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INTEGRATED DRY NO_x/SO₂ EMISSIONS CONTROL SYSTEM

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QUARTERLY REPORT NO. 4

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1.0 EXECUTIVE SUMMARY

This Quarterly Report summarizes the Integrated Dry NO_x/SO₂ Emissions Control System Project (DOE Agreement No. DE-FC22-91PC90550) progress for the months of October, November and December, 1991.

Public Service Company of Colorado (PSCC) activities focused on review and approval of drawings issued for construction of the various systems with the exception of the dry injection system design which is still underway. Specifications were written, bid proposals were issued and some contracts awarded to procure the various systems listed above or more fully described in Section 4.0 below. PSCC submitted a draft Environmental Monitor Plan to the U. S. Department of Energy (DOE) for review and approval prior to its release. PSCC's Construction continued to work on the flyash, dry injection, urea injection and distributed control systems.

Stone & Webster Engineering Corporation (SWEC) continued with electrical design of the various system, completed electrical design on the urea injection equipment and issued drawings for construction and completed the heat trace specification for same. SWEC also completed design and logic drawings for the burner management system. Babcock & Wilcox (B&W) completed design of the humidification system, low NO_x burner and NO_x ports and started preoutage construction.

Noell, Inc. (Noell) completed mechanical, electrical design and material procurement for the urea system. The Colorado School of Mines (CSM) continues with its engineering research. Fossil Energy Research Corporation (FERCO) completed and submitted a draft baseline test, completed baseline boiler test and began a draft plan for the urea testing.

2.0 INTRODUCTION

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_x/SO₂ Emissions Control System Project. This project includes low NO_x burners with NO_x ports (post firing air injection), humidification and dry sorbent injection. This quarterly report covers the quarterly period October, November, and December, 1991. This report covers project activities for the fourth three month period of the project.

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, engineering and drafting work continued on the overall project layout. Engineering design work of the flyash collection system, layout for the injection control panel, the humidification system, mechanical and electrical of the urea injection system, burners, and the distributed control system were completed. Continued engineering and drawing work of the dry sorbent injection system is still underway. A continuous emissions monitor specification was also completed. Project management activities consisted of scheduling and reporting activities and completion of DOE's project management review process with Grant-Thornton. Engineering research activities continued with CSM. They began design on the gas handling system and continued work on the batch reactor design.

Under Phase IIA, purchasing activities of materials and equipment for the major systems continued. Contracts were awarded for the humidification building and continuous emissions monitor system.

Under Phase IIB, construction activities continued on the major systems with the exception of the humidification system. Construction on the urea system is 95% completed. FERCO completed the baseline testing plan and testing.

3.0 PROJECT DESCRIPTION

3.1 BACKGROUND

The goal of this project is to demonstrate the removal up to 70% of the NO_x and 70% of the 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 conventional ash removal equipment. These processes include low- NO_x burners, NO_x ports and urea injection for NO_x control, sodium or calcium based sorbent injection for SO_2 control, and flue gas humidification to enhance the reactivity of the SO_2 control compound.

The low NO_x burners reduce NO_x formation by a combination coal/air combustion staging and the use of NO_x ports. Urea injection downstream of the burners reacts chemically with NO_x to form nitrogen and water.

Sodium and calcium based reagents react with the SO_2 in the flue gas to form sulfites and sulfates, lowering the emissions of 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.

A sodium based injection system can convert nitrogen oxide (NO) to nitrogen dioxide (NO_2) which is one form of NO_x , and is visible in the stack plume under certain conditions. Ammonia, from the urea injection, reduces the NO_2 concentration by reacting with the NO_2 . Thus, system integration will alleviate a potential undesirable side effect of 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 United States application of low- 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 NO_x/SO_2 Emissions Control System is a multi-part process in which low- NO_x burners, NO_x ports, and urea injection is used to control NO_x . Sodium based sorbent injection or calcium based sorbent injection, combined with in-duct humidification is used for SO_2 removal.

B&W XCL Burner

NO_x , formed during the combustion of fossil fuels, consists of NO_x formed from fuel bound nitrogen, thermal NO_x , and prompt NO_x . NO_x formed from fuel bound nitrogen results from the oxidation of nitrogen which is bonded to the fuel molecules. Thermal NO_x forms when nitrogen in the combustion air dissociates and oxidizes at flame temperatures in excess of 2800°F. Prompt NO_x forms during the combustion process when hydrocarbon radicals dissociate atmospheric nitrogen, which then oxidizes.

The B&W XCL burner achieves increased NO_x reduction effectiveness by incorporating fuel staging along with air staging. Most of low- NO_x burners reduce 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 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_x 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_x Ports

NO_x ports are used in conjunction with low-NO_x burners to increase the effectiveness of air staging. NO_x ports provide the final air necessary to ensure complete combustion. Conventional single jet NO_x ports are not capable of providing adequate mixing across the entire furnace. The B&W dual zone NO_x 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_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 air swirl control.

The combined use of the B&W XCL burners and dual zone NO_x ports is expected to reduce NO_x emissions by up to 70%.

Urea Injection

NO_x reduction in utility boilers can also be accomplished by injecting urea into the furnace. The urea reacts with the NO_x 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_x 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_x 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 SO₂ 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 SO₂ 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% SO₂ while using sodium based products and maintaining high sorbent utilization.

Dry sodium based reagent injection systems reduce SO₂ emissions. However, NO₂ formation has been observed in some applications. NO₂ is red/brown gas. A visible plume may form as the NO₂ in flue gas exits the stack. Previous tests have shown that ammonia slip from the urea injection system reduces the formation of NO₂, 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 SO₂ removal. SO₂ 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 SO₂ removal effectiveness.

Humidification

In addition to the selection of the proper injection point, the effectiveness of the calcium based reagent in reducing SO₂ 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 SO₂ removal. Up to 50% SO₂ removal is expected when calcium reagents are used in conjunction with flue gas humidification.

Participants

PSCC is the Project Manager for the project, and is responsible for all aspects of project performance. PSCC will engineer the dry injection system and the modifications to the fly ash system, provide the host site, train the operators, provide selected site construction services, provide start-up services and maintenance and assist in the testing program.

B&W is responsible for engineering, procurement, fabrication, installation, and shop testing of the XCL burners, NO_x ports, humidification equipment, and associated controls, will assist in the testing program, and will provide for the commercialization of the technology. Noell, Inc. is responsible for the engineering, procurement and fabrication of the urea system. FERCO will conduct the testing program. Western Research Institute will characterize the waste materials and recommend disposal options. Colorado School of Mines will provide research in the areas of bench scale chemical kinetics for the NO_x formation reaction. SWEC will assist PSCC with the engineering efforts. Cyprus Coal, Amax Coal, and Coastal Chemical, Inc. will supply the coal and urea for the project.

4.0 PROJECT STATUS

This project Quarterly Report Number 4 covers the quarterly period for October, November, and December, 1991. This report discusses progress on a task basis for Phase I, IIA and IIB. The numeric listings after the task descriptions described below are accounting measures according the various levels and phases within the project.

4.1 PHASE I - ENGINEERING AND DESIGN

4.1.1 Flyash System 1211: PSCC completed the foundation design, and drawings were issued for construction in November. United Conveyor Company, the supplier for the dry fly ash collection system, designed and issued drawings. These drawings were reviewed and approved by PSCC in December. Similarly, a specification was written for a mechanical contractor to erect the system. PSCC also completed the piping design and drawings of the water supply to the dry unloader. SWEC began the electrical design and drawings for the system.

4.1.2 Dry Injection System 1212: PSCC nearly completed the dry injection design and began detailed mechanical drawings. The original design was modified to include an air to air heat exchanger to cool the blower outlet air. The foundation design and drawings for the injection building were issued for construction. SWEC has completed the layout for the injection control panel and continued work on the wiring design.

4.1.3 Humidification System 1213: B&W completed the humidification system design. B&W issued flow diagrams and general arrangements to PSCC for comment and were approved. A significant number of platforms were added to B&W's workscope to allow access around the humidification ductwork. During the design it was discovered that the original steel design for the inlet ductwork was insufficient for the ductwork and the new loads.

PSCC completed design of the additional stiffener beams added to the steelwork to provide sufficient strength. Design changes were implemented to use a variable speed pump for flow control. This will save significant capital and lower operating costs of the original design. Testing was completed on one humidification lance to determine shield air requirements. Also, PSCC began the foundation design and drawings for the humidification compressor building and wrote a specification for the building.

SWEC began electrical design of the humidification system.

4.1.4 Urea Injection System 1220: Noell, Inc. completed all mechanical and electrical design work on the urea injection system. Some additional design was required and completed to support field changes during the construction of the system. Noell continued work on the programmable logic controller (PLC) and computer programming that controls the system. SWEC complete the electrical design for the urea injection equipment and issued construction drawings to PSCC. SWEC also completed the heat tracing specification. PSCC completed design and drawings for the platforms required in and around the urea building.

4.1.5 Burners and NO_x Ports 1230: B&W completed the design for the low NO_x burner and NO_x ports. Significant redesigning was required due to a change from the XCL gas burner to the older radial style burner. This change was required by PSCC as the XCL gas burner had cooling air requirements that could not be met with existing plant equipment. Although significant redesigning was required, the net cost of the project was reduced by lowering capital equipment requirements. The redesign will also be much simpler in operation. Drawings have been issued for all items although some additional design and drafting work is required on final revisions of the drawings. Due to unexpected loads from the twelve burner disc actuators, PSCC added an additional motor control center to

the firing aisle. The specification for asbestos removal from the flue gas recirculation duct was completed. SWEC completed the design and logic drawings for the burner management system. One major change this quarter was the ability to fire individual gas burners verses the original plan to fire burner groups of three.

4.1.6 Continuous Emissions Monitors 1241: PSCC completed the specification for the continuous emission monitor (CEM) system. Many potential suppliers were evaluated but only a few could supply the required equipment. Problems were encountered with potential suppliers to determine the best method to monitor ammonia (NH_3) and also nitrous oxide (N_2O) as there has been little demand for continuous monitoring of these gases.

4.1.7 Distributed Control System 1242: Westinghouse Electric Company completed its design of the distributed control system and issued to PSCC logic and construction drawings for the equipment. The system was shop tested in December and passed all tests and specification requirements. Programming and maintenance personnel training was completed this period. PSCC continued work on the design and programming of the graphic interface for the control system. The engineering terminal and simulator were setup in the recently completed Engineering Building to continue checkouts and programming of the system. Work began on organizing an operator training program for the new control system. Due to the high work load of the control system, PSCC requested additional engineering assistance from SWEC on the control design. SWEC is now responsible for the wiring and junction box design for the control system. SWEC completed the design of all transmitter locations and issued drawings for construction. A specification was completed for the coal feeder variable speed drive upgrade. PSCC completed design and specification for an enclosure for the data processing units (DPU) located in the housepower room. An enclosure is required to provide a controlled environment and to provide shielding from possible interference from the large breakers.

4.1.8 Project Management 1251: PSCC continued work required to complete overall management of the project and to perform the required reporting requirements. A project management review was completed at DOE's request by Grant Thornton. The overall review was basically positive although there were some suggestions on improved tracking of the scope of work changes.

4.1.9 Consulting 1252: Review of various contracts and patent issues were completed by legal consultants. The patent application was reviewed by the patent examiner but a continuing application was prepared to refine some patent information. The application remains active. Radian completed the final draft of the Environmental Monitor Plan although some further changes may be required upon further review by the DOE.

4.1.10 Engineering Research 1260: CSM interviewed graduate students to work on the project. Additionally, CSM continued with preliminary analyses including thermodynamic calculations and a study of previous experimental work performed for EPRI. They began the gas handling system design and ordered equipment and gases. Continued engineering and design work for the bench scale batch reactor for NO_x formation research. CSM also obtained experimental data to analyze the simulated flue gas and fluidized absorbent. FERCO drafted and submitted a baseline test plan October 2, 1991. A mobile laboratory was delivered on site November 4, 1991. FERCO also reviewed and discussed the Environmental Monitoring Plan prepared by Radian with PSCC and suggested changes. FERCO started and finished the baseline boiler tests November 11, 1991 and December 13, 1991, respectively. A draft test plan for the urea testing is being prepared.

PSCC completed and submitted a draft of the Environmental Monitor Plan to DOE, and continued discussions with DOE on the details. PSCC met with Tom Arrigoni and Jerry Hebb of DOE for a project progress visit and to discuss

changes in the Environmental Monitor Plan, respectively. The WPDF factory test was completed on the distributed control system.

4.2 PHASE IIA - PROCUREMENT

4.2.1 Flyash System 1311: No equipment for the flyash system was purchased this quarter. PSCC issued bid proposals for a mechanical contractor to erect the system.

4.2.2 Dry Injection System 1312: All major items were purchased during the quarter including the silos, screw feeders, blowers, splitters, air locks, silo gate valves and bin vent filters. The pulverizers were shipped in late December.

4.2.3 Humidification System 1313: Century Contractors was awarded the contract to supply and erect the humidification building. B&W purchased material for the humidification system and the humidification lances were released for construction. Steel was ordered to stiffen existing ductwork steel.

4.2.4 Urea Injection System 1320: PSCC purchased the heat tracing control panel and material for the urea piping. All Noell supplied equipment was received during the quarter. Some welding quality problems occurred and all piping on the urea quench tank skid needed repair to meet code requirements. After a site visit by PSCC's Quality Assurance, the problems were solved and all remaining equipment was acceptable.

4.2.5 Burners and NO_x Ports 1330: B&W issued purchase orders for the humidification air foil lance assemblies and components, coal pipe couplings, NO_x damper drives, NO_x plenum and air monitors. B&W also released purchase orders for expansion joints, sootblower piping, the humidification thermocouple grid, ceramic burner pipe, lighter scanner air pipe and secondary NO_x air ducts.

4.2.6 Continuous Emissions Monitors 1341: PSCC awarded the CEM system contract to Altech.

4.2.7 Distributed Control System 1342: Purchase orders were issued for the pressure transmitters to Honeywell and Ashcroft. A request to sole source Baily for parts to update some older actuators with positioners was completed. Various other smaller equipment was ordered. The Westinghouse distributed control system was shipped and received.

4.3 PHASE IIB - CONSTRUCTION AND STARTUP:

4.3.1 Flyash System 1411: PSCC's Construction crews began work on the foundation for the fly ash silo in late December.

4.3.2 Dry Injection System 1412: The building was completed for the dry sorbent injection system. A ductbank was installed from the DSI building to the urea building to allow routing of power cables from the main electrical power center.

4.3.3 Humidification System 1413: No activity to report this quarter.

4.3.4 Urea Injection System 1420: PSCC's Construction has completed 95% of all mechanical work for the urea injection system. Noell provided a construction supervisor during the period to ensure the equipment was installed according to its requirements. Although the normal construction and fitup problems occurred, no major difficulties were encountered. The two urea storage tanks were delivered in November or about two months behind the original schedule. The tanks had significant weld and painting quality problems but their late delivery did not significantly affect the construction schedule.

AFIC was awarded a contract to supply and install all piping insulation and insulation of the urea and quench tanks which work is currently 50% completed.

Sturgeon Electric was awarded the electrical construction contract and began work in November setting the main power centers in the dry sorbent injection building. Conduit was run to all major skids. Except for the insulation, the heat tracing was completed and electrical construction is currently 70% completed.

4.3.5 Burners and NO_x Ports 1430: B&W construction started work October 7, 1991. B&W cleaned the existing gas recirculation duct and installed blanking plates to allow work on the duct with the unit on line. After inspection, B&W determined the gas recirculation duct would be reusable with minor repair. Asbestos removal began and was completed on the gas recirculation duct.

4.3.6 Continuous Emissions Monitors 1441: No activity to report during this quarter.

4.3.7 Distributed Control System 1442: The engineering building that will house the engineering workstation and the distributed processing units for the outside environmental equipment was completed in October. PSCC's Construction erected a platform to locate the building's HVAC unit.

4.3.8 Project Management 1451: PSCC continues to manage the construction activities of the project and perform the required reporting functions.

4.3.9 Consulting 1452: No activity to report during this quarter.

4.3.10 Construction Management 1453: PSCC setup an on site office and assigned James Fischer as the field engineer to coordinate field activities.

4.3.11 Engineering Research 1460: No activity to report during this quarter.

4.3.12 Testing 1471: FERCO completed the baseline test plan in November. Baseline testing began in November and was completed by mid-December.

4.3.13 Operations and Maintenance 1472: No activity to report during this quarter.

5.0 PLANNED ACTIVITIES

The planned activities for the next quarter, January, February and March, 1992, include the following:

1. Erect silo foundation, silo and begin fly ash piping and electrical construction of same.
2. Complete wiring design of the dry injection system, specification, issue bid proposals and purchase order for piping, set pulverizers, erect silos, set feeders and fabricate and erect piping and start electrical construction.
3. Complete electrical wiring design and begin construction of the humidification system. Continue and start B&W pre-outage and outage construction, respectively, erect the humidification building and start humidification manhole and fabrication, tie in piping and install compressor.
4. Continue with B&W and PSCC construction of the burner and NO_x ports. More specifically, B&W and/or PSCC will remove the burner roof, erect scaffolding, remove asbestos from the burner area, demolish the I-R soot blowers, secondary air duct and coal piping and burners and, install and insulate ductwork.
5. PSCC will start design and drawings of the continuous emission monitor system and install a temporary variable speed drive to test urea injection.
6. SWEC will continue design of the distributed processing unit (DPU) graphics and install DPU and enclosure walls, run conduit and install boiler transmitters, run conduit for the control room and fire aisle and, install coal feeders.
7. Continue NO_x formation research and urea testing.

6.0 SUMMARY

Phase I - Engineering and Design: Engineering and drafting work continued on the overall project layout. Engineering design work of the flyash collection system, layout for the injection control panel, the humidification system, mechanical and electrical of the urea injection system, burners, and the distributed control system were completed. Continued engineering and drawing work on the dry sorbent injection system is still underway. A continuous emissions monitor specification was completed. Project management activities consisted of scheduling and reporting activities and DOE's project management review process with Grant-Thornton was completed. Engineering research activities continued with CSM. They began design on the gas handling system and continued work on the batch reactor design.

Phase IIA - Procurement: Procurement of materials, contracts and specification for the above systems continued. Contracts were awarded for the humidification building and continuous emissions monitor system.

Phase IIB - Construction and Startup: Construction activities continued on the major systems with the exception of the humidification system. Construction on the urea system is 95% completed. FERCO completed the baseline testing plan and baseline testing.

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