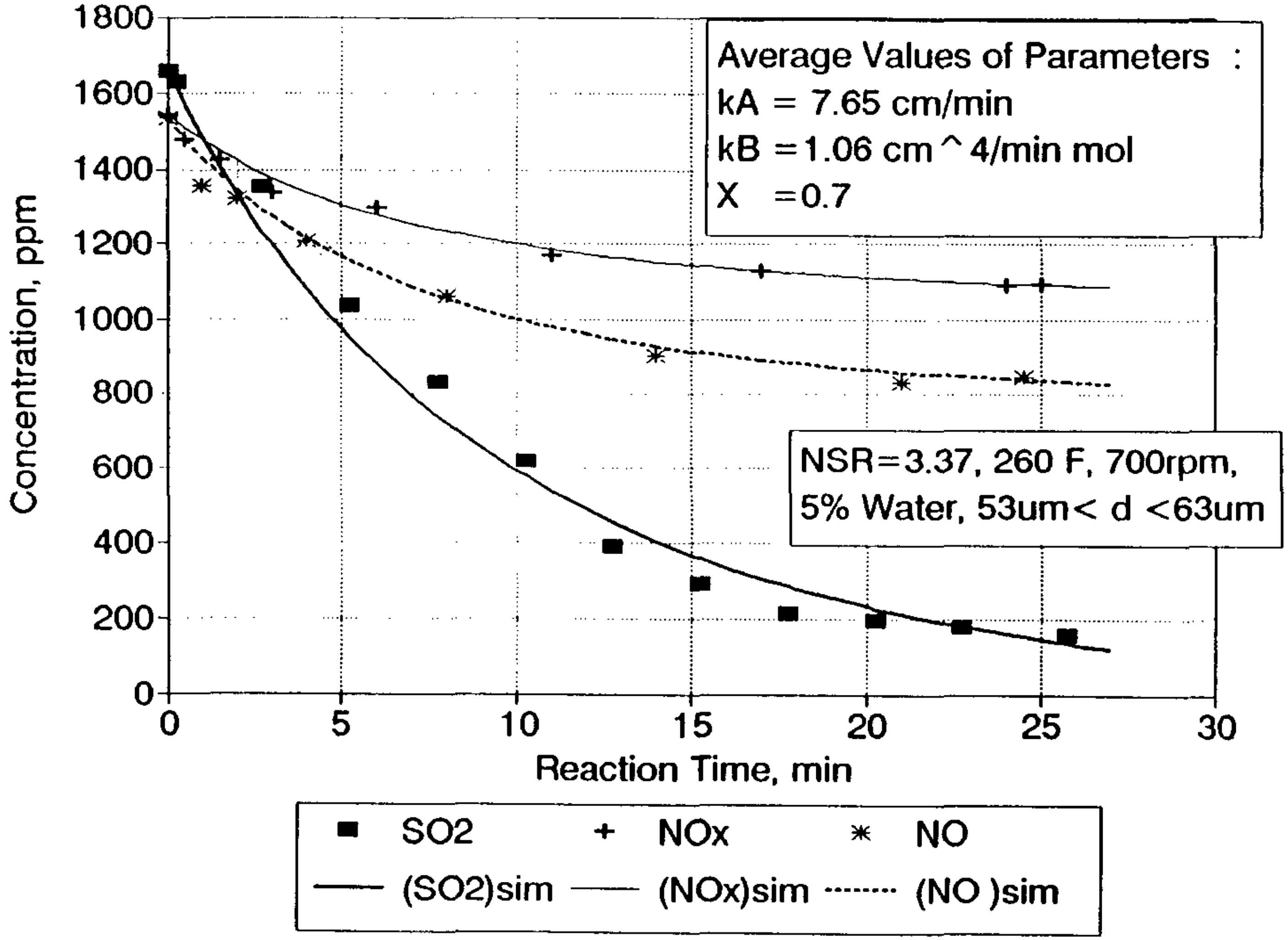


Figure A-7. SO_2 and NO_x Removal by Sodium Bicarbonate Comparison of the Bench-Scale Results and Chemical Kinetic Model for Sodium Bicarbonate

APPENDIX B

Detailed Data Summary for Parametric Tests

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: *Sodium Bicarbonate (b)* *.274 Na wt*

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	<u>2Na</u>	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	<u>ΔNO</u> ΔSO2	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2i	<u>ΔNO</u>	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	°F	°F	°F
613	8/4/93:0810	90	5.10	s	0	0	0.0	0.00	0	-0.5	-3	4.5	15	0.0	15	-5.54	-0.7	-2	0.0	0.87	0	266	61	0.0	202	266	254	253
613	8/4/93:1230	90	5.40	s	0	0	0.0	0.00	0	1.0	6	11.7	40	0.0	40	7.16	3.4	11	0.0	1.88	0			0.0		199	263	265
613	8/4/93:1445	90	5.20	s	100	0	94.3	2.26	8	66.3	376	21.1	70	0.0	70	0.19	17.2	54	0.0	0.14	0	275	72	0.0	266	263	265	267
613	8/4/93:1700	90	5.30	s	100	60	148.0	3.55	75	75.1	425	22.2	72	0.0	72	0.17	19.4	61	0.0	0.14	0	277	72	0.0	265	258	262	264
614	8/6/93:0820	91	5.40	s	0	0	0.0	0.00	0	-1.7	-7	1.6	6	1.6	7	-1.08	-6.2	-24	1.6	3.63	0	261	61	0.0	255	240	246	245
614	8/6/93:1230	90	5.50	s	58	0	53.5	1.85	29	28.5	112	7.1	24	6.3	31	0.27	-1.2	-6	6.3	-0.05	0	276		0.0	268	259	262	262
614	8/6/93:1340	90	5.40	s	55	0	50.6	1.74	34	28.2	111	5.1	17	4.8	22	0.20	-0.5	-4	4.8	-0.04	0	277	70	0.0	269	260	263	265
614	8/6/93:1500	90	5.50	s	55	0	50.6	1.73	51	53.0	211	8.9	30	7.6	37	0.18	3.8	12	7.6	0.06	0	278	73	0.0	270	264	266	268
614	8/6/93:1520	90	5.50	s	55	0	50.6	1.74	53	55.4	218	8.7	29	8.7	37	0.17	3.8	13	8.7	0.06	0	278	73	0.0	270	264	266	268
614	8/6/93:1600	90	5.50	s			0.0	0.00	61	55.4	218	8.7	29	8.7	37	0.17	3.8	13	8.7	0.06								
615	8/9/93:0900	95	5.00	s	0	0	0.0	0.00	0	-1.6	-6	7.1	24	1.4	25	-3.95	3.2	1	1.4	-0.13	0	275	66	0.0	267	250	256	256
615	8/9/93:1100	93	5.10	s	0	32	27.4	0.86	30	32.9	137	-16.2	-54	4.4	-50	-0.36	-19.9	-71	4.4	-0.52	0	282	71	0.0	274	263	267	269
615	8/9/93:1310	93	5.10	s	0	32	27.4	0.90	37	35.0	140	3.7	12	0.2	12	0.09	3.0	0	0.2	0.00	0	285	75	0.0	277	269	271	274
615	8/9/93:1440	92	5.10	s	0	32	27.4	0.89	42	39.8	162	1.8	5	5.7	11	0.07	11.4	33	5.7	0.20	0	286	78	0.0	278	271	273	275
615	8/9/93:1540	92	5.20	s	0	32	27.4	0.89	41	41.8	171	2.9	8	5.9	14	0.08	8.3	24	5.9	0.14	0	288	79	0.0	279	272	274	276
615	8/9/93:1540	92	5.20	s	0	32	27.4	0.89	41	41.8	171	2.9	8	5.9	14	0.08	8.3	24	5.9	0.14	0	288	79	0.0	279	272	274	276
616	8/10/93:1125	95	5.00	s	0	0	0.0	0.00	0	-1.3	-5	-1.2	-4	1.3	-3	0.51	1.1	-5	1.3	0.92	0	281	78	0.0	274	263	266	268
616	8/10/93:1410	109	4.40	s	36	0	32.2	0.90	37	37.0	149	2.1	7	5.4	12	0.08	7.7	21	5.4	0.14	0	290	79	0.0	282	275	277	282
616	8/10/93:1450	109	4.60	s	36	0	32.2	0.91	38	40.1	159	5.0	17	5.2	22	0.14	6.8	22	5.2	0.14	0	290	79	0.0	281	275	277	
617	8/10/93:1559	110	4.80	s	72	0	67.2	1.89	66	65.5	260	7.5	25	21.2	46	0.18	9.9	48	21.2	0.19	0	288	77	0.0	277	272	274	280
617	8/10/93:1630	110	4.60	s	72	0	67.2	1.86	69	68.4	275	5.7	18	21.6	40	0.14	10.3	48	21.6	0.18	0	288	77	0.0	278	272	274	
618	8/11/93:0815	100	4.70	s	0	0	0.0	0.00	0	-1.8	-7	-2.2	-6	1.0	-5	0.73	-5.9	-22	1.0	3.06	0	274	67	0.0	267	252	258	258
618	8/11/93:1110	99	4.50	s	17	17	27.0	0.82	47	39.5	162	2.4	8	2.5	10	0.06	-9.5	-30	2.5	-0.19	0	281	71	0.0	272	263	266	269
618	8/11/93:1250	100	4.60	s	17	17	27.0	0.83	35	34.8	138	6.1	18	5.3	23	0.17	7.7	21	5.3	0.15	0	288	74	0.0	279	270	273	275
619	8/11/93:1430	93	4.70	s	63	0	58.4	1.91	66	65.6	265	-0.7	-2	10.6	8	0.03	10.6	40	10.6	0.15	0	285	76	0.0	275	271	273	276
620	8/11/93:1710	86	5.50	s	63	0	58.4	2.11	69	68.5	268	0.5	2	27.1	29	0.11	10.9	56	27.1	0.21	0	277	82	0.0	269	263	265	267
621	8/12/93:0820	100	4.80	s	0	0	0.0	0.00	0	-2.1	-10	-2.1	-7	0.8	-6	0.61	5.4	10	0.8	-1.03	0	272	68	0.0	265	253	258	258
622	8/13/93:0730	102	4.90	s	0	0	0.0	0.00	0	-4.2	-16	-8.6	-25	0.6	-24	1.52	2.1	-2	0.6	0.14	0	274	65	0.0	266	241	249	247
622	8/13/93:1030	101	4.50	s	78	0	72.9	2.34	71	70.8	268	4.5	13	24.4	37	0.14	10.5	52	24.4	0.19	0	285	68	0.0	276	268	272	274
622	8/13/93:1140	101	4.60	s	78	0	72.9	2.34	72	71.8	272	6.0	18	21.3	39	0.14	11.1	49	21.3	0.18	0	286	71	0.0	276	270	273	276
622	8/13/93:1337	102	4.60	s	78	0	72.9	2.37	71	70.3	260	3.3	10	30.6	40	0.15	8.5	52	30.6	0.20	0	290	74	0.0	279	271	275	278
622	8/13/93:1624	102	4.70	s	78	0	72.9	2.33	75	77.5	292	7.7	23	20.2	43	0.15	11.6	51	20.2	0.18	0	290	77	0.0	280	273	276	280
623	8/16/93:0840	100	3.50	s	77	0	71.9	2.34	0	-4.4	-16	-5.0	-11	1.3	-10	0.59	-2.4	-11	1.3	0.66	0	281	64	0.0	274	257	263	262
623	8/16/93:1200	100	3.60	s	78	0	72.9	2.33	70	74.5	287	8.5	18	11.1	29	0.10	15.4	40	11.1	0.14	0	290	70	0.0	280	270	274	273
623	8/16/93:1340	100	3.60	s	0	78	70.6	2.26	65	66.1	254	12.8	31	5.4	37	0.14	7.0	15	5.4	0.06	0	292	73	0.0	281	272	276	276
623	8/16/93:1545	110	3.40	s	0	86	78.2	2.27	65	64.5	248	13.0	33	9.8	43	0.17	13.0	39	9.8	0.16	0	300	77	0.0	289	283	284	287
624	8/17/93:0730	96	3.80	s	0	0	0.0	0.00	0	-1.4	-5	-4.1	-11	0.1	-11	1.95	9.5	23	0.1	-4.28	0	270	69	0.0	264	249	255	254
624	8/17/93:0940	95	3.70	s	0	74	66.9	2.25	65	65.3	250	2.5	7	7.1	14	0.06	12.9	40	7.1	0.16	0	271	69	0.0	264	253	258	258
624	8/17/93:1200	93	3.80	s	0	74	66.9	2.28	71	71.4	276	5.6	15	7.9	23	0.08	16.0	49	7.9	0.18	0	277	71	0.0	266	259	263	263
625	8/18/93:0810	102	5.40	s	0	0	0.0	0.00	0	4.9	20	1.9	6	2.4	9	0.42	0.7	-6	2.4	-0.29	0	274	71	0.0	268	256	260	259
625	8/18/93:1110	100	4.90	s	86	0	80.7	2.46	66	66.0	265	5.3	17	25.5	43	0.16	4.9	34	25.5	0.13	0	276	70	0.0	267	257		263

PSCC Arapahoe Uni
Calcs based on:

		Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							
Test	Date & Time	NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	Comments
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
613	8/4/93:0810	236	519	427		11.50	7.30	222	49	380		10.44	8.21	7.05	211	417	379		10.36	8.16	7.15	
613	8/4/93:1230	240	720	430		11.72	7.25	232	42	372		10.24	8.18	7.15	207	489	372		10.35	8.06	7.05	
613	8/4/93:1445	240	720	430		11.72	7.25	230	27	395		10.65	8.60	6.65	177	282	130		10.61	8.62	6.95	
613	8/4/93:1700	240	720	430		11.72	7.25	224	22	390		10.66	8.33	6.85	171	231	95		10.55	8.29	7.15	
614	8/6/93:0820	242	32	292	-1	11.14	7.20	243	13	281	-5	10.72	8.68	6.55	223	24	268	-4	10.22	8.27	7.42	2xfeed sprocket
614	8/6/93:1230	242	32	292	-1	11.14	7.20	242	14	270	-7	10.37	8.10	6.90	214	73	187	-2	10.31	7.97	7.32	
614	8/6/93:1340	242	32	292	-1	11.14	7.20	244	15	282	-6	10.76	8.39	6.36	214	66	190	-3	10.29	7.93	7.25	
614	8/6/93:1500	242	32	292	-1	11.14	7.20	240	13	281	-6	10.55	8.27	6.55	200	43	124	-1	10.12	7.87	7.45	
614	8/6/93:1520	242	32	292	-1	11.14	7.20	241	13	280	-6	10.64	8.37	6.45	201	36	117	0	10.23	7.89	7.35	
614	8/6/93:1600	242	32	292	-1	11.14	7.20	241	13	280	-6	10.64	8.37	6.45	201	36	117	0	10.23	7.89	7.35	Post cal feed
615	8/9/93:0900	255	324	335	2	12.15	6.70	245	32	293	-6	10.77	8.65	6.40	221	271	290	-5	10.53	8.53	6.75	add B cal
615	8/9/93:1100	255	324	335	2	12.15	6.70	242	37	295	-6	10.77	8.63	6.45	266	161	190	-3	10.49	8.45	7.00	feed erratic
615	8/9/93:1310	255	324	335	2	12.15	6.70	237	37	284	-5	10.81	8.55	6.40	204	278	165	-4	9.63	7.92	7.90	O2 erratic,B mill
615	8/9/93:1440	241	28	331	1	12.25	6.70	213	15	309	-5	11.55	8.90	5.45	188	22	171	-1	10.80	8.34	6.68	
615	8/9/93:1540	241	28	331	1	12.25	6.70	220	10	307	-5	11.45	8.71	5.66	192	19	164	0	10.64	8.11	6.90	
615	8/9/93:1540	241	28	331	1	12.25	6.70	220	10	307	-5	11.45	8.71	5.66	192	19	164	0	10.64	8.11	6.90	post cal feed
616	8/10/93:1125	272	27	329	2	12.25	6.40	261	15	322	-6	11.78	9.58	5.08	237	21	294	-4	10.77	8.87	6.60	new A feed cal
616	8/10/93:1410	272	27	329	2	12.25	6.40	250	19	308	-5	11.64	9.51	5.20	223	2	180	-1	10.99	9.02	6.30	
616	8/10/93:1450	273	57	335	0	12.71	6.35	256	14	302	-5	11.57	9.35	5.32	223	38	169	-1	10.96	8.92	6.32	
617	8/10/93:1559	273	57	335	0	12.71	6.35	251	14	300	-5	11.45	9.79	5.35	203	50	97	11	10.94	9.29	6.30	
617	8/10/93:1630	272	49	335	0	12.68	6.35	247	13	305	-6	11.52	9.78	5.30	202	45	90	10	10.91	9.32	6.32	
618	8/11/93:0815	241	91	365	0	13.26	5.65	225	19	305	-5	11.51	9.46	5.50	217	34	295	-4	10.97	9.09	6.25	load/mills erratic
618	8/11/93:1110	241	91	365	0	13.26	5.65	259	18	329	-5	12.09	9.75	4.52	223	27	177	-3	10.96	8.85	6.30	
618	8/11/93:1250	249	46	339	0	12.70	6.15	230	15	300	-6	11.36	9.31	5.45	202	32	186	-2	10.96	8.89	6.20	
619	8/11/93:1430	269	27	334	-1	12.35	6.40	244	42	328	-5	12.37	9.89	4.25	210	27	99	3	11.00	8.92	6.18	
620	8/11/93:1710	259	20	322	0	11.98	6.90	233	17	300	-5	11.60	9.99	5.10	185	17	83	14	10.40	8.96	7.00	
621	8/12/93:0820	276	19	380	2	12.67	6.40	257	13	360	-6	12.14	9.95	4.65	235	14	330	-4	10.98	9.06	6.30	abort, hi P
622	8/13/93:0730	259	22	310	2	12.43	6.25	230	23	293	-6	11.74	9.73	4.90	224	16	275	-5	10.78	9.02	6.45	cleaned inj sys
622	8/13/93:1030	257	35	326	-1	12.77	6.12	234	21	299	-5	11.95	9.48	4.80	187	26	80	13	11.15	8.80	6.15	Na flow?
622	8/13/93:1140	256	28	323	-2	12.80	6.20	229	19	287	-6	11.50	9.26	5.40	187	24	76	9	11.02	8.83	6.30	
622	8/13/93:1337	256	28	323	-2	12.80	6.20	229	17	283	-5	11.50	8.85	5.40	184	23	78	17	11.00	8.46	6.45	
622	8/13/93:1624	256	28	323	-2	12.80	6.20	230	16	285	-5	11.33	8.86	5.50	185	25	60	9	10.78	8.43	6.45	
623	8/16/93:0840	208	154	352	0	13.84	4.60	196	88	322	-6	12.94	10.11	3.50	188	89	309	-4	12.02	9.30	4.90	
623	8/16/93:1200	208	154	352	0	13.84	4.60	187	53	331	-5	12.98	9.76	3.45	150	126	78	4	12.27	9.19	4.72	
623	8/16/93:1340	208	154	352	0	13.84	4.60	210	30	322	-5	12.66	9.53	3.90	168	75	102	-1	12.08	8.93	5.00	abort
623	8/16/93:1545	236	98	363	-2	14.04	4.50	225	33	331	-5	12.88	9.59	3.50	175	113	109	3	12.18	9.02	4.75	higher load
624	8/17/93:0730	258	40	338	-1	13.40	5.60	229	46	329	-5	12.89	10.11	3.45	210	40	294	-5	11.52	9.07	5.50	
624	8/17/93:0940	258	40	338	-1	13.40	5.60	229	49	319	-6	12.56	10.01	3.90	193	36	98	0	11.38	9.05	5.82	
624	8/17/93:1200	258	40	338	-1	13.40	5.60	227	45	319	-6	12.27	9.66	4.10	187	37	82	0	11.29	8.82	5.80	
625	8/18/93:0810	269	44	250	2	13.06	5.75	256	21	318	-6	11.65	10.15	5.00	235	29	285	-4	11.13	9.67	5.90	
625	8/18/93:1110	270	31	345	1	12.92	5.95	260	17	315	-5	11.94	9.99	4.80	205	22	97	13	11.08	9.25	6.30	

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na/S*	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO/ΔSO2	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2I	ΔNO/ΔSO2	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	°F	°F	°F
626	8/19/93:0750	101	3.80	s	0	0	0.0	0.00	0	-0.7	-3	-0.6	-2	2.9	1	-0.39	-1.2	-12	2.9	4.12	0	274	66	0.0	268	253	261	260
626	8/19/93:1005	100	3.80	s	0	83	75.4	2.28	68	68.0	276	9.7	27	3.6	31	0.11	16.7	44	3.6	0.16	0	273	67	0.0	265	257	264	265
627	8/20/93:0725	102	3.40	s	0	0	0.0	0.00	17	-0.3	-2	7.0	21	0.4	21	-11.44	1.3	-5	0.4	2.68	0	274	65	0.0	267	251	260	260
627	8/20/93:0930	101	3.40	s	0	100	91.4	2.15	58	57.7	298	15.1	45	7.2	52	0.17	9.9	26	7.2	0.09	0	276	66	0.0	267	256	265	266
627	8/20/93:1150	101	3.50	s	0	100	91.4	2.11	59	59.9	315	14.2	42	11.8	54	0.17	9.4	29	11.8	0.09	0	281	69	0.0	270	262	272	271
628	8/30/93:1202	100	4.40	b	25		0.0	0.00			438		292	4.8	297	0.68		331	4.8	0.76	0	268		0.0	264	248		
628	8/30/93:1650	100	4.40	b	25		0.0	0.00		7.6	41	-9.4	-27	4.7	-23	-0.55	3.6	11	4.7	0.27	0	268		0.0	267	255		
628	8/30/93:1830	100	4.60	b	25		0.0	0.00		34.1	192	5.1	15	4.8	20	0.10	16.3	53	4.8	0.28	0	279		0.0	274	260		
628	8/30/93:1851	100	4.60	b	25		0.0	0.00		39.3	222	3.6	10	7.3	18	0.08	14.9	51	7.3	0.23	0	279		0.0	274	260		
629	8/31/93:0918	100	4.40	b	0		0.0	0.00		-0.8	-4	-1.2	-3	1.8	-2	0.46	1.1	-1	1.8	0.31	0	275		0.0	274	253		
629	8/31/93:0918	100	4.40	b	25		0.0	0.00		-0.8	-4	-1.2	-3	1.8	-2	0.46	1.1	-1	1.8	0.31	0	275		0.0	274	253		
630	8/31/93:1208	47	6.70	b	25		0.0	0.00		46.1	247	5.4	16	22.9	38	0.16	7.1	37	22.9	0.15	0	251		0.0	250	246		
630	8/31/93:1322	47	6.70	b	25		0.0	0.00		57.7	309	12.2	35	11.5	47	0.15	13.8	45	11.5	0.14	0	251		0.0	250	246		
630	8/31/93:1403	47	6.70	b	25		0.0	0.00		62.6	335	18.9	54	7.1	61	0.18	20.3	60	7.1	0.18	0	251		0.0	250	246		
631	8/31/93:1657	104	4.40	b	25		0.0	0.00		35.1	197	-0.6	-2	12.1	10	0.05	4.2	19	12.1	0.10	0	284		0.0	278	264		
631	8/31/93:1715	104	4.20	b	25		0.0	0.00		33.8	187	1.3	4	10.9	15	0.08	6.5	26	10.9	0.14	0	289		0.0	282	268		
632	9/01/93:0810	100	4.60	s	0		0.0	0.00		-2.5	-13	0.1	0	1.7	2	-0.14	4.5	9	1.7	-0.63	0	267		0.0	262	247		
632	9/01/93:0810	100	4.60	s	0	100	91.4	2.04		61.8	340	5.7	15	16.0	31	0.09	9.7	38	16.0	0.11	0	267		0.0	262	247		
632	9/01/93:1040	100	4.60	s	0	100	91.4	2.04		61.8	340	5.7	15	16.0	31	0.09	9.7	38	16.0	0.11	0	273		0.0	266	260		
633	9/01/93:1109	100	4.60	s	0	100	91.4	2.04		64.9	357	9.5	25	18.9	44	0.12	13.5	51	18.9	0.14	0	267		0.0	262	247		
633	9/01/93:1235	100	4.60	s	0	100	91.4	2.04		61.5	339	14.3	38	16.4	55	0.16	18.0	61	16.4	0.18	0	267		0.0	262	247		
634	9/01/93:1419	100	4.60	s	0	100	91.4	2.04		58.6	323	9.5	25	30.3	56	0.17	13.4	62	30.3	0.19	0	267		0.0	262	247		
635	9/02/93:0741	102	4.00	s	0	20	16.1	0.37		-3.0	-15	-4.4	-13	1.9	-11	0.70	1.7	0	1.9	0.00	0	267		0.0	263	247		
635	9/02/93:0903	102	4.00	s	0	20	16.1	0.37		12.0	62	-1.8	-5	2.9	-2	-0.04	4.1	9	2.9	0.14	0	267		0.0	263	247		
635	9/02/93:1002	102	4.10	s	0	20	16.1	0.38		12.5	63	2.3	7	1.8	8	0.13	6.9	17	1.8	0.27	0	267		0.0	263	247		
636	9/02/93:1002	102	4.10	s	0	30	25.5	0.60		24.1	122	5.1	15	2.8	18	0.15	9.6	26	2.8	0.22	0	267		0.0	263	247		
636	9/02/93:1145	101	4.10	s	0	30	25.5	0.65		29.5	140	6.9	20	3.5	24	0.17	11.4	33	3.5	0.23	0	263		0.0	258	249		
636	9/02/93:1215	101	4.10	s	0	30	25.5	0.65		28.7	136	4.3	12	3.2	16	0.12	8.9	25	3.2	0.18	0	263		0.0	258	249		
637	9/02/93:1256	101	4.10	s	0	40	34.9	0.90		45.0	213	5.9	17	6.4	24	0.11	10.5	33	6.4	0.15	0	262		0.0	257	248		
638	9/02/93:1256	101	4.10	s	0	55	49.0	1.26		52.4	248	8.2	24	7.0	31	0.12	12.6	40	7.0	0.16	0	262		0.0	257	248		
639	9/02/93:1450	101	4.10	s	0	20	16.1	0.42		20.4	96	4.6	14	3.4	17	0.18	7.0	19	3.4	0.20	0	262		0.0	257	248		
639	9/02/93:1611	101	4.10	s	0	20	16.1	0.43		16.9	76	1.4	4	5.3	10	0.13	11.4	33	5.3	0.44	0	262		0.0	257	248		
640	9/03/93:0825	100	4.60	b	31	0	0.0	0.00		-1.4	-6	-1.0	-3	-0.2	-3	0.53	11.4	33	-0.2	-5.32	0	274		0.0	271	251	261	
640	9/03/93:1030	100	4.30	b	31	0	0.0	0.00		-1.4	-6	-1.0	-3	-0.2	-3	0.53	11.4	33	-0.2	-5.32	0	278		0.0	273	258	274	
640	9/03/93:1130	102	4.40	b	31	0	0.0	0.00		2.6	11	-0.4	-1	0.9	0	-0.04	11.9	36	0.9	3.20	0	280		0.0	275	262	270	
640	9/03/93:1230	102	4.50	b	31	0	0.0	0.00		7.2	32	0.0	0	2.6	2	0.08	9.8	29	2.6	0.91	0	285		0.0	280	269		
640	9/03/93:1320	102	4.50	b	31	0	0.0	0.00		3.0	13	0.0	0	2.6	3	0.19	9.9	29	2.6	2.14	0	286		0.0	281	270		
640	9/03/93:1443	102	4.30	b	31	0	0.0	0.00		16.4	77	-2.6	-8	22.1	14	0.19	16.9	73	22.1	0.95	0	291		0.0	286	274		
640	9/03/93:1535	102	4.30	b	31	0	0.0	0.00		27.0	126	7.8	22	4.5	27	0.21	25.3	86	4.5	0.68	0	294		0.0	292	279		
640	9/03/93:1609	102	4.40	b	31	0	0.0	0.00		35.6	166	4.6	13	7.0	20	0.12	22.7	79	7.0	0.47	0	295		0.0	292	281		
640	9/03/93:1645	102	4.30	b	31	0	0.0	0.00		42.8	200	8.6	25	10.6	36	0.18	26.0	94	10.6	0.47	0	296		0.0	292	281	289	

PSCC Arapahoe Uni
Calcs based on:

Test	Date & Time	Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							Comments
		NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
626	8/19/93:0750	255	458	350	2	12.73	5.65	242	57	320	-6	11.54	9.67	5.00	232	270	310	-4	11.50	9.57	5.55	
626	8/19/93:1005	255	458	350	2	12.73	5.65	229	60	325	-6	12.24	10.30	4.40	195	280	99	-3	11.78	9.99	5.15	
627	8/20/93:0725	242	1140	475	3	13.38	5.20	237	181	420	-5	11.95	9.84	4.80	217	1175	415	-4	11.71	9.68	5.05	SO2 out DL bad
627	8/20/93:0930	242	1140	475	3	13.38	5.20	235	174	403	-4	11.78	9.79	4.90	192	1025	168	1	11.66	9.73	5.10	
627	8/20/93:1150	242	1140	475	3	13.38	5.20	233	119	407	-5	11.79	9.77	5.00	190	1053	162	4	11.63	9.79	5.10	
628	8/30/93:1202	272	43	372	1	13.18	6.20	252	225	372	-4	13.08	9.54	3.70								Sodium bicarb cal
628	8/30/93:1650	272	43	372	1	13.18	6.20	244	55	442	-4	12.80	9.09	4.30	220		342			9.10	6.70	
628	8/30/93:1830	272	43	372	1	13.18	6.20	242	144	459	-4	13.00	9.26	4.40	210	105	281	0	11.87	8.46	5.60	stm coil, not steady
628	8/30/93:1851	272	43	372	1	13.18	6.20	242	144	459	-4	13.00	9.26	4.40	210	55	257	2	11.88	8.46	5.70	stm coil, not steady
629	8/31/93:0918	255	110	405	1	13.47	5.80	247	116	375	-5	12.72	9.29	4.30	230	101	350	-3	11.87	8.76	5.50	baseline
629	8/31/93:0918	255	110	405	1	13.47	5.80	247	116	375	-5	12.72	9.29	4.30	230	101	350	-3	11.87	8.76	5.50	not steady
630	8/31/93:1208	198	31	376	0	10.74	8.80	194	25	353	-5	10.25	7.73	7.50	156	29	176	10	7.23	7.20	8.50	not steady
630	8/31/93:1322	198	31	376	0	10.74	8.80	194	25	353	-5	10.25	7.73	7.50	151	27	138	3	9.55	7.20	8.50	not steady
630	8/31/93:1403	198	31	376	0	10.74	8.80	194	25	353	-5	10.25	7.73	7.50	142		122			7.20	8.50	not steady
631	8/31/93:1657	262	167	487	1	13.56	5.80	246	127	458	-4	12.71	9.53	4.30	218	93	273	6	11.65	9.08	5.60	steady state
631	8/31/93:1715	262	167	487	1	13.56	5.80	249	101	461	-4	12.67	9.59	4.00	215	130	277	5	11.77	9.02	5.50	steady state
632	9/01/93:0810	238	154	490	0	13.59	5.60	224	100	449	-4	12.62	9.29	4.20	206	166	426	-3	11.95	8.81	5.40	baseline
632	9/01/93:0810	238	154	490	0	13.59	5.60	222	56	450	-4	12.50	8.99	4.40	182	39	159	8	11.80	8.48	5.60	
632	9/01/93:1040	238	154	490	0	13.59	5.60	222	56	450	-4	12.50	8.99	4.40	182	39	159	8	11.80	8.48	5.60	
633	9/01/93:1109	238	154	490	0	13.59	5.60	222	56	450	-4	12.50	8.99	4.40	173	54	147	11	11.87	8.55	5.50	
633	9/01/93:1235	238	154	490	0	13.59	5.60	222	56	450	-4	12.50	8.99	4.40	166	102	162	9	11.76	8.25	5.50	
634	9/01/93:1419	238	154	490	0	13.59	5.60	222	56	450	-4	12.50	8.99	4.40	164	68	173	19	11.59	8.26	5.60	
635	9/02/93:0741	262	39	454	1	13.52	5.60	244	35	428	-5	12.73	9.20	4.20	233	36	406	-3	11.82	8.59	5.50	
635	9/02/93:0903	262	39	454	1	13.52	5.60	244	35	428	-5	12.73	9.20	4.20	226	32	346	-3	11.75	8.50	5.55	
635	9/02/93:1002	262	39	454	1	13.52	5.60	243	44	414	-4	12.50	9.08	4.40	219	43	336	-3	11.78	8.43	5.60	
636	9/02/93:1002	262	39	454	1	13.52	5.60	243	44	414	-4	12.50	9.08	4.40	213	49	293	-2	11.87	8.58	5.50	
636	9/02/93:1145	262	39	454	1	13.52	5.60	245	58	390	-4	12.69	9.35	4.20	210	74	256	-1	12.00	8.97	5.30	
636	9/02/93:1215	262	39	454	1	13.52	5.60	245	58	390	-4	12.69	9.35	4.20	212	50	254	-2	11.87	8.79	5.60	
637	9/02/93:1256	262	39	454	1	13.52	5.60	245	58	390	-4	12.69	9.35	4.20	209	70	199	1	11.91	8.80	5.40	
638	9/02/93:1256	262	39	454	1	13.52	5.60	245	58	390	-4	12.69	9.35	4.20	206	69	174	1	12.10	8.96	5.20	
639	9/02/93:1450	262	39	454	1	13.52	5.60	252	57	389	-4	12.71	9.44	4.10	222	63	289	-1	12.06	8.90	5.20	
639	9/02/93:1611	279	35	411	2	13.63	6.10	257	33	372	-7	12.45	9.20	4.30	232	40	288	-2	12.00	8.80	5.40	
640	9/03/93:0825	294	34	387	2	13.65	6.10	265	33	362	-4	12.67	8.81	4.20	245	33	336	-4	11.80	8.18	5.60	
640	9/03/93:1030	294	34	387	2	13.65	6.10	265	33	362	-4	12.67	8.81	4.20	245	33	336	-4	11.80	8.18	5.60	
640	9/03/93:1130	294	34	387	2	13.65	6.10	265	33	362	-4	12.67	8.81	4.20	243	25	323	-3	11.72	8.15	5.60	
640	9/03/93:1230	294	34	387	2	13.65	6.10	270	29	360	-5	12.51	8.72	4.40	247	26	308	-3	11.69	8.03	5.70	
640	9/03/93:1320	294	34	387	2	13.65	6.10	270	29	360	-5	12.51	8.72	4.40	251	31	327	-3	11.87	7.92	5.50	
640	9/03/93:1443	294	34	387	2	13.65	6.10	234	29	369	-5	12.17	8.51	5.00	218	34	302	12	11.99	8.00	5.40	
640	9/03/93:1535	294	34	387	2	13.65	6.10	234	29	369	-5	12.17	8.51	5.00	207	40	262	-2	11.86	7.94	5.50	
640	9/03/93:1609	294	34	387	2	13.65	6.10	234	29	369	-5	12.17	8.51	5.00	212	31	231	0	11.97	8.01	5.50	
640	9/03/93:1645	294	34	387	2	13.65	6.10	234	29	369	-5	12.17	8.51	5.00	203	36	208	3	12.00	8.03	5.30	

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO/ΔSO2	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2i	ΔNO/ΔSO2	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	°F	°F	°F
640	9/03/93:1715	102	4.40	b	31	0	0.0	0.00		46.6	218	10.6	31	12.1	43	0.20	27.6	102	12.1	0.47	0	297		0.0	293	283	290	
640	9/03/93:1745	102	4.40	b	31	0	0.0	0.00		50.0	234	13.3	39	14.0	53	0.22	29.8	111	14.0	0.48	0	298		0.0	294	285	291	
640	9/03/93:1755	102	4.40	b	31	0	0.0	0.00		51.4	240	11.8	34	14.4	49	0.20	28.6	107	14.4	0.45	0	298		0.0	295	285	292	
641	9/07/93:0900	100	4.20	s	0	0	0.0	0.00		4.4	18	3.2	9	2.6	11	0.62	6.9	13	2.6	0.74	0	285		0.0	281	265	275	
641	9/07/93:1100	100	4.20	s	0	35	30.2	0.96		43.4	167	6.0	16	5.3	21	0.12	12.9	34	5.3	0.20	0	284		0.0	281	267	277	
641	9/07/93:1246	100	4.20	s	0	35	30.2	0.94		37.1	147	5.7	15	6.4	21	0.15	10.5	28	6.4	0.19	0	284		0.0	281	267	277	
641	9/07/93:1451	100	4.20	s	0	35	30.2	0.83		33.1	147	3.0	7	4.0	12	0.08	13.0	34	4.0	0.23	0	284		0.0	281	267	277	
641	9/07/93:1536	100	4.30	s	0	35	30.2	0.80		34.5	160	10.0	26	3.9	30	0.19	15.7	41	3.9	0.26	0	282		0.0	278	273	278	
641	9/07/93:1645	100	4.10	s	0	35	30.2	0.77		29.6	143	7.7	20	9.4	29	0.21	13.2	39	9.4	0.27	0	277		0.0	273	265	278	
							0.0			35.5	153	6.5	17	5.8	23	0.15												
642	9/08/93:0938	100	3.40	s	0	0	0.0	0.00		-1.5	-8	3.9	8	1.2	10	-1.23	4.5	5	1.2	-0.61	0	272		0.0	267	250	278	
642	9/08/93:1525	100	3.40	s	0	40	34.9	0.79		35.5	192	12.2	27	2.9	30	0.15	12.0	23	2.9	0.12	0	276		0.0	273	262		
642	9/08/93:1631	100	3.40	s	0	40	34.9	0.79		35.5	192	12.2	27	2.9	30	0.15	12.0	23	2.9	0.12	0	276		0.0	273	262		
642	9/08/93:1640	100	3.40	s	0	40	34.9	0.79		35.3	191	11.8	26	2.4	28	0.15	11.7	22	2.4	0.11	0	276		0.0	273	262		
643	9/09/93:0858	100	3.40	s	0	21	16.7	0.42		-2.2	-11	4.5	10	2.3	12	-1.14	7.5	12	2.3	-1.10	0	272		0.0	268	245	256	
644	9/13/93:0800	100	3.80	s	0	0	0.0	0.00		-5.8	-22	0.0	0	0.0	0	0.00	6.4	11	0.0	-0.51	0	262	51	0.0	255	238	249	246
644	9/13/93:1030	100	3.40	s	0	16	12.3	0.39		28.8	111	-1.6	-3	2.2	-1	-0.01	14.9	34	2.2	0.31	0	260	46	0.0	253	242	252	250
645	9/13/93:1300	98	3.50	s	0	24	19.8	0.60		36.3	151	7.5	16	3.4	19	0.13	11.5	24	3.4	0.16	0	263	48	0.0	255	241	252	251
645	9/13/93:1320	98	3.40	s	0	24	19.8	0.58		34.2	145	4.4	9	2.3	12	0.08	18.4	42	2.3	0.29	0	264	48	0.0	256	245	252	251
646	9/13/93:1500	100	3.40	s	0	35	30.2	0.86		47.7	206	5.2	11	2.7	13	0.07	12.3	25	2.7	0.12	0	262	46	0.0	254	242	253	251
647	9/13/93:1620	100	4.10	s	0	35	30.2	0.87		27.5	118	5.3	13	1.6	14	0.12	9.2	19	1.6	0.16	0	262	45	0.0	254	241	252	250
648	9/14/93:0815	100	3.40	s	0	0	0.0	0.00		-0.9	-4	2.2	5	0.6	5	-1.36	7.1	10	0.6	-2.76	0	262	45	0.0	256	240	250	249
649	9/14/93:0945	102	3.40	s	0	54	48.1	1.34		56.9	246	9.1	21	0.1	21	0.08	10.9	20	0.1	0.08	0	264	46	0.0	256	243	254	253
649	9/14/93:1025	100	3.50	s	0	54	48.1	1.36		59.7	258	10.0	22	2.6	25	0.10	10.2	20	2.6	0.08	0	266	47	0.0	258	244	255	255
650	9/14/93:1035	100	3.50	s	0	44	38.7	1.08		54.3	239	11.4	25	3.5	29	0.12	11.3	23	3.5	0.10	0	269	48	0.0	258	250	259	259
650	9/14/93:1045	100	3.50	s	0	44	38.7	1.07		52.9	234	8.7	19	3.5	22	0.09	11.7	24	3.5	0.10	0			0.0				
650	9/14/93:1155	100	3.50	s	0	44	38.7	1.07		53.4	237	8.6	18	6.2	24	0.10	11.6	26	6.2	0.11	0			0.0				
650	9/14/93:1205	100	3.50	s	0	44	38.7	1.07		53.6	237	8.2	18	3.8	21	0.09	11.2	23	3.8	0.10	0			0.0				
651	9/14/93:1543	100	3.50	s	0	35	30.2	0.73		36.3	185	4.8	10	4.5	15	0.08	8.8	19	4.5	0.10	0	280	57	0.0	273	261	270	271
652	9/14/93:1650	100	3.40	s	0	42	36.8	0.90		42.0	211	8.9	19	4.9	24	0.11	9.0	19	4.9	0.09	0	281	58	0.0	274	263	272	271
653	9/14/93:1710	100	3.50	s	0	42	36.8	0.87		42.5	221	8.4	18	3.1	21	0.09	9.6	20	3.1	0.09	0	282	57	0.0	274	264	273	274
654	9/15/93:0730	100	3.90	s	0	0	0.0	0.00	0	-2.2	-12	0.8	2	1.3	3	-0.27	4.4	4	1.3	-0.32	0	264	49	0.0	258	233	246	244
654	9/15/93:1000	99	4.00	s	0	67	60.3	1.37	56	53.3	290	10.7	26	24.1	50	0.17	12.5	49	24.1	0.17	0	278	53	0.0	269	257	265	266
654	9/15/93:1250	99	3.90	s	0	67	60.3	1.37	53	53.3	292	16.3	40	17.6	58	0.20	14.2	47	17.6	0.16	0	287	61	0.0	278	268	274	276
654	9/15/93:1350	99	4.00	s	0	67	60.3	1.34	55	56.1	312	14.4	32	16.6	49	0.16	19.5	59	16.6	0.19	0	288	62	0.0	280	270	276	278
655	9/16/93:0940	80	4.70	s	0	16	12.3	0.34	21	22.5	124	5.7	12	7.9	20	0.16	4.2	9	7.9	0.08	0	268	57	0.0	261	248	258	255
656	9/16/93:1120	80	4.60	s	0	27	22.7	0.65	38	38.0	200	9.0	19	14.7	34	0.17	6.3	22	14.7	0.11	0	271	58	0.0	263	253	261	259
657	9/16/93:1320	80	4.60	s	0	35	30.2	0.87	50	51.4	271	5.8	12	14.6	26	0.10	11.1	32	14.6	0.12	0	272	60	0.0	265	255	263	262
658	9/16/93:1500	80	4.50	s	0	43	37.7	1.13	59	58.5	297	10.0	22	16.5	39	0.13	61.6	329	16.5	1.11	0	275	61	0.0	266	256	265	263
659	9/16/93:1550	80	4.60	s	0	50	44.3	1.32	62	62.5	316	11.9	26	15.3	41	0.13	14.6	42	15.3	0.13	0	275	67	0.0	266	256	266	264
659	9/16/93:1620	80	4.60	s	0	50	44.3	1.35	62	62.4	311	11.2	24	15.7	40	0.13	13.5	39	15.7	0.13	0	275	67	0.0	266	256	266	264

PSCC Arapahoe Uni
Calcs based on:

		Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							
Test	Date & Time	NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	Comments
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
640	9/03/93:1715	294	34	387	2	13.65	6.10	234	29	369	-5	12.17	8.51	5.00	197	43	194	4	12.03	8.15	5.30	
640	9/03/93:1745	294	34	387	2	13.65	6.10	234	29	369	-5	12.17	8.51	5.00	191	37	183	6	12.10	8.10	5.20	
640	9/03/93:1755	294	34	387	2	13.65	6.10	234	29	369	-5	12.17	8.51	5.00	194	49	178	6	12.12	8.13	5.20	
641	9/07/93:0900	237	143	383	0	14.02	5.70	213	19	318	-6	11.75	9.23	5.20	199	97	296	-4	11.74	9.55	5.50	
641	9/07/93:1100	237	143	383	0	14.02	5.70	208	46	302	-5	11.96	9.53	4.90	185	111	165	-1	11.83	9.48	5.40	
641	9/07/93:1246	237	143	383	0	14.02	5.70	209	94	303	-6	12.02	9.46	5.20	189	227	187	-1	11.77	9.25	5.50	
641	9/07/93:1451	237	143	383	0	14.02	5.70	206	31	358	-5	12.19	9.32	4.60	188	184	229	-2	11.93	9.05	5.30	
641	9/07/93:1536	237	143	383	0	14.02	5.70	210	34	365	-5	12.09	9.43	4.90	184	223	236	-2	12.08	9.35	5.10	
641	9/07/93:1645	238	266	455	1	14.25	5.50	211	29	382	-5	12.15	9.87	4.70	183	205	262	2	12.09	9.68	5.10	
642	9/08/93:0938	204	738	518	1	15.05	4.20	188	99	435	-5	12.98	9.78	3.80	176	614	432	-4	12.75	9.68	4.15	9/8 A Feeder cal
642	9/08/93:1525	204	738	518	1	15.05	4.20	191	61	459	-5	12.93	9.68	3.70	163	512	291	-2	12.83	9.50	4.00	" ", Mills-5000rpm
642	9/08/93:1631	204	738	518	1	15.05	4.20	191	61	459	-5	12.93	9.68	3.70	163	512	291	-2	12.83	9.50	4.00	
642	9/08/93:1640	204	738	518	1	15.05	4.20	191	61	459	-5	12.93	9.68	3.70	162	524	288	-2	12.75	9.46	4.20	
643	9/09/93:0858	206	511	484	1	14.86	4.50	187	61	407	-5	12.80	9.78	4.00	173	344	407	-3	12.62	9.64	4.35	Erratic feed all day
644	9/13/93:0800	218	65	367	0	14.62	5.00	197	35	320	-4	12.83	9.07	3.90	187	92	320	-3	12.42	8.77	4.80	
644	9/13/93:1030	218	65	367	0	14.62	5.00	180	177	330	-4	13.13	9.22	3.65	170	198	221	-2	12.64	8.86	4.65	
645	9/13/93:1300	200	363	388	0	14.50	4.60	182	170	352	-4	13.04	9.31	3.80	160	310	216	-1	12.79	9.04	4.40	
645	9/13/93:1320	218	65	367	0	14.62	5.00	183	124	362	-4	13.05	9.33	3.70	165	212	227	-2	12.69	8.93	4.50	
646	9/13/93:1500	205	289	430	1	14.94	4.45	182	141	372	-4	13.35	9.52	3.50	162	234	185	-1	12.91	9.14	4.35	
647	9/13/93:1620	215	58	410	1	14.30	5.20	197	28	350	-4	12.60	9.07	4.35	178	40	244	-3	12.32	8.77	5.00	mill off
648	9/14/93:0815	198	475	420	1	14.81	4.45	180	182	373	-4	13.14	9.64	3.55	168	260	360	-3	12.67	9.24	4.30	
649	9/14/93:0945	207	285	403	0	14.50	4.85	192	49	358	-4	12.65	9.28	4.15	170	172	150	-4	12.44	9.10	4.60	
649	9/14/93:1025	202	556	425	0	14.72	4.55	191	101	366	-4	13.01	9.52	3.75	162	218	141	-1	12.55	9.12	4.55	
650	9/14/93:1035	200	316	430	0	14.48	4.65	190	78	370	-4	12.80	9.40	3.90	160	300	163	-1	12.65	9.09	4.50	
650	9/14/93:1045	200	316	430	0	14.48	4.65	185	81	375	-4	12.78	9.34	3.80	160	290	170	-1	12.52	9.02	4.45	
650	9/14/93:1155	200	316	430	0	14.48	4.65	185	81	375	-4	12.78	9.34	3.80	158	245	168	1	12.57	9.01	4.45	
650	9/14/93:1205	200	316	430	0	14.48	4.65	185	81	375	-4	12.78	9.34	3.80	160	255	167	-1	12.59	9.00	4.50	
651	9/14/93:1543	200	230	488	0	14.26	4.55	185	104	440	-4	13.09	9.70	3.45	163	209	265	0	12.61	9.24	4.40	
652	9/14/93:1650	198	381	505	0	14.50	4.45	188	70	428	-4	12.89	9.60	3.60	160	200	237	0	12.62	9.29	4.35	
653	9/14/93:1710	198	381	505	0	14.50	4.45	185	68	445	-3	12.91	9.67	3.60	160	203	245	-1	12.52	9.22	4.35	
654	9/15/93:0730	209	185	490	3	13.70	5.24	194	36	445	-4	12.49	9.47	4.35	184	119	437	-3	12.15	9.17	4.98	base
654	9/15/93:1000	215	161	496	1	13.52	5.40	196	16	430	-4	12.15	8.96	4.90	150	121	192	14	11.77	8.55	5.60	#6 & 12 BH comp of
654	9/15/93:1250	211	109	502	0	13.90	5.12	201	18	440	-4	12.34	8.96	4.65	146	80	194	10	11.78	8.52	5.55	
654	9/15/93:1350	211	109	502	0	13.90	5.12	190	40	460	-4	12.55	9.19	4.20	140	111	190	10	12.07	8.69	5.20	
655	9/16/93:0940	177	39	455	1	12.77	6.15	170	8	415	-4	11.61	8.79	5.58	150	45	312	2	11.50	8.63	6.02	80 MWe
656	9/16/93:1120	176	174	458	0	13.02	6.00	169	23	399	-5	11.49	8.76	5.55	140	116	242	6	11.52	8.65	5.87	
657	9/16/93:1320	182	80	452	0	13.23	5.85	164	26	410	-5	11.96	9.04	5.10	138	59	192	6	11.61	8.65	5.70	
658	9/16/93:1500	435	74	435	0	13.02	5.95	172	15	380	-6	11.37	8.61	5.70	140	37	154	7	11.40	8.56	6.00	
659	9/16/93:1550	187	39	435	0	13.12	5.95	172	17	390	-5	11.71	8.94	5.25	137	40	143	7	11.61	8.73	5.62	
659	9/16/93:1620	187	39	435	0	13.12	5.95	173	16	383	-6	11.64	8.84	5.30	138	37	140	6	11.59	8.69	5.73	

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO/ΔSO2	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2i	ΔNO/ΔSO2	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc		scfm	°F	°F	gpm	°F	°F	°F	°F
660	9/18/93:0900	60	6.50	s	0	15	11.4	0.53	35	36.3	152	-0.4	-1	2.3	1	0.01	7.2	16	2.3	0.10	0	253	59	0.0	247	234	244	242
661	9/18/93:1020	60	6.50	s	0	20	16.1	0.75	47	47.1	198	1.5	4	3.7	8	0.04	9.3	22	3.7	0.11	0	254	55	0.0	248	235	245	243
662	9/18/93:1210	60	6.40	s	0	25	20.8	0.92	51	50.6	224	2.1	6	2.6	8	0.04	12.3	31	2.6	0.14	0	257	56	0.0	251	238	248	245
663	9/18/93:1340	60	6.50	s	0	32	27.4	1.15	56	55.6	259	5.6	14	2.5	17	0.07	12.7	30	2.5	0.12	0	256	57	0.0	249	242	249	247
664	9/18/93:1650	60	6.40	s	0	46	40.5	1.57	56	55.9	283	4.1	11	26.0	37	0.13	11.8	52	26.0	0.18	0	254	55	0.0	247	237	246	242
673	9/24/93:0850	110	4.00	s	0	0	0.0	0.00	0	-3.4	-14	-11.0	-26	1.9	-25	1.78	5.3	8	1.9	-0.57	0	277	56	0.0	271	244	256	260
673	9/24/93:1150	110	3.90	s	0	80	72.5	2.04	64	63.6	253	5.0	13	12.5	26	0.10	10.1	34	12.5	0.14	0	279	57	0.0	272	262	271	274
674	9/24/93:1300	110	3.90	s	40	41	71.9	2.03	77	77.1	305	8.1	22	12.3	34	0.11	11.8	40	12.3	0.13	0	280	57	0.0	271	264	271	275
675	9/24/93:1450	110	4.00	s	76	0	71.0	2.01	72	72.1	284	7.4	21	21.0	42	0.15	9.7	42	21.0	0.15	0	281	59	0.0	273	264	272	275
676	9/27/93:0840	99	4.00	s	0	0	0.0	0.00	0	-1.9	-9	-2.8	-7	1.6	-5	0.64	8.4	18	1.6	-2.14	0	268	58	0.0	264	245	256	256
676	9/27/93:1240	99	3.90	s	40	41	71.9	2.09	64	67.5	287	12.6	37	27.0	64	0.22	10.7	53	27.0	0.18	0	282	59	0.0	275	266	274	274
677	9/27/93:1750	99	4.00	s	44	45	79.5	2.04	64	62.7	303	-2.8	-5	16.1	12	0.04	1.8	13	16.1	0.04	0	290	66	0.0	283	278	283	287
677	9/27/93:1805	99	4.00	s	44	45	79.5	2.04	64	66.1	319	-0.6	-1	16.5	16	0.05	3.9	17	16.5	0.05	0	290	66	0.0	283	278	283	287
680	10/04/93:1450	100	3.20	s	24	0	20.0	0.61	24	23.3	94	-3.0	-7	3.0	-4	-0.04	0.9	-1	3.0	-0.02	0	291	67	0.0	284	273	281	282
681	10/05/93:0800	100	3.40	s	0	0	0.0	0.00	24	-3.7	-21	-9.5	-21	-0.9	-22	1.05	5.4	8	-0.9	-0.38	0	266	58	0.0	262	250	258	258
682	10/05/93:1010	100	3.50	s	26	0	22.5	0.49	24	16.8	95	-10.9	-25	2.7	-22	-0.24	6.4	14	2.7	0.14	0	267	60	0.0	261	249	257	259
683	10/05/93:1230	100	3.40	s	50	0	45.8	0.99	24	44.2	251	3.6	8	8.9	17	0.07	4.9	16	8.9	0.06	0	277	64	0.0	269	259	268	269
684	10/05/93:1400	100	3.30	s	73	0	68.1	1.49	24	58.8	329	6.6	15	11.2	27	0.08	16.2	48	11.2	0.15	0	279	69	0.0	271	266	272	274
685	10/05/93:1540	100	3.20	s	96	0	90.4	2.02	24	70.2	385	11.3	26	9.5	35	0.09	18.5	50	9.5	0.13	0	282	70	0.0	272	267	274	276
686	10/06/93:0910(	102	3.50	s	0	0	0.0	0.00	24	-2.5	-15	12.8	36	1.5	38	-2.55	5.8	8	1.5	-0.51	0	269	60	0.0	265	248	258	259
687	10/06/93:1210	101	3.60	s	30	0	26.4	0.55	24	20.5	118	3.8	9	2.9	11	0.10	8.3	17	2.9	0.14	0	282	66	0.0	275	264	272	273
687	10/06/93:1300	101	3.50	s	30	0	26.4	0.56	24	25.5	145	15.0	42	3.6	45	0.31	8.2	19	3.6	0.13	0	288	68	0.0	281	270	277	279
688	10/06/93:1510	101	3.50	s	50	0	45.8	1.04	24	46.6	248	17.1	48	9.9	57	0.23	11.5	34	9.9	0.14	0	285	71	0.0	278	272	278	282
689	10/06/93:1800	101	3.50	s	65	0	60.3	1.49	24	60.2	296	18.6	52	13.4	65	0.22	12.3	40	13.4	0.14	0	281	72	0.0	272	269	274	276
690	10/06/93:1700	101	3.50	s	83	0	77.8	2.03	24	69.7	325	18.1	52	13.1	65	0.20	13.6	44	13.1	0.14	0	281	76	0.0	272	267	273	275
691	10/07/93:0750	101	4.20	s	0	0	0.0	0.00	24	-4.1	-18	11.6	38	3.0	41	-2.37	3.6	4	3.0	-0.26	0	265	58	0.0	260	245	255	256
692	10/07/93:1100	100	4.10	s	20	22	34.6	0.90	24	45.2	214	15.2	45	3.2	48	0.22	10.4	27	3.2	0.12	0	273	61	0.0	265	255	264	265
693	10/07/93:1400	100	4.10	s	32	34	57.5	1.56	24	66.2	299	18.8	53	13.5	66	0.22	14.4	45	13.5	0.15	0	269	63	0.0	263	256	264	266
694	10/07/93:1500	100	4.10	s	40	42	72.8	2.02	24	75.6	335	21.2	61	11.5	72	0.22	15.8	47	11.5	0.14	0	270	62	0.0	262	255	263	265
695	10/07/93:1600	100	4.10	s	48	51	89.1	2.45	24	79.8	355	19.0	54	11.3	65	0.18	14.7	44	11.3	0.13	0	272	62	0.0	263	256	264	265
696	10/07/93:1750	99	4.30	s	35	37	63.3	1.78	24	71.8	316	5.5	14	18.3	32	0.10	15.2	55	18.3	0.17	0	266	60	0.0	258	251	260	258
722	11/4/93 9:10	110	3.20	s	0	0	0.0	0.00	0	0.0	0	2.8	6	2.2	8		8.7	16	2.2		0	269	67	0.0	269	251	259	260
723	11/4/93 11:40	110	3.20	s	26	0	23.0	0.49	30	30.8	160	4.7	11	2.7	13	0.08	3.3	4	2.7	0.02	0	270	51	0.0	264	256	262	266
724	11/4/93 14:40	110	3.30	s	0	29	24.5	0.50	28	30.0	164	1.7	4	3.0	7	0.04	9.1	18	3.0	0.11	0	263	49	0.0	267	255	261	262
725	11/4/93 16:30	110	3.20	s	15	16	24.4	0.51	34	34.5	185	6.1	14	2.6	16	0.09	11.1	23	2.6	0.12	0	266	46	0.0	259	263	251	260
726	11/5/93 8:00	109	3.40	s	0	0	0.0	0.00	0	-0.7	-4	4.4	10	2.8	12	-3.30	2.1	0	2.8	0.00	0	262	43	0.0	256	238	262	244
727	11/5/93 9:30	108	3.30	s	50	0	46.7	1.01	54	55.9	294	14.0	32	3.7	36	0.12	11.6	23	3.7	0.08	0	265	42	0.0	256	245	261	254
728	11/5/93 13:00	110	3.70	s	0	53	47.1	1.02	50	51.3	264	8.9	20	-0.1	20	0.08	10.6	22	-0.1	0.08	0	266	43	0.0	258	249	265	259
729	11/5/93 14:40	110	3.50	s	26	28	46.6	0.99	56	54.8	289	7.2	17	3.8	21	0.07	9.0	21	3.8	0.07	0	260	44	0.0	252	248	258	257

PSCC Arapahoe Uni
Calcs based on:

		Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							
Test	Date & Time	NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	Comments
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
660	9/18/93:0900	199	17	301	0	10.70	8.70	184	18	278	-5	1.10	7.93	7.40	169	14	164	-3	9.58	7.50	8.38	60 Mwe
661	9/18/93:1020	195	16	300	0	10.76	8.65	180	16	280	-6	10.17	7.87	7.35	162	15	137	-3	9.60	7.48	8.32	
662	9/18/93:1210	198	12	312	0	10.72	8.72	180	14	298	-5	10.20	7.84	7.22	160	11	135	-3	9.63	7.40	8.32	
663	9/18/93:1340	190	13	332	0	10.74	8.72	178	11	312	-5	10.15	8.15	7.20	153	12	127	-3	9.61	7.74	8.28	
664	9/18/93:1650	191	11	360	0	10.73	8.80	181	10	343	-5	10.36	8.01	7.12	142	9	138	11	9.67	7.51	8.30	post bh clean?
673	9/24/93:0850	247	52	362	3	13.84	5.12	210	31	340	-5	12.93	10.13	3.60	212	37	323	-3	12.12	9.40	5.00	base
673	9/24/93:1150	248	43	364	1	13.88	5.20	222	22	322	-5	12.38	9.60	4.40	192	49	112	5	12.10	9.37	5.10	B feeder
674	9/24/93:1300	250	36	362	1	13.82	5.15	225	19	320	-4	12.41	9.71	4.40	188	31	70	6	12.05	9.37	5.15	A & B feeder
675	9/24/93:1450	252	44	358	1	14.07	5.10	235	18	325	-5	12.60	9.86	4.10	188	27	85	11	12.05	9.34	5.15	A feeder
676	9/27/93:0840	242	48	390	1	13.66	5.71	210	13	354	-5	12.48	9.06	4.62	202	39	340	-3	11.98	8.62	5.55	base
676	9/27/93:1240	244	149	278	1	13.48	5.76	233	20	331	-4	11.99	8.60	5.20	177	106	104	17	11.80	8.44	5.70	3 mills
677	9/27/93:1750	144	382	418	0	13.26	6.00	128	42	360	-5	11.48	8.99	5.70	117	234	132	7	11.45	8.82	5.95	Urea Inj
677	9/27/93:1805	144	382	418	0	13.26	6.00	128	42	360	-5	11.48	8.99	5.70	114	196	120	8	11.51	8.83	5.95	Urea Inj
680	10/04/93:1450	210	293	383	2	14.37	4.40	198	143	355	-4	13.56	9.50	3.20	187	226	253	-1	12.99	9.10	4.40	A feeder, low blr spd
681	10/05/93:0800	222	66	508	3	13.75	5.30	190	68	485	-2	13.19	9.62	3.75	195	103	470	-2	12.58	9.11	4.85	Base
682	10/05/93:1010	235	75	515	2	14.03	5.40	198	41	475	-4	13.00	9.51	3.85	202	69	368	-1	12.52	8.98	5.00	A feeder
683	10/05/93:1230	215	293	528	2	14.68	4.70	202	68	480	-2	13.09	9.42	3.80	175	201	250	5	12.74	9.20	4.85	
684	10/05/93:1400	228	103	520	2	14.55	5.05	200	41	475	-3	13.11	9.36	3.78	165	69	182	6	12.63	8.92	4.95	
685	10/05/93:1540	220	153	512	2	14.82	4.80	195	44	465	-3	13.17	9.37	3.75	155	115	130	5	12.89	9.08	4.75	
686	10/06/93:0910(	228	1265	530	4	13.83	5.15	225	80	453	-3	11.99	8.77	5.15	200	998	475	-2	12.32	9.17	4.75	Base
687	10/06/93:1210	212	235	555	2	14.88	4.70	190	49	480	-3	12.85	9.47	4.05	175	280	370	-1	13.01	9.50	4.50	A feeder
687	10/06/93:1300	233	1429	550	2	14.61	4.60	222	121	448	-4	12.21	8.85	4.99	190	1034	340	-1	12.47	8.96	4.70	
688	10/06/93:1510	233	1330	500	1	14.41	4.78	220	60	415	-4	11.98	8.70	5.15	178	668	225	4	12.47	9.07	4.85	
689	10/06/93:1800	237	1062	468	1	14.72	4.48	225	67	390	-3	12.20	8.84	4.85	173	631	155	8	12.52	9.12	4.80	
690	10/06/93:1700	240	886	434	1	14.39	4.90	228	87	368	-4	12.09	8.78	4.95	178	606	112	7	12.50	9.09	4.80	
691	10/07/93:0750	255	686	385	2	13.51	5.80	255	28	318	-5	11.48	8.61	5.65	223	298	330	-3	11.88	8.84	5.65	Base
692	10/07/93:1100	235	65	410	1	13.97	5.82	235	30	370	-3	12.08	9.04	5.00	190	58	195	-1	12.14	8.94	5.55	A&B feeders
693	10/07/93:1400	230	53	410	1	14.12	5.50	230	29	360	-5	12.30	9.51	4.65	170	52	117	6	12.23	9.35	5.25	
694	10/07/93:1500	233	68	408	1	14.38	5.20	233	35	355	-4	12.21	9.55	4.55	168	61	83	5	12.26	9.53	5.15	
695	10/07/93:1600	233	65	390	1	14.11	5.40	233	39	358	-5	12.27	9.64	4.50	170	48	68	4	12.25	9.59	5.35	
696	10/07/93:1750	240	55	240	2	13.69	5.75	208	28	350	-4	12.26	9.57	4.65	172	49	93	10	12.07	9.36	5.50	
722	11/4/93 9:10	220	942	488	2	14.49	3.80	190	105	433	-4	13.02	9.57	3.55	183	977	433	-2	12.81	9.32	3.60	Base, A cal
723	11/4/93 11:40	210	1200	500	2	14.47	3.65	200	651	458	-4	13.43	9.77	3.10	180	681	303	-1	12.75	9.32	3.90	A feeder only
724	11/4/93 14:40	220	722	510	1	14.50	4.00	190	192	470	-4	13.21	9.70	3.50	178	450	318	-1	12.86	9.34	4.10	B feeder only
725	11/4/93 16:30	220	977	520	2	14.62	4.10	199	540	470	-3	13.30	9.81	3.20	180	870	300	-1	12.86	9.38	3.70	A&B feeders
726	11/5/93 8:00	205	1444	510	4	14.48	3.30	195	570	460	-4	13.27	9.45	3.20	184	137	463	-2	13.12	9.26	3.25	Base
727	11/5/93 9:30	213	1117	510	2	14.77	3.60	200	201	452	-4	13.06	9.31	3.60	168	916	198	0	12.94	9.14	3.75	A feeder
728	11/5/93 13:00	218	134	505	1	14.61	3.70	198	219	455	0	13.37	9.55	3.10	175	107	215	0	13.00	9.23	3.65	B feeder
729	11/5/93 14:40	228	556	495	1	14.55	3.90	203	216	445	-3	13.09	9.43	3.80	180	673	195	0	12.82	9.20	4.30	A&B feeders

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed	Na A (w)	B (e)	Injector cal Flow	$\underline{2Na}$ S*	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	$\underline{ΔNO}$ ΔSO2	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2I	$\underline{ΔNO}$ ΔSO2	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	°F	°F	°F
730	11/8/93 10:50	100	4.10	s	69	0	65.5	1.56	69	69.3	357	11.9	30	1.6	31	0.09	9.2	20	1.6	0.06	0	268	46	0.0	258	249	257	259
731	11/8/93 13:40	100	4.20	s	36	38	65.9	1.52	64	64.3	342	14.8	37	1.1	38	0.11	9.5	18	1.1	0.05	0	270	50	0.0	262	257	262	264
732	11/8/93 15:00	101	4.30	s	0	73	65.9	1.49	58	58.8	317	8.6	21	8.6	30	0.09	6.4	18	8.6	0.06	0	272	51	0.0	263	257	262	266
732	11/8/93 15:55	101	4.30	s	0	73	65.9	1.49	58	58.7	317	11.3	28	11.3	39	0.12	9.2	27	11.3	0.08	0	272	51	0.0	263	257	262	266
732	11/8/93 16:05	101	4.30	s	0	73	65.9	1.49	58	62.6	338	16.1	40	10.5	50	0.15	14.1	38	10.5	0.11	0	272	51	0.0	263	257	262	266
732	11/8/93 16:15	101	4.30	s	0	73	65.9	1.49	58	63.5	342	15.9	39	10.6	50	0.15	13.9	38	10.6	0.11	0	272	51	0.0	263	257	262	266
733	11/9/93 8:00	110	4.20	s	28	29	49.5	1.03	44	42.8	229	1.2	3	6.4	9	0.04	4.2	11	6.4	0.05	0	270	42	0.0	262	248	256	257
733	11/9/93 8:40	110	4.20	s	28	29	49.5	1.06	48	47.7	249	6.8	18	6.4	25	0.10	12.7	37	6.4	0.15	0	273	45	0.0	264	252	261	263
733	11/9/93 11:10	110	4.20	s	27	29	48.5	1.11	49	49.6	243	9.1	24	6.1	30	0.12	10.0	27	6.1	0.11	0	281	48	0.0	274	265	272	274
733	11/9/93 14:40	110	4.20	s	23	24	39.8	1.01	48	44.0	193	4.2	12	5.0	17	0.09	6.8	19	5.0	0.10	0	285	55	0.0	278	272	281	280
734	1/17/93 8:00	110	3.80	s	0	0	0.0	0.00	0	64.4	269	12.4	33	-6.6	27	0.10	-0.7	1	-6.6	0.00	0	266	58	0.0	258	247	256	
734	1/17/94 11:00	110	3.70	s	70	0	66.5	1.75	70	71.5	303	8.0	19	5.5	25	0.08	13.4	33	5.5	0.11	0	265	65	0.0	258	252	260	
734	1/17/94 14:10	111	3.50	b	0	0	0.0	0.00	0	1.1	5	0.9	2	4.4	7	1.27	0.3	-2	4.4	-0.37	0	262	62	0.0	257	246	253	
735	1/17/94 15:00	110	3.70	b	0	42	47.0	0.98	17	17.0	84	1.0	2	4.1	7	0.08	2.0	3	4.1	0.03	0	263	55	0.0	257	247	255	
735	1/17/94 17:40	111	3.70	b	0	43	48.1	0.96	25	25.7	132	3.8	9	2.4	12	0.09	3.8	8	2.4	0.06	0	258	48	0.0	252	243	251	
735	1/17/94 18:10	111	3.70	b	0	45	50.3	1.04	26	30.2	148	1.0	2	2.0	4	0.03	7.6	18	2.0	0.12	0	258	48	0.0	252	243	251	
735	1/17/94 19:05	111	3.80	b	0	43	48.1	0.98	42	42.1	210	4.8	12	4.3	16	0.08	5.9	14	4.3	0.07	0	258	46	0.0	252	244	251	
735	1/17/94 19:50	111	3.80	b	0	43	48.1	0.98	35	32.0	159	3.6	9	5.1	14	0.09	4.7	14	5.1	0.09	0	258	45	0.0	252	243	250	
735	1/17/94 20:35	111	3.80	b	0	43	48.1	0.96	25	26.3	135	4.8	12	3.2	15	0.11	3.1	8	3.2	0.06	0	258	45	0.0	252	245	249	
735	1/17/94 21:15	111	3.60	b	0	43	48.1	0.95	17	19.0	98	0.4	1	3.0	4	0.04	1.5	3	3.0	0.03	0	259	44	0.0	252	243	250	
735	1/17/94 22:05	111	3.60	b	0	45	50.3	0.96	30	28.9	154	2.6	6	4.1	10	0.07	5.4	14	4.1	0.09	0	258	43	0.0	251	243	250	
735	1/17/94 22:50	111	3.60	b	0	47	52.6	1.00	36	37.7	203	6.0	16	10.1	26	0.13	7.9	24	10.1	0.12	0	258	43	0.0	252	243	251	
735	1/17/94 23:35	111	3.70	b	0	47	52.6	0.98	45	43.6	237	9.6	25	10.9	36	0.15	8.0	27	10.9	0.11	0	258	42	0.0	252	243	251	
735	1/18/94 0:20	111	3.60	b	0	47	52.6	1.00	48	48.2	259	7.9	20	12.6	33	0.13	5.8	22	12.6	0.08	0	258	42	0.0	252	244	251	
735	1/18/94 1:20	111	3.50	b	0	47	52.6	1.00	24	27.5	148	4.6	12	6.8	18	0.12	3.8	12	6.8	0.08	0	258	41	0.0	252	244	251	
735	1/18/94 2:05	111	3.50	b	0	47	52.6	1.02	38	39.4	208	9.2	23	13.8	36	0.17	15.4	50	13.8	0.24	0	258	41	0.0	252	244	252	
735	1/18/94 2:50	111	3.40	b	0	47	52.6	1.00	43	44.9	242	6.4	16	13.3	29	0.12	9.5	34	13.3	0.14	0	257	41	0.0	251	243	251	
735	1/18/94 3:35	111	3.40	b	0	47	52.6	0.99	44	42.7	231	6.4	17	12.1	29	0.12	7.1	29	12.1	0.12	0	253	41	0.0	248	241	249	
735	1/18/94 4:15	111	3.40	b	0	47	52.6	0.99	45	44.7	242	4.2	11	11.9	23	0.09	6.6	26	11.9	0.11	0	255	40	0.0	249	241	248	
735	1/18/94 4:55	111	3.60	b	0	47	52.6	0.99	45	45.0	243	7.9	20	9.8	29	0.12	11.1	35	9.8	0.15	0	254	40	0.0	248	240	248	
735	1/18/94 6:15	111	3.40	b	0	47	52.6	1.00	23	21.8	117	4.3	11	4.2	15	0.13	5.1	15	4.2	0.13	0	254	49	0.0	248	239	246	
735	1/18/94 7:00	111	3.70	b	0	47	52.6	0.98	33	31.9	174	5.6	14	9.4	24	0.14	12.6	41	9.4	0.23	0	256	45	0.0	249	238	247	
735	1/18/94 8:00	111	3.80	b	0	47	52.6	0.99	39	39.2	211	6.6	17	7.2	24	0.11	8.0	25	7.2	0.12	0	256	48	0.0	250	238	248	
735	1/18/94 9:00	111	3.40	b	0	47	52.6	1.03	44	44.8	234	7.2	18	10.1	28	0.12	8.7	29	10.1	0.12	0	263	49	0.0	256	243	253	
735	1/18/94 10:00	111	3.70	b	0	47	52.6	1.07	22	25.4	128	1.6	4	5.3	9	0.07	2.7	9	5.3	0.07	0	276	62	0.0	269	256	264	
735	1/18/94 12:00	110	3.70	b	0	47	52.6	1.05	25	27.8	143	-1.2	-3	4.1	1	0.01	1.1	3	4.1	0.02	0	282	72	0.0	275	264	271	
735	1/18/94 14:30	109	3.80	b	0	45	50.3	1.05	41	44.4	220	5.0	13	5.5	19	0.08	7.6	28	5.5	0.13	0	279	74	0.0	273	264	270	
735	1/18/94 15:20	111	3.50	b	0	43	48.1	1.00	48	50.3	247	15.2	41	8.5	49	0.20	9.0	28	8.5	0.11	0	277	73	0.0	271	265	271	
735	1/18/94 16:20	110	3.60	b	0	43	48.1	1.03	57	56.8	273	3.6	9	8.1	17	0.06	7.9	26	8.1	0.10	0	277	68	0.0	272	265	272	
735	1/18/94 17:30	110	3.70	b	0	42	47.0	1.02	33	39.4	188	4.4	11	8.7	20	0.11	3.4	14	8.7	0.07	0	274	65	0.0	270	266	270	
735	1/18/94 18:30	111	3.60	b	0	42	47.0	1.03	52	53.5	249	9.6	26	9.2	35	0.14	8.4	29	9.2	0.12	0	276	63	0.0	270	265	270	

PSCC Arapahoe Uni
Calcs based on:

		Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							
Test	Date & Time	NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	Comments
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
730	11/8/93 10:50	215	268	442	1	13.28	5.05	209	37	423	-3	12.53	8.82	4.35	175	237	124	-1	12.22	8.85	5.00	A
731	11/8/93 13:40	210	432	480	2	13.62	4.75	210	46	441	-3	12.62	8.87	4.20	170	222	150	-2	12.32	8.64	4.95	A&B
732	11/8/93 15:00	212	603	480	3	13.70	4.90	208	113	450	-3	12.73	8.93	4.10	175	317	177	4	12.32	8.57	4.85	B, BH clean
732	11/8/93 15:55	212	603	480	3	13.70	4.90	208	113	450	-3	12.73	8.93	4.10	170	470	180	7	12.55	8.76	4.60	repeat
732	11/8/93 16:05	212	603	480	3	13.70	4.90	208	113	450	-3	12.73	8.93	4.10	162	477	164	6	12.54	8.75	4.52	repeat
732	11/8/93 16:15	212	603	480	3	13.70	4.90	208	113	450	-3	12.73	8.93	4.10	162	481	160	6	12.54	8.73	4.55	repeat
733	11/9/93 8:00	241	741	482	3	13.94	4.80	214	89	430	-3	12.35	8.79	4.68	203	602	242	2	12.33	8.63	4.95	Initial, temp test
733	11/9/93 8:40	252	677	473	2	13.80	5.10	225	92	431	-3	12.80	8.99	4.25	198	578	218	3	12.39	8.66	4.80	* before clean
733	11/9/93 11:10	241	998	446	2	14.30	4.45	226	138	417	-2	13.12	9.09	3.75	193	730	202	3	12.68	8.76	4.40	BH clean @10:53
733	11/9/93 14:40	254	546	385	2	14.07	4.70	233	91	368	-3	12.83	8.86	4.05	209	400	197	2	12.46	8.49	4.80	BH clean @~14:52
734	1/17/93 8:00	210	575	340	-9	12.33	5.45	225	189	350	-1	12.88	9.19	4.00	195	452	120	-6	12.31	9.06	4.60	Base
734	1/17/94 11:00	210	445	348	3	12.37	6.00	210	329	365	-3	12.98	9.34	3.55	178	589	98	2	12.43	8.98	4.50	Running out sc
734	1/17/94 14:10	218	622	405	2	12.92	5.60	222	186	405	-4	12.63	9.17	3.90	208	509	385	0	12.23	8.89	4.55	Base
735	1/17/94 15:00	218	697	420	1	13.05	5.60	218	192	418	-4	13.00	9.37	3.85	202	489	330	-1	12.23	8.88	4.70	Bicarb
735	1/17/94 17:40	215	672	418	1	13.01	5.55	218	222	440	-2	13.14	9.50	3.55	197	503	310	0	12.54	9.05	4.45	NOTE: 1% Econ
735	1/17/94 18:10	215	660	408	2	12.84	5.75	210	463	430	-2	13.24	9.57	3.25	193	506	281	0	12.50	8.89	4.40	O2 Leak From
735	1/17/94 19:05	211	828	425	1	13.04	5.40	212	313	432	-3	12.98	9.46	3.45	190	506	240	1	12.47	8.95	4.20	1/17/93 8:00
735	1/17/94 19:50	211	829	430	1	13.00	5.35	210	365	431	-1	13.10	9.46	3.45	189	644	280	3	12.55	9.01	4.25	Pulverizer Trip
735	1/17/94 20:35	211	877	435	2	13.10	5.40	217	256	442	-1	13.19	9.47	3.45	194	664	310	2	12.56	8.99	4.30	BH clean @ 20:30
735	1/17/94 21:15	214	799	446	2	13.02	5.35	213	236	446	-2	13.00	9.39	3.55	200	576	345	0	12.42	8.92	4.35	end clean @ 21:10
735	1/17/94 22:05	217	962	463	2	13.16	5.25	213	302	465	-2	13.16	9.46	3.35	193	739	313	2	12.40	8.92	4.30	
735	1/17/94 22:50	222	670	450	2	12.69	5.75	224	201	457	-4	12.62	9.12	3.80	191	478	269	4	12.28	8.89	4.70	
735	1/17/94 23:35	220	541	455	1	12.88	5.70	225	118	457	-3	12.74	9.22	3.95	187	573	248	6	12.32	8.89	4.60	
735	1/18/94 0:20	218	905	456	2	13.26	5.30	221	229	454	-3	12.63	9.12	3.85	185	545	225	7	12.37	8.87	4.55	
735	1/18/94 1:20	215	903	449	2	12.93	5.55	220	247	460	-2	12.85	9.27	3.65	196	672	320	4	12.38	8.89	4.35	BH cln 00:45-01:20
735	1/18/94 2:05	219	496	436	2	12.58	6.00	215	172	454	-2	12.85	9.24	3.55	175	445	262	9	12.44	8.92	4.35	
735	1/18/94 2:50	213	884	452	2	12.82	5.55	211	312	467	-1	13.08	9.44	3.40	175	468	242	10	12.31	8.82	4.45	NOTE: 1% Econ
735	1/18/94 3:35	222	803	455	2	12.94	5.60	220	192	458	0	12.88	9.28	3.80	185	368	248	10	12.19	8.70	4.75	O2 Leak From
735	1/18/94 4:15	218	555	455	1	13.02	5.80	218	266	464	-1	12.97	9.38	3.60	185	403	239	9	12.09	8.70	4.80	1/17/93 8:00
735	1/18/94 4:55	220	296	451	1	12.95	5.65	215	151	460	-2	13.03	9.32	3.70	180	294	240	7	12.34	8.83	4.60	
735	1/18/94 6:15	220	341	455	2	13.13	5.65	221	145	460	-1	13.02	9.31	3.65	196	267	339	3	12.32	8.80	4.65	BH cln 05:15-05:50
735	1/18/94 7:00	230	385	449	2	12.80	6.00	220	185	465	-1	13.00	9.27	3.75	188	183	298	6	12.35	8.83	4.75	
735	1/18/94 8:00	217	568	462	1	13.17	5.50	218	242	470	-1	13.11	9.39	3.35	185	285	268	5	12.43	8.83	4.45	
735	1/18/94 9:00	220	691	445	1	13.03	5.35	215	276	445	-2	12.88	9.26	3.70	183	507	235	7	12.25	8.81	4.45	
735	1/18/94 10:00	218	786	437	1	13.10	5.45	217	242	431	-2	12.87	9.12	3.60	197	486	303	3	12.19	8.62	4.60	BH cln 09:35-10:00
735	1/18/94 12:00	220	691	428	1	12.75	5.70	215	76	431	-2	12.76	9.17	4.00	205	456	298	1	12.20	8.63	4.75	
735	1/18/94 14:30	225	447	405	1	12.74	6.00	222	176	422	3	12.97	9.18	3.75	195	496	222	7	12.24	8.59	4.70	BH cln 12:50-13:25
735	1/18/94 15:20	211	571	410	1	12.87	5.75	228	109	415	-1	12.71	9.07	3.90	178	464	197	6	12.44	8.75	4.65	
735	1/18/94 16:20	220	645	410	1	12.88	5.70	212	158	408	-1	12.96	9.18	3.80	187	359	167	5	12.39	8.73	4.70	
735	1/18/94 17:30	212	610	393	1	12.98	5.70	217	164	405	-2	13.07	9.27	3.75	190	437	233	6	12.32	8.68	4.65	BH cln 16:55-17:30
735	1/18/94 18:30	220	539	385	1	12.75	5.85	227	84	395	-1	12.93	9.10	3.80	188	323	175	7	12.42	8.66	4.62	

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na/S	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO/ΔSO2	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2I	ΔNO/ΔSO2	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	°F	°F	°F
735	1/18/94 19:35	111	3.60	b	0	41	45.9	1.01	52	51.8	240	10.0	24	2.1	26	0.11	9.3	21	2.1	0.09	0	277	63	0.0	271	264	271	
735	1/18/94 20:35	111	3.60	b	0	41	45.9	1.02	56	56.1	257	6.1	16	4.9	21	0.08	6.9	19	4.9	0.07	0	276	62	0.0	270	264	269	
735	1/18/94 21:20	111	3.60	b	0	41	45.9	1.04	32	25.9	117	0.9	2	1.9	4	0.04	2.8	7	1.9	0.06	0	277	63	0.0	271	264	269	
735	1/18/94 22:20	111	3.80	b	0	41	45.9	1.05	46	48.4	216	5.5	14	5.8	20	0.09	8.8	26	5.8	0.12	0	277	63	0.0	271	264	270	
735	1/18/94 23:15	111	3.40	b	0	39	43.7	1.01	55	55.1	244	8.9	24	7.0	31	0.13	11.8	37	7.0	0.15	0	276	61	0.0	271	265	271	
735	1/19/94 0:05	111	3.80	b	0	39	43.7	1.02	55	54.6	237	7.8	21	7.8	29	0.12	4.1	17	7.8	0.07	0	272	62	0.0	267	262	268	
735	1/19/94 0:35	111	3.50	b	0	39	43.7	1.02	52	52.7	230	1.7	4	9.2	14	0.06	1.7	10	9.2	0.05	0	271	61	0.0	265	264	265	
735	1/19/94 1:10	111	3.50	b	0	39	43.7	1.03	20	20.1	87	5.7	15	2.1	17	0.20	6.9	16	2.1	0.18	0	271	61	0.0	266	259	265	
735	1/19/94 4:35	111	3.60	b	0	38	42.6	0.99	40	46.3	203	17.6	46	1.9	48	0.23	17.3	41	1.9	0.20	0	269	61	0.0	264	258	260	
735	1/19/94 5:15	111	3.70	b	0	38	42.6	0.99	14	15.3	67	1.5	4	3.5	7	0.11	-0.3	-2	3.5	-0.03	0	268	61	0.0	263	256	261	
735	1/19/94 6:10	111	3.70	b	0	38	42.6	1.00	25	14.8	65	4.7	12	2.1	14	0.22	0.6	0	2.1	0.00	0	262	65	0.0	258	252	257	
735	1/19/94 7:10	112	3.60	b	0	38	42.6	0.96	17	18.3	82	8.0	20	1.1	21	0.26	7.0	17	1.1	0.20	0	263	66	0.0	257	249	256	
735	1/19/94 8:10	111	3.70	b	0	38	42.6	0.97	20	19.1	86	5.2	13	2.3	16	0.18	5.1	12	2.3	0.14	0	266	71	0.0	260	250	258	
735	1/19/94 9:00	111	3.70	b	0	38	42.6	0.97	8	10.1	45	2.9	7	1.9	9	0.21	-1.1	-4	1.9	-0.08	0	269	73	0.0	262	253	260	
735	1/19/94 10:10	111	3.70	b	0	38	42.6	0.97	20	18.5	83	7.4	19	1.8	21	0.25	4.9	11	1.8	0.13	0	274	73	0.0	268	257	265	
735	1/19/94 11:10	111	3.50	b	0	39	43.7	0.99	25	25.7	115	5.9	15	1.8	17	0.15	1.3	2	1.8	0.02	0	275	76	0.0	269	260		
735	1/19/94 12:10	111	3.80	b	0	39	43.7	0.99	37	38.6	175	3.2	8	2.5	10	0.06	8.8	22	2.5	0.13	0	276	77	0.0	270	260	268	
735	1/19/94 13:00	110	3.90	b	0	39	43.7	0.99	22	29.3	133	2.7	7	3.3	10	0.08	7.2	18	3.3	0.14	0	275	78	0.0	269	262	267	
735	1/19/94 13:40	111	3.70	b	0	39	43.7	0.98	42	46.3	210	7.9	21	3.4	24	0.11	5.4	15	3.4	0.07	0	274	74	0.0	268	261	267	
735	1/19/94 14:10	111	3.70	b	0	39	43.7	0.98	54	56.6	257	10.7	27	6.3	34	0.13	9.0	27	6.3	0.10	0	274	77	0.0	269	262	268	
735	1/19/94 14:40	110	3.90	b	0	40	44.8	1.03	60	62.9	281	11.3	29	8.5	38	0.13	10.0	31	8.5	0.11	0	275	78	0.0	269	263	268	
735	1/19/94 15:10	110	3.70	b	0	40	44.8	1.01	66	67.2	307	7.0	17	9.0	26	0.09	13.7	43	9.0	0.14	0	275	74	0.0	270	264	269	
735	1/19/94 15:50	111	3.60	b	0	40	44.8	1.00	70	71.2	326	13.2	33	9.1	42	0.13	17.5	52	9.1	0.16	0	274		0.0		263		
735	1/19/94 16:00	111		b	0	40	44.8	1.01	71	72.2	325	9.0	23	8.7	31	0.10	15.2	47	8.7	0.14	0	274	72	0.0	269		269	
735	1/19/94 16:10	111		b	0	40	44.8	1.00	72	72.2	329	10.6	27	8.5	35	0.11	12.1	37	8.5	0.11	0			0.0			269	
735	1/19/94 17:00	111	3.70	b	0	40	44.8	1.00	51	54.8	251	6.5	17	13.7	30	0.12	11.6	42	13.7	0.17	0	274	69	0.0	267	264	268	
735	1/19/94 18:40	111	3.80	b	0	40	44.8	1.01	54	56.0	252	7.9	21	4.6	25	0.10	12.7	37	4.6	0.15	0	272	66	0.0	266	261	267	
735	1/19/94 19:40	111	3.80	b	0	40	44.8	1.01	64	64.1	290	11.4	30	6.0	36	0.12	11.8	34	6.0	0.12	0	272	64	0.0	265	260	266	
735	1/19/94 20:35	111	3.60	b	0	40	44.8	1.03	67	64.9	287	5.8	15	6.4	21	0.07	7.9	24	6.4	0.08	0	266	62	0.0	261	259	261	
736	1/19/94 21:10	100	3.80	b	36	0	42.4	1.11	31	30.6	132	-8.6	-20	6.1	-14	-0.11	-2.7	-4	6.1	-0.03	0	262	60	0.0	256	253	257	
736	1/19/94 22:10	100	3.70	b	34	0	40.1	1.02	59	60.4	269	9.4	22	14.8	37	0.14	13.3	45	14.8	0.17	0	255	58	0.0	249	246	252	
736	1/19/94 23:10	100	3.90	b	34	0	40.1	1.05	63	63.2	272	-2.1	-4	12.2	8	0.03	6.8	26	12.2	0.09	0	252	56	0.0	246	241	247	
736	1/20/94 0:10	100	3.90	b	34	0	40.1	1.04	48	49.8	218	8.9	22	6.6	28	0.13	8.6	24	6.6	0.11	0	253	54	0.0	246	239	246	
736	1/20/94 1:10	100	3.80	b	34	0	40.1	1.05	54	53.8	232	6.1	14	7.7	22	0.09	11.2	32	7.7	0.14	0	253	52	0.0	245	237	245	
736	1/20/94 2:10	100	3.90	b	34	0	40.1	1.05	52	52.8	229	9.9	24	6.6	31	0.13	7.4	21	6.6	0.09	0	252	50	0.0	245	237	245	
736	1/20/94 3:10	100	3.70	b	34	0	40.1	1.06	46	41.1	175	1.1	2	6.3	9	0.05	3.7	11	6.3	0.06	0	251	50	0.0	244	236	242	
736	1/20/94 3:55	100	3.80	b	34	0	40.1	1.07	28	26.4	112	-0.3	-1	6.5	6	0.05	5.6	17	6.5	0.15	0	250	49	0.0	243	236	242	
736	1/20/94 5:10	100	4.00	b	34	0	40.1	1.05	42	44.4	191	0.2	0	9.9	10	0.05	7.8	26	9.9	0.14	0	249	48	0.0	242	233	240	
736	1/20/94 6:10	100	3.90	b	34	0	40.1	1.06	43	48.2	206	6.5	16	11.9	27	0.13	12.0	39	11.9	0.19	0	248	52	0.0	241	232	240	
736	1/20/94 6:50	100	4.00	b	34	0	40.1	1.04	48	48.7	212	-19.3	-48	13.4	-34	-0.16	-16.7	-32	13.4	-0.15	0	241	59	0.0	242	233	241	
737	1/20/94 7:50	111	4.20	b	40	0	47.1	1.11	47	47.3	205	3.4	9	13.6	23	0.11	4.8	24	13.6	0.12	0	257	59	0.0	251	238	248	

PSCC Arapahoe Uni
Calcs based on:

		Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							
Test	Date & Time	NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	Comments
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
735	1/18/94 19:35	208	759	395	1	13.11	5.20	209	164	400	-1	13.31	9.41	3.45	180	582	186	0	12.66	8.90	4.10	
735	1/18/94 20:35	217	577	380	2	12.69	5.75	221	122	393	-2	13.06	9.17	3.65	192	441	163	2	12.53	8.77	4.60	
735	1/18/94 21:20	221	506	370	1	13.02	5.65	220	139	385	-1	13.03	9.14	3.65	205	583	270	1	12.54	8.75	4.55	BH cln 20:45-21:20
735	1/18/94 22:20	222	617	378	1	12.77	5.70	220	180	385	-1	13.22	9.31	3.50	190	347	186	3	12.26	8.58	4.65	
735	1/18/94 23:15	225	559	360	1	12.79	6.10	225	103	375	-1	12.89	9.07	3.85	189	139	160	5	12.46	8.70	4.70	NOTE: 1% Econ
735	1/19/94 0:05	220	760	365	1	12.97	5.85	230	89	365	-1	12.99	8.99	4.00	196	400	158	6	12.34	8.49	4.80	O2 Leak From
735	1/19/94 0:35	215	523	360	1	12.49	5.75	220	90	373	-2	12.92	8.98	3.70	195	324	165	6	12.18	8.46	4.80	1/17/93 8:00
735	1/19/94 1:10	225	658	370	2	12.49	5.75	226	86	365	-2	12.84	8.91	3.90	203	407	280	0	12.23	8.44	4.60	BH cln 00:35-01:10
735	1/19/94 4:35	215	553	360	3	12.85	5.85	220	65	368	-2	12.76	8.89	4.00	195		214				4.60	
735	1/19/94 5:15	215	323	355	2	12.44	5.95	225	73	369	-2	12.64	8.81	3.95	208	276	297	1	12.23	8.34	4.80	BH cln 04:40-05:15
735	1/19/94 6:10	210	538	372	2	12.85	5.50	219	81	370	-1	12.79	8.82	3.85	199	426	303	1	12.34	8.54	4.50	
735	1/19/94 7:10	215	491	373	1	12.86	5.60	218	93	380	-1	12.88	8.94	3.80	193	501	300	0	12.40	8.55	4.40	
735	1/19/94 8:10	215	711	372	1	12.90	5.65	217	119	380	-2	12.89	8.91	3.85	197	517	297	0	12.38	8.48	4.45	
735	1/19/94 9:00	212	850	380	1	13.02	5.30	218	123	380	-2	12.98	8.96	3.80	203	599	330	0	12.42	8.56	4.40	BH cln 08:25-09:00
735	1/19/94 10:10	210	708	373	1	12.75	5.70	218	101	380	-2	12.74	8.74	3.90	195	506	301	0	12.47	8.58	4.35	
735	1/19/94 11:10	210	769	380	1	13.08	5.40	217	85	378	-2	12.74	8.67	4.00	195	487	270	0	12.24	8.35	4.65	
735	1/19/94 12:10	218	416	378	1	12.93	5.85	212	130	388	-2	13.15	9.09	3.65	192	318	225	0	12.57	8.60	4.60	BH cln 12:20-12:55
735	1/19/94 13:00	217	273	372	1	12.70	6.10	212	73	380	-2	12.75	8.92	4.10	197	241	260	1	12.46	8.64	4.65	
735	1/19/94 13:40	210	245	378	1	12.79	6.00	220	66	382	-1	12.99	9.03	3.95	190	194	195	2	12.32	8.53	4.80	
735	1/19/94 14:10	213	424	377	1	12.99	5.75	217	76	382	-1	12.83	8.98	4.00	182	249	160	4	12.59	8.69	4.60	
735	1/19/94 14:40	215	488	380	1	12.94	5.65	220	73	380	-2	13.02	9.06	3.80	180	296	135	6	12.42	8.62	4.55	NOTE: 1% Econ
735	1/19/94 15:10	220	382	372	1	12.80	6.10	213	101	390	-1	13.02	9.13	3.70	180	367	121	6	12.47	8.62	4.65	O2 Leak From
735	1/19/94 15:50	220	382	372	1	12.80	6.10	215	88	385	-2	12.82	8.99	4.00	173	299	107	5	12.51	8.68	4.60	1/17/93 8:00
735	1/19/94 16:00	220	382	372	1	12.80	6.10	212	95	382	-1	12.95	9.07	3.85	178	302	102	6	12.53	8.69	4.55	
735	1/19/94 16:10	218	467	380	1	12.97	5.80	218	91	387	-1	12.96	9.07	3.80	178	277	102	6	12.47	8.60	4.70	
735	1/19/94 17:00	220	443	373	1	12.65	6.15	215	107	385	-1	12.84	9.02	3.95	182	293	167	10	12.33	8.55	4.65	BH cln 16:25-16:55
735	1/19/94 18:40	222	261	360	2	12.63	6.35	220	122	380	-1	13.02	9.17	3.90	190	280	160	3	12.35	8.55	4.70	
735	1/19/94 19:40	220	255	375	2	12.93	5.90	225	68	386	-1	13.06	9.13	3.75	185	200	132	4	12.35	8.61	4.60	
735	1/19/94 20:35	220	356	372	1	13.11	5.80	220	104	378	-1	13.12	9.27	3.70	190	284	125	4	12.48	8.79	4.70	
736	1/19/94 21:10	205	229	369	2	12.68	6.25	200	68	360	-1	12.55	8.99	4.10	195	198	230	4	12.12	8.52	5.40	BH cln 20:35-21:10
736	1/19/94 22:10	207	274	369	1	12.92	6.05	200	56	369	-1	12.78	9.06	4.20	162	278	140	10	12.35	8.72	4.90	
736	1/19/94 23:10	197	354	370	2	13.01	5.90	184	133	365	-1	12.95	9.22	3.80	165	133	125	9	12.15	8.59	5.00	
736	1/20/94 0:10	201	310	368	2	13.16	6.00	207	84	369	-1	13.04	9.29	3.90	173	182	175	4	12.33	8.76	4.85	
736	1/20/94 1:10	201	210	365	2	12.85	6.15	200	108	369	-1	13.12	9.26	3.65	169	189	159	5	12.44	8.74	4.80	
736	1/20/94 2:10	199	296	365	2	13.13	5.90	205	84	360	-1	12.82	9.08	4.15	171	214	162	4	12.54	8.83	4.90	
736	1/20/94 3:10	205	501	380	2	13.89	5.00	194	125	362	-2	13.02	9.16	3.80	175	241	200	3	12.42	8.69	4.85	O2 Leak Fixed
736	1/20/94 3:55	215	260	375	2	13.55	5.25	196	73	355	-1	12.78	8.95	4.10	180	173	246	4	12.26	8.57	5.05	
736	1/20/94 5:10	215	200	375	2	13.73	5.10	190	119	360	-1	13.07	9.18	4.05	172	152	190	7	12.32	8.58	4.95	
736	1/20/94 6:10	221	223	372	2	13.50	5.30	202	88	358	-1	12.88	9.05	4.05	169	209	175	9	12.16	8.55	5.00	
736	1/20/94 6:50	220	167	381	2	13.64	5.15	205	75	360	-1	12.88	9.16	4.20	220	213	174	9	12.35	8.68	5.15	
737	1/20/94 7:50	240	87	380	2	13.79	5.30	225	48	355	-1	12.83	9.01	4.35	195	124	177	10	12.20	8.55	5.25	

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	$\underline{2Na}$ S*	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	$\frac{\Delta NO}{\Delta SO_2}$	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2	$\frac{\Delta NO}{\Delta SO_2}$	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min		%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc		scfm	°F	°F	gpm	°F	°F	°F	°F
737	1/20/94 10:40	111	4.20	b	29	0	34.2	0.83	32	32.4	136	-1.3	-4	13.1	10	0.07	5.4	24	13.1	0.18	0	260	63	0.0	253	241	250	
737	1/20/94 11:10	111	4.20	b	29	0	34.2	0.85	33	34.1	141	0.4	1	12.2	13	0.09	6.4	27	12.2	0.19	0	261	66	0.0	254	243	252	
737	1/20/94 11:50	111	4.20	b	28	0	33.1	0.83	35	34.7	140	-2.0	-6	13.1	8	0.05	-5.1	-4	13.1	-0.03	0	264	66	0.0	257	246	254	
737	1/20/94 13:00	111	4.40	b	28	0	33.1	0.84	38	38.5	154	1.0	3	10.7	13	0.09	6.7	27	10.7	0.17	0	268	71	0.0	261	251	258	
737	1/20/94 13:25	111	4.10	b	28	0	33.1	0.88	38	36.1	139	-1.2	-3	10.4	7	0.05	1.9	14	10.4	0.10	0	269	70	0.0	261	255	259	
737	1/20/94 14:15	111	4.30	b	0	34	38.2	1.00	8	7.2	28	-2.4	-7	3.0	-4	-0.13	2.2	6	3.0	0.22	0	270	73	0.0	263	254	260	
737	1/20/94 15:00	111	4.40	b	0	34	38.2	1.00	19	19.2	75	-4.7	-13	2.9	-10	-0.13	1.4	4	2.9	0.05	0	271	68	0.0	264	256	262	
737	1/20/94 15:40	111	4.20	b	0	34	38.2	1.00	25	28.0	109	-3.3	-9	5.4	-4	-0.03	6.4	21	5.4	0.19	0	272	65	0.0	265	257	262	
737	1/20/94 16:10	111	4.30	b	0	34	38.2	1.00	31	35.1	137	0.8	2	7.0	9	0.07	8.9	31	7.0	0.22	0	272	63	0.0	266	258	263	
737	1/20/94 16:50	111	4.20	b	0	34	38.2	1.00	43	44.1	171	5.6	16	8.0	24	0.14	6.6	24	8.0	0.14	0	272	61	0.0	265	258	264	
737	1/20/94 18:40	111	4.20	b	0	34	38.2	1.02	57	58.3	222	27.3	76	14.4	90	0.41	27.1	86	14.4	0.39	0	264	57	0.0	258	257	258	
737	1/20/94 19:20	111	4.10	b	0	34	38.2	1.02	37	38.2	146	1.0	3	18.5	21	0.15	5.1	27	18.5	0.19	0	262	56	0.0	256	253	257	
737	1/20/94 20:20	111	4.20	b	0	34	38.2	1.00	35	37.9	148	2.8	8	8.2	16	0.11	8.6	31	8.2	0.21	0	268	55	0.0	261	252	259	
737	1/20/94 21:20	111	3.90	b	0	34	38.2	1.01	47	49.4	190	3.7	9	8.7	18	0.10	7.0	25	8.7	0.13	0	267	53	0.0	260	252	259	
737	1/20/94 22:20	111	3.70	b	0	34	38.2	1.02	52	53.3	203	4.7	12	10.1	22	0.11	8.3	28	10.1	0.14	0	266	52	0.0	260	252	259	
737	1/20/94 23:20	111	3.70	b	0	34	38.2	1.03	57	55.5	209	7.1	18	7.8	26	0.12	9.4	29	7.8	0.14	0	267	51	0.0	261	251	260	
737	1/21/94 0:15	111	3.70	b	0	34	38.2	1.03	30	31.0	117	7.6	20	5.4	26	0.22	6.1	19	5.4	0.16	0	264	51	0.0	258	250	257	
737	1/21/94 1:15	111	3.60	b	0	34	38.2	1.05	46	47.5	176	5.8	15	10.4	25	0.14	7.7	29	10.4	0.16	0	264	50	0.0	258	249	257	
737	1/21/94 2:15	111	3.70	b	0	33	37.1	1.02	51	50.0	186	4.4	11	9.2	21	0.11	2.7	13	9.2	0.07	0	264	49	0.0	258	249	256	
737	1/21/94 3:15	111	3.80	b	0	33	37.1	1.03	53	52.3	192	4.0	10	8.8	19	0.10	3.5	14	8.8	0.07	0	264	48	0.0	258	249	256	
737	1/21/94 4:05	111	3.70	b	0	33	37.1	1.02	53	51.4	190	6.1	16	6.4	22	0.12	3.4	12	6.4	0.06	0	264	48	0.0	258	251	255	
737	1/21/94 4:40	111	3.70	b	0	33	37.1	1.00	20	20.9	79	1.1	3	2.1	5	0.06	4.6	13	2.1	0.16	0	265	49	0.0	258	249	255	
737	1/21/94 5:40	111	3.70	b	0	33	37.1	1.01	33	32.9	123	1.7	4	6.0	10	0.08	2.0	7	6.0	0.06	0	265	48	0.0	258	248	256	
737	1/21/94 7:00	111	3.80	b	0	33	37.1	1.01	33	35.5	132	2.4	6	5.1	11	0.08	4.6	14	5.1	0.11	0	265	57	0.0	259	248	257	
737	1/21/94 9:00	112	3.70	b	28	0	33.1	0.86	15	17.9	69	2.0	5	2.2	7	0.10	1.3	2	2.2	0.02	0	268	64	0.0	261	248	257	
737	1/21/94 10:10	111	3.80	b	26	0	30.7	0.82	20	22.1	84	0.6	1	3.2	5	0.06	2.2	5	3.2	0.06	0	272	70	0.0	264	252	260	
737	1/21/94 11:25	111	3.90	b	26	0	30.7	0.83	25	34.9	132	14.2	37	1.1	38	0.29	17.0	44	1.1	0.33	0	278	74	0.0	270	261	265	
737	1/21/94 12:05	111	3.70	b	0	33	37.1	1.01	22	21.4	80	0.8	2	3.7	6	0.07	3.9	10	3.7	0.13	0	281	74	0.0	272	262	269	
737	1/21/94 13:05	111	3.70	b	0	33	37.1	1.02	43	46.7	173	6.1	16	6.5	22	0.13	7.7	24	6.5	0.14	0	283	76	0.0	275	265	272	
737	1/21/94 14:05	111	3.60	b	0	33	37.1	1.04	66	68.5	249	5.4	13	12.3	26	0.10	10.1	34	12.3	0.14	0	285	77	0.0	278	269	276	
737	1/21/94 14:40	111	3.70	b	0	32	35.9	1.02	75	76.6	275	6.4	16	13.7	29	0.11	8.8	33	13.7	0.12	0	286	76	0.0	279	271	277	
737	1/21/94 15:25	111	3.70	b	0	32	35.9	1.01	81	80.2	290	15.6	41	14.2	55	0.19	13.9	47	14.2	0.16	0	287	71	0.0	281	276	279	
737	1/21/94 16:10	112	3.60	b	0	32	35.9	0.98	57	59.6	220	2.3	6	18.6	24	0.11	5.9	31	18.6	0.14	0	287	70	0.0	281	275	280	

see NaSum763

PSCC Arapahoe Uni
Calcs based on:

Test	Date & Time	Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							Comments
		NO	CO	SO_2	NO_2	CO_2	O_2	NO	CO	SO_2	NO_2	CO_2	H_2O	O_2	NO	CO	SO_2	NO_2	CO_2	H_2O	O_2	
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
737	1/20/94 10:40	247	149	350	2	13.47	5.60	223	49	342	-2	12.59	8.91	4.50	203	115	218	8	12.12	8.57	5.40	BH cln 8:45-9:15
737	1/20/94 11:10	247	183	359	2	13.66	5.45	223	54	338	-1	12.75	9.02	4.35	200	112	210	8	12.08	8.52	5.30	
737	1/20/94 11:50	227	96	352	2	13.48	5.65	227	50	330	-1	12.72	9.10	4.40	205	77	200	9	11.86	8.40	5.60	
737	1/20/94 13:00	252	124	342	2	13.36	5.50	230	57	330	-1	12.84	9.15	4.25	205	109	190	7	12.18	8.63	5.30	
737	1/20/94 13:25	250	117	340	2	13.47	5.40	233	46	318	0	12.87	9.17	4.20	210	103	188	8	12.07	8.54	5.45	BH cln 13:40-14:10
737	1/20/94 14:15	248	165	337	2	13.70	5.20	225	84	320	-1	12.70	9.08	4.25	215	141	280	1	12.13	8.57	5.20	
737	1/20/94 15:00	250	122	338	2	13.49	5.50	227	53	320	-1	12.68	8.99	4.35	220	89	242	1	12.02	8.52	5.40	
737	1/20/94 15:40	252	94	330	1	13.40	5.60	222	67	320	-1	12.78	9.04	4.30	210	94	215	3	11.99	8.48	5.40	
737	1/20/94 16:10	260	62	322	2	13.18	5.70	232	50	318	-2	12.65	8.96	4.45	212	78	195	4	12.00	8.51	5.35	
737	1/20/94 16:50	243	131	338	2	13.54	5.40	232	47	321	-1	12.82	9.08	4.20	199	80	168	6	12.09	8.58	5.25	
737	1/20/94 18:40	240	117	330	2	13.63	5.30	228	61	311	-1	12.66	9.07	4.40	145	79	122	10	11.96	8.45	5.40	
737	1/20/94 19:20	245	140	338	2	13.84	5.30	225	55	312	-3	12.27	8.84	4.40	195	150	181	12	12.35	8.82	5.30	BH cln 18:45-19:20
737	1/20/94 20:20	251	170	339	2	13.64	5.40	222	39	315	0	12.43	9.03	4.55	201	126	188	7	12.10	8.60	5.20	Steam Coil to Max
737	1/20/94 21:20	239	265	349	2	14.15	4.65	218	163	327	0	13.21	9.43	3.70	192	232	157	7	12.65	8.94	4.60	Drop CR O2 to 3.7%
737	1/20/94 22:20	238	280	345	2	13.99	4.80	220	95	324	-2	13.11	9.33	3.75	190	178	143	6	12.48	8.82	4.70	
737	1/20/94 23:20	237	232	347	2	14.06	4.60	217	78	318	-1	13.00	9.24	3.85	186	234	135	6	12.45	8.79	4.65	
737	1/21/94 0:15	237	357	340	2	14.16	4.65	226	85	319	0	13.04	9.20	3.85	195	229	210	4	12.30	8.69	4.65	BH cln 23:40-00:15
737	1/21/94 1:15	240	270	338	2	13.94	4.70	223	71	315	0	13.04	9.16	3.75	190	162	156	8	12.44	8.73	4.70	
737	1/21/94 2:15	230	601	339	2	14.45	4.45	219	110	316	-1	13.19	9.23	3.75	190	297	149	7	12.62	8.87	4.70	
737	1/21/94 3:15	230	545	339	2	14.06	4.50	217	115	311	-2	13.03	9.17	3.80	191	225	141	6	12.50	8.74	4.65	
737	1/21/94 4:05	229	532	340	2	14.13	4.40	219	111	313	-1	13.01	9.09	3.85	191	269	145	4	12.47	8.67	4.65	
737	1/21/94 4:40	242	315	336	1	13.95	4.55	215	111	315	0	13.26	9.21	4.00	203	345	240	2	12.70	8.78	4.65	BH cln 04:05-04:40
737	1/21/94 5:40	230	525	342	2	14.29	4.30	214	111	320	-1	13.20	9.19	3.70	195	448	204	4	12.75	8.83	4.55	
737	1/21/94 7:00	235	464	340	2	14.17	4.55	218	136	320	-1	13.28	9.24	3.60	197	459	195	4	12.64	8.75	4.55	
737	1/21/94 9:00	230	553	352	2	14.19	4.45	212	147	320	-1	12.76	8.98	4.20	200	371	255	1	12.36	8.67	4.70	BH cln 07:50-08:25
737	1/21/94 10:10	238	505	240	2	14.05	4.65	218	108	317	-1	12.88	9.03	4.10	208	356	240	1	12.46	8.70	4.60	BagCal @ 10:30
737	1/21/94 11:25	240	433	330	2	14.04	4.80	218	132	315	-1	13.23	9.29	4.00	200		220				4.85	gave 29.3lb/minl
737	1/21/94 12:05	240	442	337	2	14.12	4.80	220	62	315	-1	12.88	9.04	4.00	205	272	236	2	12.34	8.62	4.80	
737	1/21/94 13:05	235	367	339	2	14.08	4.60	218	99	315	-1	13.08	9.24	3.75	190	378	160	5	12.59	8.82	4.55	BagCal=40.3lb/min
737	1/21/94 14:05	230	573	335	2	14.06	4.70	210	213	311	-2	12.91	9.13	3.70	177	409	92	8	12.43	8.73	4.70	
737	1/21/94 14:40	230	544	335	2	14.25	4.40	213	156	311	-1	13.06	9.19	3.50	175	326	68	10	12.44	8.69	4.65	
737	1/21/94 15:25	235	549	335	2	14.18	4.50	222	64	303	-1	12.85	9.07	4.00	170	389	58	10	12.58	8.78	4.55	BH cln 15:35-16:05
737	1/21/94 16:10	238	324	330	1	14.04	4.75	218	121	313	-2	12.88	9.03	3.85	187	310	120	13	12.18	8.53	4.75	

see NaSum763

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na	SO2 ppmc	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO/ΔSO2	Economizer NO Calc - - - ΔNOx	ΔNO	ΔNO2I	ΔNO/ΔSO2	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin
		MWe	%wet	b/s	%	%	lb/min	S*	dry	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	°F	°F
763	1/31/94 8:45	109	4.52	b	0	0	0.0	0.00	408	0	2.0	8	-0.7	-2	2.9	1	0.13	5.9	10	2.9	1.25	0	247	39	0.0	244	223	235
763	1/31/94 10:05	109	4.51	b	34	0	40.1	1.03	404	9	9.6	39	-11.6	-31	3.1	-28	-0.72	-6.9	-25	3.1	-0.64	0	248	40	0.0	244	228	238
763	1/31/94 11:05	109	4.00	b	33	0	38.9	0.99	408	15	14.2	58	-3.7	-10	3.7	-6	-0.11	0.4	-4	3.7	-0.07	0	254	49	0.0	248	231	242
763	1/31/94 14:30	100	4.40	b	33	0	38.9	0.94	467	33	41.9	196	5.0	14	10.2	25	0.13	6.0	22	10.2	0.11	0	253	51	0.0	246	234	243
763	1/31/94 15:40	100	4.40	b	33	0	38.9	0.98	449	50	48.6	218	3.2	9	12.1	21	0.10	7.0	31	12.1	0.14	0	253	51	0.0	247	236	245
763	1/31/94 16:43	100	4.40	b	33	0	38.9	1.01	436	57	55.2	241	7.4	21	15.0	36	0.15		-245	15.0	-1.02	0	253		0.0	247	237	246
763	1/31/94 17:30	110	4.20	b	33	0	38.9	1.15	348	52	51.9	181	7.5	20	18.5	39	0.22		-235	18.5	-1.30	0	257		0.0	253	243	
763	1/31/94 18:15	109	3.90	b	33	0	38.9	1.25	324	79	77.9	253	-15.8	-40	29.6	-10	-0.04	4.5	36	29.6	0.14	0	258		0.0	253	243	251
763	1/31/94 19:15	110	4.10	b	27	0	31.9	1.01	324	92	90.6	294	-14.5	-36	34.6	-2	-0.01	-1.4	27	34.6	0.09	0	256		0.0	252	243	251
763	1/31/94 21:20	100	4.45	b	27	0	31.9	0.90	400	72	68.1	272	7.5	20	18.3	39	0.14	15.5	60	18.3	0.22	0	245	35	0.0	239	232	241
763	1/31/94 22:20	100	4.15	b	30	0	35.4	1.01	399	61	62.0	247	10.4	30	21.2	51	0.21	16.5	65	21.2	0.26	0	245	34	0.0	239	229	239
763	1/31/94 23:05	75	5.90	b	23	0	27.2	1.02	395	64	67.9	268	5.3	15	22.8	38	0.14	8.7	45	22.8	0.17	0	238	33	0.0	233	225	233
763	2/1/94 0:05	75	5.94	b	23	0	27.2	1.00	402	73	78.7	316	14.0	42	24.7	67	0.21	16.9	73	24.7	0.23	0	236	33	0.0	230	220	230
763	2/1/94 1:05	75	5.99	b	23	0	27.2	0.97	413	82	86.0	355	15.7	47	26.4	73	0.21	16.1	75	26.4	0.21	0	236	34	0.0	231	218	229
763	2/1/94 1:45	75	5.93	b	23	0	27.2	1.03	391	84	84.9	332	17.7	51		51	0.15	20.8	60	0.0	0.18	0	241	35	0.0	234	220	231
763	2/1/94 2:45	50	7.75	b	20	0	23.7	1.32	380	88	89.4	339	1.7	5	34.9	40	0.12	9.7	60	34.9	0.18	0	234	36	0.0	228	218	228
763	2/1/94 3:45	50	7.89	b	20	0	23.7	1.32	379	91	90.6	344	7.4	21	36.5	57	0.17	13.9	74	36.5	0.21	0	232	37	0.0	226	215	224
763	2/1/94 4:40	50	7.88	b	20	0	23.7	1.33	376	89	88.4	333	9.9	28	36.4	64	0.19	12.6	70	36.4	0.21	0	233	37	0.0	226	214	224
763	2/1/94 6:10	105	4.15	b	24	0	28.4	0.99	308	57	74.2	228	3.7	11	37.7	49	0.21	9.4	64	37.7	0.28	0	248	34	0.0	242	228	239
763	2/1/94 7:05	105	4.56	b	24	0	28.4	1.00	307	82	84.4	259	2.9	8	38.4	46	0.18	14.7	80	38.4	0.31	0	248	45	0.0	244	231	241
763	2/1/94 8:44	105	4.40	b	24	0	28.4	1.03	297	79	78.3	233	-11.9	-30	32.0	2	0.01	9.7	58	32.0	0.25	0	257		0.0	251	237	247
763	2/1/94 9:50	99	4.50	b	24	0	28.4	0.85	381	55	54.9	209	-2.7	-8	27.3	20	0.09	4.2	35	27.3	0.17	0	255		0.0	248	237	246
763	2/1/94 11:04	99	4.60	b	28	0	33.1	0.97	390	58	59.8	233	4.1	11	21.0	32	0.14	10.4	48	21.0	0.21	0	256		0.0	250	236	247
763	2/1/94 12:10	99	4.40	b	28	0	33.1	0.98	386	61	60.8	235	1.0	3	19.0	22	0.09	7.5	36	19.0	0.16	0	256		0.0	250	239	248
763	2/1/94 13:15	99	4.40	b	29	0	33.9	1.02	380	66	64.6	246	-2.3	-6	16.7	10	0.04	9.8	40	16.7	0.16	0	257		0.0	250	240	248
763	2/1/94 14:20	99	4.50	b	29	0	33.9	0.98	394	69	67.5	266	-6.8	-17	17.3	0	0.00	8.6	37	17.3	0.14	0	256		0.0	248	239	248
763	2/1/94 15:20	99	4.40	b	29	0	33.9	1.01	384	69	55.1	212	15.2	47	11.6	59	0.28	12.3	43	11.6	0.20	0	256		0.0	249	242	246
763	2/1/94 16:10	99	4.10	b	29	0	33.9	0.99	391	45	62.4	244	9.8	27	23.5	50	0.21	17.9	73	23.5	0.30	0	255		0.0	249	240	248
763	2/1/94 16:45	99	4.50	b	29	0	33.9	0.96	403	62	63.4	256	3.3	9	25.6	35	0.14	11.2	54	25.6	0.21	0	256		0.0	250	240	248
763	2/1/94 17:42	97	4.60	b	29	0	33.9	1.02	388	73	75.0	291	5.6	16	27.8	43	0.15	3.5	32	27.8	0.11	0	254		0.0	247	239	247
763	2/1/94 18:50	97	4.50	b	29	0	33.9	1.00	394	78	78.8	310	3.4	10	26.9	37	0.12	-1.6	17	26.9	0.06	0	252		0.0	246	237	246
763	2/1/94 19:50	97	4.70	b	29	0	33.9	0.98	405	83	83.0	336	2.8	8	24.5	32	0.10	2.4	27	24.5	0.08	0	251		0.0	244	236	245
763	2/1/94 22:45	90	4.95	b	28	0	33.1	1.00	415	65	65.5	272	5.2	15	31.9	47	0.17	9.4	57	31.9	0.21	0	244		0.0	237	228	236
763	2/2/94 0:20	90	4.95	b	28	0	33.1	0.98	420	71	71.1	299	3.9	12	37.5	49	0.16	5.7	51	37.5	0.17	0	246		0.0	239	227	238
763	2/2/94 1:20	90	4.93	b	28	0	33.1	1.01	409	75	73.7	302	7.3	21	27.6	48	0.16	11.3	58	27.6	0.19	0	244		0.0	238	227	236
763	2/2/94 2:20	90	4.94	b	28	0	33.1	1.02	406	73	73.5	298	6.0	17	28.7	46	0.15	8.5	50	28.7	0.17	0	244		0.0	237	226	236
763	2/2/94 3:20	90	4.94	b	28	0	33.1	1.04	399	72	77.0	307	15.8	47	19.2	66	0.21	23.2	92	19.2	0.30	0	243		0.0	237	226	236
763	2/2/94 4:35	90	4.94	b	28	0	33.1	1.05	393	75	75.6	297	2.8	8	21.1	29	0.10	12.4	54	21.1	0.18	0	243		0.0	236	224	235
763	2/2/94 5:35	90	4.90	b	27	0	31.9	1.02	392	75	71.5	280	-1.8	-5	22.1	17	0.06	8.6	42	22.1	0.15	0	243		0.0	236	224	234
763	2/2/94 6:35	90	4.92	b	27	0	31.9	1.03	387	72	68.9	266	-1.1	-3	20.1	17	0.06	11.5	50	20.1	0.19	0	243		0.0	236	223	234
763	2/2/94 7:35	90	5.44	b	26	0	30.7	0.99	388	66	61.5	239	-10.9	-31	20.9	-10	-0.04	-5.2	2	20.9	0.01	0	241		0.0	235	224	234

PSCC Arapahoe Uni
Calcs based on:

Test	Date & Time	Economizer Exit, dry (1-12) NO	CO	SO2	NO2	CO2	O2	Baghouse Inlet Gas Analysis, wet NO	CO	SO2	NO2	CO2	H2O	O2	Stack Gas Analysis, wet NO	CO	SO2	NO2	CO2	H2O	O2	Comments
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
763	1/31/94 8:45	250	46	335	5	12.62	5.00	220	23	330	-4	11.34	10.74	4.20	210	40	310	-1	11.06	11.01	4.75	AMill OOS,Bmrs
763	1/31/94 10:05	242	37	335	5	12.48	5.10	218	22	325	-3	11.31	10.51	4.30	225	24	275	0	10.84	10.41	5.25	2,3,7 Firing Gas
763	1/31/94 11:05	245	42	341	4	12.67	4.80	219	27	331	-3	11.58	10.67	4.15	213		270			11.00	4.80	
763	1/31/94 14:30	251	466	421	3	13.60	5.20	242	141	392	-1	12.90	9.04	4.00	207	164	213	7	12.10	8.48	5.10	Nat. Gas Off
763	1/31/94 15:40	260	310	421	2	14.12	4.90	243	302	388	0	13.15	9.30	3.50	204	197	181	9	12.20	8.50	5.10	
763	1/31/94 16:43							242	262	376	-2	13.02	9.45	3.50	197	499	157	11	12.38	8.71	4.70	BH cln 17:00-17:35
763	1/31/94 17:30							220	26	279	-3	11.42	10.79	4.30	183	36	130	12	11.10	10.99	4.70	Nat. Gas On
763	1/31/94 18:15	273	34	280	2	12.55	4.90	208	25	261	-4	11.60	10.99	4.20	203	20	54	19	10.80	10.50	5.20	
763	1/31/94 19:15	249	36	274	1	12.65	5.00	206	30	266	-2	11.65	11.16	3.90	191	20	23	25	10.75	10.49	5.20	
763	1/31/94 21:20	260	461	355	4	13.91	4.90	235	445	349	0	13.29	9.41	3.30	188	316	104	15	12.45	8.66	4.50	Nat. Gas Off
763	1/31/94 22:20	271	84	350	3	13.87	5.10	250	145	340	-4	12.87	9.03	3.75	195	374	122	14	12.58	8.75	4.65	
763	1/31/94 23:05	240	64	314	2	12.57	6.60	230	40	310	-1	12.10	8.43	5.10	181	34	90	15	11.17	7.69	6.60	
763	2/1/94 0:05	244	40	310	2	12.48	6.70	230	53	308	-1	12.39	8.62	5.40	169	40	62	17	11.31	7.78	6.35	
763	2/1/94 1:05	240	45	320	2	12.68	6.55	230	54	320	2	12.32	8.61	5.25	162	50	42	21	11.40	7.87	6.30	
763	2/1/94 1:45	239	39	317	2	12.64	6.60	229		309			8.43	5.00	170		42			7.69	6.55	
763	2/1/94 2:45	197	24	250	2	10.15	9.40	190	25	253	-2	10.36	7.19	7.50	146	21	24	19	9.41	6.44	8.95	
763	2/1/94 3:45	198	23	250	2	10.29	9.20	189	19	251	-2	10.27	7.10	7.60	135	19	21	20	9.37	6.44	9.00	
763	2/1/94 4:40	191	25	248	1	10.34	9.20	190	19	250	-1	10.32	7.12	7.55	132	19	26	21	9.41	6.47	8.92	
763	2/1/94 6:10	270	36	251	3	12.24	5.60	241	33	247	0	11.57	10.53	4.35	190	27	60	28	10.55	10.02	5.30	Nat. Gas On
763	2/1/94 7:05	270	42	250	2	12.30	5.55	225	38	246	-2	11.39	10.39	4.40	201	22	41	31	10.44	9.84	3.50	
763	2/1/94 8:44	270	42	250	2	12.30	5.55	212	38	244	-2	11.57	10.64	4.00	191	24	48	22	10.52	10.08	5.50	
763	2/1/94 9:50	260	76	340	4	13.52	5.20	238	56	322	-1	12.90	8.91	3.90	202	46	132	21	11.88	8.11	5.40	Nat. Gas Off
763	2/1/94 11:04	260	76	340	4	13.52	5.20	238	97	331	1	13.16	9.11	3.80	196	121	124	17	12.21	8.39	5.00	
763	2/1/94 12:10	260	76	340	4	13.52	5.20	238	97	326	-1	12.97	8.96	3.90	203	65	118	14	11.97	8.26	5.20	
763	2/1/94 13:15	260	76	340	4	13.52	5.20	228	109	325	-2	12.93	9.15	3.70	196	86	103	11	11.88	8.29	5.50	
763	2/1/94 14:20	260	76	340	4	13.52	5.20	224	155	340	-1	13.22	9.28	3.50	205	106	101	12	12.19	8.45	5.00	
763	2/1/94 15:20	260	76	340	4	13.52	5.20	253	40	312	-1	12.43	9.06	4.50	201	125	137	9	12.18	8.57	4.90	clean start
763	2/1/94 16:10	260	76	340	4	13.52	5.20	233	380	333	0	13.13	9.34	3.70	176	311	116	19	12.37	8.60	5.00	clean finish
763	2/1/94 16:45	260	76	340	4	13.52	5.20	229	99	333	-1	13.00	9.21	4.20	189	177	115	19	11.92	8.45	5.20	
763	2/1/94 17:42	238	105	342	4	13.53	5.10	238	54	329	0	12.95	9.19	3.80	186	51	76	21	12.07	8.49	5.10	
763	2/1/94 18:50	238	105	342	4	13.53	5.10	239	38	326	-1	12.63	9.06	4.20	195	40	65	20	11.97	8.47	5.30	
763	2/1/94 19:50	238	105	342	4	13.53	5.10	233	54	343	0	12.98	9.27	3.80	189	41	54	19	12.02	8.47	5.20	
763	2/1/94 22:45	248	43	341	3	12.84	6.10	230	47	330	0	12.56	8.95	4.80	181	43	107	24	11.42	8.11	5.85	BH cln 22:05-22:40
763	2/2/94 0:20	248	48	349	3	13.14	5.95	235	45	335	-1	12.44	8.83	4.80	180	34	89	27	11.64	8.20	6.10	
763	2/2/94 1:20	246	47	348	2	13.10	5.85	229	45	332	0	12.44	8.80	4.55	176	42	81	21	11.67	8.16	5.75	
763	2/2/94 2:20	246	61	345	2	13.49	5.85	230	50	324	-1	12.36	8.76	4.80	180	36	80	20	11.42	8.00	5.95	
763	2/2/94 3:20	260	44	325	3	12.80	6.45	231	309	312	0	11.86	8.46	5.15	175	81	70	15	12.09	8.47	5.50	
763	2/2/94 4:35	245	60	325	2	12.17	6.10	221	66	321	-2	12.27	8.61	4.50	182	46	72	14	11.44	7.96	5.80	
763	2/2/94 5:35	245	49	327	2	13.01	6.15	222	47	320	-3	12.21	8.56	4.50	185	37	81	14	11.43	7.96	6.25	
763	2/2/94 6:35	250	45	322	3	12.39	6.25	222	65	315	-2	12.11	8.49	4.55	189	35	89	13	11.20	7.75	6.05	
763	2/2/94 7:35	246	44	331	2	12.85	6.00	226	32	310	0	11.86	8.20	4.90	204	26	104	14	10.93	7.44	6.90	

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

				Sorbent Feed			Injector cal		SO2	ΔSO2 Reduction			ΔNOx - - - -		ΔNO2	ΔNO	ΔNO	Economizer NO Calc - - -				Humidification				Baghouse Temps		
Test	Date & Time	Load	O2cr	Na	A (w)	B (e)	Flow	2Na	ppmc	Cmp	Calc						ΔSO2	ΔNOx	ΔNO	ΔNO2i	ΔNO/ΔSO2	Air	Taho	Tw	H2O	Grid	Out	IDin
		MWe	%wet	b/s	%	%	lb/min	S*	dry	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc		scfm	°F	°F	gpm	°F	°F	°F
763	2/2/94 8:20	90		b	26	0	30.7	0.98	392	69	69.0	271	10.1	28		28	0.10	17.0	48	0.0	0.18	0	241		0.0	235	224	234
763	2/2/94 9:50	100	4.12	b	28	0	33.1	0.96	392	61	62.6	245	-9.9	-21	5.6	-16	-0.06	8.7	26	5.6	0.10	0	251		0.0	244	229	239
763	2/2/94 10:55	100	4.20	b	29	0	34.2	1.02	380	56	62.3	237	-10.0	-21	7.8	-14	-0.06	8.6	27	7.8	0.11	0	254		0.0	248	233	243
763	2/2/94 12:00	100	4.10	b	29	0	34.2	1.02	379	68	68.7	260	3.5	9	7.8	17	0.06	5.5	18	7.8	0.07	0	258		0.0	252	239	248
763	2/2/94 13:00	100	4.10	b	29	0	34.2	1.01	382	79	81.0	309	8.6	23	6.8	29	0.09	6.4	20	6.8	0.07	0	263		0.0	255	242	252
763	2/2/94 13:48	80	6.00	b	29	0	34.2	1.28	372	90	90.4	336	19.4	64	12.0	76	0.23	13.2	47	12.0	0.14	0	260		0.0	253	243	251
763	2/2/94 14:00	80	6.00	b	23	0	27.2	1.02	372		90.4	336	19.4	64	12.0	76	0.23	13.2	47	12.0	0.14	0			0.0			
763	2/2/94 15:00	80	6.00	b	24	0	28.4	1.06	375	78	77.6	291	4.6	13	12.6	25	0.09	14.8	51	12.6	0.18	0	256		0.0	251	242	250
763	2/2/94 16:00	80	6.00	b	24	0	28.4	1.05	377	81	78.9	297	-2.0	-5	9.9	5	0.02	10.7	36	9.9	0.12	0	252		0.0	248	242	246
763	2/2/94 17:00	80	6.00	b	24	0	28.4	1.06	374	81	79.5	297	0.2	0	13.3	14	0.05	16.6	58	13.3	0.20	0	248		0.0	243	237	243
763	2/2/94 18:03	80	6.00	b	24	0	28.4	1.06	375	75	74.7	280	3.3	9	15.7	25	0.09	12.7	48	15.7	0.17	0	246		0.0	240	232	239
763	2/2/94 19:07	80	6.00	b	24	0	28.4	1.06	372	82	84.9	316	2.8	8	18.4	26	0.08	17.3	68	18.4	0.21	0	244		0.0	239	229	237
763	2/2/94 19:55	90	4.92	b	24	0	28.4	0.95	374	59	64.7	242	-6.1	-14	12.9	-2	-0.01	10.2	37	12.9	0.15	0	247		0.0	240	233	238
763	2/2/94 21:05	90	4.93	b	25	0	29.5	0.99	374	71	72.7	272	-1.2	-3	27.0	24	0.09	7.6	46	27.0	0.17	0	247		0.0	241	231	239
763	2/2/94 22:05	90	4.92	b	25	0	29.5	0.98	379	74	74.2	281	2.4	6	21.9	28	0.10	10.7	49	21.9	0.17	0	245		0.0	239	229	237
763	2/2/94 23:05	90	4.91	b	25	0	29.5	0.99	375	76	73.9	277	1.5	4	18.9	23	0.08	12.3	49	18.9	0.18	0	245		0.0	237	226	234
763	2/3/94 0:05	90	4.90	b	25	0	29.5	0.99	374	75	72.0	269	4.5	12	15.6	27	0.10	11.9	46	15.6	0.17	0	244		0.0	237	225	234
763	2/3/94 1:05	90	4.89	b	25	0	29.5	0.99	375	72	71.5	268	1.2	3	15.3	18	0.07	6.6	30	15.3	0.11	0	243		0.0	237	224	233
763	2/3/94 2:05	90	4.92	b	25	0	29.5	0.99	374	70	68.7	257	4.3	11	11.2	22	0.09	15.6	53	11.2	0.20	0	241		0.0	235	222	231
763	2/3/94 3:05	90	4.92	b	25	0	29.5	0.99	372	69	71.0	264	2.3	6	12.4	18	0.07	13.8	49	12.4	0.19	0	239		0.0	232	220	229
763	2/3/94 4:05	90	4.90	b	25	0	29.5	1.00	369	69	70.2	259	2.5	6	13.3	20	0.08	15.6	56	13.3	0.22	0	239		0.0	233	220	229
763	2/3/94 5:05	90	4.88	b	25	0	29.5	1.00	371	75	74.5	276	0.0	0	13.2	13	0.05	10.5	41	13.2	0.15	0	239		0.0	233	220	229
763	2/3/94 6:05	90	4.90	b	25	0	29.5	1.01	365	39	46.0	168	-8.4	-22	22.7	0	0.00	0.3	20	22.7	0.12	0	240		0.0	233	220	228
763	2/3/94 7:05	90	4.82	b	25	0	29.5	1.02	364	62	62.5	227	-0.3	-1	27.3	27	0.12	8.0	48	27.3	0.21	0	239		0.0	233	220	229
763	2/3/94 8:25	90	4.90	b	25	0	29.5	1.01	367	70	70.7	259	1.1	3	22.5	25	0.10	11.5	49	22.5	0.19	0	240		0.0	232	218	228
763	2/3/94 10:00	90	4.90	b	0	26	29.3	1.02	360	80	81.7	294	5.8	14	21.2	35	0.12	12.5	51	21.2	0.17	0	240		0.0	234	221	229
763	2/3/94 11:20	90	5.40	b	0	26	29.3	1.00	365	83	83.1	304	3.7	10	26.7	37	0.12	9.4	50	26.7	0.17	0	252		0.0	243	227	236
763	2/3/94 12:20	90	5.40	b	0	26	29.3	1.00	366	84	84.7	310	3.1	9	23.5	32	0.10	8.0	42	23.5	0.14	0	256		0.0	249	234	243
763	2/3/94 13:22	90	5.40	b	0	26	29.3	0.98	375	83	82.6	310	2.8	8	23.2	31	0.10	7.5	40	23.2	0.13	0	258		0.0	253	239	247
763	2/3/94 15:20	70	6.62	b	0	20	22.7	0.94	378	81	79.9	302	-2.9	-8	19.8	12	0.04	12.3	50	19.8	0.17	0	253		0.0	248	241	246
763	2/3/94 16:30	70	6.60	b	0	21	23.8	1.00	374	81	80.7	302	2.2	6	22.2	28	0.09	12.7	57	22.2	0.19	0	250		0.0	245	236	242
763	2/3/94 17:33	90	5.40	b	0	27	30.4	0.99	384	46	50.7	195	-2.3	-7	30.2	24	0.12	5.9	45	30.2	0.23	0	256		0.0	248	240	244
763	2/3/94 18:45	90	5.40	b	0	27	30.4	0.96	395	68	71.1	281	0.9	3	41.7	44	0.16	9.9	70	41.7	0.25	0	257		0.0	250	239	246
763	2/3/94 19:43	90	5.50	b	0	28	31.5	0.98	404	73	73.5	297	2.7	8	39.0	47	0.16	11.9	73	39.0	0.25	0	255		0.0	249	238	246
763	2/3/94 21:55	90	5.43	b	0	28	31.5	0.97	409	75	74.0	303	4.3	12	28.9	41	0.14	11.4	56	28.9	0.18	0	249		0.0	243	233	240
763	2/3/94 23:05	90	5.39	b	0	29	32.6	1.02	401	71	72.1	289	10.5	31	21.6	52	0.18					0	248		0.0	242	231	239
763	2/4/94 0:05	90	5.41	b	0	29	32.6	1.02	402	71	71.6	288	3.6	10	25.1	35	0.12					0	247		0.0	240	229	237
763	2/4/94 1:05	90	5.39	b	0	29	32.6	1.02	400	69	72.1	289	4.5	13	24.9	37	0.13	13.4	58	24.9	0.20	0	247		0.0	240	228	237
763	2/4/94 2:05	90	5.38	b	0	29	32.6	0.99	411	71	72.3	297	-0.2	-1	25.5	25	0.08					0	246		0.0	239	227	237
763	2/4/94 3:05	90	5.42	b	0	29	32.6	1.00	409	71	71.4	292	3.7	10	23.5	34	0.12					0	245		0.0	238	226	235
763	2/4/94 3:45	90	5.41	b	0	29	32.6	1.00	409	46	45.5	186	-4.3	-12	29.0	17	0.09	4.5	38	29.0	0.20	0	246		0.0	238	229	235

PSCC Arapahoe Uni
Calcs based on:

Test	Date & Time	Economizer Exit, dry (1-12) NO ppm	CO ppm	SO2 ppm	NO2 ppm	CO2 %	O2 %dry	Baghouse Inlet Gas Analysis, wet NO ppm	CO ppm	SO2 ppm	NO2 ppm	CO2 %	H2O %	O2 %	Stack Gas Analysis, wet NO ppm	CO ppm	SO2 ppm	NO2 ppm	CO2 %	H2O %	O2 %	Comments
763	2/2/94 8:20	246	44	331	2	12.85	6.00	221		315			8.76	4.70	181		89			8.20	6.10	
763	2/2/94 9:50	225	472	345	3	13.26	5.10	194	680	356	1	13.33	9.50	2.65	180	403	115	5	11.80	8.37	5.10	BHcln 1007-1042
763	2/2/94 10:55	225	472	345	3	13.26	5.10	195	829	346	0	13.30	9.58	2.60	180	488	113	6	11.86	8.44	5.00	
763	2/2/94 12:00	225	472	345	3	13.26	5.10	223	211	334	0	13.18	9.20	3.20	193	224	97	6	12.34	8.54	4.50	
763	2/2/94 13:00	225	472	345	3	13.26	5.10	228	166	330	0	13.12	9.25	3.50	191	346	59	6	12.37	8.74	4.50	
763	2/2/94 13:48	231	37	286	4	11.59	7.10	251	37	285	0	11.52	8.16	5.50	178	33	25	8	10.76	7.55	6.70	
763	2/2/94 14:00	231	37	286	4	11.59	7.10	251	37	285	0	11.52	8.16	5.50	178	33	25	8	10.76	7.55	6.70	
763	2/2/94 15:00	231	37	286	4	11.59	7.10	212	48	291	-1	11.73	8.22	5.30	179	37	61	8	10.94	7.64	6.40	
763	2/2/94 16:00	231	37	286	4	11.59	7.10	208	41	293	-1	11.98	8.54	5.20	182	36	55	6	10.95	7.77	6.90	
763	2/2/94 17:00	231	37	286	4	11.59	7.10	206	87	302	-1	12.25	8.79	4.60	172	49	55	9	11.01	7.89	6.50	
763	2/2/94 18:03	231	37	286	4	11.59	7.10	213	35	290	-1	11.73	8.49	5.30	174	28	66	10	10.68	7.67	6.90	
763	2/2/94 19:07	243	25	286	3	11.84	7.20	213	35	288	-1	11.75	8.45	5.30	173	27	39	12	10.73	7.63	6.90	
763	2/2/94 19:55	235	64	323	2	13.21	5.60	200	151	317	-1	12.82	9.29	3.80	180	71	100	9	11.40	8.16	5.65	BH cln 19:30-20:05
763	2/2/94 21:05	241	62	312	2	12.91	5.80	218	99	310	0	12.77	9.20	4.15	178	29	76	20	11.33	8.15	5.90	
763	2/2/94 22:05	241	62	324	2	13.37	5.45	216	94	317	-1	12.96	9.24	4.00	174	59	74	16	11.67	8.31	5.65	
763	2/2/94 23:05	237	87	321	2	13.22	5.55	212	128	318	-2	12.90	9.19	3.80	172	84	74	13	11.65	8.21	5.65	
763	2/3/94 0:05	240	73	320	2	13.18	5.50	217	64	312	-1	12.70	8.93	4.10	178	81	80	11	11.71	8.24	5.50	
763	2/3/94 1:05	227	92	320	2	13.16	5.55	214	79	317	-1	12.73	9.00	3.90	176	63	80	10	11.59	8.14	5.80	
763	2/3/94 2:05	240	64	319	2	13.25	5.60	211	75	316	-1	12.88	9.10	3.90	173	78	89	8	11.59	8.05	5.65	
763	2/3/94 3:05	237	166	319	2	12.97	5.65	211	142	318	0	13.07	9.09	3.70	174	66	82	10	11.73	8.15	5.60	
763	2/3/94 4:05	246	42	308	2	12.68	6.15	216	65	305	-1	12.44	8.73	4.30	180	42	82	9	11.26	7.85	5.95	
763	2/3/94 5:05	238	45	314	2	13.07	5.70	212	59	311	0	12.54	8.77	4.05	180	50	71	10	11.48	7.95	5.80	
763	2/3/94 6:05	240	36	309	2	12.72	5.85	219	48	301	-1	12.36	8.57	4.35	195	30	145	16	11.16	7.64	6.15	
763	2/3/94 7:05	235	45	319	2	13.06	5.55	209	48	301	1	12.51	8.62	4.30	169	40	102	21	11.48	7.85	5.90	
763	2/3/94 8:25	223	65	315	3	13.04	5.75	200	107	307	-1	12.72	8.77	4.10	161	64	81	16	11.51	7.90	5.80	
763	2/3/94 10:00	223	65	315	3	13.04	5.75	209	86	304	-1	12.62	8.74	4.00	161	59	50	15	11.67	7.97	5.70	
763	2/3/94 11:20	240	39	305	3	12.57	6.00	220	43	293	0	12.16	8.43	4.80	173	30	45	19	11.10	7.63	6.30	
763	2/3/94 12:20	240	39	305	3	12.57	6.00	223	33	293	-1	12.06	8.39	4.80	179	31	41	17	11.09	7.62	6.30	
763	2/3/94 13:22	240	39	305	3	12.57	6.00	225	29	302	-1	12.06	8.54	4.70	179	28	47	16	11.10	7.69	6.40	
763	2/3/94 15:20	222	28	282	3	11.30	7.60	200	46	291	-2	11.62	8.34	5.40	166	31	51	12	10.25	7.33	7.40	
763	2/3/94 16:30	225	24	275	2	11.12	8.00	210	28	278	-2	11.28	8.16	5.90	165	21	47	13	10.00	7.21	7.80	
763	2/3/94 17:33	257	30	317	3	12.57	6.30	237	29	310	-1	12.27	8.90	4.60	194	24	136	21	10.96	7.93	6.40	end of cleaning
763	2/3/94 18:45	257	30	317	3	12.57	6.30	235	32	321	0	12.36	8.98	4.50	176	24	82	30	11.07	7.99	6.40	
763	2/3/94 19:43	257	30	317	3	12.57	6.30	231	31	324	0	12.29	8.87	4.70	173	28	77	28	11.16	8.05	6.40	
763	2/3/94 21:55	250	37	330	5	12.61	6.35	229	35	320	-3	11.73	8.64	5.10	180	41	76	18	11.33	8.16	6.40	
763	2/3/94 23:05							229	38	317	0	12.25	8.84	4.90	174	41	82	16	11.37	8.09	6.10	
763	2/4/94 0:05							228	38	321	-1	12.10	8.78	4.80	180	34	82	17	11.19	7.93	6.40	
763	2/4/94 1:05	246	36	339	5	12.62	6.35	225	34	320	-2	11.95	8.63	4.80	177	35	81	16	11.04	7.84	6.30	
763	2/4/94 2:05							224	48	333	-1	12.49	8.97	4.55	181	32	82	18	11.17	7.95	6.40	
763	2/4/94 3:05							225	52	328	-1	12.56	8.95	4.70	179	30	85	16	11.15	7.86	6.30	
763	2/4/94 3:45	250	33	331	4	12.31	6.30	229	39	328	-1	12.40	8.81	4.70	193	46	160	20	11.12	7.93	6.40	

PSCC Arapahoe Unit 4 Sodium Injection Summary

Calcs based on: Sodium Bicarbonate (b) .274 Na wt

Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na	SO2 ppmc	ΔSO2 Cmp	Reduction Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO / ΔSO2	Economizer NO Calc - - - ΔNOx	ΔNO	ΔNO2I	ΔNO / ΔSO2	Humidification Air	Taho	Tw	H2O	Baghouse Temps Grid	Out	IDin
		MWe	%wet	b/s	%	%	lb/min	S*	dry	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	°F	°F
763	2/4/94 5:05	90	5.24	b	0	29	32.6	1.01	406	70	70.3	285	12.6	37	34.3	71	0.25					0	245		0.0	238	226	234
763	2/4/94 6:55	90	5.26	b	0	29	32.6	0.99	411	69	73.0	300	-2.4	-7	33.2	27	0.09	13.8	72	33.2	0.24	0	243		0.0	237	224	233
763	2/4/94 8:05	90	5.25	b	0	29	32.6	1.00	407	69	69.7	284	5.3	15	27.4	42	0.15					0	241		0.0	234	223	227
763	2/4/94 9:20	90		b	0	29	32.6	1.00	410	72	71.8	295	4.6	14	29.6	43	0.15					0			0.0			225
763	2/4/94 11:00	90	5.25	b	0	29	32.6	0.88	466	64	64.5	301	3.9	11	30.5	42	0.14	12.3	64	30.5	0.21	0	252		0.0	245	229	237
763	2/4/94 12:05	90	5.25	b	0	33	37.1	0.92	502	75	76.8	386	-1.3	-4	32.2	29	0.07					0	259		0.0	252	238	245
763	2/4/94 13:05	90	4.92	b	0	36	40.4	0.97	521	80	79.2	413	5.9	16	19.5	35	0.09					0	260		0.0	254	243	249
763	2/4/94 14:05	90	4.93	b	0	37	41.5	1.00	520	71	70.9	369	-1.2	-3	21.2	18	0.05	13.0	54	21.2	0.15	0	260		0.0	254	243	250
763	2/4/94 15:05	90	4.90	b	0	37	41.5	0.96	543	78	77.0	418	-0.5	-1	15.6	15	0.03					0	259		0.0	253	244	250
763	2/4/94 16:00	90	4.88	b	0	39	43.7	1.02	536	50	50.9	273	-2.7	-7	34.9	28	0.10					0	254		0.0	248	244	245
763	2/4/94 16:50	90	4.89	b	0	39	43.7	1.06	515	67	70.2	362	-5.0	-12	46.8	34	0.09					0	253		0.0	246	240	244
763	2/4/94 18:05	90	4.88	b	0	37	41.5	1.00	519	76	73.0	379	-5.3	-13	36.5	24	0.06	14.3	72	36.5	0.19	0	258		0.0	252	242	248

PSCC Arapahoe Uni
Calcs based on:

		Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							
Test	Date & Time	NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	Comments
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
763	2/4/94 5:05							233	30	326	0	12.21	8.77	4.70	162	41	89	25	11.37	8.08	6.00	
763	2/4/94 6:55	260	34	335	4	12.53	6.30	219	44	329	-1	12.10	8.47	4.80	180	53	81	23	11.77	8.19	6.15	
763	2/4/94 8:05							231	41	330	-1	12.48	8.68	4.60	177	39	90	20	11.62	7.99	6.20	
763	2/4/94 9:20							237	35	328	0	12.47	8.64	4.80	175	27	80	20	10.77	7.42	7.00	
763	2/4/94 11:00	255	32	380	3	12.87	6.30	230	32	370	-1	12.45	8.67	4.90	180	29	120	21	11.34	7.81	6.30	
763	2/4/94 12:05							227	52	408	-1	12.54	8.93	4.50	179	32	83	22	11.28	7.87	6.50	
763	2/4/94 13:05							220	174	430	0	12.69	9.05	4.25	171	75	80	15	11.82	8.34	5.95	
763	2/4/94 14:05	249	79	425	4	13.08	5.95	216	187	429	-1	12.94	9.26	4.20	179	184	111	14	11.66	8.22	6.05	
763	2/4/94 15:05							210	191	459	-1	13.03	9.26	3.85	176	151	94	11	11.95	8.41	5.70	
763	2/4/94 16:00							216	149	441	-1	12.91	9.20	4.25	174	91	195	25	11.73	8.31	5.90	
763	2/4/94 16:50							211	186	430	-2	13.09	9.45	4.00	161	94	113	33	11.76	8.30	6.00	
763	2/4/94 18:05	243	54	431	4	13.32	5.80	204	138	442	-1	13.35	9.65	3.65	160	37	104	26	11.69	8.36	5.90	

PSCC Arapahoe Unit 4 Sodium Injection Summary--Air Toxics Testing
Calcs based on: Sodium Bicarbonate (b) .274 Na wt
Sodium Sesquicarbonate (s) .297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO/ΔSO2	SO2 inlet	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2I	ΔNO/ΔSO2	Humidification Air	Taho	Tw	H2O	Humid calc T2c	H2Oe	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		ppmcd	%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	%w	°F	°F	°F	°F
699	10/11/93:1330	75	6.00		0	0	0.0	0.00	0	-7.8	-33	-9.8	-28	1.2	-27	0.81	423	10.1	29	1.2	-0.88	0	272	61	0.0		7.32	267	248	258	259
699	10/11/93:1431	75	6.00		0	0	0.0	0.00	0	-7.7	-33	-7.2	-21	1.8	-19	0.58	426	4.5	10	1.8	-0.29	0	275	61	0.0		7.61	270	254	261	263
699	10/11/93:1530	76	5.90		0	0	0.0	0.00	0	-7.3	-31	-7.6	-22	1.1	-21	0.68	426	6.2	15	1.1	-0.48	0	277	62	0.0		7.63	272	257	264	267
699	10/11/93:1630	76	6.00		0	0	0.0	0.00	0	-8.8	-37	-12.1	-34	1.6	-33	0.89	420	5.2	11	1.6	-0.31	0	277	62	0.0		7.58	272	259	266	269
699	10/11/93:1710				0	0	0.0			-1.4	-6	-2.3	-6	2.4	-4	0.70	397	4.8	9	2.4	-1.68	0			0.0		7.31				
699	10/11/93:1740	76	5.90		0	0	0.0	0.00	0	-1.1	-4	-3.7	-10	1.6	-8	1.89	398	6.0	12	1.6	-2.84	0	277	62	0.0		7.27	272	260	267	270
699	10/11/93:1830	76	5.90		0	0	0.0	0.00	0	-1.3	-5	-4.2	-11	1.6	-9	1.81	392	3.9	6	1.6	-1.19	0	276	61	0.0		7.34	271	260	266	270
699	10/11/93:1930	76	5.90		0	0	0.0	0.00	0	-1.9	-7	-2.8	-7	1.1	-6	0.87	391	5.9	12	1.1	-1.63	0	274	60	0.0		7.51	270	258	265	269
700	10/12/93:1200	75	5.30		0	0	0.0	0.00	0	-1.3	-5	0.2	0	0.7	1	-0.23	389	6.3	11	0.7	-2.18	0	266		0.0		7.92	261	243	253	251
700	10/12/93:1300	75	5.30		0	0	0.0	0.00	0	-2.0	-8	0.8	2	0.9	3	-0.36	386	3.2	3	0.9	-0.43	0	269	60	0.0		8.00	264	247	257	255
700	10/12/93:1400	75	5.30		0	0	0.0	0.00	0	-2.0	-8	-3.0	-7	0.1	-7	0.88	383	2.2	0	0.1	-0.04	0	271	60	0.0		8.03	265	250	259	257
700	10/12/93:1500	75	5.30		0	0	0.0	0.00	0	-2.2	-8	-2.9	-7	0.5	-6	0.75	381	5.4	9	0.5	-1.14	0	272	61	0.0		7.83	266	251	261	259
700	10/12/93:1600	75	5.30		0	0	0.0	0.00	0	-2.0	-8	-3.4	-8	0.8	-7	0.94	379	3.7	5	0.8	-0.67	0	272	61	0.0		7.87	268	254	262	261
700	10/12/93:1700	75	5.30		0	0	0.0	0.00	0	-2.2	-9	-0.9	-2	1.0	-1	0.15	382	4.3	6	1.0	-0.75	0	272	61	0.0		7.82	267	254	262	261
700	10/12/93:1800	74	5.40		0	0	0.0	0.00	0	-2.4	-9	3.1	7	0.8	8	-0.90	376	6.4	11	0.8	-1.21	0	271	60	0.0		7.88	266	253	262	260
700	10/12/93:1900	75	5.30		0	0	0.0	0.00	0	-2.1	-8	-0.9	-2	1.1	-1	0.12	375	2.0	0	1.1	-0.05	0	271	59	0.0		7.87	265	253	261	261
700	10/12/93:2000	75	5.30		0	0	0.0	0.00	0	-3.3	-12	-0.8	-2	1.5	0	0.04	377	5.4	9	1.5	-0.72	0	270	59	0.0		7.86	265	252	261	261
701	10/13/93:0810	75	5.20		0	0	0.0	0.00	0	-3.8	-15	-2.8	-7	-1.2	-8	0.52	390	6.4	12	-1.2	-0.78	0	256	48	0.0		7.83	250	235		242
701	10/13/93:0900	75	5.40		0	0	0.0	0.00	0	-2.4	-9	-1.8	-4	1.0	-3	0.38	381	2.8	3	1.0	-0.33	0	258	50	0.0		7.92	253	236	246	243
701	10/13/93:1000	75	5.40		0	0	0.0	0.00	0	-2.0	-8	-5.2	-12	1.1	-11	1.45	380	1.6	0	1.1	0.03	0	264	53	0.0		8.01	258	240	252	248
701	10/13/93:1100	74	5.30		0	0	0.0	0.00	0	-2.1	-8	-3.7	-9	1.3	-7	0.91	381	4.3	7	1.3	-0.80	0	267	55	0.0		7.90	262	245	255	252
701	10/13/93:1200	76	5.20		0	0	0.0	0.00	0	-1.8	-7	-5.4	-13	0.6	-12	1.82	377	2.7	2	0.6	-0.35	0	270	58	0.0		7.99	265	248	258	256
701	10/13/93:1300	74	5.30		0	0	0.0	0.00	0	-2.0	-7	-0.5	-1	1.1	0	0.02	377	6.0	11	1.1	-1.53	0	273	61	0.0		7.87	267	251	261	259
701	10/13/93:1410	75	5.30		0	0	0.0	0.00	0	-2.5	-10	-4.9	-11	0.8	-10	1.09	378	5.2	9	0.8	-0.89	0	273	61	0.0		7.72	269	254	263	261
701	10/13/93:1500	75	5.30		0	0	0.0	0.00	0	-2.7	-10	-3.5	-8	0.3	-8	0.79	378	5.6	10	0.3	-1.03	0	274	62	0.0		7.77	269	255	264	263
701	10/13/93:1600	75	5.20		0	0	0.0	0.00	0	-1.4	-5	-2.2	-5	0.5	-5	0.87	380	5.1	8	0.5	-1.44	0	274	63	0.0		7.85	270	256	265	263
702	10/14/93:0830	100	4.40	s	50	0	46.7	1.50	61	61.8	236	4.7	11	12.0	23	0.10	381	13.3	37	12.0	0.16	0	263	49	0.0		8.58	257	243	254	253
702	10/14/93:0930	101	4.30	s	50	0	46.7	1.47	66	65.1	251	1.3	3	12.5	16	0.06	385	9.5	31	12.5	0.13	0	266	50	0.0		8.62	258	245	256	256
702	10/14/93:1020	100	4.40	s	50	0	46.7	1.52	64	64.3	242	6.9	17	8.8	26	0.11	377	14.3	43	8.8	0.18	0	268	52	0.0		8.58	260	247	159	259
702	10/14/93:1120	99	4.40	s	50	0	46.7	1.54	63	63.6	240	6.5	16	9.4	26	0.11	377	10.3	31	9.4	0.13	0	271	55	0.0		8.66	263	251	261	263
702	10/14/93:1230	100	4.30	s	50	0	46.7	1.55	67	66.6	247	6.9	16	7.9	24	0.10	370	14.0	39	7.9	0.16	0	274	59	0.0		8.66	267	255		266
702	10/14/93:1330	99	4.30	s	50	0	46.7	1.56	63	55.3	206	6.4	15	12.7	28	0.14	372	12.4	39	12.7	0.19	0	277	60	0.0		8.51	270	261	269	268
703	10/14/93:1700	99	4.40	s	0	53	47.1	1.53	63	63.9	244	4.8	11	7.9	19	0.08	381	14.7	41	7.9	0.17	0	271	58	0.0		8.59	265	257	264	265
703	10/14/93:1800	99	4.50	s	0	53	47.1	1.53	65	65.5	250	3.1	7	8.3	16	0.06	381	7.9	22	8.3	0.09	0	271	58	0.0		8.73	263	256	264	266
703	10/14/93:1900	99	4.50	s	0	53	47.1	1.53	65	64.6	246	10.0	25	8.1	33	0.14	381	13.9	39	8.1	0.16	0	270	57	0.0		8.77	263	255	263	265
703	10/14/93:2000	99	4.30	s	0	53	47.1	1.50	65	63.9	248	9.3	24	6.4	30	0.12	388	14.3	40	6.4	0.16	0	271	55	0.0		8.73	264	254	263	266
703	10/14/93:2105	99	4.20	s	0	53	47.1	1.46	66	65.2	260	8.9	22	6.5	29	0.11	399	16.2	46	6.5	0.18	0	270	55	0.0		8.78	262	254	262	265
703	10/14/93:2200	99	4.40	s	0	53	47.1	1.53	67	66.1	252	7.3	19	6.3	25	0.10	381	10.8	31	6.3	0.12	0	270	55	0.0		8.99	263	253	262	265
704	10/15/93:0830	100	4.20	s	0	53	47.1	1.56	57	57.7	214	5.8	14	9.8	24	0.11	371	16.5	51	9.8	0.24	0	260	48	0.0		8.84	253	240	250	250
704	10/15/93:0930	100	4.10	s	0	53	47.1	1.51	59	63.0	241	3.5	8	8.3	17	0.07	383	7.7	23	8.3	0.09	0	263	52	0.0		9.20	255	243	253	254
704	10/15/93:1030	100	4.30	s	0	53	47.1	1.48	59	60.8	237	4.8	11	6.1	17	0.07	390	13.9	37	6.1	0.16	0	265	53	0.0		9.09	257	246	256	256
704	10/15/93:1130	99	4.20	s	0	53	47.1	1.53	62	58.9	224	1.3	3	8.0	11	0.05	381	9.0	25	8.0	0.11	0	267	56	0.0		8.96	260	248	258	259
704	10/15/93:1230	99	4.20	s	0	53	47.1	1.55	63	63.4	239	9.8	24	7.1	31	0.13	376	14.0	37	7.1	0.15	0	270	57	0.0		8.94	263	251	261	262

PSCC Arapahoe Uni
Calcs based on:

		Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							
Test	Date & Time	CO	NO2	CO2	O2	SO2	NO	CO	NO2	CO2	H2O	O2	SO2	NO	CO	NO2	CO2	H2O	O2	SO2	NO	Comments
		ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	
699	10/11/93:1330	23	2	13.38	8.50	340	240	15	-3	11.33	7.94	6.85	293	201	16	-2	11.35	7.91	7.80	292	203	#15,semiVOST
699	10/11/93:1431	23	1	13.18	8.05	338	232	13	-3	11.35	7.94	6.90	294	203	17	-2	11.43	7.99	7.70	296	202	gas analysis ?
699	10/11/93:1530	17	2	13.16	8.10	331	238	12	-3	11.22	7.92	7.00	292	203	14	-3	11.33	7.97	7.75	294	204	gas analysis ?
699	10/11/93:1630	17	2	13.17	8.15	335	239	11	-4	11.35	8.03	6.80	292	202	12	-3	11.39	7.96	7.75	294	208	gas analysis ?
699	10/11/93:1710	14	1	11.64	7.60	303	220	12	-4	10.71	7.49	6.73	280	199	12	-3	10.41	7.35	7.25	273	194	gas correct
699	10/11/93:1740	16	1	11.55	7.68	302	218	12	-4	10.88	7.65	6.45	286	197	12	-3	10.50	7.33	7.15	275	193	
699	10/11/93:1830	15	1	11.52	7.65	294	214	13	-4	10.78	7.62	6.60	279	194	11	-3	10.44	7.34	7.28	269	191	
699	10/11/93:1930	15	1	11.78	7.30	309	221	12	-4	10.92	7.82	6.20	286	199	11	-3	10.67	7.61	6.80	279	195	respan
700	10/12/93:1200	22	1	12.15	6.95	318	196	14	-4	11.42	8.39	5.60	295	183	19	-3	11.12	8.08	6.20	287	175	#16,semiVOST
700	10/12/93:1300	27	0	12.20	6.85	317	196	13	-4	11.49	8.45	5.55	293	189	16	-3	11.20	8.22	6.10	288	180	
700	10/12/93:1400	24	0	12.21	6.80	312	193	14	-4	11.49	8.48	5.50	292	181	19	-4	11.24	8.28	6.00	288	180	
700	10/12/93:1500	17	0	11.94	7.06	304	199	13	-4	11.61	8.47	5.42	292	185	14	-3	11.11	8.13	6.20	283	180	
700	10/12/93:1600	24	0	12.13	7.05	310	196	12	-4	11.49	8.49	5.45	290	184	17	-3	11.07	8.11	6.22	281	180	
700	10/12/93:1700	21	0	12.06	7.10	301	198	11	-4	11.38	8.31	5.72	287	187	17	-3	11.06	8.04	6.35	281	180	
700	10/12/93:1800	30	0	11.97	7.12	301	191	10	-4	11.30	8.33	5.80	281	183	23	-3	11.18	8.17	6.20	280	172	
700	10/12/93:1900	26	0	12.09	7.10	298	191	10	-4	11.26	8.27	5.87	279	183	16	-3	11.04	8.07	6.33	276	178	
700	10/12/93:2000	23	0	11.92	7.20	299	191	12	-4	11.38	8.40	5.72	283	180	18	-3	11.13	8.14	6.25	282	174	
701	10/13/93:0810	22	0	11.86	7.35	302	196	14	-3	11.75	8.59	5.50	297	182	16	-3	11.02	8.21	6.30	292	178	#17,semiVOST
701	10/13/93:0900	17	0	11.89	7.20	301	195	10	-4	11.44	8.51	5.64	287	187	14	-3	11.05	8.24	6.24	282	182	
701	10/13/93:1000	14	0	11.93	7.15	302	195	9	-4	11.35	8.54	5.70	285	182	11	-3	11.05	8.27	6.35	278	182	
701	10/13/93:1100	15	0	11.94	7.20	302	194	9	-4	11.55	8.58	5.50	290	182	12	-3	11.12	8.21	6.28	281	178	
701	10/13/93:1200	17	0	11.82	7.10	300	196	10	-4	11.61	8.66	5.42	288	183	16	-3	11.32	8.38	6.00	282	185	
701	10/13/93:1300	13	0	11.95	7.15	299	198	9	-4	11.45	8.50	5.52	287	187	11	-3	11.16	8.18	6.18	280	179	
701	10/13/93:1410	13	0	11.83	7.25	297	194	9	-4	11.55	8.51	5.35	291	181	11	-3	11.05	8.07	6.25	281	178	
701	10/13/93:1500	13	0	11.80	7.20	298	199	9	-4	11.45	8.44	5.50	288	184	8	-3	11.02	8.09	6.30	280	180	
701	10/13/93:1600	13	0	11.92	7.20	298	193	9	-4	11.61	8.62	5.35	292	184	11	-4	11.11	8.18	6.15	281	178	
702	10/14/93:0830	41	3	12.82	5.65	322	221	59	-5	12.64	9.21	4.10	317	204	69	5	12.21	8.84	4.80	116	177	Toxics #18
702	10/14/93:0930	116	1	13.06	5.65	323	225	60	-5	12.52	9.26	4.10	320	206	140	5	11.63	8.64	5.40	103	178	coal sample
702	10/14/93:1020	36	0	13.13	5.70	328	227	36	-4	12.89	9.39	3.85	318	211	44	4	12.18	8.87	4.70	108	180	
702	10/14/93:1120	76	0	13.36	5.55	328	225	37	-4	12.70	9.36	3.90	317	216	30	4	12.17	8.92	4.95	108	182	
702	10/14/93:1230	37	0	13.12	5.60	324	220	56	-4	12.78	9.48	3.75	314	206	40	2	12.23	9.00	4.70	99	175	
702	10/14/93:1330	43	0	13.06	5.65	321	222	24	-5	12.19	9.05	4.25	307	206	43	5	12.07	8.89	4.75	133	177	
703	10/14/93:1700	39	0	12.92	5.80	328	219	57	-4	12.67	9.40	3.95	319	199	66	2	12.20	8.96	4.70	110	175	Toxics #19
703	10/14/93:1800	58	0	13.20	5.60	338	214	44	-5	12.44	9.37	4.05	317	203	37	2	12.05	8.93	5.00	103	179	
703	10/14/93:1900	42	0	13.21	5.65	334	226	37	-5	12.57	9.41	4.10	316	215	40	2	12.12	8.99	4.85	107	179	
703	10/14/93:2000	37	0	13.08	5.70	340	227	29	-4	12.44	9.34	4.20	320	212	37	2	12.05	9.02	4.85	111	180	
703	10/14/93:2105	40	0	13.22	5.60	345	234	33	-4	12.75	9.55	3.85	336	216	48	1	12.31	9.13	4.70	111	182	
703	10/14/93:2200	40	0	13.18	5.55	332	229	32	-3	12.41	9.49	4.25	312	214	38	2	12.10	9.23	4.95	101	185	
704	10/15/93:0830	44	1	13.25	5.60	329	232	64	-2	13.01	9.64	3.80	313	206	44	6	12.07	9.01	4.90	124	174	Toxics #20
704	10/15/93:0930	74	0	13.55	5.30	333	218	63	-4	12.72	9.77	3.90	320	204	167	3	12.19	9.30	4.80	112	180	
704	10/15/93:1030	65	0	13.38	5.45	342	224	64	-4	12.91	9.84	3.75	329	202	33	1	12.24	9.29	4.70	122	177	
704	10/15/93:1130	62	0	13.37	5.50	337	223	48	-5	12.67	9.64	3.90	319	205	55	2	12.17	9.16	5.05	122	182	
704	10/15/93:1230	65	0	13.55	5.30	332	220	49	-5	12.47	9.41	4.05	313	205	84	1	12.28	9.17	4.55	111	174	

PSCC Arapahoe Unit 4 Sodium Injection Summary--Sodium/Humidification Tests

Calcs based on: Sodium Bicarbonate (b) 0.274 Na wt

Sodium Sesquicarbonate (s) 0.297 Na wt

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na	ΔSO2 Reduction Cmp	Calc		ΔNOx - - - -		ΔNO2	ΔNO	ΔNO/ΔSO2	Economizer NO Calc - - ΔNOx	ΔNO	ΔNO2i	ΔNO/ΔSO2	Humidification Air	Taho	Tw	H2O	Humid calc T2c	H2Oe	Baghouse Temps Grid	Out	IDin	Opsis
		MWe	%wet	b/s	%	%	lb/min	S*	%	%	ppmc	%	ppmc	ppmc	ppmc		%	ppmc	ppmc	ΔSO2	scfm	°F	°F	gpm	°F	%w	°F	°F	°F	°F
665	9/20/93:0810	100	3.60	s	0	41	35.8	0.99	0	-0.2	-1	0.8	2	-0.5	2	-2.11	6.9	14	-0.5	-18.82	3855	279	64	47.0	183	8.88	177	181	183	185
665	9/20/93:1410	100	3.60	s	0	41	35.8	1.03	60	58.7	250	3.4	8	0.1	8	0.03	4.5	5	0.1	0.02	3843	285	63	49.0	183	8.90	176	178	180	181
665	9/20/93:1640	100	3.60	s	0	41	35.8	1.07	64	64.2	264	5.5	14	-0.3	13	0.05	11.1	23	-0.3	0.09	3823	288	63	50.0	186	8.86	176	179	181	182
666	9/21/93:0730	99	4.00	s	0	37	32.1	1.03	0	27.2	105	2.5	6	3.1	9	0.09	6.1	11	3.1	0.10	0	275	56	0.0	275	9.00	267	247	256	255
666	9/21/93:1040	100	4.50	s	0	38	33.0	1.02	42	43.2	172	3.7	10	7.0	17	0.10	4.3	12	7.0	0.07	0	286	64	0.0	286	8.54	279	267	276	278
666	9/21/93:1300	100	4.50	s	0	38	33.0	0.99	40	42.0	172	3.3	9	6.0	15	0.09	3.7	10	6.0	0.06	4261	289	67	0.0	289	8.50	281	273	280	282
666	9/21/93:1420	100	4.60	s	0	38	33.0	1.00	51	49.6	201	1.2	3	2.3	5	0.03	4.7	8	2.3	0.04	4111	288	67	23.0	241	8.67	234	242	242	247
666	9/21/93:1530	101	4.40	s	0	38	33.0	1.02	52	49.9	196	2.5	7	1.2	8	0.04	5.6	11	1.2	0.06	3968	291	67	34.0	223	8.89	217	223	223	228
666	9/21/93:1630	101	4.50	s	0	38	33.0	1.03	63	56.9	222	0.6	1	0.5	2	0.01	6.5	12	0.5	0.05	3747	290	65	56.0	180	8.90	179	193	188	198
667	9/22/93:0720	100	3.90	s	0	0	0.0	0.00	0	-3.5	-17	5.9	14	0.9	15	-0.86	8.6	14	0.9	-0.78	0	274	58	0.0	274	9.74	269	249	259	257
667	9/22/93:0930	103	3.90	s	0	25	20.8	0.49	31	28.8	144	5.2	12	0.1	13	0.09	6.5	9	0.1	0.07	3844	276	63	47.0	184	9.66	179	184	186	188
668	9/22/93:1150	103	3.40	s	0	50	44.3	1.04	69	68.5	347	5.0	11	1.3	12	0.04	3.7	3	1.3	0.01	3830	278	62	48.0	178	10.21	174	175	178	180
669	9/22/93:1300	103	3.30	s	0	71	64.1	1.57	72	72.3	351	-1.2	-3	1.4	-1	0.00	6.6	12	1.4	0.03	3810	279	62	50.0	180	9.53	173	174	178	179
670	9/22/93:1420	103	3.30	s	0	90	81.9	2.12	90	90.0	415	2.5	6	1.1	7	0.02	10.0	20	1.1	0.05	3821	277	61	50.0	178	9.54	174	173	176	177
671	9/22/93:1550	103	3.50	s	0	44	38.7	1.03	62	61.2	275	5.7	13	0.7	14	0.05	9.6	19	0.7	0.07	3822	277	63	49.0	179	9.62	174	173	176	177
672	9/22/93:1700	103	3.50	s	0	43	37.7	1.06	63	66.4	282	2.7	6	0.5	7	0.02	5.7	8	0.5	0.03	3786	275	61	53.0	169	9.71	164	165	168	169
678	9/29/93:0815	100	4.00	s	0	0	0.0	0.00	0	-4.1	-19	5.6	17	0.5	18	-0.92	2.4	0	0.5	0.02	0	255	52	0.0	255	9.18	250	231	241	238
679	9/29/93:0800	101	3.90	s	0	0	0.0	0.00	0	-5.0	-20	8.4	25	0.5	26	-1.28	5.3	9	0.5	-0.42	4087	264	63	25.5	213	8.78	207	222	224	228
679	9/29/93:1100	100	4.00	s	0	39	33.9	1.08	53	45.6	177	6.8	21	3.5	25	0.14	1.8	1	3.5	0.01	4004	277	63	32.5	211	8.80	208	207	209	211
679	9/29/93:1240	99	4.00	s	0	39	33.9	1.09	48	46.9	182	11.6	37	0.7	38	0.21	8.0	19	0.7	0.10	3977	282	65	34.5	212	8.41	208	206	208	211
679	9/29/93:1500	99	4.10	s	0	39	33.9	1.09	56	58.9	227	10.0	32	1.4	34	0.15	3.0	5	1.4	0.02	3948	286	65	37.0	210	8.60	207	205	208	212
697	10/08/93:0740	102	3.70	s	0	0	0.0	0.00	0	-4.6	-21	-0.9	-2	0.4	-2	0.10	3.9	11	0.4	-0.51	0	266	48	0.0	266	9.23	260	241	252	250
698	10/08/93:1040	101	3.80	s	22	24	38.4	1.01	68	66.4	306	-0.1	0	0.9	1	0.00	-8.2	-20	0.9	-0.06	3868	269	61	43.0	183	9.12	173	181	182	184

PSCC Arapahoe Uni
Calcs based on:

Test	Date & Time	Economizer Exit, dry (1-12)						Baghouse Inlet Gas Analysis, wet							Stack Gas Analysis, wet							Comments
		NO	CO	SO2	NO2	CO2	O2	NO	CO	SO2	NO2	CO2	H2O	O2	NO	CO	SO2	NO2	CO2	H2O	O2	
		ppm	ppm	ppm	ppm	%	%dry	ppm	ppm	ppm	ppm	%	%	%	ppm	ppm	ppm	ppm	%	%	%	
665	9/20/93:0810	240	47	410	0	14.13	5.05	212	29	363	-4	12.48	9.03	4.35	193	59	333	-4	11.70	11.99	4.97	Humid only
665	9/20/93:1410	223	180	393	0	14.09	4.90	208	27	350	-5	12.48	9.00	4.30	185	142	133	-5	11.87	12.14	4.82	NaSC
665	9/20/93:1640	231	118	385	0	14.00	5.20	208	21	338	-4	12.53	9.14	4.27	179	78	110	-4	11.71	12.36	4.95	
666	9/21/93:0730	229	86	353	2	13.70	5.15	211	29	316	-5	12.31	9.17	4.40	190	84	215	-2	11.88	8.73	5.45	Base
666	9/21/93:1040	233	56	350	1	13.43	5.70	217	16	310	-5	11.76	8.54	5.22	198	56	171	1	11.76	8.38	5.65	
666	9/21/93:1300	225	86	357	1	13.33	5.80	213	26	320	-4	11.90	8.63	5.08	190	46	175	1	11.38	8.28	5.95	
666	9/21/93:1420	225	57	350	1	13.32	5.65	205	26	318	-5	11.84	8.74	5.05	188	54	150	-3	11.44	10.03	5.68	
666	9/21/93:1530	237	86	352	0	13.60	5.50	215	23	310	-5	12.08	8.96	4.90	195	85	145	-3	11.44	10.83	5.45	
666	9/21/93:1630	238	64	353	1	13.62	5.50	213	26	312	-5	12.10	9.09	4.70	192	52	122	-4	11.16	12.06	5.40	
667	9/22/93:0720	215	212	463	2	13.91	5.07	193	40	397	-5	12.09	9.63	4.75	180	258	408	-4	12.34	9.61	4.85	
667	9/22/93:0930	213	247	472	1	14.03	5.18	197	41	402	-4	12.42	9.78	4.50	173	167	265	-4	11.70	12.52	5.00	
668	9/22/93:1150	205	715	490	1	14.81	4.15	187	123	415	-4	12.74	9.93	4.15	165	259	122	-3	12.02	12.96	4.50	
669	9/22/93:1300	215	234	453	1	13.97	5.15	190	74	400	-4	12.64	9.88	4.12	174	231	101	-3	11.84	12.86	4.82	
670	9/22/93:1420	215	236	421	0	14.05	5.10	191	91	383	-4	12.79	9.97	3.95	170	286	35	-3	11.96	12.80	4.60	
671	9/22/93:1550	215	222	407	0	14.11	4.90	195	70	372	-4	12.83	9.90	4.00	168	207	132	-3	11.90	12.81	4.65	
672	9/22/93:1700	215	309	397	1	14.20	4.85	197	65	352	-4	12.79	9.94	4.02	173	152	107	-3	11.73	13.01	4.80	
678	9/29/93:0815	250	226	419	3	13.81	5.45	239	21	361	-4	12.05	9.09	5.10	220	175	367	-3	11.97	8.99	5.45	base/abort
679	9/29/93:0800	250	491	372	2	13.59	5.50	239	24	312	-4	11.67	8.67	5.20	207	405	310	-4	11.37	10.37	5.60	base
679	9/29/93:1100	258	363	349	1	13.62	5.45	248	26	298	-5	11.67	8.57	5.35	216	254	153	-2	11.21	10.60	5.70	
679	9/29/93:1240	260	409	345	1	13.34	5.70	250	52	298	-4	11.60	8.31	5.40	211	464	151	-3	11.15	10.59	5.55	
679	9/29/93:1500	256	607	347	1	13.43	5.45	254	32	301	-4	11.74	8.50	5.15	212	377	115	-2	11.30	10.76	5.65	
697	10/08/93:0740	245	66	430	-3	14.54	5.15	215	41	375	-3	12.53	9.37	4.45	210	52	380	-3	12.71	9.37	4.90	Base
698	10/08/93:1040	220	24	373	-3	14.83	5.25	220	24	373	-3	12.58	9.30	4.48	198	32	113	-2	12.02	12.19	5.30	A&B feeders

PSCC Arapahoe Unit 4 Sodium Bicarbonate/Air Heater Injection Summary — Sodium Bicarbonate (b) .274 Na wt.
Modified for Air Heater Injection — Sodium Sesquicarbonate (s) .297 Na wt.

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (e)	Injector cal Flow	2Na/S*	NOx econ	SO2 ppmc	ΔSO2 Reduction Inlet	Stk	ΔBh	Util	ΔNOx Calcs---ΔN2O Overall	Na	ΔNOx	ΔNOx - - - - In/out		ΔN2O out/ec	ΔNO2 in/aho	ΔNO2 in/out	ΔNO in/out	Econ NO Calc ΔNOx	ΔNO	ΔNO2i	Baghouse Temps Taho	Grid	Out	IDin	Economizer Exit, dry (1-12): Base O2	SO2	NO	CO	NO2	CO2	N2O
		MWe	%wet	b/s	%	%	lb/min	S*	ppmd	dry	%	%	ppmc	%	%	%	%	%	ppmc	ppmc	ppmc	ppmc	ppmc	ppmc	ppmc	ppmc	°F	°F	°F	°F	%dry	ppm	ppm	ppm	ppm	%	ppm
790	4/14/94 10:00	100	4.50	b	0	0	0.0	0.00	285	433	3.2	1.9	-6		4.0	4.1	19.6	9.6	-24	2		-3.5	-28	11.4	8	1.9	277	270	255	265	5.95	376	238	39	2	12.66	1.1
790	4/14/94 13:45	100	4.30	b	0	34	38.2	1.06	285	319	21.6	34.2	51	32.2	5.5	7.8	0.9	8.5	-21	0		-1.9	-23	15.6	14	-5.3	281	275	268	273	5.95	376	238	39	2	12.66	1.1
790	4/14/94 14:45	100	4.40	b	0	34	38.2	1.06	285	298	27.1	48.4	87	45.8	6.8	11.1	11.6	6.4	-16	2		-0.2	-16	19.6	19	-5.5	281	275	267	274	5.95	376	238	39	2	12.66	1.1
790	4/14/94 15:45	100	4.40	b	0	34	38.2	1.05	285	289	30.1	59.7	122	57.1	12.2	11.7	5.7	2.9	-7	2		1.6	-5	35.0	37	-5.2	280	275	267	273	5.95	376	238	39	2	12.66	1.1
790	4/14/94 16:45	100	4.40	b	0	34	38.2	1.06	285	288	29.0	60.8	129	57.1	10.5	16.3	7.1	1.3	-3	2		3.9	1	30.2	34	-3.7	277	272	264	271	5.95	376	238	39	2	12.66	1.1
790	4/14/94 17:30	100	4.30	b	0	0	0.0	0.00	280	401	1.9	22.3	83		3.6	18.0	39.6	11.0	-27	4		-0.5	-27	10.0	10	3.6	275	269	262	268	5.90	340	235	96	2	12.76	-1.0
791	4/15/94 7:40	101	4.50	b	0	0	0.0	0.00	283	403	1.9	1.4	-2		1.3	9.2	120.2	11.7	-29	4		-3.4	-33	3.7	0	0.2	265	259	240	251	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 8:30	100	4.30	b	0	33	37.1	1.04	283	282	29.9	45.3	62	43.5	4.4	12.1	31.6	8.9	-22	4		-1.5	-24	12.5	11	-4.7	266	261	245	254	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 9:15	100	4.40	b	0	32	35.9	1.01	283	271	32.4	43.4	44	42.9	7.8	11.5	18.8	4.2	-11	4		4.3	-6	22.2	26	-4.3	267	261	250	256	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 10:15	100	4.40	b	0	32	35.9	1.02	283	263	34.2	56.0	87	55.1	11.2	16.4	11.4	1.1	-3	4		9.9	7	31.9	42	-0.8	269	264	251	259	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 11:15	100	4.40	b	0	32	35.9	1.01	283	263	34.4	60.9	106	60.0	10.4	16.0	14.2	2.5	-6	4		10.1	4	29.7	40	1.2	273	267	254	261	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 12:15	100	4.40	b	0	32	35.9	1.00	283	273	32.6	64.6	130	64.4	18.7	24.2	4.6	-7.0	17	2		11.1	28	53.3	64	2.1	275	268	257	264	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 13:20	100	4.40	b	0	32	35.9	1.01	283	270	32.7	66.6	136	65.7	8.1	17.1	17.7	5.2	-13	4		7.9	-5	22.9	31	0.0	277	271	259	261	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 14:15	100	4.40	b	0	32	35.9	1.01	283	270	33.3	69.7	147	69.3	8.7	17.1	17.5	3.1	-8	4		9.5	2	24.9	34	-0.1	280	274	262	271	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 15:15	100	4.50	b	0	32	35.9	1.01	283	263	34.8	71.5	148	70.9	7.9	21.2	16.2	2.9	-7	4		9.4	2	22.6	32	-1.8	282	275	265	274	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 15:55	100	4.40	b	0	32	35.9	1.01	283	284	29.8	55.0	102	54.7	4.1	17.5	20.0	2.6	-7	2		19.1	12	11.6	31	9.3	283	278	271	275	6.00	341	236	64	1	13.01	-0.8
791	4/15/94 17:00	100	4.40	b	0	32	35.9	1.01	283	274	32.4	63.5	128	63.1	7.8	12.8	11.8	3.0	-8	3		20.5	13	22.1	43	10.6	285	278	271	277	6.00	341	236	64	1	13.01	-0.8
792	4/18/94 8:30	110	3.90	b	0	0	0.0	0.00	278	523	1.9	0.5	-7		0.1	3.9		-3.2	9	3	0	-4.1	5	0.2	-4	-3.9	286	281	263	274	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 9:30	110	4.00	b	0	47	52.6	1.05	278	423	17.9	52.0	176	49.5	10.9	12.6	26.5	-11.7	33	8	5	-6.7	24	30.6	22	-13.7	291	285	272	281	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 10:30	110	3.90	b	0	47	52.6	1.04	278	412	20.9	67.0	240	64.5	11.5	13.2	13.7	-11.0	30	4	6	15.5	46	32.2	48	9.6	294	289	278	287	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 11:45	110	3.90	b	0	47	52.6	1.06	278	402	21.1	67.9	239	64.0	10.8	16.0	12.4	-12.5	36	4	7	16.0	52	30.4	48	9.9	297	293	284	292	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 12:35	110	3.90	b	0	47	52.6	1.06	278	0		68.2		64.3	13.3	18.3	10.5			4				37.2	53		298	293	288	292	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 13:10	110	3.80	b	0	47	52.6	1.07	278	398	21.5	55.4	172	51.9	4.6	9.1	20.4	-5.6	16	3	7	32.6	48	12.9	45	25.8	298	292	288	292	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 13:40	110	3.90	b	0	47	52.6	1.07	278	0		63.4		59.4	7.7	12.1	15.0			3				21.6	58		298	294	288	293	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 14:40	110	3.90	b	0	47	52.6	1.02	278	426	20.1	66.2	246	65.3	7.2	10.7	21.3	-11.1	32	4	7	33.1	65	20.1	53	26.9	297	293	286	294	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 15:40	110	3.90	b	0	47	52.6	1.03	278	0		65.4		63.3	4.9	11.0	23.9			3				13.7	45		298	294	289	294	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 17:30	110	4.00	b	0	47	52.6	1.01	278	437	18.7	67.0	259	66.5	8.5	13.4	17.4	-11.9	35	4	8	27.7	62	23.9	52	19.6	295	292	288	293	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 18:50	110	3.90	b	0	47	52.6	1.01	278	0		53.1		52.7	3.7	8.8	34.4			4				10.2	56		294	289	287	291	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 19:20	110	3.90	b	0	47	52.6	1.01	278	0		64.1		63.7	5.4	10.4	25.2			4				15.0	66					290	5.40	466	241	56	2	13.49	-1.6
792	4/18/94 19:50	110	3.90	b	0	47	52.6	1.01	278	0		62.0		61.6	4.0	9.1	35.0			4				11.2	61					289	5.40	466	241	56	2	13.49	-1.6
793	4/19/94 9:40	110	3.90	b	0	23	25.5	0.51	278	422		17.7		34.4	20.5	20.8	2.8			2				58.7	55		287	281	287	276	5.40	439	241	42	2	13.58	2.0
793	4/19/94 11:25	110	3.80	b	0	23	25.5	0.54	278	0		31.7		58.5	4.9	2.8	3.1			0				13.6	12		291	285	274	283	5.40	439	241	42	2	13.58	2.0
793	4/19/94 12:25	110	3.80	b	0	23	25.5	0.57	278	0		39.9		70.3	4.6	7.4	-12.9			-2				12.9	13		294	289	278	285	5.40	439	241	42	2	13.58	2.0
793	4/19/94 13:09	110	3.80	b	0	21	23.3	0.52	278	0		26.2		50.5	0.4	3.3	-91.5			-1				1.3	7		294	289	278	285	5.40	439	241	42	2	13.58	2.0
793	4/19/94 14:00	110	3.80	b	0	21	23.3	0.53	278	0		37.9		71.6	0.6	3.7	-63.2			-1				1.8	14		295	290	280	286	5.40	439	241	42	2	13.58	2.0
793	4/19/94 15:20	110	3.80	b	0	21	23.8	0.55	278	0		35.6		65.2	-0.5	4.5	97.7			-1				-1.5	7		294	289	279	280	5.40	439	241	42	2	13.58	2.0
793	4/19/94 16:40	110	3.90	b	0	21	23.8	0.55	278	391	11.7	30.8	85	55.8	-0.3	9.1	64.5	-5.6	17	0	3	4.0	21	-0.8	3	0.7	292	286	269	268	5.40	439	241	42	2	13.58	2.0
794	4/21/94 8:00	110	3.60	b	0	0	0.0	0.00	279	448	-5.1	0.1	22		-2.6	-4.2	-1.1	-7.0	22	0	2	-3.9	18	-11.8	-15	-5.1	272	264	246	258	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 10:00	110	3.60	b	0	55	61.7	1.57	283	283	30.1	86.1	227	54.8	10.0	10.3	10.3	-9.4	27	3	8	4.3	31	28.4	33	-4.4	279	274	262	272	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 10:35	110	3.60	b	0	55	61.7	1.57	283	0		90.6		57.7	19.6	19.9	2.3			1				55.9	54						5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 11:10	110	3.60	b	0	55	61.7	1.49	283	302	29.1	75.3	197	50.5	2.7	4.1	93.3	-9.1	26	7	11	35.7	64	7.6	43	25.0	283	276	270	276	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 12:10	110	3.60	b	0	55	61.7	1.53	283	286	31.2	85.9	227	56.2	6.9	10.2	14.1	-9.2	27	3	9	42.1	69	19.6	62	32.9	279	280	270	279	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 13:05	110	3.60	b	0	55	61.7	1.51	283	284	32.3	89.4	240	59.0	7.9	12.9	15.3	-9.6	28	3	10	39.7	68	22.5	62	29.6	286	280	273	280	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 15:06	110	3.60	b	0	55	61.7	1.54	283	419	29.0	92.1	386	59.9	8.8	14.1	13.9	-15.3	47	3	11	34.4	61	25.0	59	34.0	288	284	278	283	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 16:00	110	3.60	b	0	55	61.7	1.53	283	80		80.7		52.8	-0.9	4.0	13.2			2				11.9	74		288	282	278	283	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 17:00	110	3.60	b	0	55	61.7	1.53	283	283	31.9	90.1	242	59.0	7.6	15.6	11.7	-12.1	36	3	11	56.6	93	21.8	79	45.6	287	281	286	282	5.30	369	247	78	1.7	13.74	-1.1
794	4/21/94 18:00	110	3.60	b	0	55	61.7	1.56	283	287	29.2	92.6	257	59.1	9.3	13.5	11.6	-19.2	62	3	11	52.1	114	26.5	79	40.8	287	281	277	282	5.30	369	247	78	1.7	13.74	-1.1

PSCC Arapahoe Uni

		Econ Exit, dry (1,2,11,12): w/Sorb							Baghouse Inlet Gas Analysis, wet (AHO 1-6, if dry)									Stack Gas Analysis, wet									
Test	Date & Time	O2	SO2	NO	CO	NO2	CO2	N2O	O2	SO2	NO	CO	NO2	CO2	H2O	N2O	NH3	O2	SO2	NO	CO	NO2	CO2	H2O	N2O	NH3	Comments
		%dry	ppm	ppm	ppm	ppm	%	ppm	%	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	ppm	ppm	ppm	%	%	ppm	ppm	
790	4/14/94 10:00	7.70	331	211	26	1	11.22	1.0	4.60	351	206	51	-3	11.91	8.69	2.9	1.0	5.65	332	209	28	-1	11.35	8.36	2.7	1.1	baseline, bicarb on 1330
790	4/14/94 13:45	7.75	300	215	23	1	11.21	0.8	4.45	260	199	103	4	12.12	9.05	2.7	2.4	5.60	203	205	59	0	11.41	8.48	1.1	2.4	FFDC clean 1325-1400
790	4/14/94 14:45	7.75	301	219	23	2	11.18	0.8	4.50	242	198	99	6	12.01	8.95	1.8	3.0	5.65	159	200	54	1	11.44	8.47	2.7	2.7	
790	4/14/94 15:45	7.70	305	209	23	1	11.26	0.8	4.40	235	192	178	7	12.28	9.25	5.1	3.2	5.55	126	188	66	3	11.53	8.61	2.5	3.2	
790	4/14/94 16:45	8.05	292	219	17	1	10.93	0.4	4.55	233	197	118	8	12.16	9.02	3.4	2.0	5.60	120	189	51	4	11.48	8.67	2.6	3.2	
790	4/14/94 17:30	8.20	291	229	15	1	10.92	-0.4	4.20	331	204	197	-2	12.34	9.31	7.0	0.6	5.55	241	205	89	1	11.46	8.63	2.1	1.3	Bicarb off 1700
791	4/15/94 7:40	8.35	289	216	20	2	11.05	-0.4	4.40	329	207	102	-2	12.50	9.11	2.9	0.0	5.85	301	210	56	-1	11.62	8.52	2.6	0.5	baseline, bicarb on 0800
791	4/15/94 8:30	8.05	290	221	21	2	11.14	0.4	4.50	229	199	99	4	12.38	9.06	2.3	3.3	6.00	162	200	42	0	11.57	8.46	2.2	2.5	FFDC clean 0840-0915
791	4/15/94 9:15	8.05	289	212	21	2	11.13	0.5	4.50	220	196	58	8	12.45	9.08	3.4	3.5	5.75	170	192	43	5	11.62	8.51	2.4	3.7	
791	4/15/94 10:15	8.00	289	217	22	2	11.21	0.2	4.30	216	195	103	10	12.63	9.23	5.1	2.7	5.70	132	181	50	9	11.70	8.59	2.0	2.5	
791	4/15/94 11:15	8.30	283	213	21	1	10.82	0.0	4.35	215	195	164	9	12.58	9.20	3.7	2.9	5.90	116	180	70	9	11.53	8.52	2.4	2.8	
791	4/15/94 12:15	8.20	288	216	21	1	11.16	0.3	4.60	220	192	92	9	12.36	9.01	4.0	3.0	6.00	105	161	47	9	11.46	8.36	1.1	2.8	
791	4/15/94 13:20	8.45	280	219	18	1	11.01	0.6	4.60	218	193	90	8	12.25	9.00	4.3	2.5	5.80	100	188	51	7	11.59	8.54	2.3	2.0	
791	4/15/94 14:15	8.40	283	218	22	1	10.92	-0.2	4.70	216	193	86	9	12.23	8.95	3.8	2.1	6.00	90	183	51	8	11.40	8.39	2.5	2.7	
791	4/15/94 15:15	8.55	279	229	14	1	10.80	-0.8	4.45	214	197	76	11	12.42	9.07	1.6	3.0	5.90	85	186	46	8	11.54	8.45	2.0	2.2	FFDC clean 1520-1555
791	4/15/94 15:55	8.55	280	226	14	1	10.86	-1.0	4.95	224	201	59	9	12.05	8.83	2.2	2.9	5.90	135	187	41	15	11.49	8.43	1.0	2.3	
791	4/15/94 17:00	8.10	290	215	23	1	11.14	-0.4	4.65	220	196	49	9	12.25	8.91	1.6	2.9	5.85	110	179	35	17	11.50	8.37	1.2	2.3	
792	4/18/94 8:30	7.50	400	217	55	1	11.88	-0.5	5.35	455	250	34	2	13.49	0.00	-1.0	1.2	5.20	410	218	33	-2	11.97	8.99	1.1	-0.8	Baseline, bicarb on 0900
792	4/18/94 9:30	7.40	389	214	54	2	11.54	0.0	5.25	370	241	55	6	13.56	0.00	0.4	1.0	5.10	193	200	51	-5	11.59	8.80	4.9	3.2	
792	4/18/94 10:30	7.35	395	215	45	2	12.00	-0.6	5.10	364	239	88	7	13.56	0.00	-1.6	1.2	4.95	135	181	51	14	12.35	9.10	2.0	2.2	
792	4/18/94 11:45	7.55	381	221	41	1	11.62	1.1	5.30	351	242	65	7	13.52	0.00	0.7	1.1	5.10	128	181	42	14	12.01	8.76	1.5	2.5	
792	4/18/94 12:35	7.55	381	221	41	1	11.62	1.1										5.20	125	174	38	14	12.09	9.10	1.6	2.9	FFDC clean 1235-1310
792	4/18/94 13:10	7.50	380	219	53	2	11.84	1.9	5.25	348	240	62	8	13.60	0.00	0.2	0.9	5.20	175	180	49	27	12.14	8.92	0.8	2.6	
792	4/18/94 13:40	7.50	380	219	53	2	11.84	1.9										5.05	145	172	49	30	12.18	8.91	1.1	2.2	
792	4/18/94 14:40	7.35	404	220	69	1	11.89	1.8	5.35	370	247	46	7	13.48	0.00	-0.4	1.6	5.10	140	175	63	27	12.26	8.99	1.9	1.5	
792	4/18/94 15:40	7.40	395	225	34	1	11.63	-0.1										5.30	139	179	22	26	12.01	8.81	1.1	2.8	
792	4/18/94 17:30	7.20	412	225	21	2	11.84	0.3	5.30	381	245	33	9	13.36	0.00	0.7	1.2	5.15	138	176	26	23	12.10	8.87	1.8	3.3	
792	4/18/94 18:50	7.20	412	225	21	2	11.84	0.3										5.15	195	172	22	37	12.13	9.20	1.3	2.4	FFDC clean 1815-1850
792	4/18/94 19:20	7.20	412	225	21	2	11.84	0.3										5.10	150	165	28	41	12.06	9.12	1.5	3.0	
792	4/18/94 19:50	7.20	412	225	21	2	11.84	0.3										5.15	158	168	31	40	12.17	9.13	1.6	1.9	
793	4/19/94 9:40	7.10	396	216	25	2	12.32	-1.2										2.00	400	213	42	-2	12.30	9.28	0.1	1.5	
793	4/19/94 11:25	7.00	377	212	257	2	12.19	2.9										5.20	255	205	131	1	12.20	9.20	2.1	2.4	
793	4/19/94 12:25	7.20	355	220	31	2	11.89	-0.8										5.15	215	205	48	2	12.17	9.27	0.5	3.3	
793	4/19/94 13:09	7.20	355	220	31	2	11.89	-0.8										5.10	265	210	32	7	12.15	9.26	0.9	2.3	FFDC cclean1230-1305
793	4/19/94 14:00	7.10	350	222	32	2	12.20	-0.5										5.10	218	205	25	11	12.13	9.26	0.9	3.5	
793	4/19/94 15:20	7.20	344	225	27	1	11.95	-0.8										6.00	211	198	23	6	11.53	8.88	0.8	2.8	
793	4/19/94 16:40	7.50	332	230	22	2	11.66	0.4	5.30	341	255	28	5	13.64	0.00	-0.3	2.1	5.20	235	211	27	5	12.07	9.44	1.4	3.6	
794	4/21/94 8:00	6.70	339	222	58	1	12.69	0.0	5.10	396	275	65	3	14.96	0.00	-2.1	1.7	4.90	333	230	52	-2	12.52	9.71	0.1	1.0	Start feed @0900
794	4/21/94 10:00	6.90	317	222	44	2	11.92	1.0	4.90	253	244	71	10	13.99	0.00	0.3	2.0	4.90	44	196	71	5	12.52	9.59	1.3	4.4	
794	4/21/94 10:35	6.90	317	222	44	2	11.92	1.0										4.85	30	180			12.52	9.59			FFDC start clean
794	4/21/94 11:10	7.10	329	222	61	1	12.45	1.9	5.20	265	257	62	11	14.73	0.00	0.3	2.1	5.10	81	185	53	29	12.38	9.62	4.5	3.6	
794	4/21/94 12:10	7.00	323	228	41	2	12.10	0.6	5.00	254	250	45	10	13.79	0.00	0.7	2.0	4.90	46	173	48	34	12.58	9.67	1.2	4.6	
794	4/21/94 13:05	7.40	317	226	41	2	11.90	0.1	5.10	251	246	40	11	13.59	0.00	3.0	2.2	5.00	35	172	36	32	12.45	9.47	1.7	3.6	
794	4/21/94 15:06	7.40	312	227	39	2	11.78	0.9	5.40	254	253	44	12	13.92	0.00	-0.2	1.4	5.30	25	171	37	28	12.21	9.25	1.7	4.4	
794	4/21/94 16:00	7.40	314	225	33	1	11.97	0.1										5.40	61	170	31	49	11.99	9.05	1.3	4.2	FFDC clean 1520-1555
794	4/21/94 17:00	7.30	317	236	35	2	12.02	-0.2	5.30	247	250	40	11	13.66	0.00	0.5	1.4	5.00	32	180	49	48	12.38	9.18	1.0	4.4	
794	4/21/94 18:00	7.30	309	226	39	2	11.80	0.6	5.40	249	266	32	12	13.91	0.00	0.0	2.4	5.10	24	159	34	42	12.36	9.10	1.4	4.0	

PSCC Arapahoe Unit 4 Sodium/AH Injection Summary **Modified for Air Heater Injection**

Sodium Bicarbonate (b) .274 Na wt.
Sodium Sesquicarbonate (s) .297 Na wt.

				Sorbent Feed			Injector cal		NOx	SO2	NOx	SO2	ΔSO2 Reduction				ΔNOx Calcs---		ΔN2O	ΔNOx		ΔN2O	ΔNO2	ΔNO	ΔNOx	ΔNO	ΔNO2	Baghouse Temps			
Test	Date & Time	Load	O2cr	Na	A (w)	B (e)	Flow	2Na	econ	ppmc	ahex	ahex	Inlet	Stk	ΔBh	Util	Overall	Na	ΔNOx	aho/stk		ec/stk	ec/stk	aho/stk	ec/stk	ec/stk	aho/stk	Taho	Grid	Out	IDin
		MWe	%wet	b/s	%	%	lb/min	S*	ppmd	dry	ppmdc	ppmdc	%	%	ppmc	%	%	%	%	%	ppmc	ppmc	ppmc	ppmc	ppmc	ppmc	ppmc	°F	°F	°F	°F
805	5/17/94 15:11	103	4.40	b	0	0	0.0	0.00	317	422	321	411	2.7	6.9	18		4.2	4.2	11.6	4.9	-16	-2	-6	-11	-14	-8	-4.5	282	274	262	269
805	5/17/94 17:46	101	4.35	b	0	34	36.2	1.00	317	427	296	335	21.5	59.7	163	59.6	10.2	9.4	9.4	5.1	-15	-3	6	-19	-33	-40	3.2	289	282	276	281
805	5/18/94 7:56	81	5.80	b	0	30	33.7	1.16	288	402	290	300	25.3	76.5	206	66.0	10.1	10.1	-0.8	13.1	-40	0	6	-38	-29	-36	-1.7	255	249	241	249
805	5/18/94 9:35	104	4.60	b	0	30	33.7	0.91	312	404	314	337	16.4	51.4	141	56.5	1.1	1.1	-25.0	3.2	-10	1	15	-22	-4	-20	11.5	278	270	260	267
805	5/18/94 12:30	104	4.60	b	0	30	33.7	0.92	325	398	327	340	14.6	51.4	146	55.6	1.8	1.8	12.5	3.7	-12	-1	6	-15	-6	-13	2.3	281	273	266	273
806	5/19/94 9:41	100	4.70	b	0	30	33.7	0.97	293	392	308	324	17.6	57.5	157	59.1	4.6	4.6	-1.6	10.2	-32	0	12	-41	-14	-28	9.2	270	263	254	261
806	5/19/94 10:00	100	4.70	b	0	30	33.7	0.97	293	392	308	324	17.6	58.2	160	59.8	3.4	3.4	1.3	9.1	-29	0	9	-34	-10	-21	5.2	270	263	254	261
807	5/19/94 11:00	80	5.90	b	0	20	22.7	0.82	318	386	305	314	18.6	54.2	137	66.1	7.0	7.0	-6.5	5.3	-16	1	9	-19	-22	-33	2.9	267	261	255	261
808	5/19/94 13:00	97	4.70	b	0	48	53.1	1.57	289	395	289	273	31.1	77.7	184	49.6	2.5	2.5	-0.9	5.7	-17	0	14	-23	-7	-23	5.9	278	273	265	270
809	5/19/94 14:00	80	5.90	b	0	48	53.7	1.92	319	390	298	284	27.2	80.2	207	41.8	12.5	12.5	-6.2	9.4	-29	2	12	-33	-40	-54	3.3	273	268	262	269
810	5/19/94 15:30	80	5.90	b	0	45	50.7	1.79	318	395	298	277	29.9	85.9	221	47.9	16.8	16.8	-3.4	14.6	-45	2	13	-48	-54	-68	3.0	272	266	260	266
810	5/19/94 16:30	80	5.90	b	0	45	50.3	1.80	323	391				85.4		47.5	18.1	18.1	-5.6			3	12	0	-59	-72		272	266	260	266
812	5/23/94 10:38	103	3.40	s	0	0	0.0	0.00	277	461	289	457	0.8	4.8	18		-3.7	-3.8	2.5	0.4	-1	0	-4	3	10	15	-4.1	281	274	263	271
812	5/23/94 12:35	102	3.40	s	0	45	39.4	0.94		507				29.0		31.0		-9.4				7	-1					267	280	271	276
813	5/23/94 14:00	110	3.90	s	0	45	39.6	1.15	325	385	325	365	5.3														-1.9	292	286	276	
813	5/23/94 15:40	107	3.90	s	0	45	39.6	1.18		385	294	311	19.2	31.2	97	26.4		9.4		6.0	-18	4	-2	-10			-8.5	290	283	276	282
814	5/23/94 16:05	108	3.80	s	0	75	67.6	2.00		385	308	293	24.0	74.7	195	37.4		13.8		15.4	-49	2	6	-47			-2.0	288	283	277	
815	5/23/94 17:45	95	4.00	s	0	75	67.6	1.66		524	278	402	23.3	67.9	234	40.8		10.6		8.9	-26	4	14	-29			3.1	282	278	275	282
816	5/23/94 19:25	95	4.10	s	0	45	39.4	0.96		527	273	441	16.3	50.1	178	52.0		8.8		8.7	-24	5	11	-26			3.2	277	272	269	274
817	5/24/94 8:10	106	3.90	s	0	0	0.0	0.00		493	298	491	0.4	-3.8	-21			6.7		5.7	-17	2	-3	-13			-4.6	277	269	254	264
817	5/24/94 11:35	105	3.90	s	0	71	63.6	1.50		496	285	410	17.3	54.7	186	36.5		10.2		6.7	-20	3	4	-13			-6.4	285	277	270	277
817	5/24/94 12:40	104	4.10	s	0	71	63.6	1.42		529	280	414	21.9	63.7	221	44.9		12.0		9.1	-26	7	6	-25			-1.5	286	279	277	278
817	5/24/94 14:11	104	4.10	s	0	71	63.6	1.50		501	275	401	20.0	48.3	142	32.2		8.3		4.5	-13	6	15	-20			6.8	284	278	273	279
817	5/24/94 15:09	105	4.00	s	0	71	63.6	1.47		507	271	387	23.7	54.1	154	36.9		8.4		6.2	-17	4	12	-21			3.5	284	278	273	278
817	5/24/94 16:09	104	3.90	s	0	71	63.6	1.55		484	281	384	20.7	55.8	170	36.0		7.5		6.8	-26	5	11	-29			3.3	278	272	268	274
817	5/24/94 17:10	105	4.10	s	0	71	63.6	1.57		473	278	380	19.7	59.8	190	38.0		6.5		9.6	-28	7	11	-31			3.4	280	273	267	274
817	5/24/94 18:00	105	4.10	s	0	71	63.6	1.57		473	272	373	21.2	63.4	199	40.3		11.1		7.1	-20	5	10	-22			2.3	280	273	268	274
817	5/24/94 18:40	105	4.10	s	0	71	63.6	1.60		465				63.9		40.0		6.7				5	10				10.9	280	273	268	281
817	5/24/94 19:17	105	4.10	s	0	71	63.6	1.57		473				41.6		26.4		7.2				4	12				13.8	280	273	268	274

PSCC Arapahoe Uni

		Economizer Exit, dry (1-12): Base							Econ Exit, dry (1,2,11,12): w/Sorb							Baghouse Inlet Gas Analysis (AHO 1-6,dry)									Stack Gas Analysis, wet									
Test	Date & Time	O2	SO2	NO	CO	NO2	CO2	N2O	O2	SO2	NO	CO	NO2	CO2	N2O	O2	SO2	NO	CO	NO2	CO2	H2O	N2O	NH3	O2	SO2	NO	CO	NO2	CO2	H2O	N2O	NH3	Comments
		%dry	ppm	ppm	ppm	ppm	%	ppm	%dry	ppm	ppm	ppm	ppm	%	ppm	%	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	ppm	ppm	ppm	%	%	ppm	ppm	
805	5/17/94 15:11	8.30	298	224	116	2	10.62	5.2	8.30	298	224	116	2	10.62	5.2	6.20	338	264	118	2	12.38	0.00	0.9	0.6	6.60	278	219	72	-2	10.79	7.99	4.1	0.6	C mill OOS, Mill @4000 rpm
805	5/17/94 17:46	8.30	298	224	116	2	10.62	5.2	8.40	299	222	74	1	10.65	2.6	6.40	272	240	60	6	12.16	0.00	0.4	1.3	6.30	124	200	78	8	11.06	8.19	3.1	2.4	Start bicarb @1645 hrs
805	5/18/94 7:56	8.20	286	205	37	2	10.95	2.0	8.20	286	205	37	2	10.95	2.0	7.40	227	219	32	9	11.58	0.00	1.3	0.0	7.60	62	165	31	7	10.36	7.68	2.0	2.1	
805	5/18/94 9:35	7.80	296	229	73	1	11.23	2.1	7.80	296	229	73	1	11.23	2.1	5.90	283	263	54	6	12.73	0.00	2.1	0.7	6.30	141	210	36	13	11.17	8.33	2.7	2.2	1 hr after clean
805	5/18/94 12:30	8.20	283	231	106	1	10.90	2.9	8.20	283	231	106	1	10.90	2.9	5.90	285	274	126	5	12.67	0.00	1.4	0.3	6.30	139	224	67	6	11.10	8.46	2.4	2.5	
806	5/19/94 9:41	7.50	294	220	131	2	11.37	3.6	7.50	294	220	131	2	11.37	3.6	6.20	266	252	62	7	12.53	0.00	3.4	1.1	6.30	120	190	67	13	11.16	8.60	3.6	2.0	
806	5/19/94 10:00	7.50	294	220	131	2	11.37	3.6	7.50	294	220	131	2	11.37	3.6	6.20	266	252	62	7	12.53	0.00	3.4	1.1	6.50	116	193	62	10	10.91	8.40	3.3	3.0	
807	5/19/94 11:00	8.50	268	221	35	1	10.55	3.1	8.50	268	221	35	1	10.55	3.1	7.30	239	232	37	7	11.47	0.00	2.7	2.0	7.50	116	188	32	8	10.23	7.83	3.9	2.3	
808	5/19/94 13:00	7.80	290	212	106	1	11.29	3.7	7.80	290	212	106	1	11.29	3.7	6.60	218	231	45	9	12.22	0.00	2.4	1.2	6.50	62	187	50	12	10.97	8.71	3.6	3.1	
809	5/19/94 14:00	8.60	269	220	34	1	10.53	2.3	8.60	269	220	34	1	10.53	2.3	7.00	221	232	35	9	11.74	0.00	2.4	1.2	7.50	51	174	29	10	10.15	8.17	3.8		
810	5/19/94 15:30	9.00	263	212	32	0	10.25	2.2	9.00	263	212	32	0	10.25	2.2	7.40	209	225	37	9	11.72	0.00	1.4	1.5	7.40	37	165	33	10	10.26	8.11	3.4	2.7	
810	5/19/94 16:30	9.25	255	211	24	0	9.68	1.5	9.25	255	211	24	0	9.68	1.5										7.40	38	166	30	9	10.18	8.07	3.7	2.9	
812	5/23/94 10:38	4.90	410	248	218	2	13.85	6.2	6.50	371	223	155	2	12.31	8.3	4.80	411	260	218	2	13.75	0.00	5.0	-1.2	5.40	335	223	170	-2	11.77	8.79	5.5	-1.3	
812	5/23/94 12:35								5.90	425	207	676	1	12.81	5.2										5.35	276	209	131	-1	11.84	8.74	5.3	0.6	
813	5/23/94 14:00	5.20	320	285	30	2	12.34	0.5	6.50	310	250	45	1	11.45	4.9	5.20	320	285	30	2	12.34	0.00	0.5	-1.1										
813	5/23/94 15:40								6.50	310	250	45	1	11.45	4.9	4.80	280	265	43	6	12.68	0.00	0.2	-1.7	5.00	163	217	38	-2	10.88	10.90	2.7	1.2	
814	5/23/94 16:05								6.50	310	250	45	1	11.45	4.9	5.00	260	274	35	8	12.56	0.00	0.4	-1.2	5.00	74	199	35	6	10.96	10.94	1.6	-0.4	
815	5/23/94 17:45								7.50	393	221	78	1	11.76	1.4	5.60	344	238	73	11	13.10	0.00	1.6	-1.8	5.90	124	184	45	12	11.62	8.63	3.0	0.2	
816	5/23/94 19:25								7.20	404	215	142	2	11.78	2.2	5.50	380	235	82	6	13.27	0.00	0.7	-0.7	5.90	194	181	82	9	11.49	8.66	3.5	0.0	
817	5/24/94 8:10								7.60	367	223	82	2	11.45	2.9	5.60	420	255	145	1	13.18	0.00	3.1	1.1	5.65	382	213	151	-2	11.63	9.13	1.5	0.5	
817	5/24/94 11:35								7.75	365	225	92	1	11.41	2.0	5.55	352	245	132	9	13.02	0.00	-1.0	1.3	5.90	165	200	99	3	11.46	8.88	2.5	2.3	
817	5/24/94 12:40								7.50	397	223	224	1	11.75	2.3	5.55	355	240	174	9	13.28	0.00	0.3	0.9	5.82	142	188	141	6	11.51	8.99	4.8	1.3	
817	5/24/94 14:11								7.80	373	220	147	1	11.56	2.3	5.60	343	235	104	9	13.11	0.00	2.8	1.1	5.90	190	187	118	13	11.47	9.07	4.3	2.6	
817	5/24/94 15:09								7.40	383	217	225	1	11.85	0.6	5.40	335	235	231	9	13.40	0.00	3.5	0.9	5.80	172	185	141	10	11.53	9.02	3.3	2.2	
817	5/24/94 16:09								7.10	374	220	202	1	11.93	3.3	5.30	335	245	131	8	13.36	0.00	4.7	0.3	5.70	159	167	106	10	11.63	9.24	3.8	2.7	
817	5/24/94 17:10								7.10	365	218	289	1	11.97	1.8	5.35	330	242	196	8	13.42	0.00	2.4	0.3	5.80	142	185	176	9	11.71	9.21	5.4	3.0	
817	5/24/94 18:00								7.30	360	222	332	1	11.87	3.3	5.30	325	237	189	8	13.49	0.00	3.1	1.0	5.60	130	187	196	8	11.70	9.05	3.9	2.6	
817	5/24/94 18:40								6.80	367	218	489	1	12.09	4.2										5.60	126	186	199	8	11.10	9.00	3.8	3.0	
817	5/24/94 19:17								7.30	360	222	332	1	11.87	3.3										5.50	209	195	118	10	11.10	9.00	2.9	3.0	

PSCC Arapahoe Unit 4 Sodium/Urea Injection Summary   Sodium Bicarbonate (b) .274 Na wt.   Sodium Sesquicarbonate (s) .297 Na wt.

Test	Date & Time	Load	O2cr	Sorbent Feed Na	A (w)	B (s)	Injector cal Flow	2Na/S*	NOx econ	SO2 ppmc	NOx ahex	SO2 ahex	ΔSO2 Reduction Stack		Util	ΔNOx - ΔN2O Overall	ΔNOx	ΔNOx aho/stk		ΔN2O ec/stk	ΔNO2 ec/stk	ΔNO aho/stk	ΔNOx ec/stk	ΔNO ec/stk	ΔNO2 aho/stk	Baghouse Temps Taho	Grid	Out	IDin
		MWe	%wet	b/s	%	%	lb/min		ppmcd	dry	ppmcd	ppmcd	%	ppmc	%	%	%	%	ppmc	ppmc	ppmc	ppmc	ppmc	ppmc	ppmc	°F	°F	°F	°F
818	5/25/94 11:45	108	4.40	s	0	66	59.4	1.54	313	439	273	384	1.6	7	1.1	0.0		-3.0	9	0	-8	6	-0.1	8	1.0	281	273	262	269
818	5/25/94 12:35	108	4.50	s	0	66	59.4	1.54	313	439	273	384	52.8	232	34.4	5.8	-0.2	3.0	-9	0	-6	-9	-18.3	-13	2.8	284	272	266	270
818	5/25/94 13:12	108	4.30	s	0	66	59.4	1.51	310	447	272	390	52.0	233	34.5	3.4	-47.8	1.3	-4	5	7	-11	-10.6	-17	15.1	284	273	269	273
818	5/25/94 14:10	108	4.30	s	0	66	59.4	1.51	310	447	272	390	58.3	261	38.6	10.5	-17.8	8.6	-26	6	8	-26	-32.9	-41	16.4	284	273	269	273
818	5/25/94 15:12	108	4.30	s	0	66	59.4	1.51	310	447	272	390	60.7	272	40.2	8.7	-15.7	6.7	-20	4	5	-21	-27.0	-32	13.1	279	268	263	270
818	5/25/94 16:06	108	4.20	s	0	66	59.4	1.51	310	447	272	390	63.0	282	41.7	7.7	-30.3	5.7	-17	7	3	-19	-24.1	-28	11.8	277	266	263	267
818	5/25/94 17:06	106	4.20	s	0	64	57.7	1.49	334	448	277	390	64.5	289	43.3	12.2	-7.9	4.9	-15	3	2	-15	-41.1	-43	11.5	276	266	263	267
818	5/25/94 18:13	105	4.20	s	0	64	57.7	1.51	334	448	277	390	54.7	245	36.3	14.9	-4.0	7.8	-24	2	14	-25	-50.3	-64	22.9	275	264	258	265
818	5/25/94 18:53	105	4.20	s	0	64	57.7	1.51	334	448	277	390	59.4	266	39.5	14.2	-2.1	7.0	-22	1	10	-24	-47.7	-57	19.0	275	264	258	265
819	5/26/94 7:30	105	3.90	s	0	0	0.0	0.00	298	442	260	386	0.3	1		2.6	-8.3	-0.7	2	1	-9	2	-8.0	1	1.3	270	261	245	255
819	5/26/94 10:05	101	4.10	s	0	24	20.1	0.56	296	435	262	381	33.3	145	59.2	1.6	-108	0.1	0	5	-5	0	-4.6	0	3.6	273	263	250	260
820	5/26/94 11:58	100	4.10	s	0	41	36.0	1.02	296	435	262	381	45.8	199	45.0	7.9	-29.5	6.6	-19	7	-2	-14	-23.5	-22	6.6	275	265	257	264
820	5/26/94 13:00	100	4.20	s	0	41	36.0	1.02	296	435	262	381	48.7	212	47.9	6.9	-23.7	5.6	-16	5	-3	-14	-20.5	-18	5.4	274	264	255	264
820	5/26/94 14:00	100	4.00	s	0	41	36.0	1.02	296	435	262	381	50.3	219	49.5	4.2	-52.4	2.8	-8	7	-4	-5	-12.5	-9	4.7	274	263	256	263
821	5/26/94 15:05	101	4.20	s	0	78	70.6	1.97	296	435	262	381	67.0	291	33.9	8.1	-12.8	6.8	-20	3	-2	-17	-24.1	-22	6.1	275	264	256	264
821	5/26/94 16:08	101	4.00	s	0	78	70.6	1.97	296	435	262	381	68.5	298	34.7	7.8	-8.0	6.5	-19	2	-1	-17	-23.2	-22	7.0	275	265	260	263
821	5/26/94 16:40	101	4.10	s	0	78	70.6	1.97	296	435	262	381	60.2	262	30.5	2.8	-71.6	1.4	-4	6	13	-19	-8.3	-21	21.0	265	265	259	265
821	5/26/94 17:00	100	3.90	s	0	78	70.6	1.99	296	435	262	381	62.2	270	31.2	6.8	-22.0	5.5	-16	4	10	-24	-20.4	-31	18.7	265	264	259	265
821	5/26/94 18:00	100	4.00	s	0	78	70.6	1.99	296	435	262	381	65.4	285	32.8	7.5	-30.5	6.1	-18	7	9	-24	-22.2	-32	17.7	274	263	257	263
822	5/27/94 7:30	102	4.80	s	0	80	72.5	2.02	331	432	277	377	0.5	2	0.2	2.3	-25.4	-4.8	15	2	-8	9	-7.6	0	0.8	268	259	240	250
822	5/27/94 9:20	102	4.80	s	0	80	72.5	2.02	331	432	277	377	57.6	249	28.5	4.6	-17.8	-2.3	7	3	13	-18	-15.4	-28	21.3				
822	5/27/94 10:20	100	4.80	s	0	80	72.5	2.03	340	438	281	382	64.6	283	31.8	11.7	-7.6	4.2	-13	3	8	-23	-40.1	-48	16.6	279	266	256	265
822	5/27/94 11:20	100	4.80	s	0	80	72.5	2.03	340	438	281	382	65.2	285	32.0	8.7	-9.3	1.0	-3	3	9	-17	-29.9	-39	17.9	279	266	256	265
822	5/27/94 12:20	100	4.80	s	0	80	72.5	2.03	340	438	281	382	65.3	286	32.1	11.8	-9.6	4.3	-13	4	7	-20	-40.2	-47	15.4	280	270	261	269

PSCC Arapahoe Uni

Test	Date & Time	Economizer Exit, dry (1-12): Base							Baghouse Inlet Gas Analysis									Stack Gas Analysis, wet									Comments
		O2	SO2	NO	CO	NO2	CO2	N2O	O2	SO2	NO	CO	NO2	CO2	H2O	N2O	NH3	O2	SO2	NO	CO	NO2	CO2	H2O	N2O	NH3	
		%dry	ppm	ppm	ppm	ppm	%	ppm	%	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	ppm	ppm	ppm	%	%	ppm	ppm	
818	5/25/94 11:45	6.10	365	259	295	2	12.71	4.1	6.10	318	226	80	-5	11.11	8.93	2.7	1.3	6.10	313	232	172	-4	11.13	8.89	3.7	1.6	Duct injection
818	5/25/94 12:35	6.10	365	259	295	2	12.71	4.1	6.10	318	226	80	-5	11.11	8.93	2.7	1.3	6.10	150	217	125	-3	11.13	9.03	3.6	2.3	FFDC clean start
818	5/25/94 13:12	6.10	364	257	295	1	12.50	-0.1	6.20	321	224	91	-5	10.94	8.95	2.1	1.1	6.00	156	213	214	6	11.26	9.14	3.6	2.8	FFDC clean finished
818	5/25/94 14:10	6.10	364	257	295	1	12.50	-0.1	6.20	321	224	91	-5	10.94	8.95	2.1	1.1	5.90	137	198	236	7	11.33	8.95	4.2	2.5	
818	5/25/94 15:12	6.10	364	257	295	1	12.50	-0.1	6.20	321	224	91	-5	10.94	8.95	2.1	1.1	5.95	128	203	120	4	11.27	9.22	3.0	2.7	
818	5/25/94 16:06	6.10	364	257	295	1	12.50	-0.1	6.20	321	224	91	-5	10.94	8.95	2.1	1.1	6.00	120	205	110	3	11.22	9.32	5.2	2.7	
818	5/25/94 17:06	6.30	350	273	140	2	12.40	1.7	6.55	313	222	43	-5	10.74	8.92	3.0	0.3	6.30	113	207	87	3	10.99	9.04	3.8	3.5	Load dropped 1640
818	5/25/94 18:13	6.30	350	273	140	2	12.40	1.7	6.55	313	222	43	-5	10.74	8.92	3.0	0.3	5.90	148	197	78	12	11.34	9.46	3.0	3.2	FFDC clean finished
818	5/25/94 18:53	6.30	350	273	140	2	12.40	1.7	6.55	313	222	43	-5	10.74	8.92	3.0	0.3	6.20	130	198	87	9	11.14	9.19	2.2	2.5	
819	5/26/94 7:30	5.70	366	253	234	4	12.92	3.5	6.00	322	217	73	-5	11.30	9.05	1.0	1.2	5.90	323	219	160	-4	11.50	9.14	3.5	1.7	
819	5/26/94 10:05	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.90	213	217	162	-2	11.42	8.97	4.6	3.5	BH clean start 1035
820	5/26/94 11:58	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.70	175	203	128	1	11.66	9.28	6.1	2.8	
820	5/26/94 13:00	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.95	163	203	166	0	11.31	9.05	4.5	3.5	
820	5/26/94 14:00	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.75	160	212	162	-1	11.36	9.21	5.8	3.6	
821	5/26/94 15:05	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.90	105	200	209	0	11.40	9.24	3.2	4.2	
821	5/26/94 16:08	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.95	100	200	131	1	11.13	9.00	2.3	3.5	BH clean start @ 1600
821	5/26/94 16:40	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	6.10	125	198	219	11	11.20	9.12	5.2	3.8	BH clean end @ 1635
821	5/26/94 17:00	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.95	120	193	197	9	11.25	9.18	4.2	3.0	
821	5/26/94 18:00	5.65	360	252	172	2	13.03	1.1	6.10	315	217	86	-4	11.15	8.87	1.8	1.5	5.90	110	193	93	9	11.39	9.21	5.9	5.9	
822	5/27/94 7:30	6.50	342	267	66	3	12.23	1.6	6.20	310	228	32	-4	11.11	8.94	2.8	2.4	6.30	307	237	39	-3	11.00	8.78	2.8	1.7	Baseline
822	5/27/94 9:20	6.50	342	267	66	3	12.23	1.6	6.20	310	228	32	-4	11.11	8.94	2.8	2.4	6.60	128	212	37	11	10.81	8.70	3.3	3.2	BH clean end 0915
822	5/27/94 10:20	6.70	337	270	57	2	12.12	0.6	6.25	313	230	45	-5	10.93	8.93	3.0	2.2	6.35	110	207	48	7	11.03	8.92	2.7	4.4	Baseline
822	5/27/94 11:20	6.70	337	270	57	2	12.12	0.6	6.25	313	230	45	-5	10.93	8.93	3.0	2.2	6.40	108	213	51	8	10.94	8.78	2.5	3.5	Baseline
822	5/27/94 12:20	6.70	337	270	57	2	12.12	0.6	6.25	313	230	45	-5	10.93	8.93	3.0	2.2	6.30	109	210	60	6	10.98	8.52	3.3	3.6	Baseline