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Integrated Dry NOx/SO2 Emissions Control System  
DOE I.D. DE-FC22-91PC90550

Gentlemen:

We are sending herewith Quarterly Technical Progress Report No. 1 in the final form, covering the first quarter of 1991.

Please advise us if you have any questions.

Very truly yours,

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INTEGRATED DRY NO<sub>x</sub>/SO<sub>2</sub> EMISSIONS CONTROL SYSTEM

QUARTERLY REPORT NO. 1

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SEPTEMBER 10, 1991

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Prepared by:

Public Service Company of Colorado

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## 1.0 EXECUTIVE SUMMARY

This Quarterly Report summarizes the Integrated Dry NO<sub>x</sub>/SO<sub>2</sub> Emissions Control System Project (DOE Cooperative Agreement No. DE-FC22-91PC90550) progress for the months of January, February, and March, 1991, and preliminary engineering activities from the period June 18, 1990 to January 1, 1991. Some activities included in this report occurred prior to the March 11, 1991 official signing of the Cooperative Agreement. DOE authorized PSCC to proceed with initial engineering work on June 18, 1990. Public Service Company of Colorado (PSCC) and the U. S. Department of Energy (DOE) executed the Cooperative Agreement on March 11, 1991.

PSCC activities focused on preliminary engineering work on the dry injection system, establishing the project management database, and beginning the activities to generate the necessary reports for the DOE reporting requirements. PSCC also began work on formalizing the agreements with the other project participants.

PSCC authorized Babcock & Wilcox (B&W) to proceed with control system design, and work on the design of the humidification system.

PSCC received quotes and placed a purchase order to Noell, Inc. for the urea injection system. PSCC authorized Noell to proceed with engineering upon receipt of the purchase order.

## 2.0 INTRODUCTION

As per the DOE Cooperative Agreement No. DE-FC22-91PC90550 dated March 11, 1991, Public Service Company of Colorado has prepared the following quarterly report for Phases I, IIA, and IIB of the Integrated Dry NO<sub>x</sub>/SO<sub>2</sub> Emissions Control System Project. This project includes Low NO<sub>x</sub> Burners with post firing air injection, humidification, and dry sorbent injection. This quarterly report primarily covers the quarterly period January, February, and March, 1991. Activities began prior to the March 11, 1991 signing of the Cooperative Agreement, based on authorization from DOE on June 18, 1990. This report covers project activities for the first three months period of the project. However, it also includes the engineering efforts from the June 18, 1990 DOE authorization to proceed.

The subject of this report is the project progress during the quarter for Phase I - Engineering and Design, Phase IIA - Procurement, and Phase IIB - Construction and Startup.

Under Phase I, the engineering work commenced based on approval of DOE to proceed prior to the official signing of the cooperative agreement. Public Service Company of Colorado (PSCC) and the U. S. Department of Energy (DOE) officially signed the Cooperative Agreement on March 11, 1991. PSCC began preliminary engineering work on the dry injection system. B&W started the control system design and the design of the humidification system.

PSCC project management activities consisted of starting to establish the database and develop the necessary software for generating the monthly reporting requirements reports.

Under Phase IIA, PSCC received quotes and placed a purchase order to Noell, Inc. for the urea injection system. PSCC authorized Noell to proceed with engineering upon receipt of the purchase order.

Under Phase IIB, there was no activity.

### 3.0 PROJECT DESCRIPTION

#### 3.1 BACKGROUND

This project's goal is to demonstrate the removal up to 70% of the  $\text{NO}_x$  and 70% of the  $\text{SO}_2$  emissions from coal fired utility boilers. It will establish an alternative emissions control technology integrating a combination of several processes, while minimizing capital expenditures and limiting waste production to dry solids that are handled with convention ash removal equipment. These processes include low- $\text{NO}_x$  burners and urea injection for  $\text{NO}_x$  control, sodium- or calcium-based sorbent injection for  $\text{SO}_2$  control, and flue gas humidification to enhance the reactivity of the  $\text{SO}_2$  control compound.

The low  $\text{NO}_x$  burners reduce  $\text{NO}_x$  formation by a combination coal/air combustion staging and the use of air ports. Urea injection downstream of the burners react chemically with  $\text{NO}_x$  to form nitrogen and water.

Sodium- and calcium-based reagents react with the  $\text{SO}_2$  in the flue gas to form sulfites and sulfates, lowering the emissions of  $\text{SO}_2$ . Humidification of the flue gas increases the reactivity of the calcium reactants. The solid reacted sorbent is removed with the flyash in the existing fabric filter.

Sodium based injection systems can convert nitrogen oxide ( $\text{NO}$ ) to nitrogen dioxide ( $\text{NO}_2$ ) which is one form of  $\text{NO}_x$ , and is visible in the stack plume under certain conditions. Ammonia, from the urea injection, reduces the  $\text{NO}_2$  concentration by reacting with the  $\text{NO}_2$ . Thus, system integration will alleviate a potential undesirable side effect of  $\text{SO}_2$  removal.

The demonstration program is directed at down-fired boilers, but the process can be utilized on other types of boilers. This project will be the first U. S. application of low- $\text{NO}_x$  burners to a down-fired boiler.

The project objectives also include demonstrating the cost effectiveness of the process and demonstrating that the process has no negative effects on normal boiler operation and does not create any other unwanted releases of gaseous or solid emissions.

#### 3.2 PROCESS DESCRIPTION

The Integrated Dry  $\text{NO}_x/\text{SO}_2$  Emissions Control System is a multi-part process in which low- $\text{NO}_x$  burners,  $\text{NO}_x$  ports, and urea injection is used to control  $\text{NO}_x$ . Sodium-based sorbent injection or calcium-based sorbent injection, combined with in-duct humidification is used for  $\text{SO}_2$  removal.

##### B&W XCL Burner

$\text{NO}_x$ , formed during the combustion of fossil fuels consists of  $\text{NO}_x$  formed from fuel bound nitrogen, thermal  $\text{NO}_x$ , and prompt  $\text{NO}_x$ .  $\text{NO}_x$  formed from fuel bound nitrogen results from the oxidation of nitrogen which is bonded to the fuel molecules. Thermal  $\text{NO}_x$  forms when nitrogen in the combustion air dissociates and oxidizes at flame temperatures in excess of 2800°F. Prompt  $\text{NO}_x$  forms during the combustion process when hydrocarbon radicals dissociate atmospheric nitrogen, which then oxidizes.

The B&W XCL burner achieves increased  $\text{NO}_x$  reduction effectiveness by incorporating fuel staging along with air staging. Most of low- $\text{NO}_x$  burners reduce  $\text{NO}_x$  by the use of air staging. Air staging reduces the amount of combustion air during the early stages of combustion. Fuel staging involves the introduction of the fuel downstream of the flame under fuel-rich conditions, causing hydrocarbon radicals to be generated. These radicals reduce  $\text{NO}_x$  levels. This is accomplished by the coal nozzle/flame stabilizing ring design of the burner. In addition, combustion air is accurately measured and regulated to each



burner to provide balanced air and fuel distribution for optimum NO<sub>x</sub> reduction and combustion efficiency. Further, the burner assembly is equipped with adjustable burner vanes to provide swirl for flame stabilization and fuel/air mixing.

#### NO<sub>x</sub> Ports

NO<sub>x</sub> ports are used in conjunction with low-NO<sub>x</sub> burners to increase the effectiveness of air staging. NO<sub>x</sub> ports provide the final air necessary to ensure complete combustion. Conventional single jet NO<sub>x</sub> ports are not capable of providing adequate mixing across the entire furnace. The B&W dual zone NO<sub>x</sub> ports, however, incorporates a central zone which produces an air jet that penetrates across the furnace and a separated outer zone that diverts and disperses the air in the area of the furnace near the NO<sub>x</sub> 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 air swirl control.

The combined use of the B&W XCL burners and dual zone NO<sub>x</sub> ports is expected to reduce NO<sub>x</sub> emissions by up to 70%.

#### Urea Injection

NO<sub>x</sub> reduction in utility boilers can also be accomplished by injecting urea into the furnace. The urea reacts with the NO<sub>x</sub> and oxygen in the gases and forms nitrogen, carbon dioxide, and water. A urea injection system is capable of removing 40% to 50% of the remaining NO<sub>x</sub> from the combustion process.

The optimum urea injection reaction temperature range is between 1700°F and 1900°F. At lower temperatures, side reactions can occur, resulting in the undesirable formation of ammonia. At higher temperatures, additional NO<sub>x</sub> is formed. Chemical additives can be injected with the urea to widen the optimum temperature range and minimize the formation of ammonia.

The urea is generally injected into the boiler as an aqueous solution through atomizers. The atomizing medium can be either air or steam. The urea and any additive are stored as a liquid and pumped into the injection atomizers.

#### Dry Reagent SO<sub>2</sub> Removal System

The dry reagent injection system consists of equipment for storing, conveying, pulverizing, and injecting sodium based products into the flue gas between the air heater and the particulate removal equipment or calcium products between the economizer and the air heater. The SO<sub>2</sub> formed during the combustion reacts with the sodium- or calcium-based reagents to form sulfates and sulfites. These reaction products are collected in the particulate removal equipment together with the fly ash and the unreacted reagent and removed for disposal. The system is expected to remove up to 70% SO<sub>2</sub> while using sodium based products and maintaining high sorbent utilization.

Dry sodium-based reagent injection systems reduce SO<sub>2</sub> emissions. However, NO<sub>2</sub> formation has been observed in some applications. NO<sub>2</sub> is red/brown gas. A visible plume may form as the NO<sub>2</sub> in flue gas exits the stack. Previous tests have shown that ammonia slip from the urea injection system reduces the formation of NO<sub>2</sub>, 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<sub>2</sub> removal. SO<sub>2</sub> removal using calcium-based reagents involves the dry injection of the reagent into the furnace at a point where the flue gas temperature is approximately 1000°F. Calcium-based materials can also be injected into the flue gas ductwork downstream of the air heater, but at reduced SO<sub>2</sub> removal effectiveness.

### Humidification

In addition to the selection of the proper injection point, the effectiveness of the calcium-based reagent in reducing SO<sub>2</sub> emissions can be increased by flue gas humidification. Flue gas conditioning by humidification involves injecting water into the flue gas stream 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 flow rate and increasing its 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-based reagent are not as reactive as sodium-based reagents, the presence of water in the flue gas, which contains unreacted reagent, provides for additional SO<sub>2</sub> removal. Up to 50% SO<sub>2</sub> removal is expected when calcium reagents are used in conjunction with flue gas humidification.

#### 4.0 PROJECT STATUS

This project Quarterly Report Number 1 covers the quarterly period for January, February, and March, 1991. This includes activities prior to the March 11, 1991 official signing of the Cooperative Agreement, and after June 18, 1990 based on DOE authorization. This report discusses progress on a task basis for each of Phases I, IIA, IIB, and III.

##### 4.1 PHASE I - ENGINEERING AND DESIGN

###### 4.1.1 Flyash System

4.1.2 Dry Injection System: PSCC began the initial engineering, and prepared the specification for the reagent pulverizers. Work continues on establishing the acceptable pulverizer bidders list, and obtaining installation lists for several suppliers.

4.1.3 Humidification System: B&W began engineering work on January 31, 1991.

4.1.4 Urea Injection System: Noell began engineering work on February 16, 1991.

4.1.5 Burners and NO<sub>x</sub> Ports: B&W began preliminary engineering work on the control design for the burners and air injection ports in January, 1991.

4.1.6 Continuous Emissions Monitors: No Activity.

4.1.7 Distributed Control System: PSCC began preliminary work on the specification and design of the distributed control system. PSCC also began activities for qualifying bidders.

4.1.8 Project Management: PSCC and Stone & Webster Engineering Corporation (SWEC) discussed several options for project management and reporting responsibilities. After looking at the various scenarios, PSCC decided that they would retain these responsibilities, and enlist SWEC's assistance on an as-needed basis.

PSCC submitted the first monthly Federal Assistance Status Report to DOE on March 27, 1991. PSCC started work on creating the extension to their normal accounting system to collect the information for DOE reporting and cost reimbursement accounting. PSCC also started work on developing a preliminary draft of the water use schedule.

4.1.9 Consulting: Contract Legal review continues as necessary for various equipment and services supply contracts.

4.1.10 Engineering Research: PSCC and Colorado School of Mines began discussions on establishing a contract to investigate the chemical kinetics involved with SO<sub>2</sub> removal by sodium based reagents.

##### 4.2 PHASE IIA - PROCUREMENT

4.2.1 Flyash System: No Activity.

4.2.2 Dry Injection System: No Activity.

4.2.3 Humidification System: No Activity.

4.2.4 Urea Injection System: PSCC evaluated the bids for the engineering, design, and material supply for the system. PSCC issued the

purchase order for this system to Noell, Inc. on March 13, 1991, and authorized them to proceed with engineering upon receipt of the Purchase Order.

- 4.2.5 Burners and NO<sub>x</sub> Ports: No Activity.
- 4.2.6 Continuous Emissions Monitors: No Activity
- 4.2.7 Distributed Control System: No Activity.

4.3 PHASE IIB - CONSTRUCTION AND STARTUP: No Activity.

- 4.3.1 Flyash System
- 4.3.2 Dry Injection System
- 4.3.3 Humidification System
- 4.3.4 Urea Injection System
- 4.3.5 Burners and NO<sub>x</sub> Ports
- 4.3.6 Continuous Emissions Monitors
- 4.3.7 Distributed Control System
- 4.3.8 Project Management
- 4.3.9 Consulting
- 4.3.10 Construction Management
- 4.3.11 Engineering Research
- 4.3.12 Operations and Maintenance

## 5.0 PLANNED ACTIVITIES

The planned activities for the next quarter, April, May, and June, 1991, include completing the development of the project management database and the software development for the reporting requirements reports, with the submittal to DOE of the draft of the reports.

PSCC will finalize the agreements with the other project participants.

The remaining participants will begin their engineering and design work on the project segments within their areas of responsibility.

PSCC will begin its engineering and site layout drawings, and begin detailed engineering on the dry sorbent injection system.

Noell will perform a furnace outlet temperature traverse, to determine the design parameters for the urea injection system.

## 6.0 SUMMARY

Phase I - Engineering and Design: PSCC and DOE signed the Cooperative Agreement on March 11, 1991. PSCC began setting up the formal project management system and formalizing the agreements with the project participants. PSCC and the project participants began engineering work on the dry injection system, the controls system, and the urea system..

Phase IIA - Procurement: PSCC issued a Purchase Order to Noell, Inc. for the urea system design and material supply.

Phase IIB - Construction and Startup: No activity.

7.0 REPORT DISTRIBUTION

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