Grant Application
for a
Lignite Coal Test
at a
Circulating Fluid Bed Facility

Presented to:

Ms. Karleen Fine, Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
Bismarck, ND 58505

Submitted by:

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Funds Requested from the North Dakota Industrial Commission:
$ 275,000

Principal Investigator:
Request for Proposal

June 30, 2005

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ABSTRACT

Circulating Fluid Bed (CFB) is a relatively new and evolving advanced technology that has great potential using high sodium lignite coal in electric generation in an environmentally enhanced manner. In a CFB combustion process, crushed coal is mixed with limestone that removes the sulfur and converts it into an environmentally-benign powder that is removed with the ash.

North Dakota electric generation companies have identified CFB as a possible generation technology for the use with the varying characteristics of Fort Union lignite. At present, the North Dakota Industrial Commission's Lignite 21 program includes MDU-Westmoreland and Great Northern Power Development both who are considering CFB technology for future generation. Basin Electric Power Cooperative is considering CFB to repower the Leland Olds Station and Minnkota Power Cooperative is considering the technology for use in the future.

CFB technology provides fuel flexibility for the clean combustion and the ability to achieve low emission without the need for costly post-combustion cleanup equipment. The CFB system uses low combustion temperatures (1500-1650 F), staging of combustion air, and in-combustor sulfur capture.

The overall objective of the proposed project is to evaluate the feasibility and performance of high sodium (8 percent and higher) lignite fuel in a CFB facility. The proposed work would generate detailed combustion, emission, and performance data using high sodium lignite to establish CFB boiler operational and design parameters that minimize risk and optimize performance.

PROJECT SUMMARY

Today coal currently provides over 50% of the electricity consumed in the United States and will remain a necessary part of our energy mix for some time to come. One of the technologies being developed for advanced coal-based electric power-generating systems is the Circulating Fluid Bed (CFB) technology. The favorable characteristics of the CFB technology with respect to varying lignite properties include in-situ capture of sulfur using inherent calcium and added limestone. The CFB technology combined with lower cost dry scrubbers would reduce sulfur emission to very low levels. The CFB uses lower temperature combustion combined with ammonia injection reduce nitrous oxide (NOx) to very low levels.

Exploring how high sodium lignite coal performs in a CFB process could have a significant economic impact on the North Dakota power industry. The construction of new power plants and the re-powering of existing North Dakota plants using this advanced CFB process could lead to new development of cost-competitive, environmentally acceptable coal-based power generation in the state.

Lignite's problematic characteristics with high sodium levels result in operational issues that are well-known in the industry's cyclone and pulverized (pc) coal plant operations. The Energy and Environmental Center (EERC) studies have shown that ash deposition (fouling), bed material agglomeration, erosion and corrosion are major operational issues. Deposition and agglomeration are impacted by alkaline magnesium, calcium and iron, and by sodium and potassium alkali. Sodium levels in Fort Union Lignite are known to vary significantly with levels reaching 12 percent (see Figure One, page 10). Due to lower combustion temperatures, a CFB may minimize slagging and fouling in the combustion section and in the downstream convective heat exchange sections. However, little information is available to evaluate CFB operational characteristics using Fort Union lignite containing high ash sodium levels.

Perceived advantages of CFB will be thoroughly examined with a test of high sodium lignite at a Circulating Fluid Bed test facility (see figure Two, page 11) Specific Issues to be addressed include:

- *The ability to better control the high ash slagging and fouling characteristics of this high sodium lignite*. The high sodium content (~8% Na_2O in ash) in Fort Union Lignite can produce severe high-temperature furnace slagging and convection section fouling. The resulting reduced heat transfer effectiveness creates operational problems that substantially increase maintenance costs. The low combustion temperatures in a CFB may minimize combustor/furnace slagging (or fouling), and greatly reduce fouling potential in down stream convective sections. The CFB low (1500-1600 ° F) combustion temperatures are anticipated to produce less sodium vaporization and subsequently less enrichment of sodium on fly ash surfaces further improving fouling behavior.

- *The ability to achieve low NOx emissions without post-combustion equipment such as SCR*. Low combustion temperatures and staging of combustion air by application of secondary admission zones results in low NOx production. Further NOx reduction can be accomplished with low cost SNCR, if necessary.

- *In-combustor sulfur capture provides the ability to utilize calcium inherently contained in the lignite.* Fort Union Lignite contains sufficient calcium that can capture sulfur thus greatly reducing or possibly eliminating the need for limestone addition. Depending upon the required emission levels, CFB offers several options to further increase sulfur capture such as injecting additional limestone into the combustor and/or scrubber system for SO_2 polishing which can be simpler than using a typical spray dryer or wet scrubber.

- *CFB technology does not require pulverization of the fuel*. The simpler fuel crushing system on CFBs result in lower grind energy and fuel drying requirements and also reduces maintenance costs and decreases the potential for mill fires and explosions.

- *CFBs utilize simpler dry ash removal systems that may provide more flexibility for combustion ash waste use as compared to conventional wet ash systems.*

The participants include Basin Electric Power Cooperative, Great Northern Power Development L.P. and Minnkota Power Cooperative.

A complete test of approximately 10 days at a Circulating Fluid Bed facility is projected to cost $550,000 based on a previous budgetary proposal. Grant applicants are requesting a $275,000 match from the North Dakota Industrial Commission.

PROJECT DESCRIPTION

The objective of the proposed test is to evaluate the performance of high sodium lignite fuel in a Circulating Fluid Bed facility. Specific technical issues include determining the effects of high sodium lignite on the CFB operating conditions while monitoring for increased ash agglomeration and deposition potential.

Specific test objectives will address:

1. *Combustion Performance* – To establish optimum combustor temperatures supporting optimum in-bed heat transfer surfacing, and recycle cyclone design requirements. Measurements will include:

- Carbon loss from bed drain and fly ash streams
- Combustion Efficiency

2. *Sulfur Capture* – To establish SO_2 clean up requirements, assess trade-offs between sulfur removal approaches, and optimize conditions for sulfur capture.
Measurements will include:

- Inherent sulfur capture from only the alkali in lignite (no limestone addition)
- Inherent sulfur capture from only the alkali in lignite with fly ash re-injection
- Inherent sulfur capture from only the alkali in lignite with FDA
- Limestone performance (reactivity)
- Limestone requirements for desired sulfur capture – combustor only
- Limestone requirements for desired sulfur capture with FDA

3. *Emissions* – To establish optimum operating conditions for emissions control, Support plant permitting, and develop emission guarantees. Measurements will include:

- Gaseous emissions at various operating conditions including SO_2, NOx, CO, N_2O, VOC/Total Hydrocarbons
- Fly ash properties including particle size, composition
- Mercury and trace metal emissions with and without FDA

4. *Bed Dynamics and Agglomeration* – To establish conditions (temperature limits, air staging) necessary to control particle agglomeration and deposit formation in the combustor, support heat transfer surfacing and pressure/fan requirements. Measurements will include:

- Combustor pressure profiles
- Circulating solids properties including particle size, composition
- Bed agglomeration (agglomerate formation with time)

5. *Convective Tube Ash Fouling* – To establish sootblowing requirements, convective tube spacing, and surfacing requirements. Measurements will include:

- Deposit properties including composition, structure, strength
- Relative deposit buildup rate
- Sootblowing performance, relative deposit bonding strength

6. *Heat Transfer* – To support furnace waterwall and convective section surfacing.

Measurements will include:

- Combustor waterwall heat transfer characteristics
- Convective tube heat transfer characteristics including impact of fouling

7. *Waste Disposal* – To establish ash handling system requirements, plant permitting and waste disposal requirements. Measurements will include:

- Split between bed drain and fly ash
- Bed drain properties including particle size, composition, and leaching characteristics (TCLP).
- Fly ash properties including particle size, composition, and leaching characteristics (TCLP).

The grant participants will send out a formal Request for Proposal (RFP) with specific testing evaluation as outlined above. Vendors expected to show interest Wheeler Power Group, Inc., Alstrom Power Inc. and Kvaerner Power. After thorough evaluation of the submitted proposals by the project participants, one vendor will be selected to do the testing.

Figure One: Fort Union Lignite Sodium Levels

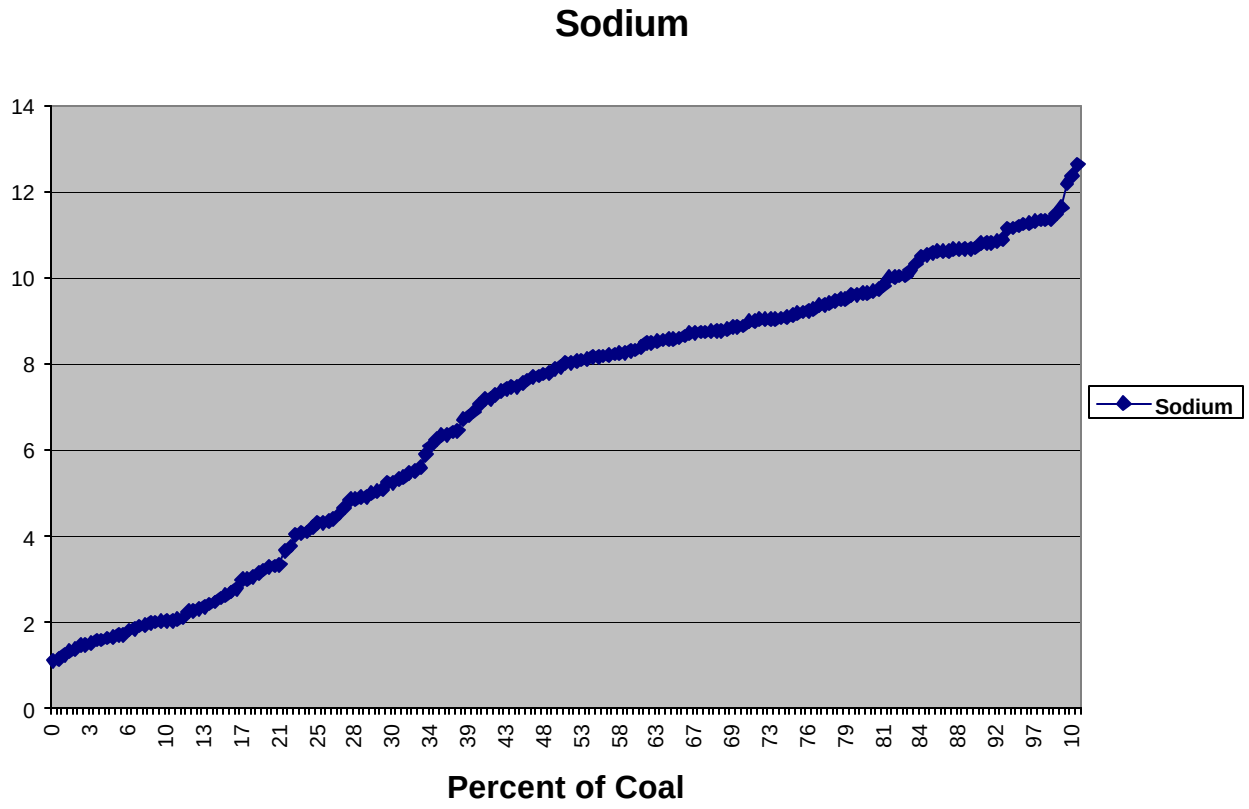
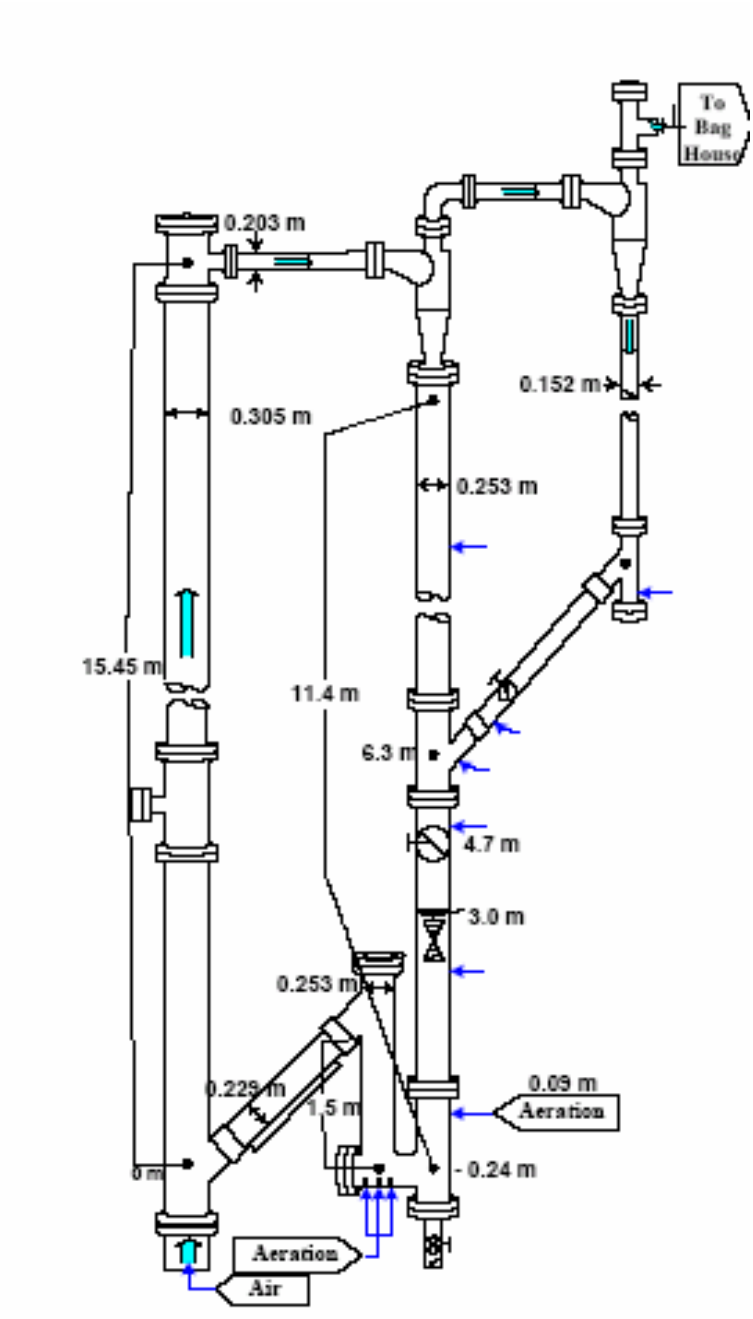


Figure Two: Schematic of a CFB test unit



Standards of Success

The use of high sodium lignite as a fuel in the circulating fluid bed will be considered a success if the CFB demonstrates stable operation without significant ash deposition or agglomerations during the approximate 10 days of operation.

If this criterion is met, the technical advantages of using lignite in the CFB will have been demonstrated. Successful testing of the CFB using lignite could lead to acceptance of this technology with possible future applications for new or retrofit of existing North Dakota units.

Background

FOSTER WHEELER:

Circulating fluidized bed (CFB) boilers have long been a specialty of Foster Wheeler. Foster Wheeler has come a long way since it delivered the world's first CFB unit for power generation in 1979. Since then, the development of Foster Wheeler's CFB technology has been characterized by two major trends: steadily increasing unit size and the incremental introduction of more advanced features.

The repowering of the massive brown coal-fired Turów power plant in Poland is a good case in point. Four units have been completed; the last two will begin generation in 2004 and 2005.

The first three units at Turów incorporate 235 MWe CFBs, while the second three feature Foster Wheeler's second-generation CFB technology. The latter units provide 260 MWe of generating capacity on the same footprint as the original 200 MWe units they are replacing.

SUPERCRITICAL CFB

Foster Wheeler has now taken the next major step forward in the development of fluidized bed combustion, and launched supercritical once-through CFB technology at full utility size. The first project of this type was confirmed in February 2003.

The project covers a 460 MWe boiler island for a power plant at Lagisza, and was placed by Poland's largest utility, Poludniowy Koncern Energetyczny (PKE). Not only will the boiler be the world's first supercritical CFB unit, it will also be the world's largest CFB design of any type to be built so far. The Lagisza plant will provide world-leading levels of efficiency and fuel usage, together with very low emissions, fully meeting the requirements of the EU's new Large Combustion Plant (LCP) directive.

Alstrom Power Inc.:

Alstrom Power provides CFB boilers ranging in capacity form 10 MW to several hundred megawatts. Alstrom supplied tow identical 250 MWe class lignite-fired CFB boilers for the Red Hills power plant in Choctaw County, Mississippi. Commercial operations commenced on April 1, 2002.

Alstrom Power also supplied two 292 MW (gross output) CFB boilers to be fired by Pennsylvania waste coal for the Seward Power Plant in East Wheatfield Township, Indiana County. The Seward plant also contains an Alstrom Power Flash Dyer Absorber (FDA) to provide for 95 percent overall (CFB and FDA) SO_2 removal. The CFB accounts for 80 percent and the FDA for 15 percent of the SO_2 removal.

Alstrom Power is also supplying a single anthracite-fired 300 MW CFB boiler unit to China. Commissioning is scheduled for 2006. Alstrom Power has a global sales and service network covering 70 countries.

KVAERNER POWER:

Kvaerner Power is a forerunner and an expert in bubbling fluidized bed (BFB) boilers for power generation from biomass and recycled fuel with steam capacity ranging from 20 to 300 MWth. Kvaerner Power's boilers using BFB technology, are suitable for wide range of fuel.

The Power Division of Kvaerner Pulping in Sweden, part of Pulp & Paper business area of the Anglo-Norwegian international engineering and construction group, Kvaerner, has won an order valued at $45 million for two large circulating fluidized bed boilers. The boilers will be installed at a new waste-to-energy plant to be operated by Sogama, near the city of La Coruna on the Northwest coast of Spain.

Kvaerner Power is to deliver a power boiler using bubbling fluidized bed (BFB) technology to a power plant at UPM's Rauma paper mill on the west coast of Finland. The power plant will be built by the new company Rauman Voima Oy which is owned by Pohjolan Voima Oy and Rauman Energia Oy. The new power plant will produce electricity, steam for the paper mill and district heat for Rauma city.

The boiler supplied by Kvaerner Power has a thermal capacity of 107 megawatt (MW) and it will burn bark, forest residue, peat, sludge and small amount of recycled fuel. The modern BFB technology fulfils the co-combustion emission requirements and the use of biofuels reduces the CO2 emissions to the atmosphere.

Qualification

Basin Electric Power Cooperative

Basin Electric Power Cooperative (Basin Electric) is one of the largest electric generation and transmission (G&T) cooperatives in the United States headquartered in Bismarck, North Dakota. Basin Electric is a consumer-owned, regional cooperative whose core business is generating and delivering electricity to wholesale customers, primarily our member systems.

Basin Electric operates electricity-generating power plants with a total capacity of 3,412 megawatts. Our two coal-based generating plants in North Dakota include the Antelope Valley Station and Leland Olds Station, located in central North Dakota. Basin Electric serves 121 rural electric member-cooperative systems that in turn serve approximately 1.8 million consumers in the nine states of North Dakota, South Dakota, Montana, Wyoming, Minnesota, Nebraska, Iowa, Colorado and New Mexico.

Basin Electric has several subsidiaries, including Dakota Gasification Company, which produces natural gas from the coal gasification process and products such as chemicals and fertilizers; Dakota Coal Company, which purchases lignite for our power plants and owns a lime processing plant. Basin Electric and its subsidiaries employ about 1,800 people.

Basin Electric's Mechanical and Performance Engineer Department manages the maintenance and construction activities supporting the generation plants, including the evaluation of pollution control processes, advanced combustion and gasification technology. The current project under Mike Paul's leadership will address the repowering of the Leland Olds Station Unit Two which has a cyclone boiler.

Foster Wheeler:

Foster Wheeler has a large share of the market for CFB steam generators. Their CFB boiler range from relatively small industrial units to large-scale installations rated at hundreds of megawatts. The largest unit operating in the United States is a Foster Wheeler 300 MWe CFB boiler installed in JEA's Northside Generating Station in Florida, fired with a blend of 80 percent pet-coke and 20 percent coal.

Alstrom Power:

Alstrom Power is the world's leading supplier of power plants, boilers (including circulating fluid bed systems) and firing systems. PPL is Alstom's boiler business research and development center maintaining this technical expertise. Alstom and PPL have extensive experience with high sodium brown coals.

Alstom makes use of its 9.9 MBtu/hr Multi-use Test Facility (MTF) to perform comprehensive pilot-scale CFB testing. This facility has been used extensively for development of CFB process improvements and new technologies as well as comprehensive fuel and sorbent performance characterizations to support new unit design and resolve field issues.

Kvaerner Power:

Kvaerner Power is a pioneer in large scale fluidized bed combustion for pulp and paper industry and power producers. Approximately 200 power boilers in operation testify to the expertise in fluidized bed technology with demanding fuels. Kvaerner Power is also the leading chemical recovery equipment supplier in the world with its 300 recovery boilers and 300 evaporation unit deliveries. Kvaerner Power has designed and manufactured the world's largest recovery units and biomass-fired fluidized bed boilers. Kvaerner Power with main operations in Finland, Sweden, USA and Brazil has annual revenues of approximately EUR 350 million and it employs 1400 people worldwide.

Value to North Dakota

The lignite mined in North Dakota is experiencing higher sodium levels and expected to continue to increase in the future. This increased sodium will create a challenge for existing units as well as building new units because of agglomeration, slagging and fouling of the boiler. The value of the CFB test will be to determine an applicable retrofit technology to address the higher sodium levels for existing units as well as for building new units.

The successful use of lignite in a CFB will benefit North Dakota lignite industry by demonstrating the technical and economic viability of lignite fuel in a CFB facility. Clearly, this technology could provide lignite-based options for new generation plants, as well as for re-powering existing plants.

Demonstrating that the high sodium lignite fuels will work without deposition and agglomerating related problems during the operation with the CFB will help market North Dakota's low cost lignite reserves as a viable fuel for the future. These CFB systems also offer the best potential competition to natural gas-based generation and the future vision of coal-based generation.

Management

Mike Paul, Manager of Mechanical and Performance Engineering, will coordinate the project. Mr. Paul is a registered Professional Engineer in the State of North Dakota with over 25 years of electric utility experience. He is also project coordinator for the Leland Olds re-powering study. Mr. Paul has the responsibility for the projects technical reviews of advanced combustion, gasification technology performance and determining if the CFB and IGCC technology is applicable to a re-powering effort.

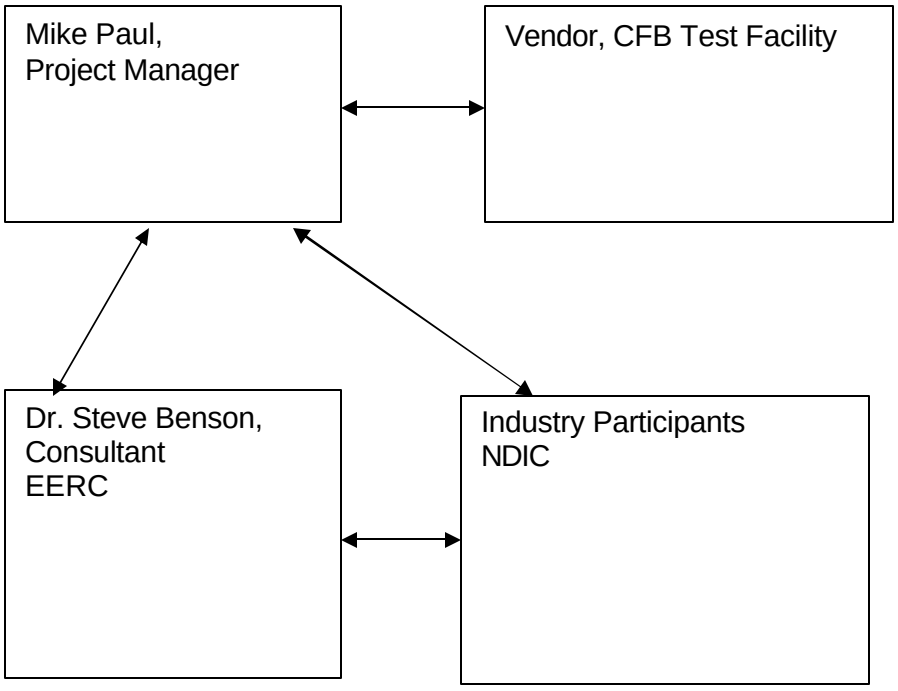
Dr. Steve Benson will provide consulting services with a focus on sodium related slagging, fouling and ash agglomerations. Dr. Benson has over 25 years of experience addressing issues of Fort Union lignite characteristics on the performance of combustion and gasification systems. His work includes the chemical and physical transformations of inorganic species in combustion gases. He has authored or co-authored over 210 publications and is the editor of eight books and *Fuel Processing Technology* special Issues.

Communication:

Communications are essential for a successful project and will consist of monthly participant's review of progress, issues, and test results and to provide recommendations as needed. The vendor and the consultant will provide written monthly summaries to the Project Manager, who will distribute the information to the project participants.

In an effort to accommodate project participants with planning, scheduling and facilitating discussion on the project the following communication flow will be followed.

Communications Flow:



Timetable

After the funding from the North Dakota Industrial Commission and other participants is in place, the lignite fuel can be selected and scheduled for delivery to the CFB facility, the approximate 10-day test can be conducted in December 2005.

A likely timetable scenario for test:

RFP issued	August 25, 2005
Vendor contract signed	September, 2005
Shipping coal	October 2005
10 day test period	December 2005
Final Report	January 2006
Evaluation of data	February 2006

Budget

This proposal requests a base amount of $275,000 from NDIC to allow additional testing of North Dakota lignite at the CFB facility. This extended test will further demonstrate the practicability of lignite as a fuel for the CFB concept. If successful, lignite may be viewed as a viable fuel for use with advanced CFB technology for new North Dakota power plants or re-powering existing power plants. CFB may be one option to help lignite remain competitive as a fuel for power generation in the deregulated wholesale power market and help industry and the state achieve the strict regulatory environment being administered by the Environmental Protection Agency (EPA).

Budget itemization

Available Funds:

NDIC	$275,000
Industry	$275,000
Total	$550,000

Expenditures:

CFB Vendor	$500,000
Lignite Shipping	$ 40,000
Consultant	$ 5,000
Travel	$ 5,000
Total	$550,000

Matching Funds

Based on discussions with the interested participants, this proposal assumes a match of $275,000 for the cost of the project. The matching funds commitment would be subject to the North Dakota Industrial Commission approval for this project, the Board of Directors approval of the participating organizations (as required) and successful negotiations of a CFB test plan that meets the project participant's needs. These organizations include Basin Electric Power Cooperative, Great Northern Power Development L.P. and Minnkota Power Cooperative These organizations have expressed an interest in participating in a review board to evaluate the viability of the CF for possible commercial development.

Tax Liability

I, Clifton T. Hudgins, certify that Basin Electric Power Cooperative does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

_____ _____

Clifton T. Hudgins
Senior Vice President
Chief Financial Official

Date

Confidential Information

All data will be placed in the public domain as part of the CFB test with high sodium lignite coal.

The final report summarizing the project and its findings will be public information.

References

1. Alstom Power at http://www.alstom.com
2. Foster Wheeler at http://fwc.com
3. Kvaerner Power at http://www.power-technolgy.com
4. Kvaerner Power at http://akerkvaervner.com

APPENDIX A

Resumes of key personnel

Letters of Support

MICHAEL W. PAUL, P.E.
Basin Electric Power Cooperative
1717 E. Interstate Avenue
Bismarck, N.D. 58503-0561
(701) 355-5691
mikepaul@bepc.com

Qualifications

- B.S., Mechanical Engineering, University of North Dakota
- Registered Professional Engineer, North Dakota
- Over 25 years of electrical utility experience with six years stationed at three coal-based power plants

Professional Experience

May 2001 to present

Basin Electric Power Cooperative, Headquarters Office, Bismarck, ND
Manager, Mechanical and Performance Engineering

Manage the Mechanical and Performance Section of the Generation Department, Engineering and Construction Division to provide professional engineering support for Basin Electric's existing operating facilities, members, and subsidiaries. Also conduct studies and planning for future generation resources as well as options for meeting future needs at existing facilities. Served as Project Coordinator for the Wyoming Distributed Generation Project and currently assigned as Project Coordinator for the Leland Olds Station Repowering Project Study.

March 1987 to May 2001

Basin Electric Power Cooperative, Headquarters Office, Bismarck, ND
Mechanical/Performance Engineering Supervisor

Supervised the Mechanical/Performance Section of the Operations & Engineering Department, Engineering Division to provide professional, cost-effective and timely mechanical design and performance engineering activities for each of our coal-fired plants, as well as for our members and subsidiaries. Activities focused on coal-based power plant operations, performance, and maintenance activities to help ensure safe, reliable, and efficient operation. Assigned as Project Engineer for the Wyoming Distributed Generation project and was actively involved in the future coal-based generation and Leland Olds Station future options studies.

January 1986 to March 1987

Minnkota Power Cooperative, Milton R. Young Station, Center, ND
Engineering Superintendent

Managed the overall generation engineering needs of Minnkota including supervision of professional staff and employees represented by a bargaining agreement. Established and directed the overall plant performance program, coordinated design changes and procurement of equipment and systems, monitored plant water management and chemistry programs, conducted economic and technical feasibility studies, provided technical support and recommendations on plant operations, prepared budgets, and directed plant documentation and drafting efforts.

August 1983 to January 1986

Basin Electric Power Cooperative, Antelope Valley Station, Beulah, ND
Results Engineer
Monitored and reported performance of plant equipment and systems, ensured proper chemistry control of all plant systems, directed plant water management including environmental concerns, supervised lab technicians, assisted in design and operational modifications of plant equipment and systems, and monitored coal quality.

September 1982 to August 1983
Basin Electric Power Cooperative, Antelope Valley Station, Beulah, ND
Mechanical Engineer
Involved with initial Unit 1 start-up, including design changes, supervised boil-out and boiler chemical cleaning, prepared and supervised equipment testing for a full American Society of Mechanical Engineers turbine test, participated in water balance and vibration monitoring, and provided technical support to plant operations and maintenance. Worked closely with design, construction, and start-up groups.

October 1979 to September 1982
Basin Electric Power Cooperative, Production/Design Division, Bismarck, ND
Mechanical Design Engineer
Monitored and directed the design and purchase of mechanical equipment and systems for the Antelope Valley and Laramie River Stations.

May 1978 to October 1979
Basin Electric Power Cooperative, Wm. J. Neal Station, Velva, ND
Mechanical Engineer
Engineering and supervision of a plant upgrade to 50 MW, compliance testing of retrofit precipitators, monitored progress of a Babcock & Wilcox pilot dry scrubber, engineering and initial test burns of sunflower hulls in the main boilers, and operating plant engineering and supervision as required.

September 1977 to May 1978
Engineering Experiment Station, University of North Dakota, Grand Forks, ND
Student Engineer
Involved in the engineering of several solar energy and heat pump projects.

June 1977 to August 1977
Clark Equipment Company, Melroe Division, Gwinner, ND
Summer Engineer
Quality control for welding, fabricating, machining, and assembling various models of the Bobcat skid steer loader.

Professional Memberships, Certifications, Organizations

- American Society of Mechanical Engineers
- Registered Professional Engineer in the State of North Dakota
- North Dakota State Department of Health, Certification as a Class II Water Treatment Plant Operator
- Energy Generation Conference Executive Committee – five years

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

Principal Areas of Expertise

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

Qualifications

Ph.D., Fuel Science, Materials Science and Engineering, 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® (CATM7) 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.