MICROBEAM
TECHNOLOGIES, INC.

www.microbeam.com

October 1, 2012

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

Dear Ms. Fine:

Subject: Microbeam Technologies Proposal entitled "Optimization Tools to Manage Coal Properties and Plant Operations"

Enclosed please find an original and copies of the subject proposal. Microbeam Technologies Incorporated is pleased to submit this proposal to develop tools to improve the operation and reliability of North Dakota lignite-fired cyclone-fired boilers retrofitted with NOx reduction systems using combustion controls. The project will update previously developed tools to manage ash-related problems. The tools include systems to manage slag flow, fireside slagging, convective pass fouling and particulate control. The project co-sponsors include Minnkota Power Cooperative, BNI Coal Ltd., and Clean Coal Solutions. Also enclosed is the $100 application fee.

If you have any questions, please contact me by telephone at (701) 777-6530 or by e-mail at sbenson@microbeam.com.

Sincerely,

Steven A. Benson, Ph.D.
President

Shipping:
4200 James Ray Drive, Ste. 193
Grand Forks, ND 58203

Mailing:
PO Box 14758
Grand Forks, ND 58208-4758

Phone: 701-777-6530
Fax: 701-777-6532
info@microbeam.com

2. Title Page

Optimization of Tools to Manage Coal Properties and Plant Operations

APPLICANT

Microbeam Technologies Incorporated

PRINCIPAL INVESTIGATOR

Steven A. Benson, PhD

DATE OF APPLICATION

October 1, 2012

AMOUNT OF REQUEST

$299,972

Shipping:
4200 James Ray Drive, Ste. 191
Grand Forks, ND 58203

Mailing:
PO Box 14758
Grand Forks, ND 58208-4758

Phone: 701-777-6530
Fax: 701-777-6532
info@microbeam.com

3. TABLE OF CONTENTS

4. ABSTRACT

Cyclone-fired plants have been redesigned to accommodate changes in operating parameters that allow for the redistribution of air in the combustion system aimed at reducing NOx formation. These changes have resulted in operating the cyclone under substoichiometric combustion conditions and adding air in the upper regions of the furnace to complete the combustion. Substoichiometric combustion conditions have resulted in changes in slag flow behavior that sometimes lead to freezing of the slag, water wall slagging, convective pass fouling, and fine particulate formation. Past tools developed to manage these issues need to be updated to include the modifications in the system design and operating parameters. The goal of this project is to develop improved tools to manage lignite properties and plant operations based on measureable lignite properties that can be used to improve low-NOx cyclone operation. In order to achieve the project goal the following objectives have been identified and include: 1) Review past and current strategies to optimize system performance, 2) Review properties of coal being delivered to the plant (current and future), 3) Determine impacts of combustion control of NOx on slag and ash behavior, 4) Improve existing tools and develop new tools for plant operations and mining personnel to utilize, and 5) Test and validate tools through testing at the plant. The key deliverables of the project will include: updated tools to facilitate the management of lignite properties and plant operations; training sessions on lignite properties, slag flow behavior, slagging/fouling, and particulate control associated with cyclone fired systems. The duration of the project will be two years. The total project cost is $399,972 with $400,000 of in-kind and cash cost share. The project participants include: Minnkota Power Cooperative, BNI Coal, Clean Coal Solutions, University of North Dakota, and Microbeam Technologies Inc.

5. PROJECT SUMMARY

Cyclone-fired plants have been redesigned to accommodate changes in operating parameters that allow for the redistribution of air in the combustion system aimed at reducing NOx formation. These changes have resulted in operating the cyclone under substoichiometric combustion conditions and adding air in the upper regions of the furnace to complete the combustion. Substoichiometric combustion conditions have resulted in changes in slag flow behavior that sometimes lead to freezing of the slag, water wall slagging, convective pass fouling, and fine particulate formation. Past tools developed to manage these issues need to be updated to include the changes in the system design and operating parameters. The goal of this project is to develop improved tools to manage lignite properties and plant operations based on measureable lignite properties that can be used to improve low-NOx cyclone operation. The specific objectives include: 1) Review past and current strategies to optimize system performance, 2) Review properties of coal being delivered to the plant (current and future), 3) Determine impacts of combustion control of NOx on slag and ash behavior, 4) Improve existing and develop new tools for plant operations and mining personnel to utilize, and 5) Test and validate tools through testing at the plant.

In order to meet the objectives, a work plan involving five tasks was developed.

> <u>Task 1. Strategies to Optimize Performance</u> – Conduct monthly workshops with power plant and mining personnel to a) discuss the development of past strategies to minimize the impact of variable lignite properties on plant performance, b) provide information on the changes to plant design and operation to manage NOx emissions on slag behavior, ash partitioning, ash deposition, and particulate control, c) identify specific needs for optimization, and d) discuss the progress of testing and validation programs.

Task 2. Coal Properties - Determine the composition and properties of ash- and slag-forming components in the cores and associated sediments in projected areas of the mine. Apply new methods to assess the physical processes involved in slag formation and slag flow measurements. These methods will be applied to selected lignite core and associated sediment samples.

Task 3. Impacts of Combustion Control of NOx on Slag and Fly Ash – Determining the partitioning processes between slag and fly ash as a function of the inorganic composition of the lignite will enable more accurate prediction of the slag flow behavior, entrained ash composition, ash deposition on heat transfer surfaces, and fine particle properties. Two one-week test burns under substoichiometric combustion conditions are planned to collect lignite, slag, and fly ash samples for detailed analysis.

Task 4. Tool Improvement and Development – Incorporating improved methods of predicting slag flow behavior based on the partitioning or split of the ash in the cyclone between slag and fly ash into predictive tools. This partitioning impacts the properties of both the slag and the fly ash. In addition, factors that impact slag flow behavior in cyclone boilers include mineral type/composition/physical properties, behavior during melting, assimilation rate, crystallization behavior, homogeneity, and viscosity. The tools will be compatible for use with the prompt gamma neutron activation (PGNAA) based full stream elemental analyzers (FSEA) on-site at MRY.

Task 5. Tool Testing and Validation - A week-long test campaign will be scheduled focusing on Unit 2. During this campaign, the lignite blend and plant operating conditions will be planned to ensure a range of lignite properties and operating conditions.

6. PROJECT DESCRIPTION

Goal:

The goal of this project is to develop improved tools to manage lignite properties and plant operations based on measureable lignite properties that can be used to improve low-NOx cyclone operation.

Objectives:

1. Review past and current strategies to optimize system performance.
2. Review current and projected future properties of lignite delivered to the plant.
3. Determine impacts of combustion control of NOx on slag and ash behavior.
4. Improve and develop new tools for plant operations and mining personnel to utilize.
5. Validate tools through testing at the plant.

Scope of Work:

Task 1. Strategies to Optimize Performance

1a. Workshops with Plant and Mining Personnel

Workshops will be held on a monthly basis in person and over the web to address the following: a) discuss the development of past strategies to minimize the impact of variable fuel quality on plant performance, b) provide information on the changes to plant design and operation to manage NOx emissions on slag behavior, ash partitioning, ash deposition, and particulate control, c) identify specific needs for optimization, and d) discuss progress of testing and validation programs.

The specific tools to be enhanced or further developed will be discussed and identified as part of the initial workshop. The possible tools to be considered include:

- Cyclone partitioning factor: slag composition and fly ash (entrained ash) in terms of a base-to-acid ratio
- Slag flow behavior: partitioning factor for slag composition (base-to-acid), foaming index, T_{250}, crystallization potential (Tcv)
- Water wall slagging index: use partitioned ash composition to calculate
- Silicate-based fouling index: use partitioned ash composition to calculate
- Silicate-based deposit strength index: use partitioned ash to calculate
- Sulfate-based fouling index: use partitioned ash to calculate
- Ash resistivity and cohesivity for ESP performance: use partitioned ash to calculate.

<u>1b. Mine Planning</u>

A review of current and future mining plans will be conducted that will enable an understanding of the properties of the lignite in the mine and the impact of mining on the delivered coal properties. Detailed examination of analysis of core samples and analysis of selected core and associated sediments will be performed.

<u>1c. Boiler Operations</u>

Review changes in boiler operations as a result of combustion control strategies to lower NOx emissions on cyclone slag flow behavior, ash partitioning between slag and fly ash, wall slagging, and convective pass fouling (silicate and sulfate based fouling).

<u>1d. Downstream Emission Control Systems</u>

Review impacts of fuel properties and changes in boiler operations on the performance of the downstream electrostatic precipitator for particulate control and scrubber for sulfur control.

Task 2. Coal Properties

<u>2a. Core Analysis</u>

The composition and properties of ash- and slag-forming components in the cores and associated sediments in projected areas of the mine will be evaluated based on existing core analysis information available at BNI. This information will be evaluated in order to ascertain the anticipated variability of the lignite in the near future. It will also be used to assist in planning test campaigns.

<u>2b. Slag Flow Measurement</u>

Microbeam currently utilizes new methods to assess slag formation and perform slag flow measurements. These methods will be applied to observe melting and assimilation behavior of selected core and sediment samples in a high temperature controlled atmosphere furnace designed for melting high-temperature ceramic materials. Specific mineral phases will be examined to observe the physical transformations that occur during the melting process. Of specific interest is the type of materials that cause slag foaming. In addition, the T_{250} will be measured upon slag heating. Conventional methods measure slag flow upon cooling.

Task 3. Impacts of Combustion Control of NOx on Slag and Fly Ash

The following subtasks will be conducted as part of two one-week test campaigns conducted at the MRY plant. During the test campaigns, coal and slag sampling will be conducted by Minnkota Power and Clean Coal Solutions (CCS) personnel. Sampling of fly ash will be performed upstream of the ESP by the University of North Dakota using a state-of-the-art fly ash particle sampling system.

3a. Slag Formation Processes

The impact of ash-forming components on the processes involved in the formation of the slag will be determined through careful examination of as-fired coal samples and slag. The coals will be characterized to determine the size, composition, and abundance of mineral grains present using computer controlled scanning electron microscopy (CCSEM), bulk ash composition, and basic coal properties. The slag will be characterized to determine bulk composition, homogeneity, crystalline phase types, and melting behavior. The slag formation processes that impact the flow behavior of the slag and the need for oil burning under low-NOx cyclone operation will be examined.

3b. Partitioning of Impurities to form Slag and Fly Ash

The partitioning processes will be determined for selected coal blends during the week long test campaigns. A state-of-the-art Dekati low pressure impactor (DLPI) will be used to aerodynamically classify and collect ash particle samples. The DLPI is a 13-stage cascade impactor for measuring gravimetric particle size distribution of very small particles. It size-classifies particles from 10 µm to 30 nm, and a filter stage accessory enables collection of particles smaller than 30 nm in diameter. Figure 1 shows the impactor and stages. The D50 cut points for sampling with the DLPI are shown in Table 1. In addition to the mass distributions of the ash materials the composition of the particles collected on each stage will be determined. At least three sets of samples will be collected each week during the test campaigns. The fly ash mass and composition will provide critical information needed to develop ash partitioning parameters as a function of the inorganic composition of the as-fired lignite and low-NOx cyclone operation. The partitioning data provides a better estimation of the slag composition and prediction of slag flow behavior. In addition, the properties of the fly ash that end up in the body of the boiler that have the potential to produce deposits on heat transfer surfaces can be determined using partitioning data. Further, this information is also important for fine particle formation that can have an impact on electrostatic precipitator performance and ash handling.

Figure 1. Dekati Low-Pressure Impactor.

Table 1. Typical D50 cut points for the Dekati Low Pressure Impactor.

Stage #	$D_{50\%}$ [1](μm)
13	10
12	6.8
11	4.4
10	2.5
9	1.6
8	1
7	0.65
6	0.4
5	0.26
4	0.17
3	0.108
2	0.06
1	0.03

[1] $D_{50\%}$ is the particle diameter where half of these particles pass through the stage and half are captured by the stage.

<u>3c. Slag Flow Properties</u>

The chemical and physical properties of slag materials that allow for the assessment of flow behavior (crystallization, degree of assimilation, phase separation) will be determined using scanning electron microscopy morphological analysis and scanning electron microscopy point count analysis (SEMPC). The physical measurements will include viscosity (T_{250} using the crucible method), surface tension (sessile drop technique), porosity (SEM image analysis), and density. The chemical measurements determined with the SEMPC and morphological analysis will include bulk composition, microstructure, crystalline phases, and chemical homogeneity.

3d. Entrained Ash Properties

The mass/size and composition distribution of entrained ash particles for selected coal blends will be analyzed. Ash collected on each stage from the DLPI in subtask 3b will be characterized to determine the overall composition. SEM imaging of the particles on each stage will be imaged to examine the microstructural features.

Task 4. Tool Improvement and Development

4a. Assessment of Performance of Current Tools

Current measures to optimize lignite properties rely mainly on the use of the base-to-acid ratio and ash contents that are derived from on-line coal analyzers at the MRY plant. These relationships were developed for the MRY units prior to the boiler NOx control modifications. In addition, the methods are limited since they do not consider system operating conditions and partitioning of the ash in the boiler. The specific areas that require improvement include slag flow, furnace convective pass plugging, ESP performance, and ash utilization properties.

4b. Partitioning of Lignite Ash-Forming Materials between Slag and Fly Ash

The split of the ash in the cyclone between slag and fly ash impacts the properties of both the slag and the fly ash. The partitioning is dependent upon the association of the ash-forming components in the lignite and operating conditions of the cyclone. The results of the analysis of samples of cyclone slag and fly ash materials for a range of coal properties will be used to determine the ash component partitioning. Based on these results empirical correlations between coal properties and operating parameters will be developed to calculate the components that end up in the slag and fly ash. The composition of the slag will be used to calculate T250 and base-to-acid ratios.

4c. Slag Flow Behavior

Additional factors that impact slag formation and flow behavior in cyclone boilers will be incorporated into the new tools. They include information on mineral type/composition/physical properties, behavior during melting, assimilation rate, foaming behavior, crystallization behavior, homogeneity, and viscosity. Microbeam will use new methods to measure slag physical properties and viscosities that will allow for better assessment of the impact of mineral type on slag flow behavior. Actual physical measurement of T_{250} can be used to compliment and validate the predictive methods.

4d. Boiler tube fouling

Low NOx cyclone boiler operations require firing under reducing environments that result in the production of CO that is subsequently combusted in the upper part of the boiler with the over-fire air. In addition, lignite particle-laden pre-drying air is injected in the upper part of the furnace resulting in combustion of the coal particles and increasing heat release in the upper part of the furnace resulting in higher temperatures entering the convective pass. Examination of methods to minimize the impacts on the upper furnace will be investigated.

4e. Particulate Control and Ash Handling

Certain types of ash produced during the combustion of Center lignite produce very fine particles that are difficult to collect in electrostatic precipitators (ESP) and produce cohesive ash materials. The cohesive ash is difficult to remove from the ESP hoppers. Samples of fly ash will be collected and aerodynamically classified and analyzed to determine the size and composition distributions of entrained ash materials. This task will be coordinated with Subtask 4b.

4f. Provide Test Version of Tools to Mine and Plant Personnel

The test version of the tools that integrate the ash partitioning in the cyclone, improved cyclone slag flow/properties predictions, high temperature fouling, and fine particulate properties control will be included in a spreadsheet that will allow mining and plant personnel easy access to the tools. The tools will be compatible for use with the prompt gamma neutron activation (PGNAA) based full stream elemental analyzers (FSEA) on-site at MRY.

Task 5. Tool Testing and Validation – Based on Managed Lignite Properties

A week-long test campaign will be scheduled that will likely focus on Unit 2 in order to validate the tools. During this test campaign, the lignite blend and plant operating conditions will be planned to ensure a range of lignite properties and operating conditions. It is anticipated that a range of conditions will represent lignite blends and operating conditions that are aimed at reducing NOx emissions while optimizing performance. The testing will include: 1) the collection of samples of coal (as-fired), slag, entrained ash, and fly ash in order to validate the performance of the tools, 2) collection of operational data in terms of combustion/operating conditions (such as blending, firing rates, air flows) and performance information (load, NOx, furnace exit temperatures, steam temperatures, opacity, slag flow monitoring).

5a. Partitioning of Ash Materials

Samples of lignite, cyclone slag, and fly ash will be collected and compared with the results obtained from the Partitioning Tool results.

5b. Slag Flow in Cyclone

The flow behavior relationships developed will be tested for selected blends of coal and the cyclone performance will be monitored.

5c. Boiler Tube Fouling

The fireside ash deposition on the convective pass surfaces will be assessed and compared to predictions. Emphasis will be on the impact of furnace exit gas temperature and substoichiometric combustion conditions on the formation of bonding phases that produce ash deposits.

5d. Fine Particle Formation and Particulate Control

Ash handling and plant opacity will be examined as a function of test conditions. The ability of the tools to predict ash cohesivity and ash resistivity will be evaluated.

Anticipated Results

Deliverables resulting from the proposed work will include the following:

1. Training of mining and plant personnel on ash and slag behavior.

2. Databases on lignite, slag, partitioning, ash deposits, and fly ash information will be developed.
3. Improved tools for managing lignite properties to minimize NOx emissions.
4. Reports that include quarterly status reports, task reports and a final report.

Facilities, Resources and Techniques

MTI has laboratory and office space located in the Center for Innovation at the University of North Dakota. MTI's offices, at 780 sq. ft., are located at the Norm Skalicky Technology Center, and laboratory space is located in the Ina Mae Rude Technology Incubator, on the west end of the University of North Dakota campus. These buildings are connected; it is approximately 140 feet from MTI offices to the laboratory. The 680-sq. ft. laboratory space contains MTI's bench-scale fluidized bed reactor system and bench-scale advanced heat exchange system. The laboratory is equipped with an automated scanning electron microscope equipped with x-ray microanalysis capabilities, sample preparation equipment, a small-scale fluidized bed combustor, a small-scale gasifier simulator equipped with a syngas cooler, a high-temperature 1700 ºC refractory testing furnace, an ash fusion furnace, chemical fractionation analysis equipment, and other laboratory equipment. The equipment is specifically designed and optimized to characterize coal and coal ash-related materials. In addition, MTI has developed numerous data analysis procedures designed to interpret the result of analysis of fuel and fuel ash related materials for clients worldwide. These techniques are used to assist combustion and gasification facilities to improve reliability and decrease maintenance costs through fuel selection/blending and optimized operating conditions. MTI has conducted over 1350 projects that involve the analysis of fuel, ash, slag, and metal materials.

Environmental and Economic Impacts

This project has the potential to economically improve the environmental performance of cyclone-fired boilers by managing lignite properties that will allow for optimum cyclone performance. Specific application of the results of this project will be cost effective measures to optimize NOx reductions through managed lignite properties.

Ultimate Technological and Economic Impacts

Managing the variability of lignite is a key challenge to overcome that will ensure the future use of lignite. Developing these tools will enable personnel associated with lignite mining and plant operations to operate the systems more efficiently.

Why the Project is needed

This project is needed to update tools used to manage cyclone-fired boiler performance in order to improve NOx reduction and plant efficiency.

7. STANDARDS OF SUCCESS

The standards for success of the project include:

- The training of operations personnel to develop an understanding of the effects of lignite properties and system operating parameters on slag flow, ash partitioning, boiler slagging/fouling, and emissions control. Training engineering and operations staff to recognize problems is key to the implementation of measures and tools to predict impacts.
- The development of database information that includes fuel quality and system operating conditions will ensure the success of the project. The information will be used to develop algorithms for incorporation into the tool for predictions.

- The algorithms will be tested with specific case studies to validate the tool. Adjustments will be made as needed.

8. BACKGROUND

Introduction

Managing the behavior of ash and slag produced during coal combustion is key to improving system efficiency, reducing cleaning outages and equipment failures, and optimizing emissions control. The many ways in which the detrimental effects of ash manifest themselves in a boiler system include fireside ash deposition on heat transfer surfaces, corrosion and erosion of boiler parts, poor slag flow, and production of fine particulates that are difficult to collect. Research, development, and demonstration programs have been conducted over the past several decades to develop a better understanding of the chemical and physical processes of ash formation, ash deposition, slag flow, and particulate control in combustion systems. This understanding is leading to the development of tools to predict and manage ash behavior. However, few studies are aimed at the behavior of North Dakota lignite. Recent papers as well as ash-related issues and compilations of work by many investigators can be found by referring to the work of Liang and others (1), Degereji and others (2), Losurdo and others (3), Zbogar and others (4,5), Harding and O'Connor (6), Vargas and others (7), Mehta and Benson (8), Schobert (9), Baxter and Desollar (10), Couch (11), Williamson and Wigley (12), Benson and others (13), Benson (14), Bryers and Vorres (15), Raask (16,17), and Benson (18).

Coal analysis methods utilized to determine the form and abundance of ash- and slag-forming components are key to developing improved tools for predicting ash behavior in combustion and gasification systems. Experience with advanced methods of analysis and associated predictions have been summarized by Laumb and others (19) and Benson and others (20). The challenge with the more sophisticated analysis methods is that they do not provide on-line real-time coal composition that can be used to blend coal or respond with other measures to manage the impacts of changes in coal properties. On-line full-stream elemental analyzers (FSEA) have the potential to provide information on the abundance of inorganic elements present in coal. However, they do not provide information on the form of the impurity in the coal. Efforts have been conducted to develop improved relationships based on the bulk analysis provided by the FSEA and the form of the impurity in the coal based on statistical and neural network methods (Salehfar and Benson (21)). Microbeam developed simplified ash prediction relationships based on the correlations between the abundance and form of ash-forming components with ash composition analysis (Laumb and Benson (22)). The simplified ash prediction relationships were incorporated into a FSEA to assess the potential impact of ash on plant performance (Swindell and others (23)).

Overview of Experience at Minnkota's MRY Plant

The Minnkota Power Cooperative Milton Young Station is a two unit mine-mouth power plant located near Center, North Dakota. Unit 1, rated at 250 MW, began producing power in 1970. Unit 2, rated at 460 MW, began producing power in 1977. Coal is supplied by BNI Coal Ltd. and mined from an adjacent lignite field consisting of three distinct seams varying from 2 ½' to 9' thick. Coal is mined using draglines and delivered to the plant with bottom-dump haul trucks.

Both units at the Young Station are base load, operate at 95% availability, and are ranked among the lowest cost coal-fired producers in the United States. Annual plant gross generation is 5.5 million MWH, consuming 4.3 million tons of coal per year. Much of the plant's success can be attributed to the low-cost lignite supply. However, significant ash-related problems associated with this lignite continually impact boiler operation and bus-bar cost.

Projects conducted at the MRY plant involved identifying key lignite properties that impact the plant performance, identifying and developing methods to measure key properties, predicting behavior based on coal properties, implementing predictive methods at the plant, and validating their performance. These studies have included:

- Development of a coal quality management system (CQMS) (Benson and others, (24)),
- Testing of an as-fired coal sampling system (Sampler Project) (Benson and others, (25)),
- Matching coal quality and boiler operations (Katrinak and others, (26)),
- Identifying the most accurate and precise FSEA analyzer (Benson and others, (27)),
- Testing of an on-line coal analyzer – factory acceptance testing and installed testing (Benson and others (28), Benson and Laumb (29)),
- Integration of ash management tools into the FSEA output (Benson (30)).

Lignite Composition – Impact on Performance

Lignite properties impact MRY plant performance in several ways that include: slag flow, fireside ash deposition, and particulate control. Most of the earlier efforts were focused on managing slag flow. The build-up of slag in a cyclone fired boiler is due to increases in slag viscosity that will decrease the ability to tap the slag. A measure of the cyclone conditions where slag will flow is the temperature at which the slag is at 250 poise, or the T_{250}. The distribution of calculated T_{250} based on the ash composition is illustrated in Figure 2. High T_{250} values have the potential to cause the slag to freeze (24). To reduce the build-up of slag in a poor performing cyclone MPC personnel will fire oil to melt the slag from the cyclones.

Up to half of the ash-forming constituents in Center lignite are organically associated. The organically associated ash-forming components consist mainly of Na, Mg, and Ca. The remaining ash-forming components consist of mineral grains that include quartz, pyrite, kaolinite, illite, montmorillonite, and mixed silicates. The lower Hagel A and B seams contain the highest levels of organically associated elements. The upper Kinneman Creek seam has higher ash and more clay minerals such as montmorillonite and illite. A database of over 200 advanced coal analyses exists.

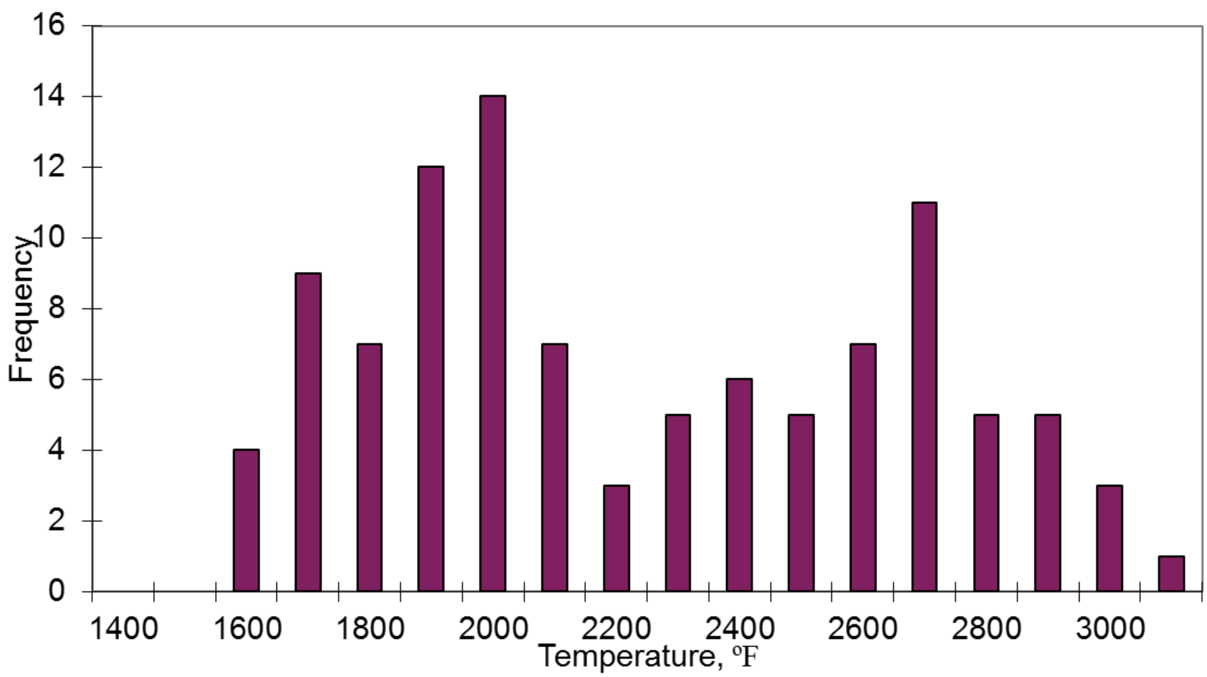


Figure 2. T_{250} Distribution for Center Lignite (24).

The minerals present in the coals that contribute to the increases in slag viscosity were montmorillonite and illite clay minerals. When the clay minerals combine with the slag, the viscosity of the slag increases due to an increase in the levels of aluminum and silicon thus causing poor flow and freezing.

Test Burn Result Summary

Lignite characteristics and boiler operations data from four scheduled test burns and four oil burn events were collected and analyzed. Data from test burns and oil burn events were used to develop a relationship between lignite characteristics and cyclone operation. The relationships developed were used to identify optimum lignite characteristics for good cyclone slag based on coal analysis parameters. Analysis of the samples indicated increases in the level of clay minerals (illite) as responsible for the increase in silica content resulting in higher T_{250}. The key coal analysis parameters included ash composition or mineral analysis and heating value (BTU/lb (as received basis)). The ash composition was used to calculate the T_{250}. The T_{250} value is the temperature where the viscosity of the slag is 250 poise, indicating easy flow from the cyclone. The T_{250} values were initially calculated using several methods but it was found that the methods do not provide sufficient accuracy to predict the suitability of the coal for cyclone firing. The uncertainties in the borderline cases are likely due to the poor T_{250} calculations, use of as-received BTU/lb values, or boiler operations. Two approaches were used to improve the relationships. The first approach was to identify other parameters that could be used to assess lignite characteristics with respect to cyclone slagging and the second approach was to improve the viscosity calculations. Figure 3 shows the relationship between oil burn event to improve slag flow and T_{250} calculations.

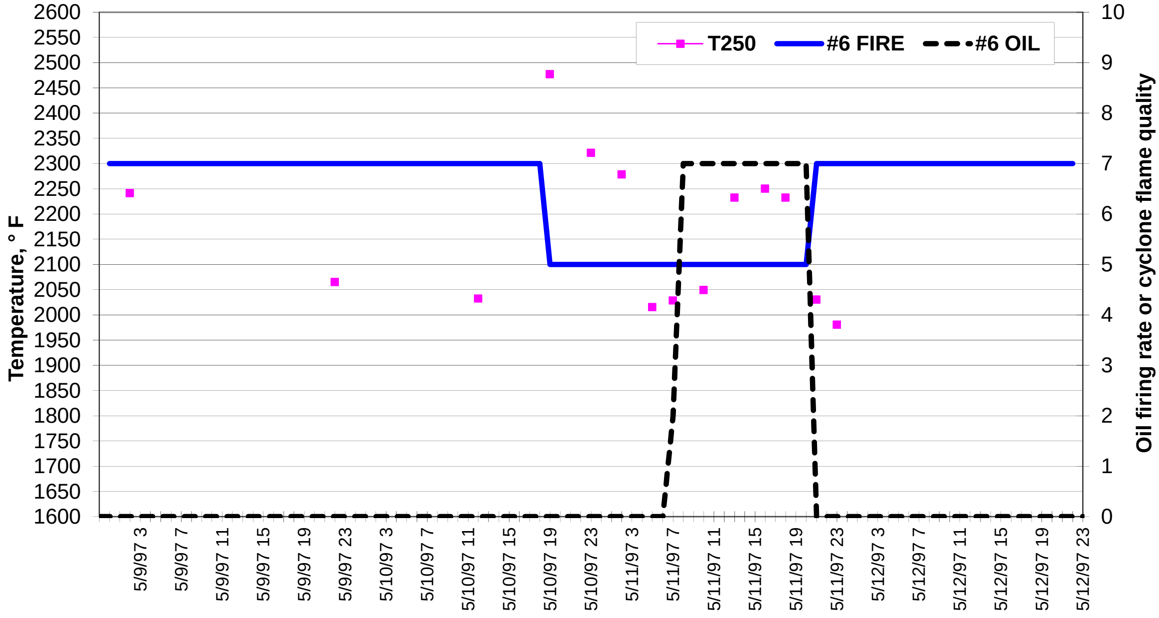


Figure 3. Relationship between T_{250} and oil burn event to manage cyclone performance.

Alternative lignite characteristic parameters, such as base-to-acid ratio and ash content, show promise in helping to predict cyclone slag flow. The base-to-acid ratio is defined as the ratio of the basic oxides of sodium, magnesium, calcium, potassium, and iron to the acidic oxides of silicon, aluminum and titanium. The data from all the test burns and oil burn events were examined and the optimum lignite characteristics for good cyclone performance based on base-to-acid ratio and ash content were determined. The optimum delivered coal would have a base-to-acid ratio above 0.6 to 0.7 and ash content below about 17 % (mf basis). (Note: Oil burning occurs when base-to-acid ratios are below 0.47 and ash quantity >20 % (mf basis)). Most lignites examined had base-to-acid ratios above 0.6 and ash below 17% (mf basis) (26).

On-Line Coal Analysis and Managing Coal Properties

In order to obtain on-line coal composition data necessary to manage lignite properties, prompt gamma neutron activation analysis systems were evaluated, tested, and installed at the

MRY plant (27-30). An ETI/ASYS Full Stream Elemental Analyzer (FSEA) was installed to determine coal ash quantity and ash composition. The FSEA is used to analyze coal as it is transported on the conveyor belt between the crushing station and the bunkers. The FSEA provides one-minute analysis of the following parameters:

Ash

Moisture

Sulfur

Heating Value

Weight

Oxides of the following elements:

Aluminum (Al_2O_3)	Base-to-Acid Ratio
Calcium (CaO)	Calculation of sulfur retained in the ash as SO_3
Iron (Fe_2O_3)	Lbs SO_2/MBTU
Potassium (K_2O)	Carbon (derived)
Magnesium (MgO)	
Manganese (MnO_2)	
Sodium (Na_2O)	
Silicon (SiO_2)	
Titanium (TiO_2)	

The errors in determining the base-to-acid ratios for the 1-minute averaging FSEA were determined through analysis of well characterized lignite samples. These static tests show good comparison to the 1-minute factory acceptance (FAT) testing (28,29) shown in Figure 4. Figure 5 shows the results of FSEA ash measurements of the coal with the belt stopped in comparison to the analysis of the coal under each analyzer conducted by standard coal analysis (MVTL).

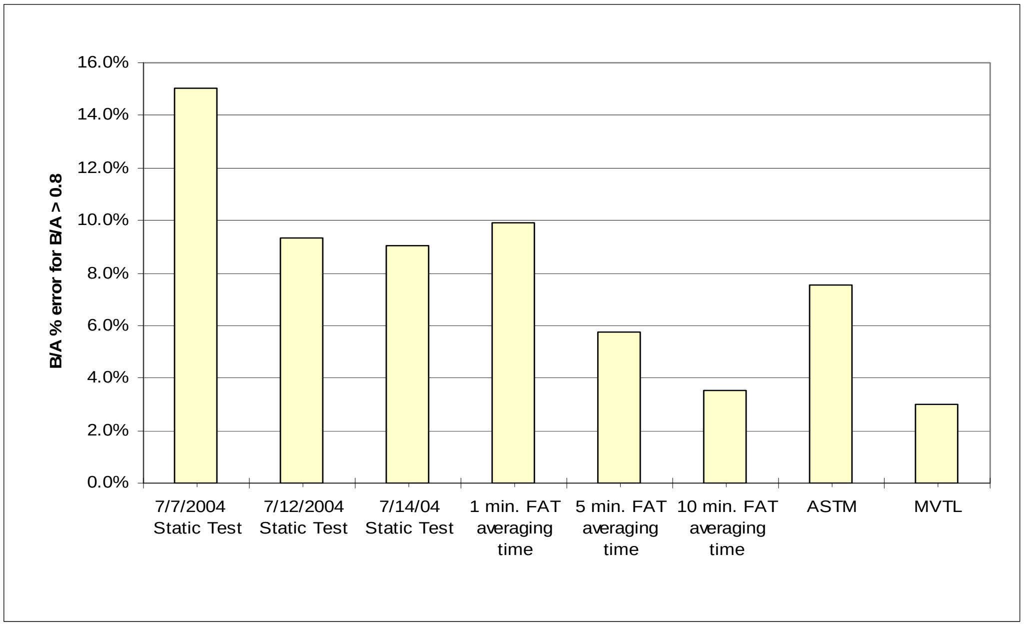


Figure 4. Percent error in calculating B/A ratio for ETI/ASYS FSEA averaging time of 1 minute for static tests performed on July 7, 12, and 14, 2004, as compared to calculated percent error for FSEA averaging times of 1, 5, and 10 minutes from the FAT, and percent error achieved by coal analysis laboratory and that specified by ASTM D 3682 (29).

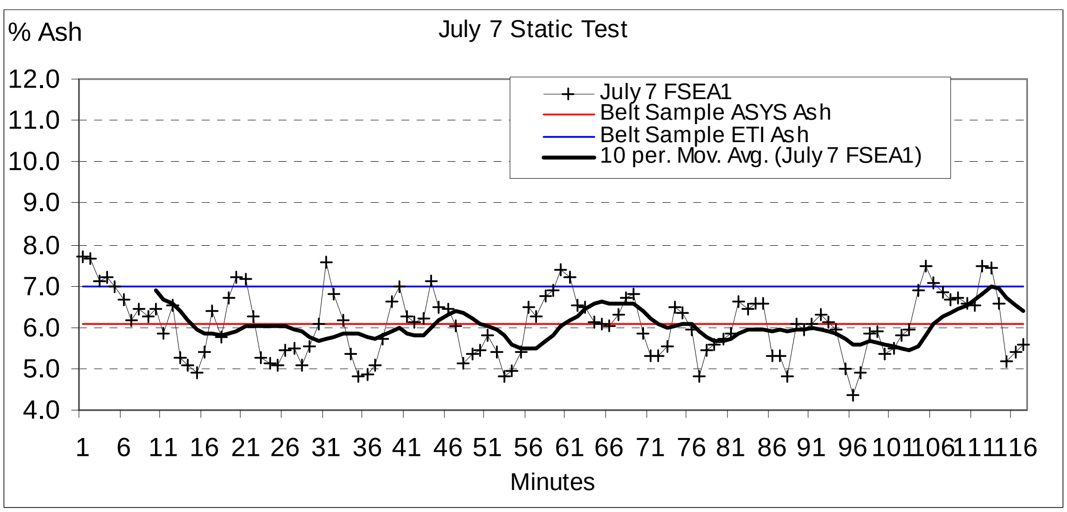


Figure 5. Comparison of the FSEA analyzer 1-minute and 10 minute averaging results with samples collected from the belt under the ASYS and ETI ash meter (29).

For moving belt measurements, trends in properties of the coal delivered to the plant can be observed with the FSEA. Figure 6 shows the results obtained for base-to-acid ratio during a time when the coal quality was changing. These changes have the potential to significantly impact power plant performance. In addition, the values fall within the average, minimum, and maximum values determined for the database of coal analysis as determined by ASTM methods. The ash deposit strength index (silicate based) calculated at 2250 ºF using simplified indices (22) correlations is an example of one of the Microbeam indices calculated from the FSEA data shown in Figure 7.

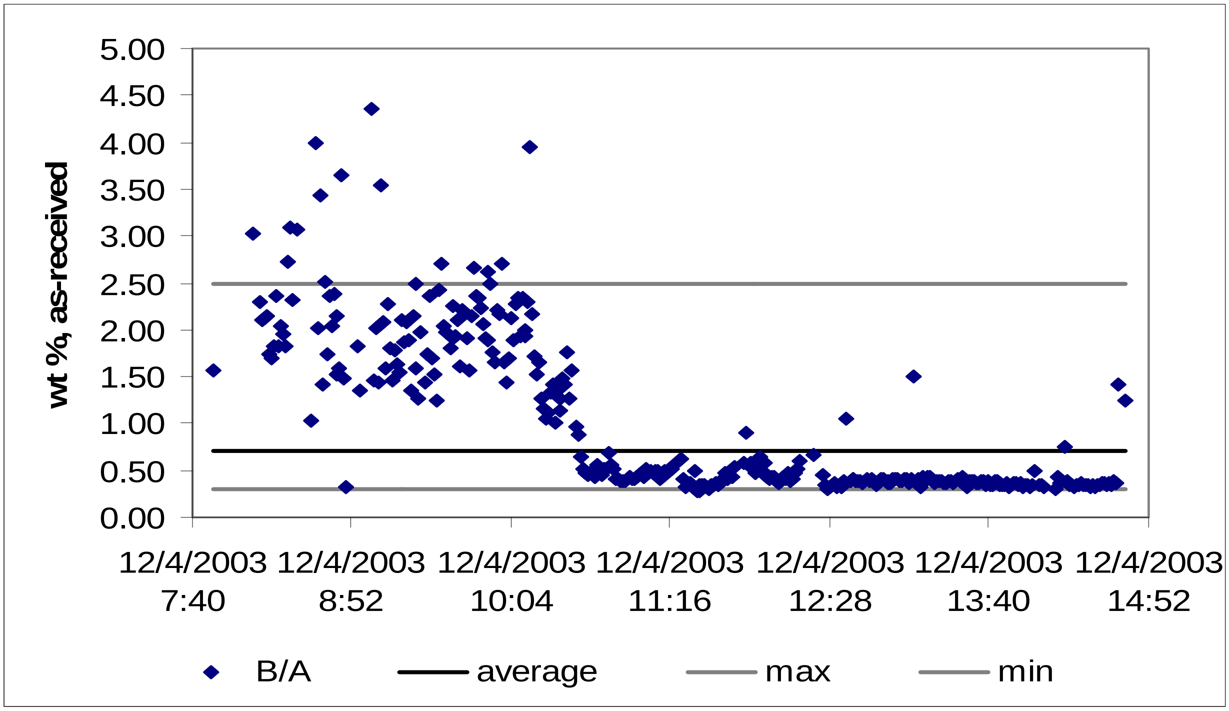


Figure 6. Moving belt FSEA results for base-to-acid ratio (B/A) compared to the maximum, minimum and average values of B/A in the database.

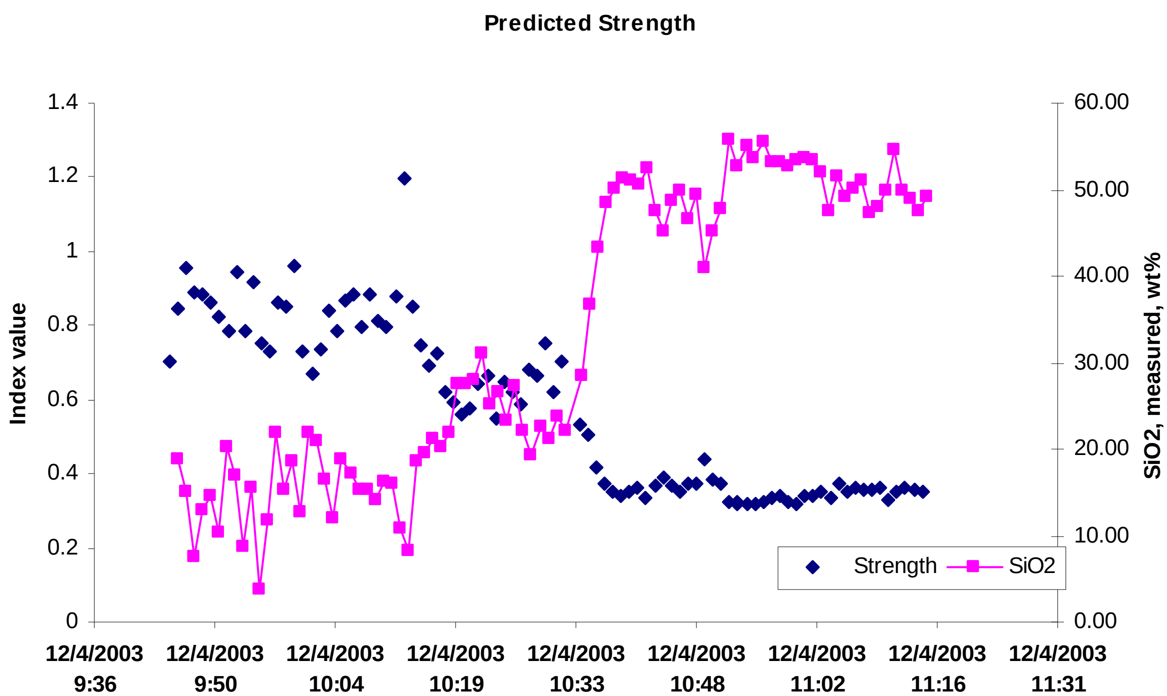


Figure 7. Moving belt FSEA results for simplified high temperature deposit strength index and SiO_2 content (30).

References

1. Liang, Q., Guo, X., Dai, Z., Liu, H., and Gong, X., An investigation on the heat transfer behavior and slag deposition of membrane wall in pilot-scale entrained-flow gasifier, Fuel 102 (2012) 491–498.
2. Degereji, M.U., Ingham, D.B., Ma, L., Pourkashanian, M., Williams, A., Numerical assessment of coals/blends slagging potential in pulverized coal boilers, Fuel 102 (2012) 345–353.
3. Losurdo, M., Spliethoff, H., and Kiel, J., Ash deposition modeling using a visco-elastic approach, Fuel 102 (2012) 145–155.
4. Zbogar, A., Frandsen, F., Jensen, P.A., and Glarborg, P., Shedding of ash deposits, Progress in Energy and Combustion Science 35 (2009) 31–56.
5. Zbogar, A., Frandsen, F.J., Jensen, P.A., and Glarborg, P., Heat transfer in ash deposits: A modeling tool-box, Progress in Energy and Combustion Science 31 (2005) 371–421.
6. Harding, N.S. and O'Connor, Ash deposition impacts in the power industry, Fuel Processing Technology 88 (2007) 1082–1093.

7. Vargas, S., Frandsen, F.J., and Dam-Johansen, Rheological properties of high-temperataure melts of coal ashes and other silicates, Progress in Energy and Combustion Science 27 (2001) 237-429.
8. Mehta, A., and Benson, S. (Eds.). *Effects of Coal Quality on Power Plant Management: Ash Problems, Management, and Solutions,* United Engineering Foundations Inc., New York, NY, and EPRI, Palo Alto, CA: 2001. 1001402
9. Schobert, H.H., (1995). *Lignites of North America.* Coal Science and Technology 23, New York, Elsevier.
10. Baxter, L., and DeSollar, R. (Eds.)(1996). *Applications of Advanced Technology to Ash-Related Problems in Boilers*. New York: Plenum Press.
11. Couch, G. "Understanding Slagging and Fouling During pf Combustion," IEA Coal Research report; 1994.
12. Williamson, J., and Wigley, F. (Eds.) (1994). *The Impact of Ash Deposition on Coal Fired Plants: Proceedings of the Engineering Foundation Conference.* London: Taylor & Francis.
13. Benson, S.A., Jones, M.L. and Harb, J.N. Ash Formation and Deposition--Chapter 4. In: *Fundamentals of Coal Combustion for Clean and Efficient Use,* edited by Smoot, L.D. Amsterdam, London, New York, Tokyo: Elsevier, 1993, p. 299-373.
14. Benson, S.A. (Ed.) (1992). *Inorganic Transformations and Ash Deposition During Combustion*. New York: American Society of Mechanical Engineers for the Engineering Foundation.
15. Bryers, R.W., Vorres, K.S. (Eds.). Proceedings of the Engineering Foundation Conference on Mineral Matter and Ash Deposition from Coal, Feb 22-26, 1988, Santa Barbara, CA, Unit Engineering Trustees Inc., 1990.
16. Raask, E. Erosion Wear in Coal Utility Boilers; Hemisphere: Washington, 1988.
17. Raask, E. Mineral Impurities in Coal Combustion; Hemisphere: Washington, 1985.
18. Benson, S.A., (Ed.) (1998). *Ash Chemistry: Phase Relationships in Ashes and Slags*, Special Issue of *Fuel Process. Technol.*; Elsevier Science Publishers: Amsterdam, 1998; Vol. 56, Nos. 1B2, 168 p.
19. Laumb, M., Benson, S.A., and Laumb, J. "Ash Behavior in Utility Boilers: A Decade of Fuel and Deposit Analyses," Presented at the United Engineering Foundation Conference on Ash Deposition and Power Production in the 21st Century, Snowbird, UT, Oct. 28 – Nov. 2, 2001.
20. Benson, S.A., Hurley, J.P., Zygarlicke, C.J., Steadman, E.N. and Erickson, T.A. Predicting Ash Behavior in Utility Boilers. Energy & Fuels vol.7 (6):746-754, 1993.
21. Salehfar, H. and Benson, S.A., Electric Utility Coal Quality Analysis Using Artificial Neural Network Techniques, Journal of NeuroComputing, Vol. 23, pp 195-206, 1996.
22. Laumb, M., Benson, S.A. "Simplified Indices for Predicting Ash Behavior for Low-Rank Coals", Presented at the 18th International Low-Rank Fuels Symposium, Billings, MT, June 24-26, 2003.
23. Swindell, D., Schwalbe, D., and Benson, S.A. "Improving Plant Performance Through Integration of ETI/ASYS Model Full Stream Elemental Analyzer (FSEA) at Minnkota Power Cooperative's Milton Young Plant", Presented at the 19th International Symposium on Lignite, Brown, and Subbituminous Coals", Billings, MT, Oct. 12-14, 2004.
24. Benson, S.A., Kong, L., Katrinak, K.A., and Schumacher, K., Coal Quality Management System, Final Report to North Dakota Industrial Commission, 1997.

25. Benson, S.A., Kong, L., Katrinak, K.A., and Peterson, W. Sampler Project, Final Report, North Dakota Industrial Commission, 1997.
26. Katrinak, K.A., Benson, S.A., Laumb, J., Schwalbe, R., and Peterson, W., Matching Lignite Characteristics and Boiler Operations, Final Report, North Dakota Industrial Commission, 2000.
27. Benson, S.A., Laumb, M.L., and Ruud, A., Specifications for On-Line Coal Analyzer using Prompt Gamma Neutron Activation Analysis (PGNAA), Report for Minnkota Power Cooperative, MTI Project 607, May 2002.
28. Benson, S.A., Laumb, M.L., and Ruud, A., Analysis of Factory Acceptance Test for On-Line Coal Analyzer using Prompt Gamma Neutron Activation Analysis, Report for Minnkota Power Cooperative, MTI Project 692, September 2002.
29. Benson, S.A., and Laumb, M.L., Analysis of Data Produced from Full Stream Elemental Analyzer Including the Ash and Moisture Meter, MTI Project 728, April 2004
30. Benson, S.A. Application of On-Line Coal Analyzers to Plant Performance, Minnesota Energy Ingenuity Conference, Great River Energy, November 2008.

9. QUALIFICATIONS

The corporate mission of Microbeam Technologies Inc. (MTI) is to provide advanced analysis tools and technologies to minimize the impacts of inorganic components in solid fuels on power system performance. Since 1992, MTI has performed more than 1,350 commercial projects providing advanced analysis of coal, ash, ceramics, metals, and other materials, and has done consulting for researchers, power industry, boiler manufacturers, coal companies, and others. In 1999, MTI received a DOE Phase I SBIR on the abatement of corrosion and plugging of hot gas filters in gasification systems. In 2002, MTI was awarded a National Science Foundation (NSF) Phase I SBIR on the use of gasification systems to recover valuable elements from the gas stream. Based on the results of the Phase I SBIR work, Phase II was awarded in 2004. MTI has completed Phase II research and development and is working on commercializing the technology.

MTI's core competency lies in the understanding of the combustion and environmental control technologies for coal, biomass, petroleum coke, and waste-fired systems. Efforts have been focused on behavior of fuel impurities in combustion and gasification systems as a function of fuel characteristics, system design, and operating conditions. The projects conducted on gasification and combustion systems have been aimed at matching fuel quality with plant design and developing methods to minimize impacts on system performance. MTI has a client base that includes customers from the United States, Canada, United Kingdom, Finland, Sweden, Hungary, Poland, Germany, Indonesia, Japan, Brazil, South Africa, India, South Korea, and Australia. Further information can be obtained from MTI's website at www.microbeam.com.

10. VALUE TO NORTH DAKOTA

A major challenge facing North Dakota lignite-fired utilities is managing highly variable lignite properties. This project will develop data and tools to identify cost effective measures to decrease NOx emissions, slag freezing, ash deposition, and particulate collection and handling problems as a function of system operation conditions and lignite blends.

11.MANAGEMENT

The project management structure is illustrated in Figure 8. The overall project management will be the responsibility of Dr. Steve Benson. Dr. Benson will coordinate work with project sponsors to review progress. Mr. Art Ruud will be responsible for the day-to- day coordination of project activities. Mr. Ruud will coordinate all project analysis.

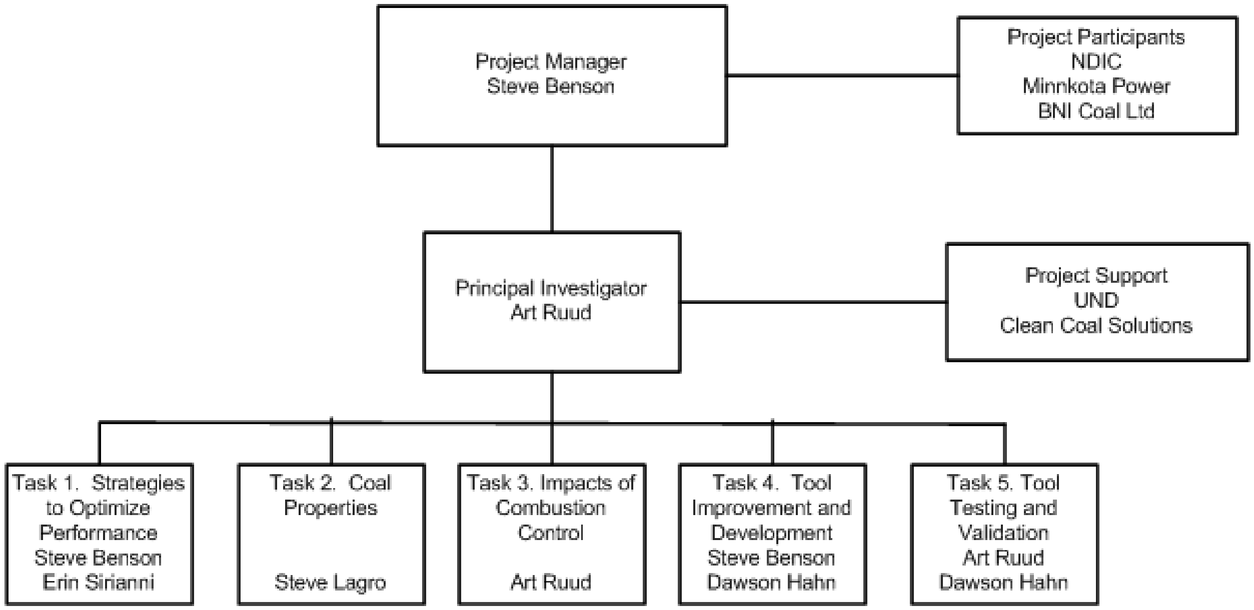


Figure 8. Project Organizational Chart.

Dr. Steve Benson will be the project manager and will be responsible for the coordination of efforts associated with testing and the development of the predictive methods. Dr. Steve Benson currently is President of MTI and Professor of Chemical and Petroleum Engineering at the University of North Dakota. Dr. Benson has over 25 years of professional experience in the behavior of fuel impurities in combustion and gasification systems that include the following areas: high temperature reaction mechanisms, coal ash slagging and fouling, inorganic constituents in coals, scanning electron microscopy analysis, and fundamentals of coal combustion. Dr. Benson has extensive experience in managing complex multidisciplinary projects for federal and state departments and agencies such as the U.S. Department of Energy and the Environmental Protection Agency. He has managed numerous projects for industry alone and for industry and government co-funded programs. Dr. Benson is a member of several professional organizations and has written or co-written over 210 publications

Mr. Arthur Ruud, Research Scientist at MTI, will be responsible for the coordination of testing and characterization of coal, slag and other materials. Mr. Ruud has a M.S. in Chemistry from the University of North Dakota, and nearly 30 years of experience in the coal combustion and analytical chemistry fields. He has a strong background in experimental design and system design and construction. Mr. Ruud has extensive experience in advanced analytical methods of analysis used to measure the form and abundance of ash-forming components in fuels and the chemical and physical properties of ash-related materials, metals, and refractories. Mr. Ruud also has experience with standard ASTM methods for coal and fuel analyses, including all standard fuel analyses.

Stephen Lagro, SEM Applications Associate, has a B.S. in Chemistry from Dickinson State University. He has extensive experience managing and conducting chemical and physical analysis of energy system-related samples. He is currently responsible for fuel, fireside deposits, refractories, metals and other related materials analysis using scanning electron microscopy and x-ray microanalysis. He is also responsible for the development of improved applications for the analysis of fuels and related materials from combustion and gasification systems. Mr. Lagro will be responsible for performing the analysis of the materials.

Dawson Hahn, SEM Applications Assistant, is currently completing a B.S. in Computer Science and a B.S. in Mathematics at the University of North Dakota. He is responsible for the development and management of computer applications in support of our advanced fuel, slag, ash deposit, and fly ash analysis. He worked at Microbeam for the past two years and will assist in any computer programming applications.

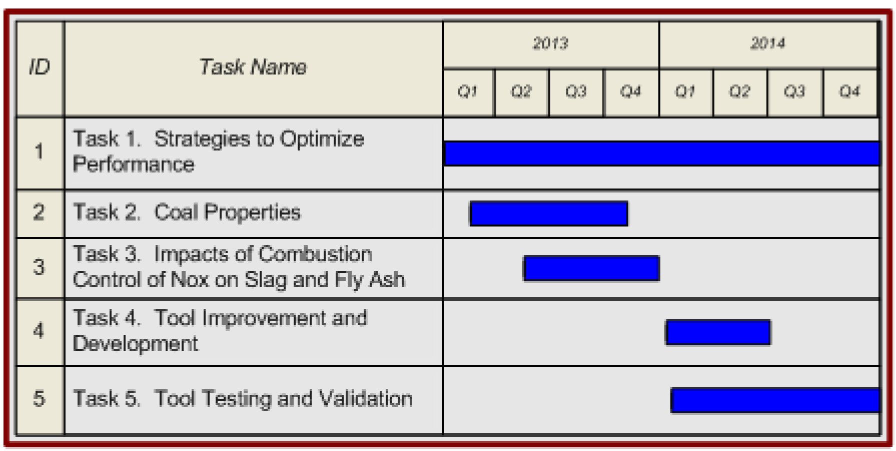
Erin Sirianni, Marketing Manager at MTI, has been employed by MTI since 2006. She has a B.A. in English from St. Olaf College and an M.A. in Journalism from the University of

Missouri School of Journalism, where she focused in science and health communication. She has over five years of experience in journalism, marketing, and public relations. Ms. Sirianni will be responsible for coordinating the workshops with Minnkota and BNI that will be conducted in person or by webinar.

12. TIMETABLE

The work is anticipated to take two years to complete. The overall project schedule is shown in Table 2.

Table 2. Overall Project Schedule.



Deliverables resulting from the proposed work will include the following:

1. Training on ash and slag behavior will be provided on a monthly basis by webinar or in person.
2. Database information on lignite, slag, partitioning, ash deposits and fly ash will be developed after the completion of Tasks 2, 3, and 5.

3. Improved tools for managing lignite properties to minimize NOx emissions. A test version will be provided at the end of Task 4.
4. Reports that include quarterly status reports, task reports and a final report.

13.BUDGET

The project budget is summarized in Table 3. The cost share is summarized in Table 4.

Table 3. Project budget by year and task (UND subcontract budget is in the appendix).

	Year 1.					
	Task 1	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Total**
Personnel	$ 17,485	$ 9,833	$ 19,237	$ -	$ -	$ 46,555
Fringe (23%)	$ 4,022	$ 2,261	$ 4,425	$ -	$ -	$ 10,708
Total Personnel	$ 21,507	$ 12,094	$ 23,662	$ -	$ -	$ 57,263
Travel	$ 2,407	$ 602	$ 1,987	$ -	$ -	$ 4,996
Communications	$ 500	$ 200	$ 200	$ -	$ -	$ 900
Supplies	$ 500	$ 100	$ 600	$ -	$ -	$ 1,200
Coal Analysis/core	$ -	$ -	$ 11,920	$ -	$ -	$ 11,920
SlagFly ash Analysis	$ -	$ 27,900	$ 17,010	$ -	$ -	$ 44,910
UND Subcontract			$ 52,562		$ -	$ 52,562
Total Direct	$ 24,914	$ 40,896	$ 107,941	$ -	$ -	$ 173,751
Indirect Cost (15%)	$ 3,737	$ 6,134	$ 16,191	$ -	$ -	$ 26,062
Total Project Expenses	$ 28,651	$ 47,030	$ 124,132	$ -	$ -	$ 199,813

	Year 2.					
	Task 1	Task 2	Task 3	Task 4	Task 5	Total Yr 2
Personnel	$ 15,863	$ -	$ -	$ 49,031	$ 22,546	$ 87,440
Fringe (23%)	$ 3,648	$ -	$ -	$ 11,277	$ 5,186	$ 20,111
Total Personnel	$ 19,511	$ -	$ -	$ 60,308	$ 27,732	$ 107,551
Travel	$ 2,407	$ -	$ -	$ 1,203	$ 1,805	$ 5,415
Communications	$ 500	$ -	$ -	$ 500	$ 500	$ 1,500
Supplies	$ 500		$ -	$ 2,000	$ 2,000	$ 4,500
Coal Analysis/core	$ -	$ -	$ -		$ 11,920	$ 11,920
SlagFly ash Analysis	$ -	$ -	$ -		$ 15,570	$ 15,570
	$ -					
UND Subcontract			$ -		$ 27,595	$ 27,595
Total Direct	$ 22,918	$ -	$ -	$ 64,011	$ 87,122	$ 174,051
Indirect Cost (15%)	$ 3,438	$ -	$ -	$ 9,602	$ 13,068	$ 26,108
Total Project Expenses	$ 26,356	$ -	$ -	$ 73,613	$ 100,190	$ 200,159

Table 3. Project budget by year and task (continued).

	Total Year 1 and 2					
	Task 1	Task 2	Task 3	Task 4	Task 5	Total Project
Personnel	$ 33,348	$ 9,833	$ 19,237	$ 49,031	$ 22,546	$ 133,995
Fringe (23%)	$ 7,670	$ 2,261	$ 4,425	$ 11,277	$ 5,186	$ 30,819
Total Personnel	$ 41,018	$ 12,094	$ 23,662	$ 60,308	$ 27,732	$ 164,814
Travel	$ 4,814	$ 602	$ 1,987	$ 1,203	$ 1,805	$ 10,411
Communications	$ 1,000	$ 200	$ 200	$ 500	$ 500	$ 2,400
Supplies	$ 1,000	$ 100	$ 600	$ 2,000	$ 2,000	$ 5,700
Coal Analysis/core	$ -	$ -	$ 11,920	$ -	$ 11,920	$ 23,840
SlagFly ash Analysis	$ -	$ 27,900	$ 17,010	$ -	$ 15,570	$ 60,480
UND Subcontract	$ -	$ -	$ 52,562	$ -	$ 27,595	$ 80,157
Total Direct	$ 47,832	$ 40,896	$ 107,941	$ 64,011	$ 87,122	$ 347,802
Indirect Cost (15%)	$ 7,175	$ 6,134	$ 16,191	$ 9,602	$ 13,068	$ 52,170
Total Project Expenses	$ 55,007	$ 47,030	$ 124,132	$ 73,613	$ 100,190	$ 399,972

Table 4. Budget Cost Share Summary.

	Participant		Inkind Matching Costs			
	Cash Share	NDIC Share	Minnkota	BNI Share	CCS	Total Inkind
Personnel		$ 133,995				
Fringe (23%)		$ 30,819				
Total Personnel		$ 164,814	$ 125,000			$ 125,000
Travel		$ 10,411				
Communications		$ 2,400				
Supplies		$ 5,700				
Coal Analysis/core		$ 23,840		$ 125,000	50,000	$ 175,000
SlagFly ash Analysis	$ 6,800	$ 53,680				
UND Subcontract	$ 80,157	$ -				
Total Direct	$ 86,957	$ 260,845				
Indirect Cost (15%)	$ 13,043	$ 39,127				
Total Project Expenses	$ 100,000	$ 299,972	$ 125,000	$ 125,000	$ 50,000	$ 300,000

14.MATCHING FUNDS

The total project cost is $399,972. Cash cost share of $100,000 is provided from Minnkota, BNI, and CCS. Minnkota and BNI will each provide $40,000. CCS will provide $20,000. A total of $300,000 of in-kind cost share from Minnkota, BNI and CCS is also provided. The cost share contributions are summarized in Table 4. Letters of interest and support for the project are attached in the Appendix.

15.Tax Liability

The applicant does not have an outstanding tax liability owed to the state of ND or any of its political subdivisions.

16.Confidential Information

No confidential information is included in the proposal.

17. APPENDICES

Minnkota Power
MPC COOPERATIVE, INC.
Your Touchstone Energy® Partner

1822 Mill Road • P.O. Box 13200 • Grand Forks, ND 58208-3200 • Phone (701) 795-4000

October 1, 2012

Steven A. Benson, Ph.D., President
Microbeam Technologies, Inc.
4200 James Ray Drive, Suite 191
Grand Forks, ND 58203

Re: Support for project entitled "Optimization of Tools to Manage Coal Properties and Plant Operations"

Dear Steve:

Minnkota Power Cooperative (MPC) is pleased to support and work with Microbeam Technologies, Inc. (MTI) in the proposed project to optimize tools to manage coal properties and plant operations. Cyclone-fired plants have been redesigned to accommodate changes in operating parameters that allow for the redistribution of air in the combustion system aimed at reducing NOx formation. These changes have resulted operating the cyclone under substochiometric combustion conditions and adding air in the upper regions of the furnace to complete the combustion. These changes have resulted in changes in slag flow behavior that sometimes leads to freezing of the slag, water wall slagging, convective pass fouling and fine particulate formation. Past tools developed in conjunction with Microbeam to manage these issues need to be updated to include the changes in the system design and operating parameters. MTI proposes to develop improved tools to manage lignite properties and plant operations based on measureable lignite properties, an improved understanding of ash and slag behavior during low-NOx cyclone operation, and plant operating that enables the optimization of boiler and associated environmental control systems performance.

Updating these tools are keys to our personnel for managing coal and plant operations to reliably operate cyclones when firing ND lignite. MPC is pleased to provide $40,000 cash cost share over the two year project. In addition, MPC will provide at least $120,000 of in-kind cost share to support coal sampling, coal analysis and plant personnel support during the week-long test campaigns.

If you have questions and require additional information, please contact Andrew Freidt Milton R. Young Station Engineering Superintendent at (701) 794-7213 or by email at afreidt@minnkota.com.

Sincerely,

MINNKOTA POWER COOPERATIVE, INC.

Luther Kvernen

Luther Kvernen
Vice President-Generation
(701) 795-4205
lkvernen@minnkota.com

WADE BOESHANS
General Manager

BNI COAL®

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

October 1, 2012

Steven A. Benson, Ph.D
President
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 191
Grand Forks, ND 58203

Re: Support for project entitled "Optimization of Tools to Manage Coal Properties and Plant Operations"

Dear Steve:

BNI Coal Ltd. is pleased to support and work with Microbeam Technologies Inc (MTI) in the proposed project to optimize tools to manage coal properties and plant operations. BNI provides coal to the MRY plant and works closely with Minnkota Power Cooperative (MPC) to manage coal properties. As a result of the redesign of the cyclone boilers to reduce NOx and changes in plant operating conditions at MRY as well as changes in coal properties anticipated as we move to other mining locations the relationships developed for managing coal properties need to be updated and tested. The past tools developed in conjunction with Minnkota Power and Microbeam to manage coal properties need to be updated to include the changes in the system design and operating parameters. MTI proposes to develop improved tools to manage lignite properties and plant operations based on measureable lignite properties, an improved understanding of ash and slag behavior during low-NOx cyclone operation, and plant operating that enables the optimization of boiler and associated environmental control systems performance.

Updating these tools is key for our mine operations personnel to manage coal quality and plant operations for reliable operation of cyclones when firing ND lignite. BNI is pleased to provide $40,000 cash cost share over the two year project. In addition, BNI will provide at least $120,000 of inkind cost share associated with projecting coal properties based on core analysis and provide support for the weeklong test campaigns.

If you have questions or require additional information please contact me.

Sincerely,

Wade Boeshans

BNI COAL, LTD.
1637 BURNT BOAT DRIVE • P.O. BOX 897 • BISMARCK, ND 58502

CLEAN COAL
SOLUTIONS LLC

October 1, 2012

Steven A. Benson, Ph.D
President
Microbeam Technologies Inc.
4200 James Ray Drive, Ste 191
Grand Forks, ND 58203

Re: Support for project entitled "Optimization of Tools to Manage Coal Properties and Plant Operations"

Dear Steve:

Clean Coal Solutions. is pleased to support and work with Microbeam Technologies Inc (MTI) in the proposed project to optimize tools to manage coal properties and plant operations. Clean Coal Solutions (CCS) has a facility on site at the Milton R. Young Plant treating the coal to reduce mercury and NOx emissions. Based on our assessment of the redesign of the cyclone boilers and changes in plant operating conditions at MRY, we believe that the plant will benefit considerably from the work Microbeam is proposing to the Lignite Energy Council.

CCS is pleased to provide $20,000 cash cost share over the two-year project. In addition, CCS will provide at least $50,000 of inkind cost share associated with coal sampling.combustion expertise, and full-stream coal analyzer data.

If you have questions and require additional information please contact me directly.

Sincerely,

Nina B. French

Dr. Nina Bergan French, P.E.
Director, Clean Coal Solutions LLC
5251 DTC Parkway, Suite 825
Greenwood Village, CO 80111
Office 707-265-0700
cell 707-732-7049

UNIVERSITY OF UND NORTH DAKOTA

THE INSTITUTE FOR ENERGY STUDIES
UPSON II ROOM 366
243 CENTENNIAL DRIVE STOP 8153
GRAND FORKS ND 58202-8153
(701) 777-2533
und.instituteforenergystudies@engr.und.edu

September 27, 2012

Art Ruud
Research Scientist
Microbeam Technologies, Inc.
4200 James Ray Drive, Ste. 193
Grand Forks, ND 58203
(701) 777-6531

Ref: Request for Proposal for Extractive Particulate as well as Method 202a Sampling Upstream of Electrostatic Precipitators

Dear Art,

This letter of commitment is to support Microbeam Technologies, Inc. in its proposed project to study emissions from a coal fired boiler unit. The Institute for Energy Studies will provide project support as follows:

1. Conducting extractive sampling of flue gas upstream and downstream of the electrostatic precipitators using a state of the art low pressure impactor. The Dekati Low Pressure Impactor (DLPI) is a 13-stage cascade impactor that is used for measuring gravimetric particle sizes. The DLPI size classifies particles from 10 microns down to 30nm, with an additional filter stage that enables the collection of particles less than 30nm in diameter.

2. Conducting dry impinger tests for condensable as well as filterable particulate matter (EPA Method 202a) upstream of the electrostatic precipitators.

3. Determination of particle size distributions and dust loadings from size-fractionated mass loadings collected by the impactor sampling.

The proposed project will be initiated upon approval of the project by Microbeam Technologies, Inc. The total cost of the proposed work is $26,281. An additional budget that covers costs for FY 2013-2014 has also been included.

If you have any questions or comments regarding this effort, please feel free to contact me by phone at 701-777-4805 or by email at charles.thumbi@engr.und.edu. I look forward to this opportunity to team up with Microbeam Technologies, Inc.

Sincerely,

Charles K. Thumbi, Research Engineer

9/27/2012
Date

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

9/25/12
Date

Attachments: Budget

Budget

	FY 2012-2013	FY 2013-2014
Salaries	$ 5,593	$ 5,873
Fringe	$2,237	$2,349
Materials & Supplies	$8,387	$8,806
Training	$500	$525
Travel	$2,327	$2,444
Total Direct	$19,044	$19,996
Indirect Costs	$7,237	$7,599
Total Cost	$26,281	$27,595

Notes

The project will be undertaken by a team of two Research Engineers.

The budget has been allocated for a five days testing campaign. It includes one day for setup, three days of testing as well as one day for teardown. An additional five days for sample preparations for MTI as well as data analysis and reporting is included in the salary estimate.

Travel is estimated to the test site located in Center, ND from Grand Forks. The travel covers a U-Haul rental (mileage, gas, insurance) as well as meals and lodging for two Research Engineers to cover the test campaign.

Materials and supplies needed for the test campaign are listed below:

Amber Bottles	1	$57
Aluminum Weighing Tins	1	$60
Beaker (400mL)	1	$79
PTFE Amber Bottles (500mL)	1	$81
Burette	1	$214
Pipette (5 mL)	1	$106
Acetone	1	$102
Hexane	1	$73
Silica (2.5kg)	1	$66
Anhydrous Calcium Sulfate	1	$34
pH Meter	1	$132
Ammonium Hydroxide (2.5 L)	1	$79

MiscoBox	1	$4,987
Method 202a Equipment+Filter	1	$1,138
Ice Cooler + Ice	1	$50
Gloves	1	$22
Towels	1	$20
Dekati Heat Muff	1	$300
Safety harness	1	$108
Dessicator	1	$112
Dekati Grease/Supplies/Fittings	1	$500
Nitrogen Gas Bottle	1	$67
	Total	$8,387

An F&A rate of 38% was used in the budgetary estimates.

A 5% escalation is included for salary, supplies, training, and travel to forecast costs for FY 2013-2014.

Disclaimer

F&A is applied to modified total direct costs, consisting of all salaries and wages, fringe benefits, materials, supplies, services, travel and subgrants and subcontracts up to the first $25,000 of each subgrant or subcontract (regardless of the period covered by the subgrant or subcontract). Modified total direct costs (MTDC) shall exclude equipment, capital expenditures, charges for patient care, tuition remission, rental costs of off-site facilities, scholarships, and fellowships, as well as the portion of each subgrant and subcontract in excess of $25,000