September 29, 2006

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
State Capitol – Fourteenth Floor
600 East Boulevard Avenue
Bismarck, ND 58505

Dear Ms. Fine:

Subject: EERC Proposal No. 2007-0012

Enclosed please find an original and 6 copies of the proposal entitled "Upgrade and Refurbishment of a Bench-Scale Entrained-Flow Slagging Gasifier." Also enclosed is the $100 application fee. The Energy & Environmental Research Center has found a high level of interest in the project from industry. We are holding a project review meeting with several potential sponsors in October.

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

Sincerely,

Steven A. Benson
Senior Research Manager

SAB/cs

Enclosures

UPGRADE AND REFURBISHMENT OF A BENCH-SCALE ENTRAINED-FLOW SLAGGING GASIFIER

EERC Proposal No. 2007-0012

Submitted to:

Ms. Karlene Fine

North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Proposal Amount: $129,000

Submitted by:

Dr. Steven A. Benson
Jason D. Laumb
Joshua J. Stanislowski

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

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Steven A. Benson, Project Manager

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

September 2006

UPGRADE AND REFURBISHMENT OF A BENCH-SCALE ENTRAINED-FLOW SLAGGING GASIFIER

ABSTRACT

One of the most widely available commercial gasifiers today is the entrained-flow style gasifier. However, little experience has been had with lignite coals in entrained-flow gasification systems. To help overcome the challenges of utilizing lignite coal with commercially available gasification systems, a bench-scale entrained-flow slagging gasifier will be built which will be used for syngas production, cleanup, and separation testing. An existing pressurized vessel at the Energy & Environmental Research Center (EERC) will be updated with a new heating system that will allow coal particles in the furnace to reach slagging gasifier temperatures in a residence time of a few seconds. The system will be constructed such that a sulfur removal test vessel and other existing separation systems at the EERC can be fitted to the entrained-flow reactor for gas cleanup testing.

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UPGRADE AND REFURBISHMENT OF A BENCH-SCALE ENTRAINED-FLOW SLAGGING GASIFIER

PROJECT SUMMARY

The Energy & Environmental Research Center (EERC) constructed and ran a pressurized drop-tube furnace in the early 1990s. This system was capable of achieving pressures of 300 psig, but no testing was completed at those pressures because of the difficulty of maintaining high temperature with increasing pressure. The system was decommissioned in 1997, but the pressurized vessel was retained. For the purposes of this project, the pressurized vessel will be recommissioned and upgraded with a new heating system and a new feed system. The new heating system will utilize innovative technology that will be designed to solve the problem of reaching adequate temperature ranges. A detailed description of the equipment to be built and a conceptual drawing can be found in Appendix B.

The gasifier will be housed in the EERC's National Center for Hydrogen Technology (NCHT) building. The system will be designed so that existing gas cleanup equipment can be used for separation and purification testing.

PROJECT DESCRIPTION

Goal

The goal of the proposed project is to upgrade and refurbish an existing bench-scale gasifier so that a temperature of 1500°C can be reached when operating at a pressure of 300 psi.

Objectives

To meet the goal of the project, the following objectives have been identified:

1. Design entrained-flow gasifier capable of reaching 1500°C at a pressure of 300 psi.
2. Procure materials

3. Construct system

4. Perform shakedown testing

Work Plan

Task 1 – Design

The design of the new heating system will be such that the furnace can maintain a temperature of 1500°C at a pressure of 300 psig. In addition, a pressurized feed system, air preheater, exit gas and slag handling system, and gas recycle system will also be designed. The heating system will be molybdenum disilicide heating elements or a novel heating system. The final design of the heating system will be part of this task.

Task 2 – Procurement of Materials

All materials needed for construction will be procured. Items exceeding $5000 will require a minimum of three bids or a sole-source justification.

Task 3 – Construction and Refurbishment of System

A new feed system and air preheater will be constructed, as well as an updated gas and slag handling system at the exit of the furnace. The heated section will be refurbished with a novel heating system and refractory insulation.

Task 4 – Shakedown Testing

The system will be tested for leaks and the ability to maintain high pressure. All heating and control systems will be tested for safety and consistency as well as the ability to maintain slagging temperatures.

Deliverables

The key deliverable for this project will be an entrained-flow gasifer capable of maintaining a temperature of 1500°C at 300 psig. Quarterly progress reports will be issued as well as a final report detailing the final operating parameters of the entrained-flow gasifier.

STANDARDS OF SUCCESS

The standards by which the success of the project will be measured will include the ability of the technology to continuously gasify carbon material at a temperature of 1500°C and a pressure of 300 psi. Consistency and reliability of the equipment will be a key factor.

This project is required to be in compliance with the EERC Quality Management System and any project-specific quality assurance (QA) procedures, thus ensuring that any requirements relating to quality and compliance with applicable regulations, codes, and protocols are adequately fulfilled. The EERC Quality Assurance Manager implements and oversees all aspects of QA/quality control (QC) for all research, development, and demonstration projects and will review the QA/QC components of this project. The EERC maintains a wide range of analytical and testing laboratories that follow nationally recognized or approved standards and methods put forth by the U.S. Environmental Protection Agency, American Society for Testing and Materials International (ASTM), the National Institute of Standards and Technology, and other agencies.

BACKGROUND

By 2025, there is expected to be an addition of 87 gigawatts of new coal electricity generating capacity in the United States. Of the 140 proposed new plants, 22 are expected to be coal gasification plants (Klara and Shuster, 2006). With this addition comes the need to gather a better understanding of the coal gasification process and its interaction with different coal types. Of the top 29 gasification projects currently under way in the world, 22 projects utilize entrained-flow gasification (Utilis Energy, 2005). It is expected that many of the new power plant additions will use entrained-flow gasification as the technology of choice.

Entrained-flow gasifiers have been operated successfully for many years, producing a wide variety of products from liquid fuels to electric power. Several types of entrained-flow gasifiers exist today, built by companies such as GE, E-Gas, Shell, and Future Energy. Entrained-flow gasification is considered a fuel-flexible technology because high temperatures (1400°–1600°C) allow for complete conversion in feedstocks with low reactivity. A wide variety of products are gasified in today’s commercial EFG operations, including bituminous coal, asphalt, fuel oil, and petroleum coke. To date, very little experience exists with entrained-flow gasifiers and lignite coals.

Traditionally, lignites have posed significant challenges when used in slagging gasification systems. Wet slurry feeds similar to a GE/Texaco entrained-flow system are not efficient with lignite coal because of lignite’s inherently high moisture content and relatively low carbon content. Analysis performed by Gray et al. indicates that with Texas lignite, a wet feed slurry would only contain 29% carbon by weight (2004). According to Gray, this would result in an overall clean cold gas efficiency of 60% on a HHV basis (Gray et al., 2004). Increased efficiency is noted when using a two-stage slurry-fed gasifier representing a Conoco Phillips E-Gas type system. Clean cold gas efficiency of 69% is thought to be possible with Texas lignite (Gray et al., 2004). Dry feed systems are the best choice for lignite gasifying efficiency, but the high moisture content of lignite coal requires that it be dried prior to feeding to prevent caking. Despite these challenges, high cold gas efficiencies with the Shell Coal Gasification Process (SCGP) have been achieved when firing lignite coal. Eurlings et al. have reported cold gas efficiencies of 80% and 81% when gasifying Texas and Alcoa Lignites, respectively, utilizing the SCGP process (1999).

High concentrations of sodium and calcium found in many lignite coals can result in serious fouling, slagging, and wall erosion issues when used in slagging gasification systems. Additionally, the sodium may cause problems with the associated gas cleanup equipment. Today, there is a large information gap regarding the entrained-flow gasification of North Dakota and other high sodium lignite coals. It is known that lignite coals can produce as much as three times more slag than bituminous coals. Phillips et al. found that when using the SCGP with Texas lignite, slag production was 33 lb per MMBtu of product gas vs. only 11 lb of slag per MMBtu of product gas when firing Illinois No. 5 bituminous coal (Phillips et al., 1993). The high concentration of sodium in North Dakota and Canadian lignite coal is expected to compound this slagging issue.

Currently, only one commercial-scale gasification plant for lignite coals exists today in the United States (Utilis Energy, 2005). The Great Plains Synfuels Plant located near Beuhlah, North Dakota, represents the only commercial-scale facility in the United States that utilizes lignite coal for gasification. Owned and operated by the Dakota Gasification Company, this plant uses the Lurgi process to convert lignite coal to syngas and, ultimately, synthesis natural gas. The fixed-bed gasification takes place at 1200°C, considerably lower than the 1500°C temperatures normally utilized in entrained-flow gasifiers. The high reactivity of lignite coal makes it a good candidate for lower-temperature gasification.

QUALIFICATIONS

A brief description of the qualifications of the principal investigator and other key personnel is listed below. Short resumes can be found in Appendix A.

Principal Investigator

Dr. Steven A. Benson, Senior Research Manager at the EERC, will serve as Principal Investigator for the project. Dr. Benson received a Ph.D. in Fuel Science, Materials Science and Engineering from the Pennsylvania State University in 1987 and a B.S. in Chemistry from Minnesota State University, Moorhead, in 1977. Dr. Benson's principal areas of expertise include the 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) methodologies to determine 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.

Coprincipal Investigator

Mr. Jason Laumb is a Research Manager at the EERC. He received an M.S. in Chemical Engineering in 2000 and a B.S. in Chemistry in 1998, both from the University of North Dakota. Prior to his current position, Mr. Laumb served as a Scanning Electron Microscopy Applications Specialist with Microbeam Technologies, Inc. Mr. Laumb has managed and comanaged numerous projects involving multidisciplinary teams of scientists and engineers. Mr. Laumb's principal areas of interest and expertise include predicting slag viscosity and boiler performance based on fuel quality and control technologies to remove mercury from combustion systems. He has coauthored several professional publications.

Other Assigned Personnel

Josh Stanislowski is a research engineer at the EERC. He received his B.S. in Chemical Engineering from the University of North Dakota in 2000. Prior to his current position, Mr. Stanislowski served as a process engineer at Innovex Inc., where his work focused on the deployment of six sigma manufacturing principles. Mr. Stanislowski's principle areas of interest and expertise include mercury control and the development of gasification technologies. He has extensive experience in the area of experimental design and analysis. He also has experience in the design and construction of bench-scale equipment.

EERC

The EERC is one of the world's major energy and environmental research organizations. Since its founding in 1949, 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.

VALUE TO NORTH DAKOTA

If the proposed project is successful, the value to North Dakota will be measured by increased use of lignite, new jobs created at gasification facilities, and centers of an emerging industry fixing themselves in North Dakota. The results of this project may allow for the use of lignite reserves in a gasification technology that is commercially available. Successful lignite testing in an entrained-flow gasifier will give added confidence to potential investors and could lead to the construction of a full-scale entrained-flow gasifier in North Dakota.

MANAGEMENT

The overall project manager will be Mr. Jason Laumb. Dr. Steven Benson will act as a project advisor. Mr. Josh Stanislowski will be responsible for leading the design team. All key personnel will be responsible for interpretation of results and writing reports. Resumes of all key personnel are enclosed in Appendix A.

Once the project is initiated, monthly or as-needed conference calls will be held with project sponsors and team members to review project status. Quarterly reports will be prepared and submitted to project sponsors for review. A meeting at the end of the project will be held to review the system and discuss directions for future work.

TIMETABLE

The proposed schedule for the project is shown in Figure 1.

ID	Task Name	Start	Finish
1	**Design, Construction, and Shakedown Testing**	**10/2/2006**	**4/30/2007**
2	Design of System	10/2/2006	12/1/2006
3	Procurement of Materials	11/13/2006	2/1/2007
4	Construction of System	12/1/2006	3/30/2007
5	Shakedown Testing	3/15/2007	4/30/2007

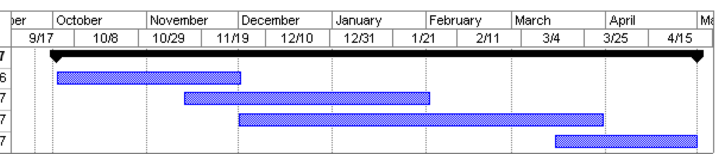

Figure 1. Schedule for upgrade and refurbishment of an entrained-flow gasifier.

BUDGET

The total project cost is estimated at $354,000. The National Center for Hydrogen Technology (NCHT) will contribute $75,000, which will combine in cost share with $150,000 from two industry sponsors ($75,000 each) and $129,000 from NDIC.

MATCHING FUNDS

The $129,000 requested from NDIC will be matched with $75,000 from NCHT and $75,000 from each of the two industry sponsors.

TAX LIABILITY

None.

CONFIDENTIAL INFORMATION

No confidential material.

REFERENCES

Eurlings, J.Th.G.M.; Ploeg, J.E.G. Process Performance of the SCGP at Buggenum IGCC. Presented at Gasification Technologies Conference, San Francisco, CA; October 1999.

Gray, D.; Salerno, S.; Tomlinson, G.; Marano, J. *Polygeneration of SNG, Hydrogen, Power, and Carbon Dioxide from Texas Lignite*; Dec 2004.

Klara, S.; Shuster, E. Tracking New Coal-Fired Power Plants: Coals Resurgence in Electric Power Generation. Department of Energy National Energy Technology Laboratory. Presented at OCES; Mar 20, 2006.

Phillips, J.N.; Kiszka, M.B.; Mahagaokar, U.; Krewinghaus, A.B. *Shell Coal Gasification Project: Final Report on Eighteen Diverse Feeds*; EPRI Project 2695-01; July 1993.

Utilis Energy. *Coal Gasification 2005: Road Map to Commercialization*; Feb 2005.

UPGRADE AND REFURBISHMENT OF A BENCH-SCALE ENTRAINED FLOW SLAGGING GASIFIER
DOE/NDIC
PROPOSED START DATE: 10/01/06
EERC PROPOSAL #2007-0012

SUMMARY BUDGET

CATEGORY	**TOTAL HRS**	**TOTAL $COST**	**INDUSTRY SHARE HRS**	**INDUSTRY SHARE $COST**	**NDIC SHARE HRS**	**NDIC SHARE $COST**	**EERC NCHT SHARE HRS**	**EERC NCHT SHARE $COST**
TOTAL DIRECT LABOR	2,704	$ 81,050	969	$ 29,531	1,735	$ 51,519	-	$ -
TOTAL FRINGE BENEFITS		$ 40,995		$ 14,721		$ 26,274		$ -
TOTAL LABOR		$ 122,045		$ 44,252		$ 77,793		$ -
OTHER DIRECT COSTS								
COMMUNICATION - PHONES & POSTAGE		$ 327		$ 227		$ 100		$ -
OFFICE (PROJECT SPECIFIC SUPPLIES)		$ 318		$ 277		$ 41		$ -
SUPPLIES		$ 3,000		$ 600		$ 2,400		$ -
GENERAL (FREIGHT, FOOD, MEMBERSHIPS)		$ 300		$ 250		$ 50		$ -
EQUIPMENT > $5000		$ 153,855		$ 78,855		$ -		$ 75,000
FEES		$ 2,308		$ -		$ 2,308		$ -
TOTAL OTHER DIRECT COST		$ 160,108		$ 80,209		$ 4,899		$ 75,000
TOTAL DIRECT COST		$ 282,153		$ 124,461		$ 82,692		$ 75,000
FACILITIES & ADMIN. RATE - % OF MTDC	VAR	$ 71,847	56%	$ 25,539	56%	$ 46,308	47.7%	$ -
TOTAL PROJECT COST		$ 354,000		$ 150,000		$ 129,000		$ 75,000

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.

UPGRADE AND REFURBISHMENT OF A BENCH-SCALE ENTRAINED FLOW SLAGGING GASIFIER
DOE/NDIC
PROPOSED START DATE: 10/01/06
EERC PROPOSAL #2007-0012

DETAILED BUDGET

LABOR	LABOR CATEGORY	HOURLY RATE	TOTAL HRS	TOTAL $COST	INDUSTRY SHARE HRS	INDUSTRY SHARE $COST	NDIC SHARE HRS	NDIC SHARE $COST	EERC NCHT SHARE HRS	EERC NCHT SHARE $COST
LAUMB, J.	PROJECT MANAGER	$ 37.72	80	$ 3,018	40	$ 1,509	40	$ 1,509	-	$ -
BENSON, S.	SENIOR RESEARCH MANAGER	$ 61.48	40	$ 2,459	20	$ 1,230	20	$ 1,229	-	$ -
STANISLOWSKI, J.	PRINCIPAL INVESTIGATOR	$ 28.73	300	$ 8,619	140	$ 4,022	160	$ 4,597	-	$ -
--------------	SENIOR MANAGEMENT	$ 59.15	108	$ 6,388	-	$ -	108	$ 6,388	-	$ -
--------------	RESEARCH SCIENTIST/ENGINEER	$ 32.92	943	$ 31,044	643	$ 21,168	300	$ 9,876	-	$ -
--------------	RESEARCH TECHNICIAN	$ 21.80	113	$ 2,463	26	$ 567	87	$ 1,896	-	$ -
--------------	TECHNOLOGY DEV. MECH.	$ 25.67	1,000	$ 25,670	-	$ -	1,000	$ 25,670	-	$ -
--------------	UNDERGRAD-RES.	$ 8.51	80	$ 681	80	$ 681	-	$ -	-	$ -
--------------	TECHNICAL SUPPORT SERVICES	$ 17.70	40	$ 708	20	$ 354	20	$ 354	-	$ -
			2,704	$ 81,050	969	$ 29,531	1,735	$ 51,519	-	$ -
ESCALATION ABOVE CURRENT BASE		0%		$ -		$ -		$ -		$ -
TOTAL DIRECT LABOR				$ 81,050		$ 29,531		$ 51,519		$ -
FRINGE BENEFITS - % OF DIRECT LABOR - STAFF		51%		$ 40,988		$ 14,714		$ 26,274		$ -
FRINGE BENEFITS - % OF DIRECT LABOR - UNDERGRAD-RES.		1%		$ 7		$ 7		$ -		$ -
TOTAL FRINGE BENEFITS				$ 40,995		$ 14,721		$ 26,274		$ -
TOTAL LABOR				$ 122,045		$ 44,252		$ 77,793		$ -
OTHER DIRECT COSTS										
COMMUNICATION - PHONES & POSTAGE				$ 327		$ 227		$ 100		$ -
OFFICE (PROJECT SPECIFIC SUPPLIES)				$ 318		$ 277		$ 41		$ -
SUPPLIES				$ 3,000		$ 600		$ 2,400		$ -
GENERAL (FREIGHT, FOOD, MEMBERSHIPS)				$ 300		$ 250		$ 50		$ -
EQUIPMENT > $5000				$ 153,855		$ 78,855		$ -		$ 75,000
GRAPHICS SUPPORT				$ 408		$ -		$ 408		$ -
SHOP & OPERATIONS SUPPORT				$ 1,900		$ -		$ 1,900		$ -
TOTAL OTHER DIRECT COST				$ 160,108		$ 80,209		$ 4,899		$ 75,000
TOTAL DIRECT COST				$ 282,153		$ 124,461		$ 82,692		$ 75,000
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 71,847	56%	$ 25,539	56%	$ 46,308	47.7%	$ -
TOTAL PROJECT COST				$ 354,000		$ 150,000		$ 129,000		$ 75,000

UPGRADE AND REFURBISHMENT OF A BENCH-SCALE ENTRAINED FLOW SLAGGING GASIFIER
EERC PROPOSAL #2007-0012

DETAILED BUDGET - FEES

GRAPHICS SUPPORT	RATE	#	TOTAL $COST
GRAPHICS (HOURLY)	$51	8	$ 408
SUBTOTAL			$ 408
ESCALATION		0%	$ -
TOTAL GRAPHICS SUPPORT			$ 408

SHOP & OPERATIONS SUPPORT	RATE	#	$COST
TECHNICAL DEVELOPMENT HOURS	$1.90	1,000	$ 1,900
SUBTOTAL			$ 1,900
ESCALATION		0%	$ -
TOTAL SHOP & OPERATIONS SUPPORT			$ 1,900

DETAILED BUDGET - EQUIPMENT

Fabricated Equipment		$COST
Induction Coil and RF Power Source	$	55,000
Water to Air Cooling System	$	10,000
Temperature Sensors & Support Equipment	$	10,000
Ceramic Tube	$	1,975
Refractory	$	10,000
Graphite Tube	$	1,102
K-Tron Feeder	$	18,700
Pressure Vessel to house feeder	$	7,500
Stainless steel piping	$	2,500
300# Flanges	$	3,000
Kaowool insulation	$	3,000
Exit & slag trap 8" piping	$	1,000
1/2 SS tubing	$	1,000
Air Pre-Heater	$	3,000
Condensing Pots	$	1,000
Mass flow controllers	$	12,000
Miscellaneous components/materials	$	13,078
Total Estimated Cost: Entrained Flow Gasifier	**$**	**153,855**

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

Background

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

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

Salaries and Fringe Benefits

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

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

Travel

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

Communications (phones and postage)

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

Office (project-specific supplies)

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

Data Processing

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

Supplies

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

Instructional/Research

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

Fees

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

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

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

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

General

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

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

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

Facilities and Administrative Cost

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

APPENDIX A

RESUMES OF KEY PERSONNEL

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

Principal Areas of Expertise

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

Qualifications

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

Professional Experience

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

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

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

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

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

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

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

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

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

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

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

Professional Memberships and Activities

United States Senate Committee on the Environment and Public Works

- One of three technical panelists invited to provide testimony on mercury control for the coal-fired power industry.
- American Chemical Society (ACS)
  - Chair – Fuel Division 2004 – Duties comprise coordinating all aspects of the division, including publications and national conferences.
  - Fuel Division – Participates on the Executive Committee involved in the coordination and direction of division activities, including outreach, programming, finances, and publications.
  - Councilor, Fuel Division – Represents the Fuel Division at the National ACS Council meeting.
  - Chair Elect, Fuel Division – August 2002 – Elected to be Chair of the Fuel Division.
  - Member, Committee on Environmental Improvement (CEI) – The committee provides advice and direction to the ACS governance on policies and programs related to the environment. Since becoming a member of the committee, we have developed policy statements on Global Climate Change, Reformulated Gasoline and MtBE, and Energy Policy. These policy statements are used to assist legislators in developing national environmental policy. Members of CEI also provide testimony on a variety of environmental issues.
- American Society for Mechanical Engineers (ASME)
  - Advisory Member, ASME Committee on Corrosion and Deposition Resulting from Impurities in Gas Streams. Developed several conferences through the International Engineering Foundation.

- ► Mercury Reduction Initiative – Minnesota Pollution Control Agency (MPCA)
  - Participated in meetings for the mercury reduction initiative and provided advice regarding mercury control technologies for electric utilities and MPCA for voluntary mercury reduction strategies.
- ► Elsevier Science, *Fuel Processing Technology*
  - Editorial board member whose role is to provide advice and direction for the journal.

Publications and Presentations

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

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Principal Areas of Expertise

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

Qualifications

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

Professional Experience

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

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

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

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

Professional Memberships

- American Chemical Society

Publications and Presentations

- Has coauthored numerous professional publications

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Principal Areas of Expertise

Mr. Stanislowski's principal areas of interest and expertise include fossil fuel combustion for energy conversion with emphasis on trace element control. He has extensive experience with process engineering, process controls, and project management. He has a strong background in gauge studies, experimental design, and data analysis.

Qualifications

B.S., Chemical Engineering, University of North Dakota, 2000.

- Extensive computer experience with Windows, word processors, spreadsheets, and database software and analytical chemistry, organic chemistry, and chemical engineering laboratory work
- Senior classes included reactor design, mass transfer, separations, thermodynamics, and process controls
- Senior design project on the formation of phosphoric acid from phosphate rock
- In-depth courses in statistical methodology including experimental design and analysis

Professional Experience:

2005 – Research Engineer, EERC, UND. Mr. Stanislowski's areas of focus include mercury control technologies and coal gasification. His responsibilities involve project management and aiding in the completion of projects. His duties include design and construction of bench- and pilot-scale equipment, performing experimental design, data collection, data analysis, and report preparation.

2001–2005 Process Engineer, Innovex, Inc., Litchfield, MN.

- Innovex, Inc. is a world-class supplier of flexible circuits to such companies as Seagate, Maxtor, Phillips, and Samsung. Innovex processes plated or laminated copper foils through a roll-to-roll process for the formation of flexible circuits.

- Employed as process engineer for various process lines including copper plating, nickel plating, tin-lead plating, gold plating, polyimide etching, copper etching, chrome etching, and resist strip and lamination. Process engineering is a high-risk, fast-paced position where critical decisions are made daily. Responsible for all aspects of the process line including quality control, documentation, final product yields, continuous process improvement, and operator training. Have gained extensive knowledge of statistical process control and statistical startup methodology. Continuously using statistical analysis and experimental design as part of daily work. Proficient with

MiniTab statistical software. Excellent communication skills with all levels of employees from operations to management.

- Normal duties include designing and overseeing experiments as a principal investigator; writing technical reports and papers, including standard operating procedures and process control plans; presenting project and experimental results to suppliers, customers, clients, and managers; engineering design and calculations; and hands-on mechanical work when troubleshooting process issues.

- Demonstrated ability to coordinate activities with varied entities through extensive project management and leadership experience:

  – Led team in reduction of excess copper, which resulted in an annual scrap reduction of approximately $1 million.

  – One of approximately 25 team leaders for companywide Six Sigma initiative. Led a diverse team consisting of engineers, operators, and technicians. Team won first place out of all teams for improving chrome etch bath control.

  – One of 25 team leaders for second companywide Six Sigma initiative. Team won first place for scrap reduction and cycle time improvement.

  – Led team in reduction of circuit bites. Team was successful in reducing defect levels by 70%.

  – Team leader for polyimide stringer reduction. Worked directly with major vendors and customers to reduce defects. Successful in lowering defect level by a factor of ten.

  – Team leader for design, implementation, and process line startup of new polyimide etching line. Worked with mechanical engineers, electrical engineers, and technicians to solve various equipment and process-related issues. Project was completed on time and resulted in improved throughput and yield.

1998–2000 Student Research Assistant, EERC, UND.
Worked as a temporary employee while attending the University and worked full time during the summer. Worked on a wide variety of projects:

- Performed data entry for Center for Air Toxic Metals® (CATM®) database. Duties included interpreting data from coal combustion and emission reports, performing calculations, organizing data, and working with database software. Worked with U.S. Geological Survey to transfer coal quality data to the CATM database. Researched technical literature for coal quality and combustion emission data for entry into the database. Gained knowledge of environmental systems and energy conversion technologies.

- Worked on CATM database programming to make it more user-friendly and intuitive. Made improvements to the database structure under the guidance of the programming engineer.

- Wrote a technical paper/peer review on the utilization of the CATM database and submitted to *Fuel Processing Technology*.

- Helped to develop program for contamination cleanup, which included interpreting and organizing technical data and aiding programmers and engineers in the formation of the database.

- Aided engineer with research proposal that included researching data on using aerogels for emission control and hands-on work preparing samples for bench-scale testing.

- Worked with engineers on development of nationwide mercury emissions model. Organized and analyzed data and aided in interpretation of results.

Other Experience

- Six Sigma Green Belt Certified –August 2004. This includes learning a very structured problem-solving methodology and applying statistical methods to achieve results. In-depth instruction in designing and running experiments.

- Team member for numerous Six Sigma Black Belt Teams. Implemented Six Sigma problem-solving methodology and aided in the successful completion of numerous process improvement teams.

- Supported the introduction of new product lines over multiple process steps.

Publications and Presentations

Laumb, J.D.; Stanislowski, J.J. *Evaluation of Lignitic Fly Ash and Biomass Fly Ash as a Reburn Fuel for* NO_X *Reduction*; Final Report (Aug 1, 2005 – Jan 31, 2006) for University of Mississippi; EERC Publication 2006-EERC-02-08; Energy & Environmental Research Center: Grand Forks, ND, Feb 2006.

APPENDIX B

DESCRIPTION OF EQUIPMENT

DESCRIPTION OF EQUIPMENT

A conceptual drawing of the entrained-flow gasifier (EFG) is shown in Figure 1. The EFG will be downfired and housed in an existing high-pressure vessel approximately 24 in. in diameter and 7 ft in length. It will fire nominally 4 lb/hr of coal and produce up to 8 scfm of fuel gas. The newly designed heating system will be capable of reaching a nominal temperature of 1500°C and will provide a consistent temperature throughout the length of the furnace. Infrared thermocouples will be used to monitor the temperature of the combustion zone, and the heat input will be automatically controlled to stay within a tight operating range. The pressure inside the alumina furnace tube will be 300 psi and will be balanced with 300 psi nitrogen atmosphere outside the alumina tube. The reactor will have the capability to run in oxygen or air-blown operation.

Pulverized coal at a nominal rate of 4 lb/hr will be fed to the furnace via a twin screw feed motor contained in a pressurized vessel. The design will allow for 8 hours of continuous use at 8 lb/hr before the coal hopper would need to be refilled. The feed system will be situated on a scale so that actual feed rates can be calculated. Combustion gases consisting of air or oxygen and steam will be used to carry the solid pulverized coal into the combustion zone.

A novel heating system will be used to reach the 1500°C temperature required of a slagging gasifier. Past testing on the pressurized drop-tube furnace indicated that high temperature could not be maintained when operating above 100 psig. The novel system is expected to be able to reach and maintain the flue gas at that temperature by utilizing a uniform heat input throughout the length of the furnace. Refractory will be used as insulation to help maintain the required temperature in the furnace. Refractory has the ability to withstand high

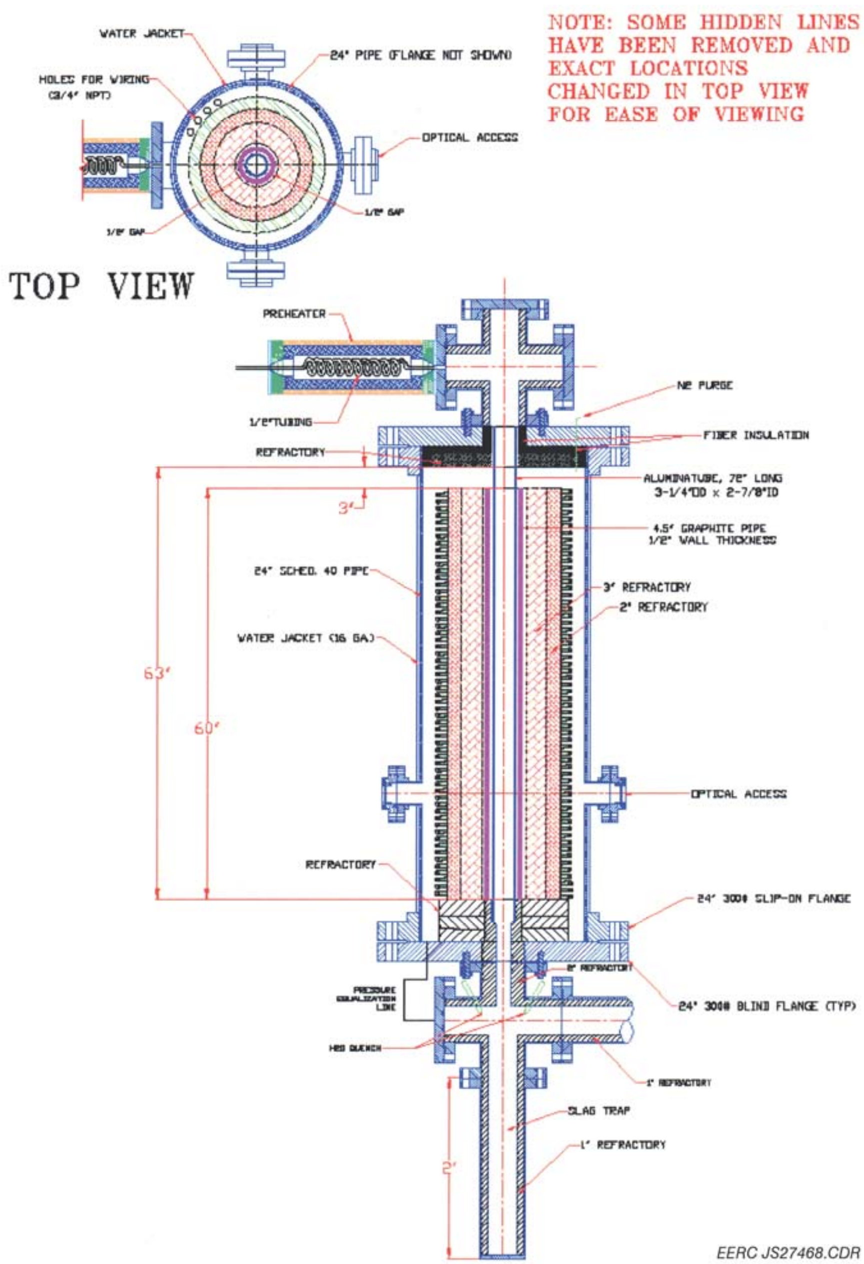

Figure 1. Entrained-flow gasifier.

temperature while retaining its insulating properties at high pressure. A water-cooled jacket surrounds the outside of the vessel and is used to remove excess heat from the system.

The gasifier is brought up to pressure by running gas through the main furnace tube and then allowing it to run through a pressure equalization line that balances the gas pressure on the inside and outside of the alumina furnace tube. The pressure equalization line ensures that during start-up and operation, the pressure on the inside and outside of the tube is equal. Unequal pressure will result in a broken furnace tube.

Gas will exit the bottom of the furnace and pass through a 90° turn where it will then be tested in subsequent pollution control devices. A provision for a water quench will be added to the bottom of the furnace. Slag also exits the bottom of the furnace and is collected in a refractory-lined slag trap.