Lignite Fuel Enhancement: Dry Process Coal Cleaning

Coal Cleaning using Air and Magnetic Separation

APPLICANTS:

The Falkirk Mining Company
P. O. Box 1087, Underwood, ND 58576

PRINCIPAL INVESTIGATOR:

Richard Weinstein, Engineering Manager
The Falkirk Mining Company

MARCH 31, 2004

AMOUNT REQUESTED: $250,000

TABLE OF CONTENTS

ABSTRACT

The Falkirk Mining Company, Great River Energy, Coteau Properties Company, Basin Electric, the North American Coal Corporation, Tractebel Power, Inc., The University of Kentucky, Electric Power Research Institute (EPRI), Energy and Environment Research Center (EERC) and Allmineral Llc. are proposing this project to lower the total cost of electric production by improving the cost, quality, and value of lignite coals. This program focuses on economically reducing the amount of sulfur, mercury, moisture, ash and other minerals in lignite. The process to be demonstrated under this project will use air and magnetic separation in a transportable pilot plant. This process will be applied to coal currently mined, with emphasis on coals that are problematic to the power plants, and to coals that are currently discarded in the mining operation. The project will provide economic and performance information to quantitatively assesses the commercialization of the process for enhancing Lignite.

A transportable 5 ton per hour pilot plant air separator (airjig) and a lab scale magnetic separator will be used to validate and expand upon the results of previous field and laboratory testing. Additionally an existing drying plant will be utilized to assist in the investigation of the stability of highly cleaned and dried lignite. The pilot plant will operate under a wide range of feed characteristics and site conditions expected in commercial operations. The project objectives are as follows:

1) Design build and operate a transportable 5 ton per hour plant utilizing dry cleaning methods to determine energy recovery of the process on various lignite coals.
2) Measure the quality of the coal, including the reduction in ash, sulfur, and mercury, and perform a series of parametric tests to optimize the dry cleaning processes.
3) Determine the impact of cleaning on the mine and power plant performance, including boiler efficiency, auxiliary power requirements, disposal issues and, emission equipment performance.
4) Determine the probable construction cost for a plant based on field testing.
5) Determine the stability of a cleaned and dried product.

This program will test a multitude of different coals and operating conditions. There are many similarities between the various lignite producing regions. The wide variety of field

conditions and various deposits of lignite will yield substantial information to improve the value of lignite. The duration of this project is approximately one year.

Total project cost is $1,331,035 of which the North Dakota Industrial Commission is requested to contribute $250,000, which is approximately 19% of the total.

PROJECT SUMMARY

”LIGNITE FUEL ENHANCEMENT: DRY PROCESS COAL CLEANING”

COAL CLEANING USING AIR AND MAGNETIC SEPARATION

Objective: Reduce the total cost of electric generation by investigating and documenting the benefits of dry cleaning methods which remove detrimental constituents from lignite coal. The project will focus on long term pilot scale field demonstrations combined with advanced analytical evaluations

This project is a continuation work directed by the Falkirk Mining Company. The program is organized into three phases.

Phase I – Basic research and testing

Phase II – Demonstration scale pilot plant

Phase III – Commercial size installation and operation

Phase I of the project was conducted in 2002 and 2003. We are now requesting funding for Phase II of the program. Phase II has the following objectives:

1. Design, build and operate a transportable five ton per hour plant utilizing dry cleaning methods to determine energy recovery of the process on various lignite coals.
2. Measure the quality of the coal including the reduction in ash, sulfur, and mercury, and perform a series of parametric tests to optimize the dry cleaning processes.
3. Determine the impact of cleaning on the mine and power plant performance, including boiler efficiency, auxiliary power requirements, disposal issues and, emission equipment performance.
4. Determine the probable construction cost for a plant based on field testing.
5. Determine the stability of cleaned and dried lignite.

Although once fairly common as a method of coal preparation in the United States, dry cleaning has virtually disappeared. (See the Background section for a review of dry cleaning processes and advances that have lead to the modern airjig.) Through a combination of changing environmental regulations and improvements in process technology, dry cleaning is poised to reemerge as an economically viable process for the coal miner and the power producer. The predominant cleaning method currently employed by the mining industry is based on wet processes. It remains uneconomic in nearly all cases to upgrade lignite by employing wet gravity separation processes due to the physical characteristics of lignite and the ash mineral particles and high inherent moisture content of lignite.

Preliminary small scale lab and field trials have demonstrated the ability of an airjig and magnetic separator to remove a significant amount of undesirable mineral constituents from lignite while at the same time recovering a very high amount of heat energy. Results of previous air jig and magnetic separation testing is included in the Background section of this document.

The proposed program will allow for substantial low cost testing of these technologies to lower the mining cost per unit of heat energy. Similarly the power plant operator should observe improvements in the form of less expensive coal combined with improved power plant performance, reliability, and reduced maintenance. During the course of this project, a significant number of tests will be conducted on a wide range of lignite coals. The primary focus will be on economically recovering more resource, and to treat those coals that are most problematic to the power plant operators. The program will also encompass evaluation of treating the entire output of a mining operation.

In developing the objectives for this program it was determined that a portable unit would most cost effectively accomplish the task of evaluating a wide range of feed characteristics in sufficient quantities to generate reliable results. By performing the testing on site, the personnel ultimately responsible for commercial evaluation will have hands on experience specific to their operation.

The project provides a low cost quantifiable method to test air and magnetic separation technologies under real world conditions to increase the recovery of coal and at the same time provide the consumer with coal that is economically improved or optimized. Due to the unavailability of a lab scale enhanced air jig and the high cost of moving a commercial unit to individual sites it was decided to build a pilot plant scale air jig. It was not feasible to use an existing commercial unit due to high cost to erect and relocate, space requirements and the high transportation cost to get sufficient coal to conduct representative and unbiased tests.

The air jig is an enhanced version of the classic air tables used previously in the coal industry. The enhancements made by the Allair jig supplied by allmineral Llc. addresses many of the short comings of previous air tables. Testing done previously using a 100 ton per hour air jig showed that a very high energy recovery is possible, with a waste stream containing a high concentration of the ash and other minerals. The process creates a segregation of cleaned materials, a non cleaned stream of fine dry material (fines), and a concentrated stream of materials very high in contaminants. The fines from the air jig process are of excellent size and moisture for treatment by magnetic separation. Testing completed in 2002 using the fines from an airjig showed that a magnetic separator would substantially improve the quality while achieving very high energy recovery. The combination of both technologies shows the potential to achieve high overall energy recovery and removal of contaminants from the lignite coal tested.

For this project the combination of a pilot scale airjig with a lab scale magnetic separator will allow us to test a wide variety of coal under varying real time conditions a low cost.

MODULE 1 WORK PLAN : FALKIRK

TASK 1 –DESIGN, CONSTRUCT, AND OPERATE A PORTABLE 5 TON PER HOUR COAL CLEANING PILOT PLANT

A portable five ton per hour plant employing dry cleaning methods will be designed, constructed, and operated during the course of this project. The objectives of this program are to determine the total economic and environmental impact of the cleaning processes for combined mine and power plant operations. The plant will be operated at two lignite locations in North Dakota, and one in Mississippi. The Mississippi site will also process lignite from Louisiana. Parametric studies will be made to assist in the determining of optimal performance settings for the plant. The primary target of the project is to determine if additional coal can be economically recovered from the mining operation and to evaluate the performance in improving the quality of fuels that are problematic. Further analysis will be made on the performance of the unit for currently delivered lignite.

TASK 2 –DATA COLLECTION AND EVALUATION.

The goal of the proposed project is to measure the performance of the unit in processing a wide variety of lignite coals. In the current mining operation a significant amount of coal is being discarded due to real and contractual limitations. The core objectives of this program are to identify the ability to economically recover additional energy resource, to economically enhance lignite's adversely impacting current operations, and to identify the economic applicability of the processes to enhance current deliveries of lignite. Weight and quality of the feed product and reject streams will be collected to provide quantitative performance of the plant. The primary qualities to be evaluated will be ash, BTU, sulfur, mercury, sodium, moisture, and other detrimental constituents. Mineral ash and the ash fusion characteristics will be analyzed also. The throughput and energy recovery will be measured for each type of feed material.

MODULE 2 WORK PLAN : UNIVERSITY OF KENTUCKY

TASK 1 –PARAMETRIC OPTIMIZATION AND EFFICIENCY STUDIES

The operating and physical parameters of the dry system will be optimized to provide an efficient density-based separation while maximizing energy recovery. The goal of this module is to significantly enhance the energy efficiency and utilization of low rank coal sources. The operating and physical parameters of the dry system will be optimized to provide an efficient density-based separation while maximizing energy recovery. Researchers from the University of Kentucky will conduct a systematic parameter evaluation. After optimization of the system has been realized, efficiency studies will be performed in which samples will be subjected to washability analysis and the data used to develop partition curves on a particle size-by-size basis.

MODULE 3 WORK PLAN : ENERGY & ENVIRONMENT RESEARCH CENTER (EERC)

TASK 1 - ADVANCED ANALYSIS OF FUELS AND DATA COLLECTION

The EERC will perform computer-controlled scanning electron microscopy (CCSEM), chemical fractionation, and high-temperature viscosity measurement on weekly (8 per site) composites of the cleaned fuel for use in the following tasks. Additionally, the EERC will provide coal mercury numbers for five weekly composite samples (40 per site). This will provide an independent verification of the mercury level in the coal.

Additionally, the EERC will construct a database that will contain all of the analytical measurements performed during the study. This will include all analysis performed by the EERC and the Coal Creek laboratory.

TASK 2 - DETERMINATION OF PLANT IMPACTS, MERCURY REMOVAL, AND WASTE DISPOSAL ISSUES.

The data gathered in Task 1 will be used to perform modeling calculations with the Predictive Coal Quality Effects Screening Tool (PCQUEST^{K}) , the Facility for the Analysis of Chemical Thermodynamics (FACT) and Vista. The PCQUEST program provides a suite of indices ranging from 0 to 100 (100 being severe), including low-temperature fouling, high-temperature fouling, slagging, slag tapping, stack-plume opacity, boiler erosion, coal grindability, and sootblowing effectiveness. The Vista program will provide the total economic impact the cleaned coal will have on the power station.

In addition, calculations will be performed with FACT. The FACT code is another computer-based model that is used for assessing fuel quality effects on ash behavior in a boiler. FACT is a thermodynamic equilibrium model that predicts molar fractions (partial pressures) of all gas, liquid, and solid stable components in a system by using principles of Gibbs free energy minimization. Output from FACT includes quantities, compositions, and viscosities of liquid and solid mineral phases; therefore, the code works well for predicting the behavior of fuel ash, including biomass-derived ash for different boiler temperature regimes.

Six coals or blends of coals and one boiler configuration will be chosen from the PCQUEST and FACT calculations for modeling with the Vista program at Black & Veatch. The boiler chosen for the study is Great River Energy's Coal Creek Station. The modeling results will provide the economic impact that the cleaned coal will have on the generation facility. The results of this modeling will be summarized in the final report.

The amount of Hg removed from the coal will also be determined. The coal Hg data collected by the Coal Creek laboratory and the independent analysis conducted by the EERC will both be used to perform mass balances to determine the amount of mercury removed by the unit. In addition to the mercury removal the spoil pile from the pilot plant will be assessed for adverse environmental impacts. This part of the project will involve leaching studies to asses acid mine drainage and review of the environmental regulations to ensure the material can be deposited back in the mine.

MODULE 4 WORK PLAN : BARR ENGINEERING

TASK 1 - ESTIMATE OF PROBABLE CONSTRUCTION COST:

Prepare a capital cost estimate for a commercial size, 100 TPH coal cleaning or beneficiation plant that uses air jig technology for use year round in North Dakota. . An estimate of the probable constructed cost of the facility will be prepared. Costs will include equipment; structural; mechanical including conveyors, dust collection, piping, and fire protection; and electrical power distribution, instrumentation, and control. Additionally the cost estimate is to include crushing and sizing coal required for optimal the air jig operation. The estimate will include engineering, materials, labor, subcontracts, overhead, profit, and contingency.

MODULE 5 WORK PLAN : GREAT RIVER ENERGY AND FALKIRK

TASK 1 – COMBINED BENEFICIATION FROM CLEANING AND DRYING

In this task a selected cleaned lignite stock will be processed in a 2 ton per hour pilot scale drying plant. The objective of this task is to determine the feasibility of producing a stable high Btu, low sulfur lignite fuel. This will be done for two different size materials. The products will be tested and observed for long term stability, including reabsorbtion of moisture, oxidation, and spontaneous combustion.

Work Plan : The Equipment and Tasks

Uncover & Recover Impacts

Loading & Hauling

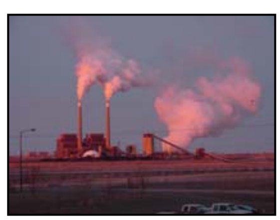
Crushing & sizing

Separation Airjig

Weighing & Sampling – Analyze & Optimize

Separation Magnetic

Drying & Segregating



The Customer
Balance of Plant Impacts

MODULE 1 WORK PLAN : FALKIRK

It is proposed to build and operate a five ton per hour coal cleaning plant. This cleaning unit will use a combination of air and magnetic separation to improve the quality of the coal. The coal will be cleaned by an airjig and by segregating magnetic from non-magnetic material.

The Allair®Jig (air jig) supplied by allmineral Llc of Alpharetta, Georgia uses fluidizing and pulsed air in combination with vibratory motion to separate heavy from lighter material. The heavier material removal is controlled by the integrated operation of a nuclear density monitor and a stargate valve. The airjig will treat the entire stream of coal. The airjig utilizes a baghouse to remove the fine particles from the air stream. Previous testing has indicated that the ash becomes concentrated in the fine particles generated by coal crushing and handling.

A magnetic separator will be used to clean the discharge from the baghouse and from the process' minus ¼ inch materials. Previous testing indicated that the size and moisture content of the baghouse fines are an ideal feed for the belt separator. In cases where the coal and ash have different magnetic susceptibility, the belt separator will segregate the materials, resulting in a clean (non-magnetic) or high ash (magnetic) product streams. The belt separator uses powerful rare earth magnets and precisely controlled feed to optimize separation and energy recovery.

In commercial applications the cleaned products of the air jig and magnetic separator may be combined. This yields a final product that recovers a substantial amount of the heat energy contained in the feed. The reject material has little heat value and contains a substantial portion of the contaminants. For applications where the contaminants do not respond to magnetic separation the overall quality constraint will determine the proper disposition of the baghouse fines.

The coal producer will benefit from this process if more coal can be recovered by this process at a lower cost. A second benefit will occur if adequate amounts of sulfur, ash, and other contaminants are removed. The positive impact to the miner would be a higher quality fuel. The net benefit to the power plant would be improved performance and reduced emissions.

This project is a joint effort of mines operated by North American Coal Corporation and its customers. It is proposed to operate this pilot plant at locations in North Dakota and Mississippi. The Mississippi location will treat coal from Mississippi and Louisiana. The pilot plant will be designed, procured, and constructed in modules for shipment to North Dakota. The plant will be installed at The Falkirk Mine and the Coteau Properties Company or their customer's power plants, Coal Creek Station and Antelope Valley Station respectively. After testing is completed in North Dakota the unit will be shipped to Mississippi.

The Objectives of the test are as follows:

1. Determine the optimal operational parameters for various coals.
2. Evaluate the cost effectiveness for specific mining applications.
3. Evaluate the impact of cleaning on the mine and plant performance and waste disposal.

Coal will be transported to the pilot plant. Coal from each mine will be specifically selected for testing. It will be necessary to crush the coal to a minus 2 inch size and segregate at a ¼ inch size. The air jig works best when the distribution of particle sizes is kept to a reasonable minimum.

Coal currently being discarded in the mining operation will be of the most interest. In addition, problematic coal currently being mined will be tested, as well as typical coal deliveries. The makeup of coal and contaminants and material handling characteristics will be representative of a wide range of expected conditions.

The performance of the unit will be determined by performing quality and weight mass balances. Samples will be taken of the feed, product, refuse, and bag house materials. The weight of material in each discharge stream will be calculated using density estimates and pile size. Scales will be used where available.

The samples will be analyzed for various coal quality parameters to determine the amount of contaminants removed, energy recovered, and quality of the coal produced including the change in the heating value of the feed coal. Further advanced analysis will be preformed by

EERC to determine the balance of plant impact from the varying products produced. Out of this analysis we will obtain the expected yield of clean coal for various feed material, determine the ability to produce material of acceptable quality, and address the overall impact of the cleaned coal on power plant performance. Additionally, the program will address the issue of handling and long term disposal associated with the detrimental constituents removed from the lignite.

The pilot plant includes everything from a crushing screening plant to load-out belts. allmineral Llc will supply an Allair Jig Plant including feed hopper, feed conveyor, product conveyor, refuse conveyor and dust conveyor, and structural steel as detailed in this document and further including an Allair Jig, model 18”X8’ with feed hopper, dust hood, dust collector, dust collector fan, working air fans, pulse air fan, hydraulic power pack and motor starters and controls for all equipment. This unit requires a flat level site approximately 100 by 200 foot including operating room for product stockpiles. The pilot plant requires a feed size of minus 2 inches with size further separated at ¼ inch.

The pilot plant is transportable and requires five flatbed trailer loads. Installation will require intermittent use of a forklift and/or crane over a five day period. An electrician will be provided by each site to provide power connections to the pilot plant. The plant will have electric motors requiring a maximum of 160 horsepower. The unit is manufactured and certified for mine site operation (meets MSHA requirements).

The pilot plant operates best on narrower ranges of sized materials. The crushed coal will be separated at ¼ inch size into two piles for feed into the pilot plant. The plant will include an air jig and a belt style magnetic separator. The air jig has a five ton per hour capacity. The magnetic separator unit will be used to process a sample of fine material captured by the baghouse and from the various products where minus ¼ inch material is processed. The magnetic separator will be a bench scale size unit capable of processing approximately 100 pounds of coal per hour.

Samples will be taken of the following coal streams on a daily basis

1. -2 inch or -1/4 inch feed coal
2. Air jig clean coal

3. Air jig refuse
4. Baghouse
5. Non-Magnetic
6. Magnetic

Automatic samples will be taken of the feed, product, baghouse and reject conveyors to obtain representative material for lab analysis. The magnetic and non-magnetic streams will be sampled and riffled to an adequate size for coal analysis. These daily samples will be analyzed for moisture, ash, sulfur, BTU, sodium, and calcium. Weekly composites will be made for each of the six sample points. If feed type changes, composites will be taken more frequently. The composite samples will be analyzed for the following:

1. Moisture, Ash, Sulfur, BTU, Sodium, and Calcium
2. Mercury
3. Sulfur Forms
4. Ash Fusion Temperatures
5. Ash Mineral Analysis
6. Size gradation

When weigh scales are not available, the material weight will be estimated based on the size of the processed material stockpiles, combined with measured density of the materials. In addition the relative humidity, temperature and pressure of the ambient conditions and baghouse exhaust will be measured to arrive at the moisture loss rate.

In addition to the testing described above, EERC will be performing advanced analytical testing, determination of cleaned fuel indices, and identifying the balance of plant impacts, as defined in Module 3. This work is performed to quantify the economic impact on the power plant from dry coal cleaning methods.

MODULE 2 WORK PLAN: UNIVERSITY OF KENTUCKY

EVALUATION OF A PNEUMATIC JIG FOR PRE-COMBUSTION CLEANING OF LOW RANK COALS

Rick Q. Honaker
Department of Mining Engineering, University of Kentucky, Lexington, Kentucky 40506-0107
Phone: (859) 257-1108; Fax: (859) 323-1962; e-mail: rhonaker@engr.uky.edu

Submitted to:

Richard Weinstein
Engineering Manager
The Falkirk Mining Company
Phone: (701) 250-2408

ABSTRACT

The extraction of coal typically results in the recovery of pure rock that ranges from small to very large quantities depending on seam thickness and other characteristics. The haulage, processing and storage of the rock represent significant energy inefficiency and have negative environmental consequences. Removal of the ash-bearing material would also provide significant benefits in combustion efficiency and post-combustion emissions. Dry processes are preferable but not commonly applied in the past due to associated process inefficiencies.

The proposed process will involve the development of a novel dry, density-based cleaning technology. Based on investigation, the novel separator has the potential to provide effective high-density separations for particle sizes up to 50 mm (2 inches). The density-based separation occurs on an aerated jigging bed whereby air fluidizes the particles and allows high density particles to migrate toward the bottom of the jigging bed. The unit provides a relatively high capacity per unit of floor space and, thus, can be mounted on a skid for easy transport at the mining operation.

The project goals are to evaluate and optimize the separation performance of the novel, dry cleaning technology for the cleaning of low rank coals. Tasks include 1) performance of a parametric test program to optimize operating conditions, 2) evaluation of the process efficiency, 3) evaluation of the unit at multiple coal producing operations and 6) performance of an economical feasibility and energy efficiency study.

STATEMENT OF PROJECT OBJECTIVES

Evaluation of a Pneumatic Jig for Pre-Combustion Cleaning of Low Rank Coals

A. OBJECTIVES

The goal of the proposed project is to significantly enhance the energy efficiency and utilization of low rank coal sources. The operating and physical parameters of the dry system will be optimized to provide an efficient density-based separation while maximizing energy recovery.

B. SCOPE OF WORK

A pilot-scale deshaling unit with a throughput capacity of 5 tons/hr will be installed at multiple coal mining sites. Researchers from the University of Kentucky will conduct a systematic parameter evaluation. After optimization of the system has been realized, efficiency studies will be performed in which samples will be subjected to washability analysis and the data used to develop partition curves on a particle size-by-size basis.

C. TASKS TO BE PERFORMED

TASK 1 PROJECT DEVELOPMENT

Immediately following the issuance of the award, a 'kick-off' meeting involving the entire project team will be held to organize the project tasks and outline the schedule associated with the two sites. If necessary, two meetings will be held to meet the logistical requirements of the coal companies.

Run-of-mine coal samples will be collected and evaluated on a particle size-by-size basis to determine the weight and impurity distributions as well as the cleanability as a function of particle density. This information will be used to determine crusher and screening requirements and the particle size fraction to feed the deshaling unit.

TASK 2 DESHALING SYSTEM INSTALLATION

The deshaling system will be transported and installed under the direction of the mining company and the assistance of the equipment manufacturer.

TASK 3 PARAMETER EVALUATION & OPTIMIZATION

The objective of this task is to optimize the operating parameters associated with the dry cleaning unit for the treatment of low rank coals. The major operating parameters of the deshaling unit are numerous and include those associated with feed properties such as particles size and density distributions and overall moisture. The moisture content of the feed coal will be monitored for each test and the climatic conditions recorded. The feed will be maintained at a specified top size of around 50 mm (2 inches).

To identify the critical operating parameter with respect to separation performance, a fractional factorial experimental design using 2 parameter value levels will be performed using parameter value ranges established by an initial exploratory test program. The exploratory program will involve random variations in the operating parameter values to determine the operable parameter value ranges. After establishing the parameter value ranges, the two-level test program will be performed. Samples of the feed, product and tailing streams will be collected and subjected to ash analysis. Separation performance response variables that will be monitored include mass yield, energy recovery, product ash content, and separation efficiency (energy recovery – ash-based material recovery).

Based on a statistical analysis of the fractional factorial test data, parameters providing a significant impact on separation performance will be identified and studied in more detail using a 3-level experimental program in which central values will be considered as well as the interactive effects of the significant parameters. A Box-Behnken design will be employed which will require about 46 tests if the number of significant parameters is reduced to five. The test results will be used to develop empirical models describing the performance response variables as a function of the operating parameter values and their associated interactions.

Using the empirical models and a non-linear optimization technique, the parameter values providing the maximum energy recovery over a range of product ash values will be identified. Additional tests will subsequently be performed to validate the optimum conditions. The total number of optimum separation performance conditions evaluated will be five.

TASK 4 PROCESS EFFICIENCY EVALUATION

This task will involve the collection of the data needed to generate efficiency values that characterize the overall performance of the dry deshaling process. The efficiency parameters will include organic efficiency, separation density, probable error value, quantity of low-density particle by-pass to the refuse stream and the quantity of high-density particle by-pass to the product stream. These values will be obtained for each of the five optimum test conditions identified in Task 3. In addition to the overall efficiency measurements, the efficiency on a particle size-by-size basis will also be assessed.

To determine the required efficiency data, the quantity of each density fraction reporting to the product and refuse stream will be measured under each of the optimum operating conditions. The data will be used to construct the partition curves from which the efficiency data will be obtained.

TASK 5 EVALUATION AT OTHER SITES

The objective of this task is to optimize the parameter values for the treatment of other low rank coal sources. Using parameter value ranges based on the findings from Phase I, a statistically designed test program will be performed in an effort to collect the data needed to develop the empirical models needed to describe the energy recovery and product ash content as a function of the operating variables. Similar to Task 3, the empirical models will be used along with a non-linear optimization method to identify sets of conditions that will provide a series of performances corresponding to maximum recovery values over a range of product ash contents.

Under the optimum conditions, optimization tests will be conducted to develop the partition curves from which the process efficiency data will be obtained.

TASK 6 ENERGY EFFICIENCY AND ECONOMIC FEASIBILITY

A thorough technical and economical study will quantify the benefits of coal cleaning for the low rank coal mining operations. The energy efficiency enhancement achieved from reduced amounts of material reporting to materials handling systems, the processing plant and the utilization facility will be quantified as part of this task. Reductions in the environmental impacts and health and safety benefits will also be addressed, but emphasis will be given to energy efficiency enhancements and economic benefits of coal cleaning.

D. DELIVERABLES

The periodic, topical and final reports shall be submitted in accordance with the contract requirements. Other deliverables will include:

1. Section in the final report describing the installation and integration of the cleaning system.

3. Task 3 Empirical models describing the separation performance variables (i.e., energy recovery, mass yield, and product ash content or ash rejection) as a function of the operating parameters for the western coal.

4. Task 3 Five sets of optimized parameters values that provide maximum energy recovery over a range of product ash values for the western coal.
5. Task 4 Five partition curves obtained under optimum operating conditions from the treatment of the western coal.

6. Task 4 Efficiency data (organic efficiency, separation density, probable error value, quantity of low-density particle by-pass to the refuse stream and the quantity of high-density particle by-pass to the product stream) achieved under optimum operating conditions when deshaling the low-rank coal.

7. Task 5 Empirical models describing the separation performance variables as a function of the

operating parameters for the other mine sites.

8. Task 4 & 5 Particle size-by-size separation performance data achieved under the optimum conditions.

9. Task 6. A feasibility study contained within the final report detailing the energy efficiency enhancements and the economical and environmental impacts of cleaning western coal by the novel dry cleaning technology.

3.5 KEY PERSONNEL (RESUMES IN ATTACHMENT 1)

Rick Q. Honaker will serve as a Co-Investigator. He is an Associate Professor of Mining Engineering at UK. He received his B.S., M.S., and Ph.D. degrees in Mining & Minerals Engineering from Virginia Tech. His research and teaching specialty is in the area of Coal and Mineral Processing. He has served as the Principal Investigator on projects with funding greater than $2.5 million in the areas of processing plant operations and optimization, gravity concentration, froth flotation, dewatering and other related areas. He has over 70 publications in journals and proceedings covering his research efforts. He is currently a member of the editorial board of three professional journals.

Susan Liu will perform the parametric and optimization studies as part of her Ph.D. studies at the University of Kentucky. The labor support cost for Ms. Liu will be covered by the Mining Engineering Foundation at the University of Kentucky. This cost-share contribution to the project is equivalent to about $26,500 annually. Ms. Liu has received her B.S. and M.S. degrees in Coal Processing from a Chinese Institute and has served as a researcher in Coal Preparation for the China Mining Institute.

Budget for Module 2 University of Kentucky

July 1, 2004 - June 31, 2005					
		Funding Agency		Univer of Kentucky	
	Monthly Rate	Units	Total	Units	Total
Senior Personnel					
Rick Honaker	$7,875.00	1.25	9,844		
Graduate Student 1	1,667	-	-	12.00	20,000
Technician	4,800	1	4,800		
Total Personnel Salaries		**2.25**	**14,644**	**12.00**	**20,000**
Fringe Benefits					
Retirement @ 10%			1,464		
FICA @ 7.65%			1,120		
Misc Fringe @ 3.0%			439		
Life/Health	432		972		
Grad Student Benefits	8.65%		-		1,730
Total Personnel Fringe			**3,996**		**1,730**
Total Personnel			**18,640**		**21,730**
Travel			7,500		
Total Travel			**7,500**		
Supplies			5,606		
Total Supplies			**5,606**		
Other Direct Costs					
Tuition					5425
Total Other Directs			**0**		
			13,106		
Total Direct Costs			**31,746**		**27,155**
Indirect Costs @26%			**8,254**		**5,650**
Total Costs			**40,000**		**32,805**

MODULE 3 WORK PLAN: ENERGY AND ENVIRONMENTAL RESEARCH CENTER

Remainder of this page is left empty

UND ENERGY & ENVIRONMENTAL RESEARCH CENTER
PROPOSAL RECORD AND INTERNAL SIGNATURE FORM

PROPOSAL NO.: 2004-0124

AGENCY OR RFP DUE DATE: ______

DATE SUBMITTED: 3-25-2004

TITLE: Lignite Fuel Enhancement: Balance of Plant Impacts

PROJECT MANAGER: Jason D. Laumb

AUTHOR AND KEY TECHNICAL CONTRIBUTORS: Steven A. Benson, Jason D. Laumb, Donald P. McCollor

CLIENT/ADDRESS: Mr. Richard Weinstein
Engineering Manager
Falkirk Mining Company
PO Box 1087
Underwood, ND 58576-1087
Phone: (701) 442-5751

PROPOSED EFFECT DATE: From: 8-1-2004 To: 8-31-2006

TOTAL FUNDS REQUESTED: $591,000 **INDIRECT COSTS REQUESTED**: $0

OPTIONS:

Does this project require a completed lobbying disclosure? __ Yes _X_ No (for Federal projects only)

Will the project involve a confidentiality agreement or proprietary information? __ Yes _X_ No

Does this proposal contain confidential information? __ Yes _X_ No

Is this proposal competitive?__ Yes __ No _X_ Unknown

SIGNATURES

Project Manager/Author	Date	Associate Director for Research	Date
Don Cox Budget Preparer	3-25-2004 Date	Technical Editor	Date
Proposal Manager	Date	Financial Review	Date
Gerald H. Groenewold, Director Energy & Environmental Research Center	Date	Dr. William D. Gosnold Jr., Interim Director Office of Research and Program Development	Date

March 25, 2004

Mr. Richard Weinstein
Engineering Manager
Falkirk Mining Company
PO Box 1087
Underwood, ND 58576-1087

Dear Richard:

Subject: EERC Proposal No. 2004-0124, “Lignite Fuel Enhancement: Balance of Plant Impacts”

I am pleased to provide you with a work plan and budget for the coal-cleaning project you requested. The work will be completed in approximately 1 year from receipt of a fully executed agreement with the Falkirk Mining Company. The total cost for the work described in the attached proposal is $909,230. This project would be a good candidate for partial funding under the Energy & Environmental Research Center’s (EERC’s) Jointly Sponsored Research Program with the U.S. Department of Energy (DOE). If the project were accepted, DOE would fund $318,230 of the project (35%). Once Falkirk Mining has accepted this proposal, a second proposal will then be sent to DOE. In the past, almost all projects submitted to DOE under this program have been accepted for funding. However, there is no guarantee that DOE will accept this project.

We are very interested in the opportunities that a coal-cleaning project such as this will provide for both power stations and mining companies. If you should need any further information, please contact me by phone at (701) 777-5114 or by e-mail at jlaumb@undeerc.org or by fax at (701) 777-5181. I look forward to working with you.

Sincerely,

Jason D. Laumb
Research Manager

JDL/drh

Enclosure

LIGNITE FUEL ENHANCEMENT: BALANCE OF PLANT IMPACTS

EERC Proposal No. 2004-0124

Submitted to:

Mr. Richard Weinstein

Engineering Manager
Falkirk Mining Company
PO Box 1087
Underwood, ND 58576-1087

Proposal Amount: $588,000

Submitted by:

Dr. Steven A. Benson
Jason D. Laumb
Dr. Donald P. McCollor

Energy & Environmental Research Center
University of North Dakota
Box 9018
Grand Forks, ND 58202-9018

Jason D. Laumb, Project Manager

Dr. William D. Gosnold Jr., Interim Director
Office of Research and Program Development

March 2004

TABLE OF CONTENTS

ContinuedY

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIGNITE FUEL ENHANCEMENT: BALANCE OF PLANT IMPACTS

ABSTRACT

The goal of the proposed project is to determine the impact a cleaned lignite fuel will have on power plant system performance and mercury emissions. Special attention will be given to fouling, slagging, grindability, and mercury reduction. To meet the goals of this project, the following objectives must be met: 1) implement Energy & Environmental Research Center (EERC) advanced analytical techniques on coal samples, 2) determine indices for cleaned fuels, and 3) identify possible plant impact from cleaned fuels.

The deliverables from this project include the impact coal cleaning will have on power plant system performance. In addition, a database including all of the sample analysis and operating data from the air jig will be provided. The duration of the project is approximately 13 months. The total project cost is $909,230. Falkirk Mining Company would provide funding in the amount of $591,000, and $318,230 would come from the EERC–U.S. Department of Energy Jointly Sponsored Research Program.

LIGNITE FUEL ENHANCEMENT: BALANCE OF PLANT IMPACTS

PROJECT SUMMARY

Lignitic coals have unique properties that provide advantages and challenges during utilization. A major challenge is the highly variable ash content. The components that make up the ash consist of mineral grains and organic elements. The primary components that contribute to the high variability in that ash content are the minerals. The minerals consist mainly of quartz, clay minerals, sulfides (pyrite), carbonates, and sulfates. The components that contribute negatively to power plant efficiency and raise environmental issues are the sulfides. The sulfide minerals, including pyrite and others, contain sulfur and trace elements such as mercury that can be emitted from the air pollution control system. In addition, pyrite also contributes to waterwall slagging. The other minerals like quartz and clay contribute to ash-related problems such as erosion, wall slagging, and convective pass fouling. Physical cleaning is one way to decrease the mineral component of the ash, thereby decreasing variability and minimizing some of the negative properties associated with lignite fuels. Further, physical cleaning will allow power plants to burn some coals that are currently being rejected at the mine. As a result, the amount of coal that can be used from a mine will be increased. Additionally the power plant will receive a higher-grade fuel with reduced ash, sulfur, and mercury contents.

The use of lignitic coal is generally in regions with limited water supplies, making cleaning by dry processing (air jigging) the only practical processing method. Air jigging is also more suitable for coal cleaning in cold climates over water-based cleaning methods.

The operating principle of the air jig is the use of air to stratify a moving bed of feed coal, resulting in the desired lower-density product atop the denser high-ash content refuse. This is then separated at the end of the moving bed, producing a stream of cleaned coal product along with a waste stream of concentrated ash. The fluidizing air moving through the bed entrains fine particles, which are collected in a cyclone and baghouse. This fine material can be subsequently subjected to magnetic separation to produce a third and fourth product stream of cleaned coal fines and concentrated ash fines, respectively.

This project will determine the potential of the air jig to remove the mineral components in the coal and will also assess the positive and negative aspects of coal cleaning on the power plant thermal and environmental performance. Based on past experience, the net effect of a cleaned coal will be a lower-ash, higher-energy fuel. However, the balance of plant effects need to be determined. Removing some of the ash components may concentrate other elements that have an adverse effect on the operation of the plant. The purpose of the proposed project is to provide an assessment of the impacts a cleaned fuel may have on power plant system performance. The project tasks include purchasing an air jig; advanced analysis of fuels and data collection; determination of plant impacts and Hg removal; and reporting.

The project team consists of Falkirk Mining Company and the University of North Dakota Energy & Environmental Research Center (EERC). We propose that funding for the project come from the EERC–U.S. Department of Energy (DOE) Jointly Sponsored Research Program (JSRP) and Falkirk Mining Company.

PROJECT DESCRIPTION

GOAL

The goal of the proposed project is to determine the impact a cleaned lignite fuel will have on power plant system performance. Special attention will be given to fouling, slagging, grindability, waste coal disposal issues, and trace element reduction, specifically, Hg.

OBJECTIVES

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

1. Implement EERC advanced analytical techniques on coal samples.

2. Determine indices for cleaned fuels.

3. Identify possible plant impact from cleaned fuels.

4. Identify potential problems associated with waste coal disposal

WORK PLAN

TASK 1 – PURCHASE AIR JIG

The 5-ton/hr air jig to be used in the project will be purchased by the EERC from Allminerals, LLC. The associated automated sampling equipment and a 10-ton/hr crusher will also be purchased from Allmineral for the project. The equipment will be ready for installation at the Falkirk site in August 2004.

TASK 2 – ADVANCED ANALYSIS OF FUELS AND DATA COLLECTION

The EERC will perform computer-controlled scanning electron microscopy (CCSEM), chemical fractionation, and high-temperature viscosity measurement on weekly composites (eight per site) of the cleaned fuel for use in the following tasks. Additionally, the EERC will provide coal mercury numbers for five weekly composite samples (40 per site). This will provide an independent verification of the mercury level in the coal.

Additionally, the EERC will construct a database that will contain all of the analytical measurements performed during the study. This will include all analysis performed by the EERC and the Coal Creek laboratory.

TASK 3 – DETERMINATION OF PLANT IMPACTS AND HG REMOVAL

The data gathered in Task 2 will be used to perform modeling calculations with the Predictive Coal Quality Effects Screening Tool (PCQUEST^{K}), the Facility for the Analysis of Chemical Thermodynamics (FACT), and Vista. The PCQUEST program provides a suite of indices ranging from 0 to 100 (100 being severe), including low-temperature fouling, high-temperature fouling, slagging, slag tapping, stack-plume opacity, boiler erosion, coal grindability, and sootblowing effectiveness. The Vista program will provide the total economic impact the cleaned coal will have on the power station.

In addition, calculations will be performed with FACT. The FACT code is another computer-based model that is used for assessing fuel quality effects on ash behavior in a boiler. FACT is a thermodynamic equilibrium model that predicts molar fractions (partial pressures) of all gas, liquid, and solid stable components in a system by using principles of Gibbs free energy minimization. Output from FACT includes quantities, compositions, and viscosities of liquid and solid mineral phases; therefore, the code works well for predicting the behavior of fuel ash, including biomass-derived ash for different boiler temperature regimes.

Six coals or blends of coals and one boiler configuration will be chosen from the PCQUEST and FACT calculations for modeling with the Vista program at Black & Veatch. The boiler chosen for the study is Great River Energy's Coal Creek Station. The modeling results will provide the economic impact that the cleaned coal will have on the generation facility. The results of this modeling will be summarized in the final report.

The amount of Hg removed from the coal will also be determined. The coal Hg data collected by the Coal Creek laboratory and the independent analysis conducted by the EERC will both be used to perform mass balances around the air jig to determine the amount of mercury removed by the unit. In addition to the mercury removal, the spoil pile from the air jig will be assessed for adverse environmental impacts. This part of the project will involve leaching studies to assess acid mine drainage and review of the environmental regulations to ensure the material can be deposited back in the mine.

TASK 4 – REPORTING

Quarterly reports containing accomplishments from the previous quarter will be provided, and a final report will encompass the entire project.

DELIVERABLES

The deliverables from this project include the impact coal cleaning will have on power plant system performance. In addition, a database including all of the sample analysis and operating data from the air jig will be provided. The deliverables will be provided in the form of a final report.

STANDARDS OF SUCCESS

The standards by which the success of the project will be measured will include the ability of the technology to produce a high-grade lignite fuel that has the added benefits of reduced emissions of mercury, particulate matter, and sulfur. The fuel must also have positive benefits from a fouling and slagging perspective.

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

BACKGROUND

In the past, incentives to upgrade lignites were small. However, because of the potential for increased environmental regulations for SO_x, NO_x, particulate matter, and mercury, upgrading lignites must be considered. Lignites present challenges due to their unique chemical and physical properties, which include high moisture content, complex associations of ash-forming components, high reactivity, and high oxygen content. In lignite, the inorganic or ash-forming components are associated with the organic structure and discrete mineral grains in the coal. The inorganic components associated with the organic structure can constitute up to 50% of the inorganic content of the coal. The organically associated elements will not be removed by physical cleaning techniques. The discrete mineral impurities are the components that will be removed by cleaning, however, many of the discrete minerals are finely dispersed within the coal matrix and difficult to remove. Thus common coal cleaning using the air jig technology will have little benefit for lignites whose inorganic components are in the form of small minerals or are largely associated with the organic matrix. The application of the technology is best suited for those lignites that have higher inorganic content in the form of larger minerals. Many lignite coals contain higher levels of ash associated as removable mineral grains. Currently, many lignite mines reject this easy-to-clean fuel because of its high ash content.

In the past, cleaning technologies have met with limited success because of the already high moisture content of lignite and because using wet cleaning processes increases the amount of surface moisture, reducing the calorific value. The cleaning technology would also reduce sulfur levels in the coal by a third to a half. The air jig would remove the pyritic sulfur.

Lignites are highly reactive and will slack upon prolonged exposure to air; therefore, lignite will need to be run through the air jig as soon as possible after mining. Lignites that have been exposed to cleaning and drying processes may also spontaneously ignite, so the cleaned lignite should be fired in the boiler as soon as possible after cleaning.

It is conceivable that not all the coal from a given lignite mine needs to be cleaned. Cleaning should be focused on high-ash- and sulfur-containing coals, as well as coal mined from areas where significant mineral parting exists. Another consideration is the production of fines, which can have the potential to result in significant energy losses. The air jig system should include a fine-coal circuit designed to clean and recover the fines.

An extensive survey of the sulfur reduction potential of 455 coal samples was conducted (1). Of the 455 samples, 44 were lignite or subbituminous coals. Figure 1 shows averaged data on ash and sulfur reduction as a function of crushing for the 44 samples of lignite and subbituminous coals. The data from the coals show that some coals are better candidates for cleaning than others. The coals that were good candidates had higher ash contents.

Cleaning technologies also have the potential to remove potentially toxic trace elements from the coal. Figure 2 shows the removal of various trace elements considered toxic from a wide range of coals (2). The results indicate the potential to remove significant portions of trace elements from coals.

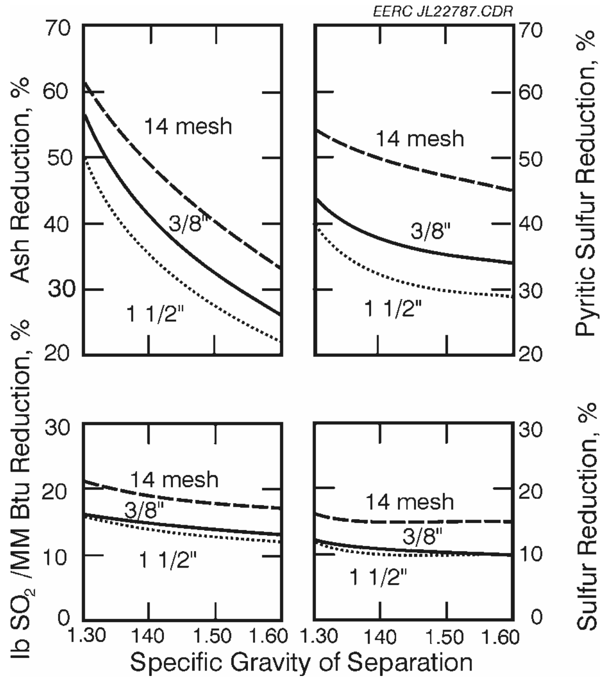


Figure 1. Average % reductions in sulfur and ash as a function of crushing severity for 44 lignite and subbituminous coals.

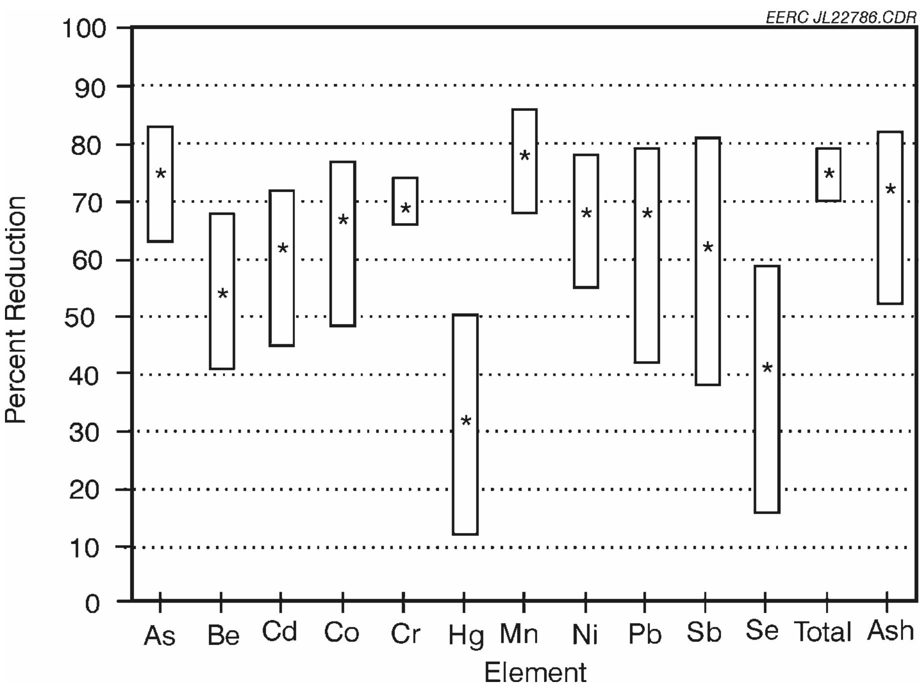


Figure 2. Removal of trace elements using commercial coal-cleaning technologies.

ASH DEPOSITION – SLAGGING AND FOULING

Coal cleaning, primarily using wet separation methods, is commonly performed at a commercial scale on high-Btu content eastern bituminous coals. Little or no large-scale coal cleaning is performed on Powder River Basin subbituminous coals or lignites, so the effects of cleaning on ash-related issues have not been determined for full-scale utility boilers.

The effects of coal cleaning on the performance of lignite coals have been studied by Durant et al. (3) and by Borio et al. (4) in a pilot-scale combustion test facility. The first study included four Texas lignites (Big Brown, Sabine, South Hallsville, and Pirkey). Three eastern bituminous coals were also included in the second study. Coal cleaning was performed using wet separation methods, and the fireside performance of the cleaned coals compared with that of run-of-mine coal.

Fuel and ash analyses indicated an overall 10% increase in the heating value of the cleaned lignite coals. There was a substantial reduction in ash content in the range of 25% to 50%, along with a small reduction in sulfur content due to the removal of pyrite. Cleaning removed primarily extraneous silica and clay particles in the reduction in the alumina and silica content of the ash. Organically bound alkali and alkaline-earth elements such as sodium and calcium and fine clays were not removed by the cleaning process, nor was organic sulfur. The ash composition thus showed a relative enrichment of iron, calcium, sodium, and magnesium.

Common coal performance indices based on coal and ash composition indicated that the reduction in ash content and abrasive ash components would significantly reduce wear and erosion of equipment and surfaces. There was no predicted decrease in slagging and fouling potential due to the cleaning; however, this prediction was not necessarily supported by the experimental combustion test results.

Experimental testing included assessment of pulverizer power consumption and wear rates, ash slagging and fouling potential, effect of deposition on heat transfer, fly ash erosion rates, and resulting emissions.

Pulverizer performance improved because of reduced power requirements per Btu processed as a result of the higher heating value of the cleaned coal. Furnace slagging deposits were usually thinner and more sintered, with a higher thermal conductivity than the run-of-mine deposits. The rate of deposit buildup and friability of convective pass deposits decreased for the clean coal, reducing the necessity for convective pass sootblowing by 30%–50%. Tube-to-deposit bonding strength decreased for three of the cleaned lignites but increased for the fourth, which was attributed to the relative increase in organically bound sodium in the latter. Tube erosion was significantly reduced by the cleaning process. Sulfur emissions were reduced commensurately with the amount of pyrite removed in the cleaning process. Although increased resistivity due to the higher alkali content and the smaller fly ash particle sizes would normally degrade electrostatic precipitator performance, this was found to be offset by the lower fly ash loading of the cleaned coal.

In summary, cleaning of lignite coals was found to provide advantages in terms of improved mill performance; decreased wear and erosion; reduced slagging and deposition, which were more easily removed; and some decrease in sulfur and particulate emissions. It was noted that the effects of cleaning, particularly on fouling and slagging behavior, were not well-predicted by conventional performance indices, and the effects and economic benefits of coal cleaning should be approached on a coal-by-coal basis.

Fireside ash deposition in utility boiler firing is dependent on fuel composition, boiler design, and operating conditions. Ash deposition on heat-transfer surfaces has been examined for many years and has resulted in voluminous literature on the subject. The general consensus of this work indicates that understanding the chemical and physical processes is necessary to predict and minimize ash deposition problems in utility boilers. Many of these processes have been formulated into computer codes. For example, computer codes exist to predict the particle-size and composition distribution of the ash produced upon combustion and simplified transport deposition and deposit growth for specific locations in the boiler.

The advances over the past several years in predicting ash behavior have been made possible as a result of more detailed and better analysis of coal and ash materials. These advanced techniques, such as CCSEM (5), are able to quantitatively determine the chemical and physical characteristics of the inorganic components in coal and ash (fly ash and deposits) on a microscopic scale. Many of the mechanisms of ash formation, ash deposition, and ash collection in combustion systems are more clearly understood as a result of these new data. This understanding has led to the development of better methods of prediction that include advanced indices.

Traditional indices such as the base-to-acid ratio, the slagging factor Rs, and fouling factor Rf, as described by Winegartner (6), are admittedly designed for selected groups of coal. Newer techniques such as CCSEM can now provide sound mineralogical data that go beyond the conventional bulk elemental oxide, moisture, and carbon measurements. This more detailed analysis has allowed for better characterization of the components within coal that can cause adverse operational effects such as tube erosion, furnace wall slagging, and tube fouling (7). Based on these more detailed analyses, a series of predictive indices has been developed by the EERC that predicts fireside performance in coal-fired utility boilers more reliably than traditional indices. These predictive indices are part of PCQUEST (8, 9).

Eight empirical indices are computed by PCQUEST, including low-temperature fouling, high-temperature fouling, slagging, slag tapping, stack-plume opacity, boiler erosion, coal grindability, and sootblowing effectiveness. The eight indices are expressed numerically as whole numbers ranging from 0 to 100. A greater value corresponds to an increase in severity or adverse effect for a given index. Input to PCQUEST consists of mineral and organically bound mineral and inorganic quantities as provided by CCSEM (5) and chemical fractionation (10) methods, respectively. Standard ASTM proximate, ultimate, and coal ash chemical analysis methods are also used to generate conventional coal characterization data as model input. Boiler specifications and operating conditions, such as the combustion system (conventional or low-NO_x), design fuel specifications, current operating load, and furnace dimensions are also used as input into PCQUEST. The indices were developed using knowledge of inorganic transformations, entrained ash formation, and ash deposition (11). Formulation and verification of the indices were accomplished using bench-, pilot-, and full-scale data to derive correlations between key inorganic constituents of the coal and their associations in the coal as they relate to combustion performance, such as the occurrence of main furnace slagging and convective pass fouling in utility boilers. The accuracy of these indices has been demonstrated through their repeated use by several utilities.

ADVANCED ANALYTICAL TECHNIQUES

CHEMICAL FRACTIONATION

Chemical fractionation is used to quantitatively determine the modes of occurrence of the inorganic elements in coal, based on the extractability of the elements in solutions of water, 1 molar ammonium acetate, and 1 molar hydrochloric acid (HCl). This type of analysis is especially important for low-rank coals or biomass fuels, which can have significant quantities of organically bound elements that are ionically dispersed within the organic matrix of the fuel and are essentially invisible to scanning electron microscopy (SEM) and mineralogical techniques. The flow diagram shown in Figure 3 illustrates the technique. A 75-g sample of !325-mesh vacuum-dried coal is stirred with 160 mL of deionized water to extract water-soluble minerals such as sodium chloride. After being stirred for 24 hours at room temperature, the water–coal mixture is filtered. The filtered coal is dried, and a portion is removed to be tested by x-ray fluorescence (XRF) to determine the percentage of each element remaining. The residues are then mixed with 160 mL of 1 molar ammonium acetate (NH_4OAc) and stirred at 70°C for 24 hours to extract the elements associated with the coal as ion-exchangeable cations present primarily as the salts of organic acids. The ammonium acetate extractions are performed two more times to effect complete removal of the ion-exchangeable cations. After the third ammonium acetate extraction, a sample of the dried residue is analyzed by XRF. The remaining

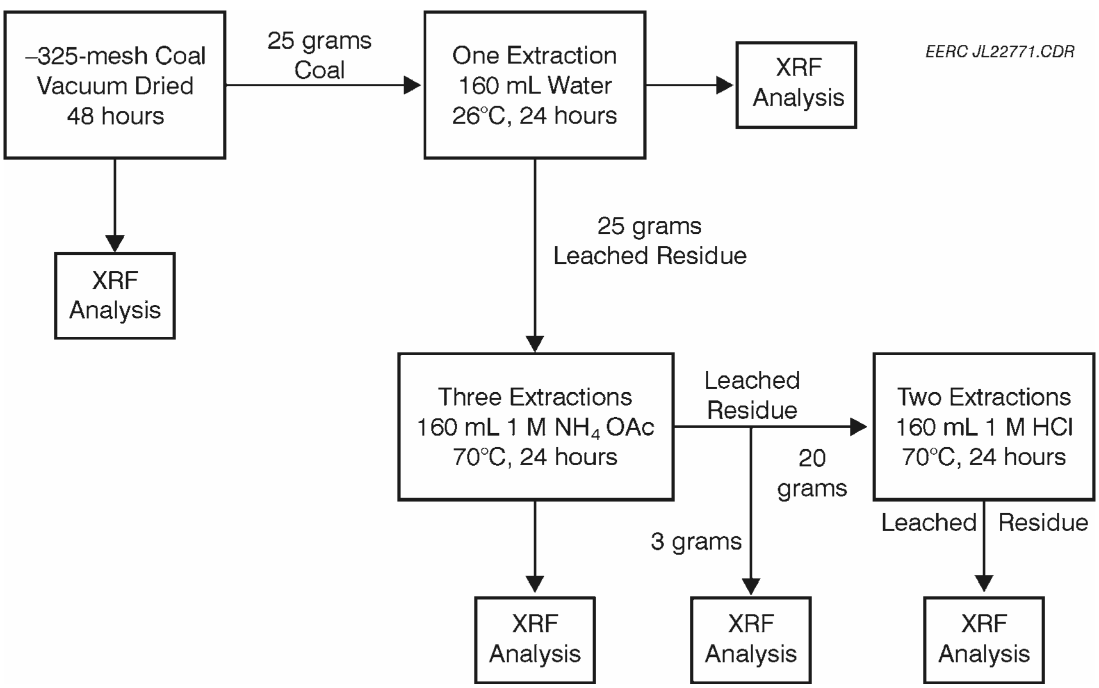


Figure 3. Flowchart of the EERC chemical fractionation procedure.

residue of the ammonium acetate extractions is then stirred with 1 molar HCl at 70°C for 24 hours to remove the elements held in coordination complexes within the organic structure of the coal, as well as acid-soluble minerals such as carbonates, oxides, and sulfates. The residue is then analyzed by XRF. The HCl extraction is repeated once.

The elements remaining in the coal after the chemical fractionation extractions are determined by difference. The nonextractable elements are associated in the coal as silicates, aluminosilicates, sulfides, and insoluble oxides.

CCSEM Analysis

Size and composition of mineral grains in coal can be determined by CCSEM, a program used in conjunction with an SEM and microprobe system and some sort of mineral characterization program. The Noran Voyager system, which is used at the EERC and many other institutions, is used to characterize inorganic components in samples of coal, char, and inorganic combustion products. The CCSEM system uses a computer to control the operation of the SEM in order to determine the size, quantity, distribution, and association of coal and mineral grains and other particulate matter. The CCSEM analysis system uses an annular backscattered electron detector to locate and size the particles. The backscattered electron detector distinguishes compounds based on the atomic number of their elements. Therefore, particles such as mineral grains appear brighter than the coal or epoxy matrix in which they are mounted. This allows the electron beam to detect the particles by noting contrast differences.

When a particle is detected, the area of the particle is measured by the electron beam rastering across micron square pixels that fill the entire area of the particle being analyzed. Mathematical algorithms and geometric expressions are used to determine the perimeter, area, and shape factor of the particle, and then an energy-dispersive spectra (EDS) analysis is taken at the near-center location of the particle or across a rastered area. The CCSEM analysis for the coal samples is performed at three different magnifications for statistical purposes, and the total mineral matter in the sample is formulated as a composite analysis. Information on particles less than 1 µm in average diameter is not generally very reliable, since 1 µm is the lower limit for the EDS analysis. The electron beam excites electrons within the different elements of the particle being analyzed, and the resulting EDS is taken for 2 seconds. Energy photon counts are accumulated for each element present and normalized to 100%. The CCSEM system analyzes for Na, Mg, Al, Si, P, S, Cl, K, Ca, Fe, Ba, and Ti. All information obtained by the CCSEM program is automatically stored in a microcomputer print file. These data are imported into files that are massaged using a mineral classification program to group the different mineral or inorganic phases according to molar ratios that correspond best with known mineral or amorphous species. Size distributions are also tabulated.

QUALIFICATIONS

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

Principal Investigator

Dr. Steven A. Benson, Senior Research Manager at the EERC, will serve as Principal Investigator for the project. Dr. Benson received a Ph.D. in Fuel Science, Materials Science, and Engineering from the Pennsylvania State University in 1987 and a B.S. in Chemistry from Minnesota State University, Moorhead, in 1977. Dr. Benson's principal areas of expertise include the management of complex multidisciplinary programs focused on solving energy production and environmental problems. Program areas include the development of 1) methodologies to minimize the effects of inorganic components on the performance of combustion/gasification and air pollution control systems, 2) methodologies to determine the fate and behavior of air toxic substances in combustion and gasification systems, 3) advanced analytical techniques to determine the chemical and physical transformations of inorganic species in combustion gases, 4) computer-based codes to predict the effects of coal quality on system performance, 5) advanced materials for coal-based power systems, and 6) training programs designed to improve the global quality of life through energy and environmental research activities.

Coprincipal Investigator

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

OTHER ASSIGNED PERSONNEL

Dr. McCollor is currently a Research Scientist in Conversion Systems at the EERC. Dr. McCollor received a Ph.D. in Physical Chemistry from the University of North Dakota in 1981 and a B.A. in Chemistry from the University of Minnesota, Morris, in 1974.

Prior to his position at the EERC, Dr. McCollor held an Association of Western Universities Postdoctoral Fellowship and was subsequently employed as a Research Chemist at the DOE Grand Forks Energy Technology Center.

Dr. McCollor's principal areas of interest and expertise include coal combustion kinetics and inorganic transformation and deposition processes. He has over 20 years experience in the collection, analysis, and interpretation of data from bench-, pilot-, and full-scale combustion systems as well as in the development of predictive models to assess combustion and ash deposition behavior.

Dr. McCollor is a member of the American Chemical Society, the American Crystallographic Association, the Combustion Institute, and the North Dakota Academy of Science and has authored or coauthored numerous presentations and publications related to combustion and ash deposition.

The work will be conducted at the three mine sites mentioned in the work plan and at the EERC. A short description of the EERC facilities is provided below.

EERC

The EERC is one of the world's major energy and environmental research organizations. Since its founding in 1949, the EERC has conducted research, testing, and evaluation of fuels, combustion and gasification technologies, emission control technologies, ash use and disposal, analytical methods, groundwater, waste-to-energy systems, and advanced environmental control systems. Today's energy and environmental research needs typically require the expertise of a total-systems team that can focus on technical details while retaining a broad perspective.

VALUE TO NORTH DAKOTA

If the proposed project is successful, the value to North Dakota will be measured by increased use of lignite, new jobs created at coal-cleaning facilities, and a cleaner environment with the reduction of mercury, particulate matter, and sulfur. This technology will also allow for the use of lignite reserves that were once thought to be unusable because of high ash content, thereby increasing the usable lignite in the state of North Dakota.

MANAGEMENT

The overall project manager will be Mr. Jason Laumb. Dr. Steven Benson will act as a project advisor. Dr. Don McCollor will be responsible for the modeling calculations and sample submissions. All key personnel will be responsible for interpretation of results and writing reports.

Once the project is initiated, monthly or as-needed conference calls will be held with project sponsors and team members to review project status. Quarterly reports will be prepared and submitted to project sponsors for review. Two detailed project review meetings will be held at the EERC during the course of the project. The timing of these meetings will coordinate with key project milestones. A meeting at the end of the project will be held to review the findings and discuss directions for future work.

TIMETABLE

The proposed schedule for the project is shown in Figure 4.

BUDGET

We propose that the funding for the project come from the EERC–DOE JSRP and Falkirk Mining Company. The total project cost is $909,230 ($591,000 Falkirk Mining Company, $318,230 EERC–DOE JSRP). The costs of the project include analytical measurements,

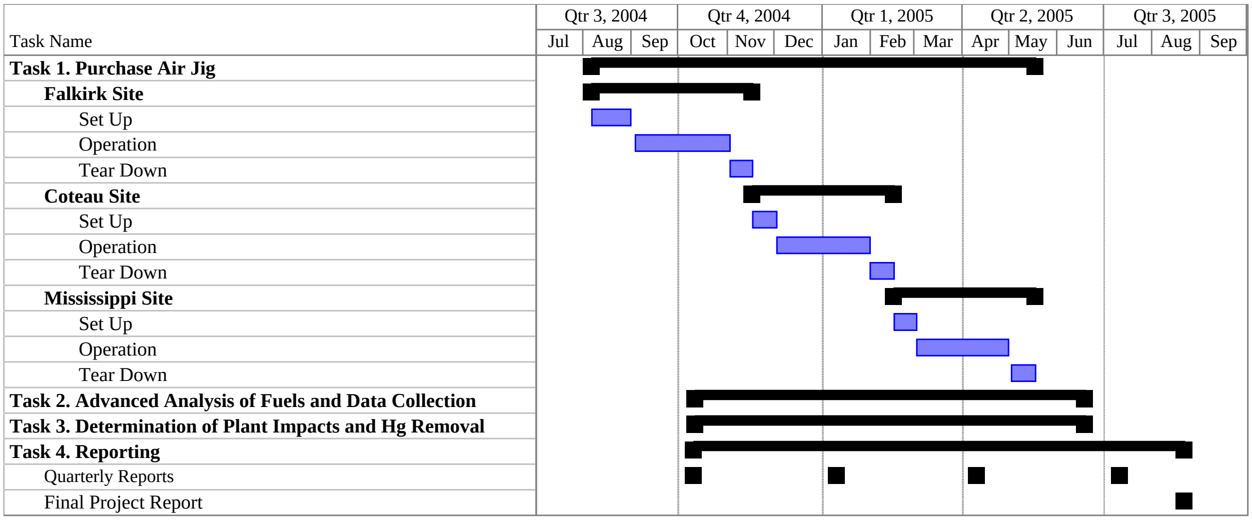


Figure 4. Schedule for Lignite Fuel Enhancement: Balance of Plant Impacts.

technical interpretation time, and labor to operate the air jig. Please refer to the budget and budget notes for details.

The EERC is requesting the Falkirk Mining Company to commit $591,000 of funding for this project. Once we have Falkirk Mining Company's commitment, we will submit the proposal to DOE, requesting approval of its share of the funding.

Three items are required from Falkirk Mining Company for inclusion in our proposal to DOE:

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

MATCHING FUNDS

It is anticipated that the funding provided by the Falkirk Mining Company will be matched at approximately 35% with funding from the EERC–DOE JSRP.

TAX LIABILITY

None.

CONFIDENTIAL INFORMATION

No confidential material.

REFERENCES

1. Cavallaro, J.S.; Johnston, M.T.; Dearbrouck, A.W. *Sulfur Reduction Potential of the Coals of the United States*; Bureau of Mines R.I. 8118, 1976.
2. DeVito, M.S.; Rosendale, L.W.; Conrad, V.B. Comparison of Trace Element Contents of Raw and Commercially Cleaned Coals. *Fuel Process. Technol.*, **1994**, *39*, 87–106.

3. Durant, J.F.; Borio, R.W.; Griffith, B.F.; Levasseur, A.A. The Effect of Coal Cleaning on Boiler Performance. Presented at the 15th Biennial Low-Rank Fuels Symposium, St. Paul, MN, May 22–25, 1989.

4. Borio, R.W.; Durant, J.F.; Levasseur, A.A.; Miemiec, L.S. Utilization of Clean Coals: Consequences on Boiler Performance and Economics. Presented at the Joint Power Generation Conference/ASME Fact Division, Dallas, TX, October 22–26, 1989.

5. Weisbecker, T.; Zygarlicke, C.J.; Jones, M.L. Correlation of Inorganic Components in U.S. Powder River Basin Coals to Full-Scale Performance. In *Proceedings of the Engineering Foundation Conference on Inorganic Transformations and Ash Deposition During Combustion*, Palm Coast, FL, March 10–15, 1991.

6. Winegartner, E.C. Coal Fouling and Slagging Parameters. Prepared by the American Society of Mechanical Engineers Research Committee on Corrosion and Deposits from Combustion Gases, ASME, 1974, 34 p.

7. Karner, F.R.; Zygarlicke, C.J.; Brekke, D.W.; Steadman, E.N.; Benson, S.A. New Analysis Techniques Help Control Boiler Fouling. *Power Eng.* **1994**, *98*, 35–38.

8. Erickson, T.A.; O'Leary, E.M.; Folkedahl, B.C.; Ramanathan, M.; Zygarlicke, C.J.; Steadman, E.N.; Hurley, J.P.; Benson, S.A. Coal Ash Behavior and Management Tools. In *The Impact of Ash Deposition on Coal-Fired Plants*; Taylor and Francis Publishing Company, 1994; pp 271–284.

9. Benson, S.A.; Hurley, J.P.; Zygarlicke, C.J.; Steadman, E.N.; Erickson, T.A. Predicting Ash Behavior in Utility Boilers. *Energy Fuels* **1993**, *7*, 746–754.

10. Zygarlicke, C.J.; Benson, S.A.; Borio, R.W. Pilot- and Bench-Scale Combustion Testing of a Wyoming Subbituminous/Oklahoma Bituminous Coal Blend. In *Coal-Blending and Switching of Low-Sulfur Western Fuels*; Bryers, R.W., Harding, N.S., Eds.; American Society of Mechanical Engineers: New York; 1994, pp 281–300.

11. Benson, S.A.; Jones, M.L.; Harb, J.N. Ash Formation and Deposition. In *Fundamentals of Coal Combustion for Clean and Efficient Use*; Smoot, L.D., Ed.; Elsevier: New York, 1993; pp 299–374.

BUDGET

SUMMARY BUDGET

LIGNITE FUEL ENHANCEMENT
FALKIRK MINING COMPANY
PROPOSED START DATE: MAY 1, 2004
EERC PROPOSAL #2004-0124

CATEGORY		TOTAL HRS	TOTAL $COST	FALKIRK MINING SHARE HRS	FALKIRK MINING SHARE $COST	EERC JSRP SHARE HRS	EERC JSRP SHARE $COST
TOTAL DIRECT LABOR		2,320	$ 70,368	-	$ -	2,320	$ 70,368
FRINGE BENEFITS - % OF DIRECT LABOR	53%		$ 37,295		$ -		$ 37,295
TOTAL LABOR			$ 107,663		$ -		$ 107,663
OTHER DIRECT COSTS							
TRAVEL			$ 2,999		$ -		$ 2,999
COMMUNICATION - PHONES & POSTAGE			$ 275		$ -		$ 275
DATA PROCESSING - SOFTWARE			$ -		$ -		$ -
OFFICE (PROJECT SPECIFIC SUPPLIES)			$ 550		$ -		$ 550
REPAIRS			$ -		$ -		$ -
SUPPLIES			$ 169		$ -		$ 169
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)			$ -		$ -		$ -
EQUIPMENT > $5000			$ 630,000		$ 591,000		$ 39,000
FEES			$ 77,396		$ -		$ 77,396
TOTAL OTHER DIRECT COST			$ 711,389		$ 591,000		$ 120,389
TOTAL DIRECT COST			$ 819,052		$ 591,000		$ 228,052
FACILITIES & ADMIN. RATE - % OF MTDC		VAR	$ 90,178	56%	$ -	47.7%	$ 90,178
TOTAL ESTIMATED COST			$ 909,230		$ 591,000		$ 318,230

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

k:\TJV\prop04\jl_falkirk.xls 3/25/2004 1:48 PM

DETAILED BUDGET

LIGNITE FUEL ENHANCEMENT
FALKIRK MINING COMPANY
PROPOSED START DATE: MAY 1, 2004
EERC PROPOSAL #2004-0124

			TOTAL		FALKIRK MINING SHARE		EERC JSRP SHARE	
LABOR	**LABOR CATEGORY**	**HOURLY RATE**	**HRS**	**$COST**	**HRS**	**$COST**	**HRS**	**$COST**
LAUMB, J.	PROJECT MANAGER	$ 29.47	400	$ 11,788	-	$ -	400	$ 11,788
BENSON, S.	PRINCIPAL INVESTIGATOR	$ 51.14	150	$ 7,671	-	$ -	150	$ 7,671
MCCOLLOR, D.	RESEARCH SCIENTIST/ENGINEER	$ 32.20	400	$ 12,880	-	$ -	400	$ 12,880
--------------	SENIOR MANAGEMENT	$ 50.49	75	$ 3,787	-	$ -	75	$ 3,787
--------------	RESEARCH SCIENTIST/ENGINEER	$ 28.30	671	$ 18,989	-	$ -	671	$ 18,989
--------------	RESEARCH TECHNICIAN	$ 19.15	464	$ 8,886	-	$ -	464	$ 8,886
--------------	TECHNICAL SUPPORT SERVICES	$ 14.90	160	$ 2,384	-	$ -	160	$ 2,384
			2,320	$ 66,385	-	$ -	2,320	$ 66,385
ESCALATION ABOVE CURRENT BASE		6%		$ 3,983		$ -		$ 3,983
TOTAL DIRECT LABOR				$ 70,368		$ -		$ 70,368
FRINGE BENEFITS - % OF DIRECT LABOR		53%		$ 37,295		$ -		$ 37,295
TOTAL LABOR				$ 107,663		$ -		$ 107,663
OTHER DIRECT COSTS								
TRAVEL				$ 2,999		$ -		$ 2,999
COMMUNICATION - PHONES & POSTAGE				$ 275		$ -		$ 275
DATA PROCESSING - SOFTWARE				$ -		$ -		$ -
OFFICE (PROJECT SPECIFIC SUPPLIES)				$ 550		$ -		$ 550
REPAIRS				$ -		$ -		$ -
SUPPLIES				$ 169		$ -		$ 169
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)				$ -		$ -		$ -
EQUIPMENT > $5000				$ 630,000		$ 591,000		$ 39,000
NATURAL MATERIALS ANALYTICAL RES. LAB.				$ 28,103		$ -		$ 28,103
FUELS & MATERIALS RESEARCH LAB.				$ 19,962		$ -		$ 19,962
ANALYTICAL RESEARCH LAB.				$ 7,886		$ -		$ 7,886
GRAPHICS SUPPORT				$ 445		$ -		$ 445
SUBCONTRACT - BLACK & VEATCH				$ 21,000		$ -		$ 21,000
TOTAL OTHER DIRECT COST				$ 711,389		$ 591,000		$ 120,389
TOTAL DIRECT COST				$ 819,052		$ 591,000		$ 228,052
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 90,178	56%	$ -	47.7%	$ 90,178
TOTAL ESTIMATED COST				$ 909,230		$ 591,000		$ 318,230

k:\TJV\prop04\jl_falkirk.xls 3/25/2004 1:48 PM

LIGNITE FUEL ENHANCEMENT
EERC PROPOSAL #2004-0124

DETAILED BUDGET - FEES

NATURAL MATERIALS ANALYTICAL RES. LAB.	RATE	#	TOTAL $COST
CCSEM	$498	16	$ 7,968
CHEMICAL FRACT.	$1,159	16	$ 18,544
SUBTOTAL			$ 26,512
ESCALATION		6%	$ 1,591
TOTAL NATURAL MATERIALS ANALYTICAL RES. LAB.			$ 28,103

FUELS & MATERIALS RESEARCH LAB.	RATE	#	$COST
ASH VISCOSITY	$1,177	16	$ 18,832
SUBTOTAL			$ 18,832
ESCALATION		6%	$ 1,130
TOTAL FUELS & MATERIALS RESEARCH LAB.			$ 19,962

ANALYTICAL RESEARCH LAB.	RATE	#	$COST
ACID EXTRACTABLE MERC	$24	120	$ 2,880
CVAA	$29	120	$ 3,480
FILTERING	$9	120	$ 1,080
SUBTOTAL			$ 7,440
ESCALATION		6%	$ 446
TOTAL ANALYTICAL RESEARCH LAB.			$ 7,886

GRAPHICS SUPPORT	RATE	#	$COST
GRAPHICS (HOURLY)	$42	10	$ 420
SUBTOTAL			$ 420
ESCALATION		6%	$ 25
TOTAL GRAPHICS SUPPORT			$ 445

k:\TJV\prop04\jl_falkirk.xls 3/25/2004 1:48 PM

LIGNITE FUEL ENHANCEMENT
EERC PROPOSAL #2004-0124

DETAILED BUDGET - TRAVEL

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES					
DESTINATION	AIRFARE	LODGING	PER DIEM	CAR RENTAL	REGIST.
Unspecified Destination (USA)	$ 1,500	$ 150	$ 51	$ 60	$ 525

PURPOSE/DESTINATION	NUMBER OF TRIPS	NUMBER OF PEOPLE	DAYS	AIRFARE	LODGING	PER DIEM	CAR RENTAL	MISC.	REGIST.	TOTAL
Conference/Unspecified Dest. (USA)	1	1	4	$ 1,500	$ 450	$ 204	$ 240	$ 80	$ 525	$ 2,999
TOTAL ESTIMATED TRAVEL										$ 2,999

DETAILED BUDGET - EQUIPMENT

DESCRIPTION	$COST
Air Jig	$ 520,000
Coal Crusher	$ 80,000
Automated Coal Samplers (2)	$ 30,000
TOTAL ESTIMATED EQUIPMENT	$ 630,000

k:\TJV\prop04\jl_falkirk.xls 3/25/2004 1:48 PM

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

Background

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

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

Salaries and Fringe Benefits

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

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

Travel

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

BL-CR56
Updated 10/7/03

Communications (phones and postage)

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

Office (project-specific supplies)

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

Data Processing

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

Supplies

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

Instructional/Research

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

Fees

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

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

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

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

General

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

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

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

Facilities and Administrative Cost

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

Module 4 Work Plan: Barr Engineering Company

March 8, 2004

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: **Request for Engineering Services**
100 TPH Coal Beneficiation Plant Cost Estimate
Barr Proposal ED/23-PRP-4015

Dear Rich:

On behalf of Barr Engineering Company, we are pleased to offer this proposal to complete the engineering needed to provide a capital cost estimate for a 100 TPH coal beneficiation plant that utilizes air jig technology. Our proposal is based on information obtained from our recent meetings and conversations.

UNDERSTANDING OF THE PROJECT

It is our understanding that you wish to retain a consultant to prepare a capital cost estimate for a commercial size, 100 TPH coal cleaning or beneficiation plant that uses air jig technology. Our understanding of the requirements of this project is outlined below.

- The proposed facility would be constructed at one of North American Coal's lignite mines in North Dakota
- Coal would be delivered to the system by mine haul trucks
- The system would include a crusher
- System design would be based on knowledge gained during a series of tests completed with a 5 TPH portable test facility which would be operated at each of the North American Coal Lignite mines in North Dakota and Mississippi
- There will be a minimum of two parallel processing lines in the air jig plant
- The plant will be enclosed with adequate heating, ventilation and dust control
- Cleaned coal will be delivered to an exterior conical storage pile
- Coarse rejects will be delivered to an exterior conical storage pile
- Dust or fine rejects will be delivered to an exterior conical pile or enclosed bin provided by others
- The system could include dryer technology being developed with GRE

SCOPE OF WORK

Project management: Activities under this task will include:

- Establishing/reviewing the project contract
- Setting up project files and controls
- Communicating with clients and associates
- Setting up internal staff communications and meetings

- Providing status reports

- Reviewing invoices and special invoicing requirements

- Holding teleconferences with you

Communications will include minutes of meetings, requests for information, transmitting drawings and data, contacts with major vendors for design information, and distributing information and data to project staff. The project manager will provide verbal updates periodically throughout the life of the project.

Conceptual Flowsheet Drawing: We will prepare a simple flowsheet drawing to illustrate the proposed process and equipment. This drawing would have minimal detail but would help define the scope of the plant for purposes of completing the conceptual layout drawings and cost estimate.

Conceptual Layout Drawings: We will provide conceptual drawings to show the layout of the facility. Drawings will include a facility plan, general elevations, and a section view of the air jig processing area to a larger scale. These drawings would have minimal detail but would show overall lengths, slopes, and information that would help us to complete preliminary design and cost estimates.

Preliminary Engineering: We will complete preliminary structural, mechanical, and electrical engineering so that an opinion of probable construction cost can be prepared for the facility.

Estimate of Probable Construction Cost: An estimate of the probable constructed cost of the facility will be prepared. Costs will include equipment; structural; mechanical including conveyors, dust collection, piping, and fire protection; and electrical power distribution, instrumentation, and control. The estimate will include engineering, materials, labor, subcontracts, overhead, profit, and contingency.

Report: Prepare a brief letter report summarizing results of our work including conceptual drawings, and cost estimates in a format suitable for including in your report to the North Dakota Industrial Commission.

Our scope of work does not include:

- Earthwork costs

- Soil testing and subsurface exploration—estimates of foundation cost will be based on assumptions for soil bearing capability

- Travel time and expense

SCHEDULE AND BUDGET

Our budget assumes that this work will be completed in the first or second quarters of 2005.
We estimate the cost of the work outlined in this letter to be $25,000. We propose to charge for our services as outlined below.

Charges for the first four tasks (project management, conceptual flowsheet, conceptual layout, and preliminary engineering) will be on an hourly rate plus expenses basis in accordance with our standard fee schedules. The estimated cost for these tasks is $20,000.

We propose to complete the estimate of probable constructed cost and report as an in-kind investment in the project. The value of these services is $5,000. We are hopeful that this can be used as a match for other funding.

Barr recognizes the potential value of this work for the lignite industry, which would allow use of currently unmarketable lignite and reduce the amount of ash and other undesired materials in fuel delivered to your customers.

PROJECT TEAM

Your project team for this work will be:

- David C. Rian, P.E. – Principal in Charge

- Matt Coughlin, P.E. – Project Manager
- Timo Peraaho P.E. – Structural and Civil
- Rick Sundvick, P.E. – Mechanical
- Jim Jagunich, P.E. – Electrical
- Don MacDonald – Cost Estimator

Thank you for the opportunity to submit this proposal. We believe that our skills and experience are well suited to this project, and we look forward to working with you. If you would like to further discuss our proposal or our capabilities, please contact me at 218-262-8605.

Very truly yours,

David C. Rian, P.E.
Vice President

c: File

MODULE 5 WORK PLAN: FALKIRK & GREAT RIVER ENERGY – STABILIZATION

Previous attempts to dry western low rank coals have been unsuccessful due to the high cost of the process, inherent danger of explosion due to high temperature and presence of coal dust, increased reactivity resulting in rapid spontaneous combustion, and handling difficulties due to the increased amount of fine dry coal.

The GRE/Falkirk coal drying process appears to have resolved all but the last item. The process uses waste heat from the power production cycle to gently remove moisture in a fluid bed dryer. During testing performed over the last 3 years the dried coal has shown that lignite can be dried in a much less hazardous process, and result in a fuel not prone to spontaneous combustion.

It is proposed to conduct a series of tests to specifically quantify and verify the ability of this process to produce a stable coal with heating value in excess of 9,000 BTU/pound. Furthermore this process will be combined with a process tailored to remove inherent sulfur and mercury from the coal in addition to inherent and dilution ash materials. These tests will also be used to determine the amount of oxidation taking place in the upgrading process.

The testing will be performed in two different campaigns. The first series of tests will utilize uncleaned coal being processed in the two ton per hour pilot plant at Coal Creek Station. Testing will be done on the feed coal and on the product streams from the dryer. The product streams are the non elutriated dried coal and the elutriated coal captured by the dust collector. A sufficient amount of material will be processed to conduct "real world" tests. The bulk tests will include building a stockpile of 100 to 200 tons to determine the long term stability. The properties to be measured and documented will be the ability to remain in a stockpile without spontaneously combusting. Reacquisition of moisture will be measured as well as loss of BTU value through weathering. To validate this process a similar stockpile of raw crushed coal should be built and similarly measured. Simultaneously with this field experiment, a test will be conducted in filling rail transportation cars with the dried and benchmarked coal. Similar measurements are to be made as with the stockpile test. This should provide us with some quantifiable data on the kinematics of long term coal storage in stockpile and rail containers.

In the second campaign cleaned coal from the five ton per hour coal cleaning plant will be tested in a similar method. This will then provide an opportunity to demonstrate the combined operation of a coal cleaning and coal drying plant. Both units have been demonstrated to remove ash, sulfur, and other undesirable minerals. This will quantify the ability to produce a coal with a high BTU level and a very low sulfur level.

The two ton per hour 7,000 BTU pilot drying plant is fairly inexpensive to run at this point. Additional costs would be incurred to reduce coal to -1/4 inch and modifications will need to be made to use the unit in a static lump drier mode. The material removal system would need to be modified. Additionally the tube bundle heat exchanger would be replaced with a multiple plate type heat exchanger. The other primary cost of operating the unit is the labor to load the coal and operate the dryer. Some instrumentation will need to be added to measure the heat generation internal to the pile. A surveillance camera could be used to verify visually the reaction of the pile for indications of spontaneous combustion.

The objective of this module is to determine the stability of lignite coal that has been cleaned and then dried.

STANDARDS OF SUCCESS

Summary for all modules

The overall effort of this program is directed toward producing a lignite product that reduces operating costs at existing power plants and reduces emissions of mercury, particulate matter, sulfur, and other undesirable constituents. The higher heating value coupled with lower emissions and decreased fuel variability has the potential to allow North Dakota lignite to compete with higher quality coal available in the market. By using dry cleaning processes for lignite, we have the potential to lower the cost of power production. The objective is to maintain and expand the market for North Dakota lignite. Using knowledge gained from this program, economic evaluation and plans for commercial units will performed by each site.

The Standards of Success for the Lignite Fuel Enhancement program will be to determine the following:

1) Determination of the best application in producing acceptable quality coal, including the potential level of production and energy recovery of the process. Calculate the financial impact of cleaning for the coal producer.
2) Characterization of the waste materials from the cleaning process and disposal implications. This includes an assessment of the disposal options and cost impacts.
3) Quantify the impact of cleaning on power plant performance, including boiler efficiency, auxiliary power requirements, disposal issues, and emission equipment performance.
4) Prepare an engineering cost estimate for the construction of a commercial plant.
5) Determine and develop procedures and protocols to produce a stable clean fuel for internal consumption and export.

BACKGROUND

Improving Power plant performance and Reducing Emissions through use of Pneumatic Dry Cleaning for Low Rank Coal

Technical Report

TR-01

Material Automation Systems and Service, Inc.
Castle Rock, CO Phone: 303-663-7431 Fax: 303-688-8981
email: mass4systems@earthlink.net

Improving Power Plant Performance and Reducing Emissions through the use of Pneumatic Dry Cleaning for Low Rank Coal

J.K. Alderman
R.J. Snoby

2001 SME Meeting
Denver, Colorado
February 26-28

Improving Power Plant Performance and Reducing Emissions through the Use of Pneumatic Dry Cleaning for Low Rank Coal

ABSTRACT

Although once fairly common as a method of coal preparation in the United States, dry cleaning has virtually disappeared. Low-rank coals used for power generation in the western U.S. are suited for dry cleaning because water has limited availability in the American west. Surface moisture added through wet cleaning offsets energy improvement achieved from mineral matter reduction. Information will be presented on the commercial application of dry cleaning in North America, the historic development and current status of the technology, and the introduction of modern processing theory and control technology to the design of dry cleaning equipment and plants.

INTRODUCTION

Significant changes in the regulation of the North American utility industry are creating an opportunity for expanding the reach of coal beneficiation technology beyond the traditional enclaves of the eastern U.S. and metallurgical coal production. As coal-fired power plants become stand-alone profit centers, competing against other plants to dispatch the lowest cost power to transmission and distribution companies, it becomes essential for power producers to minimize the costs of generation and maximize the generation capacity at their plants. The quality of coal consumed by the plant cannot be overlooked in achieving these goals.

Consuming high-ash and high-sulfur coal in the production of power contributes to:

- Pulverizer wear
- Boiler tube wear
- Soot-blowing
- Slagging
- Fouling
- SO2 related costs
- Parasitic losses
- Loss of availability
- Loss of generation capacity

While commercial coal cleaning technology has been available to address all of these issues, there has been a lack of development in the coalfields of western North America because of a lack of financial incentives, accurate information and awareness of coal washability, and a resistance to traditional water-based processing technology. Within the last two years, improvements in air-based dry gravity separation technology provide opportunities to coal producers and consumers alike to benefit from improved coal quality.

Allmineral Llc, based in Alpharetta, Georgia, and one of the leading international firms in conventional jigging technology, has applied their expertise in jigging and control instrumentation to developing a modern air jig and an advanced dry cleaning process system. Allmineral has developed a new air jig design, advancing technology virtually unchanged since the early 1940's, to incorporate improvements in air distribution, feed control, automatic separating density control, and process design to substantially improve the performance of the air jig compared to the prior state of the art.

The remainder of the discussion will be devoted to the occurrence and nature of high-ash, low-rank coals in North America, benefits of cleaned coal for the utility industry, the history and development of dry cleaning technology, and the technology of the allmineral AllAir Jig.

COAL QUALITY IN NORTH AMERICA

Coal quality data from the Federal Energy Regulatory Commission (FERC) for 1999 provides ash, sulfur, and energy content data for most of the coal consumed by U.S utilities. In comparing the ash content of different coals, it is important to incorporate the energy content as well. Over 50% of the coal consumed by U.S. utilities contain less than 3.55 kg/GJ of ash. There are a number of regions in North America where the ash content of the coal consumed substantially exceeds this value, as shown in Figure 1. In the U.S, the Southern Lignite region of Louisiana, Mississippi, and Texas, the San Juan Basin in New Mexico, and the lignite fields of North Dakota, produce coal with the approximate cumulative analysis shown in Table 1.

The Southern Lignite Region and San Juan basin have very high average ash contents and the North Dakota lignites are characterized by moderately high ash. Southern and North Dakota lignites are low to moderate for SO2 emissions, and the San Juan Basin coals are fairly low in SO2 emissions. The available data suggests that the Canadian extension of the Northern lignite region has lignite with characteristics similar to the lignites of North Dakota. Information on the subbituminous coals of Alberta indicates these coals have an ash content similar to the coal produced in the San Juan Basin.

Limited washability data on core samples suggest that these high ash coals can be cleaned by commercial methods to reduce ash content by up to 50% and SO2 content by up to 30%, depending upon the specific raw coal characteristics. It has been frequently noted that the iron and sodium contents of the ash, contributors to slagging and fouling, respectively, are associated with the pyrite in the coal, and therefore are reduced through cleaning. Reductions in the percentage of iron and sodium in the coal ash of 30% and higher are frequently observed.

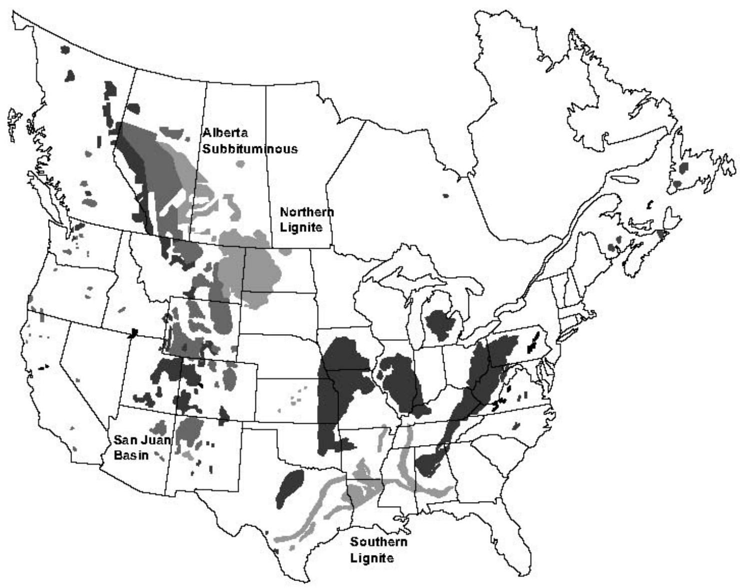


Figure 1. North American Coalfields

Table 1. U.S. Coal Mining Regions with High Ash Content

Region	Total Tons	Ash%	kJ/kg
Southern Lignite	52.3M	17.2	15,773
San Juan Basin	24.9M	19.6	21,826
North Dakota	30.5M	9.6	16,506

BENEFITS OF IMPROVED COAL QUALITY FOR COAL CONSUMERS AND COAL PRODUCERS

The high ash coals identified above result in higher costs for coal consumers from the pit to the ash pond. In many cases much of the ash-forming material is nearly pure mineral matter, containing little or no energy; therefore, dollars spent to load and haul what is essentially rock are wasted from the customer's perspective.

Rock wears out the material handling system, crushers, and pulverizers. Significant electrical energy is consumed pulverizing material with no energy content. Pulverizer capacity is wasted. Pyrite that could be removed by cleaning aggravates boiler slagging, contributing to a loss of capacity at high loads. The high ash content also contributes to slagging problems. Ash fouling in the convection passes is a function of the coal sodium content and is exponentially related to the ash content of the coal (Tufte et al, 1976). Ash accumulation on the tubes in this region can impact heat transfer, soot blowing, tube failure, and fan horsepower. In some cases, the high ash content of the coal overloads the particulate removal system requiring load reduction to avoid exceeding opacity limits. Removing pyrite from raw coal not only reduces wear and slagging, but can reduce the amount of gas necessary to scrub to meet SO2 emission limits, or can generate SO2 credits for the plant. Reducing the ash and pyrite content by cleaning also reduces the costs of ash and sludge disposal for the plant.

Certainly reducing raw coal ash and pyrite can provide significant cost savings in the area of pulverizer and boiler maintenance. Sensitivity analysis has shown that the major driver for coal cleaning on high-ash, low-rank coals is an increase in generating capacity, either through improvements in availability or elimination of conditions that require unit derating. Increasing generating capacity by 1% to 2%, when combined with O&M cost savings at the plant, can easily provide a very attractive payback from the capital investment and operating costs for coal cleaning.

Coal consumers can also derive a range of environmental benefits from cleaning raw coal. Reducing the ash content of the coal consumed reduces the quantity of ash disposed and potentially reduces particulate emissions. Refuse from the cleaning plant is returned to the pit virtually unaltered. Pyrite reductions from coal cleaning reduce SO2 emissions and scrubber sludge disposal. Heavy metals such as mercury and arsenic can often be associated with pyrite, and therefore, can be reduced by gravity separation (Akers et al, 1998).

From a coal producer's perspective, coal cleaning is a cost of production that can be recovered only by higher prices or increased production. In today's competitive market, the only way to realize a higher price for a better quality product is to work with existing customers and demonstrate the benefits to them, or to move the beneficiated product into plants willing to pay a quality premium.

Another way to recover the costs of cleaning is by increasing the productivity of the mine while reducing average costs. Millions of tons of high quality coal are discarded every year due to contamination by dilution rock from material bounding the coal seam. In many cases, treating this material in a cleaning plant will make a product that is of higher quality than the run-of-mine coal, and costs significantly less to produce. Recovering discarded coal can improve mine profitability, open new markets for higher quality fuel, and extend the reserve base of the mine.

Dry cleaning provides a number of advantages for western coal producers and consumers versus conventional water-based processing. With wet cleaning, much of the improvement in energy content derived from ash reduction is offset by surface moisture gain. Some low-rank coals can breakdown upon exposure to water, resulting in moisture and handling problems from excessive fines. The cost of disposal of fine coal slurry, including chemicals and impoundment construction and maintenance, can be significant. Freezing in winter months is also a concern for water-based plants. Finally, in many parts of the west, adequate quantities of water for wet processing are simply not available.

HISTORIC DEVELOPMENT OF DRY CLEANING TECHNOLOGY

Dry cleaning for coal encompasses a number of processes and devices. Dry cleaning processes have generally exploited differences between coal and refuse such as hardness, shape, coefficient of friction, resilience, specific gravity, and paramagnetism.

The Bradford Breaker, introduced in 1893 (Austin, 1991) and known today as the rotary breaker, is essentially a cylindrical trommel screen with shelves added to lift raw coal to the top of the cylinder and allowing it to fall onto hard metal plates of the cylinder shell. Coal, because it is softer than rock, breaks and falls through perforations in the plates. Rock is advanced to the end of the cylinder, where it is captured in an internal scoop and ejected from the breaker.

Machines for separating coal and refuse based upon differences in the coefficients of friction were made as early as 1868 (Mitchell, 1942). The Pardee Spiral Separator, introduced in 1898, and the Langerfield Separator, introduced in 1903, represent significant developments in friction based technology.

The Berrisford Separator (Mitchell, 1942; Horsfall, 1980), introduced in 1925, employed not only coefficient of friction differences, but also differences in resilience and specific gravity to effect a separation between coal and refuse. As shown in Figure 2, the Berrisford Separator is an inclined, polished glass plate. Refuse particles tend to slide down the plate at low velocity, while more resilient coal particles bounce down the plate at a much higher velocity. As a consequence, when exiting the plate coal particles travel further than refuse and are thereby separated, as is clear in the figure. Ideally, there is a requirement for the individual particles to flow down the plate separately, so unit capacity is very low.

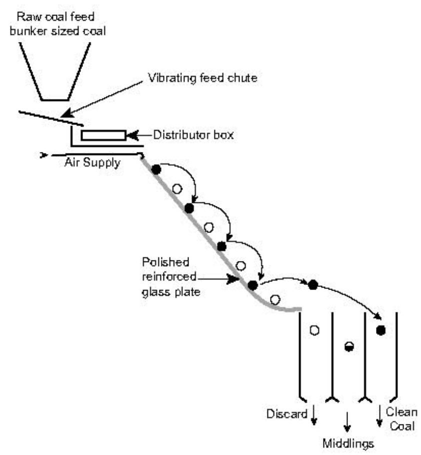


Figure 2. Berrisford Separator

Dry paramagnetic separation (Oder, 1987) is a relatively recent development in dry cleaning technology. Mineral matter in coal has a higher magnetic susceptibility than does the organic coal. By subjecting a flowing stream of fine coal to a strong magnetic field, mineral matter can be attracted from the stream of raw coal toward the source of the magnetic field, and separated from the lower ash coal. This technology has not been used commercially.

Most commercial dry cleaning processes have employed air to assist the separation. These pneumatic processes can be divided into air-heavy medium devices, air tables, and the air jig. Of these, the air jig has had the greatest commercial impact.

In the early 1930's, the Fraser Air-Sand process used air to fluidize a bed of minus 12M sand to produce a heavy medium separation (Coal Age, 1934). The separating principal is illustrated in Figure 3. This device was said to be effective for cleaning 50mm x 10mm raw coal. The machine circulated 3.0 tons of sand for every ton of coal cleaned and sand losses amounted to 1.5 kg per ton of raw coal.

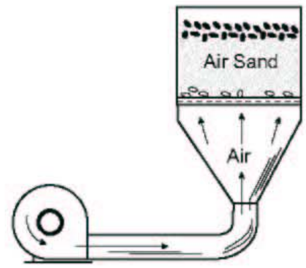


Figure 3. Fraser Air-Sand Separator

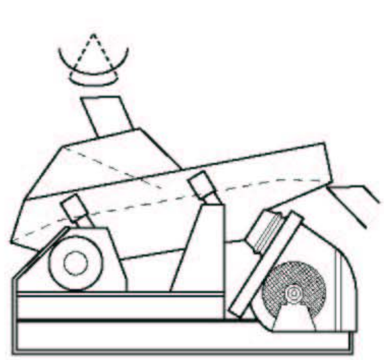


Figure 5. Saxon Cleaner

More recent research on air-heavy medium separation has been described in both the U.S. and China (Weintraub et al, 1979; China University, 1994). Research in the U.S. employed laboratory-scale equipment and focused upon separating very closely-sized coal feeds in an air-magnetite medium. Research in China also employed an air magnetite medium, but the equipment employed ranged from laboratory-scale to a 50 tph system for 50mm x 6mm raw coal. The 50 tph system was operated at separating gravities ranging from 1.30 – 2.00 with an efficiency of 85%. This device is shown in Figure 4.

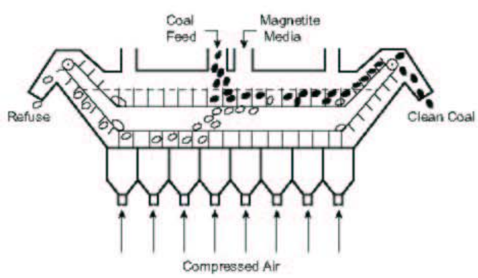


Figure 4. Air Magnetite Separator

A very simple air table, the Saxon Cleaner (Horsfall, 1980), is illustrated in Figure 5. This device is also known as a stoner, and is used to remove stones from agricultural products. Raw coal is fed to the middle portion of the counter-current machine and a constant stream of air is blown through a wire mesh deck. The air helps lift the lighter coal enough to allow the coal to flow with gravity and against the direction of flow imparted by an eccentric drive to the deck. These devices have a relatively low capacity and are inefficient.

One of the earliest air tables, the Sutton, Sutton, and Steele (or Triple–S) table was installed at coal mines in Oklahoma and New Mexico prior to 1924 (Mitchell, 1942; Arms, 1924). The air table shown in Figure 6 is similar in appearance and function to a Deister Table. While both units share a riffled, sloping deck, the Triple S table employs air instead of water as the fluidizing agent. As with the Saxon Cleaner, coal flows with gravity and refuse is conveyed uphill in a counter-current flow by the eccentric motion of the deck. The riffles, installed over the wire mesh deck, channel the refuse toward the heavy product discharge. The lighter coal, assisted by air, can pass up and over the riffles, and discharges at the lower corner of the deck, as indicated in Figure 6. Air tables must maintain a consistent feed quality and thin material bed in order to be effective. For these reasons, feed must be closely sized and unit capacity is low.

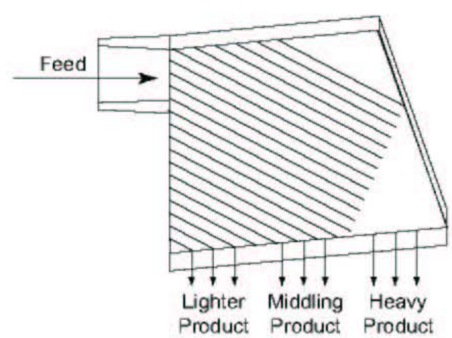


Figure 6. Sketch of a Typical Air Table

6

DEVELOPMENT OF THE AIR JIG

The Stump AirFlow Jig, shown in Figure 7, was developed by Earl Stump in 1932. The machine is an inclined, vibrating perforated deck. Pressurized air, about 2.5 kPa, is pulsed up through the perforated deck and stratifies the raw coal into a lower layer of dense refuse and an upper layer of lighter coal. Refuse was removed from the bed with three draws, evenly distributed over the length of the deck. A forth draw for middlings was located at the discharge end of the deck. The multiple refuse draws resulted in a thin bed of material, low in refuse content, in residence on the deck, relative to conventional jigs. As this condition caused a differential air resistance between the feed end and discharge end of the air jig, ceramic balls were placed in permeable chambers below the bed deck to mitigate short-circuiting of air. The layer of ceramic balls was progressively thicker from the feed end to the discharge end of the deck. Early machines were only 0.46m x 0.61m wide (Mitchell, 1942) but design changes over the years resulted in the "Super AirFlow" machine, a 2.4m wide deck with a capacity of up to 135 tph of 50mm x 0 feed per unit.

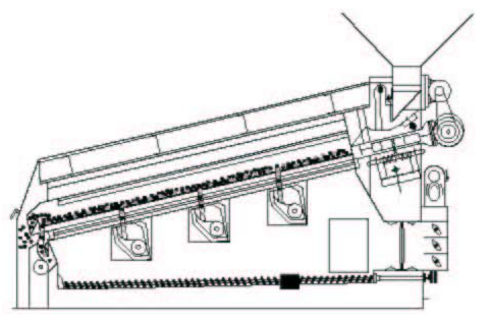


Figure 7. Stump AirFlow Jig

In the late 1930's, an attempt was made to automate the discharge of refuse from the air jig by mechanically monitoring the air pressure below the layer of ceramic balls (Davis et al , 1939). It was believed that as a bed of refuse built up on the deck, the increased resistance would cause pressure to increase under the deck, and this higher pressure would activate a mechanical float, which would in turn activate a refuse discharge gate. The design was ineffective and all future machines were furnished with manual controls.

The U.S. DOE conducted performance tests of AirFlow jigs in 1979 at two preparation plants in Pennsylvania. The air jigs evaluated treated feeds of 25mm x 0 and 50mm x 0 at feed rates up to 135 tph. Tests showed the air jigs provided some cleaning down to 0.6mm. However, losses of coal to the refuse were significantly higher than would be expected from processing by water-based technology.

The AirFlow jig was the most popular dry cleaning device among the competitive commercial dry cleaning technologies because of its high unit capacity, ability to clean a wide range of sizes in a single machine, and relatively efficient performance. The last commercial air jigs in the U.S. were decommissioned in the early 1990's. Air jigs were displaced by water-based processing methods which are better able to cope with the dirtier, high surface moisture feeds produced by modern underground mining methods.

In the early 1970's, some experimental work was done on a centrifugal air jig, a device employing the principles of jigging in a centrifuge (Symonds, 1971). Laboratory-scale tests showed effective separations with a particle size range of up to 8:1 on the coarser size feeds (12-13mm topsize). The device was not commercialized.

OPERATING PRINCIPLES OF THE ALLAIR JIG

The AllAir jig is unique among dry cleaning devices in so far as it replicates most of the operating principles of modern wet jigs. These principles include:

- Differential Acceleration
- Free Settling
- Hindered Settling
- Consolidation Trickling
- Superimposed Pulsation Stroke
- Automatic Density Control

In addition, the AllAir jig is the product of an extensive engineering design effort. As a result, the AllAir jig provides an even distribution of feed to the air deck, an even distribution of air across the entire width and length of the air deck, and a single refuse discharge gate at the discharge end of the jig. This discharge design enables effective hindered settling and consolidation trickling. The AllAir jig is shown in Figure 8.

While physically resembling the Stump Air Jig, operationally the units are fundamentally very different. The Stump jig is a thin layer separation device that depends more upon the principles of tabling than jigging. Air distribution across the deck is dependent upon the resistance provided by the coal on the deck and ceramic marbles beneath the deck. Feed variations result in short-circuiting and boiling of stratified material in the bed. The multiple refuse discharge gates maintain a thin bed of refuse over most of the length of the bed. This leads to excessive misplaced material, especially in the coarser sizes.

The AllAir jig is a deep-bed separator that exploits the full advantages of hindered settling and consolidation trickling. Feed is introduced to the deck of the jig from a surge hopper using a variable speed star gate. This permits the controlled, full-width distribution of feed across the deck. Each revolution of the star gate delivers a controlled volume of feed, and the engineered design of the discharge throat eliminates material bridging.

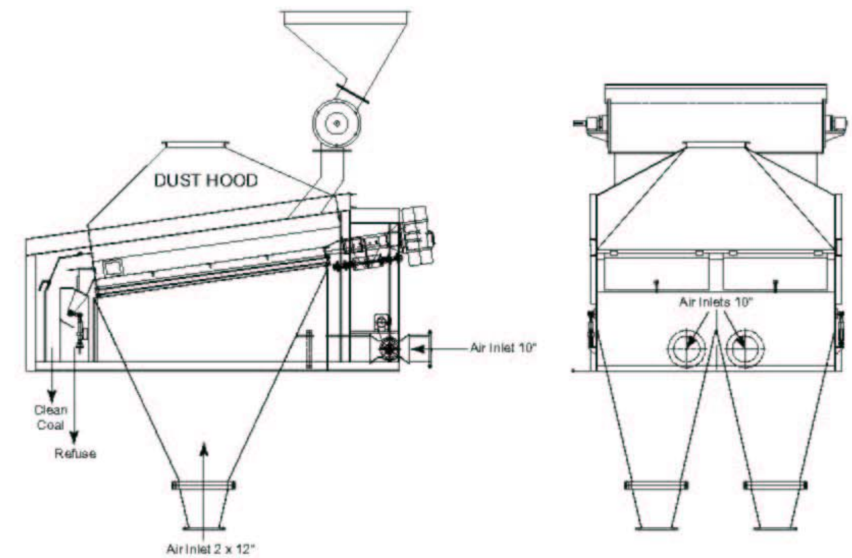


Figure 8. AllAirjig

Air is provided to the jig in two forms: a continuous flow and a superimposed, pulsated air flow that provides the impetus for stratification and consolidation trickling. This system is analogous to the operation of a wet jig. The perforated deck and hutch design work together to provide an even distribution of air across the deck, independent of the coal burden on the deck, unlike other known air-based gravity separators. This prevents short-circuiting and unnecessary loss of coal to the refuse.

Dry cleaning is the lowest cost technology, in terms of both capital and O&M costs, for cleaning coal. The process system will generally consist of sizing, density separation, and dust collection. No process water is required and therefore, no mill water pond or slurry impoundment is necessary. No drying, chemicals, or magnetite is required. Refuse can be back-hauled to the pit in essentially the same physical form as it left.

The hutch structure uniformly distributes air to all areas of the jigged bed reducing turbulence and dead spots. A pulsed air stroke is superimposed upon a constant stream of rising air currents, allowing the modern air jig to independently control stroke amplitude, frequency and acceleration. Thus, stratification of the feed material is enhanced.

By employing only a single discharge mechanism, the modern air jig is able to maintain a reserve layer of high density material through the entire length of the jig bed. This bed of sink product provides a barrier to the specifically lower density coal. Thus, misplacement of coal is minimized.

Another major improvement of the modern air jig is related to the separation of the high-density sink products from the low-density particles. Rather than depending on fixed manual discharge openings, or thin bed, counter-current separations, the modern air jig monitors the quality of product and reacts automatically to variations. It is a fundamentally superior approach, and used by most modern wet jigging equipment suppliers. Prior to the introduction of the modern air jig, an automatic bed level control system was never successfully employed.

By designing a discharge system that keeps the low-density particles a fixed distance from the screen bed, it is difficult for these light particles to be misplaced to refuse. The layer of high-density particles also enhances the hindered settling and consolidated trickling aspects of the jigging stroke. In short, an automatic bed level control system not only minimizes the misplacement of coal, but improves stratification.

The practical limit to bed depth occurs when the rising air currents are no longer sufficient to lift the bed, and allow migration of specifically lighter particles upward. The four classical stages of a jig stroke are shown in Figure 9.

1. Differential acceleration of the bed of particles as the material bed is initially lifted from a position of rest.
2. Free settling as the bed is distended and discreet particles decelerated, or begin to fall, according to their individual falling velocities.
3. Hindered settling as the bed begins to compact; the particles collide thus impeding free settling.

4. Consolidation trickling, which occurs as the larger particles lock together, and fine, typically higher-density particles fall through the voids. This last phase is particularly effective on the fine, liberated pyrite.

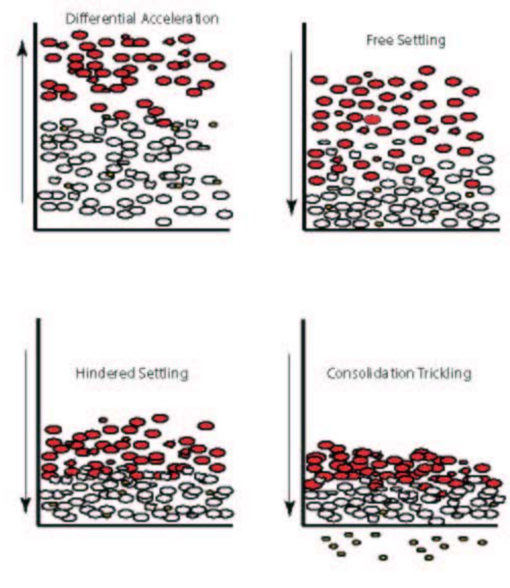


Figure 9. Four Classical Stages of the Jig Strokes

PROCESS DESIGN CONSIDERATIONS

The AllAir jig takes advantage of prior art, and builds on it. This applies to process circuitry as well. Some design considerations that apply for modern air jig plants include:

1. Limiting the top size of the feed to 45mm is necessary because it is nearly impossible to effectively jig particles greater than 50mm in air.
2. Processing coarse sizes and fine sizes separately. Processing unsized feeds such as 50mm x 0 results in excessive misplaced material.
3. The specific feed rate must reflect the difficulty of separation. This means greater specific capacity is possible with larger mean particle size feeds. Maximum loading of a modern air jig should be limited to 27-54 tph per meter of width.
4. Air jigs, like their cousins the wet jigs, require discreet particles. 6% surface moisture is generally considered the upper limit.
5. Dust must be controlled and contained in a safe and effective manner.

ADVANTAGE AIR

There is a demand in the market for an efficient dry separation device. Consider the breadth of applications involving black and white separations.

$$R = (\rho_a - \rho_m)/(\rho_b - \rho_m)$$

The above formula provides an insight into the difficulty of separating materials of differing densities, where

R – Ratio of particle diameters of different density but equal settling rate

ρ_a – density of material a

ρ_b – density of material b

ρ_m – density of medium

The separation ratio for pyrite and coal in air would be

$R - (5.0-0.00124)/(1.35-0.00124)$

$R - 3.7$

The separation ratio for rock and coal in air would be

$R - (2.6-0.00124)/(1.35-0.00124)$

$R - 1.9$

Experiments have shown the effects of hindered settling nearly double these values to 6.7 and 3.4, respectively (Arms, 1924).

Traditionally, separation ratios greater than 1.5 have proven to be economic in coal systems. Additionally, pre- and post-treatment of water, dewatering of fines and the disposal of wet fines are not a cost burden for a dry separation system. In some places, water for processing simply is not available. Because of these considerations, air jigging is the only practical, economic alternative for many producers and consumers of high ash coal.

Air jig plants can remove dilution rock from coal with minimal loss of energy. Air jig plants do not require water treatment, removal of water from fines, nor disposal of wet fines. Air jig plants require minimal amounts of water, usually only for such needs as safety and hygiene. Air jig plants tend to remove some moisture from the feed material due to the relatively high volume of circulating air. Air jig plants cost less to build and operate than wet processing plants.

CONCLUSIONS

The AllAir jig has been specifically engineered to effectively process coals such as those found in western North America. Dry cleaning provides quantifiable benefits for the following situations:

1. Low-rank, moderate ash coals that would forego most of the benefits of ash reduction through the moisture gain associated with wet processing.
2. Coals located in arid areas, lacking the water resources required for wet processing, or areas in which severe winter freezing is an issue.
3. Coals that breakdown upon exposure to water. Either the coal, or associated mineral matter, in some coals can disintegrate during wet processing, resulting in process problems and slimes treatment and disposal issues.
4. Top and bottom coal contaminated with out-of-seam dilution and discarded in the mining process. Dry cleaning can provide an economical means of recovering saleable coal.

The specific yield is increased, due to the higher precision of separation that can be expected, and the salvage of coal that has heretofore been discarded due to contamination of dilution rock. The modern air jig offers the promise of low investment and operating costs, and improved yields.

The AllAir jig is not the perfect solution for every coal beneficiation application on western coals. However, for mines or consumers that can benefit from removal of excessive ash and/or pyrite without employing water, dry cleaning can provide attractive economic returns.

REFERENCES

1934, "Air-Sand Process Cleans Railroad and Industrial Coal at Chickasaw Mine," Coal Age, Vol. 39, No. 9, September, pp 342-343.

1994, Coal Dry Beneficiation Technology with Air-Dense Medium Fluidized Bed, Mineral Processing Research Center, China University of Mining and Technology, December, 36 pp.

Akers, D.J., Raleigh, C.E. Jr., 1998, "The Mechanisms of Trace Element Removal During Coal Cleaning," Proceedings from Coal Preparation, Volume 19, No. 3-4, March, pp. 257-269.

Arms, Ray W., 1924, "Dry Cleaning of Coal," Transactions AIME, February, pp. 758-774.

Austin, Leonard G., 1991 "Chapter 5. Size Reduction", Coal Preparation, 5th Edition, Joseph W. Leonard, III, Editor, Society for Mining, Metallurgy, and Exploration, Inc., Littleton, Colorado, pp. 187-219.

Davis, D. H., Hanson, V.D., 1939 , "Some Factors Affecting Results When Air Cleaning Fine Coal," Mining Congress Journal, May, pp. 10-16.

Horsfall, D.W., 1980, "Section 7: Dry Cleaning and Dedusting," Coal Preparation for Plant Operators, The South African Coal Processing Society, Cape Town, South Africa, pp. 109-118.

Mitchell, David R., 1942, "Progress in Air Cleaning Coal," Transactions AIME, February, pp. 116-137.

Oder, R.R., 1987, "Dry Magnetic Beneficiation of Pennsylvania Coal," Proceedings of Fourth Annual Pittsburgh Coal Conference, September-October, 13 pp.

Symonds, D.F., 1971, "Research into a New Method of Dry Cleaning Coal and Ores," Thesis submitted to the University of Nottingham for the Degree of Doctor of Philosophy, pp. 178-182.

Tufte, P.H., Gronhovd, G.H., Sondreal, E.A., Selle, S. J., 1976, "Ash Fouling Potentials of Western Subbituminous Coals Determined in a Pilot-Plant Test Furnace," Proceedings of the American Power Conference, Volume 38, pp. 661-671.

Weintraub, M., Deurbrouck, A.W., Thomas, R.H., 1979, "Dry-Cleaning Coal in a Fluidized Bed Medium," RI-PMTC-4(79), Department of Energy, Division of Fossil Fuel Extraction, Pittsburgh, PA, January, 18 pp.

BACKGROUND

COMBINING TECHNOLOGIES TO MAKE LIGNITE INTO A PREMIUM FUEL: USING INTEGRATED AIR AND MAGNETIC SEPARATION

Richard S. Weinstein*
Engineering Manager
Falkirk Mining Company
P. O. Box 1087
Underwood, ND 58576

Robin R. Oder, Ph.D.
President and CEO
EXPORTech Company, Inc
P. O. Box 588
New Kensington, PA 15068

Richard J. Snooby
President
Allmineral Llc
1360 Union Hill Road
Building 1, Suite F
Alpharetta, Georgia 30004

ABSTRACT

Combined air and magnetic separation technologies show promise to yield a high energy recovery and the removal of a significant amount of the undesirable materials contained in North Dakota Lignite. This improvement is made possible by taking advantage of the natural differences in the densities of coal and waste material combined with the higher magnetic susceptibility of the waste materials. By combining the strengths of each technology, there emerges a combined process that exceeds the potential of each technology taken on its own. This technology has the potential to recover additional lignite and/or to enhance the quality of coals utilized by power plants.

Using an allmineral Llc Allair® Jig plant in combination with a EXPORTech ElectriMag™ Belt Separator results in an ash, SO_2, and mercury reduction in excess of 10 percent, while yielding 95% energy recovery. The combination of an Allair® Jig Plant processing -2 inch lignite with a ElectriMag™ belt Separator handling the -1/4 inch fine reject is an ideal combination of processes that takes advantages of the strength of each technology.

The objective Falkirk Mining Company and Great River Energy, owner of the Coal Creek Power Station located 7 miles South of Underwood North Dakota, was to find a dry cleaning process that would improve the overall efficiency and economics of the mine and power plant.

INTRODUCTION

Lignite is faced with major challenges in the form of market forces in the electric generation industry, and mounting pressures in complying with clean air standards. Due to inexpensive mining costs and less restrictive environmental issues in the past, most lignite cleaning has been limited to very crude in–the-pit cleanup before shipment. To do this, the mining company has discarded or avoided low heating value coal and minimized dilution with waste material that lowered the heating content. Enough cleaning was done to fit the contractual commitments or to a point that allowed unrestricted power output with respect to the heating value of the coal. This has resulted in coal or energy losses that can typically run up to 20% or higher for some of the coal seams at Falkirk.

Today the coal miner and power plant operator must focus more on the overall mine plus power plant (bus-bar) cost of energy to thrive and survive in the long run. Just meeting contractual tonnage and quality limits for a miner may result in lower coal demand if the power plant suffers from increased maintenance outages, reduced performance, and/or reduced operation due to environmental compliance.

A simple solution to these vexing problems is to economically recover more of the resource while eliminating the contaminants that cause problems for the power plant. North Dakota lignite crushed to a 2 inch size results in the generation of a very high percentage of fine material. It is not unusual to see the -1/4 inch material represent nearly 50% of the lignite. The fine material also has a high clay content. While water is readily available at Falkirk, many western locations have a shortage of available water for wet processing. The high surface area of fines and wet processing moisture gain would be very detrimental to the heating value of Falkirk Lignite. The combination of a high percentage of fines, clay content, and water related issues steered Falkirk to investigate dry processing.

EXPERIMENTAL

Tests utilizing air and magnetic separation technologies were conducted in 2002 to evaluate the potential of dry cleaning methods for a typical high ash coal from the Falkirk mine. For the tests, coal was taken from a seam that had an in place thickness of approximately 4 feet. Mining conditions were dry and visibility good so one could conclude that the coal was typical of normal deliveries. On September 17, 2002 the coal was mined (see Figure 1) and reduced to -3 ½ inch size and then stockpiled at the Coal Creek Station.

Figure 1. Mining four foot thick seam for dry cleaning: September 17, 2003

The coal was stockpiled as shown in Figure 2. Note the clear distinction between the coal and associated contamination incidentally added during the loading operation. Inspection of the coal seam in the pit indicated that the light color material was probably waste material from below the seam. Several samples were taken by drilling the seam before mining and after the coal was stockpiled. Analysis of these samples indicated that the quality of the coal was typical of normal deliveries.

Figure 2. Falkirk Coal after crushing September 2002: Coal Creek Station

The shortfall of dry cleaning using Air separation is that the losses in fines can be quite high and the misplacement of coal and waste material can be high. The Allair® Jig (see Figure 3) has shown good separation and low energy loss on the coarse product circuit however, there were a substantial amount of fine rejects that had higher ash content than the feed.

Figure 3. allmineral Llc Allair® Jig: October 2002

The Lignite was shipped to a commercial Allair® Jig. At this site the lignite was reduced from -3 ½ inch to -2 inch. Typically this unit would operate on either a coarse or a fine stream of coal. Since only 24 tons of coal was shipped it was decided to run the Falkirk Coal in a single batch with no size separation. Theoretically the Allair® Jig operates more efficiently when a tighter particle distribution is processed. The system was purged and the Falkirk coal was run through as a batch with samples taken of the feed, coarse product, baghouse fines, and reject material throughout the test. The test took approximately 20 minutes. Figure 2 below shows the three project streams. From left to right they are; reject into truck, fines conveyor center, and product stream to the right.

Figure 4. allmineral Llc Allair® Jig: October 2002

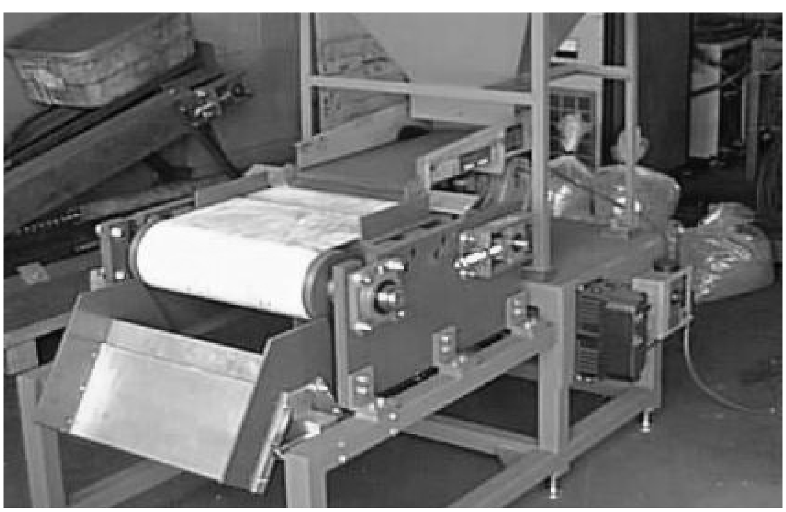
A positive feature of the Allair® Jig is the ability to produce a coarse waste reject material containing very little lignite. At the same time the clean product stream had a significant amount of the waste removed.

A negative feature of the Allair® Jig is that the baghouse captured fines turned out to be a high percentage of the initial feed. The main purpose of the baghouse is to control particle emission from the jig and in some cases to assist in the cleaning. Nearly all the material captured by the baghouse was -1/4 inch in size, and had little or no surface moisture. The fines had a ash level higher than the feed coal, and a BTU level lower than the feed coal. In some cases it might just warrant to throw the fines away and sell only the coarse cleaned material.

The next issue is what to do with the fines and its impact on economics. A representative sample of the baghouse fines reject from the Allair® Jig was then run through a bench scale model of the ElectriMagTM belt Separator shown below (see Figure 3). Lab results showed that the waste materials had a much higher magnetic susceptibility than the coal, and a distinct separation was achieved

Magnetic separators function effectively when the particle size is small, the material has little surface moisture and the feed has both magnetic waste and non magnetic coal. Air is used in the Allair® Jig to fluidize and stratify the bed of coal. This has the effect of removing most of the surface moisture in the fines. The size and moisture of the baghouse material is suitable for magnetic separation without further processing. It is quite possible that both surface and inherent moisture content of the product coal and the fines was lowered measurably by the air. The fines need no further size reduction or drying to make effective use of a magnetic separator. Thus fine coal reject material from the Allair® Jig is a very good feed for the ElectriMagTM belt Separator.

Figure 3. EXPORTech ElectriMag™ belt Separator



The laboratory model ElectriMag™ belt Separator has multiple splitters on the discharge end. The coal was passed through the device and the individual splits were sampled and analyzed. These splits can then used to determine an optimal setting for making a single separation cut.

RESULTS AND DISCUSSION

The results from the Allair® Jig and the ElectriMag™ belt Separator are shown below in Tables 1.

Table 1. Quality and Energy Recovery Allair® and ElectriMag™

	% Moisture	% Ash	BTU/Lb	% Sulfur	% Sodium In Ash	Pounds SO2 /MMBTU	%Energy Recovery
Feed (Allair®)	30.65	19.72	5,956	0.92	3.34	3.10	100.00
Product (Allair®)	32.40	12.73	6,663	0.88	4.80	2.64	76.70
Fines (Allair®)	24.61	27.32	5,635	1.03	2.27	3.67	20.30
Cleaned Fines (ElectriMag™)	26.59	19.50	6,477	1.07	2.96	3.29	18.70
Reject (Allair® & ElectriMag™)	18.69	59.04	2,072	1.43	1.37	13.76	4.60

Looking at the Allair® Jig (Table 2) results we see that improvement in heating value and reductions in ash and sulfur dioxide (SO2) have very positive implications for a power plant. However the 76.7% energy recovery for the coarse product is not very good. The fines segregated by the Jig are of very marginal quality from a power plant operational standpoint.

Table 2. Allair® Jig: Change in Fuel Quality and Energy Recovery

	Moisture	Ash	Sulfur	BTU	SO2	Sodium	Hg (ppm)	#Hg/ TBTU	Energy Recovery
Falkirk raw coal	30.56	19.72	0.92	5,955	3.09	3.34	*	*	100.00%
Air Jig Product	32.40	12.73	0.88	6,663	2.64	4.80	*	*	76.70%
Change	6%	-35%	-4%	12%	-15%	44%	*	*	-23.30%

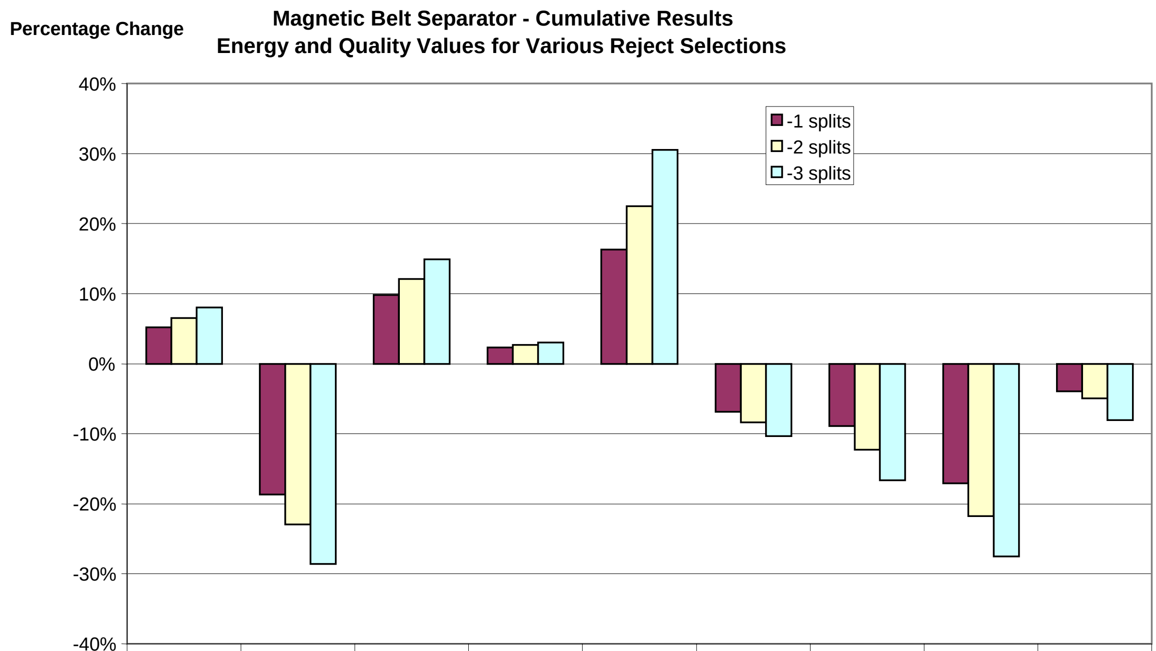
If the fines were to be recombined with the coarse product we would have a product better than we started with as shown below in Table 3. The improvement is still substantial and the Energy Recovery reached 97.05%. Mercury measurements were not available for the Jig test.

Table 3. Allair® Jig: Change in Fuel Quality and Energy Recovery

	Moisture	Ash	Sulfur	BTU	SO2	Sodium	Hg (ppm)	#Hg/ TBTU	Energy Rec
Falkirk raw coal	30.56	19.72	0.92	5,955	3.09	3.34	*	*	100.00%
Jig prod + Raw Fines	30.92	16.20	0.88	6,392	2.75	3.78	*	*	97.05%
Change	1%	-18%	-4%	7%	-11%	13%	*	*	-2.95%

The next step involved treating a representative sample of fines with the ElectriMag™ belt separator. As stated previously the fines were essentially all -1/4 inch in size and had very little surface moisture after discharge from the baghouse. The samples were run through the ElectriMag™ Belt Separator without any pretreatment. The lab bench size ElectriMag™ Belt separator is fitted with a series of cutters that make multiple segregations based on magnetic field response of the material and other physical handling characteristics. Each sample generated 5 to 6 splits. The improvement in quality and change in energy recovery is shown in the Figure 4 and Table 5 as shown below. The results show the cumulative change as additional material is removed by each successive segregation. The most magnetic material is removed first and each subsequent split had less response to magnetic separation.

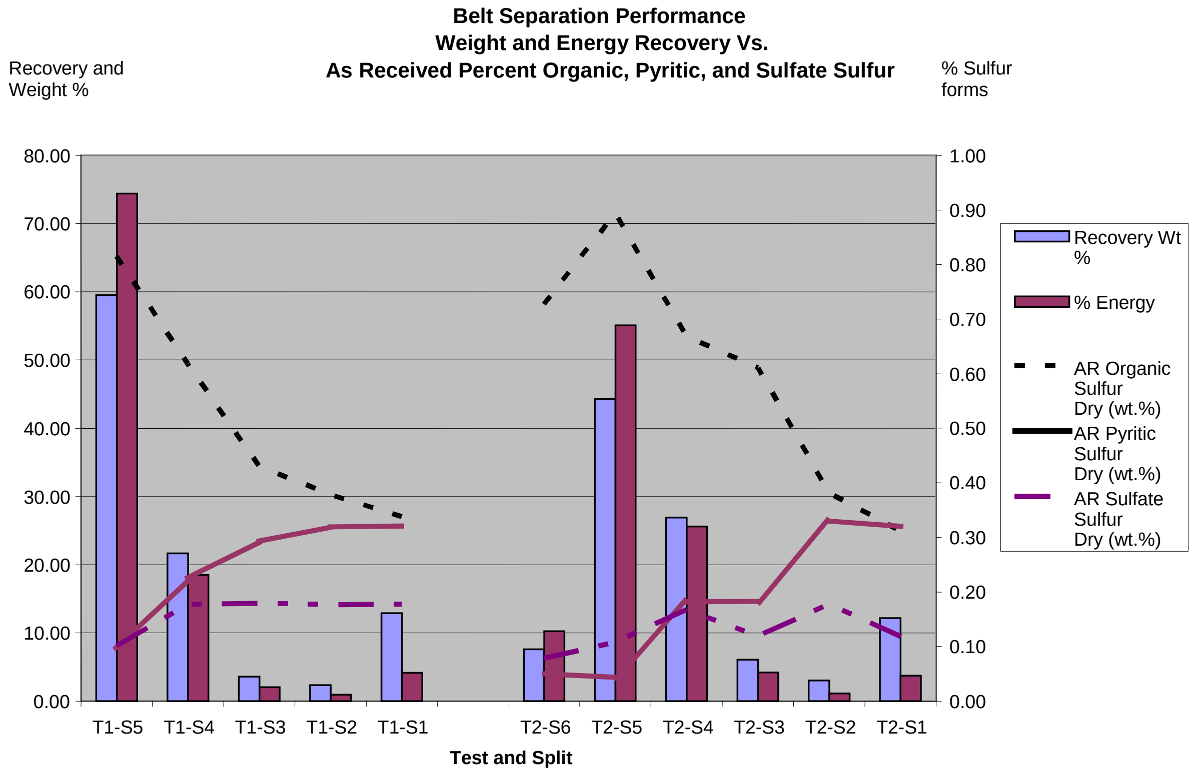
Figure 4. EXPORTech ElectriMag™ belt – Cumulative Separator Energy and Quality Changes



	Moist	Ash	BTU	Sul	Na	SO2	Hg (ug/g)	Lb HG/TBTU	Energy Recovery
-1 splits	5.2%	-18.7%	9.8%	2.3%	16.3%	-6.9%	-8.9%	-17.0%	-3.9%
-2 splits	6.5%	-23.0%	12.1%	2.7%	22.5%	-8.4%	-12.3%	-21.7%	-5.0%
-3 splits	8.0%	-28.6%	14.9%	3.0%	30.5%	-10.4%	-16.7%	-27.5%	-8.1%

The results show a high recovery of energy from the fines and a resulting large decrease in ash, SO2, and pounds of mercury per trillion BTU. Note that the sulfur percentage increased suggesting little magnetic susceptibility of the minerals containing sulfur. This is graphically presented in the analysis of sulfur forms shown in Figure 5. There is a definite removal of pyritic sulfur and, to a lesser extent, for sulfate sulfur. Most distinct is the high level of reported organic sulfur that is bound to the nonmagnetic coal and minerals.

Figure 5.Distribution of Sulfur forms in Splits by ElectriMag™ Belt separator



Early in 2002, magnetic separation tests were done on daily coal samples obtained by Great River Energy at the Coal Creek Station. These earlier tests showed similar reductions in contaminants and improvements in heat content. A very interesting result of the earlier "lower ash coals" tested was seen in the ash fusion and sodium results. The ash fusion temperatures for both oxidizing and reducing environments showed a general increase of around 50 degrees Farenheight while experiencing a significant increase in sodium. In the October 2002 test we also observed an increase in Sodium in the coal. It is possible that this test would also show no degradation in the ash fusion temperatures because total mineral ash analysis showed similar changes.

Table 4. EXPORTech ElectriMagTM belt Separator Energy and Quality Values

	Moist	Ash	Sul	BTU	Na	SO2	Hg (ug/g)	Lb HG/TBTU	Energy Recovery
Feed	24.61	27.32	1.03	5,635	2.27	3.67	0.093	16.583	100.00%
-1 splits	25.89	22.21	1.06	6,189	2.64	3.42	0.085	13.756	96.08%
-2 splits	26.21	21.04	1.06	6,316	2.78	3.36	0.082	12.979	95.04%
-3 splits	26.59	19.50	1.07	6,477	2.96	3.29	0.078	12.024	91.90%

Conclusions

The October 2002 testing demonstrated that the combined deployment of Air and Magnetic separation resulted in a product coal that could have significant positive impact on mine and plant operation. Table 5 below summarizes the quality and relative change of the feed and potential products resulting from combinations of air and magnetic separation. Further testing is needed to determine if the same percentage improvement could be seen on other coal seams or even for the full coal deliveries.

Table 5. Summary results for various product combinations- Allair® and ElectriMag™ Dry Cleaning

Quality	Moist	Ash	Sulfur	BTU	Sodium	SO2/MMBTU	Energy Recovery
Feed	30.65	19.72	0.92	5,956	3.31	3.09	100.0%
Product	32.40	12.73	0.88	6,663	4.64	2.63	76.7%
Prod + Fines	30.92	16.20	0.88	6,392	3.78	2.74	97.1%
Prod + Cleaned Fines	31.53	14.11	0.88	6,604	4.25	2.67	95.4%
Percent change	Moist	Ash	Sulfur	BTU	Sodium	SO2/MMBTU	Energy Recovery
Feed							
Product	5.7%	-35.4%	-4.8%	11.9%	40.4%	-14.9%	-23.3%
Prod + Fines	0.9%	-17.8%	-5.0%	7.3%	14.2%	-11.5%	-2.9%
Prod + Cleaned Fines	2.9%	-28.4%	-4.4%	10.9%	28.5%	-13.8%	-4.6%

Mercury measurements were obtained for the ElectriMag™ Belt separator. These measurements showed a 27.5% reduction in pounds of mercury per trillion BTU. Further testing will be needed to determine if similar reductions in mercury are possible from the Allair® Jig.

The technologies applied here resulted in a high energy recovery rate and significant improvement in quality for a coal having high ash and low amounts of pyritic sulfur. Due to the expected low cost of these technologies it is believed that significant opportunities exist to enhance the quality of existing deliveries and to improve mining recovery through recovery of additional coal currently lost in the mining operation.

One of the most serious maintenance and reliability issues for a power plant is the erosive nature of ash combined with high velocity of the flue gas stream. A reduction of 25% in ash combined with lower flue gas velocities as a result of improved coal should decrease the number of unscheduled outages due to erosion problems. The end result of erosion is typically experienced in the form of steam tube or water wall leaks, resulting in significant outages, both scheduled and unscheduled. During these periods base loaded plants must buy replacement power while a valuable asset remains idle.

Selective use of dry cleaning on selected coals or on the entire feed stream can have a dramatic impact on the emission control system design and operation. These dry cleaning technologies show great promise to remove ash and other minerals that sulfur and mercury is associated with. Preliminary data from limited testing shows a correlation between sulfur, ash and mercury. Lignite with high concentrations of ash and pyrite treated with dry cleaning processes should result in greatly reduce the peak levels of sulfur and mercury emissions. This should translate into lower operating cost and potential output increases without the installation of additional emission control equipment.

From the mining side there are many opportunities to lower costs by economically recovering acceptable quality material from substandard and highly contaminated lignite coal. Field observations in a typical lignite operation often identify situations where incidental and planned operations result in waste material containing a significant percentage of good quality coal. With many operations faced with high and increasing striping ratio (yards of waste material removed to recover a ton of coal) the recovery of more energy can be very economic. The typically dry nature of surface lignite mining combined with the simple and low cost characteristics of dry cleaning shows promise to lower the cost of delivering suitable quality coal for power generation.

Plans are underway to seek funding for long term field testing of these dry cleaning technologies. The long term demonstrations will process a wide variety of lignite's under varying operating conditions. These long term field demonstrations will assist in determining the applicability of dry cleaning technologies in surface lignite operations.

ACKNOWLEDGEMENTS

I wish to thank and personnel from Great River Energy's, Coal Creek Station for providing the coal for this work and for sponsoring the processing and laboratory activities.

Background

Air and Magnetic Separation Testing Results

Air and Magnetic Separation Testing Results

Over the last year a series of lignite coal samples were beneficiated (cleaned) using Air and magnetic/electromagnetic separation processes. Falkirk coal mined from the Riverdale field was crushed and stacked out in an open-air stockpile at Coal Creek Station in August 2002. This coal was then shipped in September 2002 to a 100 ton per hour Air-Jig located at the Holmes Limestone Coal Company located in Plainfield Ohio. In the Air-Jig a portion of the processed coal is segregated out through a dust capturing bag house. A representative sample of the bag house fines was then processed using a magnetic belt separator located at the offices of EXPORTech Inc. in New Kensington Pennsylvania.

The intention of the tests was to determine the ability of these processes to remove non-energy contaminants from the lignite while retaining the maximum amount of heat energy. With Clean air regulations becoming more stringent the need to economically produce electric power will become more costly due to increased "after the boiler "cleaning equipment. Often utilities have selected to switch to cleaner fuels to meet the tightened regulations or to install expensive emission cleaning equipment. Coal cleaning is a way to preserve existing production sources and minimize plant modifications while meeting the tightened regulations. It is quite likely that a combination of pre and post combustion processes will yield the overall lowest cost while meeting these new regulations.

The initial results of testing conducted from April, 2002 through January 2003 are quite encouraging. It appears that the simple process of using air and magnetic/ electromagnetic separation equipment will substantially reduce emissions while yielding a reasonable energy recovery. Four tests were conducted resulting in six sets of results.
The following table is a brief summary of the results achieved with the air-jig and magnetic belt separator.

Parameter	Average Change	Range
Energy Recovery	95%	91.9% to 98.9%
% Ash	-23%	-15% to -31%
% Sulfur	-0.5%	+8% to -8%
BTU/lb.	+10%	-2% to +19%
Pounds SO2/Million BTU	-5.5%	-9% to -14%
Mercury (ppb)	-13%	-6% to -18%

On the following page is a diagram showing the equipment used and the quality of the feed coal and the resulting clean and rejected material.
Additional testing is proposed for 2003 and 2004 to confirm these results and refine operating and capital costs for these processes.

	Moist	Ash	BTU	Sul	Na	SO2	Energy Recovered
Feed	30.65	19.72	5,956	0.92	3.34	3.10	100.00

Air Jig

Belt Separator

	Moist	Ash	BTU	Sul	Na	SO2	Energy Recovered
Final Prod	31.53	14.11	6,604	0.88	4.25	2.67	**95.4**

	Moist	Ash	BTU	Sul	Na	SO2	Energy Recovered
Reject air-jig & Mag sep	18.69	59.04	2,072	1.43	1.37	13.76	**4.6**

QUALIFICATIONS

Key Personnel (Appendix A – Key Personnel Resumes):

Richard Weinstein, Engineering Manager, The Falkirk Mining Company

Richard J, Snoby, President Allmineral Llc, Alpharetta, Ga

Dr. Steven Benson: Senior Research Manager, Energy and Environmental Research Center

Jason D Laumb: Research Manager Energy and Environmental Research Center

Dr. Donald P McCollor: Research Scientist, Energy and Environmental Research Center

Dave O'Conner: Manager-Combustion Effects, Electric Power Research Institute

Dr Rick Honaker: Associate Professor of Mining Engineering University of Kentucky

Justin Burggraff : Operations Manager Coteau Properties Company, North American Coal

Vern Lund: Mining Engineer: Mississippi Lignite Mining, North American Coal

Mark Ness: Systems Engineer, Great River Energy

Dave Rian: Vice President, Barr Engineering

VALUE TO NORTH DAKOTA

The Sponsors are proposing to demonstrate processes to increase the quality and value of North Dakota lignite by decreasing mining costs while economically reducing the ash, sulfur, mercury, moisture, and ash minerals. The processes utilize the principals of air/density and magnetic separation to remove a portion of the heavier and more magnetically susceptible materials from the coal. This project will benefit both the coal miner and consumer. Mining costs will be improved by economically recovering more of the in-place reserves. Secondly, the quality of the coal is improved which will have a positive impact on the operation of a power plant.

North Dakota lignite is at an economic disadvantage with other western coals due to the lower heating value and higher mineral contaminants. Improvements in the heat content coupled with a reduction in contaminants can significantly decrease the amount of emissions from the power industry. Much of the close to the surface reserves will be depleted over time and the industry is headed toward increased cost for the production of lignite. Similarly as emission standards become more stringent the lower quality of lignite makes compliance potentially more costly.

Furthermore, significant amounts of coal are discarded in the mining process. Mines with thin seams, typical of many lignite operations, have coal losses of 15% or more. A great deal of these losses are due to coal quality considerations. The results from preliminary small scale testing has shown that dry coal cleaning techniques can improve most of the quality values while recovering a very high percentage of the energy content. The results shown here are representative of the performance when treating a typical marginal lignite.

Coal Cleaning
Air Jig - Belt Separator Results

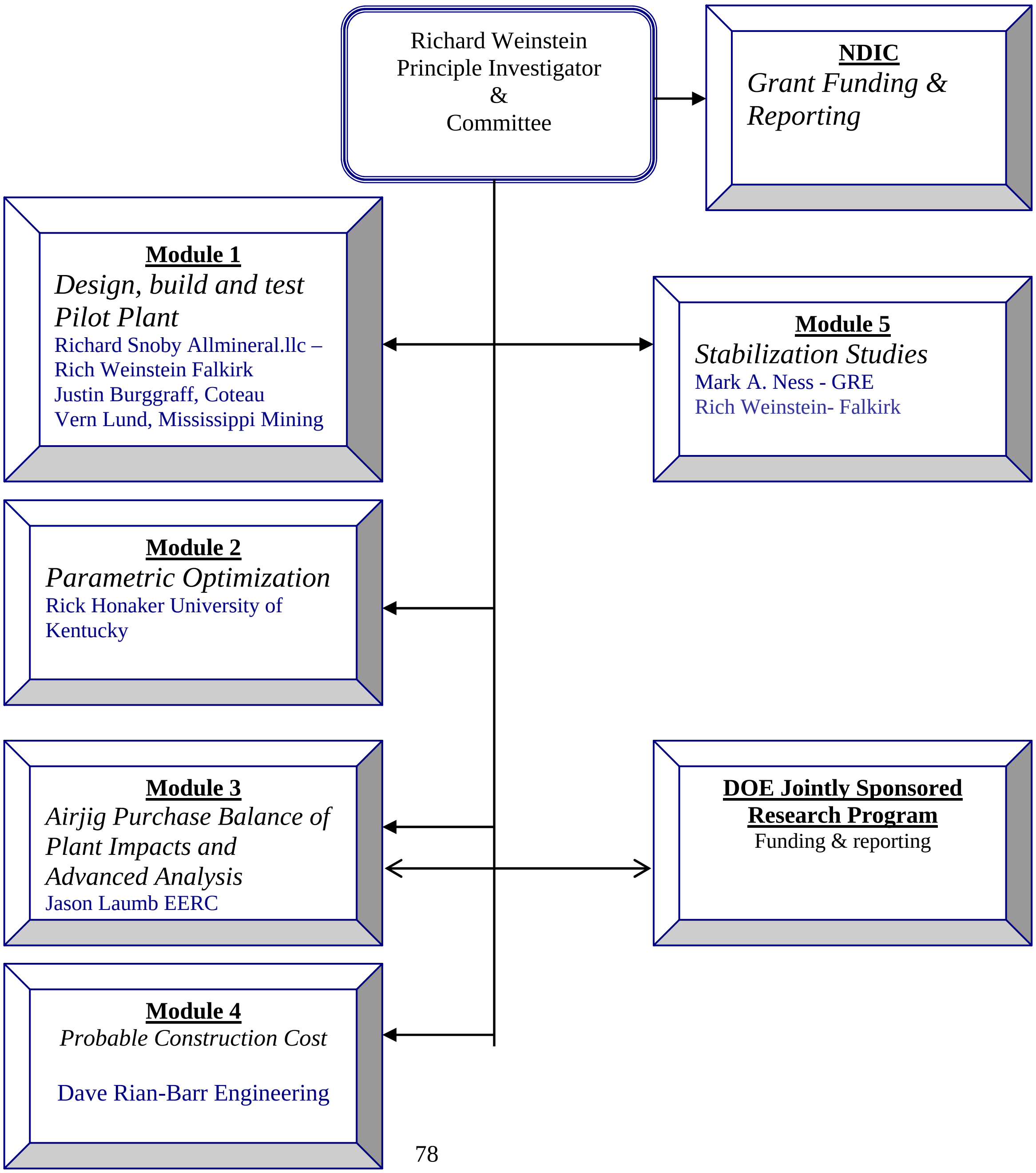
Quality	Results
Coal Recovery	95.4%
BTU/Lb.	+ 11.2%
Ash	- 28.5%
Sulfur	- 1.5%
SO2/MMBTU	-11.2%
Lb Hg/TBTU	-27.5%*
Lb Na/MMBTU	-17.9%
Moisture	+2.9%

* Mercury Reduction for Belt Separator only

Overall, the ability to produce coal at a lower cost while simultaneously reducing the environmental impacts will position lignite much more favorably with competing fuel sources. This project is tailored toward commercializing processes to economically accomplish this objective.

Management

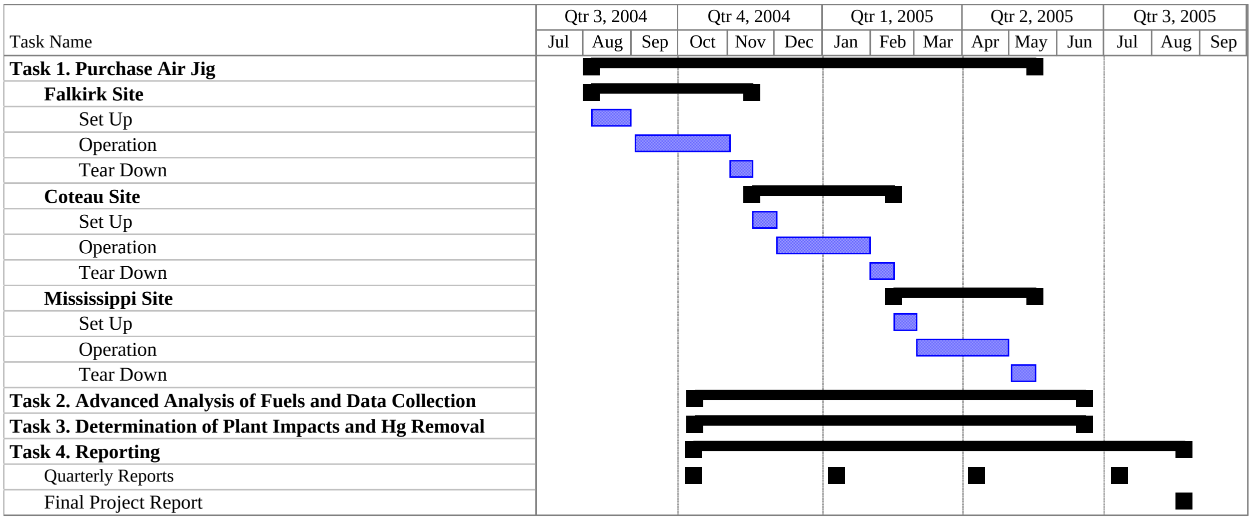
The proposed project will be managed and coordinated by Richard Weinstein, who will serve as the contact point for the Industrial Commission, Falkirk, Great River Energy, Coteau, Basin Electric, North American Coal Corporation, Tractebel Power, University of Kentucky, EERC, and EPRI. Falkirk will act as the primary applicant and contract coordinator. The following organizational chart summarizes the management structure that will be used for the project:



The Committee referenced in the above organizational chart is composed of the Key Personnel listed in the “Qualifications” section of this application. The committee will meet and otherwise communicate on a regular basis to keep everyone abreast of developments. These meetings and communications will serve as the basis for the interim reports. The final project report will be created as a joint effort of the committee. Reports will be filed at the completion of initial startup, thereafter one month after completing testing at each site. A final report will be published two months after completion of all testing. Reports will alternatively be filed according to the NDIC and DOE requirements.

TIMETABLE

The proposed schedule for the project is shown below. This is the same timetable shown in the work.



BUDGET AND MATCHING FUNDS

Falkirk Mining Company under the scope of this project and participating entities requests $250,000 in matching from The North Dakota Industrial Commission. The contribution being made by the sponsoring partners excluding the NDIC is $879,035 in cash and $202,000 of in kind contributions. The NDIC is requested to support this project with a cash contribution of $250,000. The DOE is being requested to fund this project with a contribution of $318,230 as detailed in the EERC proposal. The total budget for Project is $1,331,035. This is a technology development project and, therefore, in itself has no return on investment. This project is being undertaken with the intention of developing technology, which will significantly improve the value of North Dakota Lignite when burned in conventional boilers. The payback for this project will come from the commercialization of this technology. The North Dakota Industrial Commission's participation in this project is critical for the project to be completed in its entirety.

COST BREAKDOWN

Pilot plant testing Budget Capital		
Air Jig	$	520,000
Magnetic Separator	$	6,000
transport	$	25,000
Crushing	$	80,000
Sampler	$	30,000
Coal Transportation	$	15,000
Office trailer	$	5,000
Storage covers	$	2,000
Labor	$	33,000
Graduate Student	$	32,805
Travel	$	12,000
Grad Student	$	9,000
Subtotal	**$**	**769,805**
Pilot plant testing Budget - In Kind		
Sample Analysis (In-Kind)	$	52,000
Management (In kind)	$	60,000
Overhead (in kind)	$	30,000
Consumable Air Jig Supplies (in kind)	$	8,500
Loader (in kind)	$	20,000
Electrical (in kind)	$	10,000
Erection Labor (in kind)	$	6,000
Construction Crane (In-Kind)	$	9,500
Power for operation (In kind)	$	6,000
Subtotal	**$**	**202,000**
Pilot plant testing Budget - Evaluation & Optimization		
Cleaning Plant Optimization (U of Kentucky)	$	40,000
Balance of Plant Impacts and Disposal (EERC)	$	279,230
Commercial Construction Cost Estimate	$	20,000
Stabilization	$	20,000
Subtotal	**$**	**359,230**

TOTAL COSTS

Pilot plant testing Budget - Total		
Capital	$	769,805
In Kind	$	202,000
Evaluation & Optimizati	$	359,230
Project Grand Total	**$**	**1,331,035**

TOTAL FUNDING

Pilot plant testing Budget - Funding		
Falkirk	$	130,000
Coteau	$	100,000
Nacco	$	100,000
EPRI	$	50,000
NDIC	$	250,000
All Minerals	$	150,000
U of K	$	32,805
EERC/DOE JSRP	$	318,230
In Kind	$	202,000
Total	**$**	**1,331,035**

TAX LIABILITY

THE FALKIRK MINING COMPANY

A SUBSIDIARY OF THE NORTH AMERICAN COAL CORPORATION
P.O. BOX 1087
UNDERWOOD, NORTH DAKOTA • (701) 442-5751

March 30, 2004

TO WHOM IT MAY CONCERN:

The Falkirk Mining Company does not have any outstanding tax liens or liabilities, and is current with all Federal and State tax reporting agencies.

If you have any questions, please contact the undersigned or Bob Carlton – Controller and Director of Tax (Corp.) at our Dallas headquarters.

Sincerely,

THE FALKIRK MINING COMPANY

William C. Thompson
Business Manager

CONFIDENTIAL INFORMATION

NONE

Appendix A -KEY PERSONNEL RESUMES

RICHARD S. WEINSTEIN

Experience:

The Falkirk Mining Company – Underwood North Dakota

2000 – Present	Engineering-Coal Research Manager
1999 – 2000	Assistant Production Manager
1998 - 1999	Manager Technical Group
1990 – 1997	Assistant Engineering Manager
1988 – 1989	Overburden Removal Manager
1985 – 1987	Senior Field Engineer
1983 – 1984	Mining Engineer

Thunder Basin Coal Company – Wright WY

1981 - 1983	Mining Engineer – Senior Mining Engineer

Kerr KcGee Nuclear Corporation – Grants NM-Casper WY

1976 - 1980	Engineer – Engineering Supervisor

The University of Arizona – Tucson AZ

1976 -1976	Geomechanics Laboratory Assistant

Magma Copper Company – San Manual AZ

1972 - 1975	Engineer Trainee – Coop Student

Education:

1971 - 1976	Bachelor of Science – Mining Engineering, University of Arizona (Tucson, AZ)
1969 -1971	Associate Applied Science – Civil Engineering, Erie Community College (Buffalo NY)

JASON D. LAUMB
Research Manager
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: jlaumb@undeerc.org

Principal Areas of Expertise

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

Qualifications

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

Professional Experience

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

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

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

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

Professional Memberships

- American Chemical Society

Publications and Presentations

- Has coauthored numerous professional publications

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℠ (CATM®) at the EERC. He is responsible for identifying research opportunities and preparing proposals and reports for clients.

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

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

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

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

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

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

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

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

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

Professional Memberships and Activities

United States Senate Committee on the Environment and Public Works

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

- Elsevier Science, *Fuel Processing Technology*
    - Editorial board member whose role is to provide advice and direction for the journal.

Publications and Presentations

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

DR. DONALD P. McCOLLOR
Research Scientist
Energy & Environmental Research Center (EERC)
University of North Dakota (UND)
PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181
E-Mail: dmccollor@undeerc.org

Principal Areas of Expertise

Dr. McCollor's principal areas of interest and expertise include coal combustion kinetics and inorganic transformation and deposition processes. He has extensive experience in the collection, analysis, and interpretation of data from bench-, pilot-, and full-scale combustion systems and in the development of predictive models to assess combustion and ash deposition behavior.

Qualifications

Ph.D., Physical Chemistry, University of North Dakota, 1981.
B.A., Chemistry, University of Minnesota, Morris, 1974.

Professional Experience

1983 – Research Scientist, EERC, UND. Dr. McCollor's responsibilities include design, construction, and operation of equipment and instrumentation for combustion research; analysis and interpretation of results from combustion tests; and development of models to predict ash transformations and deposition.

1981 – 1983 AWU Postdoctoral Fellow and Research Chemist, Grand Forks Energy Technology Center, U.S. Department of Energy, Grand Forks, North Dakota. Dr. McCollor's responsibilities included conducting research to characterize inorganic species in coal and products from coal combustion. Computer-based statistical and data reduction methods were extensively used to interpret data from a variety of analytical instruments. Position included research to develop and modify sampling techniques and analytical methods.

Professional Memberships

- American Chemical Society
- American Crystallographic Association
- The Combustion Institute
- North Dakota Academy of Science

Publications and Presentations

- Has authored or coauthored numerous publications

Mr. David O'Connor

EPRI

Mr. O'Connor has 17 years experience managing complex, multi-party, multidisciplinary energy research and development projects at EPRI on fuels and their applications in power generation and combustion. Mr. O'Connor directs the development and implementation of lignite projects at EPRI. He provides technical leadership, programmatic guidance, technology transfer, and fiscal management of the effort. Additionally, he provides research planning, schedule and budget control, and project management for other fuel-related efforts, including slagging, fouling, fuel-related SCR catalyst degradation, biomass power generation, co-firing petroleum coke, novel material handling advances, and utility fuel procurement procedures, tools, and software. He holds a BS degree in mining engineering from the South Dakota School of Mines and Technology.

Rick Q. Honaker

Rick Homaker will serve as a Co-Investigator. He is an Associate Professor of Mining Engineering at UK. He received his B.S., M.S., and Ph.D. degrees in Mining & Minerals Engineering from Virginia Tech. His research and teaching specialty is in the area of Coal and Mineral Processing. He has served as the Principal Investigator on projects with funding greater than $2.5 million in the areas of processing plant operations and optimization, gravity concentration, froth flotation, dewatering and other related areas. He has over 70 publications in journals and proceedings covering his research efforts. He is currently a member of the editorial board of three professional journals.

APPENDIX B LETTERS OF SUPPORT

EERC
Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

15 North 23rd Street — PO Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

March 30, 2004

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: Letter of Support for Falkirk Mining Proposal Entitled "Lignite Fuel Enhancement: Dry Process Coal Cleaning"

Dear Mr. Weinstein:

The Energy & Environmental Research Center (EERC) is pleased to show our support through participation for the proposed lignite-beneficiation demonstration project at North Dakota lignite mines.

The approach for utilizing dry cleaning methods and magnetic separation to remove waste and undesirable materials from currently unmarketable or less desirable lignite deposits is innovative and has broad application to lignite coals being burned for electric power generation. We see significant benefits in resource utilization and reduction of trace metal and particulate emissions when this project is successful.

We confirm our interest in this work and fully support the goals and objectives of this project. We appreciate the opportunity to participate in the demonstration project and look forward to being able to assist you in applying the technique more broadly following the successful demonstration of the 5-ton/hour unit at your lignite mines. The successful completion of this project will have a positive economic impact on the lignite industry in the state of North Dakota and will have applicability to low-rank fuels in general.

Sincerely,

Jason D. Laumb
Research Manager

JDL/rlo

Printed on Recycled Paper

EXPORTech Company, Inc.

Building 242, Schreiber Industrial District, 12th Street
P. O. Box 588, New Kensington, PA 15068-0588
(724) 337-4415 / FAX (724) 337-4470
www.magneticseparation.com

March 26, 2004

Mr. Richard S. Weinstein
Engineering Manager
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: NDIC Lignite Research Program Grant Application
Support for Falkirk Mining Proposal
"Lignite Fuel Enhancement: Dry Process Coal Cleaning"

Dear Mr. Weinstein:

EXPORTech Company, Inc., is pleased to endorse and show our support for the proposed lignite-beneficiation demonstration project at North Dakota Lignite mines.

The approach for utilizing dry cleaning methods and magnetic separation to remove waste and undesirable materials from currently unmarketable lignite deposits is innovative and potentially has broad application to lignite coals being burned for electric power generation. We see significant benefits in resource utilization and emissions reduction if this initiative is successful.

We confirm our interest in this work and fully support the goals of the project. We appreciate the opportunity to participate in the demonstration project and look forward to being able to assist you in applying the technique more broadly following the successful demonstration of the 5 ton per hour unit at your lignite mines.

Yours truly,

[illegible]
[illegible]

UK
UNIVERSITY OF KENTUCKY

Department of Mining Engineering
College of Engineering
230 Mining & Mineral Resources Bldg.
Lexington, KY 40506-0107
(859) 257-8026
Fax: (859) 323-1962
www.uky.edu/dept/mining

March 24, 2004

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: NDIC Lignite Research Program Grant Application
Support for Falkirk Mining Proposal
"Lignite Fuel Enhancement: Dry Process Coal Cleaning"

Dear Mr. Weinstein:

The University of Kentucky is pleased to endorse and show our support for the proposed lignite-beneficiation demonstration project.

The approach for utilizing dry cleaning methods and magnetic separation to remove waste and undesirable materials from currently unmarketable lignite deposits is innovative, and potentially has broad application to lignite coals being burned for electric power generation. We see significant benefits in resource utilization and emissions reduction if this initiative is successful.

We confirm our interest in this work and fully support the goals of the project. We appreciate the opportunity to participate in the demonstration project and look forward to being able to assist you in applying the technique more broadly following the successful demonstration of the 5 ton per hour unit at your lignite mines.

In support of the project, the University of Kentucky will provide in-kind support in the form of manpower for the design and performance of the experimental program as well as performance data analysis. The in-kind contribution devoted to the project will be $32,805.

We look forward to working with you on this very promising project.

Regards,

Rick Honaker

Rick Honaker
Associate Professor

An Equal Opportunity University

COTEAU
THE COTEAU PROPERTIES COMPANY

A SUBSIDIARY OF THE NORTH AMERICAN COAL CORPORATION

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

Marc M. Schulz
President

March 26, 2004

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: NDIC Lignite Research Program Grant Application
Support for Falkirk Mining Proposal
"Lignite Fuel Enhancement: Dry Process Coal Cleaning"

Dear Mr. Weinstein:

The Coteau Properties Company is pleased to endorse and show our support for the proposed lignite beneficiation demonstration project at North Dakota lignite mines.

The approach for utilizing dry cleaning methods and magnetic separation to remove waste and undesirable materials from currently unmarketable lignite deposits is innovative, and potentially has broad application to lignite coals being burned for electric power generation. We see significant benefits in resource utilization and emissions reduction if this initiative is successful.

We confirm our interest in this work, and fully support the goals of the project. We appreciate the opportunity to participate in the demonstration project, and look forward to being able to assist you in applying the technique more broadly following the successful demonstration of the five ton per hour unit at lignite mines.

Sincerely,

THE COTEAU PROPERTIES COMPANY

Marc M. Schulz
President

MMS:lr

March 26, 2004

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: Support for Falkirk Mining, Dry Lignite Beneficiation Project

Dear Mr. Weinstein:

As President of the Coal Preparation Society of America, I would like to express my support for the dry, lignite-beneficiation demonstration project you are proposing. Beyond the obvious benefits of improved reserve recovery, improved coal quality, and improved power plant performance, I have seen data that demonstrate coal beneficiation reduces emissions of SO_x, NO_x, Mercury, and CO_2. CO2 reduction is the direct result of the improved boiler efficiency available through the use of beneficiated coal and lignite.

I believe this project will be of substantial benefit to North Dakota and the nation as a whole.

Regards,

John K. Alderman
President
Coal Preparation Society of America

allmineral Llc
1360 Union Hill Rd.
Building 1 – F
Alpharetta, GA 30004
Telephone: 770 410-0220
Telefax: 770 410-807

March 25, 2004

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: NDIC Lignite Research Program Grant Application
Support for Falkirk Mining Proposal

Dear Mr. Weinstein:

Allmineral Llc is pleased to endorse and show its support for the proposed dry, lignite-beneficiation demonstration project. Efficiently utilizing our natural resources benefits every American by minimizing the cost of electricity. Dry cleaning of lignite will extend the mine's reserve life while providing the power plant with a more consistent product.

For coal producers, dry beneficiation can provide a competitive edge in productivity and quality. Coal that might normally be discarded in the pit due to excessive ash or sulfur can be upgraded to market quality through dry cleaning.

The electric utility will receive a more consistent lignite product that is lower in ash and sulfur. It is likely the lignite will be lower in mercury as well. All of these benefits are expected to translate into lower cost electricity while being environmentally friendly.

We confirm our interest in this work and fully support the goals of the project. Thank you for the opportunity to participate in the demonstration project

Sincerely,

Richard J. Snoby
President

LEHIGH University

Edward K. Levy, Sc.D.
Director

Energy Research Center
117 ATLSS Drive
Bethlehem, PA 18015-4729
(610) 758-4090 Fax (610) 758-5959
e-mail: ekl0@lehigh.edu

March 26, 2004

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

SUBJECT: NDIC Lignite Research Program Grant Application
Support for Falkirk Mining Program
"Lignite Fuel Enhancement: Dry Process Coal Cleaning"

Dear Mr. Weinstein:

I am very pleased to endorse and recommend your proposed lignite beneficiation project for funding by the NDIC Lignite Research Program.

The work we have done with Great River Energy shows large potential benefits from removing minerals from lignite prior to feeding it into a boiler. Mercury and SO_2 emissions are reduced, and wear and tear on pulverizers and conveying equipment should be less. The proposed scope of work for your project is innovative and promises to advance the state of the art.

Good luck with your proposal.

Sincerely yours,

Edward Levy
Director

EKL/jlj

Mr. Richard S. Weinstein
Falkirk Mining Company
Box 1087
Underwood, ND 58576

Subject: NDIC Lignite Research Program Grant Application
Support for Falkirk Mining Proposal
"Lignite Fuel Enhancement:
Dry Process Coal Cleaning"

Dear Mr. Weinstein:

Minnkota Power Cooperative, Inc. is pleased to endorse and show our support for the proposed lignite-beneficiation demonstration project at North Dakota lignite mines.

The approach for utilizing dry cleaning methods and separation to remove waste and undesirable materials from currently unmarketable lignite deposits is innovative, and potentially has broad application to lignite coals being burned for electric power generation. We see significant benefits in resource utilization and emissions reduction if this initiative is successful.

We confirm our interest in this work and fully support the goals of the project. We look forward to the successful demonstration of the 5-ton per hour unit at your lignite mines and to the possible future application for our entire industry.

Yours very truly,

MINNKOTA POWER COOPERATIVE, INC.

Luther Kvernen
Vice President-Generation

gae