March 31, 2004

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

Dear Ms. Fine:

Subject: EERC Proposal No. 2004-0234, "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms"

Enclosed are the original, six copies, and a PDF of the subject proposal. The lignite-fired power industry has been proactive in advancing the understanding of and identifying control options for mercury in coal combustion flue gases. Approximately 1 year ago, the Energy & Environmental Research Center (EERC) began a series of Hg-related discussions with the North Dakota Mercury Task Force. This proposal is submitted to address the knowledge gaps in mercury–sorbent interactions to meet the challenges of controlling mercury emissions from lignite-fired power plants. Also enclosed is the $100 application fee.

If you have any questions or comments, please contact me by phone at (701) 777-5018 or by e-mail at ccrocker@undeerc.org.

Sincerely,

Charlene R. Crocker
Research Scientist

CRC/cs

Enclosures

c/enc: Harvey Ness, Lignite Research Council

INVESTIGATION OF MERCURY AND CARBON-BASED SORBENT REACTION MECHANISMS

EERC Proposal No. 2004-0234

Submitted to:

Ms. Karlene Fine

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

Proposal Amount: $54,000

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March 2004

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INVESTIGATION OF MERCURY AND CARBON-BASED SORBENT REACTION MECHANISMS

ABSTRACT

The overall objective of the project is to improve the mercury capture efficiency of carbon-based sorbents through a better understanding of mercury–sorbent reaction mechanisms. This fundamental investigation of physicochemical surface characteristics of sorbents exposed to flue gas containing mercury vapors will provide information for the development of more effective and lower-cost sorbents to control elemental mercury emissions from combustion systems firing low-chlorine North Dakota lignite coals. The proposed project is focused on ascertaining the role of HCl in promoting the oxidation of elemental mercury and the role of the carbon structure in providing active sites for oxidation of mercury and SO_2 and the subsequent binding of the oxidation products as well as refining the mechanistic model for elemental mercury capture and control. The approach includes an examination of lignite flue gas–mercury interactions on carbon sorbents, evaluation of sorbent surface chemistry, investigation of the effects of surface modifications on kinetics and capture, and evaluation of the effectiveness of activated carbons prepared from Fort Union lignite. The research is structured to provide insight resulting in refinement of the mechanisms of elemental mercury capture in low-chlorine fuel combustion applications.

The project is schedule for 20 months with a total cost of $240,870, of which $46,870 is requested from the U.S. Department of Energy and $50,000 will be requested through the Energy & Environmental Research Center's Center for Air Toxic Metals® program. Commercial partners have committed to providing cash and in-kind funding of $90,000. Of this, EPRI has committed to funding $18,000 of the program. $54,000 is requested from the North Dakota Industrial Commission.

INVESTIGATION OF MERCURY AND CARBON-BASED SORBENT REACTION MECHANISMS

PROJECT SUMMARY

Sorbent injection for removing mercury involves adsorption of mercury species by a solid sorbent injected upstream of a particulate control device such as a fabric filter (FF) (baghouse) or electrostatic precipitator (ESP). Many potential mercury sorbents have been evaluated (1). Activated carbon injection is the most mature technology available for mercury control. For activated carbons to be successful, they must effectively sorb Hg^0 and Hg^{2+}. Testing has demonstrated that the chemical speciation of mercury in the flue gas controls its capture mechanism and ultimate environmental fate. The capture and retention of mercury on carbon-based sorbents are dependent upon the particle size, chemical and physical characteristics of the sorbent surface, and flue gas composition. These factors have had a major impact on the effectiveness of mercury control using activated carbon sorbents.

Most activated carbon mercury control research has been performed in fixed-bed reactors that simulate relatively long-residence-time (gas–solid contact times of minutes or hours) mercury capture by a FF filter (2–4). However, it is important to increase the reactivity of the sorbents for short-residence-time (seconds) in-flight capture of Hg^0 because most of the coal-burning boilers in the United States employ cold-side ESPs for controlling particulate matter emissions. The projected annual cost for activated carbon adsorption of mercury in a duct injection system is significant. Carbon-to-mercury weight ratios of 3000–18,000 (gram of carbon injected per gram of mercury in flue gas) have been estimated to achieve 90% mercury removal from a coal combustion flue gas containing 10 $\mu g/Nm^3$ of mercury (5). More efficient carbon-based sorbents are required to enable

lower carbon-to-mercury weight ratios to be used, thus reducing the operating costs of carbon injection.

The overall goal of this Energy & Environmental Research Center (EERC) project is to improve the mercury capture efficiency of carbon-based sorbents in flue gases typical of firing lignite and other low-chlorine, low-sulfur fuels through a better understanding of mercury–sorbent reaction mechanisms. The work will involve a fundamental investigation of physicochemical surface characteristics of sorbents exposed to flue gas that contains mercury vapors. The objectives of the project include the following: 1) determining the role of HCl in promoting the oxidation of elemental mercury, 2) determining the role of the carbon structure in providing active sites for oxidation of mercury and SO_2 and the subsequent binding of the oxidation products, and 3) refining the model.

In order to meet these objectives, the research plan will involve examining lignite flue gas–mercury interactions on carbon sorbents, evaluating sorbent surface chemistry, investigating the effects of carbon structure on kinetics and capture, and refining the mechanistic model of elemental mercury capture in low-chlorine fuel combustion applications.

PROJECT DESCRIPTION

Goals and Objectives

The goal of this EERC program is to improve the mercury capture efficiency of carbon-based sorbents through a better understanding of mercury–sorbent reaction mechanisms. The work will involve a fundamental investigation of physicochemical surface characteristics of sorbents exposed to flue gas that contains mercury vapors.

The objectives of the project include the following: 1) determining the role of HCl in promoting the oxidation of elemental mercury, 2) determining the role of the carbon structure in providing active sites for oxidation of mercury and SO_2 and the subsequent binding of the oxidation

products, and 3) evaluation of sorbents prepared from coal-based materials provided by project partners.

Work Plan

The research will be carried out in three tasks.

Task 1 – Flue Gas–Mercury Interactions on the Carbon Sorbent

Hydrochlorination Effects on Sorbent Kinetics. In bench-scale sorption tests, the amount of HCl in the flue gas has a significant effect on the initial Hg^0 capture kinetics on carbon-based sorbents, where higher levels (50 ppm HCl) eliminate the induction period. A proposed mechanism for oxidation requires acid activation of the graphene-edge carbene site for oxidation to occur (6). Pretreatment of the sorbent with aqueous HCl has the same effect in bench-scale testing (7), but pilot-scale testing using stored samples of the pretreated sorbent failed to demonstrate an improved sorption capacity.

The nature of the sorbent–Cl bond(s) will be investigated for several hydrochlorinated (aqueous, gas, alternative compounds) Flue gas desulfurization (FGD) sorbents utilizing bench-scale mercury sorption testing with flue gas constituents at levels representative of firing lignite or other low-chlorine, low-sulfur coals. Since previous test results have indicated that the low HCl level in the flue gas representative of lignite-fired combustion systems required a significant induction period before effective Hg^0 capture on carbon-based sorbents occurred, the investigation of pretreated sorbent will provide insight into the oxidizing interactions of the carbon surface with Hg^0 and other flue gas constituents. Halogen-impregnated sorbents will be loaded to various stages of capacity with Hg^0 using the bench-scale screening test apparatus. The loaded sorbents will undergo x-ray photoelectron spectroscopy (XPS) analysis, which determines the oxidation state and bonding

associations of surface atoms present at detectable levels. The results of the following tests will be compared to previously collected data. The research will focus on two areas:

1) The effects of various chlorine impregnation techniques will be investigated. The performance of aqueous, gas phase, and alternative halogenating agents ($SOCl_2$, for example) will be compared.
2) The influence of HCl and other acids on the NO_2-assisted oxidation of SO_2 to SO_3 will be evaluated to address the question of whether the SO_2 oxidation site is the same site that performs the Hg oxidation. The reaction kinetics for the various acids will be determined and correlated with mercury oxidation. The possibility of an induction period for sulfur(VI) formation at low flue gas HCl concentration will be investigated. The rate of sulfur(VI) formation will be determined by titration, ion-selective electrode, or ion chromatography.

Evaluation of Surface Chemistry. Surface chemistry plays a major role in mercury capture on sorbents, which has yet to be well defined. The development of a method to integrate various analytical techniques for the evaluation of oxidation and binding potential of sorbent surfaces will increase the understanding of surface interactions and provide an assessment tool for newly developed sorbents. This effort uses several analytical techniques to identify correlations between the kinetics of mercury oxidation and capacity on virgin or modified (e.g., impregnated) sorbents and various structural parameters. Test procedures include oxygen content, temperature-programmed desorption, Boehm titrations, Raman spectroscopy, and electron paramagnetic resonance (EPR) spectroscopy. The oxygen-content desorption with CO/CO_2 measurement will be used to evaluate potential correlations between activity of sorbent and CO/CO_2 evolution on heating which indicate oxygen binding on edge structure. The Boehm titration procedures determine oxygen functional

groups at the surface. Raman spectroscopy may detect some sulfur groups participating in surface oxidation and/or binding reactions. There is also a need to distinguish halide formations on the surface of sorbents exposed to flue gas. Raman spectroscopy will be investigated as a potential distinguishing tool. EPR indicates the presence of free radicals at the surface. These may be important intermediates in Hg^0 oxidation reactions. The exact number and variety of tests to be performed are dependent on the relevant data obtained from each test based on methods development work included in the task.

Task 2 – Investigation of the Effects of Surface Modifications on Kinetics and Capture and Evaluation of Activated Carbons

Surface Modification Effects on Kinetics. As there appears to be competition between mercury and SO_2 on the surface oxidation sites, it is important to identify activation conditions that improve selectivity of carbons for mercury and less selectivity for SO_2. This task will focus on conditions that pertain to surface modifications that could alter the properties of the carbonaceous material. The effectiveness of two surface modifications will be determined. XPS analyses and the suite of surface chemistry analyses will be used to determine the nature of modifications that improve mercury capture through halogenation or other means.

Evaluation of Activated Carbons. Currently, most carbon sorbent development activities have concentrated on a commercially available activated carbon—DARCO® FGD. Limited research suggests that activated carbons prepared from Fort Union lignites may have equal or improved capability to sorb the mercury present in combustion flue gas. All activated carbons tested to date initially exhibited poor sorption kinetics in low-Cl flue gas conditions. The important questions to be answered are which carbons can be activated by HCl or other treatments to achieve the highest Hg-sorption rates and what conditions of activation will achieve optimum capture for each activated

carbon. Under this task, several activated carbons will be prepared from coals provided by project partners. The exact number of coals prepared and the extent of enhancing efforts will depend on the number of commercial partners and their interests. Activated carbons can be prepared in the 2.5-in.-diameter fixed-bed furnace and the 6-in.-diameter new rotary kiln system, providing information for process scale-up issues for charring and activated carbon preparation. The activated carbons will be evaluated for Hg^0 sorption using the bench-scale test apparatus. The various coal-derived carbons may exhibit different capacities for Hg^{2+} versus Hg^0 sorption because of different mineral content and functional groups. Sorption mechanisms are not the same for mercury in elemental versus the oxidized state. However, the option to evaluate sorbent performance for $HgCl_2$ is not included in the current budget.

Evaluation of Coal Characteristics. The final activity under this task is determination of the availability of materials possessing the most promising characteristics for producing effective activated carbons for mercury control. Coal-seam core data provided by commercial project partners will be examined and compared to the characteristics of the test coals to determine how representative the most promising coals are in the various seams of the Fort Union lignites.

Task 3 –Reporting and Management

This task will involve coordination of all project activities, reporting, and communication between project participants and partners. Reporting will consist of meetings with partners and project participants, quarterly reports, a final report, and presentation of results at a national scientific meeting.

DELIVERABLES

An improved fundamental understanding of the gas–sorbent interactions for mercury emission control will result from the proposed research. Specific anticipated results include:

- Development of highly effective, lower-cost Hg sorbent.
- A description of the role of HCl in promoting the oxidation of Hg^0 at the sorbent surface.
- A description of the fate of halogens for mercury control in halogen-impregnated sorbents.
- An evaluation of sorbent surface chemistry.
- A comparison of EERC-developed activated carbons prepared from commercial partner materials.
- An evaluation of the effects of sorbent surface modifications.
- Presentation of the results at a technical conference and to the U.S. Department of Energy (DOE).
- Quarterly and final reports detailing the progress and results of the research.

The proposed research will be carried out using the facilities of the EERC's Process Chemistry and Development Laboratory (PCDL) and Mercury Research Laboratory (MRL) (www.undeerc.org). XPS analysis will be performed at Physical Electronics, Inc. (PHI), in Eden Prairie, Minnesota (www.phi.com). The PCDL has facilities for the development and analysis of different types of product and by-product streams. These analyses provide the data necessary for the calculation of material balances, conversions, and product qualities for several ongoing engineering projects at the EERC. Equipment is in place for ashing, solubility testing, numerous American Society for Testing and Materials standard tests, coal cleaning, and a variety of general and specialized analytical testing, including wet-chemical testing.

The MRL specializes in bench-scale systems studying mercury, SO_x/NO_x, catalysts, sorbents, and related work. Two bench-scale systems capable of simulating flue gas conditions such as temperature, particulate loadings, air-to-cloth ratios, and various gas concentrations (e.g., SO_2, O_2, CO, CO_2) are used. The MRL has mercury continuous emission monitors (CEMs) to perform bench-scale mercury-screening activities. The PCDL and MRL have over 10 years of experience developing and screening potential sorbents and filter materials, evaluating catalyst materials, and performing SO_x/NO_x in flue gas research.

PHI manufactures, sells, and provides on-site analytical services using highly specialized surface analysis instrumentation. XPS, also known as electron spectroscopy for chemical analysis, is the most widely used surface analysis technique because of its relative simplicity in use and data interpretation. PHI has instrumental analysts and technical support engineers with several years of experience and continuous training on the latest surface analysis equipment and techniques.

Environmental impacts of the research while under way will be minimal. Technological and economic impacts of the ultimate product could be substantial in terms of elemental mercury control from lignite-fired combustion systems. The U.S. Environmental Protection Agency (EPA) determined that mercury emissions from power plants pose significant hazards to public health and must be reduced. EPA is scheduled to promulgate regulations by December 2004, with full compliance expected by 2007. Activated carbon injection (ACI) is the most mature technology available for mercury control. Development of a sorbent capable of effective elemental mercury control will be extremely beneficial to lignite production and combustion facilities in meeting the imminent regulations.

STANDARDS OF SUCCESS

The overall success of the project will be based on the ability to develop an understanding of the role of hydrochloric and similar halogenated species in promoting the capture of mercury on sorbents used for control in utilities burning low-chlorine coals and how to optimize the preparation and use of these sorbents. Thus models and understanding based on the results are expected to be useful for the optimization and improvement of emission control technologies in the power industry by up to and potentially exceeding 90%.

Since the project is a scientific investigation as opposed to a field-testing exercise, the achievement of these goals will be measured by standards appropriate to the scientific and engineering community. Of primary importance is publication of the project results in refereed journals (two publications) and presentation at a scientific and engineering meeting of national and global scope (one meeting). Results of commercial significance will be rapidly patented so that the findings can be released to consortium members and the general public as appropriate. The detailed model(s) developed and improved as a result of the project will be disseminated, and the adoption and subsequent use of these models by the EERC, consortium members, and the public will be noted. Although the latter will occur after conclusion of the project, the records will show that the project was successful.

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

and protocols. Table 1 outlines project QC. Specific to the measurement and control of mercury emissions, the following quality parameters have been defined.

Table 1. Project Quality Measures

QA/QC Control Measure	Purpose/Clarification
EERC QMS, including *Quality Manual* and quality policy and procedures	Ensure organizationwide compliance with QMS and applicable regulations, codes, and protocols based on ISO9000 standards. Authorized and supported by EERC management.
Project-Independent QA Manager at the EERC (David Brekke)	Assist research managers to plan QA for projects, does reviews and random audits for compliance assurance.
Perform Hg Mass Balance with Values 100% ± 20%	Determine total amount of Hg to be accounted for and determine removal rates.
EERC Expertise in Analytical Methods and CEM Sampling for Hg	Understand potential problems that can occur, troubleshoot, ability to get valid data under difficult conditions.
Hg CEM Calibrations Daily, at least; if target not met, may require that additional calibration or maintenance be done and repeat QA/QC check	PS Analytical: sample clean air drawn through carbon trap followed by injecting known Hg standard. This procedure is done four times to determine scatter (internal QA/QC EERC standard is that $R^2 = 0.999$).
Chain-of-Custody Procedures	Ensure integrity of samples at all steps, including sample identification, analysis, and storage.
Interim Team Audit	Use expertise of team members to ensure consistent quality, double-check analytical systems.
Team direction by Consortium and DOE	Ensure that communication issues and problems are addressed to ensure objectives of project are attained.
Quarterly Conference Calls (or as needed)	Ensure effective communications between all team members, address developing issues, resolve problems.
Information Transfer via FTP Site	Allows efficient transfer of data between team members.

The most important aspect of QA/QC is the expertise of the team conducting sorbent testing and spectroscopic measurements. The EERC research personnel are highly trained and experienced, having conducted hundreds of sampling tests. In addition, the EERC team members are considered experts in the operation of Hg CEMs, which are still considered to be in the developmental phase. The EERC has successfully demonstrated these instruments for 2 weeks or longer at nine different

power plants over the past 3 years. The EERC has actively used these instruments in bench-, pilot-, and full-scale tests for over 7 years.

BACKGROUND

During the pilot-scale lignite and utility-scale Fort Union coal tests using ESP and ESP–FF particulate controls, maximum mercury removal efficiencies for ACI ranged from 45% to 75% and 85%, respectively, with 7–25 lb/MMacf carbon injection concentration required. Conversely, mercury removal efficiency was never >70%, regardless of the ACI rate, into the Powder River Basin subbituminous coal combustion flue gas. This limitation is probably caused by the small amount of acidic flue gas constituents, such as HCl, that promote mercury-activated carbon sorption. Testing conducted at a lignite-fired power plant equipped with a spray dryer baghouse firing Fort Union lignite indicated poor performance of conventional ACI to control mercury (8). The results indicate poor control efficiency for injection of FGD carbon (NORIT Darco FGD) in a spray dryer baghouse system (9). The poor results are due to the low-acid-gas-containing flue gas and the high proportion of elemental mercury in the flue gas stream. The iodine-impregnated activated carbon showed approximately 90% control.

Researchers at the EERC and elsewhere are striving to attain a more thorough understanding of mercury species reactions on activated carbon surfaces in order to produce more efficient sorbents. Mercury-reactive surface functional groups thought to have an impact on mercury capture include acidic carboxyl, lactone, hydroxyl, and carbonyl functionalities or alkaline pyrone and chromene functionalities (7, 10–12). Functional groups containing inorganic elements such as bromine, chlorine, or sulfur are also possibilities (13–15). Although halogen- and sulfur-bearing surface functional groups are not well characterized, the beneficial role of halogens and sulfur in capturing mercury species on activated carbons is well established (7, 16). Recently, Laumb and

others (17) and Benson and others (18) have characterized sorbents exposed to flue gas and elemental mercury, and the results indicate that the key surface components that impact the oxidation and retention of mercury on the surface of the carbon result from the chemisorption of the chlorine and sulfur species from the flue gas. The chlorine species react to form organically associated chlorine on the surface, and it appears that the organically associated chlorine on the carbon is the key site responsible for bonding with the Hg^{2+} species.

Olson and others (19) have developed a model of the chemical mechanism of mercury oxidation and binding that offers more detail on the nature of the bonding site and its interaction with flue gases and mercury. This model, shown in Figure 1, uses the concept of zigzag carbene structures recently proposed by Radovic and Bockrath (20). It is hypothesized that the mechanism involves the reaction with HCl to form stable carbenium ion intermediates. These intermediate species can then promote oxidation of elemental mercury and create sites for bonding. The exact mechanism of reaction is currently not well understood. A detailed understanding of these mechanisms will provide information for the development of more effective and lower-cost sorbents.

A zigzag-edge carbene site comprises the basic binding site for which the various acid–gas components and the Hg(II) compete. Figure 2 provides more details of the role of chlorine. The conversion of carbene to carbenium ion by HCl and other acids generates an oxidation site and is consistent with the promotion effect of acids on mercury oxidation. The mechanistic model shows Hg^0 oxidation by the carbenium ion to the organomercury intermediate and subsequent oxidation by NO_2 to the bound Hg(II) species. Ultimately, the refined model will have the potential to be used to describe flue gas–activated carbon interaction behavior and to predict capture efficiency. In addition, knowledge developed from this model will be useful for stabilizing Hg(II) on the sorbent and promoting the kinetics of mercury capture. A better understanding of the interactions and effects of

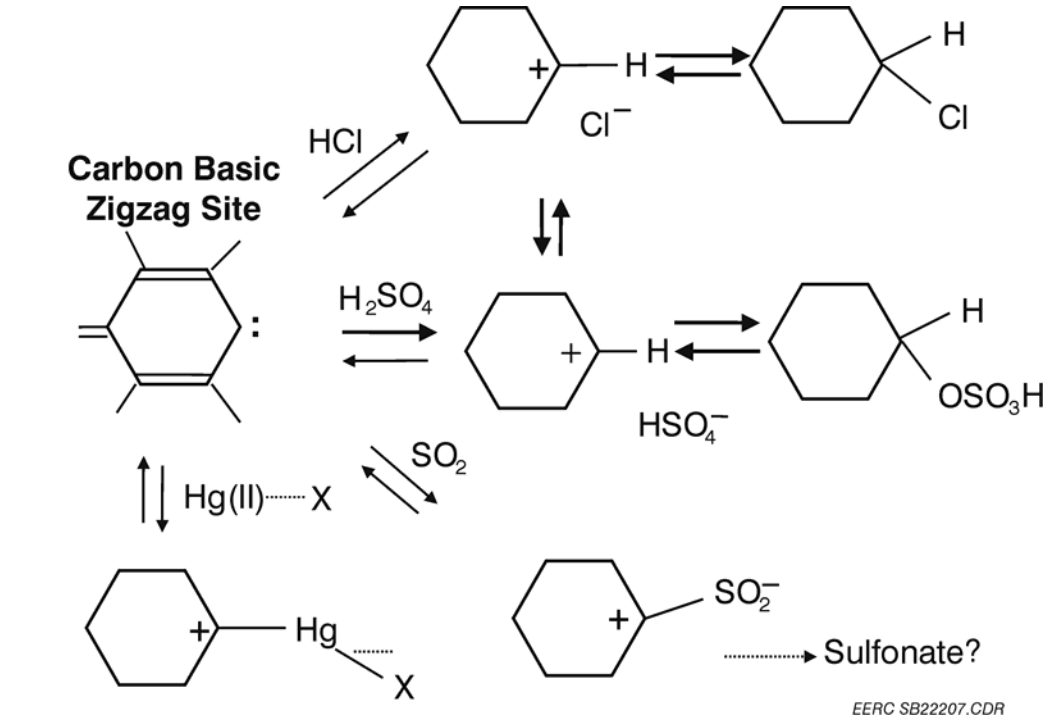


Figure 1. Binding site model for activated carbon.

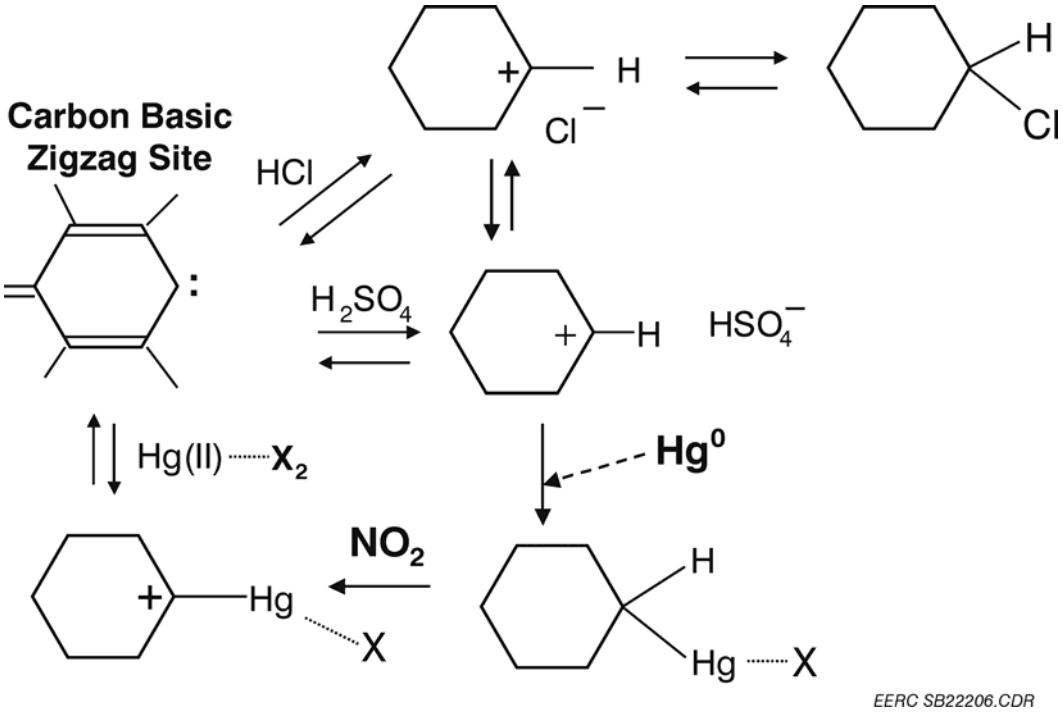


Figure 2. Oxidation site model for activated carbon—the role of hydrochlorination in generating carbenium oxidant (6).

flue gas constituents and conditions will result in an improved mechanistic model and the development of more effective sorbents for mercury capture and control.

QUALIFICATIONS

The EERC of the University of North Dakota is one of the world's major energy and environmental research organizations. Since its founding in 1949 as the U.S. Bureau of Mines Robertson Lignite Research Laboratory, 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 team has more than four decades of basic and applied research experience producing energy from all ranks of coal, with particular emphasis on low-rank coals. As a result, the EERC has become the world's leading low-rank coal research center. EERC research programs are designed to embrace all aspects of energy-from-coal technologies from cradle to grave, beginning with fundamental resource characterization and ending with waste utilization or disposal in mine land reclamation settings.

The future of North Dakota energy production depends upon developing connections between energy and the environment that will allow the extraction of sufficient energy and other resources from our environment in a manner that does not jeopardize its integrity and stability.

The EERC has been a leader in mercury research for several years and is viewed as an expert in the field. In recent years, EERC researchers have been in the forefront of advancing the understanding of mercury chemistry, measurement, transformations, solid–gas interactions, and the development of control technologies.

VALUE TO NORTH DAKOTA

A major challenge facing North Dakota lignite-fired power plants is the control of mercury emissions. The mercury species in combustion flue gases produced from North Dakota lignite plants is primarily elemental and much more difficult to control than oxidized mercury forms. The project is aimed at gaining insight into the mercury capture and oxidation properties of carbon-based sorbents to develop a better cost-effective sorbent to oxidize and control the emissions of mercury during the combustion of North Dakota lignites. Developing effective mercury control technologies for North Dakota lignites will aid in maintaining and potentially increasing the use of lignite for power generation in the future.

MANAGEMENT

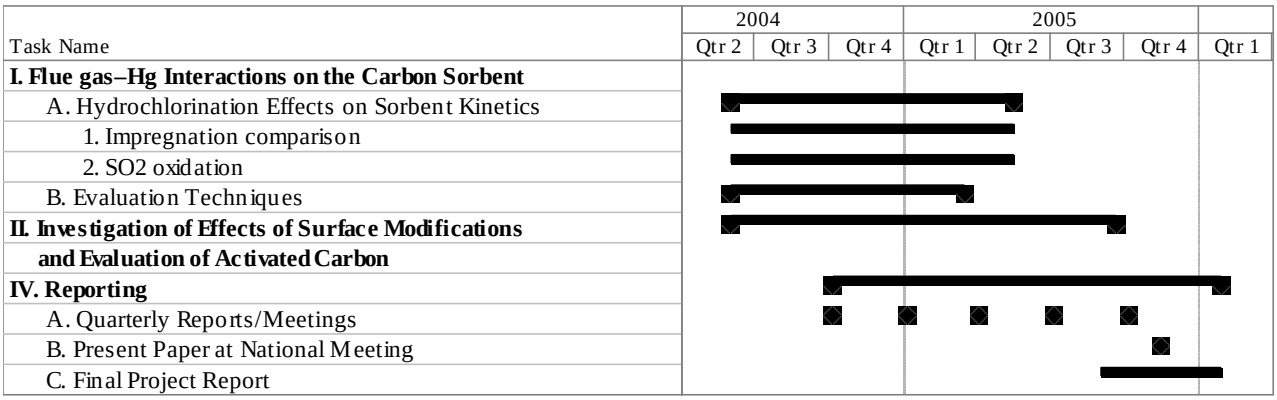
Ms. Charlene R. Crocker will be the EERC Project Manager responsible for the oversight of the project. Ms. Crocker has 10 years of experience in mercury and chlorine analysis and measurement in coal combustion and sorbent development. Principal Investigators Dr. Edwin S. Olson and Dr. Steven A. Benson will assist with project tasks. Dr. Olson has more than 39 years of experience in carbon and coal structure and reactivity, mercury analysis, emission, adsorption chemistry, coal liquefaction, and gasification catalysis. Dr. Benson has more than 25 years in coal utilization and environmental control technologies and has managed numerous projects involving government and industry participants. They will be assisted by experienced EERC technicians.

Resumes of key personnel are included in Appendix A.

PROJECT TIMETABLE

The project will be initiated upon receipt of DOE funding and approval of the project by the North Dakota Industrial Commission (NDIC). It is anticipated that the proposed work will be carried out over a 20-month time frame. Surface chemistry, investigation, and reporting tasks will be

ongoing throughout the project. Additional effort during Year 1 will focus on stability studies and iodine modifications. The remaining work plan will be completed in Year 2.



BUDGET

The budget outlining the costs for the project is enclosed. The total cost of the project is $240,870.

The EERC is requesting NDIC to commit $54,000 of funding for this project. Once we have NDIC's commitment, we will submit the proposal to DOE, requesting approval of its share of the funding.

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

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

MATCHING FUNDS

The total cost of the project is $240,870. Cost-share funding to be requested from the EERC–DOE Jointly Sponsored Research Program is $46,870. Funding requested from NDIC is $54,000. Cash and in-kind funding from commercial partners, including EPRI, is anticipated to total $90,000. $50,000 has been requested from the Center for Air Toxic Metals® in support of this project. Letters of commitment from the commercial partners and EPRI toward this project are included in Appendix B.

TAX LIABILITY

None of the participants in this research proposal have outstanding tax liabilities to the state of North Dakota.

CONFIDENTIAL INFORMATION

No confidential information is expected to result from performance of this project.

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SUMMARY BUDGET

INVESTIGATION OF MERCURY AND CARBON-BASED SORBENT REACTION MECHANISMS
NDIC
PROPOSED START DATE: 6/1/04
EERC PROPOSAL #2004-0234

CATEGORY	TOTAL HRS	TOTAL $COST	DAK. WEST. SHARE HRS	DAK. WEST. SHARE $COST	EPRI SHARE HRS	EPRI SHARE $COST	NDIC SHARE HRS	NDIC SHARE $COST	CATM SHARE HRS	CATM SHARE $COST	EERC JSRP SHARE HRS	EERC JSRP SHARE $COST
TOTAL DIRECT LABOR	1,621	$ 51,382	204	6,062	158	5,865	471	17,463	273	$ 6,778	515	$ 15,214
FRINGE BENEFITS		$ 27,232		$ 3,213		$ 3,108		$ 9,256		$ 3,592		$ 8,063
TOTAL LABOR		$ 78,614		$ 9,275		$ 8,973		$ 26,719		$ 10,370		$ 23,277
OTHER DIRECT COSTS												
TRAVEL		$ 5,962		$ -		$ 793		$ 2,379		$ 909		$ 1,881
COMMUNICATION - PHONES & POSTAGE		$ 95		$ 6		$ 8		$ 16		$ 20		$ 45
OFFICE (PROJECT SPECIFIC SUPPLIES)		$ 160		$ 10		$ 14		$ 31		$ 50		$ 55
SUPPLIES		$ 1,028		$ 292		$ 18		$ 82		$ 214		$ 422
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)		$ 70		$ -		$ 4		$ 32		$ 15		$ 19
FEES		$ 35,425		$ 32		$ 1,729		$ 5,356		$ 22,274		$ 6,034
TOTAL OTHER DIRECT COST		$ 42,740		$ 340		$ 2,566		$ 7,896		$ 23,482		$ 8,456
TOTAL DIRECT COST		$ 121,354		$ 9,615		$ 11,539		$ 34,615		$ 33,852		$ 31,733
FACILITIES & ADMIN. RATE - % OF MTDC	VAR	$ 62,516	56%	$ 5,385	56%	$ 6,461	56%	$ 19,385	47.7%	$ 16,148	47.7%	$ 15,137
TOTAL COST		$ 183,870		$ 15,000		$ 18,000		$ 54,000		$ 50,000		$ 46,870
IN-KIND COST SHARE - COAL COMPANIES		$ 57,000										
TOTAL PROJECT COST		$ 240,870										

NOTE: Due to limitations within the University's accounting system, the system does not provide for accumulating and reporting expenses at the Detailed Budget level. The Summary Budget is presented for the purpose of how we propose, account, and report expenses. The Detailed Budget is presented to assist in the evaluation of the proposal.

DETAILED BUDGET

INVESTIGATION OF MERCURY AND CARBON-BASED SORBENT REACTION MECHANISMS
NDIC
PROPOSED START DATE: 6/1/04
EERC PROPOSAL #2004-0234

LABOR	LABOR CATEGORY	HOURLY RATE	TOTAL HRS	TOTAL $COST	DAK WEST SHARE HRS	DAK WEST SHARE $COST	EPRI SHARE HRS	EPRI SHARE $COST	NDIC SHARE HRS	NDIC SHARE $COST	CATM SHARE HRS	CATM SHARE $COST	EERC JSRP SHARE HRS	EERC JSRP SHARE $COST
CROCKER, C.	PROJECT MANAGER	$ 27.03	280	$ 7,568	-	$ -	40	$ 1,081	119	$ 3,217	30	$ 811	91	$ 2,459
BENSON, S.	PRINCIPAL INVESTIGATOR	$ 51.14	94	$ 4,807	-	$ -	24	$ 1,227	70	$ 3,580	-	$ -	-	$ -
OLSON, E.	PRINCIPAL INVESTIGATOR	$ 44.38	212	$ 9,409	-	$ -	45	$ 1,997	135	$ 5,991	-	$ -	32	$ 1,421
PAVLISH, J.	RESEARCH SCIENTIST/ENGINEER	$ 47.14	8	$ 377	-	$ -	-	$ -	-	$ -	8	$ 377	-	$ -
SHARMA, R.	RESEARCH SCIENTIST/ENGINEER	$ 26.36	80	$ 2,109	-	$ -	20	$ 527	60	$ 1,582	-	$ -	-	$ -
MIBECK, B.	RESEARCH SCIENTIST/ENGINEER	$ 22.93	160	$ 3,669	-	$ -	-	$ -	-	$ -	160	$ 3,669	-	$ -
ZOLA, J.	RESEARCH TECHNICIAN	$ 22.25	128	$ 2,848	-	$ -	-	$ -	-	$ -	-	$ -	128	$ 2,848
WIXO, C.	RESEARCH TECHNICIAN	$ 24.89	40	$ 996	-	$ -	-	$ -	-	$ -	-	$ -	40	$ 996
----------	SENIOR MANAGEMENT	$ 50.49	45	$ 2,272	-	$ -	-	$ -	-	$ -	-	$ -	45	$ 2,272
----------	RESEARCH SCIENTIST/ENGINEER	$ 28.30	450	$ 12,735	204	$ 5,773	24	$ 679	72	$ 2,038	28	$ 792	122	$ 3,453
----------	RESEARCH TECHNICIAN	$ 19.15	74	$ 1,417	-	$ -	-	$ -	-	$ -	29	$ 555	45	$ 862
FOERSTER, L.	TECHNICAL SUPPORT SERVICES	$ 13.22	10	$ 132	-	$ -	-	$ -	-	$ -	10	$ 132	-	$ -
----------	TECHNICAL SUPPORT SERVICES	$ 14.90	40	$ 596	-	$ -	5	$ 75	15	$ 223	8	$ 119	12	$ 179
			1,621	$ 48,935	204	$ 5,773	158	$ 5,586	471	$ 16,631	273	$ 6,455	515	$ 14,490
ESCALATION ABOVE CURRENT BASE		5%		$ 2,447		$ 289		$ 279		$ 832		$ 323		$ 724
TOTAL DIRECT LABOR				$ 51,382		$ 6,062		$ 5,865		$ 17,463		$ 6,778		$ 15,214
FRINGE BENEFITS - % OF DIRECT LABOR		53%		$ 27,232		$ 3,213		$ 3,108		$ 9,256		$ 3,592		$ 8,063
TOTAL LABOR				$ 78,614		$ 9,275		$ 8,973		$ 26,719		$ 10,370		$ 23,277
OTHER DIRECT COSTS														
TRAVEL				$ 5,962		$ -		$ 793		$ 2,379		$ 909		$ 1,881
COMMUNICATION - PHONES & POSTAGE				$ 95		$ 6		$ 8		$ 16		$ 20		$ 45
OFFICE (PROJECT SPECIFIC SUPPLIES)				$ 160		$ 10		$ 14		$ 31		$ 50		$ 55
SUPPLIES				$ 1,028		$ 292		$ 18		$ 82		$ 214		$ 422
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)				$ 70		$ -		$ 4		$ 32		$ 15		$ 19
PARTICULATE ANALYSIS				$ 21,987		$ -		$ -		$ -		$ 21,987		$ -
PROCESS CHEM. & DEV. LAB.				$ 6,997		$ -		$ 1,699		$ 5,298		$ -		$ -
GRAPHICS SUPPORT				$ 441		$ 32		$ 30		$ 58		$ 287		$ 34
OUTSIDE LAB				$ 6,000		$ -		$ -		$ -		$ -		$ 6,000
TOTAL OTHER DIRECT COST				$ 42,740		$ 340		$ 2,566		$ 7,896		$ 23,482		$ 8,456
TOTAL DIRECT COST				$ 121,354		$ 9,615		$ 11,539		$ 34,615		$ 33,852		$ 31,733
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 62,516	56%	$ 5,385	56%	$ 6,461	56%	$ 19,385	47.7%	$ 16,148	47.7%	$ 15,137
TOTAL COST				$ 183,870		$ 15,000		$ 18,000		$ 54,000		$ 50,000		$ 46,870
IN-KIND COST SHARE - COAL COMPANIES				$ 57,000										
TOTAL PROJECT COST				$ 240,870										

DETAILED BUDGET - FEES

PARTICULATE ANALYSIS	**RATE**	#	**TOTAL $COST**
BENCH SCALE SIMULATOR (PER HOUR)	$104	160	$ 16,640
MERCURY CEM (PER DAY)	$215	20	$ 4,300
SUBTOTAL			$ 20,940
ESCALATION		5%	$ 1,047
TOTAL PARTICULATE ANALYSIS			$ 21,987

PROCESS CHEM. & DEV. LAB.	**RATE**	#	**$COST**
MISC (HOURLY)	$49	136	$ 6,664
SUBTOTAL			$ 6,664
ESCALATION		5%	$ 333
TOTAL PROCESS CHEM. & DEV. LAB.			$ 6,997

GRAPHICS SUPPORT	**RATE**	#	**$COST**
GRAPHICS (HOURLY)	$42	10	$ 420
SUBTOTAL			$ 420
ESCALATION		5%	$ 21
TOTAL GRAPHICS SUPPORT			$ 441

DETAILED BUDGET - TRAVEL

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	ECON AIRFARE	LODGING	PER DIEM	CAR RENTAL	MILEAGE	REGIST.
Unspecified Destination (USA)	$ 800	$ 150	$ 51	$ 60	$ -	$ 525
Bismarck, ND	$ -	$ 50	$ 20	$ -	$ 0.31	$ -
Eden Prairie, MN	$ -	$ 80	$ 51	$ -	$ 0.31	$ -
Morgantown, WV (via Pittsburgh, PA)	$ 1,200	$ 150	$ 47	$ 60	$ -	$ -

PURPOSE/DESTINATION	NUMBER OF TRIPS	NUMBER OF PEOPLE	NUMBER OF DAYS	NUMBER OF MILES	AIRFARE	MILEAGE	LODGING	PER DIEM	CAR RENTAL	MISC.	REGIST.	TOTAL
Nat'l Conference/Unspecified Dest. (USA)	1	1	5	-	$ 800	$ -	$ 600	$ 255	$ 300	$ 100	$ 525	$ 2,580
Contract Rvw Mtg/Bismarck, ND	2	1	2	600	$ -	$ 372	$ 100	$ 80	$ -	$ 40	$ -	$ 592
Sample analysis/Eden Prairie, MN	2	1	2	750	$ -	$ 465	$ 160	$ 204	$ -	$ 80	$ -	$ 909
Contract Rvw Mtg/Morgantown, WV (Pittsburgh, PA)	1	1	3	-	$ 1,200	$ -	$ 300	$ 141	$ 180	$ 60	$ -	$ 1,881
TOTAL ESTIMATED TRAVEL												$ 5,962

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

Background

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

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, subcontracts) is for planning purposes only. The principal investigator may, as dictated by the needs of the work, reallocate the budget among approved items or use the funds for other items directly related to the project, subject only to staying within the total dollars authorized for the overall program. The budget prepared for this proposal is based on a specific start date; this start date is indicated at the top of the EERC budget or identified in the body of the proposal. Please be aware that any delay in the start of this project may result in an increase in the budget. Financial reporting will be at the total project level.

Salaries and Fringe Benefits

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

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

Travel

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

Communications (phones and postage)

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

Office (project-specific supplies)

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

Data Processing

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

Supplies

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

Instructional/Research

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

Fees

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

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

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

General

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

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

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

Facilities and Administrative Cost

The facilities and administrative rate (indirect cost rate) included in this proposal is the rate that became effective July 1, 2002. Facilities and administrative cost is calculated on modified total direct costs (MTDC). MTDC is defined as total direct costs less individual items of equipment in excess of $5000 and subcontracts/subgrants in excess of the first $25,000 for each award.

APPENDIX A

RESUMES OF KEY PERSONNEL

CHARLENE R. CROCKER
Research Chemist
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5000 Fax: (701) 777-5181
E-Mail: ccrocker@undeerc.org

Principal Areas of Expertise

Ms. Crocker's principal areas of interest and expertise include mercury and halogens in coal combustion, developing carbon-based mercury control sorbents, airborne particulate matter instrumentation, water quality monitoring and analytical methods, development and implementation of fish consumption surveys, general public and K–12 education, laser-induced breakdown spectroscopy (LIBS), atomic absorption spectroscopy (AAS) (flame, graphite furnace, and hydride generation), inductively coupled plasma spectroscopy (ICP), trace element analysis of water, coal and coal by-products, and atomic fluorescence spectroscopy (AFS).

Qualifications

B.S., Chemistry, University of North Dakota, 1994
B.A., French, Colby College, Waterville, ME, 1986

Professional Experience

1994 – Research Chemist, Responsibilities include managing projects relating to environmental management and air quality; collaborating with other scientists on development of carbon-based flue gas sorbents, particulate matter (PM) sampling, fish consumption survey development, corrosion of ceramic and alloy materials, coal ash, water purification, and surface decontamination research; proposal and report writing, data analysis, presentation of results, and budget tracking; developing PM sampling protocols; participating in development of a water-based geoscience education program and outreach activities for school children; directing activities of student assistants; developing and implementing analytical methods employing LIBS. Previous duties performed in the Analytical Research Laboratory focused on water quality and energy-related analyses. Responsibilities included preparing and analyzing ultratrace element samples in aqueous and inorganic media using AAS, ICP, and IC; recording and disseminating analytical results and quality control checks; performing research on ultratrace elemental analysis of mercury using AFS; and preparing reagents and solutions.

1993 – 1994 Research Assistant, EERC, UND. Ms. Crocker's responsibilities included preparing and analyzing ultratrace element samples in inorganic media; performing research on ultratrace element analysis of mercury in air using AFS; and preparing reagents and solutions.

1990 Naturalist, Deep Portage Conservation Reserve, Hackensack, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental

education programs for children and adults; evaluating curriculum; and organizing lending of educational learning stations.

1988 – 1990 Sanctuary Manager, Wetlands, Pines & Prairie Audubon Sanctuary, Warren, Minnesota. Ms. Crocker's responsibilities included planning and conducting environmental education programs; organizing chapter meetings; publishing the Sanctuary newsletter; and performing administrative tasks.

1988 Park Ranger/Interpreter, Boston Harbor Islands State Park, Boston, Massachusetts. Ms. Crocker's responsibilities included interpreting natural and human history; developing special programs and leading walking tours of the islands; and conducting school programs.

Publications and Presentations

Has coauthored several publications

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

Principal Areas of Expertise

Management of complex multidisciplinary programs focused on solving energy production and environmental problems. Program areas include the development of 1) methodologies to minimize the effects of inorganic components on the performance of combustion/gasification and air pollution control systems; 2) the fate and behavior of air toxic substances in combustion and gasification systems; 3) advanced analytical techniques to determine the chemical and physical transformations of inorganic species in combustion gases; 4) computer-based codes to predict the effects of coal quality on system performance; 5) advanced materials for coal-based power systems; and 6) training programs designed to improve the global quality of life through energy and environmental research activities.

Qualifications

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

Professional Experience

1999 – Senior Research Manager/Advisor, EERC, UND. Responsible for the direction of projects and programs on the impact of inorganic species on the performance of combustion and associated environmental control systems. Specific areas of focus include the direction of the EPA Center for Air Toxic Metals at the EERC, advanced methods of materials analysis, and application of computer models to energy and environmental issues.

1994 – 1999 Associate Director for Research, EERC, UND. Responsible for the direction of programs related to integrated energy and environmental systems development. EERC research, development, and demonstration programs involve fuel quality effects on power system performance, advanced power systems development/demonstration, computational modeling, advanced materials for power systems, and analytical methods for the characterization of materials. Specific areas of focus included the direction of the EPA Center for Air Toxic Metals at the EERC, ash behavior in combustion and gasification systems, hot-gas cleanup, and analytical methods of analysis. Responsible for identifying research opportunities and the preparation of proposals and reports for clients.

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

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

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

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

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

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

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

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

Professional Memberships

- The Combustion Institute
- ASME Research Committee on Corrosion and Deposits from Combustion Gases
- American Chemical Society, Fuel Division Member
- Industrial Liaison, American Chemical Society Division of Fuel Chemistry

Publications and Presentations

- Has authored/coauthored over 180 publications and is the editor of six books and Special Issues

DR. EDWIN S. OLSON
Senior Research Advisor
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
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Phone: (701) 777-5000 Fax: (701) 777-5181
E-Mail: eolson@undeerc.org

Principal Areas of Expertise

Dr. Olson's principal areas of interest and expertise include carbon and coal structure and reactivity, mercury sorption, water purification chemistry, enzyme-catalyzed esterification and desulfurization reactions, chromatography, organic trace analysis, mass spectrometry, and organic spectroscopy.

Qualifications

Ph.D., Chemistry and Physics, California Institute of Technology, 1964.
B.A., Chemistry, magna cum laude, St. Olaf College, 1959.

Professional Experience

1994 – Senior Research Advisor, EERC, UND. Novel activated carbons for air and water treatment were designed and tested.

1988 – President, Universal Fuel Development Associates, Inc. Dr. Olson served as Project Manager for Phase I and II Small Business Innovation Research projects involving water purification, nonaqueous enzymatic solubilization of coal materials, oxygenate synthesis from agricultural materials. and DBP removal from drinking water and for DOE projects involving geotechnical characterizations and fine-particle catalysts for coal liquefaction.

1983 – 1994 Research Supervisor, Fuel Conversion and Process Chemistry Division, EERC, UND. Dr. Olson performed hydrotreating and HDS catalyst, and coal liquefaction, and gasification research and analytical methods development.

1980 – 1983 Research Chemist, Grand Forks Energy Technology Center, U.S. Department of Energy. Dr. Olson developed analytical methods for coal conversion products by GC, MS, HPLC, and NMR and trace organics in air, water, and fly ash.

1968 – 1980 Professor of Chemistry, South Dakota State University. Taught graduate/under-graduate courses in organic, biochemistry, and instrumental analysis. Research in homogeneous catalysts, organic synthesis.

1977 Visiting Professor, University of Notre Dame (summer).

1972 – 1976 Visiting Staff Member, Los Alamos Scientific Laboratory (summers).

Dr. Olson also has experience at the University of California, Los Angeles, Department of Biochemistry, and at Idaho State University, Department of Chemistry.

Publications and Presentations (over 180 total)
Recent refereed Publications

- Olson, E.S.; Laumb, J.D.; Benson, S.A.; Dunham, G.E., Sharma, R.K..; Mibeck, B.A.; Miller, S.J.; Holmes, M.J.; Pavlish, J.H. *J. Phys. IV France* **2003**, *107*, 979.

- Olson, E.S.; Sharma, R.K.; Aulich, T.R. Ester Fuels and Chemicals from Biomass. *Appl. Biochem. Biotechnol*. **2003**, *105-108*, 843.

- Olson, E.S.; Sharma, R.K.; Pavlish, J.P. On the Analysis of Mercuric Nitrate in Flue Gas by GCMS. *Anal. Bioanal. Chem*. **2002**, *374*, 1045.

- Pavlish, J.P.; 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. *Fuel Process. Technol*. **2003,** *82*, 89.

- Olson, E.S.; Kjelden, M.R.; Schlag, A.J.; Sharma, R.K. Levulinate Esters from Biomass Wastes. In *Chemicals and Materials from Renewable Resources*; Bozell, J.J., Ed.; ACS Symposium Series 784; American Chemical Society, Ch. 5, 2001, pp 51–63.

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APPENDIX B

LETTERS OF COMMITMENT

POWERING PROGRESS THROUGH
SCIENCE AND TECHNOLOGY

EPRI

September 29, 2003

Dr. Steven A. Benson
Senior Research Manager
Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202-9018

Dear Steve:

Subject: Proposal entitled "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms"

This letter is in response to your request for participation in the proposed EERC project entitled "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms". EPRI agrees to contribute funds of $18,000 cash to the two-year project. It is understood that the EPRI's funding for this project will provide cost share to NDIC and federal funding from the U.S. Department of Energy and will come from our membership funding. Any questions regarding EPRI's involvement in the project may be directed to me.

Yours Truly,

Ramsay

Ramsay Chang
Manager, Air Emissions Control
EPRI
PO Box 10412
Palo Alto, Ca 94303-0813
Tel: 650-855-2535 Fax: 650-855-8759

-----Original Message-----
From: Pavlish, John H.
Sent: Friday, March 26, 2004 2:16 PM
To: Benson, Steven A.
Cc: Laumb, Jason

Subject: Support for Project Entitled "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms"

Steve,

The Energy and Environmental Research Center, through its Environmental Protection Agency (EPA) sponsored Center for Air Toxic Metals (CATM) program would like to express its interest and support for the project titled "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms". The goal and objectives of the proposed project support a research need that has been identified as a priority by members of the CATM Research Advisory Council. As CATM Director, through this program I have allocated $50,000 in funds to support this effort. This project has been reviewed and accepted by the CATM Science Advisory Committee and I do not expect any problems in getting final approval from EPA.

Please contact me if there are any questions that arise about the participation of CATM. I can be contacted by phone at (701) 777-5268, by fax at (701) 777-5181, or by e-mail at jpavlish@undeerc.org.

Sincerely,

John Pavlish
CATM Director
Senior Research Manager
Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202
Phone: (701)777-5268
Fax: (701)777-5181
Email: jpavlish@undeerc.org

-----Original Message-----
From: Doug Kathol [mailto:dkathol@Westmoreland.com]
Sent: Friday, March 26, 2004 12:22 PM
To: Sbenson@undeerc.org
Cc: jlaumb@undeerc.org; Patrick Wright; Todd Myers

Subject: Investigations of mercury and carbon-based sorbents

Steven

This letter is in response to your request for participation in the proposed Energy and Environmental Research Center (EERC) project entitled "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms". Westmoreland agrees to contribute $18,000 total cost share to the two-year project. Of the $18,000 provided $15,000 will be cash and $3,000 will be an in-kind contribution. The in-kind contribution is based on proximate analysis done for the Coyote power station. It is understood that Westmoreland's funding for this project will be used as cost share to receive cash funding from North Dakota Industrial Commission (NDIC) and federal funding from the U.S. Department of Energy.

Best regards,

Doug Kathol
Vice President - Development
Westmoreland Coal
3rd Floor, 2 North Cascade Avenue
Colorado Springs, CO 80903

COTEAU
THE COTEAU PROPERTIES COMPANY

A SUBSIDIARY OF THE NORTH AMERICAN COAL CORPORATION

FREEDOM MINE
204 County Road 15
Beulah, ND 58523-9475
(701) 873-2281 • Fax (701) 873-7226

March 30, 2004

Jason Laumb
Energy & Environmental Research Center
15 North 23rd Street
Grand Forks, ND 58202-9018

Subject: NDIC Lignite Research Program Grant Application
Support for EERC Proposal
"INVESTIGATION OF MERCURY AND CARBON BASED SORBENT REACTION MECHANISMS"

Dear Mr. Laumb:

This letter is in response to your request for participation in the proposed Energy and Environmental Research Center (EERC) project entitled "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms". Coteau agrees to contribute $18,000 in-kind to the two-year project. Coteau agrees to furnish EERC with short proximate coal analyses and a sample of coal, to be used in testing at EERC. It is understood that Coteau's funding for this project will be used as cost share to receive cash funding from North Dakota Industrial Commission (NDIC) and federal funding from the U.S. Department of Energy.

Yours truly,

Dennis R. James
Staff Geologist

FALKIRK
THE FALKIRK MINING COMPANY
A SUBSIDIARY OF THE NORTH AMERICAN COAL CORPORATION

P.O. BOX 1087
UNDERWOOD, NORTH DAKOTA 58576 • (701) 442-5751

March 30, 2004

Jason Laumb
Energy & Environmental Research Center
15 North 23rd Street
Grand Forks, ND 58202-9018

Subject: NDIC Lignite Research Program Grant Application
Support for EERC Proposal
"INVESTIGATION OF MERCURY AND CARBON BASED SORBENT REACTION MECHANISMS"

Dear Mr. Laumb:

This letter is in response to your request for participation in the proposed Energy and Environmental Research Center (EERC) project entitled "Investigation of Mercury and Carbon-Based Sorbent Reaction Mechanisms". Falkirk agrees to contribute $18,000 in-kind to the two-year project. Falkirk agrees to furnish EERC with short proximate coal analyses and a sample of coal, to be used in testing at EERC. It is understood that Falkirk's funding for this project will be used as cost share to receive cash funding from North Dakota Industrial Commission (NDIC) and federal funding from the U.S. Department of Energy.

Yours truly,

Dennis R. James
Staff Geologist

MICHAEL J. HUMMEL
President & General Manager

BNI COAL®

PHONE (701) 222-8828
FAX (701) 222-1547

March 29, 2004

Dr. Steve A. Benson
Energy & Environmental Research Center
University of North Dakota
P. O. Box 9018
Grand Forks, North Dakota 58202-9018

Dear Steve;

Thank you for inviting BNI Coal, Ltd. to participate in the "Investigation of Mercury & Carbon-Based Sorbent Reaction Mechanisms" consortium. We will participate on an in-kind basis by providing lignite for testing and quality data that demonstrates a value of $18,000.

We would anticipate that our in-kind contribution would be met through preparation and delivery of lignite coal samples (one 55 gallon drum ($500) and assembly and delivery of coal quality data ($17,500).

Sincerely,

MJ Hummel

Copy: Charlene C. Crocker
Jason Laumb