Energy & Environmental Research Center

MERCURY CONTROL TECHNOLOGIES FOR ELECTRIC UTILITIES BURNING LIGNITE COALS

EERC Proposal No. 2002-0061

Submitted to:

Ms. Karlene Fine

Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue Department 405
State Capitol
Bismarck, ND 58505-0840

Amount of Request: $150,000

Submitted by:

John H. Pavlish
Steven A. Benson
Michael J. Holmes

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

John H. Pavlish, Project Manager

Dr. William D. Gosnold Jr., Interim Director
Office of Research and Program Development

January 2002

TABLE OF CONTENTS

Continued . . .

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

MERCURY CONTROL TECHNOLOGIES FOR ELECTRIC UTILITIES BURNING LIGNITE COALS

ABSTRACT

Based on health, emissions, and scientific data, the U.S. Environmental Protection Agency and the Canadian Council of the Ministries of Environment have determined that Hg emitted from utility power plants should be reduced. U.S. and Canadian power plants burning lignite have shown higher elemental mercury (Hg^0) emissions than plants burning bituminous coals. This form of Hg is much more difficult to remove. North Dakota produces over 30 million tons of lignite annually, and thousands of tons of lignite are fired by North Dakota power plants daily. The Energy & Environmental Research Center (EERC) is proposing a 3-year, 2-phase consortium project to develop and demonstrate Hg control technologies for utilities that burn lignite coal. The overall intent is to help maintain the viability of lignite-fired energy production by providing the local utilities lower-cost options for meeting future Hg regulations. Phase I objectives are to better understand Hg interactions with flue gas constituents, test a range of technologies targeted at removal of Hg^0 from flue gases, and demonstrate the effectiveness of the most promising technologies at the pilot scale. The commitments received from North Dakota utilities, Saskatchewan Power, and Environment Canada show the importance of these objectives to the lignite-fired power industry.

Phase I work is proposed here. The Phase II field demonstration will be proposed following completion and evaluation of Phase I. Phase I funding requested from the North Dakota Industrial Commission is $150,000, with matching funds of $200,000 ($100,000 each) from Saskatchewan Power and Environment Canada, $25,000 cash and in-kind services from Luscar Ltd., $125,000 total from North Dakota utilities and EPRI, and $333,000 through the EERC–U.S. Department of Energy Jointly Sponsored Research Program, for a total of $833,000 for Phase I.

MERCURY CONTROL TECHNOLOGIES FOR ELECTRIC UTILITIES BURNING LIGNITE COALS

PROJECT SUMMARY

The Energy & Environmental Research Center (EERC) is proposing a practically oriented, applied research consortium project that will focus on developing cost-effective mercury control technologies for utilities burning lignite coals. Based on health, emissions, and scientific data, the U.S. Environmental Protection Agency (EPA) and the Canadian Council of the Ministries of Environment have determined that mercury from utility power plant emissions should be reduced. In the United States, mercury regulations are scheduled for promulgation by 2004, and full compliance is expected by 2007. Power plants in the United States and Canada burning lignite coals have demonstrated higher elemental mercury emissions (Hg^0) compared to plants burning bituminous coals. This form of mercury has proven to be much more difficult to remove than oxidized forms and will require an innovative approach.

The EERC is proposing a 3-year, 2-phase consortium project to develop cost-effective mercury control technologies for electric utilities burning lignite coals. Throughout this 3-year program, the EERC will develop, test, and demonstrate cost-effective sorbent-based technologies that can be used to reduce mercury emissions from plants burning lignite coal. The overall intent is to help maintain the viability of lignite-fired energy production by providing local utilities lower-cost options for meeting future mercury regulations. Phase I of this project is proposed here and will be 13 months in duration. Phase I objectives are to develop a better understanding of mercury interactions with flue gas constituents, test a range of sorbent-based technologies targeted at oxidation and removal of Hg^0 from power plant flue gases, and demonstrate the effectiveness of the most promising technologies to capture mercury at the pilot-scale. Phase II will be proposed at the end of Phase I. The Phase II

objective is to demonstrate and quantify the effectiveness, performance, and cost of the most promising technology from Phase I at a sponsor owned /operated power plant. Saskatchewan Power has expressed interest in hosting the Phase II demonstration at its Poplar River Power Plant and is willing to consider providing a major portion of the Phase II funding along with Environment Canada.

The Phase I approach is to work with the consortium members to identify the most promising options for mercury control in coal-fired power plants firing lignite coal. Sorbents identified from literature and through the input of consortium members will be evaluated in the EERC's bench-scale sorbent-screening system. Three to five of the most promising sorbents identified in these screening tests will then be further evaluated at the pilot scale. In addition to evaluating different sorbents, the pilot testing will serve to identify and demonstrate the impacts of sorbent preparation/size, sorbent feed rate, flue gas temperature, equipment configuration, and other key operating variables. At the end of Phase I demonstrations, the technology showing the most commercial potential will be selected for field demonstration (to be proposed as Phase II) based on pilot-scale results and input from the consortium.

PROJECT DESCRIPTION

Background

Mercury is an immediate concern for the U.S. electric power industry because of EPA's December 2000 decision that regulation of mercury from coal-fired electric utility steam-generating units is appropriate and necessary under Section 112 of the Clean Air Act. After extensive study, EPA determined that mercury emissions from power plants pose significant hazards to public health and must be reduced. The EPA *Mercury Study Report to Congress* (1997) (1) and the *Utility*

Hazardous Air Pollutant Report to Congress (1998) (2) both identified coal-fired boilers as the largest single category of atmospheric mercury emissions in the United States, accounting for about one-third of the total anthropogenic emissions. EPA is scheduled to propose regulations by December 2003 and promulgate them by December 2004, with full compliance expected by 2007. The exact form of regulation is uncertain at this time. While EPA is developing a regulation based on a maximum achievable control technology approach, Congress is discussing a multipollutant (SO_x, NO_x, and Hg) bill commonly referred to as the 3P approach. Under both approaches, mercury is expected to be reduced by 90% by 2010.

Similarly, Canada has established a consultative process to develop "Canadawide standards" for mercury emissions from coal-fired electricity generation. The process is to evaluate and discuss, in conjunction with a multistakeholder advisory group, options for achieving cost-effective reductions in mercury emissions. The intent is to have a draft standard for review by the Ministers of the Environment from all Canadian jurisdictions by June 2002. It is likely that this draft will undergo extensive public and government review and be finalized in early 2003. The most common discussion points for this standard are to achieve significant (>50%) emissions reductions by 2010, with a review in 2005 to address the emerging science in the United States and elsewhere on mercury control. The emissions reductions are likely to be achieved by controlling emissions based on coal mercury concentrations rather than directly from some baseline emissions rate. The question of controlling mercury emissions from lignite is particularly important in Canada, as about 30% of the mercury emitted from this sector in Canada is derived from Saskatchewan lignite.

Mercury Is a Health Concern

Mercury is a neurological toxin which can cause impairment of mental, sensory, and motor functions to humans, particularly to developing fetuses and children. A congressionally mandated reassessment of the toxicological effects of mercury issued by the U.S. National Research Council (3) in August 2000 reaffirmed EPA's low mercury exposure reference dose of 0.1 μg/kg per day as the scientifically justifiable level for the protection of childbearing women, based on quantifiable findings for low-dose exposure in a large study population in the Faroe Islands. Prompted by these health concerns, mercury is the chemical contaminant responsible, at least in part, for the issuance of approximately 2000 fish consumption advisories. Almost 68% of all advisories issued in the United States are a result of mercury contamination in fish and shellfish. Freshwater lake advisories have more than doubled in the last 5 years, resulting in over 40 states that have issued fish advisories because of mercury. Furthermore, the U.S. Food and Drug Administration recently issued an advisory limiting consumption of certain ocean fish. In the northern and eastern parts of Canada, extensive and stringent advisories against eating the fish are issued.

Mercury Emissions from Lignite Coals May Be Difficult to Control

In general, lignite coals contain comparable levels of mercury but significantly lower levels of chlorine compared to bituminous coals. Lignite coals are also distinguished by their much higher calcium contents. These differences in analysis have been shown to have important effects on the quantity and form of mercury emitted from a boiler and on the capabilities of different control technologies to remove mercury from flue gas. The high Cl content that is characteristic of many bituminous coals has consistently been shown to increase the fraction of the more easily removable oxidized form of mercury in the total mercury emission. Conversely, experimental results indicate that low-chlorine coals predominantly form Hg^0 which is substantially more difficult to remove than oxidzed/ionic mercury (Hg^{2+}). Additionally, the high Ca content generally found in lignite coal appears to further reduce the oxidizing effect of the already low Cl content by removing part of the Cl throughout the combustion process.

A few years ago, the EERC spearheaded a project that evaluated mercury emissions and potential controls for several North Dakota lignites. Results from this project confirm that most of the mercury is emitted in the elemental form. Additionally, two utilities (Ontario Power Generation and Saskatchewan Power Corporation [SaskPower]) in Canada that use lignite have performed tests which consistently show that mercury is emitted primarily in the elemental form. Changes in mercury speciation and removal measured across different pollution control devices have been correlated with fuel properties in two papers presented at the September 2000 Air Quality II Conference organized by the Center for Air Toxic Metals (CATM) at the EERC (4, 5). Mercury removals were consistently lower for low-chlorine coals. Based on limited data, test results show that certain sorbents[1] appear to have promise in controlling Hg^0 emissions. EPRI has also tested some sorbent-based technologies on a small slipstream that may have merit to demonstrate at a larger scale, such as a pilot-scale combustion system. In short, recent findings have indicated that several factors impact mercury control, which may provide new opportunities and options for control. However, these options are clearly in need of additional pilot-scale testing and full-scale demonstration before they can be widely applied.

Objectives

The EERC is proposing to build on these previous efforts by further developing, testing, and demonstrating effective sorbent-based technologies to control mercury emissions from power plants firing lignite coals. Specific objectives include:

[1] Throughout this proposal, the term "sorbent" is used to describe flue gas additives that oxidize elemental mercury to an ionic form and/or remove the mercury from the gas phase through adsorption or absorption mechanisms.

- Developing a better scientific understanding of mercury interactions with flue gas constituents which will lead to the development and demonstration of effective control technologies in lignite-fired systems.
- Testing a range of sorbent-based technology options that target oxidation and removal of Hg^0 from power plant flue gases.
- Demonstrating in pilot-scale facilities the ability of sorbent-based technologies to capture Hg.
- Selecting the most promising technology for Phase II demonstration and quantification of sorbent technology effectiveness, performance, and cost at a power plant owned/operated by SaskPower.

Approach

The proposed project will focus on testing and demonstration of effective sorbents for mercury control from electrical power plants firing lignite coals. Preliminary data from both laboratory and field tests indicate that both oxidation and removal can be achieved by injecting finely dispersed solid catalytic sorbents that can be removed in an electrostatic precipitator (ESP) or fabric filter (6–8). Sorbent preparation (i.e., grinding) and production to a small and narrow size range and good dispersion into the flue gas serve to promote a high level of diffusional mass transfer from the bulk flue gas to the particle surfaces. Competing reactions with the gas species commonly found in flue gas, including SO_2, NO_x, HCl, and water vapor, have been found to be immensely important and must be considered during sorbent performance tests (9–11). A combination of SO_2 and NO_2 (even small amounts) has been found to reduce the effective capacity of sorbents tested in a laboratory thin-bed reactor, apparently because of the possible formation and desorption of mercury nitrate hydrate. Several different avenues of research can be pursued to improve on mercury conversion and collection via sorbent technology by addressing improvements in dispersion and diffusion, surface chemistry of sorbent materials, sorbent utilization, optimization of operating conditions, and addition of sorbent contactor collectors.

Based on initial interest expressed by project sponsors, the work plan will focus primarily on the development, testing, and demonstration of sorbent injection technologies in combination with particulate removal devices (ESPs and fabric filters) for effective mercury removal. Phase I efforts will focus on bench- and pilot-scale testing to explore and identify sorbents, operating conditions, and combinations of particulate control devices which show promise for full-scale application. Phase II activities will focus on the demonstration of the most promising sorbent technology at a lignite-fired power plant owned/operated by SaskPower. The following provides a more detailed discussion of the scope of work proposed for Phase I of the project. The details of the test matrix are subject to change based on input from the consortium members. A general overview of the current plans for Phase II is also included. The current proposal is limited to the Phase I scope, and the Phase II effort will be formally proposed toward the end of Phase I.

Phase I – Testing and Demonstration of Sorbents at EERC Pilot-Scale Facility

Work under this phase will focus on selecting, screening, and prioritizing appropriate sorbent-based technology options and, as needed, further developing a scientific understanding of mercury interactions with flue gas components that will guide implementation and application of the technology at a large power plant. Activities will focus on selection and screening of various sorbents under varying operating conditions in combination with an ESP and fabric filter.

At the start of Phase I, a meeting will be held with all project participants to discuss and select which sorbents offer the most potential for mercury removal. The availability of suitable sorbent materials for lignite applications will be a key consideration. Other issues related to technology maturity, performance, cost, and implementation will also be considered.

Sorbent screening will be performed in the EERC Mercury Research Laboratory (MRL) at the bench scale. A thin-film fixed-bed reactor will be used for a portion of the tests, and an entrained-flow reactor will be used for the remaining tests. The fixed-bed system provides information relating to sorbent capacity and applicability to a range of flue gas conditions. The entrained-flow reactor provides a means of testing sorbent reactivity by controlling the in-flight contact time while minimizing sampling effects. An ESP module will be used to remove the sorbent and fly ash particles without exposing the gas to a fixed bed containing these solids.

Approximately 30 tests will be completed to screen different sorbents, sorbent enhancements/modifications, gas species interactions, oxidation potential, and gas temperature impacts. Results from previous flue gas characterizations at lignite-fired power plants will be evaluated to determine the simulated flue gas composition for bench-scale testing. These initial screening measurements will evaluate mercury capture effectiveness, oxidation potential, and capacity for the selected sorbents. If feasible, new sorbents will be formulated based on test results and newly acquired scientific findings and understanding. For example, it is expected that activated carbons produced from North Dakota and/or Saskatchewan lignites will be among the candidate sorbents. Bench-scale test results will be used to provide a relative ranking of the sorbents as a primary input to help downselect to the most promising (three to five) sorbents for pilot-scale evaluations. The most promising sorbents will be tested in the EERC pilot-scale combustor under varying conditions and particulate control device arrangements. Operating conditions will be discussed and decided upon by all project sponsors.

Key parameters will be evaluated using the EERC pilot-scale particulate test combustor (PTC). Table 1 provides an initial test matrix for Phase I PTC testing, including the variables likely to be evaluated. Note that the matrix represents preliminary plans for testing, and the details may change as a result of feedback from the consortium and based on results from the bench-scale sorbent screening.

Table 1. Preliminary Test Matrix for PTC Testing

Test	Coal	Sorbent	Temperature (F)	Particulate Control	Sorbent Size	Sorbent Ratio
Baseline (T1)	Canada Coal 1 (C1)	Sorbent 1 (S1)	300	ESP	As Rec'd	10,000
Test 2 (T2)	C1	S1	400	ESP	As Rec'd	10,000
T3	C1	S1	300	ESP	Fine	10,000
T4*	C1	S1	300	ESP	Fine	5,000
T5	C1	S1	300	Baghouse	As Rec'd	10,000
T6	C1	S1	400	Baghouse	As Rec'd	10,000
T7	C1	S1	300	Baghouse	Fine	10,000
T8*	C1	S1	300	Baghouse	Fine	5,000
T9-28	C1	S2 – S4	Repeat Critical Parameters for Remaining Three Sorbents			
Downselect to Two Sorbents						
T29 – 40	US Coal C2	Best 2	Repeat Critical Parameters for Coal 2			

* Use the entrained-flow reactor test module.

As can be seen in Table 1, the preliminary plans for PTC testing include variation of multiple test parameters. Some of the key parameters to be considered include the following:

- Two lignite coals, one from North Dakota and one that SaskPower burns. Final selection of the lignite coals will be based on project sponsorship and decided on by project sponsors during discussions at the project kickoff meeting.

- Capture of mercury using an ESP, with and without sorbent. Performance for sorbent injection coupled with an ESP may be limited. Thus only a minimum number of tests will be performed.
- Capture of mercury using a fabric filter, with and without sorbent.
- Capture of mercury using an ESP followed by a polishing fabric filter, with and without sorbent. SaskPower has indicated that this is its preference, although other options may have some merit.
- Capture of mercury using an ESP followed by an advanced hybrid particulate collector.
- Evaluation of up to five sorbents (activated carbon, lignite-derived carbons, calcium silicates, etc.) either injected upstream of an ESP or fabric filter. Consideration will be given to commercially available sorbents and other potential sorbents available in the United States and Canada. In all cases, attention will be given to sorbent size, which may require special preparation.
- Consideration of pressure drop and cleaning cycle.
- Evaluation of flue gas temperature impact in the range of 250°–400°F.
- Leaching tests on sorbents and fly ash to determine mercury stability. Although recent experimental data suggest that mercury is rather stable once captured and collected along with the fly ash, additional tests are warranted for lignite ashes for which few data exist. Additionally, by using a polishing particulate control device, the mercury will likely be concentrated and may have a tendency to leach. Analyses proposed here are simply to answer this question and are not intended for in-depth investigation.

A more detailed test matrix will be developed based on discussion and input from the project sponsors. The proposed Phase I effort includes approximately 5 weeks of pilot-scale testing in the

PTC, including roughly 40 tests to cover a range of sorbents, process configurations, and operating conditions. Details of the test matrix will consider inputs from the consortium members and bench-scale test results.

Data generated from pilot-scale tests will be reduced, interpreted, and reported in a Phase I summary report. Phase I results will be presented and used to guide activities and decisions related to Phase II. In addition to the Phase I summary report, quarterly reports will be issued to update the consortium members on the project results, and review meetings will be held to present data and solicit feedback.

Phase II – Demonstration of Sorbent-Based Technology at Saskatchewan Power Plant

Results produced under Phase I will be used to guide the design and application of the most promising technology identified for Phase II demonstration. Currently, it is envisioned that a sorbent in combination with a polishing fabric filter may prove to be the most promising approach. Under this assumption, Phase II activities will proceed with the demonstration of a select sorbent that will be injected upstream of a newly installed fabric filter. SaskPower has indicated that it is willing to provide a host site for this demonstration. The Poplar River Station in south central Saskatchewan is the proposed site for Phase II activities. Additionally, SaskPower along with some of the Canadian regulatory agencies will consider providing funding to cost share the installation of the necessary equipment identified under Phase I to fully assess the effectiveness of the most promising sorbent technology. Assuming that Poplar River is the site, a potential demonstration project could involve the installation of a sorbent injection system along with a polishing fabric filter designed and sized to treat one-fourth to one-half of the flue gas from one of the two units. Activities under this phase will include design, construction, and testing (short- and long-term) to fully assess and demonstrate the technology for mercury capture effectiveness.

Facilities and Capabilities

The EERC has the trained personnel, analytical facilities, and laboratory and field testing equipment needed to support this project, including analytical equipment, continuous mercury monitors (CMMs), and a full-range of bench- and pilot-scale systems. No equipment purchases are anticipated.

Mercury Research Laboratory

The MRL specializes in bench-scale systems studying Hg, SO_x/NO_x, catalysts, and capabilities for other similar work (Figure 1). Two bench-scale systems capable of simulating flue gas conditions, such as temperature, particulate loadings, air-to-cloth ratios, and different gas concentrations (e.g., SO_2, O_2, CO, CO_2), are used for varied experimentation.

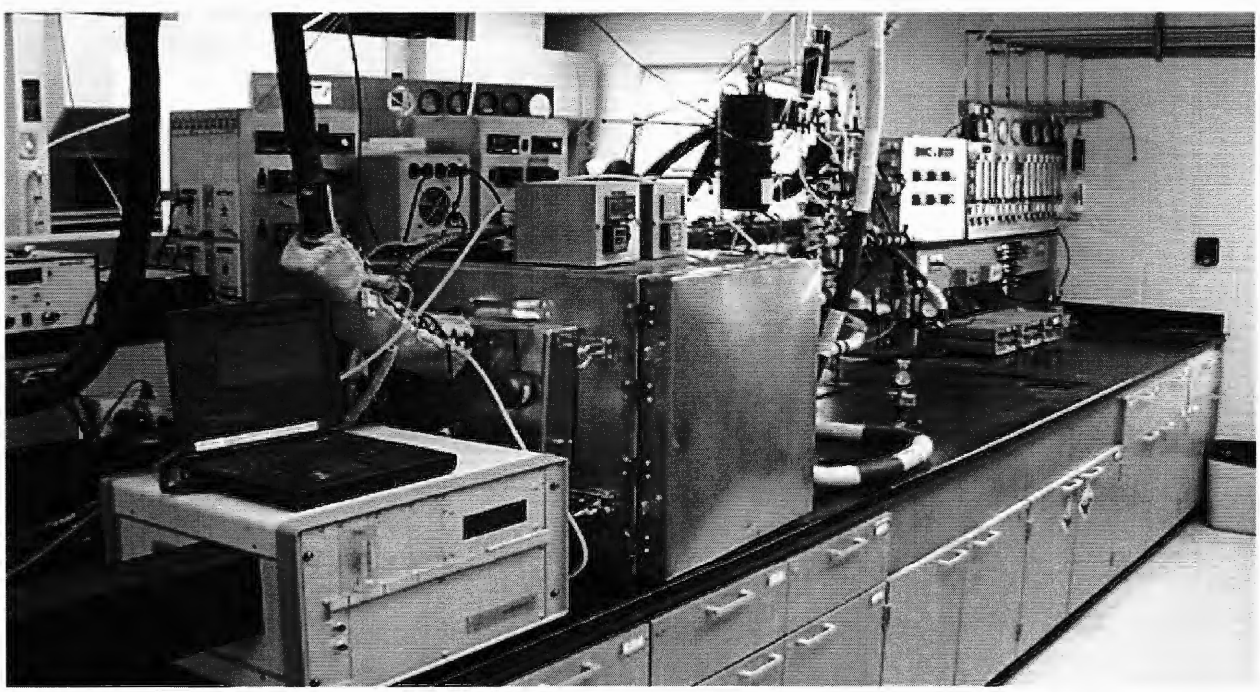

Figure 1. EERC Mercury Research Laboratory.

The EERC has numerous analyzers (listed below) and is experienced with many sampling and analytical standards and methods.

Analyzers

- Two Semtech mercury analyzers
- EPM mercury analyzer
- Three Sir Galahad mercury analyzers
- BIOS gas flow calibrator
- Gilibrator gas flow calibrator
- Porter mass flow controllers
- Three portable ECOM gas analyzers
- Bench-scale test cells
- TSI Tris-Jet aerosol generator
- TSI aerodynamic particle sizer
- TSI condensation particle counter
- Three Tekran mercury analyzers

Sampling Methods

- Method 5 – Determination of Particulate Emissions from Stationary Sources
- Modified Method 5 – Determination of Volatile Organic Compounds from Stationary Sources
- Method 6 – Determination of Sulfur Dioxide Emissions from Stationary Sources
- Method 8 – Determination of Sulfuric Acid Mist and Sulfur Dioxide Emissions from Stationary Sources
- Method 13 – Determination of Total Fluoride Emissions from Stationary Sources
- Method 17 – Determination of Particulate Emissions from Stationary Sources (in-stack filtration method)
- Method 23 – Determination of Halogenated Organics from Stationary Sources
- Method 26 – Determination of Hydrogen Chloride Emissions from Stationary Sources
- Method 29 – Determination of Metals Emissions in Exhaust Gases from Hazardous Waste Incineration and Similar Combustion Processes (Sb, As, Ba, Be, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Se, Ag, Tl, and Zn)

- Tris-buffer method
- Ontario Hydro method
- Other mercury-sampling methods that are not yet recognized or validated by EPA, including the Research Triangle Institute method and dry Ontario Hydro method
- Method 101A – Determination of Mercury from Stationary Sources
- Ammonia sampling to determine the amount of ammonia in a sample from a stationary source
- Rader sampler for high-volume particle collection

Bench-Scale Testing Services

- Ash resistivity to determine the resistivity of fly ash
- Particle characteristics to help determine collection efficiencies
- Mercury and other trace elements
- Particle reentrainment
- Screening of potential sorbents and/or filter materials
- Evaluation of SO_x/NO_x impacts
- Evaluation of ammonia impacts
- Catalyst evaluations
- Ash and particle characteristics testing, including cohesion measurements

Pilot-Scale Combustion Facilities – Particulate Test Combustor

The PTC is a 550,000-Btu/hr pulverized coal-fired unit designed to generate fly ash and flue gas chemistry representative of that produced in a full-scale utility boiler (Figure 2). Coal is introduced to the primary airstream via a screw feeder and ejector. An electric air preheater is used for precise control of the combustion air temperature. The PTC instrumentation permits system

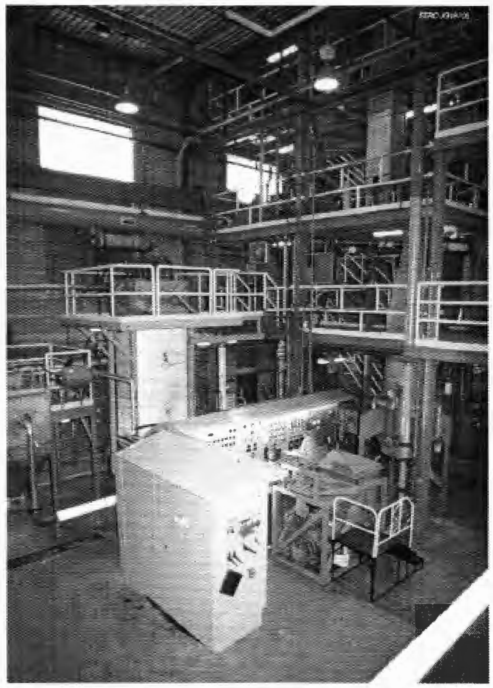

Figure 2. Particulate test combustor with electrostatic precipitator and baghouse.

temperatures, pressures, flow rates, flue gas constituent concentrations, and baghouse or ESP operating data to be monitored continuously and recorded on a data logger.

The PTC is designed to operate in conjunction with either a fabric filter or ESP. The baghouse vessel is a 20-in.-i.d. chamber that is heat-traced and insulated, with the flue gas introduced near the bottom. Since the combustor produces about 200 acfm of flue gas at 300°F, three 13-ft by 5-in. bags provide an air-to-cloth ratio of 4 ft/min. Each bag is cleaned separately with its own diaphragm pulse valve. In order to quantify differences in pressure drop for different test conditions, the bags are cleaned on a time basis, rather than with the cleaning cycle initiated by pressure drop. Once bag cleaning is initiated, all three bags are pulsed in rapid succession on-line.

Instead of directing the flue gas through a fabric filter, a single-wire, tubular ESP can be used in its place. The ESP is designed to provide a specific collection area of 125 ft^2 of area/1000 acfm at 300°F. Since the flue gas flow rate for the PTC is 130 scfm, the gas velocity through the ESP is

5 ft/min. The plate spacing for the unit is 11 in. The ESP has an electrically isolated plate that is grounded through an ammeter, allowing continual monitoring of the actual plate current to ensure consistent operation of the ESP from test to test. The tubular plate is suspended by a load cell which helps to monitor rapping efficiency. In addition, sight ports are located at the top of the ESP to allow for on-line inspection of electrode alignment, sparking, rapping, and dust buildup on the plate. The ESP was designed to facilitate thorough cleaning between tests so that all tests can begin on the same basis.

Field Sampling Capabilities

The EERC has two fully equipped trailers that have been used for sampling activities at numerous power plants. These trailers house all the equipment necessary to perform a number of EPA methods, including EPA Methods 5 and 17 for particulate sampling. This includes sampling boxes, probes, weighing scales, filters, filter holders, and any railings that may be necessary. However, what makes EERC field sampling capabilities unique is the ability to do mercury analysis in the field. In doing so, the EERC maintains an exceptionally high level of quality control and quality assurance. Because the mercury blank and spike results are obtained in the field (usually within 4–6 hours), any problems can be corrected immediately. If the samples are sent to a laboratory for analysis, the results are not known until after the sampling team has left the facility. To do the mercury analysis in the field, the EERC trailer is equipped with a Leeman cold-vapor atomic adsorption spectrophotometer and a DMA-80 analyzer (Milestone, Inc). The DMA-80 allows the EERC to do coal and ash mercury analysis in the field. This technique was recently validated as EPA Method 7473, entitled "Mercury in Solids and Solutions by Thermal Decomposition Amalgamation and Atomic Absorption Spectrophotometry."

In addition to the equipment necessary to perform mercury wet-chemistry sampling procedures, the EERC also has three different types of CMMs:

- Two Semtech mercury 2010s
- Three PS Analytical Sir Galahads
- Three Tekrans

The EERC has used these monitors successfully to directly measure stack emissions in all the field sampling done for the past 3 years.

STANDARDS OF SUCCESS

The standards of success for Phase I of this project will be measured through successful pilot-scale demonstration of one or more mercury control options for lignite-fired power plants. The mercury control technologies need to demonstrate technical viability and the potential for economic viability based on process arrangement, conditions, and sorbent requirements. The technical standards of success will be measured by the ability of the selected technologies to effectively reduce mercury emissions by at least 50%, with minimal modifications to existing plant equipment. The economic standards of success will be based on the technologies' ability to reduce mercury emission for less than $20,000/lb-Hg removed based on sorbent equipment requirements, utilization rates, and required plant modifications. Earmarks by EPA range from $5000–$25,000/lb-Hg removed, and DOE estimates are from $25,000–$70,000/lb-Hg. The technology demonstrating the best technical and economical merits under Phase I will be selected and proposed for large-scale field demonstration at the host utility in Phase II.

BACKGROUND

The EERC has been a leader in mercury research for several years and is viewed as an expert in the field. Additionally, the EERC has over 50 years of experience with low-rank coals and has a track record as a leading research, development, demonstration, and commercialization organization. In recent years, EERC researchers have been in the forefront of advancing the understanding of mercury chemistry, measurement, transformations, solid–gas interactions, and development of control technologies. Progress has been made in developing sorbents that will remove mercury from plants firing low-rank coals, but many challenges still remain. Some sorbents have improperly been tested and reported in peer-reviewed literature by others to be effective at capturing Hg^0 in tests performed on bench-scale systems using simple simulated gas mixtures or, in some cases, just nitrogen. EERC research has shown that tests performed without the full complement of gas species in the coal combustion flue gas lead to false conclusions about sorbent effectiveness and application. Fly ash properties and flue gas constituents such as nitrogen oxides, sulfur dioxide, chlorine (Cl_2 and HCl), and water vapor all play a critical role in the ability of a sorbent (or ash) to capture Hg^0. The EERC has tested various gold-coated materials, carbon-based sorbents, sulfides, and metal oxide sorbents that show promise in controlling Hg^0 in combustion flue gases. Additionally, the EERC has tested unique materials and conditioned fabrics that preliminarily show oxidizing promise.

QUALIFICATIONS

The project will be managed by Mr. John Pavlish, with assistance from Mr. Mike Holmes and Dr. Steve Benson. Mr. Pavlish has managed numerous federal and commercial projects involving mercury research and control and is the Director of Center for Air Toxic Metals, a multiyear, multimillion-dollar program at the EERC. Mr. Pavlish's primary duties will be to oversee all activities within the project and ensure that all project objectives and milestones are met.

Mr. Holmes is an expert in the field of mercury and flue gas emissions control. He has managed numerous projects involving sorbent testing and development for mercury control as well as duct injection, dry scrubbing, and wet scrubbing projects for the control of mercury and SO_2 emissions. Mr. Holmes' primary duties for the project will be to oversee and coordinate all day-to-day activities related to pilot- and full-scale testing and demonstration.

Dr. Benson is an expert in the field of fuel conversion, ash behavior issues, and the fate and formation of toxic trace elements. Dr. Benson previously served as director of CATM and is very knowledgeable on mercury issues. His primary duties to the project will be to oversee and lead the technology development efforts, with an emphasis on fundamental research that will lead to design of effective control technologies.

Detailed resumes are attached in Appendix A.

VALUE TO NORTH DAKOTA

The project will focus on developing effective mercury control sorbent technologies for conventional power plants firing lignite coals equipped with ESPs, fabric filters, scrubbers, and with and without low-NO_x burners. It is anticipated that key information will be delivered to consortium members throughout the duration of the project, with all results and deliverables transferred to project sponsors by the end of the project. Key deliverables that will be realized by participants include:

- Information on mechanisms of mercury transformations and interactions with fly ash, flue gas components, sorbents, and oxidizing catalysts.

- Results on mercury emissions and reduction potential for various sorbent-based control technology options that are directly applicable to program participants.
- Performance and cost data to assist in developing an overall compliance strategy. Data available will be directly applicable to coals and plants that are part of this project.
- Collaborative research and interaction between stakeholders with an interest in developing cost-effective control technologies.
- Immediate access to comprehensive reports.
- Access to presentations and peer-reviewed technical journal articles prior to publication. The project team will be involved in authoring or coauthoring publications.
- Demonstration of the technology at a power plant (Phase II). Data generated from demonstration will provide invaluable insight into technology applicability. Overall effectiveness of the technology will be quantified as well as limitations and/or problems of implementation. This demonstration will be proposed as Phase II at the end of Phase I of the project.

In North Dakota, over 18,000 jobs, $1.3 billion in business volume, and $60 million in tax revenue are generated by the lignite industry each year. North Dakota produces over 30 million tons of lignite annually, and thousands of tons of lignite are fired by North Dakota power plants daily (12). North Dakota's economy depends on lignite production and use. Determining cost-effective technologies that will increase its efficient and environmentally safe use will, ultimately, lead to the demand for greater production. Preliminary data also suggest that activated carbon produced from high-sodium North Dakota lignite may be an effective sorbent for mercury control for a utility market reaching across the United States and Canada. Increased lignite production and use in North Dakota will result in more jobs in all lignite-related industries in the state.

MANAGEMENT

The proposed project is organized as a consortium; therefore, each participant will have equitable input into the direction and access to the deliverables of the project. Regular meetings will be held to share information, facilitate communication among all project participants, and guide project decisions. The project will be executed by the EERC, with project management responsibilities under Mr. John Pavlish. Mr. Pavlish will receive technical support as well as assistance in management of the project tasks from Mr. Mike Holmes and Dr. Steve Benson. Figure 3 provides an overview of the project management plan.

TIMETABLE

The project is scheduled for a 2 ½- to 3-year period, with specific milestones to be developed after the initial meeting with all project sponsors. Phase I activities proposed here will be completed within 13 months. Phase II activities are expected to be completed within 1½ to 2 years, with

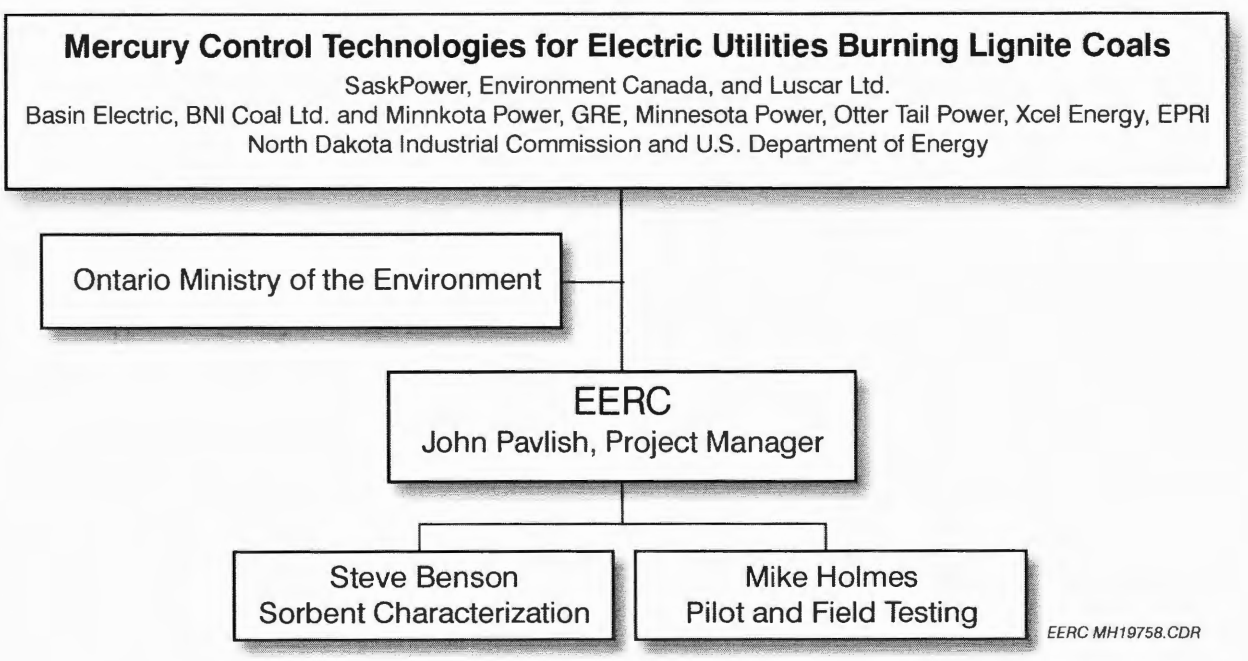

Figure 3. Project management overview.

construction activities completed within 12 to 18 months and demonstration tests completed in the following 6 to 9 months. Figure 4 provides the project schedule with primary Phase I milestones. The Phase II timetable assumes 2 years are required for completion, but the actual schedule may be shorter, depending on the Phase I results. Key results will be delivered to project sponsors throughout the duration of the project via planning and review meetings, quarterly reports, and a final report documenting the Phase I results.

BUDGET

Approximate costs for the project by phase are listed in Table 2. The estimated cost for Phase I is based on the test parameters discussed earlier. Phase II costs cannot be further refined at this time, as the specifics of Phase II activities are dependent upon the results from Phase I. Phase II work will be proposed upon completion and evaluation of Phase I work. Since this project is proposed as a multiphase project, it is presumed that all sponsors are willing to participate in and provide funding to support activities for both phases, assuming favorable review of the Phase I results. A detailed budget is attached to this proposal.

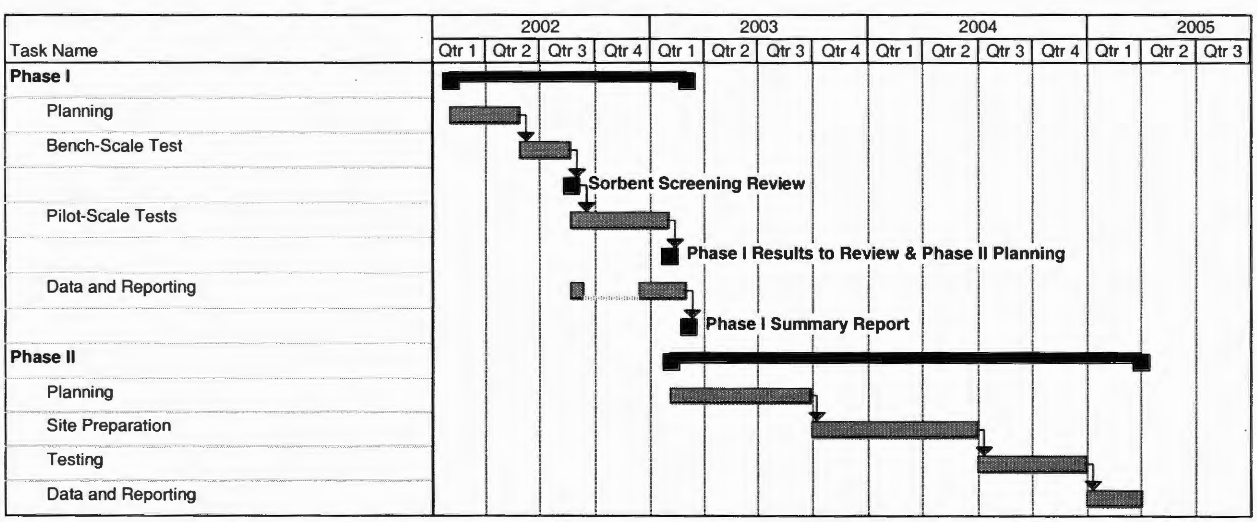

Figure 4. Project schedule.

Table 2. Project Costs by Task

Phase	Phase Name	Cost
I	Development and Testing of Sorbents at EERC Pilot-Scale Facility	$833,000
II	Demonstration of Sorbent Technology at SaskPower Plant	$1,500,000 - to - $5,000,000

MATCHING FUNDS

Phase I funding requested from the North Dakota Industrial Commission (NDIC) is $150,000, with matching funds consisting of $200,000 ($100,000 each) from SaskPower and Environment Canada, $25,000 cash and in-kind services from Luscar Ltd., $125,000 total from North Dakota utilities and EPRI, and $333,000 through the EERC–DOE Jointly Sponsored Research Program (JSRP), for a total of $833,000 for Phase I.

Again, the details of Phase II will be worked out based on consideration of Phase I results, input from consortium members, and SaskPower facility requirements for the host site. A possible funding scenario for Phase II is provided here for discussion purposes and includes approximately $2–$4 million from SaskPower and Environment Canada, $200,000 from NDIC, $100,000 from North Dakota utilities and EPRI, and approximately $350,000 through the EERC–DOE JSRP. Approximately 75% of the funds would go toward design, construction, and related demonstration activities. The remaining 25% would go to support short- and long-term sampling, monitoring, testing, and technology verification activities.

A majority of the required matching funds identified above are already committed. Letters of commitment are included in Appendix B for Environment Canada, SaskPower, and three of the North Dakota utilities. Luscar Ltd. is reviewing the opportunity to join the consortium with its upperlevel management, but has expressed considerable interest. EPRI and the remaining utilities have already committed $35,000 to this project, and additional funding is being considered.

Three items are required from NDIC for inclusion in our proposal to DOE:

- A formal commitment to the project. This can be a letter of commitment, a purchase order, or a signed contract.
- A biographical sketch or resume for the NDIC project manager and/or key technical contributor.
- A short overview of NDIC.

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.

REFERENCES

1. U.S. Environmental Protection Agency. *Mercury Study Report to Congress Volume I: Executive Summary*; EPA-452/R-97-003; Office of Air Quality Planning and Standards and Office of Research and Development: Dec 1997.
2. U.S. Environmental Protection Agency. *Utility Hazardous Air Pollutant Report to Congress*; Office of Air Quality Planning and Standards and Office of Research and Development: Feb 1998.
3. National Research Council. *Toxicological Effects of Methylmercury*; Report for U.S. Environmental Protection Agency; National Academy Press: Washington, DC, Aug 2000.

4. Chu, P.; Goodman, N.; Behrens, G.; Roberson, R. Total and Speciated Mercury Emissions from U.S. Coal-Fired Power Plants. In *Proceedings of the Air Quality II: Mercury, Trace Elements, and Particulate Matter Conference*; McLean, VA, Sept 19–21, 2000.

5. Senior, C.; Helble, J.; Mamani-Paco, R.; Sarofim, A. Predicting the Speciation of Mercury Emissions from Coal-Fired Power Plants. In *Proceedings of the Air Quality II: Mercury, Trace Elements, and Particulate Matter Conference*; McLean, VA, Sept 19–21, 2000.

6. Miller, S.J.; Laudal, D.L.; Dunham, G.E.; Chang, R.; Bergman, P.D. Pilot-Scale Investigation of Mercury Control in Baghouses. Presented at the EPRI/DOE International Conference on Managing Hazardous and Particulate Air Pollutants, Toronto, Ontario, Canada, Aug 15–18, 1995.

7. Miller, S.J.; Dunham, G.E.; Olson, E.S.; Brown, T.D. Flue Gas Effects on a Carbon-Based Mercury Sorbent. *Fuel Process. Technol.* **2000**, *65–66*, 343–363.

8. Miller, S.J.; Olderbak, M.R.; Zhuang, Y. *Advanced Hybrid Particulate Collector*; Final Technical Report, Phase I and II, for U.S. Department of Energy Contract No. DE-AC22-95PC95258; Energy & Environmental Research Center: Grand Forks, ND, Dec 2000.

9. Miller, S.J.; Dunham, G.E.; Olson, E.S. Controlling Mechanisms That Determine Mercury Sorbent Effectiveness. Presented at the 92nd Air & Waste Management Association Annual Meeting, St. Louis, MO, June 20–24, 1999; Paper No. 99-898.

10. Dunham, G.E.; Olson, E.S.; Miller, S.J. Impact of Flue Gas Constituents on Carbon Sorbents. Presented at the Air Quality II: Mercury Trace Elements, and Particulate Matter, McLean, VA, Sept 19–21, 2000.

11. Dunham, G.E.; Miller, S.J.; Brown, T.D. Effects of Oxygen, Moisture, and Acid Gases on Mercury Capture with Carbon Sorbents. Presented at the Air & Waste Management Association Mercury in the Environment Speciality Conference, Minneapolis, MN, Sept 15–17, 1999.

12. Lignite Energy Council. www.lignite.com (accessed Dec 2001).

BUDGET

MERCURY CONTROL TECHNOLOGIES FOR ELECTRIC UTILITIES BURNING LIGNITE COALS
NDIC/SASK POWER/ENVIRONMENT CANADA/UTILITIES CONSORTIUM/DEPARTMENT OF ENERGY
PROPOSED START DATE: 02/01/2002
EERC PROPOSAL #2002-0061

		TOTAL		NDIC SHARE		SASK POWER SHARE		ENVIRON CAN SHARE		UTILITIES SHARE		EERC JSRP SHARE	
CATEGORY		**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**
TOTAL DIRECT LABOR		8,711	$ 255,270	1,541	$ 45,165	1,028	$ 30,122	1,028	$ 30,122	1,541	$ 45,165	3,573	$ 104,696
FRINGE BENEFITS - % OF DIRECT LABOR	55%		$ 140,398		$ 24,841		$ 16,567		$ 16,567		$ 24,841		$ 57,582
TOTAL LABOR			$ 395,668		$ 70,006		$ 46,689		$ 46,689		$ 70,006		$ 162,278
OTHER DIRECT COSTS													
TRAVEL			$ 10,155		$ 5,758		$ 2,895		$ -		$ -		$ 1,502
COMMUNICATION - PHONES & POSTAGE			$ 2,226		$ 394		$ 263		$ 263		$ 393		$ 913
OFFICE (PROJECT SPECIFIC SUPPLIES)			$ 3,710		$ 656		$ 438		$ 438		$ 657		$ 1,521
REPAIRS			$ 750		$ 133		$ 88		$ 88		$ 134		$ 307
SUPPLIES			$ 4,000		$ 750		$ 500		$ 500		$ 610		$ 1,640
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$ 4,505		$ 800		$ 534		$ 534		$ 809		$ 1,828
FEES			$ 131,743		$ 18,905		$ 13,528		$ 16,423		$ 24,794		$ 58,093
TOTAL OTHER DIRECT COST			$ 157,089		$ 27,396		$ 18,246		$ 18,246		$ 27,397		$ 65,804
TOTAL DIRECT COST			$ 552,757		$ 97,402		$ 64,935		$ 64,935		$ 97,403		$ 228,082
FACILITIES & ADMIN. RATE - % OF MTDC		VAR	$ 280,243	54%	$ 52,598	54%	$ 35,065	54%	$ 35,065	54%	$ 52,597	46%	$ 104,918
TOTAL ESTIMATED COST - US DOLLARS			$ 833,000		$ 150,000		$ 100,000		$ 100,000		$ 150,000		$ 333,000

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. 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. Financial reporting will be at the total project level.

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.

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 include estimated 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 and analytical fees are established and approved at the beginning of each fiscal year, and charges are based on a per sample or hourly rate depending on the analytical services performed. Additionally, laboratory analyses may be performed outside the University when necessary.

Graphics services 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, 1995. 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[1] and subcontracts/subgrants in excess of the first $25,000 of each award.

---

[1] The equipment threshold is stated at $5000 in anticipation of the pending Facilities and Administrative Cost Rate Agreement. The proposal has been submitted to the Department of Health and Human Services with a stated effective date of July 1, 2001.