September 28, 2007

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

Dear Ms. Fine:

Subject: EERC Proposal No. 2008-0075

Enclosed please find an original and seven copies of the Energy & Environmental Research Center (EERC) proposal entitled "Center for Air Toxic Metals® (CATM®) Program Affiliates Membership for the North Dakota Industrial Commission (NDIC)." Also enclosed is the $100 application fee.

Research staff at the EERC are very appreciative of the ongoing support that the NDIC has provided as we seek to find solutions to energy and environmental issues facing our state and our nation. Through CATM, we continue to investigate emerging issues that are most relevant to industry. In doing so, we are able to perform cutting-edge research that provides answers to industry when needed. Recent examples of this would be the mercury-related work we performed that provided answers well in advance of regulations.

We value your past and current participation in our CATM Affiliates Program, and we look forward to the opportunity to continue to serve the needs of our state through the continued membership and support of the NDIC. Should you have any questions as you evaluate your continued participation in this program, please contact me by telephone at (701) 777-5268 or by e-mail at jpavlish@undeerc.org.

Sincerely,

John H. Pavlish
Director, Center for Air Toxic Metals®

JHP/csc

Enclosures

c/enc: Jeff Burgess, Lignite Energy Council

CENTER FOR AIR TOXIC METALS® PROGRAM AFFILIATES MEMBERSHIP FOR THE NORTH DAKOTA INDUSTRIAL COMMISSION

EERC Proposal No. 2008-0075

Submitted to:

Karlene Fine

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

Proposal Amount: $45,000

Submitted by:

John H. Pavlish
Lucinda L. Hamre

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

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John H. Pavlish, Project Manager

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

September 2007

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CENTER FOR AIR TOXIC METALS® PROGRAM AFFILIATES MEMBERSHIP FOR NDIC

ABSTRACT

Energy and industry-related environmental issues—especially as they pertain to toxic trace metals—have gained and continue to receive national attention. Since 1992, when the U.S. Environmental Protection Agency established the Center for Air Toxic Metals (CATM®) Program at the Energy & Environmental Research Center, CATM has answered critical questions related to toxic metal transformations and pathways; sampling, measurement, and analysis of toxic metal emissions; control technologies; computer modeling; and health risks related to toxic concentrations of trace metals. A comprehensive "cradle-to-grave" approach puts this information in the hands of stakeholders through technology transfer, workshops, conferences, training material and courses, and support for general public outreach and education.

The CATM Affiliates Program comprises member organizations that serve several functions—they bring industry perspective to the ongoing forum on air toxic metal issues, provide input regarding emerging issues, and vote to establish future CATM research priorities. Affiliates provide a complement to science advisors who provide peer-review feedback to ensure the technical quality of the research.

While the last 3 years of research has focused primarily on mercury, CATM's research objectives are much broader, driven by the interests and needs of the participating members. As an ongoing program, CATM will continue to work with its members—Otter Tail Power Company, Tennessee Valley Authority, Basin Electric Power Cooperative, TransAlta Corporation, the North Dakota Industrial Commission (NDIC), Doosan-Babcock, and other North Dakota organizations—to identify and perform research that is most critical and of interest. To enable CATM to address long-term issues, NDIC is encouraged to renew its 3-year membership at a fixed-cost price of $45,000. Optionally, a 1-year commitment is available for $18,000.

CENTER FOR AIR TOXIC METALS® PROGRAM AFFILIATES MEMBERSHIP FOR THE NORTH DAKOTA INDUSTRIAL COMMISSION

PROJECT SUMMARY

Energy- and industrial process-related environmental issues—especially as they pertain to toxic trace metals—have gained and continue to receive national attention. To establish a strong research program targeting critical, timely air toxic issues, the U.S. Environmental Protection Agency (EPA) established the Center for Air Toxic Metals (CATM®) Program at the Energy & Environmental Research Center (EERC) in 1992. Since then, CATM has answered many critical questions related to toxic metal transformations and pathways; sampling, measurement, and analysis 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. CATM strives to develop and provide critical data and predictive methodologies to stakeholders that include commercial, research, conservation, and governmental entities, as well as imparting this knowledge to students and the general public.

During the past 3-year period of the North Dakota Industrial Commission's (NDIC's) membership, CATM research has focused primarily on mercury, which will continue to be an emphasis for energy production systems and industrial/commercial processes. However, the program is recognized to be broader in scope, addressing other trace metal issues as they become of critical importance to participating members.

Participating members in the CATM Affiliates Program (CATM AP) typically include those from industry and commercial entities that have a research need and vested interest in resolving air toxic issues. CATM AP is designed to scientifically address these issues and meet the many challenges facing

industry and government and facilitate discussions with regulatory agencies to develop and implement reasonable and effective standards. Membership through CATM AP provides immediate access to a comprehensive air toxics research program. Partnerships through CATM AP with proactive organizations provide the necessary direction to ensure that CATM research meets both short- and long-term goals and needs; Affiliate members help to shape the future program by guiding CATM's research goals and research priorities. Their continued input into the dialogue concerning toxic metals is valued and helps to shape the future of research conducted at the EERC and, specifically, through CATM.

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 CATM-sponsored workshops, educational courses, and conferences, as well as on computer software developed through CATM.
- An up-to-date source of information, publications, and reports.
- Representation and a voice regarding air toxic metal issues, as each member organization designates a CATM advisor who becomes an active, voting member of the Partners Advisory

Committee (PAC) and assists in defining the direction and scope of future research activities conducted through CATM.

- Access to Jointly Sponsored Research Program (JSRP) funds. Sponsorship for CATM, CATM AP, and the JSRP has integrated funds available from the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI), 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 environmental issues germane to energy and industrial 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, incinerating, and industrial systems and on preventing and minimizing the effect of these metals on public health and 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.

Anticipated Program Outcomes

The anticipated outcomes of the CATM Program include the following:

- Elucidation of air toxic transformation mechanisms and pathways in energy production, incinerating, and industrial systems.

- Development and demonstration of emission technologies for toxic metals; various mercury control technologies are presently being developed and tested at the bench, pilot, and full scale. Control technologies for other trace metals that are likely to be regulated/controlled in the future are also covered under CATM's scope research and will gain a more prominent role in future activities.
- Development and demonstration of environmentally sound methods to utilize and dispose of residuals.
- Development and validation of methods to sample, measure, 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. Many of the CATM and EERC research projects related to air toxic metals are described in Appendix A, showing results of CATM's research.

CATM uses a cradle-to-grave approach related to energy production (from fossil fuels, wastes, and other feedstocks) and industrial production in an environmentally responsible manner; to reduce emissions of air toxic metals; and to assist impacted organizations to meet pending regulations and control challenges. This approach involves developing a detailed understanding of fuels or feedstock characteristics, transformation of fuel components during conversion, development of appropriate sampling/analytical techniques, effective control technologies, methods to utilize and dispose of residuals, and related health impacts of toxic metal concentrations.

To address these challenges, CATM is organized into five integrated but separate program areas; the program structure is outlined below.

Program 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 or feedstock 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.

Program Area 2 – Analytical Methods Development. Research in this program area includes the development of methods to determine the abundance and association of air toxic metals in a variety of fuel resources, feedstocks, and wastes; measuring and speciating the metals in the various process streams from combustion, gasification, and industrial 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 facilities is the ultimate goal.

Program Area 3 – Control Technologies. Development of effective control technologies for industry is a high priority for CATM. Research in this key program area focuses on pursuing and identifying opportunities for minimizing and controlling trace element emissions in combustion, gasification, and industrial 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 injection techniques (including precombustion, combustion, and postcombustion methods for energy systems) 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.

By-products from combustion, gasification, and industrial systems are inevitable, and although the amount of by-products produced is variable depending on the system, consideration is warranted regardless of the quantity. Coal and other fuels produce a high volume of by-product materials in varying forms containing different metal concentrations. Developing proper management options for these materials, whether they are disposed of or utilized, is essential and is a CATM goal. Other industrial applications are likely to produce by-products that may require special handling and/or treatment processes.

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 invertebrate, 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 trace metal (especially 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 invertebrate and animal studies, and examining heavy metal accumulation in the development and pathology of cardiac disease. As research in this area proceeds, development of predictive tools will be an important contribution to the arena of toxic metals research and physiological risk.

Program Area 5 – Technology Commercialization and Education. Efforts in this research area focus on disseminating technical information (concerning trace metals) produced by CATM to Affiliates 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 training programs; 3) coordinating CATM annual meetings with the PAC, Science Advisory Committee (SAC), and EPA as an invited party; 4) coordinating research planning activities through the Research Advisory Council (RAC) and coordinating research review by the SAC; and 5) overall administration of CATM AP.

DELIVERABLES

CATM has been and continues to be a leader in research on air toxic metals and provides its research to CATM Affiliates, attendees of CATM's 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, waste incineration, gasification, and industrial 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 a center within the EERC, CATM adheres to this system. As part of the QMS, an EERC quality manual was developed and put into place as policy to guide research projects. Additionally, the CATM Program at the EERC has a quality assurance (QA) plan in effect that addresses trace metal emissions research at the EERC; CATM's QA and quality control (QC) plans have been reviewed and approved by EPA. In addition, EPA requires CATM to prepare QA project plans for review and acceptance prior to beginning active research. Compliance with the guidelines established by these guiding documents and procedures ensures that the EERC adequately fulfills governmental and private client requirements relating to quality and compliance with applicable regulations, codes, and protocols, resulting in research and data of the highest quality.

As stated earlier, CATM AP 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 over the last 12 years. This success can be expected to continue over the next 3 years. These successes are highlighted in Appendices A and B.

Peer review is an integral factor of CATM's quality management system. On an annual basis, the CATM RAC, which comprises the SAC and CATM AP members, reviews and critiques past, current, and future research. In addition, numerous peer-reviewed (and non-peer-reviewed) technical and scientific documents (papers, reports, articles, etc.) are published (see annual report in Appendix B). Last, periodic peer reviews are conducted by an EPA-appointed panel that oversees all dimensions of CATM's structure, research, and reporting. The 2003 peer review panel indicated that CATM was among the finest of the EPA-funded centers. CATM is expecting another peer review assessment soon.

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. The issues pertaining to energy production, industrial systems, and environmental responsibility have gained public attention, both domestically and internationally.

To help address these issues, the CATM Program at the EERC was established in 1992. Since then, the EPA-funded CATM Program has answered many critical questions related to health risks of toxic levels of trace metals, toxic metal transformations and pathways, sampling and measurement of toxic metal emissions, and related toxic metal control technologies. CATM work has furthered the 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, regular meetings, and workshops and conferences.

Without question, the demand for a strong research program targeting critical and timely air toxic issues is greater now than ever before. As an example, comments received in reference to the 2005 Clean Air Mercury Rule and subsequent lawsuits in the United States show that many key questions remain concerning mercury—both for the electric generation sector and other industries. This is also the case for our neighbors in Canada and other countries.

Other industries including waste-to-energy, industrial production, and cement industries are also facing more restrictive trace metal emission rules with which they must comply. Although numerous control strategies are being evaluated by several entities, those organizations which are affected by regulation must strive to put these strategies into effect. Several questions related to toxic trace metals continue to be raised and must be answered quickly—especially in an energy sector that is already facing many challenges, although other industries are being impacted. Although the past 4 years has focused primarily on mercury, CATM's research has been focused and will continue to focus on the broader scope of toxic metals research, with continued emphasis at this time on mercury.

QUALIFICATIONS

The EERC has been conducting timely, relevant research for over 50 years. With a staff of over 300, 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. Resumes for key personnel can be found in Appendix C.

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

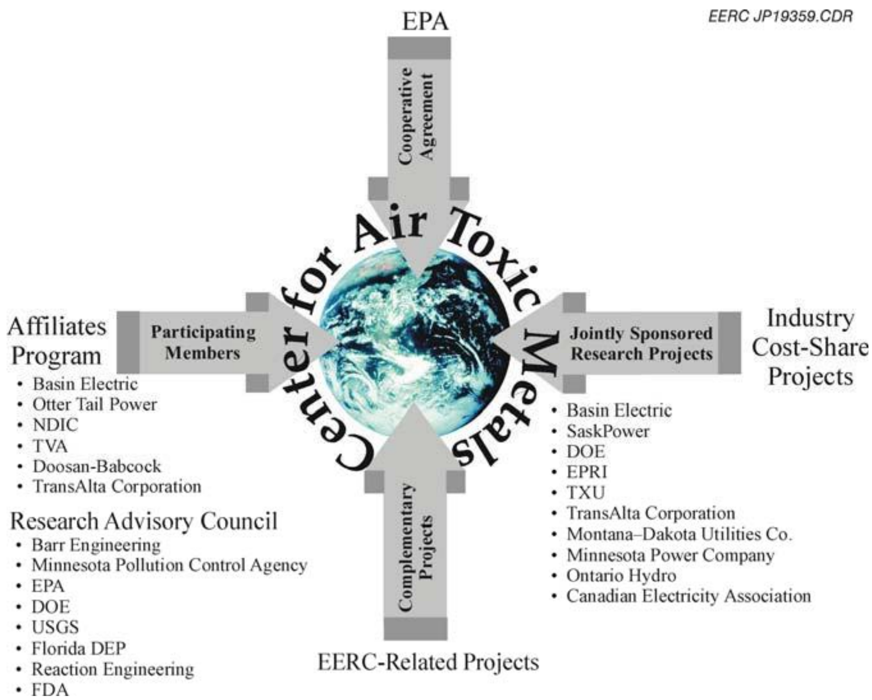

Figure 1. CATM – a multiclient program at the focal point of metals research.

that are focused on solving near- and long-term problems related to energy and environment. See Appendix A for EERC and CATM research projects of interest.

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 research on air toxic metals. Qualified managers for each of the 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 C.

RESEARCH ADVISORY COUNCIL

The CATM RAC consists of two committees, referred to as CATM's PAC and SAC. The PAC comprises representatives from each CATM Affiliates organization. The role of the PAC is to provide direction and feedback to the CATM Director and program area managers, as well as to identify and prioritize research needs.

The role of the SAC, which consists of knowledgeable members from industry, government, and academia, is to ensure that the research activities that are proposed and conducted through CATM are scientifically valid, have a strong experimental plan, utilize appropriate analytical techniques, and meet overall QC guidelines.

On an annual basis, the CATM RAC reviews the deliverables from the previous year's research and discusses the proposed ideas for the next year's research. Although the PAC votes on the ideas, the SAC provides formative counsel during the annual meeting and also reviews the proposal prior to its submission to EPA. Program area leaders within CATM respond to pointed review questions regarding the focus of the project, experimental design, and possible ways to optimize resources.

VALUE TO NORTH DAKOTA

In our country and in our state, the issues pertaining to energy and industrial production systems and environmental responsibility issues are increasingly under scrutiny and have ever greater impacts on our economy, the way business is conducted, 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, the EERC has worked closely with North Dakota entities to further develop and field-test several mercury control technologies that will allow North Dakota and Canadian stakeholders to meet environmental regulations. CATM continues to work to evaluate the impact of using various mercury control technologies; part of this applied research is to determine the impact of these technologies on other flue gas constitutents, especially other trace metal transformations and capture. Researchers from the EERC and the CATM Program will continue to lead in the research and development of these effective technologies, which will help to enable North Dakota power plants to meet future challenges in an environmentally responsible and economical manner.

CATM Affiliates Contribution to North Dakota's Interests

The CATM AP is designed to meet the many challenges, especially those that are just emerging, facing industry and government and aids industry in interfacing with regulatory agencies and government in a constructive manner. Membership immediately and continuously provides the participant with access to a comprehensive scientific air toxics research program, including the most current research information and research professionals who act as conduits to other research organizations, commercial entities and other stakeholders. Proactive organizations seeking to minimize risk and provide input into long- and short-term planning will benefit greatly from this program.

Affiliates Membership Benefits

Membership in CATM AP 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 CATM-sponsored workshops, educational courses, and conferences, as well as on computer software developed through CATM.
- Up-to-date source of information, publications, and reports.

- Representation and a voice regarding air toxic metal issues, as each member organization designates a CATM advisor who becomes an active, voting member of the PAC and assists in defining the direction and scope of future research activities conducted through CATM.
- Access to JSRP funds. Sponsorship for CATM, CATM AP, and the JSRP has integrated funds available from EPA, DOE, EPRI, multiclient consortia, and individual sponsors.

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 numerous publications, including several that are peer-reviewed. The CATM Director's management efforts will be guided by three management groups: CATM AP members through PAC, EPA project management, and RAC.

The EERC has been conducting timely, relevant research for over 50 years. With a staff of over 300, 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 and CATM research projects of interest.

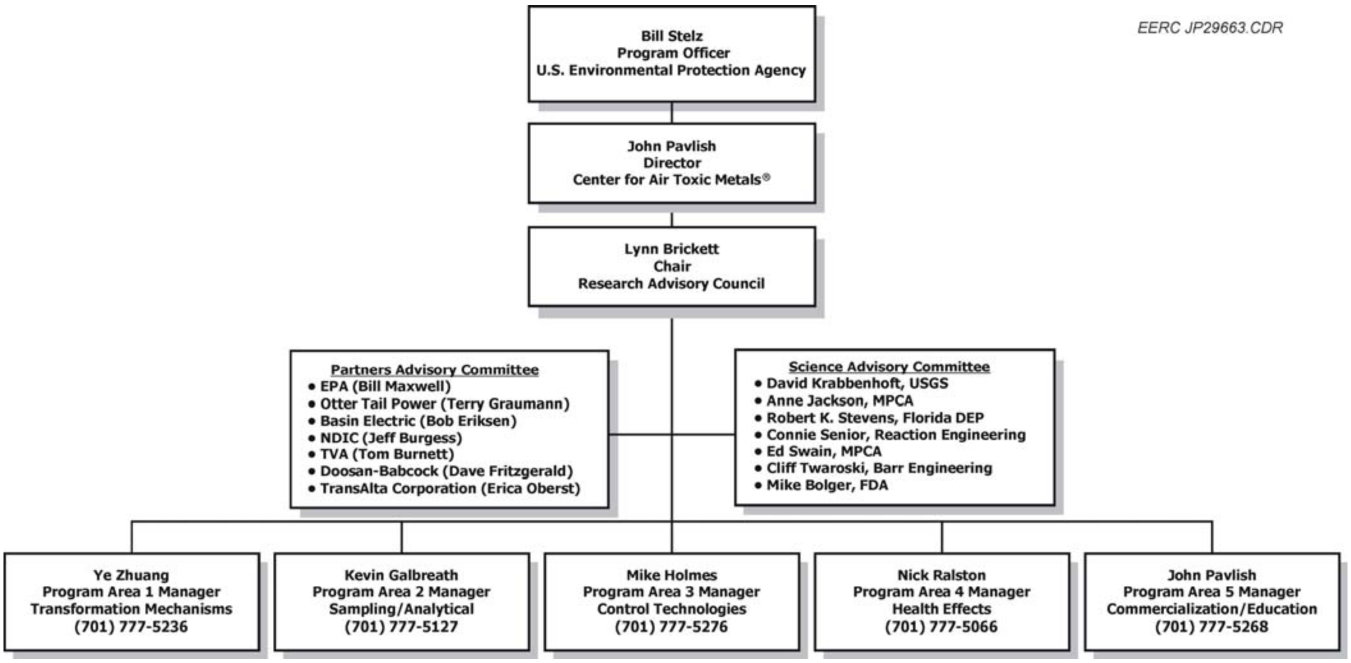

Figure 2. Organizational chart for the CATM Program.

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 often extending to multiple years. CATM encourages its members to provide longer-term commitments to facilitate projects whose long-term scope requires more than 1 year to adequately research; a 3-membership is encouraged for new and renewing members.

COST

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 NDIC renew its membership and fund a 3-year commitment for $45,000 on a fixed-cost basis. A 1-year membership is also available for $18,000.

CATM AP is a program distinct from the federal funding provided by EPA and, thus, is not reported to EPA as cost share. Present Affiliates include Basin Electric Power Cooperative, Doosan-

Babcock, the NDIC, Otter Tail Power Company, Tennessee Valley Authority, and TransAlta Corporation. In addition to CATM AP, EPA has provided base funding in excess of $17 million and continues to fund CATM at approximately $1–$2 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 the University of North Dakota (UND). The EERC receives no appropriated funding from the state of North Dakota and is funded through federal and nonfederal grants, contracts, and other agreements. Although the EERC is not affiliated with any one academic department, university faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

Intellectual Property

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

Budget Information

The proposed work will be done on a fixed-price basis. The project manager may, as dictated by the needs of the work, incur costs in accordance with Office of Management and Budget (OMB) Circular A-21 found at www.whitehouse.gov/omb/circulars. Escalation of labor and EERC recharge center rates is incorporated in to the budget when a project's duration extends beyond the current fiscal year. Escalation is calculated by prorating an average annual increase over the anticipated life of the project.

The cost of this project is based on a specific start date indicated at the top of the EERC budget. Any delay in the start of this project may result in a budget increase. Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

Salaries: The EERC employs administrative staff to provide required services for various direct and indirect support functions. Salary estimates are based on the scope of work and prior experience on projects of similar scope. 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. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project will be paid an amount over their normal base salary, creating an overload which is subject to limitation in accordance with university policy. Costs for general support services such as contracts and intellectual property, accounting, human resources, purchasing, shipping/receiving, and clerical support of these functions are included in the EERC facilities and administrative cost rate.

Fringe Benefits: Fringe benefits consist of two components which are budgeted as a percentage of direct labor. The first component is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services, and covers vacation, holiday, and sick leave (VSL). This percentage is applied to direct labor for permanent staff eligible for VSL benefits. The second component is estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions.

Travel: Travel is estimated on the basis of UND travel policies which can be found at www.und.edu/dept/accounts/policiesandprocedures.html. Estimates include General Services

Administration (GSA) daily meal rates. Travel may include site visits, field work, meetings, and conference participation as indicated by the scope of work and/or budget.

Equipment: If equipment is budgeted, it is discussed in the text of the proposal and/or identified more specifically in the accompanying budget detail.

Supplies – Professional, Information Technology, and Miscellaneous: Supply and material estimates are based on prior experience and may include chemicals, gases, glassware, nuts, bolts, and piping. Computer supplies may include disks, paper, memory, software, and toner cartridges. Maps, sample containers, minor equipment, signage, and safety supplies may be necessary as well as other organizational materials such as subscriptions, books, and reference materials.

Subcontracts/Subrecipients: Not applicable.

Professional Fees/Services (consultants): Not applicable.

Other Direct Costs

Communications and Postage: Telephone, cell phone, and fax line charges are generally included in the facilities and administrative cost. Direct project costs may include line charges at remote locations, long-distance telephone, postage, and other data or document transportation costs.

Office (project-specific supplies) and Printing: General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are generally included in the facilities and administrative cost. Budgeted project office supplies include items specifically related to the project such as copies and printing.

Food: Food 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.

Professional Development: Fees 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 by the research team.

Operating Fees and Services – EERC Recharge Centers, Outside Labs, Freight: EERC recharge center rates for 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 production of such items as report figures, posters, and/or PowerPoint images for presentations, maps, schematics, Web site design, professional brochures, and photographs.

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

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

Facilities and Administrative Cost: The facilities and administrative rate (indirect cost rate) included in this proposal became effective July 1, 2005. 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 subawards in excess of the first $25,000 for each award.

TAX LIABILITY

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

CONFIDENTIAL INFORMATION
No confidential information is included in this proposal.

REFERENCES
None.

APPENDIX A

CATM AND EERC RESEARCH PROJECTS RELATED TO AIR TOXIC METALS

CATM RESEARCH PROGRAMS AND RELATED EERC EXPERIENCE

CATM EXPERIENCE

The Center for Air Toxic Metals® (CATM®'s) success as a program includes many noteworthy accomplishments. Among these is the outstanding success of the Air Quality Conferences, which 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. In addition, CATM researchers have been involved in ongoing international venues, including the Mercury Emissions from Coal International Working Group and other international forums. 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 recently 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 conducted through the EERC and the CATM Program, including overviews of the work that is presently being conducted.

EERC-RELATED RESEARCH PROGRAMS AND EXPERIENCE

The University of North Dakota's (UND's) EERC 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, emission 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 product companies.

Of the nearly 300 EERC employees, which includes positions supported on campus and support staff and students, more than 180 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 245,000 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-product 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.

Since 1990, the EERC has conducted over 200 mercury projects, ranging from fundamental mercury chemistry projects to full-scale demonstrations of mercury control technologies. Through its years of experience, the EERC has gained expertise in measurement that is among the best in the world. For over 16 years, the research staff at the EERC has conducted mercury testing involving both wet-chemistry methods (the Ontario Hydro [OH] method) and continuous mercury monitors (CMMs).

The EERC owns and maintains testing equipment to conduct full-scale projects involving sampling and measurement and has a highly trained team of technicians who are able to conduct measurement sampling with great care. The EERC, especially through CATM®, continues to improve upon existing measurement methods, as well as to develop new analytical methods and instrumentation to ensure that measurement techniques and analysis are always progressing. In addition, the EERC has worked extensively with several emission monitor vendors to assist them in continuous improvement of their instruments, software, and protocols. This expertise has resulted in better analyzers available to the general research community and commercial clients.

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 system 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 fabric filters (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.

The EERC and CATM have been working with other industries as well to ensure that their air toxic metal needs are being addressed. At this time, the Center is working with commercial clients to address needs related to gasification, waste-to-energy, and the cement industries. These research areas, along with other commercial client needs, will encompass greater resources in the future. In addition, although CATM and the EERC are considered world leaders in mercury research, other trace metals are increasingly becoming focal points of concern. CATM's research will increasingly address trace metals other than mercury.

The EERC has well-established working relationships with numerous private and public organizations worldwide. These relationships involve contracts with individual utilities and groups of utilities participating in cooperative multiclient projects. The EERC also has 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 product companies. New technologies can be developed from conceptual ideas through proof-of-concept demonstration in the flexible EERC reactor systems.

EERC EXPERIENCE RELATED TO MEASUREMENT OF AIR TOXIC METALS

The EERC has over 50 years of coal research, with extensive experience on low-rank coals (lignite and subbituminous). Since 1990, the EERC has conducted over 200 mercury projects, ranging from fundamental mercury chemistry projects to full-scale demonstrations of mercury control technologies.

The EERC has been the primary contractor for several full-scale mercury control measurement projects cofunded by DOE, electric utilities, and other commercial entities under Phases I, II, and III of the "Mercury Control Technology Field Testing and Related Mercury Control Research and Development" Program. In addition, the EERC has been conducting measurement sampling at utilities since 1996, numbering over 50 coal-fired units. We have learned and continue to disseminate information related to measurement errors and biases that can be introduced during measurement and ways to overcome several sampling problems. Further, the EERC goes significantly beyond the requirements of the OH method to ensure that the lessons learned over the years result in quality, reliable data.

Over the last few years, the EERC has conducted continuous mercury monitor training sessions for government, research, and utility personnel.

While the EERC is proud of its ability to deliver quality research outcomes in measurement, analysis, and interpretation to government entities in both the United States and Canada, almost all EERC mercury projects have been at least partially funded by industrial sources including the Electric Power Research Institute, over 45 different power companies, and vendors of control technologies.

The EERC is considered a leading expert in mercury measurement in coal-fired flue gas. The OH mercury speciation method (ASTM [American Society for Testing and Materials] International D6784-02) was partially developed and validated by the EERC. In fact, the method was written for ASTM by EERC personnel. For over 5 years, the EERC has actively worked with vendors of mercury continuous emission monitors to help them provide instruments that will effectively meet the needs of power producers and the research community. The EERC has done mercury sampling at over 50 different plants in North America during the past 10 years as part of various research programs.

Several power plants have asked the EERC to provide analytical support and quality assurance/quality control (QA/QC) control for their programs. The EERC has extensive experience with the OH sampling method, U.S. Environmental Protection Agency (EPA) Method 29, and EPA Method 101 analysis for mercury, as well as analysis of coal, fly ash, wet flue gas desulfurization (FGD) materials, and other coal combustion by-products. The EERC participates in extensive round-robin testing and maintains a rigorous centerwide QA/QC program.

Much of the new measurement and analytical research is conducted through the CATM Program, which is further reported on in the annual report in Appendix B.

CATM MERCURY-RELATED EXPERIENCE

The CATM Program is built on successful partnerships and proven accomplishments. Among these is the outstanding success of the Air Quality Conferences, which 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 DOE and 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 measurement-related research that has been, or is currently being, conducted through the CATM Program. For more detailed information, please refer to CATM's Web site at www.undeerc.org/catm, as well as the annual report for CATM found in Appendix B.

Mercury Transformations in Coal Combustion Flue Gas

CATM continues to seek cost-effective ways to transform elemental mercury to the oxidized form in order to promote mercury capture. This has previously proven most challenging in low-chlorine coals, but recent tests with coal additives have been very successful.

Research has provided additional insights into the mechanisms by which both heterogeneous and homogeneous transformations occur in coal combustion systems to affect mercury, and the role of other flue gas components in these complex reactions is becoming clearer.

Reactions between gaseous mercury and halogen species in a high-temperature flue gas regime are very fast. By adding halogens into the combustion zone, the mercury–flue gas chemistry is quite different from the normal low-rank, halogen-lean coal flue gas. Ongoing mercury kinetics studies have indicated that kinetic effects limiting the transformation of Hg^0 at temperatures >400°C are greatly reduced by the addition of halogens in the combustion zone.

CATM continues to evaluate unburned carbon for its benefits as a mercury sorbent, both with and without additives.

The specific mechanisms by which active sites sorb mercury continue to be studied, but research this year shows that sulfur likely plays a prominent role.

HCl is the critical factor in determining the level of mercury oxidation with and without an SCR. However, an SCR was seen to improve mercury oxidation with increased HCl. SO_2/SO_3 was found to have minimal effect, with SO_2 slightly reducing mercury and SO_3 slightly improving mercury oxidation, but both effects were statistically insignificant.

Measurement of Halogens

The overall goal of this ongoing project is to use existing methods and develop improved methods for evaluating the effects of halogens on the conversion of Hg^0 to inorganic and organic Hg compounds with coal combustion flue gas. This project is currently under way to accomplish two main goals:

- Perform Hg halogen analyses on coal, fly ash, and Hg sorbent samples and statistically evaluate the results for interelemental correlations.
- Modify and simplify EPA Method 26A for determining the concentrations and speciation of Cl and Br in coal combustion flue gas.

Development of a Laser-Based Mercury Continuous Emission Monitor

This work applied fundamental research toward developing a laser-based method for measuring elemental mercury. Experiments were conducted using two different excitation schemes as well as argon and nitrogen carrier gases. Research will continue toward improving the detection limit of this method.

Methods to Improve Measurement of Mercury and Chlorine in Combustion Flue Gases

The EERC is striving to improve the mercury measurement results obtained with impinger-based methods, such as ASTM International Method D6784-02 (Ontario Hydro), and a CMM (e.g., Semtech Hg 2000, PS Analytical [PSA] Sir Galahad, Tekran) by investigating a potential source of analytical bias: the mercury–fly ash interactions that occur on filter media (i.e., glass fibers) may promote the formation of Hg^{1+}, $^{2+}$ and/or particle-associated mercury forms (Hg[p]), thus negatively biasing Hg^0 measurements.

A second-generation, small ESP was constructed, tested, and successfully showed that it could be used to effectively remove most of the bias that is introduced by the fly ash on accurate measurement of Hg, Cl, and HCl in flue gas.

Development of an Oxidized Mercury-Spiking System

This project focused on design of an oxidized mercury-spiking system based on the catalytic effects gold films can exhibit on mercury and chlorine.

Development of Mercury Control Technologies

Bench-scale tests were performed to evaluate and aid in the development of Hg sorbents and additives.

The effect of SO_3 on sorbents was explored by completing a full-factorial matrix of tests with four variables at two levels. The results showed that SO_3 in the flue gas mixture can have varying effects on the reactivity and capacity of the activated carbon (AC) sorbents. NO_2, NO, and O_2 are the contributors to mercury oxidation at the carbon surface, while HCl has a small effect on the oxidation rate.

A novel mercury sorbent enhancement technology has been developed to reduce the amount of AC required for mercury control in coal-fired utilities.

Particle-size distributions of AC injected into flue gas are not generally dependent on method of injection. However, using a piston/wire brush dry powder dispenser seemed to offer better performance than the standard volumetric screw feeder, which tended to agglomerate the AC.

Modeling Mercury Speciation in Coal Combustion Systems and Interactions on Activated Carbon

A quantum mechanical approach has been employed in the study of mercury interactions with flue gas components on the AC surface. Initial results based on free energy and enthalpy data for the elementary reactions on the AC surface seem to indicate that predominantly aromatic compounds will suffer a larger energy penalty in oxidizing elemental mercury at room temperature as compared to aliphatic counterparts. For example, the insertion step of Hg^0 on the graphene edge surface is not thermodynamically favorable at 298.15 K. On the other hand, surface activation by acidic flue gas components and the capture of Cl ions by the chemisorbed mercury adducts is feasible and may yield organomercury chlorine compounds, which eventually release the captured Hg as $HgCl_2$ at breakthrough.

Developing SCR Technology Options for Mercury Oxidation in Western Fuels

The project evaluated the ability of selective catalytic reduction (SCR) catalysts to oxidize mercury. Used SCR catalysts and new SCR catalysts formulated to enhance mercury oxidation, as well as the use of additives to enhance oxidation, were tested. The first catalyst tested was an existing formulation that Haldor Topsoe currently manufactures. A second set of tests was conducted on several new formulations developed in cooperation with Haldor Topsoe. The catalyst was tested in flue gas compositions similar to what is found in plants burning Powder River Basin (PRB) and lignite coals. The use of oxidation additives to promote the formation of oxidized mercury to levels of those seen for eastern coals was a primary emphasis.

The results of the baseline test indicated elemental mercury concentrations in the range of 85%–100%. The testing of three other catalysts, resulted in elemental mercury concentrations of 90%–100%, 70%–100%, and 60%–100%.

A catalyst and an additive injected upstream was tested, yielding promising oxidation. However, data were limited, and additional testing is needed.

Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms

Fort Union lignite-fired power plants have shown a limited ability to control mercury emissions in currently installed electrostatic precipitators (ESPs), dry scrubbers, and wet scrubbers. This low level of control can be attributed to the high proportions of elemental mercury present in the flue gas, which occurs in low-acid flue gas environments. The overall goal of the project is to improve the mercury capture efficiency of carbon-based sorbents in flue gases typically resulting from firing lignite and other low-chlorine, low-sulfur fuels through a better understanding of mercury–sorbent reaction mechanisms.

Based on the results of experiments conducted thus far, the carbon surface collects SO_2 from the flue gas and forms S(VI). At the same time, the chlorine content at the sorbent surface decreases. This continues until the sorbent capacity is reached.

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

The objective of this effort was to provide information on the stability of mercury and air toxic elements associated with coal combustion by-products (CCBs) under conditions relevant to typical CCB management practices. Controlled laboratory experiments were used to evaluate a wide variety of fly ash samples and FGD materials. Samples were obtained primarily from full-scale coal-fired power plants under both normal operating conditions and during mercury emission control demonstrations. The following are some preliminary observations:

- Analysis of the carbon forms data revealed that samples with anisotropic or isotropic coke as the dominant carbon form included samples with the higher mercury content. Those samples also generally contained AC from mercury emission control.

- Total mercury content and leachate concentrations of samples generated both with and without mercury emission controls present did not correlate and were independent of the short-term leaching procedures used.

- Results obtained from experiments to evaluate long-term ambient-temperature release of mercury from CCBs ranged from a net release to a net sorption of mercury. Replicate tests frequently yield highly variable results, but the extremely low levels both of sorption and release of mercury indicate that this release mechanism has very low potential to impact the loading of mercury in the atmosphere.

- Mercury is generally released at temperatures greater than 200°C, and in many samples, all the mercury is released when exposed to a temperature of 750°C.

- Organomercury compounds are present in leachates and vapor generated in experiments performed to evaluate mercury release under microbiologically mediated conditions.

Technology Commercialization, Education, and Publication

To facilitate the transfer of technical information produced by CATM, several communication vehicles are used, including participation in both domestic and international conferences, symposia, workshops, and other educational programs, and annual meetings; quarterly reports on topical issues related to mercury through a collaborative project funded by CATM Affiliates, DOE, and CEA; and the publication of a newsletter that is also available electronically. In addition, the CATM Director and staff provide input into various public forums during the year to assist in the development of venues of technology transfer that may not be directly funded by CATM.

APPENDIX B

CATM ANNUAL REPORT 2006

This appendix can be accessed at the following web site location:

http://www.undeerc.org/catm/programareas.html

APPENDIX C

RESUMES OF KEY PERSONNEL

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

Principal Areas of Expertise

Mr. Pavlish is a Senior Research Advisor and the Director of the multiyear, multimillion dollar Center for Air Toxic Metals® (CATM®) Program at the Energy & Environmental Research Center of the University of North Dakota. He has over 20 years of experience with advanced combustion systems to solve operational and environmental problems. His principal areas of interest and expertise include air toxic issues; hazardous air pollutants (HAPs) with special emphasis on mercury; and coal combustion process and power plant system performance, including economic and feasibility analyses. Mr. Pavlish is a registered professional engineer.

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–Present: 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 fundamental and applied projects involving air toxic metals (especially mercury), fuel impacts on energy conversion systems, emissions control technologies, biomass utilization, fuel cell applications, and technical and economic evaluations of various advanced emissions control and energy conversion systems.

1994–2003: Senior Research Manager, EERC, UND. Mr. Pavlish's responsibilities included managing research programs related to emissions and control of air toxic substances. His responsibilities also included planning and supervising energy research programs involving laboratory, pilot, and field testing including 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.

1993–1994: Research Manager, Fuels and Materials Science, EERC, UND.

1984–1993: Unit Leader/Systems Engineer, Black & Veatch Engineers–Architects, Kansas City, Missouri. Mr. Pavlish's responsibilities included providing engineering/technical advice; developing, overseeing, and maintaining projects for coal quality impact studies to evaluate the impacts that coal/ash constituents have on the combustion process, power plant equipment, overall plant performance, and unit/plant/system generation costs.

Patents

Olson, E.S.; Holmes, M.J.; Pavlish, J.H. Process for Regenerating a Spent Sorbent. International Patent Pending PCT/US04/12828, April 23, 2004.

Olson, E.S.; Holmes, M.J.; Pavlish, J.H. Sorbents and Flue Gas Additives for the Oxidation and Removal of Mercury. U.S. Provisional Patent, August 30, 2004.

Professional Memberships and Activities

- U.S. Representative, Mercury Emissions from Coal (MEC) International Experts Working Group on Reducing Emissions from Coal, in association with the International Energy Agency (IEA) Clean Coal Centre, 2004 – present
- Advisory Member, BiNational Strategy Utility Mercury Reduction Committee
- Advisory Member, Minnesota Pollution Control Agency (MPCA) Research Advisory Committee
- Advisory Member, Advanced Emissions Control Development Program

Selected Publications and Presentations

Thompson, J.; Pavlish, J.; Martin, C.; Wiemuth, B.; Pletcher, S. Enhanced Sorbent Injection for Mercury Control at TXU Power's Big Brown Station. Presented at 2007 Electric Power Conference and Exhibition, Chicago, IL, May 1–3, 2007.

Center for Air Toxic Metals. *Center for Air Toxic Metals 2005 Annual Report*; Annual Report of the Center for Air Toxic Metals, organized and administered through the University of North Dakota Energy & Environmental Research Center, for U.S. Environmental Protection Agency Contract No. R 827649-01; 2006.

Hill Brandt, K.L.; Holmes, M.J.; Wocken, C.A.; Pavlish, J.H.; Eriksen, B.; Brickett, L.A. Field Testing of Mercury Control for Lignite-Fired Systems with Activated Carbon and Sorbent Enhancement Additives. In *Proceedings of the 9th Annual Electric Utilities Environmental Conference*; Tucson, AZ, Jan 22–25, 2006.

Jones, M.L.; Pavlish, J.H. Ash Behavior & Mercury Control in Coal Combustion Short Courses, Maui, HI, Nov 30 – Dec 1, 2006.

Pavlish, J.H.; Almlie, J.C. EERC Field Test Experience of Mercury Control Technologies for Power Plants Burning U.S. Western Coals. In *Proceedings of the Symposium on Western Fuels: 20th International Conference on Lignite, Brown, and Subbituminous Coals*; Denver, CO, Oct 24–26, 2006.

Pavlish, J.H. Understanding Mercury Speciation, Variability, and Operational Impacts on Mercury Control. Presented at Mercury 2006, 8th International Conference on Mercury as a Global Pollutant, Madison, WI, Aug 6–11, 2006; Paper No. S-622.

Pavlish, J.H.; Laudal, D.L.; Holmes, M.J.; Hamre, L.L.; Musich, M.A.; Weber, G.F.; Hajicek, D.R.; Pavlish, B.M. *Technical Review of Mercury Technology Options for Canadian Utilities – A Report to the Canadian Council of Ministers of the Environment*; Final Report; EERC Publication 2005-EERC-03-07; Energy & Environmental Research Center: Grand Forks, ND, March 2005.

Zhuang, Y.; Zygarlicke, C.J.; Thompson, J.S.; Pavlish, J.H. Chlorine-Induced Mercury Transformation in a High-Temperature Coal Flue Gas. In *Proceedings of Air Quality V: Mercury, Trace Elements, SO_3, and Particulate Matter Conference*; Arlington, VA, Sept 19–21, 2005.

Dunham, G.E.; Pavlish, J.H. State of the Art of Mercury Measurement for Coal-Fired Utilities. Abstract presented at the EPA Environmental Research Seminar, Denver, CO, May 2004.

Olson, E.S.; Laumb, J.D.; Benson, S.A.; Dunham, G.E.; Sharma, R.K.; Mibeck B.A.; Crocker, C.R.; Miller, S.J.; Holmes, M.J.; Pavlish, J.H. The Mechanistic Model for Flue Gas–Mercury Interactions on Activated Carbons: The Oxidation Site. *Prepr. Pap.—Am. Chem. Soc., Div. Fuel Chem*. **2004**, *49* (1), 279–280.

Pavlish, J.H. Improving Sorbents by Understanding Mercury–Sorbent Interactions. Abstract presented at the Mercury Emissions from Coal Workshop: First International Experts Workshop, Glasgow, Scotland, May 13–14, 2004.

Zhuang, Y.; Thompson, J.S.; Zygarlicke, C.J.; Pavlish, J.H. Development of a Mercury Transformation Model in Coal Combustion Flue Gas. *Environ. Sci. Technol*. **2004**, *38* (21), 5803–5808.

Laudal, D.L.; Thompson, J.S.; Pavlish, J.H.; Brickett, L.; Chu, P.; Srivastava, R.K.; Lee, C.W.; Kilgroe, J. Mercury speciation at Power Plants Using SCR and SNCR Control Technologies. *EM* **2003**, *Feb* 16–22.

Pavlish, J.H.; Sondreal, E.A.; Mann, M.D.; Olson, E.S.; Galbreath, K.C.; Laudal, D.L.; Benson, S.A. A Status Review of Mercury Control Options for Coal-Fired Power Plants. Special Mercury Issue of *Fuel Process. Technol*. **2003**, *82* (2–3), 89–165.

MICHAEL J. HOLMES
Deputy Associate Director for Research
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000, Fax (701) 777-5181, E-Mail: mholmes@undeerc.org

Principal Areas of Expertise
Mr. Holmes' principal areas of interest and expertise include emission 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. 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
2005–Present: Deputy Associate Director for Research, EERC, UND. Mr. Holmes currently oversees fossil energy research areas at the EERC, including hydrogen production, advanced energy systems, and emission control technology projects involving mercury, SO_2, NO_x, H_2S, and particulate.

2001–2004: Senior Research Advisor, EERC, UND. Mr. Holmes was involved in research in a range of areas, including emission control, fuel utilization, process development, and process economic evaluations. Specific duties included 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 improved oil lighter burners, limestone injection multistaged burning, the ESOx process, the SNRB process, and the limestone injection dry scrubbing process.

Professional Memberships

National Hydrogen Board of Directors
Subbituminous Energy Coalition
- Board Member, 2003–Present

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Patents

Holmes, M.J.; Pavlish, J.H.; Olson, E.S.; Zhuang, Y. High-Energy Halogen Disassociation for Mercury Control Systems. U.S. Patent Application 2005-220810, Sept 7, 2005.

Olson, E.S.; Holmes, M.J.; Pavlish, J.H. Sorbents for the Oxidation and Removal of Mercury. U.S. Patent Application 2005-209163, Aug 22, 2005.

Olson, E.; Holmes, M.; Pavlish, J.; Process for Regenerating a Spent Sorbent. International Patent Application PCT/US2004/012828, April 23, 2004.

Madden, D.A.; Holmes, M.J.; Alkaline Sorbent Injection for Mercury Control. U.S. Patent 6,528,030 B2, Nov 16, 2001

Madden, D.A.; Holmes, M.J.; Alkaline Sorbent Injection for Mercury Control. U.S. Patent 6,372,187 B1, Dec 7, 1998

Holmes, M.J.; Eckhart, C.F.; Kudlac, G.A.; Bailey, R.T. Gas Stabilized Reburning for NO_X Control. U.S. Patent 5,890,442, Jan 23, 1996.

Holmes, M.J. Three Fluid Atomizer. U.S. Patent 5,484,107, May 13, 1994.

Bailey, R.T.; Holmes, M.J. Low-Pressure Loss/Reduced Deposition Atomizer. U.S. Patent 5,129,583, March 21, 1991.

Awards

Lignite Energy Council Distinguished Service Award, Government Action Program (Regulatory), 2005.
Lignite Energy Council Distinguished Service Award, Research and Development, 2003.

Selected Publications and Presentations

Holmes, M.J. Enhancing Carbon Reactivity for Mercury Control in Coal-Fired Power Plants: Results from Leland Olds, Stanton, and Antelope Valley Stations. Presented at the DOE NETL's Mercury Control Technology R&D Program Review meeting, Pittsburgh, PA, Dec 11–13, 2006.

Holmes, M.J. Large-Scale Testing of Enhanced Mercury Removal in Subbituminous Coals. Presented at the Subbituminous Energy Coalition Meeting, Denver, CO, March 8, 2006

Wocken, C.A.; Holmes, M.J.; Laudal, D.L.; Pflughoeft-Hassett, D.F.; Weber, G.F.; Ralston, N.V.; Miller, S.J.; Dunham, G.E.; Olson, E.S.; Raymond, L.J.; Pavlish, J.H.; Sondreal, E.A.; Benson, S.A. *Mercury Information Clearinghouse*; Final Report (Oct 1, 2003 – March 31, 2006) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40321; EERC Publication 2006-EERC-04-05; Energy & Environmental Research Center: Grand Forks, ND, April 2006.

Holmes, M.J.; Pavlish, J.H. Mercury Control – Power Plants Equipped with Scrubbers with and Without Selective Catalytic Reduction (SCR) for NO_x Control. In *Air Quality V: Mercury, Trace Elements, SO3, and Particulate Matter Preconference Workshops*; Arlington, VA, Sept 18, 2005.

Holmes, M.J. Mercury Emission Control Options for Electric Utilities Burning Low-Rank Coals. In *Proceedings of the 18th International Low-Rank Fuels Symposium*; Billings, MT, June 24–26, 2003.

Holmes, M.J.; Amrhein, G.T.; Bailey, R.T.; Downs, W.; Kudlac, G.A.; Madden, D.A. *Advanced Emissions Control Development Program – Phase III*; Final Report (Sept 1, 1997 – Dec 31, 1998) for U.S. Department of Energy Contract No. DE-FC22-94PC94251–22, OCDO Grant Agreement No. CDO/D-922-13, and McDermott Technology, Inc., Contract No. CRD-1310; McDermott Technology, Inc.: Alliance, OH, July 1999.

DR. YE ZHUANG
Research Engineer
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000, Fax (701) 777-5181, E-Mail: yzhuang@undeerc.org

Principal Areas of Expertise

Dr. Zhuang's principal areas of interest and expertise include air pollution control with an emphasis on particulate, SO_3, and mercury emissions. Dr Zhuang has been working in various mercury research activities from fundamental study on mercury-flue gas chemistry reactions in different plant configurations to mercury control technology development such as enhanced sorbent. Dr. Zhuang has participated in a number of field demonstration projects sponsored by U.S. Department of Energy.

Qualifications

Ph.D., Environmental Engineering and Science, University of Cincinnati, May 2000.
M.S., Mechanical Engineering, Beijing Polytechnic University, March 1995.
B.E., Mechanical Engineering, Beijing Polytechnic University, July 1992.

Professional Experience

2000–Present: Research Engineer, EERC, UND. Dr. Zhuang's responsibilities include environmental emissions control; equipment design and fabrication; proposal and technical report and paper preparation; presenting research; and interacting with industry and government organizations.

1996–2000: Teaching/Research Assistant, University of Cincinnati. Dr. Zhuang's responsibilities included investigating trace heavy metal formation mechanisms in combustion, applying vapor-phase sorbent technology to emission control, characterizing and improving ESP performance, and performing kinetic studies on the fate of Hg in a combustion environment.

1995–1996: Research Associate, Beijing Polytechnic University, China. Dr. Zhuang's responsibilities included developing liquid jet impingement technology for microelectronic cooling, investigating enhanced heat transfer by magnetic fluid, and characterizing heat transfer and fluid mechanics in heating and ventilation systems.

Professional Memberships

American Association of Aerosol Research

Selected Publications and Presentations

Zhuang, Y.; Laumb, J.D.; Liggett, R.; Holmes, M.J; Pavlish, J.H. Impacts of Acid Gases on Mercury Oxidation Across SCR Catalyst. *Fuel Process. Technol. 88*, 929–934; 2007

Zhuang, Y.; Thompson, J.S.; Zygarlicke, C.J.; Pavlish, J.H. Impact of Calcium Chloride Addition on Mercury Transformations and Control in Coal Flue Gas. *Fuel* **2007**, accepted for publication.

Pavlish, J.H.; Almlie, J.C.; Hamre, L.L.; Zhuang, Y.; Wiemuth, B.; Pletcher, S.M. Development and Testing of Mercury Control Technologies for Power Plants Burning Texas Lignites. In *Proceedings of the 9th Annual Electric Utilities Environmental Conference*; Tucson, AZ, Jan 22–25, 2006.

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Zhuang, Y.; Thompson, J.S.; Zygarlicke, C.J.; Pavlish, J.H. Development of a Mercury Transformation Model in Coal Combustion Flue Gas. *Environ. Sci. Technol*. **2004**, *38* (21), 5803–5808.

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KEVIN C. GALBREATH
Research Manager
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
Phone: (701) 777-5000, Fax: (701) 777-5181, E-Mail: 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–Present: 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–Present: 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, UND. 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, UND. 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, UND. 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.

Selected Publications and Presentations

Benson, S.A.; Holmes, M.J.; McCollor, D.P.; Mackenzie, J.M.; Crocker, C.R.; Kong, L.; Galbreath, K.C.; Dombrowski, K.; Richardson, C. *Large-Scale Mercury Control Technology Testing for Lignite-Fired Utilities – Oxidation Systems for Wet FGD*; Final Report (Sept 26, 2003 – March 31, 2007) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-03NT41991 and North Dakota Industrial Commission Contract No. FY04-L-125l; EERC Publication 2007-EERC-03-12; Energy & Environmental Research Center: Grand Forks, ND, March 2007.

Galbreath, K.C.; Schulz, R.L.; Toman, D.L.; Nyberg, C.M.; Huggins, F.E.; Huffman, G.P.; Zilloux, E.J. Nickel and Sulfur Speciation of Residual Oil Fly Ashes from Two Electric Utility Steam-Generating Units. *J. Air Waste Manage. Assoc*. **2005**, 55, 309–318.

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Galbreath, K.C.; Schulz, R.L.; Toman, D.L.; Nyberg, C.M.; Huggins, F.E.; Huffman, G.P.; Zilloux, E.J. Nickel Speciation of Fly Ash from Residual Oil-Fired Power Plants. In *Proceedings of the Air Quality IV: Mercury, Trace Elements, and Particulate Matter Conference*; Arlington, VA, Sept 22–24, 2003.

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Zygarlicke, C.J.; Zhuang, Y.; Galbreath, K.C.; Thompson, J.S.; Holmes, M.J.; Tibbetts, J.E.; Schulz, R.L.; Dunham, G.E. Experimental Investigations of Mercury Transformations in Pilot-Scale Combustion Systems and a Bench-Scale Entrained-Flow Reactor. In *Proceedings of the Air Quality III: Mercury, Trace Elements, and Particulate Matter Conference*; Arlington, VA, Sept 10–12, 2002; Energy & Environmental Research Center: Grand Forks, ND, 2002.

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Galbreath, K.C.; Toman, D.L.; Zygarlicke, C.J.; Pavlish, J.H. Trace Element Partitioning and Transformations During Pulverized Coal Combustion of Bituminous and Subbituminous U.S. Coals in a 7-kW Combustion System. *Energy Fuels* **2000**, *14*, 1265–1279.

NICHOLAS V.C. RALSTON
Research Scientist
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018 USA
Phone: (701) 777-5000, Fax: (701) 777-5181, E-Mail: nralston@undeerc.org

Principle Areas of Expertise
Dr. Ralston's areas of interest include studies of selenium physiology and molecular mechanisms mercury toxicity. His work involves analytical approaches to quantitative assessment of mercury-selenium interactions at the molecular, cellular, organism, population, and environmental levels. Program areas study the pathophysiology of toxic metal and particulate pollutant exposures as well as strategies for prevention and remediation of effects of toxicity. The roles of trace elements in human health, particularly in countering toxic agent exposures, are a further area of acute interest.

Qualifications
Ph.D., Biomedical Research Biochemistry, Mayo Medical Center, 1995.
B.S., Biology Composite, Mayville State University, 1978.

Professional Experience
2005–Present: Health Effects Research Manager, Center for Air Toxic Metals® (CATM®), EERC, UND. Dr. Ralston's responsibilities include overseeing research projects that study pathological effects and physiological responses to toxic metal exposures in human and animal studies.

2002–Present: Research Scientist, EERC, UND. Dr. Ralston's primary research responsibility involves studies of the pathological effects of methylmercury exposures on selenium physiology. His current research examines the mechanisms of selenium-dependent protection against toxic effects of methylmercury at the molecular, cellular, organism, population, and environment level.
These studies range from environmental studies of mercury–selenium interactions in plants, insects, squid, ocean and freshwater fish, dolphins, and whales, to pathology studies of animal and human tissues that may reflect effects of these interactions in etiology of disease states. Development of the proposed Selenium-Health Benefit Value seafood safety criterion is a recent accomplishment.

1998–2002: Research Biochemist, Grand Forks Human Nutrition Research Center (GFHNRC), U.S. Department of Agriculture (USDA). Dr. Ralston applied acute and chronic inflammation models to selenium studies and also discovered low-molecular-weight selenomolecules are abundant in brain, a previously unsuspected feature of selenium metabolism. He developed the capillary electrophoresis method for quantifying discrete boron complexes in biological samples and identified high boron binding affinities with diadenosine polyphosphate signal molecules.

1996–1998: Research Fellow, Bowman Gray Medical School, Wake Forest University, Winston-Salem, North Carolina. Dr. Ralston studied precursor–product relationships in the biosynthetic pathway for sn-1-sn-1' Bis(monoacyl-glycerol)phosphate (BMP), an important phospholipid whose unique stereochemistry is required to protect cells against damage from endogenous lipases. This important and highly protective phospholipid comprises up to 50% of the lipid in lysosome membranes and ~20% of the total phospholipid present in alveolar macrophages.

1989–1995: Biomedical Research Fellow, Mayo Medical Center, Rochester, Minnesota. Defined molecular mechanisms of arachidonate metabolism that are responsible for Byssinosis, a chronic pulmonary inflammatory disease caused by exposure to industrial organic dust particulates.

1979–1989: Research Technician, Chemist, Research Biologist, GFHNRC, USDA. Following increasing involvement in laboratory studies of mineral nutrition in human and animal studies became head of methods development team leading research in development of new analytical methods for trace element enzyme activity measurements for establishing nutrient requirements.

1976–1979: High School Science Teacher, Roosevelt Public School, Carson, North Dakota.

Selected Publications

Ralston, N.V.C.; Blackwell; J.L.; Raymond, L.J. Importance of Molar Ratios in Selenium-Dependent Protection Against Methylmercury Toxicity. *Biol. Trace Element Res.* Special Issue **2007**, in press.

Kaneko, J.J.; Ralston, N.V.C. Selenium and Mercury in Pelagic Fish in the Central North Pacific near Hawaii *Biol. Trace Element Res.* Special Issue **2007**, in press.

Cooper, L.T.; Rader, V.; Ralston, N.V.C. The Roles of Selenium and Mercury in the Pathogenesis of Viral Cardiomyopathy. *Congest. Heart Fail.* **2007**, in review.

Raymond, L.J.; Ralston, N.V.C. The Importance of Mercury–Selenium Interactions in Risks Associated with Methylmercury Exposure: A Review. **2007**, *Nutr. Res. Rev.*, in review.

Ralston, N.V.C.; Finley, J.W. Acute and Chronic Inflammation in Rats is Influenced by Source and Amount of Dietary Selenium. *Biofactors* **2007**, in review.

Ralston, C.R.; Blackwell, J.L.; Ralston, N.V.C. Effects of Dietary Selenium and Mercury on the House Crickets (*Acheta domesticus* L.): Implications of Environmental Coexposures. *Environmental Bioindicators* **2006**, *1* (1), 98–109.

Wocken, C.A.; Holmes, M.J.; Laudal, D.L.; Pflughoeft-Hassett, D.F.; Weber, G.F.; Ralston, N.V.; Miller, S.J.; Dunham, G.E.; Olson, E.S.; Raymond, L.J.; Pavlish, J.H.; Sondreal, E.A.; Benson, S.A. *Mercury Information Clearinghouse*; Final Report (Oct 1, 2003 – March 31, 2006) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40321; EERC Publication 2006-EERC-04-05; Energy & Environmental Research Center: Grand Forks, ND, April 2006.

Raymond, L.J.; Ralston, N.V.C. Mercury: Selenium Interactions and Health Implications. *Seychelles Medical and Dental Journal*, Special Issue, **2004,** *7* (1) 72–77.

Sondreal, E.A.; Benson, S.A.; Pavlish, J.H.; Ralston, N.V. An Overview of Air Quality III: Mercury, Trace, Elements, and Particulate Matter. *Air Quality III: Mercury, Trace Elements, and Particulate Matter*, Special Issue of *Fuel Process. Technol.* **2004**, *85* (6–7), 425–440.

Ralston, N.V.C.; Hunt, C.D. Transmembrane partitioning of boron and other elements in RAW 264.7 and HL60 cell cultures. *Biol. Trace Element Res.* **2004**, 98(2), 181–191.

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Ralston, N.V.C.; Schmid, P.J.; Schmid, H.H.O. Agonist Stimulated Phospholipid Turnover in Alveolar Macrophages. *Biochim. Biophys. Acta* **1998**, *1393* (1), 211–221.

Bates, P.J.; Ralston, N.V.C.; Vuk-Pavlovic, Z.; Rohrbach, M.S. Calcium Influx Is Required for Tannin-Mediated Arachidonic Acid Release from Alveolar Macrophages. *Am. J. Physiol.* **1995**, *266*, 33–40.A

Castro, M.; Ralston, N.V.C.; Morgenthaler, T.I.; Limper, A.H.; Rohrbach, M.S. Candida lbicans Stimulates Arachidonic Acid Liberation from Alveolar Macrophages Through α-Mannan and ß-Glucan Cell Wall Components. *Infect. Immun*. **1994**, *62*, 3138–3145.

Ralston, N.V.C.; Rohrbach, M.S. Mass Determination of the Fatty Acids Released from Tannin-Stimulated Alveolar Macrophages. *Lipids* **1994**, *29* (2) 103–2109.

Milne, D.B.; Sims, R.L.; Ralston, N.V.C. Manganese Content of Cellular Components of Blood. *Clin. Chem.* **1990**, *36*, 3450–3452.

Johnson, P.E.; Hunt, J.E.; Ralston, N.V.C. The Effect of Past and Current Dietary Zinc Intake on Zinc Absorption and Endogenous Excretion in the Rat. *J. Nutr.* **1987**, *118*, 1205–1209.

Milne, D.B.; Ralston, N.V.C.; Wallwork, J.C. Zinc Content of Cellular Components of Blood: Methods for Cell Separation and Analysis Evaluated. *Clin. Chem*. **1985**, *31* (1), 65–69.

Milne, D.B.; Wallwork, J.C.; Ralston, N.V.C.; Korynta, E.G. Zinc Content of Blood Cellular Components and Spleen and Lymph Node Mononuclear Cells in Zinc–Deficient Rats. *J. Nutr.* **1985**, *115*, 1073–1078.

Milne, D.B.; Ralston, N.V.C.; Wallwork, J.C.; Korynta, E.G.; Sandstead, H.H. A Critical Evaluation of Zinc in Blood Cellular Components as an Index of Zinc Status. *Am. J. Clin. Nutr.* **1984**, *39*, 688.

Milne, D.B.; Wallwork, J.C.; Ralston, N.V.C. Analysis of Zinc in Blood Cellular Components as a Means of Assessment of Zinc Status. In *Trace Elements in Man and Animals-5*; Mills, C.F.; Bremner, I.; Chesters, J.K., Eds.; CAB, Farnham Royal: UK, 1984; pp 271–275.