UND ENERGY & ENVIRONMENTAL RESEARCH CENTER
PROPOSAL RECORD AND INTERNAL SIGNATURE FORM

PROPOSAL NO.: 2005-0079

AGENCY OR RFP DUE DATE: 10-1-2004

DATE SUBMITTED: 10-1-2004

TITLE: Center for Air Toxic Metals® Affiliates Program – 3-Year Continuation of Membership

PROJECT MANAGER: John H. Pavlish

AUTHOR AND KEY TECHNICAL CONTRIBUTORS: Lucinda L. Hamre, John H. Pavlish, Steven A. Benson, Christopher J. Zygarlicke, Kevin C. Galbreath, and Michael J. Holmes

CLIENT/ADDRESS:
Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

PROPOSED EFFECT DATE: From: 1-1-2005 To: 12-31-2007

TOTAL FUNDS REQUESTED: $45,000 **F & A COSTS REQUESTED**: $NA

OPTIONS: One year membership at $18,000

Does this project require a completed lobbying disclosure? __Yes _X_ No (for Federal projects only)

Will the project involve a confidentiality agreement or proprietary information? __Yes _X_ No

Does this proposal contain confidential information? __Yes _X_ No

Is this proposal competitive? _X_ Yes __No __Unknown

SIGNATURES

Project Manager/Author	Date	Associate Director for Research	Date
Not Applicable			
Budget Preparer	Date	Technical Editor	Date
Proposal Manager	Date	Financial Review	Date
Dr. Gerald H. Groenewold, Director Energy & Environmental Research Center	Date	Dr. Barry I. Milavetz, Interim Director Office of Research and Program Development	Date

October 1, 2004

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Dear Ms. Fine:

Subject: EERC Proposal No. 2005-0079, "Center for Air Toxic Metals® Affiliates Program – 3-Year Continuation of Membership"

Enclosed please find an original and seven copies of the subject proposal along with a check for $100. This proposal is a request from the Energy & Environmental Research Center (EERC) for $45,000 to extend the existing membership by 3 years for the North Dakota Industrial Commission (NDIC) under the Center for Air Toxic Metals® (CATM®) Affiliates Program. Unlike most projects, the CATM program is intended to be an ongoing project. Organizations joining through the Affiliates Program may join year-to-year, but are strongly encouraged to commit to a 3- to 5-year agreement in order to conduct research that is more far-reaching in its scope.

Through the Affiliates Program, NDIC will continue to receive many benefits, as outlined in the enclosed proposal. We appreciate the ongoing, long-term support that NDIC has provided to our state through its support of projects at the EERC and for past participation in the CATM Affiliates Program. We are appreciative of NDIC's ongoing support, feedback, and participation in this research to promote environmental quality and efficient use of energy resources. I look forward to your continued participation.

This transmittal letter represents a binding commitment by the EERC to complete the project described in EERC Proposal No. 2005-0079, submitted to NDIC on October 1, 2004.

If you have any questions related to CATM or the Affiliates Program, please contact me by telephone at (701) 777-5268, by fax at (701) 777-5181, or by e-mail at jpavlish@undeerc.org.

Sincerely,

John H. Pavlish
Senior Research Advisor

JHP/drh

Enclosures

CENTER FOR AIR TOXIC METALS® AFFILIATES PROGRAM – 3-YEAR CONTINUATION OF MEMBERSHIP

EERC Proposal No. 2005-0079

Submitted to:

Ms. Karlene Fine

Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Amount of Request: $45,000

Submitted by:

John H. Pavlish
Lucinda L. Hamre
Steven A. Benson
Kevin C. Galbreath
Michael J. Holmes
Christopher J. Zygarlicke

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

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John H. Pavlish, Project Manager
Energy & Environmental Research Center

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Dr. Barry I. Milavetz, Interim Director
Office of Research and Program Development

October 2004

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CENTER FOR AIR TOXIC METALS® AFFILIATES PROGRAM – 3-YEAR CONTINUATION OF MEMBERSHIP

ABSTRACT

Energy production and environmental responsibility issues—especially as they pertain to toxic trace metals—have gained national attention and will have major impacts on our economy and our way of life. To establish a strong research program targeting critical, timely air toxic issues, the U.S. Environmental Protection Agency established the Center for Air Toxic Metals® (CATM®) program at the Energy & Environmental Research Center in 1992. Since then, CATM has answered many critical questions related to toxic metal transformations and pathways, sampling and measurement of toxic metal emissions, control technologies, computer modeling, and health risks related to toxic concentrations of trace metals. CATM takes a comprehensive "cradle-to-grave" approach to solve air toxic metal emission problems that includes putting this information in the hands of stakeholders through technology transfer, workshops, conferences, training material and courses, and support for general public outreach and education.

While the past 3 years of the North Dakota Industrial Commission's (NDIC's) membership has focused primarily on mercury, CATM's research has been, and will continue to be, focused on the larger scope of toxic metals, with continued emphasis on mercury research until pressing questions are answered. As an ongoing program, CATM's partnership with Otter Tail Power Company, Tennessee Valley Authority, Basin Electric Power, NDIC, and other North Dakota entities provides synergy with other organizations to address these pressing matters. To provide further incentive to partner with CATM, membership fees have recently been reduced, and agreements are also being pursued with numerous commercial entities. To enable CATM to address long-term issues, NDIC is encouraged to make a 3-year commitment for $45,000.

CENTER FOR AIR TOXIC METALS® AFFILIATES PROGRAM – 3-YEAR CONTINUATION OF MEMBERSHIP

PROJECT SUMMARY

The Center for Air Toxic Metals® (CATM®) was initiated in 1992 at the Energy & Environmental Research Center (EERC) of the University of North Dakota (UND) through the U.S. Environmental Protection Agency (EPA) Office of Environmental Engineering and Technology Demonstration. CATM is a partnership among government, industry, and academia that is focused on pollution prevention, control technologies, and related health issues. As part of ongoing research activities at the EERC, CATM strives to develop and provide critical data and predictive methodologies to industry, EPA, and other state and federal agencies in order to help better define regulations and provide a forum for industry input and interaction. The CATM focus is on furthering the current understanding of the behavior of potentially toxic metals in coal-fired utilities, other fossil fuel systems, waste-to-energy systems, and waste incinerators. CATM goals are to develop methods to prevent or reduce air toxic metal emissions, predict the fate of metals, determine the effectiveness of control devices, identify new control technologies, investigate the health impacts of toxic concentrations of metals, and inform affiliate members and the public of CATM research findings.

The CATM Affiliates Program (CATMAP), organized and maintained since 1993, facilitates the participation of organizations as partners in various technical program areas. These partnerships provide the necessary direction to ensure that the research conducted meets both short- and long-term goals and needs. To enable CATM to address long-term issues, CATM encourages a 3-year commitment for $45,000. An optional membership is available on an annual basis for $18,000 a year. Membership provides numerous benefits including the following:

- Direct access to EERC experts who can provide technical advice on solving problems associated with air toxic metals.
- Rapid access to state-of-the-art research on air toxic metal sampling, analysis, control, and predictive techniques.
- Research and development at a fraction of the cost available to a single organization.
- Interaction with other affiliates, regulatory agencies, and research institutions interested in air toxic metals.
- Discounted rates on computer software developed through CATM as well as on CATM-sponsored workshops, educational courses, and conferences.
- Up-to-date source of information, publications, and reports.
- Representation, as each member organization provides a CATM advisor who assists in defining the direction and scope of research activities related to air toxic metals.
- Access to Jointly Sponsored Research Program (JSRP) funds. Sponsorship for CATM, CATMAP, and the JSRP has integrated funds available from EPA, the U.S. Department of Energy, EPRI, Gas Technology Institute, multiclient consortia, and individual sponsors.

PROJECT DESCRIPTION

Goals and Objectives

The overall goal of CATM is to continue to meet the many challenges facing regulatory agencies, government, and industry through relevant, timely research on energy production, environmental control technologies, and other environmental issues.

The mission of CATM is to provide a nationally coordinated and practically oriented multidisciplinary research and development and training program on the prevention, formation, behavior, and control of toxic metal emissions from energy-producing and incinerating systems and on preventing and minimizing the effect of these metals on the environment through partnerships developed with industry, academia, and government.

The primary goal of CATM is to develop key information on the behavior of air toxic substances that allows for the prediction of the fate of air toxic metals, the enhancement of existing control technologies, the identification of new control technologies, the demonstration of advanced control technologies, the optimization of utilization and disposal of residuals, and pollution prevention.

The anticipated outcome of the CATM Program includes the following:

- Elucidation of air toxic transformation mechanisms and pathways in energy production and incinerating systems.
- Development and demonstration of emission technologies for toxic metals.
- Development and demonstration of environmentally sound methods to utilize and dispose of residuals.
- Development and validation of methods to sample and analyze air toxics.
- Development of predictive tools and databases.
- Evaluation of the health impacts of toxic concentrations of metals.
- Development of partnerships with industry and government.
- Development of environmental awareness and pollution prevention programs through education via university courses, workshops, conferences, seminars, and 1-day courses.
- Commercialization of results and technologies.

Work Plan

The approach taken to meet the goals and objectives of CATM involves developing partnerships with government, industry, and academia to conduct practically oriented research that will facilitate the prevention and control of air toxic metal emissions. The EERC and others are conducting research on air toxic metals behavior; many of the EERC programs are described in Appendix A, showing our proven successes. The cradle-to-grave approach related to the production of energy from fossil fuels or wastes in an environmentally responsible manner involves developing a detailed knowledge of fuel composition and characteristics, transformation of components during conversion, effective control technologies, methodologies to utilize and dispose of residuals, and related health impacts of toxic metal concentrations. CATM is organized into five integrated program areas. The program areas are coupled to predictive modeling and development of databases that allow for data accessibility and interpretation. In addition, the overall effort is coordinated with education and technology transfer.

The work plan for this proposed project consists of five separate project areas as outlined below.

Project Area 1 – Air Toxic Metals Transformation, Transport, and Sorption Mechanisms

This vital area focuses on determining the chemical and physical transformations of trace element emissions as a function of the association and abundance of the trace elements in fuel and of system design and operating conditions. This area will continue to focus on 1) the development of air toxic pollution prevention strategies, 2) development of predictive and explanatory models, and 3) testing and development of control methodologies and technologies.

Project Area 2 – Analytical Methods Development

Research in this Program Area 2 includes the development of methods to determine the abundance and association of air toxic metals in a variety of fuel resources and wastes, measuring and speciating the metals in the various process streams of the combustion and gasification systems, performing in situ measurements, and providing analytical support for the other program areas. The long-term goal of this program area is to develop sufficiently versatile instrumentation methods and sampling procedures to detect and measure atomic and molecular species, solid or gaseous, which are present at a variety of locations throughout bench-, pilot-, and commercial-scale conversion systems. Developing better, more accurate, flexible, and low-cost sampling and analytical instruments that can be applied and utilized at full-scale plants is the ultimate goal.

Program Area 3 – Control Technologies

Research in this key program area focuses on pursuing and identifying opportunities for minimizing and controlling trace element emissions in combustion and gasification systems, including prevention and minimization of toxic element formation (i.e., fuel-to-energy conversion efficiency improvements and recycling); development and capture by sorbents using precombustion, combustion, and postcombustion injection techniques in conjunction with high-efficiency fine-particle control; and development, demonstration, and implementation of new, innovative technologies. Prevention or minimization of emissions of air toxic elements includes many factors, ranging from improvements in process operation to retrofitting or installing new high-efficiency collection equipment.

Developing low-cost control alternatives such as sorbent technologies will continue to be a priority. Fundamental data are needed to develop new sorbents or to extend the effectiveness of existing commercially available sorbents. Efforts will focus on determining air toxic metal sorbent interactions, the characteristics of the sorbent material, the optimal location for injection into the system, the mechanisms of formation/transformation and metal speciation, the influence of system conditions (operating and physical state), and cost-effectiveness.

Ash production is inevitable from combustion and gasification systems, and although the amount of ash produced is variable depending on the fuel, the solid residue requires consideration regardless of the quantity. Coal and other fuels produce a high volume of solid residues in varying forms containing different metal concentrations. Developing proper management options for these residues, whether they are disposed of or utilized, is essential and is a CATM goal.

Program Area 4 – Health Effects

Human health impacts drive legislation and the control strategies of toxic metals. Projects in this program area study the exposure risks of metals on target tissues of the nervous, endocrine, and cardiopulmonary systems at the molecular, cellular, and tissue levels in animal and human subjects. CATM is developing, demonstrating, and applying innovative approaches to characterize risk and evaluate preventive and protective measures. A comprehensive approach is used to define and correlate relationships that will prove useful to those developing control strategies and legislators. Current efforts focus on mercury–selenium interactions and possible ways to partially offset toxicity of trace metals, evaluating the role of selenium in aquatic environments and implications for mercury bioaccumulation, assessing mercury's impacts on growth and development through animal studies, and examining heavy metal accumulation in the development and pathology of cardiac disease.

Program Area 5 – Technology Commercialization and Education

Efforts in this research area focus on disseminating technical information (concerning trace metals) produced by CATM to the affiliate members and other sponsoring agencies, as well as providing training opportunities for both students and professionals. Major activities include 1) publishing and distributing the *CATM Newsletter*; 2) offering the short course training program; 3) coordinating CATM annual meetings with EPA as the invited party, program affiliates, and the Research Advisory Council (RAC); 4) coordinating research planning activities through the RAC and coordination of research review by the Science Advisory Committee (SAC); and 5) overall administration of CATMAP.

Deliverables

CATM has been and continues to be a leader in the research of air toxic metals and provides its research to CATM affiliates, those who attend conferences and educational outreach activities, and utility and government leaders. The success of the program can be measured by continuing to provide the following expected deliverables:

- Identification of air toxic metal pollution prevention options
- Determination of air toxic transformation mechanisms in fossil fuel and waste incineration systems
- Development of technologies to monitor and control metals behavior and emissions
- Development of environmentally sound methods to utilize and dispose of residuals
- Development of methods to sample and analyze air toxics
- Development and evaluation of methods to assess health impacts of toxic metals.
- Development of predictive tools and databases

- Development of training and educational courses
- Commercialization of results and technologies

STANDARDS OF SUCCESS

The EERC established and formalized a quality management system (QMS) in August 1988. As part of the QMS, a quality manual was developed and put into place as policy to guide research projects. Compliance with this manual and its supporting documents ensures that the EERC adequately fulfills governmental and private client requirements relating to quality and compliance with applicable regulations, codes, and protocols. Additionally, the CATM Program at the EERC has a quality assurance (QA) plan in effect that addresses trace metal emissions research at the EERC. The CATM QA and quality control (QC) plans have been reviewed and accepted by the EPA. The proposed project will follow the guidelines of the EERC quality manual and the CATM QA plan to ensure that the information and data that are produced and published are at high acceptable quality. As stated earlier, the CATMAP is intended and structured to be an ongoing research program with the ability to address critical research issues as they arise. The success of the CATM program can be gauged by its success as a program over the last 12 years. This success can be expected to continue over the next 3 years of this request. These successes are exemplified in Appendix A.

BACKGROUND

Worldwide, concern is growing over emissions of trace metals considered to be air toxics. More stringent metal emission regulations have been promulgated for many industries and are expected to be further implemented in Europe, the United States, and elsewhere. To help address these issues, EPA established the CATM Program at the EERC in 1992. Since then, CATM has answered many critical questions related to health risks, toxic metal transformations and pathways, sampling and measurement of toxic metal emissions, and related toxic metal control technologies. New work also focuses on the health impacts of toxic levels of trace metals. CATM work has furthered our understanding of air toxic issues and resolved many key questions put forth by affiliate sponsors. Affiliate partners have been kept informed of CATM progress and results through numerous mailings and regular meetings.

Without question, the demand for a strong research program targeting critical and timely air toxic issues is greater now than ever before. EPA has confirmed that it is on target to promulgate a mercury control rule by March 2005. Comments received in reference to this rule show that many key questions remain concerning mercury. Although numerous control strategies are being discussed and utilities strive to put these strategies into effect, even more questions are raised that must be answered quickly—especially in an energy sector that is already facing many challenges. Although the past 3 years of the North Dakota Industrial Commission's (NDIC's) membership has focused primarily on mercury, CATM's research has been and will continue to focus on the larger scope of toxic metals, with continued emphasis on mercury research.

QUALIFICATIONS

The EERC has been conducting timely, relevant research for over 50 years. With a staff of over 270, the qualifications of researchers associated with CATM cover nearly every discipline related to environmental and energy issues. In addition, CATM researchers collaborate with other organizations to provide synergy with other experts.

To accomplish the mission and goal of CATM, the EERC fosters partnerships through relationships with industry, academia, and government. CATM is at the focal point or hub of these partnerships, which are key to effective research and development programs, as depicted in Figure 1. The EERC has an excellent reputation for developing multidisciplinary, multiclient research and development programs that are focused on solving near- and long-term problems related to energy and environment. See Appendix A for EERC projects related to CATM's research.

Program Area Managers and Principal Investigators

The project management plan has been assembled in such a way as to take full advantage of the multidisciplinary nature of the EERC research team. The plan is modular in design and fully integrated to facilitate the efficient interaction and cooperation of the very diverse team of experts needed to perform the research on air toxic metals. Qualified managers for each of the

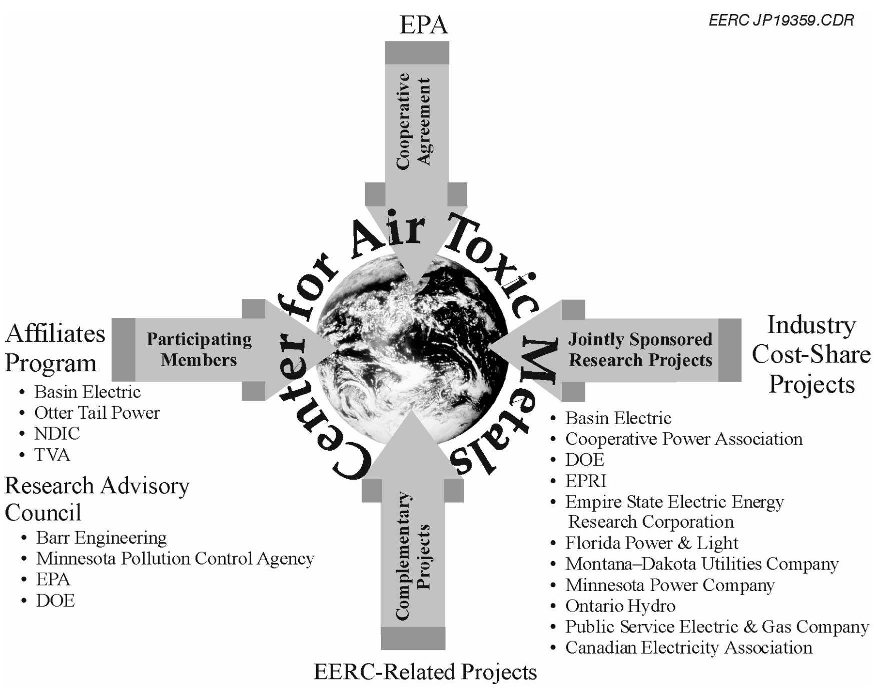

Figure 1. CATM — a multiclient program at the focal point of metals research.

five parallel program areas (air toxic metal transformation mechanisms, analytical methods development, control technologies, health effects, and technology commercialization and education) are shown in Appendix B.

Research Advisory Council

The CATM RAC consists of two committees, referred to as the partners advisory council (PAC) and the SAC. The role of the PAC is to identify and prioritize research needs and ideas. Representatives from each affiliate member organization provide direction, prioritized emphasis on needed areas of research, and feedback to CATM researchers. The role of the SAC, which consists of members from industry, government, and academia, is to ensure that the research activities that are proposed and conducted through the CATM are scientifically valid, have a strong experimental plan, utilize appropriate analytical techniques, and meet overall QC guidelines.

VALUE TO NORTH DAKOTA

In our country and in our state, the issues pertaining to energy production and environmental responsibility have gained national attention and will have major impacts on our economy and our way of life. As the nation's sixth largest producer of energy, North Dakota is a key player in this arena. CATM has partnered with NDIC and other North Dakota entities to provide synergy with agencies and organizations to address these pressing issues. As an example, over the past 2 years, the EERC has developed and field-tested several mercury control technologies that show much promise. The fundamental knowledge that has been gained through the CATM Program led to the development of these effective technologies, which will help to enable North Dakota power plants to meet forthcoming mercury regulations.

What Is the Affiliates Program?

The CATMAP is designed to meet the many challenges facing industry and government and will aid industry in interfacing with regulatory agencies and government in a constructive manner. Membership immediately and continuously provides the participant with access to an air toxics research program. Proactive organizations seeking to minimize risk and provide input into long- and short-term planning will benefit greatly from this program.

Affiliates Membership Benefits

The consortium established by CATMAP represents a unique opportunity to leverage limited research dollars in order to deal with toxic metal emission issues in an efficient and cost-effective manner. Partnerships established with government agencies and other affiliates will result in opportunities to implement cost-effective solutions to emission problems facing industry today. CATMAP provides access to EPA personnel and contractors involved in the research and development on air toxic emissions mandated by the Clean Air Act Amendments and provides a forum for members to voice concerns and keep current on the latest EPA studies and strategies. CATM will focus its efforts to provide the deliverables that were mentioned earlier in this proposal. CATM will continue research in areas that are of prime importance to the energy and environmental fields.

MANAGEMENT

Figure 2 shows the management structure of CATM. Overall project management and coordination of efforts will be the responsibility of the CATM Director, Mr. John Pavlish, who has over 20 years of power plant experience related to pollution control and has authored

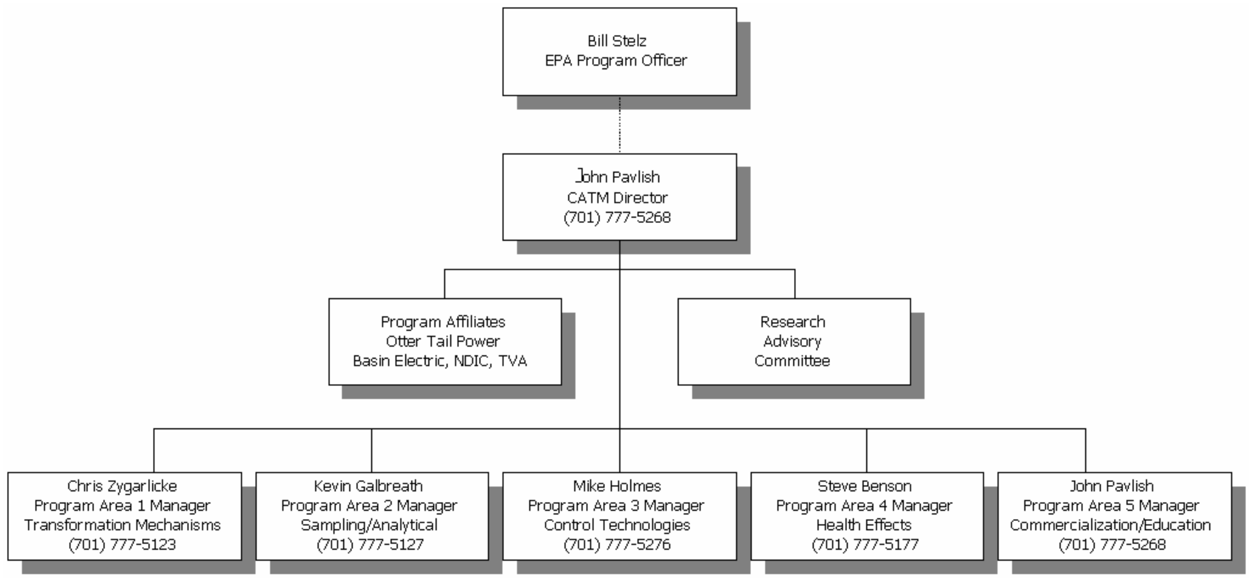

Figure 2. Organizational chart for the CATM Program.

numerous publications. The CATM Director's management efforts will be guided by three management groups: CATMAP members, EPA project management, and the RAC.

TIMETABLE

Unlike many other projects, CATM has an ongoing mission that addresses both short- and long-term research needs germane to the energy and environmental needs of industry, government, and other entities. Membership fees cover projects within the five stated areas for funding periods of at least 1 year, but possibly extending to multiple years. CATM encourages its members to provide longer-term commitments to facilitate projects whose long-term scope require more than 1 year to adequately research.

BUDGET

A detailed budget is not provided because of the ongoing nature of CATM and the nature of partnership affiliation. As stated, the EERC requests that the NDIC renew its membership and fund a 3-year commitment for $45,000. It should be noted that the previous 3-year commitment cost NDIC $75,000. Affiliate members direct CATM's research goals and research priorities.

MATCHING FUNDS

The Affiliates Program is a program distinct from the federal funding provided by EPA and thus, is not reported to EPA as cost share. Present Affiliates include NDIC, Tennessee Valley Authority, Basin Electric Power, and Otter Tail Power Company. In addition to the Affiliates Program, EPA has provided base funding in excess of $10 million and continues to fund CATM at approximately $1.0 million per year. Expenditures may be included as described in the budget notes below.

Budget Notes

Background

The EERC is an independently organized multidisciplinary research center within 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 fixed-price basis. The budget prepared for this proposal has been prepared 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.

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 http://www.und.edu/dept/accounts/employeetravel.html. Estimates include General Services Administration 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 May 11, 2004. 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.

TAX LIABILITY

The EERC? a research organization within UND, 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 this proposal.

REFERENCES

None.

APPENDIX A

CATM RESEARCH PROGRAMS AND RELATED EXPERIENCE

CATM RESEARCH PROGRAMS AND RELATED EXPERIENCE

CATM EXPERIENCE

CATM's success as a program includes many noteworthy accomplishments. Among these is the outstanding success of the Air Quality conferences that have drawn international experts in the fields of air toxic metals from around the world to present the most current research to an audience of stakeholders. CATM research has been highlighted in numerous peer-reviewed journals; among the most prominent recent publications is the special issue "Status Review of Mercury Control Options for Coal-Fired Power Plants" published by *Fuel Processing Technology* in 2003. The CATM Program also has combined the resources of all of its sponsors with those of the U.S. Department of Energy (DOE) and the Canadian Electric Association (CEA) to produce quarterly reports that are available free of charge on the CEA and CATM Web sites.

Following are synopses of some of the research that has been conducted through the CATM Program, including overviews of the work that is presently being conducted.

CATM 2002 Project Results

Coal Combustion Flue Gas Effects on Mercury Speciation

Program Area 1 of CATM has been actively supporting research in coal combustion flue gas effects on mercury speciation. It was verified both by an on-line mercury analyzer system and Ontario Hydro mercury sampling and speciation that ?-Fe_2O_3 reactively captures elemental mercury (Hg^0). Combustion testing in a 42-MJ/hr combustion system revealed that an abundance of Hg^{2+}, HCl, and ?-Fe_2O_3 in Blacksville coal combustion flue gas catalyzes Hg^{2+} formation and that HCl may be an important Hg^0 reactant. In addition, experiments confirmed that the filtration of Absaloka and Falkirk combustion flue gases through a 150°C fabric filter (FF) coated with ?-Fe_2O_3 results in about 30% of the Hg^0 in Absaloka and Falkirk flue gases being converted to Hg^{2+} and/or Hg(p). 100 ppmv HCl injection into the Absaloka combustion flue gas converted most of the Hg^0 to Hg^{2+}(gas), whereas HCl injection into the Falkirk flue gas converted most of the Hg^0 and Hg^{2+} to Hg(p). Addition of ?-Fe_2O_3 and HCl did not have a synergistic effect on Hg^0 oxidation. Much heavier FF loadings of ?-Fe_2O_3 essentially doubled the baghouse Hg(tot) removal efficiency. Evidence is insufficient to decipher whether ?-Fe_2O_3 reactively captured Hg or if the additional surface area alone provided by heavy FF loadings of ?-Fe_2O_3 accounted for the improved baghouse Hg(tot) capture. In summary, by injecting economical concentrations of ?-Fe_2O_3 as an oxidizing agent upstream of a filtration device, removal efficiencies for total mercury were doubled.

In addition to studying oxidizing agents for Hg^0, the construction of a portable bench-scale entrained-flow reactor (EFR) was completed and used to study the transformation rate (kinetics) of Hg^0 to Hg^{2+} and/or Hg(p) in coal combustion flue gas. The reactor was specially designed and constructed for time–temperature studies. Experiments were run using a subbituminous coal that produces a low-acid flue gas. Hg transformations were not detected in the reactor above 275°C, but at 150°C, Hg(tot) and Hg^0 were transformed primarily into Hg(p) with increasing residence time.

Development of Sampling and Analytical Tools to Assess Mercury Speciation

Advances in definitive speciation of Hg^{2+} compounds in a flue gas stream from development of methods for cryogenic and solvent trapping of certain volatile Hg^{2+} and their analysis by mass spectrometry (MS) continued. The analysis of mercuric chloride and mercuric nitrate by gas chromatography (GC) and identification by MS is now better understood, and the unusual behavior of mercuric nitrate on this technique was documented in a refereed publication. A method for transferring mercuric chloride from the initial cryotrap to the GC–MS was further developed, but problems were encountered in the application with high-moisture flue gas. Improvements were made in the construction and use of a continuous vapor source for mercuric nitrate. These insights in the behavior of the oxidized mercury species have benefitted the development of a model for the chemisorption of Hg^0 on a carbon sorbent surface. The combination of these efforts and subsequent improvement will lead to quantitative speciation methods with high levels of confidence for the major volatile oxidized mercury species.

Airborne Mercury-Sampling Method Development

The Energy & Environmental Research Center (EERC), in conjunction with the University of North Dakota (UND) High-Altitude Balloon Group, completed five test-launch missions from August 2001 to December 2003. The goal of the project is to determine the potential for use of high-altitude weather balloons for sampling atmospheric Hg to determine atmospheric distribution, at altitude, downgradient from Hg emission sources.

The payload for the missions included a five-port sampler, gold-coated sand traps, and a 12-L pump. The mission durations were less than 3 hours, and the maximum altitude sampled was 75,400 feet. Results show the distribution of atmospheric mercury concentrations which range from 0.03 to 1.4 ng/m^3. Concentrations are highest nearer the ground surface and decrease with altitude to less than 0.2 ng/m^3. Higher concentrations are generally observed below approximately 20,000 feet.

Development of Mercury Control Technologies

This project is focused on developing and testing promising sorbents and catalysts that have high reactivities to provide rapid in-duct mercury capture or oxidation when injected upstream of a particulate control device. In-duct capture sorbents will provide a useful method for both electrostatic precipitators (ESPs) and baghouses, while the ability to oxidize mercury will make scrubbers more effective in removing mercury.

A dual functionality model for mercury–flue gas interactions with carbon sorbents has been developed. This model shows a two-step oxidation and capture process. Certain acid gases are needed for the oxidation step. As mercury is captured, SO_2 poisons the binding site for Hg(II) on the sorbent surface and leads to breakthrough. The mercury that is emitted from the sorbent after breakthrough is entirely an oxidized mercury species, consistent with the model.

Tests were completed with an EFR to evaluate the effect of residence time on the level of oxidation of mercury when coal is burned in the EERC pilot-scale combustion test facility. Results showed that both lower temperature and longer residence time lead to a higher fraction of oxidized mercury. EFR tests also demonstrated the effect of residence time and carbon injection rate on in-flight capture of mercury when activated carbon (AC) is injected into the flue gas stream.

The EERC fixed thin-bed reactor has been used for many years as an approach to evaluate a variety of sorbents. Little testing of this system with real flue gas had previously been completed. Direct comparison tests were completed sampling real flue gas and simulated flue gas. Results that showed the simulated flue gas results were similar to results sampling real flue gas provided confidence that the fixed thin-bed test protocol is a valid approach to screen and compare sorbents.

Modeling and Database Development

The CATM modeling efforts have continued to develop approaches to predict and understand toxic trace elements from thermal sources. These efforts include the development and improvement of computer-based predictive tools using statistical and artificial intelligence-based approaches.

The extensive collection of data from governmental, industrial, and research sources was utilized to develop advanced statistical relationships using ash chemistry along with an artificial intelligence-based application to understand the speciation of trace elements produced from coal-fired systems. This information is important to understand the forms of the trace elements produced and to improve the control of the toxic trace elements from thermal sources. The compiled data, along with the computer-based tools, are available to researchers and others interested in trace element information.

Stability of Mercury in Coal Combustion By-Products and Sorbents

This continuing project focused on three primary tasks with the goal of determining the mechanisms of mercury release from coal combustion by-products (CCBs). The tasks included studying the impact of microbial activity on the release of mercury from fly ash, determining the leachability of mercury from various CCBs, determining the level of mercury vapor offgasing from CCBs, and continuing to develop thermal desorption techniques to identify mercury compounds present on CCBs.

The effect of microbial activity on the release of mercury from one fly ash was tested. Hg^0 release was measured, but experimental difficulties prevented organomercury measurements. A second fly ash will be evaluated, with results available in the first quarter of 2003.

Leaching was performed on 47 CCB samples using three leaching procedures, both short- and long-term tests. Two-thirds of the results show no detectable mercury leachability. Leaching will continue as samples are available.

Six CCB samples previously tested through CATM were evaluated in duplicate for the release of mercury vapor at ambient temperature. Blank measurements are currently being tested. The improved apparatus used in the current experimentation indicates that the release of mercury vapor is an order of magnitude lower than previously thought. Preliminary results indicate an average release of 2.9×10^{-9} lb Hg/ton CCB/yr.

Thermal desorption curves have been generated for various CCB samples. Experimental work was done to determine the thermal curve for devolatilization of mercuric chloride from quartz granules.

Mercury Releases from Crude Oil and Other Fuels

Information related to the content and fate of mercury from crude oil and other fuels (referred to as alternative fuels) is limited. Evaluation of existing information and additional acquisition and analysis of samples are needed to better quantify the mercury associated with utilization of both crude oils and alternative fuels such as biomass, oil sands, tar sands, and oil shale.

The United States consumes 19.6 MM barrels/day of oil, which is roughly equivalent to the amount of coal consumed domestically on a tonnage basis. Consequently, depending on the associated levels of mercury released to the environment during production and utilization of that oil, the potential exists for significant contribution to the global mercury pool. Currently available literature indicates that mercury concentrations of produced crude oils vary widely from below analytical detection limits to ppm levels, with a majority of the reported samples in the single-digit ppb levels. In comparison, the information collection request for coal showed average mercury concentrations for the major coal types ranging from 49 to 126 ppb. While most of the crude oil samples are at concentrations below these levels, the literature does indicate that there are regions with very high concentrations of mercury (thousands of ppb). Additional research is needed in this area to evaluate mercury concentrations in crude oils at the source, before it is removed during production and processing.

Mercury data for alternative fuels are limited. The need for better data becomes increasingly important as more interest and emphasis are placed on utilizing local and renewable sources of energy, such as biomass, oil sands, tar sands, oil shale, etc. In general, mercury levels in sources of biomass are expected to be relatively low, but higher values have been observed (e.g., up to 71 ppb for leaf and tree needle litter). Thus more data are needed to identify typical and range values. Limited data show that there can also be significant levels of mercury in oil sands and oil shale and that analysis of a representative sample set is warranted.

Nickel, Chromium, and Arsenic Speciation of Ambient Particulate Matter in the Vicinity of an Oil-Fired Utility Boiler

Ambient particulate matter (PM), PM_{10}, and $PM_{2.5}$ were sampled continuously during August 26–31, 2002, from an urban State and Local Air Monitoring Stations site in the vicinity of two oil- and gas-burning power plants. Urban PM, PM_{10}, and $PM_{2.5}$ samples were analyzed using x-ray absorption fine structure spectroscopy (XAFS) during October 18–22, 2002, at the National Synchrotron Light Source at Brookhaven National Laboratory, New York. XAFS is being used to directly determine the speciation of As, Cr, and Ni in ambient PM, PM_{10}, and $PM_{2.5}$ samples. Knowledge of the relationship between oil- and gas-burning power system emissions and ambient air quality will ultimately result in a more realistic inhalation-based risk assessment. Such an assessment is necessary for the U.S. Environmental Protection Agency (EPA) to properly address public health risks and regulatory decisions.

Transition Metal Speciation of Fossil Fuel Combustion Flue Gases

Five representative Powder River Basin (PRB) subbituminous coal fly ash samples, containing 45 to 80 ppm Cr, were obtained from the EERC Coal Ash Resources Research Consortium℠ and analyzed using XAFS. The XAFS data are being reduced and interpreted. Thermochemical equilibrium calculations suggest that carcinogenic hexavalent chromium compounds do not occur in PRB subbituminous coal fly ashes. Results will be available next year.

Fundamental Study of SCR Impact on Mercury Speciation

Previous testing conducted by the EERC to evaluate the impact of selective catalytic reduction (SCR) on mercury speciation included 4 weeks of pilot-scale testing and full-scale sampling at six different power plants. The results from these studies indicated that the impact is coal-specific. It is speculated that SO_2/SO_3 and HCl/Cl_2 concentrations play a pivotal role. Bench-scale tests using a fixed-bed system will be conducted to help determine the effects of these gases. A full-factorial design is being used to evaluate the independent variables, which include the reactor (none, SCR), presence of acid gases (HCl and SO_2/SO_3), fly ash type, and residence time. Results will be available next year.

Long-Term Mercury Monitoring

Long-term monitoring (25–30 days) of mercury emissions and data evaluation was completed at two different power plants. The results indicate that mercury emissions can be quite variable, presenting a control challenge. The variability is due to mercury variability in coal, load, changes in operating conditions, and other factors not fully understood.

Mercury Monitoring at North Dakota Power Plants

Previous testing of coal-fired utilities indicates that mercury speciation and emissions are coal-specific. Long-term tests (approximately 20 days) using continuous mercury monitors (CMMs) are needed to investigate variability, especially pertaining to the combustion of lignite coals. Although the testing was on North Dakota utilities, the data are useful beyond the state since U.S. power plants burning lignite have shown higher Hg^0 emissions than plants burning bituminous coals. This form of mercury is more difficult to remove than oxidized forms and requires innovative measures to control the emissions from the range of combustion and environmental control systems in North Dakota. This project will provide information that can be used to more accurately estimate mercury emissions from lignite-fired power plants and begin formulating a comprehensive strategy that will address critical issues related to mercury control. Results will be available next year.

Potential Impact of Selenium on Mercury Toxicity

It has become clear through CATM research that the relationship between selenium and mercury is not simply that selenium has a protective effect against mercury toxicity through its ability to bind up the mercury. Instead, mercury toxicity is the result of its selenium sequestration, inducing a deficiency of low molecular weight selenium necessary for synthesis of the essential selenoenzymes. The lack of these enzymes is particularly dangerous in neuronal tissues since these cells have no backup systems for free radical detoxification in brain cells. Loss of selenium-dependent free radical detoxification enzymes causes extensive cell damage and death in fetal brains when maternal methylmercury consumption is excessive relative to selenium. Furthermore, once the redox state inside the cell switches from its normal reducing state to become an oxidizing environment, the essential reduced forms of selenomolecules diminish, and selenoenzyme synthesis is abolished, leading to a sustained loss of redox control. Thus even a brief exposure to excess mercury may result in a self-perpetuating deficiency in selenoenzyme synthesis, termed the “selenium tailspin.”

Technology Commercialization, Education, and Publication

To facilitate the transfer of technical information produced by CATM, several communication vehicles are used, including participation in conferences, symposia, workshops, and other educational programs; annual meetings and peer review; and the publication of a semiannual newsletter.

The EERC, through CATM, EPA, and DOE, has organized and sponsored four conferences on Air Quality: Mercury, Trace Elements, and Particulate Matter, held in 1998, 2000, 2002, and 2003. The first two conferences were held in Tysons Corner, McLean, Virginia. The last two conferences were held in Arlington, Virginia. Air Quality V: Mercury, Trace Elements, and Particulate Matter is scheduled to be held September 2005, in Arlington, Viringia. The Air Quality conference is a forum for reviewing the current state of science and policy on the pollutants mercury, trace elements, and PM in the environment.

The CATM Web page has been maintained throughout the year and can be accessed at www.undeerc.org. Copies of the *CATM Newsletter* are available, as well as download access to the CATM database. The CATM Web page is continuing to undergo major reconstruction and updates.

CATM 2003 Project Results

Mercury Transformations in Coal Combustion Flue Gas

Although prior bench-scale studies using synthetic coal combustion flue gas showed significant Hg^0 oxidation effects due to nitrogen oxide (NO_x), similar NO_2 injections into a laboratory-scale combustion system firing a subbituminous coal did not show significant Hg speciation. The lack of heterogeneous Hg^0–NO_x reactions in the 42-MJ combustion system suggests that components of coal combustion flue gases and/or fly ashes inhibit heterogeneous Hg^0–NO_x reactions or the residence time–temperature conditions in this combustion system are much different relative to bench-scale flue gas simulators. Kinetic experiments designed to obtain quantitative data on the time–temperature oxidation of Hg^0 were performed in an EFR that received a slipstream of subbituminous coal flue gas. Hg transformations were not detected in the reactor at 400° and 275°C. At 150°C, however, Hg(gas) and Hg^0 were transformed primarily into Hg(p) with increasing residence time. In this same system, significant mercury transformation from the bulk gas phase to the particulate phase was observed at high temperatures of 440°–878°C when 200 ppmv HCl was injected into the combustion zone, which might be the result of atomic chlorine production followed by a superfast flue gas quenching rate of 4833°C/s.

Nickel, Chromium, and Arsenic Speciation of Ambient Particulate Matter in the Vicinity of an Oil-Fired Utility Boiler

Ambient PM, PM_{10}, and $PM_{2.5}$ were sampled continuously during August 26–31, 2002, from an urban State and Local Air Monitoring Stations site in the vicinity of two oil- and gas-burning power plants. Urban PM, PM_{10}, and $PM_{2.5}$ samples were analyzed using XAFS during October 18–22, 2002, at the National Synchrotron Light Source at Brookhaven National Laboratory, New York. Preliminary XAFS data reduction procedures indicate that Ni and Cr were present in sufficient concentrations in all three samples to obtain good x-ray absorption spectra; however, As was below the detection limit (˜ 2 ppm). XAFS is being used to directly determine the speciation of Ni and Cr in ambient PM, PM_{10}, and $PM_{2.5}$ samples.

Transition Metal Speciation of Fossil Fuel Combustion Flue Gases

XAFS spectroscopy measurements of five western U.S. PRB subbituminous coal fly ashes sampled from power plants equipped with various pollution control equipment indicated that about 10%–30% of their total Cr contents (47–79 ppm) exist as hexavalent chromium (Cr^{6+}). These relatively high Cr^{6+} proportions support the hypothesis that western U.S. PRB subbituminous coal fly ashes contain greater proportions of Cr^{6+} relative to eastern U.S. bituminous coal fly ashes.

Thermodynamic modeling of $Mg(OH)_2$ residual (No. 6 fuel) oil injection indicates that even though $MgSO_4 \cdot 6H_2O$ is formed, $NiSO_4$ remains stable at <700°C. The addition of $Mg(OH)_2$ is predicted to promote the formation of an oxide spinel compound, $NiAl_2O_4$, at the expense of a nickel silicate compound, Ni_2SiO_4.

Fundamental Study of the Impact of SCR on Mercury Speciation

Previous testing conducted by the EERC to evaluate the impact of SCR on mercury speciation indicated that the impact is coal-specific. This conclusion has been borne out on numerous projects. To investigate the role that SO_2/ SO_3 and HCl/Cl_2 concentrations in the coal play, bench-scale tests using a fixed-bed system were conducted to help determine the effects of these gases. A full-factorial design was used to evaluate the independent variables, which include the reactor (none, SCR), presence of acid gases (HCl and SO_2/ SO_3), fly ash type, and residence time. The presence of ammonia depended on reactor mode.

The results show that the presence of acid gas is the critical factor in determining the level of mercury oxidation. Also, there is a clear correlation between the presence of acid gas and an SCR reactor on the level of mercury oxidation.

Development of Mercury Sampling and Analytical Techniques

Because current methods of determining mercury speciation do not distinguish the inorganic forms of Hg^{2+} in a flue gas stream, there is a significant need for better sampling and analytical methods to be developed so that the data can be applied to accurate models of mercury behavior. This project focused on methods of sampling, analysis, and definitive identification and quantitation of Hg^{2+} species and compounds. Cryogenic and cold organic solvent trapping of volatile Hg^{2+} species from bench- and pilot-scale flue gas was used to isolate different mercury compounds and examine the transfer of mercury compounds containing nitrogen, sulfur, oxygen, and chlorine. Volatilization, separation, and transfer of the various mercuric compounds was refined to allow subsequent identification of these compounds. MS–GC analytical methods were developed and refined to allow identification of mercury compounds and resulting behaviors. In particular, the behavior of mercuric chloride ($HgCl_2$) and mercuric nitrate are now better understood. These insights into the behavior of the Hg^{2+} species have benefited the development of a model for the chemisorption of Hg^0 on a carbon sorbent surface, leading to a better understanding of the mechanics of possible mercury control technologies.

Longer-Term Testing of Continuous Mercury Monitors

At the time this project was initiated, very little information existed concerning how mercury emissions varied over time and whether CMMs, given their state of development, could be used long-term to assess variability. To answer this question and to evaluate how CMMs operated in the field for prolonged periods of time, longer-term monitoring (25–30 days) of mercury emissions and data evaluation was completed at four different power plants. The results indicate that mercury emissions can be quite variable over a 1-month period.

Long-Term Mercury Monitoring at North Dakota Power Plants

This field-sampling project was initiated to obtain mercury data concerning the variability and speciation of mercury emissions at two North Dakota power plants that combust Fort Union lignite and to further demonstrate use of CMMs in the field. Mercury continuous emission monitors and the Ontario Hydro method were used to collect these data for use in developing mercury control strategies for North Dakota utilities. Along with analyses of coal, fly ash, and scrubber sludge, and operational emission data from the plant, these data show that although the speciation of emissions is highly variable with Fort Union lignites, plant configurations and operations may serve to reduce that variability.

Development of a Laser Absorption Continuous Mercury Monitor

Experiments are being prepared in which two-photo frequency-modulation spectroscopy measurements are made of mercury in a closed cell. This has included the procurement of major pieces of equipment such as the diode laser system and an optical spectrum analyzer. Other equipment that has been acquired include a Tektronix oscilloscope, a LeCroy digital storage data acquisition system, Horiba imaging spectra-photometer, and various other hardware. Results using this instrument will become available over the next year.

Development of Mercury Control Technologies

This project is intended to develop and test promising mercury control technologies such as sorbents that will provide rapid in-duct capture of mercury, sorbent regeneration, catalysts to oxidize Hg^0 for capture in a wet scrubber, modification of wet scrubbing techniques to enhance mercury capture, or cleaning of the coal before combustion. A further goal is to determine the interaction between flue gas constituents, mercury species, and sorbents. This information has been used to develop and refine a dual functionality model for mercury–flue gas interactions with carbon sorbents. Protocol development for bench- and pilot scale testing is an ongoing task in this program, with a current focus on an EFR. To expand our understanding of mercury capture by AC in flue gas, a full-factorial matrix of bench-scale fixed-bed tests was completed to determine the effects of the flue gas constituents on the capture of $HgCl_2$. Under some conditions, significant reduction of Hg^{2+} to Hg^0 occurs across the AC bed.

Developing SCR Technology Options for Mercury Oxidation in Western Fuels

The project will evaluate the ability of SCR catalysts to oxidize mercury. The study will include both currently used SCR catalysts and new SCR catalysts formulated to enhance mercury oxidation, as well as the use of additives to enhance oxidation. The first catalyst to be tested will be an existing formulation that Haldor Topsoe currently manufactures. A second set of tests will be conducted on several new formulations developed in cooperation with Haldor Topsoe. The catalyst will be tested in flue gas compositions similar to what is found in plants burning PRB and lignite coals and will be varied accordingly. The use of oxidation additives to promote the formation of Hg^{2+} to levels seen for eastern coals will also be a primary emphasis.

Modeling Mercury Speciation in Coal Combustion Systems

A preliminary mercury transformation model has been developed. This model integrates a general dynamic equation (GDE) model with a kinetic Hg interaction model. The CHEMKIN-based mercury speciation model has not been integrated to the model yet since it has not been made available. Both the GDE model and the kinetic model need to be further refined and validated. Both models need to incorporate test results that account for the Hg oxidation resulting from additives and sorbent injection. The GDE model also needs to take into account particle nucleation and coagulation in the postcombustion environment.

Stability of Mercury in Coal Combustion By-Products and Sorbents

This continuing project focused on three primary tasks with the goal of determining the mechanisms of mercury release from CCBs. The major focus this past year was directed toward understanding releases of mercury from microbial activity in CCBs under a disposal setting. Three ash samples were evaluated in triplicate under aerobic versus anaerobic and fed versus starved conditions. Hg^0 and organomercury releases were evaluated. Results to date have been confusing; however, general trends have emerged. The mercury released from the CCB slurry was generally higher in the samples fed with glucose versus starved samples and in aerobic versus anaerobic conditions.

Researchers worked with EPA in an effort to determine a standard leaching protocol for environmental characterization of CCBs for environmentally sensitive elements in addition to mercury. A paper was presented at the 2003 International Ash Utilization Symposium with the intent to elevate awareness of the issues related to selection of leaching procedures.

The thermal effects on mercury vapor release were evaluated through long-term ambient release and thermal desorption at elevated temperatures. The method for the determination of blank values for the long-term ambient release of mercury from six ash samples previously studied under CATM was improved. This confirmed that the CCBs studied earlier acted as mercury sinks. Thermal desorption curves were determined for a large variety of samples, and attempts were made to determine if speciation of mercury forms was possible.

Mercury in Alternative Fuels

This project was focused on expanding CATM research to additional alternative fuels. Thirteen candidate fuel sources were collected, air-dried, and analyzed for residual moisture and mercury concentration. Each sample was completely digested, and mercury content was determined with cold-vapor atomic absorption. A National Institute for Standards and Technology standard was also analyzed as a control. Biomass samples were collected from growers in rural areas of North Dakota, Minnesota, Wisconsin, and Iowa at least 50 miles from the nearest power plant. Common cattail had the highest mercury concentration of all samples analyzed, requiring further study.

Studies of Mercury Metabolism and Selenium Physiology

Selenium's protective influence against mercury toxicity is well documented, but mercury toxicity's effects on selenium physiology are less well understood. Toxic concentrations of mercury are known to impair selenium-dependent physiological processes, possibly through direct sequestration of cellular selenium. It appears likely that formation of insoluble mercury selenides divert selenium from its normal role in synthesis of selenoproteins.

Studies are under way to examine the interactions of mercury and selenium at the molecular, cellular, animal, and human population level. Binding affinities between mercury and selenium are being examined through in vitro studies applying a quantitative chromatography system. The impact of mercury toxicity on selenium-dependent activities at the cellular level is being examined at the tissue, organ, and organism level through in vivo studies in animal models. The relationship between mercury neurodevelopmental toxicity and selenium status in relation to human mercury consumption is being quantified through a study of selenium status in maternal–fetal pairs selected from a population from the Seychelles Islands with known exposures to high quantities of methylmercury from fish in a collaboration with Dr. Thomas Clarkson's Mercury Research group from the University of Rochester, New York.

CATM 2004 Projects under Way

Mercury Transformation in Coal Combustion Flue Gas

The EERC is proposing to separate unburned carbon particles from two carbon-rich fly ashes that were effective in capturing mercury. Carbon concentrates will be characterized in detail to determine which physical and chemical properties may be important in capturing mercury.

A portable bench-scale EFR will be used to determine mercury oxidation and particulate formation rates as a function of coal types (at least two highly differing in rank and composition), flue gas residence time, and flue gas temperature.

Sulfur species in unburned carbon from coal or tire rubber will be explored as possible reaction sites for oxidizing and stabilizing gaseous mercury.

Halogen additives will be investigated in combination with tetrasulfide flue gas injection to determine the impact on mercury oxidation and capture. Finally, the effects of SO_2, SO_3, and HCl on mercury speciation in the presence of SCR catalyst material and a coal flue gas environment will be tested in a bench-scale system.

Methods to Improve Measurement of Mercury in Combustion Flue Gases

The EERC is proposing a two-task effort to improve the mercury measurement results obtained with impinger-based methods, such as American Society for Testing and Materials Method D6784-02 (OH), and CMMs (e.g., Semtech Hg 2000, PS Analytical Sir Galahad, Tekran). Accurate mercury measurement results are required for EPA to properly regulate mercury emissions from coal-burning electric utility steam-generating units. Our efforts will investigate potential sources of analytical bias including:

- The removal of CO_2 from flue gas by a $SnCl_2$–NaOH solution that also captures acid gases and reduces gaseous mercurous and mercuric compounds ($Hg^{1+,2+}$) to Hg^0, which positively biases total mercury concentration measurements.
- Mercury–fly ash interactions that occur on the filter medium (i.e., glass fibers) and promote the formation of $Hg^{1+,2+}$ and/or particle-associated mercury forms (Hg[p]), which negatively biases Hg^0 concentration measurements.

Mercury Control Technologies

Based on health, emissions, and scientific data, the EPA and the Canadian Council of the Ministries of Environment have determined that the amount of mercury emitted from utility power plants should be reduced. In January 2004, EPA released draft rules for utility mercury regulations, and final rules will be released by the end of 2004. With mercury regulations near, improvements in mercury control options and reductions in costs are extremely important and the primary focus of this project.

Sorbent injection is the most mature technology for reducing mercury emissions. Based on current projections, the amount of sorbent needed to serve the U.S. market is expected to be very large. Sorbents can be either injected as a powder or used in fixed or moving beds. The low concentrations of mercury in flue gases from coal-fired systems and high fractions of the mercury emitted in elemental form from many coals result in a low reactivity between AC and mercury. New methods are being developed to increase this reactivity in order to minimize changes required for the utility systems and to reduce costs associated with capital equipment and carbon injection. In addition, research continues on development of control options to optimize use of pollution control equipment available on scrubbed systems.

This project includes five tasks focused on optimizing technologies and minimizing costs for mercury control in coal-fired utilities. Task 1 – Bench-Scale Mercury Control Sorbent Development continues the development and screening of mercury sorbents based on continuous progress in understanding mercury capture mechanisms and sorbent models developed within CATM and elsewhere. An area of particular focus is to better understand the effect of SO_3 on sorbent capacity. Task 2 – Pilot-Scale Tests will be performed to evaluate technical improvements under development in the CATM Program and assess potential cost savings. The pilot-scale tests will be coordinated with other CATM activities relating to transformation, measurement, and control. Task 3 – New Sorbent Development and Mechanisms for Mercury Flue Gas Interactions investigates the chemistry of mercury capture on halide-containing sorbents using the EERC's EFR. Related work will be performed to understand the role of carbon structure in the oxidation and capture of mercury by halides and other reagents. Task 4 – Regeneration directly addresses the need for increased carbon capacity by developing sorbent regeneration technologies. New techniques will be demonstrated for removing the accumulation of sulfates blocking full utilization of sorbent capacity and adding halogen sites to improve reactivity. Task 5 – Mercury Control Using Quenched Halogenated Flue Gas will include proof-of-concept testing of a novel mercury control technique based on maintaining high levels of atomic halogens in the flue gas. The use of halogens to enhance mercury oxidation and control has been shown to be effective. Maximizing the amount of the more reactive species will reduce the total amount of halogen required and the associated cost, as well as minimize the balance of plant impact.

Modeling Mercury Interactions on Activated Carbons

The project will evaluate the interaction of proposed zigzag and armchair carbon graphene edge structures with Hg(II) and acid gases. Quantum mechanical calculations of energy minima will provide thermodynamic and kinetic constants for the proposed intermediates and their conversions. Likewise, the calculations involving interaction of proposed carbenium ion intermediates with Hg^0 will provide useful information on the oxidation of mercury on a carbon surface. The EERC study will utilize a Sun Fire V1280 Server.

The Impact of Mercury–Selenium Interactions on Aquatic Ecosystems

Mechanisms of selenium-dependent decreases in mercury accumulation in lake fish remain poorly understood. This project will examine the molecular, physiologic, and ecologic mechanisms responsible for selenium-dependent mercury retirement from organisms of interest in aquatic food webs through comparison of concentrations of these elements in relevant water, sediment, and biological samples.

Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms

The EERC is developing a fundamental research consortium that will focus on improving the mercury capture efficiency of carbon-based sorbents in flue gases typical of plants firing lignite and other low-chlorine, low-sulfur fuels through a better understanding of mercury sorbent reaction mechanisms. Power plants burning lignite and subbituminous coals have demonstrated significantly higher mercury emission percentages than those burning bituminous coals.

AC injection upstream of pollution control devices such as an FF (baghouse) or ESP is the most mature technology available for mercury control. The projected annual cost for AC adsorption of Hg in a duct injection system is significant. Carbon-to-mercury weight ratios of 3000–18,000 (lb carbon injected/lb Hg in flue gas) have been estimated to achieve 90% Hg removal from a coal combustion flue gas containing 10 μg/Nm^3 of Hg. Many potential mercury sorbents have been evaluated. For ACs to be successful, they must effectively sorb both Hg^0 and Hg^{2+}. The evaluations have demonstrated that the chemical speciation of mercury in the flue gas controls its capture and ultimate environmental fate. The capture and retention of mercury on carbon-based sorbents are dependent upon the particle size, chemical and physical characteristics of the sorbent surface, and flue gas composition. These factors have had a major impact on the effectiveness of mercury control using AC sorbents. However, the physicochemical basis for these impacts is not understood. More efficient carbon-based sorbents are needed to lower the carbon-to-mercury weight ratios used, thus reducing cost.

The project is aimed at developing better sorbents to control mercury emissions in subbituminous- and lignite coal-fired power plants equipped with an FF, ESPs, and wet and dry scrubbers through investigation of surface reaction mechanisms by which carbon sorbents oxidize and capture mercury. The research plan examines flue gas–mercury interactions on carbon sorbents and sorbent surface chemistry, studies the effects of surface modifications to the carbon structure on kinetics and capture, and evaluates the efficiency of ACs prepared with surface modifications in low-chlorine fuel combustion applications. It is anticipated that the results of this research will enhance understanding of mercury–sorbent interactions in flue gas conditions typical of western subbituminous and lignite coal combustion, resulting in recommendations for improvements in AC sorbent effectiveness. This experimental research complements the computational modeling of surface interactions planned under Project 4 by providing a synergistic approach to elucidating the mechanisms that drive oxidation, sorption, and poisoning. The activities proposed under this task build on knowledge gained under Project 3 activities, with an emphasis on commercial participation.

Development of an Oxidized Mercury Spiking System

Periodic testing of CMMs with known concentrations of Hg^0 and reactive gaseous mercury (RGM) is necessary for identifying changes in performance (called relative accuracy testing). The need exists for a reliable source of RGM, preferably mercuric chloride, that can be mounted close to the probe inlet of the CMM. A gold membrane has been used to generate RGM by reacting Hg^0 with Cl_2. Variables affecting this reaction and preliminary data suggest it is possible to reliably convert a substantial percentage of Hg^0 to RGM (>75%) while keeping the reactor small enough to be mounted to the end of a CMM probe. This project will evaluate the possibility of developing a reliable calibration and spiking system for Hg^{2+} using chlorine and a gold membrane as key components of the system.

Canadian Electric Association – Mercury Program R&D Information Clearinghouse

In response to the need identified by CEA, the EERC, with support from the CEA, CATM, and DOE, has created and is maintaining an information clearinghouse on global research and development activities in the areas of mercury monitoring and control. Through this project, the EERC is building on past experience by incorporating efforts with existing EERC, DOE, and CATM programs to effectively satisfy the need for comprehensive quarterly information updates related to mercury measurement and control research and development, both in North America and internationally. The combination of resources from these organizations along with existing EERC efforts relating to the study of the science, measurement, and control of mercury emissions will provide more detailed assessment and reporting of developments in these areas on a quarterly basis.

Mercury and Air Toxic Element Impacts of Coal Combustion By-Product Disposal and Utilization

This effort is focused on the evaluation of CCBs for their potential to release mercury and other air toxic elements under different controlled laboratory conditions and investigate the release of these same air toxic elements in select disposal and utilization field settings to understand the impact of various emission control technologies.

Information collected during Year 1 was evaluated and interpreted together with past EERC data and similar data from other studies. Results were used to determine if mercury release from CCBs, both as currently produced and produced with mercury and other emission controls in place, is a realistic environmental issue.

The 3-year project was designed to develop baseline information on release mechanisms of select elements in both conventional CCBs and modified or experimental CCBs. In Year 1, the modified or experimental CCBs were selected to represent CCBs from systems that have improved emission controls. Controlling these emissions has a high potential to change the chemical characteristics and environmental performance of CCBs.

The development of reliable methods to determine the release of mercury from CCBs provided a means of evaluating the environmental risk associated with CCB management practices. Using appropriate methods to develop a data set of currently produced CCBs and CCBs produced under experimental/simulated conditions provided a baseline for the CCB industry to understand the impact of various emission control technologies.

EERC RELATED RESEARCH PROGRAMS AND EXPERIENCE

The EERC of UND is one of the world's major energy and environmental research organizations. Since its founding in 1951, the EERC has conducted research, testing, and evaluation of fuels, combustion and gasification technologies, emissions control technologies, ash use and disposal, analytical methods, groundwater, waste-to-energy systems, and advanced environmental control systems. Today's energy and environmental research needs typically require the expertise of a total-systems team that can focus on technical details while retaining a broad perspective.

The EERC has well-established working relationships with numerous private and public organizations throughout the United States and the world. These relationships involve contracts with individual utilities, as well as contracts involving groups of utilities participating in cooperative multiclient projects. The EERC has also established working relationships with hundreds of groups worldwide, including federal and state agencies, universities, coal companies, utilities, research and development firms, equipment vendors, architecture and engineering firms, chemical companies, and agricultural products companies.

Of the over 270 EERC employees, which includes positions supported on campus and support staff and students, more than 115 are full-time professional scientists, engineers, and technicians available to address current problems and assess future needs. The EERC engineering and scientific research staff has at its disposal state-of-the-art analytical and engineering facilities. The main EERC facilities—with over 216,000 square feet of laboratory, pilot plant, and office space—are located on the southeast corner of the UND campus. High-severity processes can be developed from conceptual ideas through proof-of-concept demonstration in the flexible EERC reactor systems. Laboratory- and pilot-scale combustors and gasifiers with capacities of up to 4.0 million Btu/hr, as well as diesel and gas turbine simulators, are available for evaluating new fuels and assessing new emission control technologies. Testing equipment is also available for full-scale sampling and measuring of system flow and temperature. Analytical techniques and instrumentation are available for the characterization of solid, liquid, and gaseous materials. Computer modeling and database development are available to assist in predicting the effects of fuel characteristics on conversion and environmental systems. Further environmental research programs include combustion by-products utilization and disposal, wastewater treatment, mine land reclamation programs, an extensive groundwater program, and others. Thus the EERC can provide a total-systems assessment of a wide variety of energy, environmental, and mineral resource research topics.

The EERC has conducted extensive research on the engineering aspects and environmental effects of carbon-based fuels combustion and gasification. Specific program areas include ash and slag chemistry, trace metals in fuels, inorganic transformations, ash deposition, coal combustion chemistry, corrosion/erosion mechanisms, fuels evaluation, fluidized-bed combustion, gas turbines, diesels, slurry combustion, SO_2 control, NO_x control, particulate control, hot-gas cleanup, clean coal technologies, advanced power systems, process development, gasification/combined cycle systems research, waste-to-energy conversion, and synthetic fuels investigations.

Studies of the formation of intermediate ash components in the form of vapors, liquids, and solids have been performed using laboratory-, pilot-, and full-scale testing in combustion and gasification systems to assess the effects of system conditions and fuel characteristics on the environmental impact associated with coal utilization. Recently, the EERC started work on several programs focusing on the behavior and effects of trace metals, including air toxic metals, in coal utilization systems.

The EERC has a wide range of analytical capabilities that have been tailored to fuels, ash, and other materials associated with energy and environmental issues; these techniques include a full range of organic, inorganic, surface and mineralogical, thermal, and physical analysis. Research has been performed to develop methods to determine the association, size, and composition of ash-forming constituents in fuels and conversion residues. Analytical techniques are now available to determine the distribution of phases in fuels, fly ashes, deposits, slags, ash utilization materials, soils, and other materials. Analytical methods development is an ongoing research activity at the EERC. The development of new analysis techniques has been an integral part of several of the EERC's most successful projects. Mathematical modeling of processes such as ash formation, trace metals partitioning, and deposition in gasification and combustion systems is also an ongoing research area at the EERC.

Extensive research on the inorganic and mineral components in fuels and conversion residues has been conducted at the EERC; these data have been related to the potential for ash utilization and environmental aspects of ash disposal. Research efforts in the area of ash utilization and disposal have been focused on 1) detailed characterization of fuels, ashes, and utilization products; 2) carefully controlled experiments and tests to relate the material's chemical and physical properties to the formation of ashes, deposits, and agglomerates; 3) use of the detailed material's data to develop and test cement mixes; and 4) experiments designed to increase the environmental acceptability of ash utilization and disposal. Waste management and disposal issues are intimately tied to a thorough understanding of groundwater issues and other environmental concerns.

The EERC groundwater research programs provide leadership by addressing key groundwater issues for the gas, agricultural, mining, and power industries. Coordinated field and laboratory efforts are based on theory and practice. EERC groundwater research focuses on a fundamental understanding of groundwater occurrence, flow, quality, chemical evolution, and groundwater–contaminant interactions. Groundwater research at the EERC is the key factor in the development of environmentally safe and economically viable residue disposal in situations where utilization is not an economical option.

Electric power generation systems in the future will have to achieve higher efficiencies and likely meet more stringent environmental controls as a result of the Clean Air Act Amendments. In order to meet these challenges, the systems designed to clean entrained ash from the gas stream must be improved. Several research programs at the EERC focus on environmental control systems designed to clean up entrained ash. These programs include investigations of high-temperature FFs, enhanced flue gas conditioning, hot-gas cleanup, flue gas cleanup, NO_x emissions, pulse-jet baghouse performance, duct injection, catalytic fabric filtration, and ceramic filter element evaluation. The more recent concerns involving trace metal emissions have resulted in the development of several programs focusing on the behavior and cleanup of trace metals from coal-fired power generation systems.

EERC EXPERIENCE RELATED TO AIR TOXIC METALS

The following is a partial list of projects at the EERC related to the work scope of the CATM program:

- Nickel Species Emission Inventory for Oil-Fired Boilers – Total funding: $333,333
- Environmental Technologies Acceptance Program – Total funding: $2,155,330

- Air Quality III: Mercury, Trace Elements, and Particulate Matter Conference – Total funding: $596,651
- Air Quality IV: Mercury, Trace Elements, and Particulate Matter Conference – Total funding: $575,000
- Fine Particulate ($PM_{2.5}$) Characterization and Source Apportionment – Total funding: $802,000
- Evaluation of Potential Selective Catalytic Reduction Catalyst Blinding During Coal Combustion – Total funding: $875,333
- Fate and Transport of Trace Elements in Groundwater – Total funding: $1,094,950
- Advanced Power System Studies – Total funding: $116,100
- Evaluation of Mercury Speciation at Power Plants Using SCR and SNCR NO_x Control Technologies – Total funding: $2,242,428
- Determination of the Speciated Mercury Inventory at Four Coal-Fired Boilers Using Continuous Mercury Monitors Midwest Generation EME – Total funding: $193,314
- Longer-Term Testing of Continuous Mercury Monitors – Total funding: $283,508
- Demonstration of a Novel Particulate Sampler for Use with Mercury Continuous Emission Monitors – Total funding: $243,950
- Mercury Control with the Advanced Hybrid Particulate Collector – Total funding: $1,429,618
- Low-Temperature NO_x Reduction Using High-Sodium Lignite-Derived Chars – Total funding: $719,184
- Nickel Speciation of Ambient Particulate Matter in Urban Air – Total funding: $116,667

- Evaluation of Mercury Speciation in a Power Plant Plume – Total funding: $66,122
- Mercury Control Technologies for Electric Utilities Burning Lignite Coals – Total funding: $833,000
- Control of Trace Elements in Gasification Systems– Total funding: $140,000
- Long-Term Monitoring at North Dakota Power Plants – Total funding: $471,667
- Pilot- and Full-Scale Demonstration of Advanced Mercury Control Technologies for Lignite-Fired Power Plants – Total funding: $1,300,000
- Enhancing Carbon Reactivity in Mercury Control in Lignite-Fired System – Total funding: $1,910,433
- Large-Scale Mercury Control Technology for Lignite-Fired Utilities – Oxidation Systems for Wet FGD – Total funding: $469,502
- Mercury Testing at Two North Dakota Power Plants – Total funding: $50,749
- Evaluation of the EnviroScrub Multipollutant System for Mercury Removal – Total funding: $62,473
- Determination of Mercury in a Power Plant Plume – Total funding: $335,000
- Mercury Measurements Using Mercury Continuous Emission Monitors to Evaluate the Effect of Combustion Modification on Mercury Speciation – Total funding: $95,832
- Mercury and Air Toxic Element Impacts of Coal Combustion By-Product Disposal and Utilization – Total funding: $575,000
- Examination of Mercury Sources in the Domestic Oil and Gas – Total funding: $85,000

APPENDIX B

RESUMES OF KEY PERSONNEL

JOHN H. PAVLISH
Senior Research Advisor
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: jpavlish@undeerc.org

Principal Areas of Expertise
Mr. Pavlish's principal areas of interest and expertise include research and consultation on air toxic issues; hazardous air pollutants (HAPs) with emphasis on mercury; the effects of fuel quality and ash on combustion, gasification, and power plant system performance; generation recovery; steam generator performance and reliability; emission reduction control technologies and flue gas-processing equipment; and economic and feasibility analyses on control technologies and energy conversion systems.

Qualifications
B.S., Mechanical Engineering, North Dakota State University, 1984.
A.A.S., Power and Machinery, University of Minnesota - Crookston, 1979.
P.E., Kansas.

Professional Experience

2000 – Center for Air Toxic Metals® Director, EERC, UND. Mr. Pavlish is a Senior Research Advisor and the Director of a multiyear, multimillion dollar Center for Air Toxic Metals (CATM®) program. His responsibilities include developing and managing an array of projects involving air toxic metals (mercury), fuel impacts on energy conversion systems, emissions control technologies for power plant applications, biomass utilization, fuel cell applications, and technical and economic evaluations of various advanced emissions control and energy conversion systems.

1994 – Senior Research Manager, EERC, UND. Mr. Pavlish's responsibilities include managing research programs related to emissions and control of air toxic substances. In an advisory role, Mr. Pavlish provides direction, vision, and technical review of future research programs. His responsibilities also include supervising research on the effects of fuel quality on combustion and gasification system performance; laboratory, pilot, and field testing; planning and performing specific research projects; evaluating the effects of coal quality and ash on power plant performance, generation recovery, steam generator performance and reliability, formation of hazardous air pollutants, assessment of various control technologies, and flue gas processing equipment; creating, developing, maintaining, testing, and validating innovative computer programs; identifying research opportunities and writing proposals and reports to meet client needs; and managing budgets and personnel on multiple projects.

1993 – 1994 Research Manager, Fuels and Materials Science, EERC, UND. Mr. Pavlish's responsibilities included supervising research on the effects of coal quality on coal combustion and gasification system performance; laboratory, pilot, and field testing; planning and performing specific research projects; evaluating the effects of coal quality and ash on power plant performance, generation recovery, steam generator performance and reliability, formation of hazardous air pollutants, assessment of various control technologies, and flue gas processing equipment; creating, developing, maintaining, testing, and validating innovative computer programs; identifying research opportunities and writing proposals and reports to meet client needs; and managing budgets and personnel on multiple projects.

1984 – 1993 Unit Leader/Systems Engineer, Black & Veatch Engineers–Architects. Mr. Pavlish's responsibilities included providing engineering/technical advice; determining and managing resources; developing and monitoring budgets; developing, overseeing, and maintaining project schedules; conducting formal/informal presentations to clients and at technical conferences; writing the technical scope of work, preparing cost estimates, and providing the supervision and organization of the proposal effort; assisting in the preparation and presentation of appropriate marketing material; planning, performing, and coordinating numerous coal quality impact studies; and creating, developing, maintaining, teaching, and validating innovative computer-based programs for evaluating the impacts that coal/ash constituents have on the combustion process, power plant equipment, overall plant performance, and unit/plant/system generation costs.

1979 – 1981 Service Technician, Crookston Implement, Inc., Crookston, Minnesota. Mr. Pavlish's responsibilities included diagnosing and reconditioning engines, transmissions, air conditioning, fuel, and hydraulic systems.

Professional Memberships

- American Society of Mechanical Engineers
- Air & Waste Management Association
- Advisory Member, BiNational Strategy Utility Mercury Reduction Committee
- Advisory Member, Minnesota Pollution Control Agency (MPCA) Research Advisory Committee
- Advisory Member, MPCA Utilities and Taconite Subcommittee
- Advisory Member, Advanced Emissions Control Development Program

Publications and Presentations

- Has authored and coauthored numerous publications.

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

Principal Areas of Expertise

Development and management of complex multidisciplinary programs 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, 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.

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)
  - Chair – Fuel Division 2004 – Duties comprise 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.

KEVIN C. GALBREATH
Research Scientist
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: kgalbreath@undeerc.org

Principal Areas of Expertise
Mr. Galbreath's principal areas of interest and expertise include trace element transformations and speciation in fossil fuel conversion flue gases and the thermal metamorphism of coal mineral matter.

Qualifications
M.S., Geology, South Dakota School of Mines and Technology, 1987.
B.S., Earth Science, North Dakota State University, 1984.

Professional Experience
2001 – Research Manager, Environmental Health, Energy Conversion Systems Group, EERC, UND. Procure and supervise projects involving trace metal emissions and characterization, ambient air quality, and inhalation health effects.

1997 – Manager, Sampling and Analytical Methods Development Program, Center for Air Toxic Metals, EERC, UND. Procure and supervise projects involving trace metal emissions and characterization, ambient air quality, and inhalation health effects.

1994 – 2001 Research Associate, Fuels Performance, EERC. Mr. Galbreath's responsibilities include conducting research on fuels and their combustion and gasification by-products, investigating such topics as fuel quality assessment and production, ash and deposit formation mechanisms, and trace element emissions. He employs full-, pilot-, and bench-scale combustion and gasification systems in solving fundamental problems related to fuel utilization.

1991 – 1994 Research Associate, Natural Materials Analytical Research Laboratory, EERC. Mr. Galbreath's responsibilities included maintaining, operating, and supervising the use of scanning electron microscopes (SEMs) and image analysis systems. He provided analytical support for research programs and developed and applied automated SEM and image analysis techniques.

1990 – 1991 Research Specialist, Inorganic Analytical Research Laboratory, EERC. Mr. Galbreath's responsibilities included operating and maintaining an automated x-ray diffractometer and an energy-dispersive x-ray fluorescence spectrometer and performing mineralogical and chemical analyses on coal, coal combustion products, and related materials (e.g., refractory, slag, bed).

1988 – 1990 Manager, AA/ICP and Chemistry Laboratories, Engineering and Mining Experiment Station, South Dakota School of Mines and Technology. Mr. Galbreath's responsibilities included operating, maintaining, and supervising the use of an AA/ICP spectrophotometer system and performing chemical analyses on a variety of materials (e.g. ores, wastewaters, manufactured products, solid wastes) for the academic, private, and public sectors.

1987 – 1990 Research Scientist, Institute for the Study of Mineral Deposits, South Dakota School of Mines and Technology. Mr. Galbreath's responsibilities included applying analytical geochemistry and modeling techniques to the petrogenesis of terrestrial and lunar materials, employing instrumental techniques including EPMA, SEM, SIMS, AAS, ICAP-AES, quantitative XRD, fluid inclusion microthermometry, and LRMS. He reviewed and edited all proposals and research manuscripts produced by institute personnel.

Professional Memberships

- Air & Waste Management Association, 1998, 1999, 2001, and 2002
- Mineralogical Society of America, 1984–1999
- Geological Society of America, 1983–1987

Publications and Presentations

- Has authored or coauthored over 80 publications

MICHAEL J. HOLMES
Senior Research Advisor
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: mholmes@undeerc.org

Principal Areas of Expertise

Mr. Holmes' principal areas of interest and expertise include emissions control (air toxics, SO_2, NO_x, H_2S, and particulate), fuel processing for production of syngas and feed gas for fuel cells, and process development and economics for advanced energy systems. He has had project management responsibilities on several large-scale projects. He is currently the project manager on two large consortium projects (totaling $7.9 million) to perform long-term field testing of mercury control technologies at lignite-fired utilities. Some other examples of project management experience include the end of Phase II and all of Phase III of the Advanced Emissions Control Development Program (multimillion dollar program focused on mercury control); a program to demonstrate the feasibility of vitrifying low-level radioactive wastes in a slagging combustion system; and several programs for development of spraying systems (dry scrubbing, wet scrubbing, duct injection technology, oil lighters, and heavy oil burners). Mr. Holmes has also had process engineering responsibilities in these and other energy and environmental related projects, as well as experience on multiple commercial contracts in the areas of dry scrubbing, wet scrubbing, and natural gas processing.

Qualifications

M.S., Chemical Engineering, University of North Dakota, 1986.
B.S., Chemistry and Mathematics, Mayville State University, 1984.

Professional Experience

2001 – Senior Research Advisor, EERC, UND. Mr. Holmes is involved in research in a range of areas, including emissions control, fuel utilization, process development, and process economic evaluations. Specific duties include marketing and managing research projects and programs, providing group management and leadership, preparing proposals, interacting with industry and government organizations, designing and overseeing effective experiments as a principal investigator, researching the literature, interpreting data, writing reports and papers, presenting project results to clients, and presenting papers at conferences.

1986 – 2001 Process Development Engineer (Principal Research Engineer), McDermott Technology, Inc., Alliance, Ohio. Mr. Holmes' responsibilities included project management and process R&D for projects involving advanced energy systems, environmental processing, combustion systems, fuel processing, and development of new process measurement techniques. He also served as Project Manager and Process Engineer for projects involving evaluation of air toxic emissions from coal-fired power plants, development of low-cost solutions for air toxic control focused on mercury emissions, demonstration of low-level radioactive liquid waste remediation, in-duct spray drying development, development of an improved oil lighter burner, limestone injection multistaged burning, the ESOx process, the SNRB process, and the limestone injection dry scrubbing process.

Patents

- Low-Pressure Loss/Reduced Deposition Atomizer (U.S. Patent 5,129,583)
- Gas Stabilization for Coal Reburning (U.S. Patent 5,890,442)
- Three Fluid Atomizer (U.S. Patent 5,484,107)
- Enhanced Control of Mercury in a Wet Scrubber Through Reduced Oxidation Air Flow (pending)
- Alkaline Sorbent Injection for Mercury Control (pending)

Publications and Presentations

- Has authored or coauthored over 50 publications, including reports that were proprietary either internally or because of agreements with external customers.

CHRIS J. ZYGARLICKE
Senior Research Manager
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: czygarlicke@undeerc.org

Principal Areas of Expertise
Mr. Zygarlicke currently oversees the EERC Center for Biomass Utilization and is one of five program area managers for the EERC Center for Air Toxic Metals® in charge of the program area entitled Air Toxic Metals Transformation Mechanisms. In the area of biomass utilization, he oversees all biomass-related activities in biopower, transportation biofuels, and bioproducts and chemicals at the EERC. He has managed over $6 million worth of bioenergy, bioproduct, and air pollution research over the past 5 years.

Qualifications
M.S., Geology, University of North Dakota, 1987.
B.S., Geology, University of Wisconsin-Platteville, 1983.

Professional Experience

2000–	Senior Research Manager, EERC, UND. Mr. Zygarlicke's responsibilities include oversight, development, and promotion of the EERC Center for Biomass Utilization (CBU); directing and expanding research and development in the use of biomass resources or feedstocks for energy (i.e., biomass cofiring, small biopower, and formulating boiler fuels); transportation fuels (ethanol, biodiesel, oxygenates for gasoline, biofuels for aviation, and hydrogen); and products (plastics, adsorbents, polymers, and other bioproducts).
1991 – 1999	Research Manager, EERC, UND. Mr. Zygarlicke's responsibilities included managing and supervising a conventional combustion group; supervising projects involving bench-scale combustion testing of various biomass, fossil fuels, wastes, and opportunity fuels; 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, mechanisms of trace metal transformations during coal or waste conversion; and writing proposals and technical project reports.
1987 – 1990	Research Associate, Combustion Studies, EERC, UND. Mr. Zygarlicke's responsibilities included project management and principal investigator duties involving fundamental research of the processes of inorganic transformations during coal combustion and writing proposals and reports applicable to ongoing coal research.

1984 – 1986 Graduate Research Fellow, Energy Research Center, UND. Mr. Zygarlicke's responsibilities included megascopic description and quantification of coal lithotypes, standard coal petrology, chemical and scanning electron microprobe analysis of inorganic constituents in coal, lignite sample collection, and statistical analysis of adsorbed inorganic constituents in low-rank coal.

Publications and Presentations

- Has authored or coauthored over 160 publications including over 40 peer-reviewed journal or book articles related to biomass, coal, oil, combustion, gasification, and air toxic emissions. He has written a guidebook for mitigating ash deposition in coal-fired utility boilers that was published by EPRI.