April 2, 2007

Ms. Karlene Fine
Executive Director
Attn: Lignite Research Program
North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505

Dear Ms. Fine:

Subject: EERC Proposal No. 2007-0216

Enclosed please find an original and seven copies of the proposal entitled "Impacts of Lignite Properties on Powerspan's NO_x Oxidation System." The EERC looks forward to the opportunity to work with NDIC on this rapidly developing opportunity. Also enclosed is the $100 application fee.

If you have any questions, please contact me by telephone at (701) 777-5177 or by e-mail at sbenson@undeerc.org.

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/jlk

Enclosures

c/enc: Jeff Burgess, Lignite Energy Council

IMPACTS OF LIGNITE PROPERTIES ON POWERSPAN'S NO_x OXIDATION SYSTEM

EERC Proposal No. 2007-0216

Submitted to:

Karlene Fine

North Dakota Industrial Commission
State Capitol
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505

Proposal Amount: $260,420

Submitted by:

Steven A. Benson
Scott G. Tolbert
Jason D. Laumb
Jill M. Mackenzie

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Steven A. Benson, Project Manager

Dr. Barry I. Milavetz, Associate VP for Research
Research Development and Compliance

April 2, 2007

TABLE OF CONTENTS

LIST OF FIGURES ... ii

LIST OF TABLES ... iii

ABSTRACT ... iv

PROJECT SUMMARY ... 1

PROJECT DESCRIPTION ... 3
- Goals and Objectives ... 3

WORK PLAN ... 4
- Task 1 – Modification of EERC Slipstream System to Incorporate ECO Reactor ... 4
- Task 2 – Installation and Shakedown Testing ... 5
- Task 3 – MRY Testing Campaign ... 6
- Task 4 – Performance Evaluation ... 8
- Task 5 – Reporting and Recommendations ... 9

DELIVERABLES ... 9

STANDARDS OF SUCCESS ... 10

BACKGROUND ... 10
- Lignite Inorganic Composition and Challenges ... 10
- Prior Testing in a High-Sodium Environment ... 12
- Powerspan's Multipollutant Control Technology Overview ... 15
- Powerspan's ECO Commercial Demonstration ... 20
- Integration Opportunity for CO_2 Separation—ECO_2™ ... 21

QUALIFICATIONS ... 23

VALUE TO NORTH DAKOTA ... 24

MANAGEMENT ... 24
- Project Manager ... 25
- Project Advisors ... 26
- Principal Investigators ... 27

Continued…

TABLE OF CONTENTS (continued)

PROJECT TIMETABLE 29

COST 29

MATCHING FUNDS 30

TAX LIABILITY 30

CONFIDENTIAL INFORMATION 31

REFERENCES 31

BUDGET AND BUDGET NOTES 33

RESUMES OF KEY PERSONNEL .... Appendix A

LETTERS OF COMMITMENT .... Appendix B

LIST OF FIGURES

1 Schematic diagram of slipstream reactor 5

2 Quartz elements prior to mounting and cross-sectioning 13

3 Backscattered electron micrograph of spent quartz electrode, showing analysis points 1 through 6 14

4 Backscattered electron micrograph of spent quartz electrode, showing analysis points 7 through 12 15

5 Backscattered electron micrograph of blank quartz element, showing analysis points 1 through 6 16

6 Backscattered electron micrograph of blank quartz element, showing analysis points 7 through 12 16

7 ECO process flow diagram 18

8 50-MW ECO Burger Commercial Unit 21

9 Overall project management organizational chart 25

LIST OF TABLES

1 Electrode Matrix for Sampling 7

2 Inspection, Electrode Swap, and Accumulating Sampling Schedule 7

3 Number of Electrodes Versus Run Time 7

4 Performance Summary of 180-day Reliability Run 21

5 Project Schedule 30

6 Budget Summary 30

IMPACT OF LIGNITE PROPERTIES ON POWERSPAN'S NO_x OXIDATION SYSTEM

ABSTRACT

The Energy & Environmental Research Center (EERC), Powerspan, and the Young 3 team (Minnkota Power Inc., Minnesota Power, Montana Dakota Utilities Co., and Basin Electric Power Cooperative) have teamed to evaluate the ability of Powerspan's dielectric barrier discharge (DBD) oxidation reactor to convert nitric oxide into nitrogen dioxide and nitric acid in a lignite-derived flue gas that contains sodium aerosols. The evaluation will be conducted using a slipstream DBD reactor system installed downstream of the electrostatic precipitator at the Milton R. Young (MRY) Unit 1 cyclone-fired boiler. The DBD reactor is one of the key components in Powerspan's multipollutant control technology that simultaneously removes SO_2, NO_x, $PM_{2.5}$, acid gases (such as hydrogen fluoride, hydrochloric acid, and sulfur trioxide), Hg, and other metals from the flue gas of coal-fired power plants.

The results of the project are expected to provide information on the potential for Powerspan electrocatalytic oxidation technology to provide NO_x reduction as well as multipollutant control for high-sodium lignite coals. Other technologies for NO_x reduction, such as selective catalytic reduction (SCR), have experienced severe plugging and blinding problems when exposed to flue gases derived from high-sodium lignite.

The project is scheduled for 7 months with a total cost of $610,985 , of which $132,800 is requested from the U.S. Department of Energy. Industry partners will provide $217,765 in cash and cash-equivalent; $260,420 is requested from the North Dakota Industrial Commission.

IMPACT OF LIGNITE PROPERTIES ON POWERSPAN'S NO_x OXIDATION SYSTEM

PROJECT SUMMARY

Minnkota Power Cooperative, Minnesota Power, Basin Electric Power Cooperative, Montana Dakota Utilities Co., and the Energy & Environmental Research Center (EERC) are evaluating air pollution control options as part of the planning process for the Milton R. Young (MRY) 3 power plant. One technology being evaluated is Powerspan's multipollutant control process called electrocatalytic oxidation (ECO). The ECO technology is designed to simultaneously remove SO_2, NO_x, $PM_{2.5}$, acid gases (such as hydrogen fluoride [HF], hydrochloric acid [HCl], and sulfur trioxide [SO_3]), Hg, and other metals from the flue gas of coal-fired power plants. In addition to the ECO technology, Powerspan is developing a cost-effective ammonia-based CO_2 removal process for coal-fired power plants called ECO_2™. ECO_2 works in conjunction with Powerspan's ECO process to capture and recover CO_2 in flue gas for enhanced oil recovery or other forms of geological sequestration.

ECO treats flue gas in three process steps to achieve multipollutant removal. The first step is a dielectric barrier discharge (DBD) oxidation reactor where an electrical discharge produces reactive O and OH radicals. The O and OH radicals react with flue gas components to oxidize NO to NO_2 and HNO_3 and a small portion of the SO_2 to SO_3 and H_2SO_4. The oxidized species are water-soluble and can be collected in the downstream scrubber. The second process step is an ammonia-based scrubber that is used to remove the SO_2 not converted by the reactor, the acid species (HNO_3 and H_2SO_4), and oxidized forms of mercury. A liquid ammonium sulfate fertilizer product is produced and recovered from the second process step. The third process step

is a wet electrostatic precipitator (WESP), which follows the scrubber. It captures acid aerosols produced by the discharge reactor, fine particulate matter, and oxidized mercury.

One of the potential challenges associated with application of the ECO multipollutant technology is the reaction of sodium aerosols produced upon combustion of lignite with the quartz components of the DBD reactor. Sodium vaporizes during combustion, and upon gas cooling, it condenses heterogeneously on surfaces (entrained particle or fireside surfaces) and homogeneously to form an aerosol that is suspended in the flue gas. Small amounts of this aerosol can get through air pollution control devices such as ESPs and baghouses. The ECO DBD reactor is located just downstream of the plant's ESP or fabric filter (FF) and will be exposed to these aerosols. The DBD reactor has quartz electrode rods inside where electric current is passed in order to generate the plasma used to oxidize NO. The temperature of the quartz electrodes is approximately 100°F higher than the gas temperature. The behavior of sodium in this environment and the impact on the performance of the DBD reactor is unknown. Sodium is known to react with quartz to produce low-melting-point sodium silicate phases and sulfur oxides to produce low-melting-point pyrosulfate phases.

The goal of this project is to evaluate the performance of the NO conversion component of Powerspan's multipollutant control technology when treating flue gases that contain sodium aerosols. This project involves exposing an operating DBD reactor to sodium containing flue gases using a slipstream downstream of the ESP at MRY Unit 1 to determine the potential impacts. The slipstream system with the DBD reactor will be operated for up to 4 months at the MRY plant. At 2-week intervals, the DBD reactor will be sampled and evaluated to determine accumulation of ash and sodium species. In addition, the ash coatings on the quartz electrodes will be examined using scanning electron microscopy combined with x-ray microanalysis to determine the degree to which sodium reacted with the quartz electrodes. The exposed electrodes will be sent to Powerspan for their evaluation of the degradation of the electrodes' performance using laboratory testing. In addition, the flue gas upstream of the reactor will be analyzed to monitor the sodium concentration. The measurements downstream of the reactor are very challenging because of the presence of acid gases, which have the potential to cause excessive corrosion to the existing ductwork, gas analysis sensors, and other equipment. The results, interpretations, and conclusions will be compiled in the form of a report and made available to all project participants and sponsors.

PROJECT DESCRIPTION

Goals and Objectives

The goal of this project is to determine the impacts of flue gases derived from high-sodium North Dakota lignite on the performance of Powerspan's DBD reactor as measured by conversion of NO to oxidized forms. In order to meet the goal of the project, the following objectives have been identified:

- Incorporate Powerspan's DBD reactor into the EERC slipstream testing system.
- Install the slipstream system at MRY Unit 1 downstream of the ESP.
- Conduct testing for up to a 4-month testing campaign.
- Evaluate the performance of the DBD reactor:
  - Measurements of degree of NO oxidation downstream of the reactor.
  - Sampling of quartz electrodes and ash material on a 2-week basis to allow for detailed analysis of the reaction of sodium with quartz as well as testing at Powerspan.

- Detailed analysis of quartz electrode surface chemistry and deposit characteristics to determine degree of reaction.

- Provide a detailed report that will include all data, interpretations, conclusions, and recommendations.

WORK PLAN

Task 1 – Modification of the EERC Slipstream System to Incorporate ECO Reactor

Equipment design/modification and construction will be conducted to incorporate Powerspan's ECO DBD reactor, power supply, and control system into the EERC's slipstream system. A simplified diagram of the slipstream system with the DBD reactor is shown in Figure 1. The slipstream system will control gas flow rates through the use of a positive displacement pump and monitor flue gas constituents, gas temperatures, and pressures throughout the system. Research will be conducted to determine if there exists a continuous gas measurement system capable of withstanding the harsh, high-temperature, acidic environment that falls within the budgeted amount. If so, one will be integrated into the slipstream system. The ECO reactor system will be equipped with an acoustic horn for cleaning. The controls for cleaning cycles will be incorporated into the slipstream control system. The participants in this task will include personnel from the EERC, Powerspan, and Minnkota.

A detailed test plan and schedule will be developed for a 16-week testing campaign. A detailed test plan will be developed to ensure all objectives and the goals of the project are met. The test plan will be developed through a collaborative effort of the EERC, Powerspan, and Minnkota. The plan will be reviewed and approved by the Young 3 team prior to initiating the 16-week test campaign.

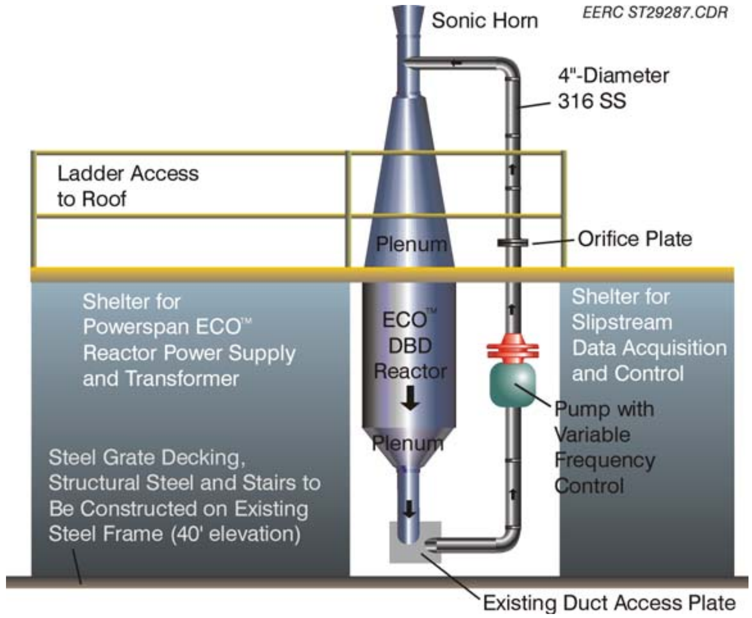

Figure 1. Schematic diagram of slipstream reactor.

Design, construction, and installation of necessary infrastructure will be conducted. This includes a platform to support the entire 8-ton slipstream system on the existing structural frame, electricity, and the data and voice communications. This work will be carried out by Minnkota, with the assistance of the EERC.

Task 2 – Installation and Shakedown Testing

Installation of supporting structure and inlet and outlet ports at MRY Unit 1 downstream of the induced draft fan will be conducted. A location for the installation has been identified, and supporting structure as well as the ports will be installed prior to and during the June 2007 Unit 1 outage. This work will be conducted by Minnkota with the assistance of the EERC and Powerspan.

Install slipstream system including the DBD reactor at MRY Unit 1. The components for the slipstream will be shipped to the MRY site. The EERC, with the assistance of Powerspan and

Minnkota, will install the system. Minnkota will provide the necessary power and other utilities to the slipstream system.

Once installed, the EERC and Powerspan will conduct shakedown testing of the slipstream DBD reactor system. This will include operation of the system as well as the ability to monitor and control the system remotely from the EERC and Powerspan's facilities. In addition, the ability to download data will also be tested.

Task 3 – MRY Testing Campaign

Data will be downloaded on a daily basis from the control and data acquisition system to the EERC computer system in Grand Forks, North Dakota. The data to be downloaded will include pressure drop, temperatures, gas composition, and gas flows. Remote monitoring and performance-checking of the system will be conducted on a daily basis to ensure proper operation of the DBD reactor as well as gas flow and temperature control. The EERC and Powerspan will be responsible for this task. In addition, daily physical checks of the slipstream system will be conducted by Minnkota to inspect for leaks and other abnormalities.

Plant operations data will be downloaded, including load, firing rate, SO_2, opacity, NO_x levels, and coal composition (full-stream elemental analysis data), to the EERC computer system in Grand Forks, North Dakota. The data will be made available to the EERC and Powerspan by Minnkota.

On-site inspection and sampling will be performed at 2-week intervals during operation. This is required to extract and replace specified reactor electrodes on a scheduled basis and to conduct a complete visual inspection of all system components, inside and out. The reactor electrode matrix, swap schedule, and exposure duration are shown in Tables 1–3, respectively. The EERC will be responsible for the biweekly inspections, sampling, and swapping of quartz

Table 1. Electrode Matrix for Sampling (randomized)

Electrode Matrix		
1	2	3
4	5	6
7	8	9
10	11	12
13	14	15

Table 2. Inspection, Electrode Swap, and Accumulating Sampling Schedule*

Week	Electrode No.		Weeks Run After Swap
2	11		14
4	15	5	12
6	4	12	10
8	3	10	8
10	6	13	6
12	7	14	4
14	2	9	2
16	1	8	0

* Two electrodes will be swapped every 2 weeks, with the exception of Week 2, where only one electrode will be swapped.

Table 3. Number of Electrodes Versus Run Time*

Weeks of Operation	Number of Electrodes
2	3
4	4
6	4
8	4
10	4
12	4
14	4
16	2

* Note: A total of 29 rods are required.

electrodes. Powerspan personnel will participate in selected sampling trips to ensure proper handling of electrodes and other system components. The EERC will send quartz electrodes to Powerspan for analysis. The specific efforts to be conducted at the 2-week sampling events include the following:

- Photograph any and all accumulations and perform inspections and maintenance of the system.
- Obtain samples of all accumulations in ductwork, reactor entrance, reactor region, quartz electrodes, and other materials.
- Conduct extractive sampling to determine the degree of NO oxidation across the DBD reactor. The methods for conditioning and measuring the flue gas downstream of the DBD reactor are extremely challenging because of the high acid content. Efforts will be made to identify an appropriate procedure for making measurements. Currently, contacts have been made with instrument vendors who may have equipment that can be used in the challenging environment.
- Extract and replace (swap) electrodes for characterization after each test period or sampling interval.

Task 4 – Performance Evaluation

Plots of pressure drop, temperature, and other trends will be made from the downloaded data on a minimum of a weekly basis. This information will provide operational trends of the system. The EERC will be responsible for plotting the data and making it available to project sponsors.

Plots of plant data will be made for load, firing rate, SO_2, opacity, and coal composition (full-stream elemental analyzer data). The Unit 1 operational data and coal quality information will be plotted along with the Task 4a information to identify trends in boiler operation and coal quality. The EERC will be responsible for plotting and interpreting the information.

Analysis of quartz electrodes will be performed in order to determine reactions of sodium and with quartz. The quartz electrodes will be analyzed using scanning electron microscopy and x-ray microanalysis to determine the degree of reaction of the ash materials with the quartz electrodes. The EERC will be responsible for this analysis.

Laboratory investigations will be conducted to determine the performance of the exposed quartz electrodes. Powerspan will install the quartz electrodes in the laboratory-scale ECO reactor system at New Hampshire-based Powerspan facilities to determine the performance of the electrodes. The specific testing will include an examination of the impact on NO_x removal efficiency across the reactor system. Powerspan will be responsible for this task.

Task 5 – Reporting and Recommendations

Meetings and conference calls will be held to discuss all results, conclusions, and recommendations on a minimum of a monthly basis during the course of the project. These meetings will be coordinated by the EERC.

The draft report will be submitted to project sponsors as defined in the project schedule on or before November 1, 2007. The report will then be finalized and submitted to project sponsors.

DELIVERABLES

Deliverables include data, interpretations, and conclusions on the performance of Powerspan's oxidation reactor in a flue gas stream derived from a high-sodium North Dakota lignite. Data will be provided during meetings and conference calls in the form of Power Point presentations regarding the progress of the project. A draft final report will be provided for review by sponsors and project participants. Once reviewed, a final report will be submitted.

STANDARDS OF SUCCESS

The overall success of the project will be based on the ability to provide information to determine the challenges and opportunities for the use of North Dakota Lignite in advanced multipollutant technologies such as Powerspan's ECO. Testing will be conducted using a slipstream system that has been used for scale-up purposes in the past and has a proven track record of providing relevant data.

The ability to assess the success of the project is based primarily on the EERC's quality management system (QMS). To ensure successful projects, the EERC adheres to an organizationwide QMS. It is authorized and supported by EERC management to define the requirements and the organizational responsibilities necessary to fulfill governmental and client requirements relating to quality assurance/quality control (QA/QC), applicable regulations, codes, and protocols.

BACKGROUND

Lignite Inorganic Composition and Challenges

The lignitic coals from the Fort Union Region of North America contain ash-forming components that consist of alkali and alkaline-earth elements (sodium, magnesium, calcium, and potassium) associated with oxygen functional groups in the organic matrix and mineral grains (quartz, clays, carbonates, sulfates, and sulfides) (1). Upon combustion, the inorganic components undergo chemical and physical transformations that produce intermediate inorganic species in the form of inorganic gases, liquids, and solids (2). The organically associated alkali elements such as sodium and potassium will vaporize and condense heterogeneously on the surfaces of entrained ash particles or homogenously to form aerosols. The organically associated alkaline-earth elements such as calcium and magnesium form small particles in the intermediate size range of 0.5 to 3 micrometers that form on the surfaces of receding char particles (2). In addition, the alkali and alkaline-earth elements combine with minerals during combustion, resulting in low-melting-point phases that cause a wide range of fireside waterwall slagging and convective pass fouling problems. The alkali- and alkaline-earth-rich particles are carried into the backpasses of the combustion system and react with flue gas to form sulfates, phosphates, and carbonates that can cause challenges for downstream air pollution control devices. Slipstream testing of selective catalytic reduction (SCR) catalysts in a high-sodium Fort Union lignite cyclone-fired boiler found severe deposition, blinding, and plugging problems in the SCR. In addition, high-sodium-containing fly ash materials have high cohesivities, causing challenges in removal from hoppers resulting in ash buildup, causing T/R (transformer-rectifiers) to trip from the formation of electrical grounds in the ESP causing shorting, resulting in poor ESP performance (3).

Because of the severe blinding and fouling of SCR catalysts in tests when North Dakota lignite was fired, there is a need for alternative technologies specifically aimed at reducing NO_x emissions for lignite-fired boilers. The Powerspan technology provides an attractive multipollutant emission control option for lignite-fired systems. This project is specifically aimed at examining the application of Powerspan's ECO reactor system to convert NO species to HNO_3 in a flue gas derived from high-sodium lignite-fired combustion.

The primary concern in the application of the ECO technology to North Dakota lignite is the possibility of sodium aerosols reacting with the quartz materials in the oxidation reactor. Sodium in North Dakota lignite is associated with the organic matrix of the coal. As described earlier, sodium is vaporized during combustion, and upon gas cooling, some of the sodium condenses homogeneously to form a submicron aerosol or fume. These aerosols are very small and can pass through ESPs and baghouses. The form of the sodium in aerosol is likely hydroxide or sulfate. These materials will react with silicate materials. The ECO quartz electrodes operate about 100°F above the flue gas temperature. The ECO quartz electrode temperatures may be as high as 465°F. Another potential problem with the application of the Powerspan ECO technology to North Dakota lignite is the potential to form sodium-rich pyrosulfates. Sodium-rich pyrosulfates, which form at 500° to 750°F, are known to cause corrosion problems. In the presence of halogens, corrosive species can form at temperatures as low as 350°F. Typical North Dakota lignite contains low levels of halogens; however, if the mercury control technology contains halogens in sorbent material or if halogens are added to the furnace to increase oxidation, this could contribute to problems related to the formation of ash deposits and corrosive layers.

Prior Testing in a High-Sodium Environment

Sodium effects testing in the lifecycle DBD reactor was conducted at Powerspan's laboratory facility. A 25% sodium hydroxide solution was injected into a propane flame to produce up to 200 ppm sodium aerosols. The DBD reactor operated at a gas flow rate of 18 scfm and an energy density of 15.2 W/scfm with a flue gas composition of 6% oxygen, 11.5% carbon dioxide, 12% water vapor, 76 ppm NO_x and up to 1,600 ppm SO_2. The flue gas flow rate and reactor power used in the laboratory testing are consistent with the gas velocities and energy densities expected in the commercial units. Initial testing shows sodium aerosols are not affecting the reactor's ability to oxidize NO to NO_2 and HNO_3.

Two electrodes were examined using scanning electron microscopy. The first sample was a "spent" quartz electrode from the sodium injection testing. The second sample was a "blank" (unused) quartz electrode used for comparison purposes (see Figure 2).

EERC ST29350.CDR

Figure 2. Quartz elements prior to mounting and cross-sectioning. The top electrode is the "blank," the bottom element is the "spent."

Backscattered electron imaging was used in the morphological analysis. Backscattered imaging differentiates between elements based on their atomic number. The brightness of the image is a function of the atomic number; higher-atomic-number elements, such as iron, appear brighter than lower-atomic-number elements such as silicon. Silicon and sodium are distinguishable from one another in backscattered electron imaging. X-ray microanalysis was performed along with the backscattered electron imaging. The electron beam was placed on the tube surfaces, and on the thin coating on the electrodes, to determine characteristic x-ray patterns for each analysis point. The x-ray spectra were then quantified.

Backscattered electron micrographs of the spent electrode are shown in Figures 3 and 4. A thin, <10μm coating was present on the surface of the quartz element. On average, the coating consisted of about 56 wt% sodium, 6.2 wt% silicon, and minor amounts of other elements. The electron beam was placed on the electrode-side of the interface with the sodium-rich coating. At this point, the average composition of the element was 77 wt% silicon, with about 3.5 wt% sodium. At analysis point 3 (Figure 4), just at the interface, sodium was quantified at 9.37 wt% and silica was slightly depleted (67.31 wt%).

For comparison purposes, the blank quartz electrode was characterized in the same manner as the spent quartz electrode. Backscattered electron micrographs of the spent electrode are

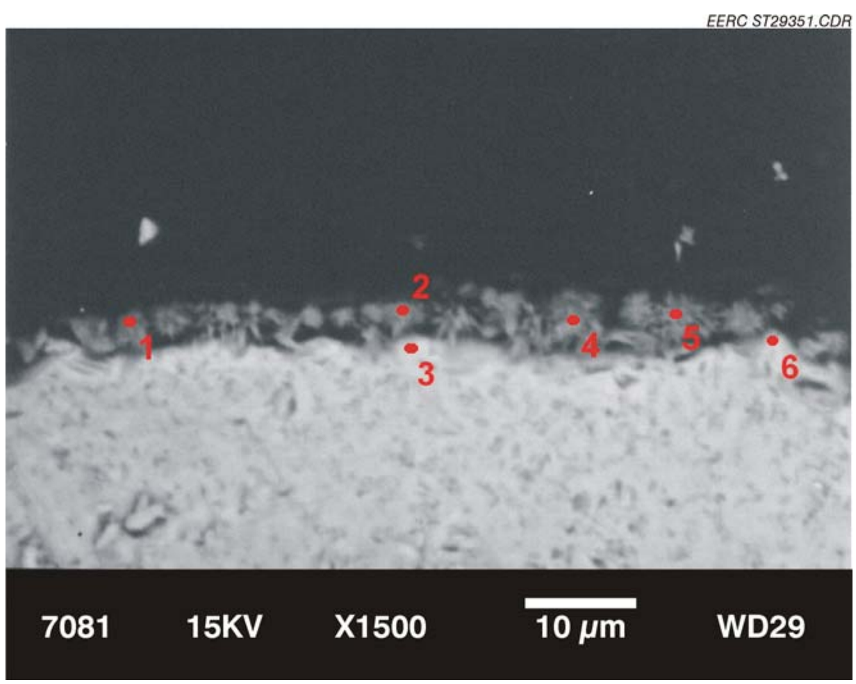

Figure 3. Backscattered electron micrograph of spent quartz electrode, showing analysis points 1 through 6.

EERC ST29352.CDR

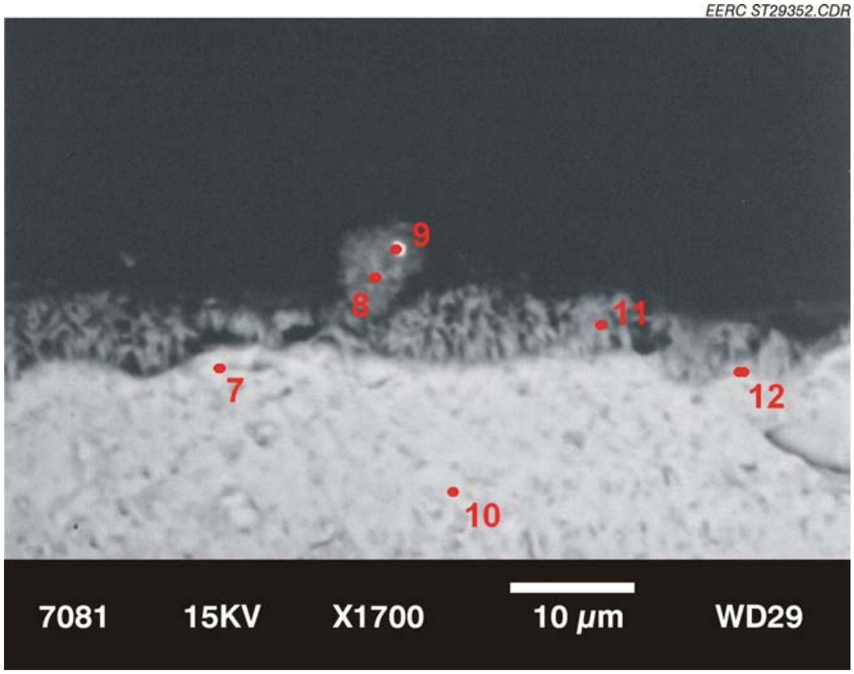

Figure 4. Backscattered electron micrograph of spent quartz electrode, showing analysis points 7 through 12.

shown in Figures 5 and 6. Morphological analysis results show the surface element was comprised of over 95 wt% silicon. Within the element (probing towards the center of the tube wall), silicon and oxygen were present. One analysis point was quantified with a small amount of sodium, likely from the background of the x-ray spectrum.

The results of the test indicate that there is no significant degradation of the electrode in a sodium-rich environment. When exposed to actual flue gas, the surface will accumulate a layer of ash. The interaction of the electrode with the ash and flue gas over time is of critical importance. To gain further understanding of this, a longitudinal, on-site test using a high-sodium coal to fire the plant is necessary.

Powerspan's Multipollutant Control Technology Overview

Powerspan's ECO integrated process has been shown to achieve significant reductions in emissions of SO_2 – 99%, NO_x – 90%, fine particulate matter, and Hg (4, 5). The ECO technology

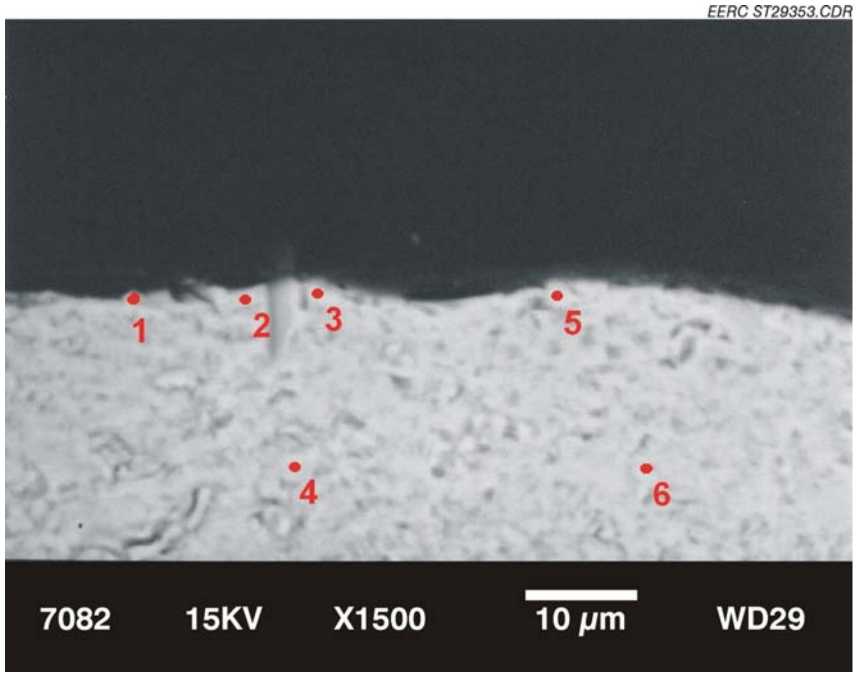

Figure 5. Backscattered electron micrograph of blank quartz element, showing analysis points 1 through 6.

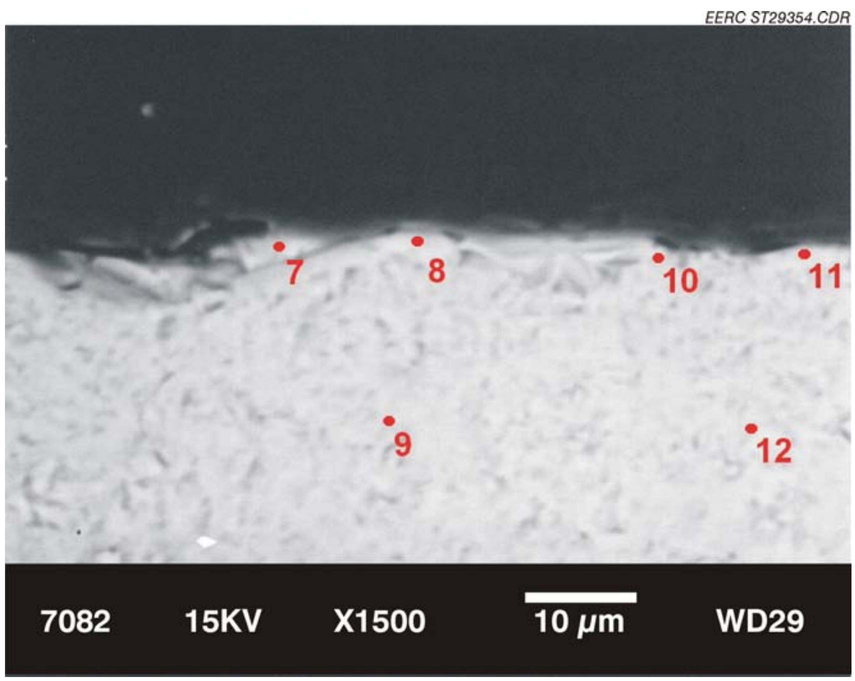

Figure 6. Backscattered electron micrograph of blank quartz element, showing analysis points 7 through 12.

is designed to simultaneously remove SO_2, NO_x, $PM_{2.5}$, acid gases (such as HF, HCl, and SO_3), Hg, and other metals from the exhaust gas of coal-fired power plants. The ECO process converts incoming NO into more soluble NO_x compounds, and then absorbs the SO_2 and NO_x compounds. The ECO process also oxidizes a portion of the elemental mercury to mercuric oxide. The converted mercuric oxide as well as oxidized mercury originally in the flue gas is collected along with aerosols and fine particles in a WESP. Additionally, the ECO process produces an ammonium sulfate fertilizer coproduct, eliminating landfill disposal of waste.

In commercial application, the ECO system is installed downstream of a power plant's existing ESP or FF as depicted in the process flow diagram of Figure 7.

ECO treats flue gas in three process steps to achieve multipollutant removal. The ECO process consists of a DBD reactor, a scrubber, and a WESP. In the first process step, a barrier discharge reactor oxidizes gaseous pollutants to higher oxides. NO is oxidized to nitrogen dioxide and nitric acid, a small portion of the sulfur dioxide is converted to sulfuric acid, and elemental mercury is oxidized to mercuric oxide. Inside the ECO DBD reactor, a quartz rod is fitted with electrodes and energized with a high-voltage, high-frequency power. This produces an electrical discharge which, in turn, creates a nonthermal plasma. The plasma produces reactive O and OH radicals that enhance oxidation of NO to NO_2 and HNO_3, SO_2 to SO_3 and H_2SO_4, and possibly Hg to HgO. These species are water-soluble and can be collected in the downstream scrubber.

The second process step is an ammonia-based scrubber. The scrubber consists of a lower and upper loop. The lower loop cools the flue gas to saturation temperatures and is used to scrub a portion of the acid species (HNO_3 and H_2SO_4) produced in the plasma, SO_2, and oxidized forms of mercury. The lower loop is where the liquid ammonium sulfate is produced and removed.

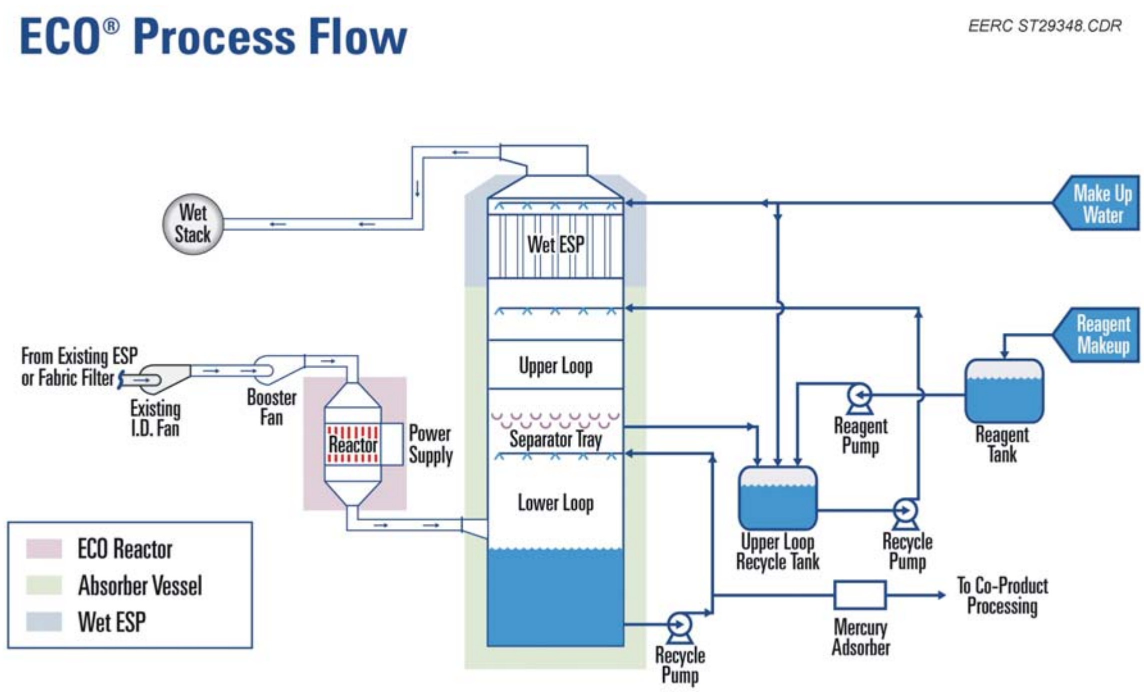

Figure 7. ECO process flow diagram.

The upper loop of the scrubber scrubs SO_2 and NO_2. The SO_2 scrubbing forms sulfite, which reacts with NO_2 to form nitrogen and sulfate. Ammonia is added to maintain pH for the scrubbing process in the upper loop. The scrubber removes the sulfur dioxide not converted by the reactor and, utilizing novel and proprietary chemical controls, removes the oxides of nitrogen produced from the NO in the reactor. Without the conversion of the NO to higher oxides in the reactor, the NO would pass through the scrubber without being captured. Therefore, the reactor and scrubber work in combination to achieve the NO_x reduction.

The third process step is a WESP, which is located above the upper loop of the scrubber. It captures acid aerosols produced by the discharge reactor, fine particulate matter, and oxidized mercury. The WESP also captures aerosols generated in the ammonia scrubber (6). The ESP is periodically washed with water, and the collected material drains to the lower loop.

All the liquid coming into the absorber tower ultimately ends up in the lower quench loop. This liquid contains all the material removed from the flue gas, which is in the form of dissolved ammonium sulfate salts, dissolved and suspended Hg and other metals, and captured fine particulate matter. The concentration of solid particulate matter in the liquid is very low, and the liquid is basically clear, unlike the slurry used in calcium-based SO_2 scrubbers.

The evaporation of water that occurs in cooling the flue gas is used to concentrate the dissolved salts in the lower loop to just below the concentration at which the ammonium sulfate solution saturates and begins to crystallize. When the lower loop reaches this concentration, a liquid stream is drawn off the loop and pumped to the coproduct processing system. This concentrated, clear liquid stream presents a very convenient opportunity to remove constituents not desired in the fertilizer coproduct, for example, the fine particulate ash and the mercury. Simple filters and absorbent beds in the flow stream accomplish this function. The processing options available for removing constituents from a clear liquid stream are significantly easier and cheaper than the processing that would be required for solids or slurries. The ammonium sulfate is then crystallized to produce a commercially valuable fertilizer. Some of the NO_x oxidized in the barrier discharge reactor precipitates as nitrate within the ammonium sulfate crystal. This ammonium nitrate is not separable from the ammonium sulfate and adds somewhat to the value of the fertilizer because it increases the nitrogen content above that which is provided by the ammonium. However, since only a fraction of the NO_x is converted to nitric acid (most is oxidized only to NO_2) and since the NO_x is a small fraction of the incoming SO_2, the concentration of ammonium nitrate is usually only a percent or two of the ammonium sulfate.

There is no liquid discharge from an ECO system. The only waste streams are the small quantity of ash that escaped the plant's particulate collection device and was captured in ECO's

WESP and the small volume of Hg adsorbent used to remove the Hg from the fertilizer liquid steam.

Powerspan's ECO Commercial Demonstration

Powerspan has been operating a 50-MW ECO unit at FirstEnergy's R.E. Burger Plant near Shadyside, Ohio, since February 2004. The technology has proven effective in reducing NO_x, SO_2, mercury, acid gases, and fine particulate matter. Fertilizer produced by the process has been sold commercially. In September 2005, Powerspan successfully completed a 180-day continuous performance test at the ECO unit.

The 50-MW Burger Commercial Unit (BCU) is a standalone, slipstream unit drawing flue gas from the Burger Plant Unit 4 or 5 ductwork at a point downstream of the plant's existing ESP. The treated flue gas is returned to the existing plant ductwork just prior to the stack. The ECO unit processes flue gas from high-sulfur, eastern bituminous coals; from mid- and low-sulfur eastern bituminous coals; and from blends of these coals with PRB (Powder River Basin) coals. Figure 8 depicts the completed ECO unit at the Burger Plant.

The BCU performed steadily, achieved predictable results, and met all performance objectives over the continuous 6-month period. At the end of the 180-day test, performance was essentially unchanged from the start of the run. The operating data indicate the unit could have continued to run indefinitely. Post-operating run internal inspections support this conclusion. A summary of the unit's performance is included in Table 4 (7).

Having demonstrated the performance objectives of the ECO technology at a plant fueled by both bituminous and subbituminous coals, Powerspan recognizes the significant market segment associated with plants fueled by lignite coal.

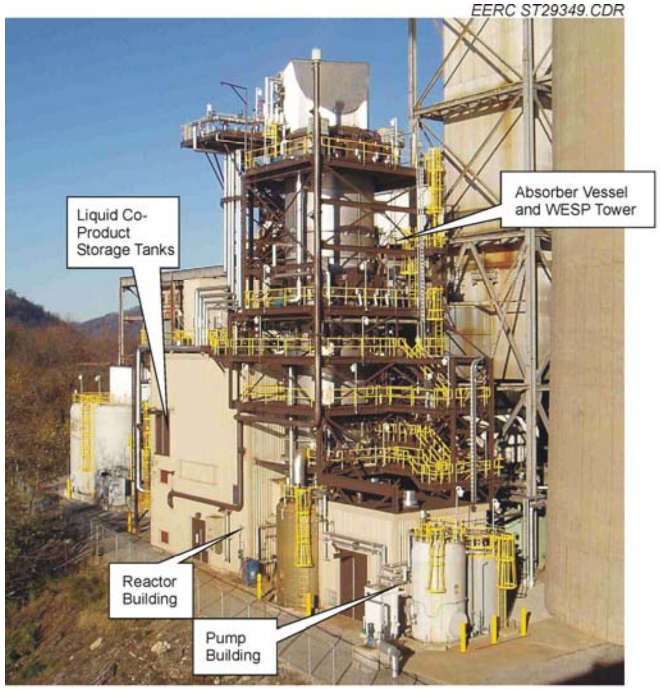

Figure 8. 50-MW ECO Burger Commercial Unit (BCU).

Table 4. Performance Summary of 180-day Reliability Run

SO_2	> 98% removal
NO_x	90% removal
Hg	80%–85% removal across the ECO system
$PM_{2.5}$	< 0.01 lb/MMBtu at outlet
Reliability	Operated continuously for 6 months (03/20/05 – 9/20/05); > 98% online availability even though, as a money saving feature, the BCU was not designed with component redundancy
Operability	Maintained performance through load following, system transients, and plant upsets
Pollutants Removed	3000 tons of SO_2 125 tons of NO_x 4.8 lb of mercury
Coproduct Generated and Sold	> 20,000 tons of liquid ammonium sulfate fertilizer (200 railcars)

Integration Opportunity for CO_2 Separation—ECO_2™

In addition to the ECO technology, Powerspan has been engaged in the development of a cost-effective CO_2 removal process for coal-fired power plants. In 2004, Powerspan and the U.S.

Department of Energy's (DOE) National Energy Technology Laboratory (NETL) entered into a cooperative research and development agreement to develop a cost-effective CO_2 removal process for coal-fired power plants (8). The regenerative process, called "ECO_2™", works in conjunction with Powerspan's ECO process for multipollutant control and uses an ammonia-based solution to capture CO_2 in flue gas and release it for enhanced oil recovery or another form of geological sequestration. The process can be applied to both existing and new coal-fired power plants and is particularly advantageous for sites where ammonia-based scrubbing of power plant emissions is employed.

Powerspan laboratory testing of the CO_2 absorption process has demonstrated 90% CO_2 removal under conditions comparable to a commercial-scale absorber, confirming test results previously obtained by the DOE under similar conditions.

In February 2005, DOE published *An Economic Scoping Study for CO_2 Capture Using Aqueous Ammonia*, which compared the cost of CO_2 capture and sequestration for a new supercritical PC power plant using conventional air pollution control equipment and monoethanol amine (MEA)-based CO_2 absorption, versus a multipollutant control system such as ECO and CO_2 removal using ammonia (i.e., ECO_2). The economic results project that 90% CO_2 capture and sequestration with the conventional pollution control systems and MEA would cost $47/ton of CO_2 removed, and the cost of electricity would be 7.6 cents/kWh. By comparison, the estimated costs for the ECO system with ammonia-based CO_2 capture and sequestration were $14/ton of CO_2 removed and 5.5 cents/kWh for electricity. Thus the projected incremental costs of CO_2 removal with ECO are less than one-third of the costs for conventional technology on pulverized coal (pc) plants (9).

In September 2005, Powerspan and FirstEnergy announced plans to pilot-test the ECO_2 technology at FirstEnergy's R.E. Burger Plant in Shadyside, Ohio (10). The ECO_2 pilot unit will process a 1-MW slipstream (20 ton CO_2/day) from the 50-MW ECO Burger Commercial Unit. The pilot program will demonstrate the ability of the CO_2 capture process to be integrated with the ECO process and will confirm process design and cost estimates.

QUALIFICATIONS

The EERC is a research facility that operates as a business unit of UND. The EERC currently has an annual budget of $45.6 million and has worked with over 955 clients in all 50 states and in 49 countries. The EERC has a multidisciplinary staff of nearly 300 with expertise and partnerships in a broad spectrum of energy and environmental programs, including nearly 60 years of research experience on lignite properties and variability; gasification processes; ash-related impacts; the fate of pollutants including Hg, particulate, and acid gases; Hg sampling, measurement, and speciation; development, demonstration, and commercialization of combustion and environmental control systems; conducting field testing and demonstrations; and advanced analysis of materials. During this project, we will rely on EERC plant operations, technicians, chemists, and engineers who will assist with design, fabrication, and operation of the equipment.

Powerspan Corp. of Portsmouth, New Hampshire, has been engaged in the development and commercialization of innovative, proprietary emission control systems and technologies for coal-fired power plants since 1994. Within that time frame, Powerspan has assembled a talented and innovative management team with diverse experience in the field of power engineering. Their Chairman and CEO, Frank Alix, is a recognized leader in the industry. The team members have played important roles with prominent technology-focused enterprises in both the public and private sectors. These enterprises include the Naval Nuclear Propulsion Program, General Dynamics, Tecogen, Teradyne, and Hamon Research-Cottrell.

As of March 2007, Powerspan employed 54 full-time employees. The majority of these employees are engaged in research and development and engineering; 11 are full time Ohio-based employees; four are engaged in manufacturing and purchasing; three are engaged in sales and marketing; and eight are engaged in finance and administration. In addition, the company employs part-time or full-time consultants in development, design, marketing, and finance.

VALUE TO NORTH DAKOTA

A major challenge facing North Dakota lignite-fired power plants is managing the impact of sodium on the performance of air pollution control devices for NO_x control. Research efforts have shown that SCR technology for NO_x reduction does not work for lignite because of the significant plugging, blinding and, possibly, poisoning of the catalysts because of sodium. This project will test a NO_x reduction technology that has application to the North Dakota lignite industry. If successful, the results of this project will provide an alternative NO_x reduction technology for North Dakota lignite, potentially resulting in the increased use of lignite for power generation in the future.

MANAGEMENT

The management structure for the project is illustrated in Figure 9. The project direction will be provided by the sponsors of the program. The sponsors include the Young 3 team led by Luther Kvernen, as well as DOE, the North Dakota Industrial Commission, and the Lignite Energy Council. In addition, project advisors from Powerspan will also provide input into the direction of the program. The project manager, Steve Benson, will be responsible for

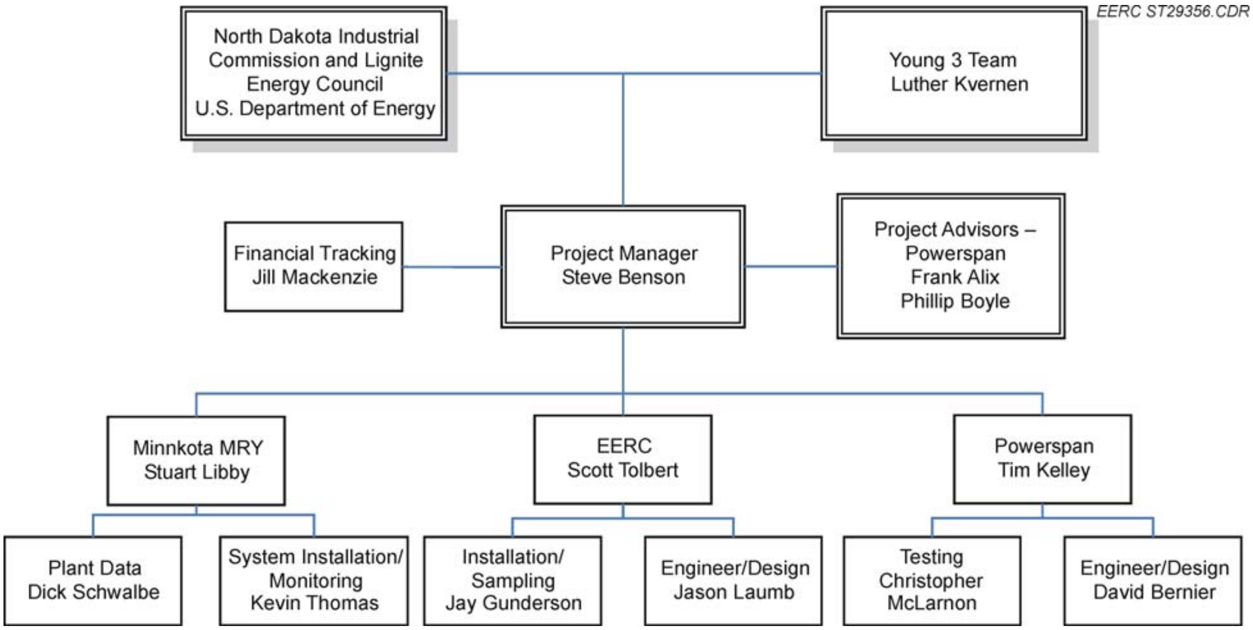

Figure 9. Overall project management organizational chart.

coordination and management of the project team and coordination with the project sponsors and advisors. Short resumes of the key personnel are as follows; more detailed resumes can be found in the appendix of key personnel.

Project Manager

Dr. Steven A. Benson will be the EERC Project Manager responsible for oversight of the project. Dr. Benson has more than 25 years in coal utilization and environmental control technologies and has managed numerous projects involving government and industry participants. The projects include the development of 1) methodologies to minimize the effects of inorganic components on the performance of combustion/gasification and air pollution control systems, 2) fate and control of air toxic substances such as mercury in combustion and gasification systems, 3) advanced analytical techniques to determine the chemical and physical transformations of fuel derived impurities in combustion gases, 4) computer-based codes to predict the effects of coal quality on system performance, 5) advanced materials for coal-based power systems, and 6) training programs. Steve has a B.S. in Chemistry from Minnesota State University (Moorhead) and a Ph.D. in Fuel Science from the Pennsylvania State University.

Project Advisors

Frank Alix, Chairman and Chief Executive Officer, cofounded Powerspan in 1994 and is coinventor on several of Powerspan's patents. Frank has over 25 years of experience in energy-related fields. Prior to assuming his present role at Powerspan, Frank worked as a venture capital investor, where he made five early-stage investments and served as a director of four companies.

Frank has over 15 years' experience in the construction, maintenance, and repair of nuclear power plants on submarines. He began his career at General Dynamics and later worked as a senior nuclear engineering manager at Portsmouth Naval Shipyard. There, Frank headed the Nuclear Test Engineering and Mechanical Engineering Divisions, where he was responsible for more than 200 engineers and technicians. As the head of the NR-1 Engineering Group, he was responsible for all electrical and mechanical propulsion plant systems during the first Submarine NR-1 Refueling overhaul, valued at over $90 million.

In his role as CEO of Powerspan, Frank has testified before the House Subcommittee on Energy and Air Quality; the Senate Subcommittee on Clean Air, Wetlands, and Climate Change; and before the Senate Environment and Public Works committee. In addition Frank has presented to former Energy Secretary Spencer Abraham at a Cambridge Energy Research Associates event, the U.S. Environmental Protection Agency, the National Coal Council, the American Coal Council, the Electric Power Generation Association, Congressional staff, and the power generating industry at large at several industry-related conferences and events.

Frank has a B.S. in Nuclear Engineering from the University of Massachusetts-Lowell and an M.B.A. from the University of New Hampshire.

Phillip D. Boyle, President and Chief Operating Officer**,** joined the Company as Vice President of Engineering in 1996 after spending 20 years with the Naval Nuclear Propulsion Program. In his role as Program Manager for Shipyard Matters, Phil was responsible for oversight and direction of nuclear work at four public and two private shipyards. Prior to this, Phil served as the Naval Reactors Representative for 8 years at the Portsmouth Naval Shipyard, overseeing maintenance and refueling of nuclear submarines. Earlier in his career, Phil led the headquarter's design group for reactor plant fluid systems for the Navy's sophisticated Fleet Ballistic Missile submarine, the TRIDENT Class. Phil holds a B.S. in Engineering Physics and a Master's of Engineering, Nuclear Engineering, both attained at Cornell University. Phil also holds an M.B.A. from the Whittemore School of Business and Economics at the University of New Hampshire.

Mr. Jason Laumb is a Research Manager at the EERC. His responsibilities include supervising projects involving bench-scale combustion testing of various fuels and wastes; supervising a laboratory that performs bench-scale combustion and gasification testing; and managerial and principal investigator duties for projects related to the inorganic composition of coal, coal ash formation, deposition of ash in conventional and advanced power systems, and mechanisms of trace metal transformations during coal or waste conversion. Mr. Laumb also has experience with numerous NO_x control technologies, including SCR, low-NO_x burners (LNBs), and overfire air staging (OFA). Additionally he has participated in the design and construction of several pilot and slipstream test facilities.

Principal Investigators

Scott Tolbert is a Research Manager at the EERC. Scott's principal area of expertise is in the design, construction, and operation of bench- and pilot-scale equipment for testing various fuel conversion and environmental control processes. He has worked on design and construction projects involving small scale combustion and gasification systems as well as gas cleanup systems. He has worked on processes for sulfur control for gasification system that have been focused on providing a clean gas stream for hydrogen production and utilization. His principal areas of interest and expertise include advanced multipollutant control and gas cleanup, hydrogen/CO_2 separation, electric vehicle drive systems, fuel cells, and electrolyzer technologies. Scott has B.S. and M.S. degrees in Industrial Technology from the University of North Dakota.

Christopher R. McLarnon, Ph.D., Vice President of Research and Development**,** joined Powerspan in 1996. He holds a Ph.D. in Chemical Engineering from the University of New Hampshire, where he also received his B.S. and M.S. degrees in Chemical Engineering. Chris has worked with radiation-initiated chemistry and its application to pollution control for over 15 years. He has supervised process development of a number of pollution control technologies for application to coal-fired power plant exhaust. Chris has also directed pilot and demonstration unit testing at operating coal-fired power plants.

David Bernier, Vice President of Engineering, came to Powerspan in 2000 from Hatch Technology Group, an engineering consulting firm that he cofounded. As President, Dave was responsible for strategic planning, business development, design/R&D coordination, marketing, and project management. In his previous position, he was Plant Operations Manager for Molten Metal Technology's Research and Development facility, where he managed the design, construction and start-up of a "first-of-a-kind" hazardous waste processing plant. He served for 9 years at the Portsmouth Naval Shipyard as a production engineer, project leader, and production engineering manager for the naval nuclear submarine refueling overhaul. Dave earned his B.S. degree in Mechanical/Nuclear Engineering from Worcester Polytechnic Institute and holds an M.B.A. from the Whittemore School of Business and Economics at the University of New Hampshire.

Joanna Duncan, Ph.D., Senior Research Scientist, joined Powerspan in 2000. She works in the R&D group testing all aspects of the ECO process at the bench, pilot, and commercial scales. She is an inventor on five patents held by Powerspan surrounding different aspects of the ECO process. In addition, she is part of the development effort of Powerspan's photochemical oxidation and ECO_2 technologies. She holds a Ph.D. in Physical Chemistry from the University of Minnesota and a B.A. in Chemistry from Bowdoin College.

PROJECT TIMETABLE

The project will be initiated upon approval of the project by the NDIC. It is anticipated that the proposed work will be carried out over 7 months. The project schedule is shown in Table 5.

COST

The total cost of this project is $610,985 (refer to Table 6). Although the MRY 3 team appears to have a low cash contribution, they will have significant cash expenditures. Examples of these expenditures are $75,625 for the Powerspan DBD reactor, power supply, and controller; $20,400 for contract engineering, electrical, and steel work; and $20,000 is estimated for the additional structural steel. The portions of the budget identified as Cash will be applied towards obtaining federal funds through the EERC. By doing so, an additional $132,800 in cash is leveraged for the project.

MATCHING FUNDS

The total cost of the project is $610,985. Cost-share funding from the EERC–DOE JSRP is $132,800. Funding requested from NDIC is $260,420. Cash funding from the MRY 3 Team is anticipated to total $2549. Cash equivalent of $215,216 is being provided by Powerspan and MRY 3.

Table 5. Project Schedule

Task Name
Task 1. Modification of Slipstream Reactor
a. Design/Modification of Reactor
b. Detailed Test Plan
Task 2. Installation and Shakedown
a. Installation of Ports
b. Installation of Slipstream
c. Shakedown
Task 3. MRY Testing Campaign
a. Slip Data
b. Plant Data
c. Quartz Rod Sampling
d. Inspections (2/day)
Task 4. Performance Evaluation
a. Plot Slipstream Operational Trends
b. Plot Plant Operational Trends
c. Chemical Analysis
d. Laboratory Testing of Exposed Quartz Rods
Task 5. Reporting
a. Project Meetings/Conference Calls
b. Draft Report to Sponsors
c. Final Report

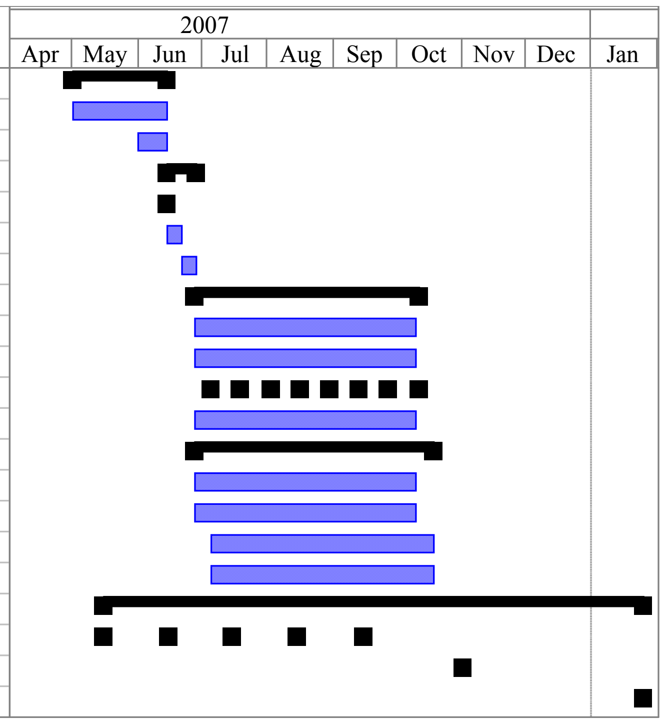

Table 6. Budget Summary

	Total	Powerspan Share	MRY 3 Share	NDIC Share	EERC JSRP Share
Cash	$395,769		$2549	$260,420	$132,800
Cash Equivalent	$215,216	$19,280	$195,936		
Total Project Cost	$610,985	$19,280	$198,485	$260,420	$132,800

TAX LIABILITY

The EERC—a research organization within the University of North Dakota, which is an institution of higher education within the state of North Dakota—is not a taxable entity.

CONFIDENTIAL INFORMATION

No confidential information is included in the proposal.

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IMPACTS OF LIGNITE PROPERTIES ON POWERSPAN'S NO_X OXIDATION SYSTEM
MRY#3 TEAM/NDIC/DOE
PROPOSED PROJECT START DATE: 5/01/07
EERC PROPOSAL #2007-0216

BUDGET

CATEGORY		Rate	TOTAL Hrs	TOTAL Cost	POWERSPAN SHARE Hrs	POWERSPAN SHARE Cost	MRY #3 TEAM SHARE Hrs	MRY #3 TEAM SHARE Cost	NDIC SHARE Hrs	NDIC SHARE Cost	EERC JSRP SHARE Hrs	EERC JSRP SHARE Cost
LABOR												
TOLBERT, S.	Project Manager	$ 37.14	500	$ 18,570	-	$ -	28	$ 1,040	350	$ 12,999	122	$ 4,531
BENSON, S.	Principal Investigator	$ 61.48	120	$ 7,378	-	$ -	-	$ -	120	$ 7,378	-	$ -
LAUMB, J.	Principal Investigator	$ 37.72	80	$ 3,018	-	$ -	-	$ -	80	$ 3,018	-	$ -
MACKENZIE, J.	Research Scientist/Engineer	$ 26.15	80	$ 2,092	-	$ -	-	$ -	80	$ 2,092	-	$ -
--------------	Senior Management	$ 59.15	117	$ 6,921	-	$ -	-	$ -	14	$ 828	103	$ 6,093
--------------	Research Scientist/Engineer	$ 32.92	386	$ 12,707	-	$ -	-	$ -	325	$ 10,699	61	$ 2,008
--------------	Research Technician	$ 21.80	214	$ 4,665	-	$ -	-	$ -	-	$ -	214	$ 4,665
--------------	Technology Dev. Mech.	$ 25.67	400	$ 10,268	-	$ -	-	$ -	400	$ 10,268	-	$ -
--------------	Technical Support Services	$ 17.70	100	$ 1,770	-	$ -	-	$ -	10	$ 177	90	$ 1,593
				$ 67,389		$ -		$ 1,040		$ 47,459		$ 18,890
Escalation Above Base		4%		$ 2,696		$ -		$ 42		$ 1,898		$ 756
TOTAL DIRECT HRS/SALARIES			1,997	$ 70,085	-	$ -	28	$ 1,082	1,379	$ 49,357	590	$ 19,646
TOTAL FRINGE BENEFITS				$ 35,743		$ -		$ 552		$ 25,172		$ 10,019
TOTAL LABOR				$ 105,828		$ -		$ 1,634		$ 74,529		$ 29,665
OTHER DIRECT COSTS												
TRAVEL				$ 6,188		$ -		$ -		$ 6,188		$ -
EQUIPMENT > $5000				$ 85,500		$ -		$ -		$ -		$ 85,500
SUPPLIES				$ 5,000		$ -		$ -		$ 5,000		$ -
SUBCONTRACT - Powerspan				$ 24,450		$ -		$ -		$ 24,450		$ -
PROFESSIONAL FEES AND SVCS (CONSULTANT)				$ 1,000		$ -		$ -		$ 1,000		$ -
COMMUNICATION - PHONES & POSTAGE				$ 555		$ -		$ -		$ 118		$ 437
OFFICE (PROJECT SPECIFIC SUPPLIES)				$ 450		$ -		$ -		$ 100		$ 350
OPERATING FEES & SVCS												
Natural Materials Analytical Res. Lab.				$ 47,840		$ -		$ -		$ 47,840		$ -
Fuels & Materials Research Lab.				$ 1,165		$ -		$ -		$ 1,165		$ -
Process Chem. & Dev. Lab.				$ 1,206		$ -		$ -		$ 1,206		$ -
Graphics Support				$ 2,122		$ -		$ -		$ 550		$ 1,572
Shop & Operations Support				$ 790		$ -		$ -		$ 790		$ -
Freight				$ 4,000		$ -		$ -		$ 4,000		$ -
TOTAL DIRECT COST				$ 286,094		$ -		$ 1,634		$ 166,936		$ 117,524
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 109,675	56%	$ -	56%	$ 915	56%	$ 93,484	47.7%	$ 15,276
PROJECT COST - CASH				$ 395,769		$ -		$ 2,549		$ 260,420		$ 132,800
CASH EQUIVALENT COST SHARE				$ 215,216		$ 19,280		$ 195,936		$ -		$ -
TOTAL PROJECT COST				$ 610,985		$ 19,280		$ 198,485		$ 260,420		$ 132,800

IMPACTS OF LIGNITE PROPERTIES ON POWERSPAN'S NOX OXIDATION SYSTEM
EERC PROPOSAL #2007-0216

DETAILED BUDGET - RECHARGE CENTERS

Natural Materials Analytical Res. Lab.	Rate	#	TOTAL $Cost
Morphology (Hourly)	$230	200	$ 46,000
Subtotal			$ 46,000
Escalation		4%	$ 1,840
Total Natural Materials Analytical Res. Lab.			$ 47,840

Fuels & Materials Research Lab.	Rate	#	$Cost
BTU	$52	10	$ 520
Proximate Analysis	$60	10	$ 600
Subtotal			$ 1,120
Escalation		4%	$ 45
Total Fuels & Materials Research Lab.			$ 1,165

Process Chemistry. & Dev. Lab.	Rate	#	$Cost
Prep/GC/CHN	$58	20	$ 1,160
Subtotal			$ 1,160
Escalation		4%	$ 46
Total Process Chemistry & Dev. Lab.			$ 1,206

Graphics Support	Rate	#	$Cost
Graphics (hourly)	$51	40	$ 2,040
Subtotal			$ 2,040
Escalation		4%	$ 82
Total Graphics Support			$ 2,122

Shop & Operations Support	Rate	#	$Cost
Technical Development Hours	$1.90	400	$ 760
Subtotal			$ 760
Escalation		4%	$ 30
Total Shop & Operations Support			$ 790

IMPACTS OF LIGNITE PROPERTIES ON POWERSPAN'S NOX OXIDATION SYSTEM
EERC PROPOSAL #2007-0216

BUDGET - TRAVEL

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	AIRFARE	PER MILE	LODGING	PER DIEM	CAR RENTAL	REGIST.
Unspecified Destination (USA)	$ 750	$ -	$ 150	$ 64	$ 75	$ 525
Center, ND	$ -	$ 0.33	$ 60	$ 25	$ -	$ -

PURPOSE/DESTINATION	NUMBER OF TRIPS	PEOPLE	MILES	DAYS	AIRFARE	MILEAGE	LODGING	PER DIEM	CAR RENTAL	MISC.	REGIST.	TOTAL
Conference/Unspecified Dest. (USA)	1	1	-	4	$ 750	$ -	$ 450	$ 256	$ 300	$ 80	$ 525	$ 2,361
Set-up/Center, ND	1	3	320	5	$ -	$ 106	$ 720	$ 375	$ -	$ 150	$ -	$ 1,351
Sample Collection/Center, ND	8	1	320	1	$ -	$ 845	$ -	$ 200	$ -	$ 80	$ -	$ 1,125
Take-down/Center, ND	1	3	320	5	$ -	$ 106	$ 720	$ 375	$ -	$ 150	$ -	$ 1,351
TOTAL ESTIMATED TRAVEL												$ 6,188

DETAILED BUDGET - EQUIPMENT

Fabricated Equipment	$COST
Control Valve	$ 5,000
Blower	$ 9,000
Air Conditioner	$ 500
Controls	$ 5,500
Sensors	$ 8,000
Stainless Steel Piping	$ 14,000
Insulation	$ 4,000
Covering	$ 2,000
Peroxide Injection	$ 2,000
Total Estimated Cost: SCR System Upgrades	$ 50,000
Shelter	$ 10,000
Electrical	$ 5,000
Air Conditioner	$ 500
Total Estimated Cost: Building Enclosure	$ 15,500
Other Equipment	
Gas Analyzer	$ 20,000
Total Equipment	$ 85,500

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

Background

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC receives no appropriated funding from the state of North Dakota and is funded through federal and nonfederal grants, contracts, or other agreements. Although the EERC is not affiliated with any one academic department, university academic faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, subcontracts) is for planning purposes only. The principal investigator may, as dictated by the needs of the work, reallocate the budget among approved items or use the funds for other items directly related to the project, subject only to staying within the total dollars authorized for the overall program. Escalation of labor and EERC fee rates is incorporated in the budget when a project's duration extends beyond the current fiscal year. Escalation is calculated by prorating an average annual increase over the anticipated life of the project. The current escalation rate of 5% is based on historical averages. The budget prepared for this proposal is based on a specific start date; this start date is indicated at the top of the EERC budget or identified in the body of the proposal. Please be aware that any delay in the start of this project may result in an increase in the budget.

Intellectual Property

If federal funding is proposed as part of this project the applicable federal intellectual property (IP) regulations may govern any resulting research agreement. In addition, in the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this agreement, such IP, including rights, title, interest, and obligations, may be transferred to the EERC Foundation, a separate legal entity.

Salaries and Fringe Benefits

As an interdisciplinary, multiprogram, and multiproject research center, the EERC employs an administrative staff to provide required services for various direct and indirect support functions. Direct project salary estimates are based on the scope of work and prior experience on projects of similar scope. Technical and administrative salary charges are based on direct hourly effort on the project. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the current average rate of a personnel group with a similar job description. For faculty, if the effort occurs during the academic year and crosses departmental lines, the salary will be in addition to the normal base salary. University policy allows faculty who perform work in addition to their academic contract to receive no more than 20% over the base salary. Costs for general support services such as grants and contracts administration, accounting, personnel, and purchasing and receiving, as well as clerical support of these functions, are included in the EERC facilities and administrative cost rate.

Fringe benefits are estimated on the basis of historical data. The fringe benefits actually charged consist of two components. The first component covers average vacation, holiday, and sick leave (VSL) for the EERC. This component is approved by the UND cognizant audit agency and charged as a percentage of direct labor for permanent staff employees eligible for VSL benefits. The second component covers actual expenses for items such as health, life, and unemployment insurance; social security matching; worker's compensation; and UND retirement contributions.

Travel

Travel is estimated on the basis of UND travel policies which can be found at www.und.edu/dept/accounts/employeetravel.html. Estimates include General Services Administration (GSA) daily meal rates. Travel includes scheduled meetings and conference participation as indicated in the scope of work.

Communications (phones and postage)

Monthly telephone services and fax telephone lines are generally included in the facilities and administrative cost. Direct project cost includes line charges at remote locations, long-distance telephone, including fax-related long-distance calls; postage for regular, air, and express mail; and other data or document transportation costs.

Office (project-specific supplies)

General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are provided through a central storeroom at no cost to individual projects. Budgeted project office supplies include items specifically related to the project; this includes duplicating and printing.

Data Processing

Data processing includes items such as site licenses and computer software.

Supplies

Supplies in this category include scientific supply items such as chemicals, gases, glassware, and/or other project items such as nuts, bolts, and piping necessary for pilot plant operations. Other items also included are supplies such as computer disks, computer paper, memory chips, toner cartridges, maps, and other organizational materials required to complete the project.

Instructional/Research

This category includes subscriptions, books, and reference materials necessary to the project.

Fees

Laboratory, analytical, graphics, and shop/operation fees are established and approved at the beginning of the university's fiscal year.

Laboratory and analytical fees are charged on a per sample, hourly, or daily rate, depending on the analytical services performed. Additionally, laboratory analyses may be performed outside the University when necessary.

Graphics fees are based on an established per hour rate for overall graphics production such as report figures, posters for poster sessions, standard word or table slides, simple maps, schematic slides, desktop publishing, photographs, and printing or copying.

Shop and operation fees are for expenses directly associated with the operation of the pilot plant facility. These fees cover such items as training, safety (protective eye glasses, boots, gloves), and physicals for pilot plant and shop personnel.

General

Freight expenditures generally occur for outgoing items and field sample shipments.

Membership fees (if included) are for memberships in technical areas directly related to work on this project. Technical journals and newsletters received as a result of a membership are used throughout development and execution of the project as well as by the research team directly involved in project activity.

General expenditures for project meetings, workshops, and conferences where the primary purpose is dissemination of technical information may include costs of food (some of which may exceed the institutional limit), transportation, rental of facilities, and other items incidental to such meetings or conferences.

Facilities and Administrative Cost

The facilities and administrative rate (indirect cost rate) included in this proposal is the rate that became effective July 1, 2006. Facilities and administrative cost is calculated on modified total direct costs (MTDC). MTDC is defined as total direct costs less individual items of equipment in excess of $5000 and subcontracts/subgrants in excess of the first $25,000 for each award.

APPENDIX A

RESUMES OF KEY PERSONNEL

DR. STEVEN A. BENSON
Senior Research Manager/Advisor
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000, Fax (701) 777-5181
E-Mail: sbenson@undeerc.org

Principal Areas of Expertise
Dr. Benson's principal areas of interest and expertise include development and management of complex multidisciplinary programs that are focused on solving environmental and energy problems, including 1) technologies to improve the performance of combustion/gasification and associated air pollution control systems; 2) transformations and control of air toxic substances in combustion and gasification systems; 3) advanced analytical techniques to measure the chemical and physical transformations of inorganic species in gases; 4) computer-based models to predict the emissions and fate of pollutants from combustion and gasification systems; 5) advanced materials for power systems; 6) impacts of power system emissions on the environment; 7) national and international conferences and training programs; and 8) state and national environmental policy.

Qualifications
Ph.D., Fuel Science, Materials Science and Engineering, The Pennsylvania State University, 1987.
B.S., Chemistry, Moorhead State University (Minnesota), 1977.

Professional Experience
1999 – Senior Research Manager/Advisor, EERC, UND. Dr. Benson is responsible for leading a group of about 30 highly specialized scientists and engineers whose aim is to develop and conduct projects and programs on power plant performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide. Efforts have focused on the development of multiclient jointly sponsored centers or consortia that are funded by a combination of government and industry sources. Current research activities include computer modeling of combustion and environmental control systems, performance of selective catalytic reduction technologies for NO_x control, carbon-based NO_x reduction technologies, mercury control technologies, particulate matter analysis and source apportionment, the fate of mercury in the environment, toxicology of particulate matter, and in vivo studies of mercury-selenium interactions. The computer-based modeling efforts utilize various kinetic, thermodynamic, artificial neural network, statistical, computation fluid dynamics, and atmospheric dispersion models. These models are used in combination with models developed at the EERC to predict the impacts of fuel properties and system operating conditions on system efficiency and emissions. Dr. Benson is Program Area Manager for Modeling and Database Development for the U.S. Environmental Protection Agency (EPA) Center for Air Toxic Metals® (CATM®)

at the EERC. He is responsible for identifying research opportunities and preparing proposals and reports for clients.

1994 – 1999 Associate Director for Research, EERC, UND. Dr. Benson was responsible for the direction and management of programs related to integrated energy and environmental systems development. Dr. Benson led a team of over 45 scientists, engineers, and technicians. In addition, faculty members and graduate students from Chemical Engineering, Chemistry, Geology, and Atmospheric Sciences have been involved in conducting research projects. The research, development, and demonstration programs involve fuel quality effects on power system performance, advanced power systems development/demonstration, computational modeling, advanced materials for power systems, and analytical methods for the characterization of materials. Specific areas of focus included the development and direction of EPA CATM at the EERC (CATM, a peer-reviewed, EPA-designated Center of Excellence, is currently in its 12th year of operation and has received funding of over $12,000,000 from government and industry sources), ash behavior in combustion and gasification systems, hot-gas cleanup, and analytical methods of analysis. He was responsible for the identification of research opportunities and the preparation of proposals and reports for clients. Dr. Benson left this position to focus efforts on Microbeam Technologies' Small Business Innovation Research (SBIR).

1986 – 1994 Senior Research Manager, Fuels and Materials Science, EERC, UND. Dr. Benson was responsible for management and supervision of research on the behavior of inorganic constituents, including air toxic metals during combustion and gasification, hot-gas cleanup (particulate gas-phase species control), fundamental combustion, and analytical methods of inorganic analysis, including SEM and microprobe analysis, Auger, XPS, SIMS, XRD, and XRF. Responsible for identification of research opportunities, preparation of proposals and reports for clients, and publication.

1989 – 1991 Assistant Professor (part-time), Department of Geology and Geological Engineering, UND. Dr. Benson was responsible for teaching courses on coal geochemistry, coal ash behavior in combustion and gasification systems, and analytical methods of materials analysis. Taught courses on SEM/microprobe analysis and mineral transformations during coal combustion.

1984 – 1986 Graduate Research Assistant, Fuel Science Program, Department of Materials Science and Engineering, The Pennsylvania State University.

1983 – 1984 Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center. Dr. Benson was responsible for management and supervision of research on the distribution of major, minor, and trace inorganic constituents and geochemistry of coals and ash chemistry related to inorganic constituents and mineral interactions and transformations during coal combustion and environmental control systems.

1980 – 1983 Research Chemist, U.S. Department of Energy (DOE) Grand Forks Energy Technology Center. Dr. Benson performed research on surface and/or chemical analysis and characterization of coal-derived materials by SEM, XRF, and thermal analysis in support of projects involving SO_x, NO_x, and particulate control; ash deposition; heavy metals in combustion systems; coal gasification; and fluidized-bed combustion.

1979 – 1980 Research Chemist, DOE Grand Forks Energy Technology Center. Dr. Benson performed research on the application of such techniques as differential thermal analysis, differential scanning calorimetry, thermogravimetric analysis, and energy-dispersive XRF analysis with application to low-rank coals and coal process-related material. In addition, research was performed on the use of x-ray analysis to measure trace elements in fuels and conversion products.

1977 – 1979 Chemist, DOE Grand Forks Energy Technology Center. Dr. Benson performed analysis on coal and coal derivatives by techniques such as wavelength-dispersive x-ray analysis, argon plasma spectrometry, atomic absorption spectrometry, thermal analysis, and elemental analysis (CHN).

1976 – 1977 Teaching Assistant, Department of Chemistry, Moorhead State University.

Awards

- Lignite Energy Council, Distinguished Service Award, Research & Development, 1997
- GEMS Award, College of Earth and Mineral Sciences, Pennsylvania State University, 2002
- Lignite Energy Council, Distinguished Service Award, Research & Development, 2003

Professional Memberships and Activities

► United States Senate Committee on the Environment and Public Works
- One of three technical panelists invited to provide testimony on mercury control for the coal-fired power industry.

► American Chemical Society (ACS)
- Member, Executive Committee, Fuel Division – 2005–present – Participates on the Executive Committee involved in the coordination and direction of division activities, including outreach, programming, finances, and publications.
- Chair, Fuel Division – 2004–2005 – Duties comprised coordinating all aspects of the division, including publications and national conferences.
- Fuel Division – Participates on the Executive Committee involved in the coordination and direction of division activities, including outreach, programming, finances, and publications.
- Councilor, Fuel Division – Represents the Fuel Division at the National ACS Council meeting.
- Chair Elect, Fuel Division – August 2002 – Elected to be Chair of the Fuel Division.
- Member, Committee on Environmental Improvement (CEI) – The committee provides advice and direction to the ACS governance on policies and programs related to the environment. Since becoming a member of the committee, we have developed policy

statements on Global Climate Change, Reformulated Gasoline and MtBE, and Energy Policy. These policy statements are used to assist legislators in developing national environmental policy. Members of CEI also provide testimony on a variety of environmental issues.

- ► American Society for Mechanical Engineers (ASME)
  - Advisory Member, ASME Committee on Corrosion and Deposition Resulting from Impurities in Gas Streams. Developed several conferences through the International Engineering Foundation.
- ► Mercury Reduction Initiative – Minnesota Pollution Control Agency (MPCA)
  - Participated in meetings for the mercury reduction initiative and provided advice regarding mercury control technologies for electric utilities and MPCA for voluntary mercury reduction strategies.
- ► Elsevier Science, *Fuel Processing Technology*
  - Editorial board member whose role is to provide advice and direction for the journal.

Publications and Presentations

- Has authored/coauthored over 210 publications and is the editor of eight books and *Fuel Processing Technology* special issues.

SCOTT G. TOLBERT
Research Manager
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
15 North 23rd Street, Stop 9018
Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5096, Fax: (701) 777-5181
E-Mail: stolbert@undeerc.org

Principal Areas of Interest and Expertise

Mr. Tolbert's principal area of expertise is in the design, construction, and operation of bench- and pilot-scale equipment for testing various fuel conversion and environmental control processes. He has worked on design and construction projects involving small-scale combustion and gasification systems as well as gas cleanup systems. He has worked on processes for sulfur control for gasification systems that have been focused on providing a clean gas stream for hydrogen production and utilization. His principal areas of interest and expertise include advanced multipollutant control and gas cleanup, hydrogen/CO_2 separation, hybrid electric vehicle drive systems, fuel cells, photovoltaics, and electrolyzer technologies.

Prior to coming to the EERC, Mr. Tolbert taught for eighteen years in UND's Department of Mechanical Engineering. Most of his work there dealt with teaching classes dealing with systems design, project management, and computer applications used in design, data acquisition, and control. Many of the additional positions identified below were extensions or overloads to his 9-month academic contract.

Qualifications

M.S., Industrial Technology, University of North Dakota, 1990
B.S., Industrial Technology, University of North Dakota, 1985

Professional Experience

2006 – Research Manager, EERC, UND, Grand Forks, North Dakota.

1990 – 2006 Assistant Professor, Department of Mechanical Engineering, UND, Grand Forks, North Dakota.

1992 – 2006 Consultant. Mr. Tolbert provided expertise on electrohydraulic machinery and ISO certifications to Toro Company Inc., Mayo Manufacturing Inc., and Hawkes Manufacturing Inc.

1998 – 2002 Assistant to the Dean, School of Engineering and Mines, UND, Grand Forks, North Dakota.

1997 – 2002 System Administrator, Computer-Aided Engineering Network, School of Engineering and Mines, UND, Grand Forks, North Dakota.

1988 – 1990 Instructor, Department of Mechanical Engineering, UND, Grand Forks, North Dakota.

Professional Memberships

- Steering Committee, Upper Midwest Hydrogen Initiative
- American Society for Engineering Education (ASSE)
- Engineering Design Graphics Division, ASEE
- Faculty Advisor, UND Society for Energy Alternatives
- UND Student Technology Fee Committee
- University Information Technology Council
- UND Academic Advising Committee
- UND Enrollment Management Summit Group

Publications and Presentations

- Has authored or coauthored several publications and presentations

JASON D. LAUMB
Research Manager
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000, Fax (701) 777-5181
E-Mail: jlaumb@undeerc.org

Principal Areas of Expertise
Mr. Laumb's principal areas of interest and expertise include biomass and fossil fuel conversion for energy production, with an emphasis on ash effects on system performance. He has experience with trace element emissions and control for fossil fuel combustion systems, with a particular emphasis on air pollution issues related to mercury and fine particulates. He also has experience in the design and fabrication of bench- and pilot-scale combustion equipment.

Qualifications
M.S., Chemical Engineering, University of North Dakota, 2000.
B.S., Chemistry, University of North Dakota, 1998.
Excel, FORTRAN, SPSS, PASCAL, C+, MAT Lab, and numerous word-processing programs.
SEM/EDS, XRD, UV/V is spectroscopy, IR spectroscopy, NMR, GC-MS, ICP/MS, and GC.

Professional Experience

2001 – Research Manager, EERC, UND. Mr. Laumb's responsibilities include supervising projects involving bench-scale combustion testing of various fuels and wastes; supervising a laboratory that performs bench-scale combustion and gasification testing; managerial and principal investigator duties for projects related to the inorganic composition of coal, coal ash formation, deposition of ash in conventional and advanced power systems, and mechanisms of trace metal transformations during coal or waste conversion; and writing proposals and reports applicable to energy and environmental research.

2000 – 2001 Research Engineer, EERC, UND. Mr. Laumb's responsibilities included aiding in the design of pilot-scale combustion equipment and writing computer programs that aid in the reduction of data, combustion calculations, and prediction of boiler performance. He was also involved in the analysis of current combustion control technology's ability to remove mercury and studying the suitability of biomass as boiler fuel.

1998 – 2000 SEM Applications Specialist, Microbeam Technologies, Inc., Grand Forks, North Dakota. Mr. Laumb's responsibilities included gaining experience in power system performance including conventional combustion and gasification systems; a knowledge of environmental control systems and energy conversion technologies; interpreting data to predict ash behavior and fuel performance; assisting in proposal writing to clients and government agencies such as NSF and DOE; preparing and analyzing coal, coal ash, corrosion products, and soil samples using SEM/EDS; and modifying and writing FORTRAN, C+ and Excel computer programs.

1998 – 2000 Graduate Teaching Assistant, UND. Mr. Laumb's responsibilities included transport phenomena and unit operations, administering and grading exams, grading homework, and answering student questions.

Professional Memberships

- American Chemical Society

Publications and Presentations

- Has coauthored numerous professional publications

JILL M. MACKENZIE
Financial Research Advisor
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000, Fax (701) 777-5181
E-Mail: jmackenzie@undeerc.org

Principal Areas of Expertise

Ms. Mackenzie's principal areas of interest and expertise include technical and financial management of projects and programs focused on solving energy-related problems in the areas of 1) biomass and fossil fuel combustion and gasification systems; 2) modeling of ash behavior, deposition, and system performance; and 3) development and testing of emission control technologies for separation, capture, and sequestration of air toxic substances as well as carbon dioxide emissions.

Qualifications

B.B.A., Economics, University of North Dakota, 1987.

Professional Experience

2006 – Financial Research Advisor, EERC, UND. Ms. Mackenzie is responsible for developing financial plans and technical management strategies for a complex array of projects and programs while teaming with highly specialized scientists and engineers in the areas of power plant performance, environmental control systems, the fate of pollutants, and computer modeling. She manages projects, provides guidance to other project managers and project teams to assure timely completion of project milestones and deliverables, and works with Senior Research Managers to facilitate the ability to meet emerging research opportunities and needs with strategic financial, personnel, and equipment planning. In addition, she provides financial leadership in the form of budget development, personnel planning, and resource allocation throughout project execution.

2003 – 2006 Research Associate, EERC, UND. Ms. Mackenzie's responsibilities included developing and managing projects to solve energy and emission challenges for the coal-fired power industry. Specific activities involve budget preparation for large projects involving testing at the EERC pilot-scale test facilities as well as full-scale coal-fired power plants; providing financial management of large projects by tracking project costs and projecting future expenditures to ensure that project milestones, reports, and deliverables are met; preparing and coordinating on-site project testing; performing data reduction and presentation of results; and writing proposals and project reports.

2001 – 2003 Research Specialist, EERC, UND. Ms. Mackenzie's responsibilities included interpretation of the chemical-related information impacting coal-fired power plant performance. A key aspect of her work is relating the chemical composition of high-temperature slag to physical properties such as viscosity and surface tension. In addition, she utilizes thermochemical equilibrium computer modeling, based on the minimization of Gibbs free energy, to determine the transformations of inorganic species into gases, liquids, and solids during combustion and gas cooling. She also writes proposals and reports applicable to energy and environmental research.

1998 – 2001 Contracts Officer, EERC, UND. Ms. Mackenzie's responsibilities included preparing, reviewing, negotiating, executing, and administering contract documents with local, national, and international clients providing funding for EERC research activities, as well as extensive use of Access database and Excel and Lotus spreadsheet applications to track research award activity and manager sponsor, project, and technical report data.

1989 – 1997 Office Manager, Dr. Greg M. Frokjer, Ltd., Grand Forks, North Dakota. Ms. Mackenzie's responsibilities included supervising office staff, administering organizational policies and procedures, implementing computer systems, training employees, designing office protocol, maintaining accounting reports, and producing production reports for budgeting and forecasting purposes.

1988 – 1989 Research Associate, Forecasting International, Ltd., Arlington, Virginia. Ms. Mackenzie's responsibilities included gathering data used to facilitate economic forecasting, analyzing current events and market forces to form future economic outlook for client companies, converting data into rough draft chapter form for ongoing book project, and using company database to write copy for magazine articles.

Professional Memberships

- American Chemical Society, Director of Preprint Subscriptions, Fuel Division, 2004 –
- UND Letterwinners Association Board of Directors 2004 –2007, President, 2007

Publications and Presentations

- Has coauthored several publications

APPENDIX B

LETTERS OF COMMITMENT

Minnkota Power
MPC COOPERATIVE, INC.
Your Touchstone Energy® Partner

1822 Mill Road • P.O. Box 13200 • Grand Forks, ND 58208-3200 • Phone (701) 795-4000

March 29, 2007

Mr. Steve Benson
Senior Research Manager
UND Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202

Subject: Letter of Interest and Financial Commitment for EERC Proposal No. 2007-0216 Entitled "Impacts of Lignite Properties on Powerspan's NO_x Oxidation System"

Dear Mr. Benson:

Minnkota Power Cooperative, Inc. (Minnkota) representing the MRY #3 Project, consisting of Basin Electric Power Cooperative, Minnesota Power, Montana-Dakota Utilities Co. and Minnkota, is pleased to participate in the proposed project entitled "Impacts of Lignite Properties on Powerspan's NO_x Oxidation System."

The development and field-testing of innovative and cost-effective technologies to address control of nitrogen oxide emissions from lignite-fired power plants is a critical need for the power industry. Powerspan's multi-pollutant control system called ECO® (Electro-Catalytic Oxidation) is designed to simultaneously remove SO_2, NO_x, $PM_{2.5}$, acid gases (such as hydrogen fluoride (HF), hydrochloric acid (HCl), and sulfur trioxide (SO_3)), Hg, and other metals from the flue gas of coal-fired power plants. In addition to the ECO technology, Powerspan is developing a cost-effective ammonia-based CO_2 removal process for coal-fired power plants called "ECO_2™." ECO_2 works in conjunction with Powerspan's ECO process to capture and recover CO_2 in flue gas for enhanced oil recovery or other forms of geological sequestration.

We feel that the testing conducted by Powerspan and the Energy & Environmental Research Center (EERC) will provide key information on the application of a multi-emissions control technology for North Dakota lignite. With the combined capabilities and experience of the proposed project execution team of Powerspan and EERC, we expect a successful project.

Minnkota is prepared to participate in the project by providing Milton R. Young Unit No. 1 coal-fired power plant as the host facility, as well as experienced and qualified personnel in the manner outlined in the proposal. This unit is uniquely suited for the proposed project as the pollution control system features a cold-side ESP. The unit fires North Dakota lignite, which at times can have significantly high sodium content. The site will be accessible to the project team for the term of the project, subject to reasonable and customary arrangements regarding site security and safety, and confidentiality.

Minnkota, representing the MRY #3 Project is pleased to offer support to the proposed program of $195,936 in-kind support of the project and $2,549 cash contribution as defined in the proposal. Of the in-kind support, $122,660 comprises the cash equivalent expenditures that will be for a Powerspan reactor, contract electrical and steel work, and materials. Our contribution will be comprised of nonfederal sources.

If you have questions please contact me at 701-795-4205.

Sincerely,

Luther Kvernen

Luther Kvernen
VP – Generation

Cc: Dave Schmitz (Basin)
Al Rudeck (Minnesota Power)
Andrea Stomberg (MDU)
Karen Thingelstad (Minnkota)

Minnkota On-Site Labor and Material Costs (Agreement with EERC)

Task	Description	Manpower	# hours	Labor Direct Rate (See Note 1)	Benefits & Payroll Taxes (? % of Direct Rate)	Labor & Benefits Rate/hr.	Cost	EERC Project # 2007-2016 Cost	Powerspan In-Kind Cost	MRY #3 Project Participant In Kind Cost	Minnkota In-Kind Cost
1	Minnkota Planning - Labor	MPC Project Supervision & Engineer	60	$41.71	$21.98	$65.00	$3,900.00	-		-	$3,900.00
		MPC Operations Department	0	$29.65	$15.63	$50.00	$0.00	-		-	-
		MPC Safety Department	0	$36.28	$19.12	$60.00	$0.00	-		-	-
2	Minnkota Preparation - Labor	MPC Project Supervision & Engineer	104	$41.71	$21.98	$65.00	$6,788.65	-		-	$6,788.65
		MPC Operations Department	0	$29.65	$15.63	$50.00	$0.00	-		-	-
		MPC Electrician	15	$32.68	$17.22	$50.00	$750.00	$750.00		-	-
		MPC Maintenance	5	$32.68	$17.22	$50.00	$250.00	$250.00		-	-
		MPC Safety Department	0	$36.28	$19.12	$60.00	$0.00	-		-	-
3	Minnkota Equipment Installation - Labor	MPC Project Supervision & Engineer	75	$41.71	$21.98	$65.00	$4,875.00	-		-	$4,875.00
		MPC Operations Department	0	$29.65	$15.63	$50.00	$0.00	-		-	-
		MPC Electrician	70	$32.68	$17.22	$50.00	$3,500.00	$3,500.00		-	-
		MPC Maintenance	40	$32.68	$17.22	$50.00	$2,000.00	$2,000.00		-	-
		MPC Lift Operator	40	$32.68	$17.22	$50.00	$2,000.00	$2,000.00		-	-
		MPC Safety Department	10	$36.28	$19.12	$60.00	$600.00	-		-	$600.00
4	Minnkota Testing - Labor	MPC Project Supervision & Engineer	40	$41.71	$21.98	$65.00	$2,600.00	-		-	$2,600.00
		MPC Operations Department	240	$29.65	$15.63	$50.00	$12,000.00	-		-	$12,000.00
		MPC Safety Department	25	$36.28	$19.12	$60.00	$1,500.00	-		-	$1,500.00
6	Purchased Material (shelters, construction items, structural steel, etc.)							$20,000.00		-	-
7	Contract Labor	Contract Electrician	80	$23.48	$30.89	$55.00	$4,400.00	$4,400.00		-	-
		Contract Iron Worker	240	$21.11	$28.89	$50.00	$12,000.00	$12,000.00		-	-
8	Contract Engineering	Structural Engineering					$4,500.00	$4,500.00		-	-
	Administrative Overhead (15% of Total Cost)							$7,410.00		-	$4,838.25
	Total							$56,810.00		-	$37,100.90
	TOTAL Minnkota On-Site Labor and Material Costs							$93,910.90			

MRY #3 Project Participant Mangement Costs (Basin, Minnkota, MDU, Minnesota Power)

	Description	Labor	Hours	Rate	Travel	Total	EERC Project # 2007-2016 Cost	Powerspan In-Kind Cost	MRY #3 Project Participant In Kind Cost	Minnkota In-Kind Cost
Project Participants										
Minnesota Power	Project oversight and operational input. Site visit, report review, and update conference calls.	$ 6,000	40	$ 150	$800.00	$6,800.00	-		$6,800.00	-
Basin Electric Cooperative		$ 3,000	20	$ 150	$100.00	$3,100.00	-		$3,100.00	-
Minnkota Electric Cooperative		$ 6,000	40	$ 150	$400.00	$6,400.00	-		$6,400.00	-
Montana Dakota Utilities		$ 3,000	20	$ 150	$100.00	$3,100.00	-		$3,100.00	-
Burns & McDonnell (MP Agreement)	Technical input and oversight.	$ 6,000	40	$ 150	$1,000.00	$7,000.00	$7,000.00			-
Total		$ 24,000			$2,400.00	$26,400.00	$7,000.00		$19,400.00	-
TOTAL MRY #3 Project Participant Management Costs							$26,400.00			

Powerspan Equipment and Fabrication Costs (Agreement with Minnkota)

	Cost	EERC Project # 2007-2016 Cost	Powerspan In-Kind Cost	MRY #3 Project Participant In Kind Cost	Minnkota In-Kind Cost
Materials					
Reactor	$ 17,625	$ 17,625		-	-
Power Supply	$ 5,500	$ 5,500		-	-
Instrument and Controls	$ 3,000	$ 3,000		-	-
Freight	$ 8,000	$ 8,000		-	-
Labor					
Design Engineering	$ 35,500	$ 35,500			
Fabrication	$ 6,000	$ 6,000			
Total	$ 75,625	$ 75,625		-	-
TOTAL Powerspan Equipment and Fabrication Costs		$75,625.00			

POWERSPAN®
Clean Energy Technology

March 30, 2007

Mr. Steve Benson
Senior Research Manager
UND Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202

Subject: Letter of Interest and Financial Commitment for EERC Proposal No. 2007-0216 Entitled "Impacts of Lignite Properties on Powerspan's NO_x Oxidation System"

Dear Mr. Benson:

Powerspan is pleased to participate in the proposed project entitled "Impacts of Lignite Properties on Powerspan's NO_x Oxidation System."

The development and field-testing of innovative and cost-effective technologies to address control of nitrogen oxide emissions from lignite-fired power plants is a critical need for the power industry. Powerspan's multi-pollutant control system called ECO® (Electro-Catalytic Oxidation) is designed to simultaneously remove SO_2, NO_x, $PM_{2.5}$, acid gases (such as hydrogen fluoride (HF), hydrochloric acid (HCl), and sulfur trioxide (SO_3)), Hg, and other metals from the flue gas of coal-fired power plants. In addition to the ECO technology, Powerspan is developing a cost-effective ammonia-based CO_2 removal process for coal-fired power plants called "ECO_2™." ECO_2 works in conjunction with Powerspan's ECO process to capture and recover CO_2 in flue gas for enhanced oil recovery or other forms of geological sequestration.

Powerspan is committed to conducting testing with the Milton R. Young #3 team (Minnkota Power Cooperative, Basin Electric, Montana Dakota Utilities Co., and Minnesota Power) and the Energy & Environmental Research Center (EERC). The proposed testing will provide critical data on the application of a multi-pollutant control technology for North Dakota lignite.

Powerspan is prepared to participate in the project by providing field support for the slipstream testing project. Additionally, Powerspan will conduct laboratory performance testing of the electrodes tested in the slipstream system at Milton R. Young #1 as well as provide experienced and qualified personnel to interpret test results. In addition, Powerspan will provide qualified personnel to review performance data from the slipstream system.

100 International Drive
Suite 200
Portsmouth, NH 03801
Tel: 603.570.3000
Fax: 603.570.3100
www.powerspan.com

The value of Powerspan's contribution to this project is presented in the attached budget, which includes $24,450 of reimbursable expenses for field support and $19,280 of in-kind contribution for laboratory testing and performance analysis. It is understood that the in-kind contribution will be applied to funding from the North Dakota Industrial Commission and are not derived from federal sources.

If you have any questions, please do not hesitate to contact me at +1 603.570.3023 or via e-mail at pboyle@powerspan.com.

Sincerely,

P Boyle

Phillip Boyle
President

Enclosure

cc: Luther Kvernen, Minnkota Power Cooperative

Powerspan Budget

Installation, Field Support and Laboratory Testing for Reactor Slipstream Testing to Evaluate the Impacts of High Sodium Lignite on Powerspan's ECO Reactor Electrodes

Category		Sub category	U/M	QTY	$/Unit	EERC Expense	Powerspan In-Kind Contribution
LABOR							
	SITE SUPPORT	2 persons x 4 trips	hr	120	$ 125	$ 15,000	
	LODGING	Meals and Lodging	day	15	$ 150	$ 2,250	
	TRAVEL	Air	trip	8	$ 900	$ 7,200	
	LAB TESTING	Electrode Performance Testing & Analysis					$ 19,280
						$ 24,450	$ 19,280