<u>Lignite Fuel Enhancement</u>
Incremental Moisture Reduction Project
Phase I

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ABSTRACT

The Falkirk Mining Company, Great River Energy, and The Coteau Properties Company are proposing to increase the quality and value of North Dakota lignite coals by economically reducing the amount of moisture contained in North Dakota lignite. The process will use waste heat from the power production process to remove only a portion of the total moisture in lignite coal.

Moisture reduction will increase the efficiency and performance of lignite as a power plant fuel. Although power plants in North Dakota are designed to operate with high moisture North Dakota lignite coals, a reduction in moisture will have significant improvements for the power plants. North Dakota lignite coals contain anywhere from 36% to 42%, as delivered to a power plant. This moisture (water) significantly impacts the use of the lignite fuel. Most of North Dakota's lignite is consumed at mine-mouth power plants. These mine-mouth power plants are located at the mines to minimize transportation and the associated costs of shipping the water in the lignite. The mine-mouth power plants then ship electricity.

Although most of North Dakota's lignite is not shipped more than a few miles, the excessive moisture in the lignite still causes significant problems for the power plants utilizing the fuel. Water in the fuel impacts the power plants throughout their systems. The high moisture content affects the material handling systems. Water reduces the heat content (BTU) of the fuel, reducing the efficiency of the fuel. Thus, reduced moisture will improve the combustion process. Also, water in the lignite converts to steam in the boiler and increases the volume of the exhaust gas stream. Reducing the volume of the exhaust gas will slow the velocity of the exhaust and allow the environmental control systems to operate more efficiently.

Lignite fired power plants generate large amounts of heat, of which a large percentage is dissipated as a waste product. Utilization of this waste heat to assist and improve moisture reduction process will increase the effectiveness of the process and change the waste heat into a valuable byproduct.

The goal of this project is to develop a process that uses waste heat to reduce the amount of moisture in lignite, before it is burned in a boiler. The reduction of moisture will be incremental and will only remove that moisture that is easily removed. The objective being to improve the efficiency of the power plant by removing the amount of moisture that results in the least cost of generation.

This grant application is for Phase I of the Incremental Moisture Reduction Project. Phase I is primarily focused on basic research and related data collection. It will define the conditions and processes that contribute to economic moisture removal. This data will also allow economics to be applied to the process and will be the basis for developing a demonstration scale project. The demonstration scale project will be Phase II and will be used to show the effectiveness and viability of the process on a large scale. Phase III of the project will be the implementation of the process in an operating power plant.

PROJECT SUMMARY

Incremental Moisture Reduction is a concept whereby lignite is dried at relatively low temperatures. Only that moisture that is easily driven off is removed. The ultimate objective is to increase the efficiency and effectiveness of the lignite as a power plant fuel.

The moisture reduction (coal drying) proposed here differs from previous coal drying efforts, by others, in that these previous attempts used high temperatures to dry the lignite to very low total moisture levels. The objective of these other attempts was to remove enough weight (moisture) to allow economic shipment over long distances. These other coal-drying attempts have not been economically viable, on a large scale, primarily because of the costs associated with the required energy input. The cost to heat lignite to 300°F or more is very expensive. Also many of these previous processes grind the coal and use additives to enhance the drying and/or to prevent re-hydration; all of which further increase the costs.

The power plants in North Dakota are located near the mines that supply their lignite fuel. These plants do not need to have all the moisture removed from the lignite, in fact they were designed to burn high moisture lignite. However, reducing the moisture content can have dramatic impacts on the cost of generating electricity, if the coal can be dried cheaply and easily. North Dakota farmers have been drying wheat and other agricultural products to improve storage and handling characteristics, we are proposing to do something similar with lignite – dry the coal to improve its burning characteristics.

An incremental reduction of moisture will increase the efficiency of a power plant's boiler. Reducing the amount of water being injected into a boiler with the fuel will allow more of the fuel's heat to be used to generate steam for the turbines. Water in the fuel has to be converted into steam, which takes energy from the process of making steam for the turbines. The reduced moisture lignite will have more BTUs per pound that will translate into a higher heat rate in the boiler and ultimately more megawatts per ton.

Reduction of the water content of the fuel reduces the amount of waste steam generated with the burning of the fuel. Waste steam is a significant part of the exit gas (exhaust) volume. The volume of the exit gas impacts many of the power plants systems. Fans are used to pull the exit gas from the boiler and drive it up the stack. These fans use electrical energy and reducing the volume of the exit gas will reduce the energy requirements of the fans. On hot, humid summer days, fan capacity can be the limiting factor for electricity generated. Reduction of the volume of the exit gas will also reduce the velocity of the gas, as it moves through the system. The reduced gas velocity will significantly decrease the erosion of the ducts, caused by the abrasive components of the exit gas. The reduced volume and velocity of the exit gas will also allow the environmental control systems to operate more efficiently. Systems designed to remove particulates and sulfur dioxide will be able to remove more at cheaper costs. Furthermore, improving the efficiency of a power plant will also mean that there will be less carbon dioxide (greenhouse gas) generated per megawatt of electricity.

The incremental reduction of moisture in lignite improves a power plant's efficiency while at the same time reducing and/or improving the emissions from the plant.

The research proposed under this grant application, is directed at determining the viability of large-scale incremental moisture reduction of North Dakota lignite coal. Overall, the project will have three phases:

Phase I – Basic research and data collection
Phase II – Demonstration scale
Phase III – Full production installation

Phase I of the project is the only part being currently proposed under this grant application. The objective of Phase I is to do basic research and data collection on incremental moisture reduction of lignite and to define the conditions and parameters necessary to optimize the moisture reduction.

Phase I will divide the incremental moisture reduction research into several modules. The modules will be a combination of bench scale tests, field projects tests, and associative data analysis. Outside consultants will be utilized, as needed, to assist in the work and to add their expertise to the project. Each module will be designed to collect data on various aspects of incremental moisture reduction and its utilization in a coal-fired power plant. The modules will be designed to be independent of each other, but they will also be designed to collect complimentary information that will help develop the total picture that will be the blueprint for the Phase II – Demonstration Scale Project.

As a concluding statement, drying materials is not an absolute science. Cook states, "dyer designs are based, not on theoretical concepts, but on data from pilot tests or from past experience." There are many variables involved in drying any substance and lignite coal is considered one of the most heterogeneous substances on earth. Consequently, the only way to understand the process of low-temperature lignite drying is to test it and try it. This project (Phase I) is proposing to do just this – To set-up tests to reduce the moisture in lignite.

PROJECT DESCRIPTION

Phase I of the Incremental Moisture Reduction Project is primarily the research phase of the project. Many questions need to be answered and probably a few more questions need to be discovered. The different parts or areas of investigation of Phase I are divided into modules. The individual modules each look at different aspects of the problem of drying lignite with low temperatures. Some aspects of the modules overlap others, but all the objectives are designed to be complimentary to each other and add to the total information needed to move on to the next phase (Demonstration Scale). The four modules included in this phase of the project are titled as follows:

Module 1 – Continuation of Falkirk's Experiments
Module 2 – UND Mechanical Engineering Department Studies
Module 3 – Plant Systems Performance Modeling
Module 4 – Outdoor Stockpile Test

Each module is described and defined below:

Module 1 – Continuation of Falkirk's Experiments

Appendix A – Preliminary Research describes the experiments Falkirk and GRE have already conducted. These experiments have obtained some very useful, positive results, they have also highlighted some questions that need to be answered. To achieve the next step and work towards some of the information we need to continue the project, Falkirk has designed a second coal drying barrel.

Figure 1 is an illustration of the plans for the second coal-drying barrel. This apparatus is designed for two primary objectives: To measure the resistance of crushed coal to airflow and to find the maximum moisture reduction rate versus airflow and temperature.

The new barrel is actually two 55-gallon barrels that are stacked one on top of the other. This will create a column of coal over six feet high. The height is important in that it will allow for more accurate measurement of the resistance the coal has to air flow – How much air pressure is needed to force air through the coal. Air pressure ports will be inserted into the sides of the barrel, evenly spaced, from top to bottom. These ports will be connected to a manometer on a periodic basis to measure the air pressure differential between any two set of ports.

It is estimated that the stacked barrel will hold about 800 pounds of crushed lignite. Near the bottom of the barrel, an expanded metal plate will hold the coal up off the floor of the barrel. This space will allow room for a 6-inch diameter duct to pump air into the barrel. As shown in Figure 1, a fan with electric air heaters will draw ambient air into the barrel, at specified temperature and airflow rate. The heaters are designed to heat the air to a maximum of 150°F and the fans to pump the air at up to 140 CFM. The temperature and airflow rate will be varied during different experiments to examine their effects on the drying rate. It is also anticipated that the manometer readings will show increasing pressure differentials as the airflow rate is increased.

Figure 1 Illustration of Falkirk's Second Coal Drying Barrel

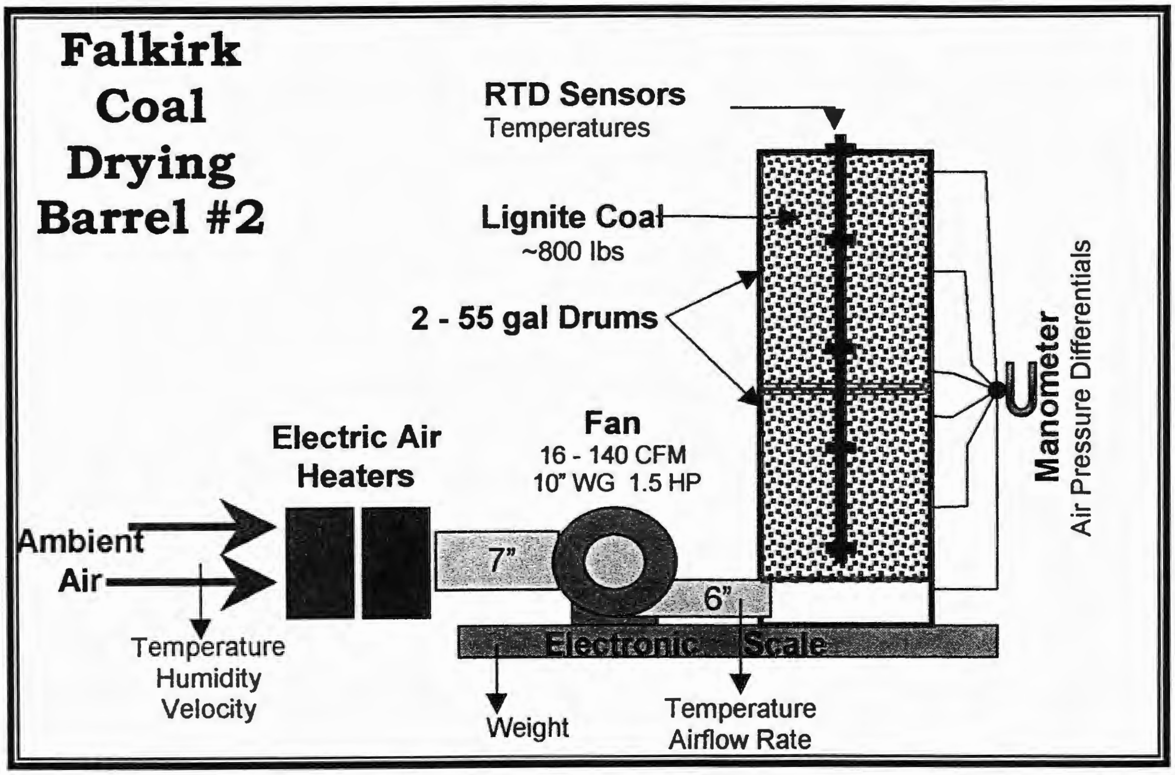


Figure 1 shows the barrel assembly sitting on an electronic scale. This is scale is capable of weighing up to 2,000 pounds to an accuracy of 0.1 pounds. Weight readings will be collected periodically during tests to determine weight loss. The weight loss will be due to the loss of moisture and allows the moisture reduction progress to be monitored in real time while the test is in progress. Care and observations will be taken to insure that the airflow is not so high as to blow coal (dust or fragments) out the top of the barrel. If coal is blown out of the barrel, the weight loss will no longer be indicative of moisture reduction. During our previous testing, a white cloth was placed on the lid of the barrel around the stack. The white cloth was monitored for coal dust/fragments, which would readily show on the white background.

Thermocouple sensors (as shown in Figure 1) will be placed on a rod that will be positioned in the middle of the barrel. The purpose of these sensors is to monitor the temperature of the crushed coal during the test. Based on the preliminary tests, it is expected that the thermocouples will show the progress of the heated air through the barrel. The input heat will be moderated by evaporation absorbing some of the heat energy. The heat of evaporation impact will lessen as the moisture is reduced, allowing the temperature to approach that of the input air. This evaporation effect should appear first near the bottom of the barrel, where the air and coal first interact. As the coal begins drying near the bottom, the evaporation effect will move up through the barrel. The thermocouples in the coal barrel will allow this effect to be tracked and monitored.

The previous paragraph describes the anticipated effect that evaporation will have on the temperature in the coal barrel. However, this description is a bit simplified. Evaporation of water is endothermic; it absorbs heat. As the heated air flows through the coal, water will evaporate and the temperature of the air will decrease. If the evaporation rate is high enough, the temperature will continue to drop as the air picks up more moisture until it is saturated (see Figure A-7 Moisture Carrying Capacity of Dry Air). At this point, saturated air will not evaporate any more water and if the temperature drops further, water would condense out of the air. The airflow rate enhances the evaporation process and can be made to work for incremental moisture reduction. The airflow rate will move the air past the coal fragments and allow water in the coal to evaporate. The continuous supply of new air will keep the evaporation active and move the air up through the barrel to evaporate additional water. The balance will be to have enough heat left in the air to avoid saturation, without wasting energy with too much heat. It is also important to minimize the airflow as pumping air does cost money.

Other thermocouples will be positioned to record the temperature of the air being brought into the system and after the heaters.

All the tests conducted under this module will use coal that is crushed and used as pulverizer feed (3"x0). In other words, the coal barrel will be filled with coal that represents actual crushed coal.

Individual tests will be run for duration ranging from 3 days to 2 weeks. Analysis of data being collected during the test will determine if the test continues or is terminated (based on the objectives).

The first test in the barrel will be with Falkirk coal from Coal Creek Station. It will be as crushed from the feed into the pulverizers. Initially the airflow will be varied to establish a range, and the first test will be set at an airflow rate near the middle of the range. The first test will also have the air temperature set at 120°F. The first test will be run long enough to establish the rate of moisture loss at the set airflow and temperature. Subsequent tests will be run to establish the relationship between moisture loss, airflow, and temperature. Each test will be designed to help bracket and define this relationship. One of the primary objectives of this module will be to determine the airflow and temperature combination that optimizes the moisture reduction rate.

It is also planned that coal will be used from The Coteau Properties Company, Freedom Mine north of Beulah, North Dakota. Once relationships are established with Falkirk coal, rerunning the tests with Coteau coal will show the similarities and differences. This comparison will be important, as it will define how different coals may react in the process and the adjustments that would be required. It will also be important to study different coals in the process as over time the coal a mine is mining, may change its properties.

The coal being used for each test will be sampled in layers as it is loaded into the barrel (about two foot layers). The coal will be sampled again when it is removed from the barrel after drying. The samples will be analyzed for the ASTM Short Proximate Analysis Suite: Total Moisture, Ash, Heat Content (BTU/lb.), and Total Sulfur. The purpose of these analyses will be to confirm the drying of the coal and to establish the general character of the coal. The analyses will also help insure that coal with unusual properties does not cause anomalous moisture reduction data.

To summarize the objectives for Module 1 – Continuation of Falkirk's Experiments, the work plan involves running multiple batches of coal through the barrel apparatus. Data will be collected on each batch of coal as it is processed in the barrel. The data will be collected to meet the following objectives:

- How much air pressure is needed to force air through crushed coal?
- Does the air pressure requirement change as air flow changes?
- What are the relationship of airflow and the rate of moisture reduction?
- What are the relationship of temperature and the rate of moisture reduction?
- How does airflow and temperature work together to effect the rate of moisture reduction?
- What is the optimum or target moisture for moisture reduction?

Module 2 – UND Mechanical Engineering Department Studies

Coal Creek Station has been working with UND's Mechanical Engineering Department to develop processes and strategies for the incremental moisture reduction project. Senior engineering students, under the direction of a professor, are designing and testing these processes as part of their senior research project.

During the initial stage of the project, a test dryer was built and heated air was circulated through a lignite bed using high airflow (ten times the flow of the Falkirk test). The objectives of this first phase was to demonstrate that lignite could be dried using air temperatures of 85°F in a relatively short time period. The initial dryer demonstrated that 25% of the lignite moisture could be removed in three hours using the Coal Creek Station waste heat. The high airflow produced several problems including suspension of coal particles and high power use.

Based on the initial results a second stage of testing is planned. The objective of the second stage is to demonstrate that airflow can be reduced to an economical level and still achieve similar drying results. This will be accomplished by adding additional heat transfer surfaces within the coal bed so that the air is not the soul source of heat for the drying process. A variable speed fan will be added to the dryer to allow the testers to vary airflow. The students will develop a model of the heat transfer process in the coal bed and demonstrate that it predicts performance. The results of this test, the heat transfer model and results of the Falkirk tests can then be used in the design of a pilot plant.

Module 3 – Plant Systems Performance Modeling

Coal Creek Station was originally designed for 6800 BTU/lb. higher heating value (HHV) lignite and 37% total moisture. Although some generalizations can be made about changes in emissions, fan power, fuel and gas flow, the net affect on a furnace and its ability to absorb energy released in that volume cannot be predicted without some discrete modeling.

Modeling will be necessary to predict the affect on such things as Boiler Performance, heat flux, efficiency and steam temperatures at various heating values. What is expected is that some computational fluid dynamic model will be needed to run a base case using standard fuel. This can be verified/calibrated with actual data and then rerun with incremental changes in fuel HHV and moisture. The results would then define an optimum level or range from which the physics for the moisture removal equipment can then be designed. It may in fact show an inability to absorb enough energy. Boiler manufacturers, EPRI and others are all capable of doing this kind of analysis.

The engineering firm selected will need to obtain specific data from the plant. They may need to test for some information not normally collected. As previously mentioned, once convergence has been established and validation with real world data verified, the input moisture content of the fuel could be reduced and the model rerun. This would yield insights into the impacts of boiler performance, including changes in FEGT, heat flux, efficiency, etc. For impacts on main and reheat steam temperatures, integration to the CFD results with a steam-side code will then follow.

Analysis will also be needed on the dried product to quantify the oxygen reactivity, the impact on particle size, quantity of fines and subsequent effects on the dust handling equipment. Lignite will need to be dried to an optimum economic level whereby no major changes to the handling system or dust suppressants will be needed and add to the cost. Therefore, that optimum level must be defined and following analysis, the data will need to be verified with dust handling vendors.

To summarize the objectives for Module 3 – Plant Systems Performance Modeling, the work plan involves developing a mathematical model of various power plant systems. The model will be used to evaluate changes in the fuel (reduced moisture and size) and its effects on plant systems. The data will be collected to meet the following objectives:

- What impacts of boiler performance can be expected?
- What impacts on steam temperatures can be expected?
- What changes in material handling can be expected due to increased dusting?
- Can the plant absorb or utilized all the additional available energy?

Module 4 – Outdoor Stockpile Test

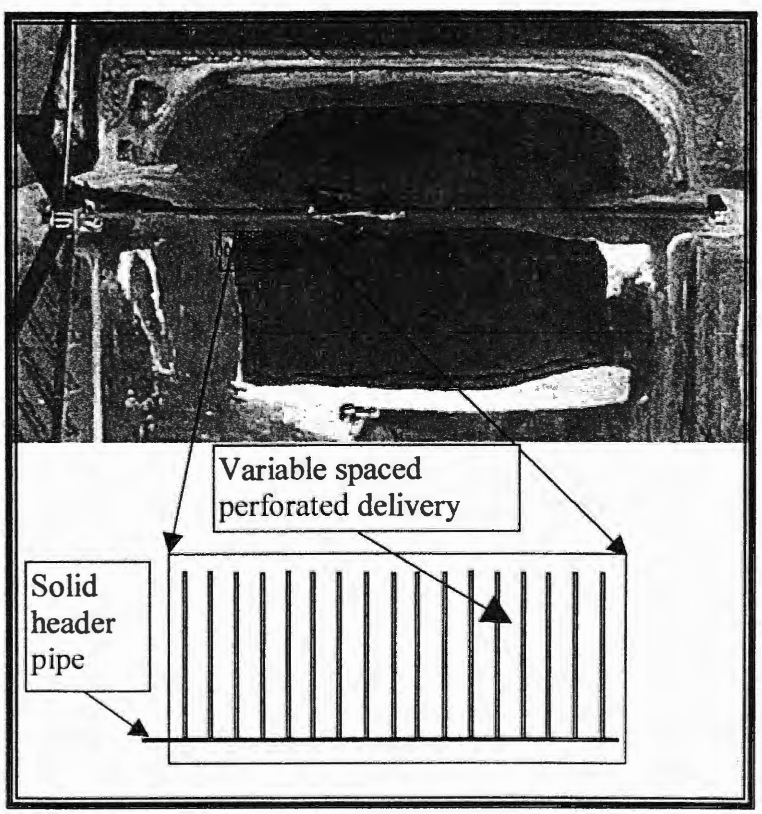
- Purpose

The photo below depicts the location and general layout for the field test project. This test is designed for two primary objectives; to determine the economics and scalability of drying lignite coal in larger quantities; and to determine the performance of Coal Creek Station in handling and burning the drying enhanced coal. This test will yield important information to further evaluate the economics and for the design of later stage tests.

- Location

The test location is shown in Figure 2. It is situated in the active lignite storage area at Coal Creek Station. The coal in this stockpile area is 3 inch minus in size. As part of normal operations, coal is periodically placed and removed from this stockpile. The timing and amount depends on power demand, equipment operation, maintenance, and the coal delivery schedule. Through normal operations, a section of the area will be cleared of coal before the test. The stockpile base is slopped away from the stacker to help drain water from the piles. This area is open to the environment so precipitation events will impact the reacquisition of water into the coal.

Figure 2 Stacker Reclaimer and Coal Stockpile Test Area



- Air delivery system

Before building the air delivery system, a bed of coal, approximately 2 foot thick will be laid down in the test area. Next, a trench will be excavated in the coal bed for the placement of a 36-inch diameter corrugated metal header pipe. Branching off from this header pipe will be a series of variably spaced, 12-inch diameter corrugated metal delivery pipes. Perforated delivery pipes will be used to allow for evenly spaced injection of air throughout the stockpile test area. The delivery pipes will be spaced at variable distances. Later sampling will determine the effect of pipe spacing on the amount of drying horizontally and vertically within in the stockpile test area. Based on the depth of the pile and weight of the overlying material the solid and perforated pipes will be fabricated corrugated metal pipes. The ends of the 36-inch and 12-inch pipes will be capped.

- Coal Stockpiling

After the pipes are laid, the trenches will be back-filled and the pipes covered using methods to minimize compaction and prevent the delivery system from being damaged. Next, the stockpile will be filled with coal delivered from the mine. This process will be controlled to ensure that the coal delivered will be of typical delivered quality and will have typical handling characteristics. Samples will be taken as the coal is placed in the stockpile, using methods to accurately establish the initial quality of the coal in the test area. After the stockpile is completed, instrumentation will be put in place to monitor the internal and surface temperature of the pile.

- Air Delivery System

The basis for this test are the results from an earlier test which showed that the flow of air past the coal removes a substantial amount of the moisture from the coal. The design of the stockpile results in a volume of approximately 400,000 cubic feet of space. Assuming that the air will move fairly equally through this mass of the coal to the nearest surface a fan sized to provide one air change every four minutes will be used to force the air through the delivery system piping. In the initial barrel tests at Falkirk at one air change per minute, there was very little measurable resistance from the coal mass. There appears to be enough space between the stockpiled coal pieces to allow the air to flow freely.

- Monitoring.

Performance of the fan and its output will be measured periodically throughout the test. In addition, the temperature readings of the air being delivered to the solid header pipe will be recorded as well as the humidity in the feed air. Temperature sensors will be placed at multiple locations within the test area of the stockpile to track the temperature during the test. For background comparison, baseline temperatures will be measured at locations away from the test area. Bulk samples will be taken from various depths during the test and the results will be used to determine when the drying has reached the test goal of 32 percent or less moisture. In addition a heat sensing gun will be used to document the overall surface temperature of the pile to provide insight into the dispersion or concentration of the air being exhausted to the surface of the pile. In addition the surface monitoring will help document heat buildup in the pile. Adjacent portions of the pile will be surveyed with the heat sensing gun. This will provide baseline information of the stockpile characteristics. With this information we will be able to compare the test area to areas outside of the air distribution grid.

- Coal Reclaim

When the coal has reached an equilibrium level or has met the desired moisture content the coal will be reclaimed. Based on the size of the air distribution grid it is estimated that approximately 15,000 tons of drying enhanced coal will be available for delivery to the power plant. Visual observations will be made of the coal handling process. The handling characteristics of the coal and the amount of dust generated will be documented. The delivery will be planned so that the dried coal will be either blended with non-dried coal or shipped directly to the boilers. Based on the sample results and the amount of coal that is dried, it is possible that several different tests can be run. It is desired to determine the effect that the various spacing of the delivery pipes has on the achieved moisture content. During the reclaim process, several samples will be taken from various depths in the stockpile. The elevation of the bucket wheel reclaimer will be controlled so sufficient samples can be taken. Care will be taken to remove all but a few feet of coal near the delivery pipes. With the delivery system integrity preserved, subsequent tests can be made.

- Measuring Plant Performance.

Based on the typical quality of delivered coal, drying to a moisture of 32% or less is expected to yield an enhanced coal with a heat value approaching 7,000 BTU/Lb. It is assumed that the test area will yield sufficient tons of dried coal at this heat value to run the boilers for some time period, so that performance from the pulverizers all the way to the exit of the exhaust gas from the stacks can be assessed. Just before entering the boiler-generator building, the coal passes through an ASTM compliant sampler, which can be set to take samples for multiple timeframes. By tracking the quality of the input coal and the resulting generation exhaust system performance, analysis can be made to document the results of burning higher heat value coal. These analyses will help confirm modeling and add empirical data on the plant's performance at various heat values of coal.

Prior to burning the drying enhanced fuel, the plant should have run on typical coal quality from the mine, and any unusual performance situations documented so they will not be confused with the effects of higher heat value coal.

- Number of tests

It is expected that waste energy at the plant will ultimately be able to provide heated air for coal drying at approximately 110 degrees Fahrenheit. From the information provided in figure A-7, it can be seen that the amount of moisture air can carry at 110 degrees Fahrenheit is approximately 5 times greater than at 70 degrees Fahrenheit. Using the initial test performance, a series of additional tests will be conducted to provide coal to successively higher BTU Values. These tests will use heated air at 110 degrees Fahrenheit by using portable Tioga heaters possibly reducing the size of the test zone. Similar testing and performance monitoring is proposed for each of four test runs:

1) Using air only
   a) Produce 7000 BTU or 32 % Moisture
   b) Produce 7800 BTU or 24% Moisture
2) Using 110 Degree air
   a) Produce 7000 BTU or 32% Moisture
   b) Produce 7800 BTU or 24% Moisture

- Timing of project.

To minimize complications due to freezing weather conditions it is proposed that the materials be purchased and the test area prepared by mid May, with coal being placed in the test area in late May. Temperature, humidity, and coal pile resistance to air flow will determine the actual duration of the first drying test. Based on preliminary results from the from barrel tests and sizing of the fan for this test, it is expected that a time frame of four weeks may be needed to reach a moisture content of 32 percent. Heavy rains in the spring and summer are possible and this would then extend the length of time needed to achieve the desired moisture content. Reclaiming the coal will be a rapid process and through normal mine operations the test area could be replenished within a few days to begin the next test. Physical testing should be completed in October.

- Restatement of purpose

The outdoor stockpile test will investigate the economics of coal drying, and large-scale design feasibility of drying lignite coal. The tests will identify handling characteristics of the dried fuel. In addition, performance will be measured and documented to determine the effect that dried fuel has on the overall plant economics.

STANDARDS OF SUCCESS

The standards of success for Phase I of the Incremental Moisture Reduction Project will be to define the following:

1. The optimal heat and air combination to remove moisture from lignite
2. The amount of pressure required to move the needed amounts of air through a volume of lignite.
3. Define various methods to deliver the air and heat to the lignite
4. Define the changes in characteristics of moisture reduced lignite
    1. Changes is size distribution
    2. Changes in grindability
    3. Changes in reactivity
5. Define the impact on the power plant systems
    1. Boiler and steam systems
    2. Pulverizers and Dust Collectors
    3. Fans
6. Issue a final report on all the activities conducted under this phase of the project.
7. Using the knowledge gained from Phase I begin developing plans for a demonstration scale plant. This will include determination of the optimal amount of moisture reduction or, in other words, a target moisture (e.g., 32%, 30%, 28%, or another total moisture amount). The optimal amount of moisture reduction will be determined by applying economics to the information gained in Phase I.

BACKGROUND

The Falkirk Mining Company mines and delivers approximately 7,000,000 tons of lignite per year to Coal Creek Station, Great River Energy at Underwood, North Dakota. Falkirk and Coal Creek have always worked together to try to improve the cost effectiveness and reduce the environmental impact of the energy facilities. Towards these ends we have looked at the moisture content of the lignite.

Lignite is a rank of coal that lies between peat and bituminous. Lignite has had its organic structure modified somewhat, but is not carbonized to the extent that bituminous coal has. A characteristic of lignite coal is its moisture content. The total moisture content of lignite ranges from less than 35% to more than 45%. Thus, a significant part of lignite is water. This water is found in the lignite in many forms. Some of the water is chemically bound to the organic molecules in the coal and a very small amount of the water is chemically bound to the minerals in the coal. Most of the water is found in the familiar form of free water. The free water in lignite is held in the pores and fractures within the coal, much of which is on a microscopic scale.

As Coal Creek and Falkirk began investigating coal drying, we found numerous references and studies. All of these drying processes had the objective of reducing the moisture in lignite to the point where it would be economic to ship lignite a long distance. They also seemed to be centered on in-line processes that involved only a few hundred tons per hour. To achieve the objective of almost no moisture (<10%) most of the processes crush or pulverize the lignite and subject it to very high temperatures (300°F-700°F). They also include additives, such as, oils, waxes, carbon dioxide, nitrogen oxide, etc. The economics of these drying processes are very high. There is a lot of energy input for these processes to work, which makes the moisture reduction very expense. Falkirk and Coal Creek decided that we could not afford to dry our lignite with any of these methods.

Engineers at Coal Creek made of observation that even a partial or incremental reduction in moisture would have significant impacts on the power plant. As this idea developed we began looking for heat sources. Generating heat costs money but with a coal burning electrical generating power plant next to a lignite strip mine we thought there would be a possibility to tap existing heat sources. One problem with tapping into existing heat sources within the power plant is that the heat is necessary and is usually in a very delicate balance, pulling heat out of the system could be detrimental to the power plant. However, heat is also a waste product of the power plant. Figure 3 Sources of Waste Heat at Coal Creek Station illustrates the two major waste heat sources: The stacks and the cooling towers. When one looks at a coal-fired power plant, you usually see a lot of white "smoke". In reality this is not smoke but steam.

Steam, we all know is just very hot water or water with enough energy in it to cause it to vaporize. Water in the exhaust stacks at a power plant must be in the form of steam to get it up and out the top. After the exhaust exits the top of the stack, the energy in it is excess or waste. The other source of waste heat shown in Figure 3 is the cooling towers. Cooling towers takes the water that was made into steam in the boiler and then turned the turbines until it lost too much of its energy. This boiler water must actually be cooled before it can be returned to the boiler to be heated again. This cooling is removing waste heat.

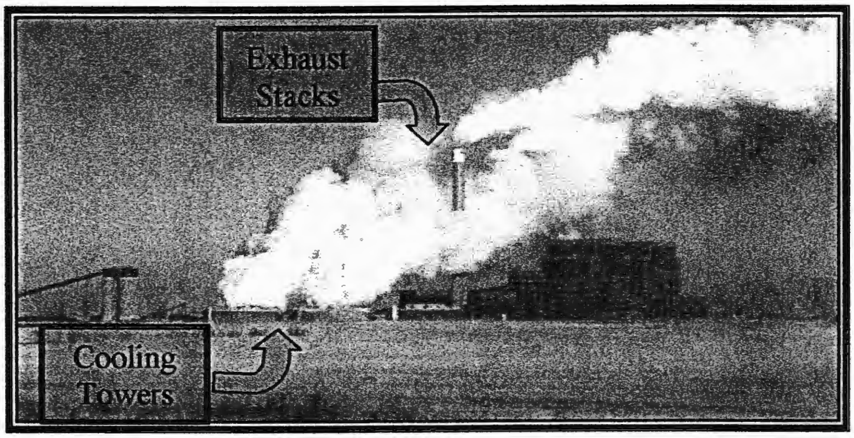
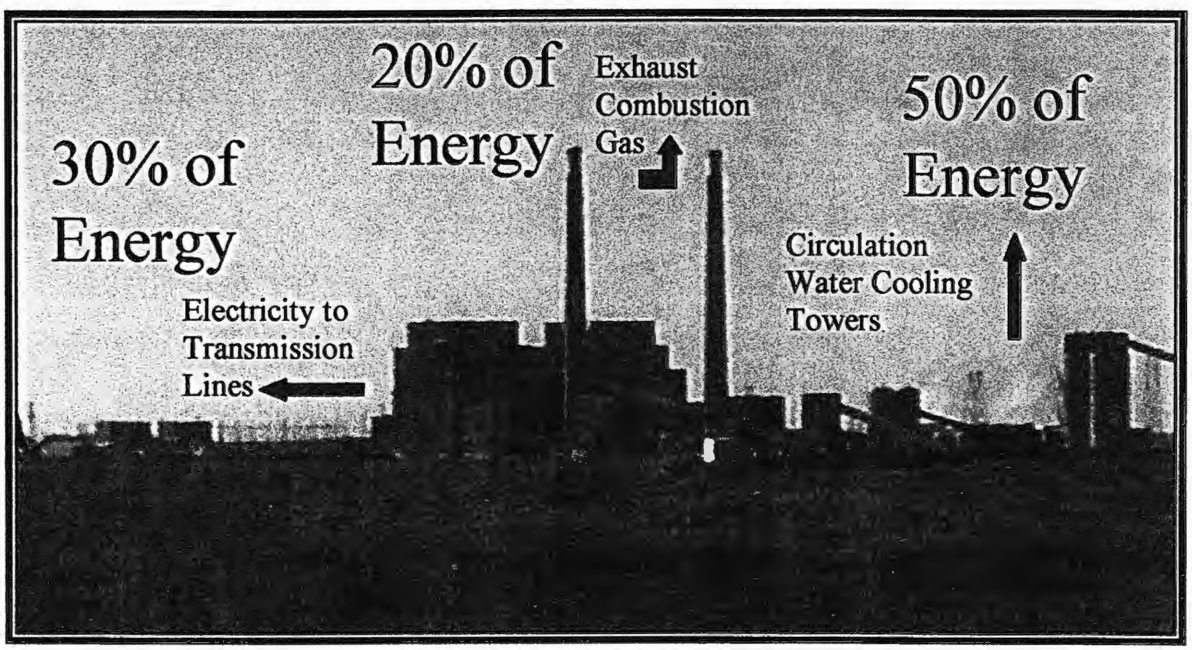


Figure 3
Sources of Waste Heat at Coal Creek Station (Underwood, ND)

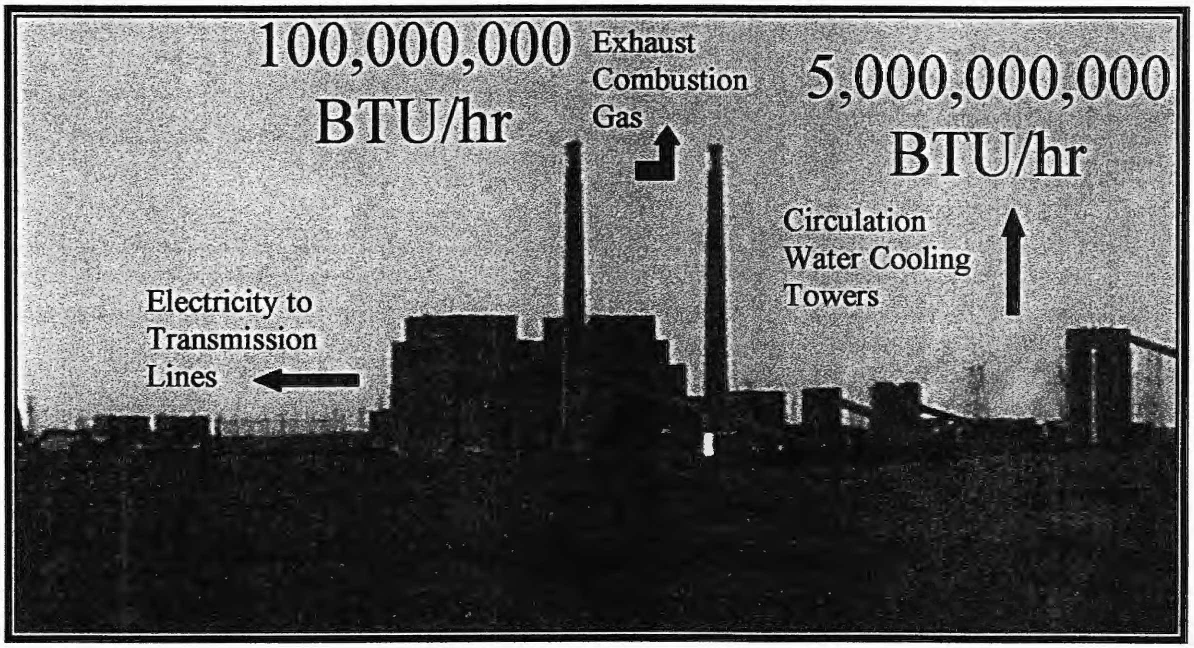
Continuing with the thought of using waste heat, as an energy source for incremental moisture reduction of lignite is the question -- How much waste heat is available? Figure 4 Balance of Energy Output from Coal Creek Station shows the major energy output streams. Most coal-fired power plants are about 30% efficient. About 30% of the total energy consumption is actually converted into electricity that is transmitted to consumers. The remaining 70% of the energy is not used or is waste (as dictated by the laws of thermodynamics). Figure 4 shows that at a power plant like Coal Creek Station there is a huge amount of energy being discharged.

Figure 4 Balance of Energy Output from Coal Creek Station



The amount of energy discharged from a power plant is very large. Figure 5 shows that for Coal Creek Station the heat energy released up the stacks is about 100,000,000 BTU/hour. From the cooling towers, it is 5 billion BTU/hour.

Figure 5 Amount of Heat Energy Released from Coal Creek Station



Capturing the heat energy being released up the stacks for use in a dry process would be difficult. Removing heat from the stack before it exits would jeopardize the energy balance in the stack and could result in excessive condensation inside the stack. The cooling towers are another matter. Water enters the towers at about 120°F and is cooled to about 90°F. It is the 30°F temperature drop that results is the 5 billion BTU/hour energy release. This water is pumped to the towers in pipes and returned in pipes, making access to this heat source relatively easy.

The problem at this point is that the cooling tower water is relatively cold. Our literature research had shown everyone had been using temperatures that were much higher. However, as was previously discussed, the other processes were also trying to take all the water from the coal. From this our question became: Could we remove some of the water from coal with low temperature drying?

To answer the question of weather or not coal could be incrementally dried with a low temperature process, Falkirk and Coal Creek undertook some preliminary testing. This preliminary research is discussed in Appendix A. We believe the results of our preliminary research have been very favorable and indicate the need for more testing, which is the objective of the work being proposed under this grant application.

QUALIFICATIONS

Key Personnel {See Appendix C – Resumes of Key Personnel}:

The Key Personnel are employees of the Applicant companies: The Falkirk Mining Company, Great River Energy – Coal Creek Station, and The Coteau Properties Company. These employees will be managing the project and/or conducting the research themselves. They will utilize the talents and expertise of other employees and hire consultants as needed to meet the needs and objectives of the project. The Key Personnel as listed below:

Dennis R. James, Staff Geologist
The Falkirk Mining Company and The Coteau Properties Company

Charles W. Bullinger, Engineering Services Leader
Great River Energy, Coal Creek Station (Underwood, ND)

Richard A. Adsero, Maintenance Engineering Manager
The Falkirk Mining Company and The Coteau Properties Company

Mark A. Ness, System Engineer
Great River Energy, Coal Creek Station (Underwood, ND)

Richard S. Weinstein, Manager Technical Group
The Falkirk Mining Company

VALUE TO NORTH DAKOTA

The benefit to North Dakota will be in the final implementation of the Lignite Fuel Enhancement -- Incremental Moisture Reduction Process in power plants within the state. This process will make the State's power plants more efficient, cost effective, and environmentally compliant. This will translate into the following benefits for the State of North Dakota:

1. Increasing the profitability of the state's electrical generation industry
2. Increasing the value of the state's lignite reserves
3. Decreasing the chances of coal being imported from out-of-state
4. Improving the environment by improving the emissions from the coal-fired power plants in the state

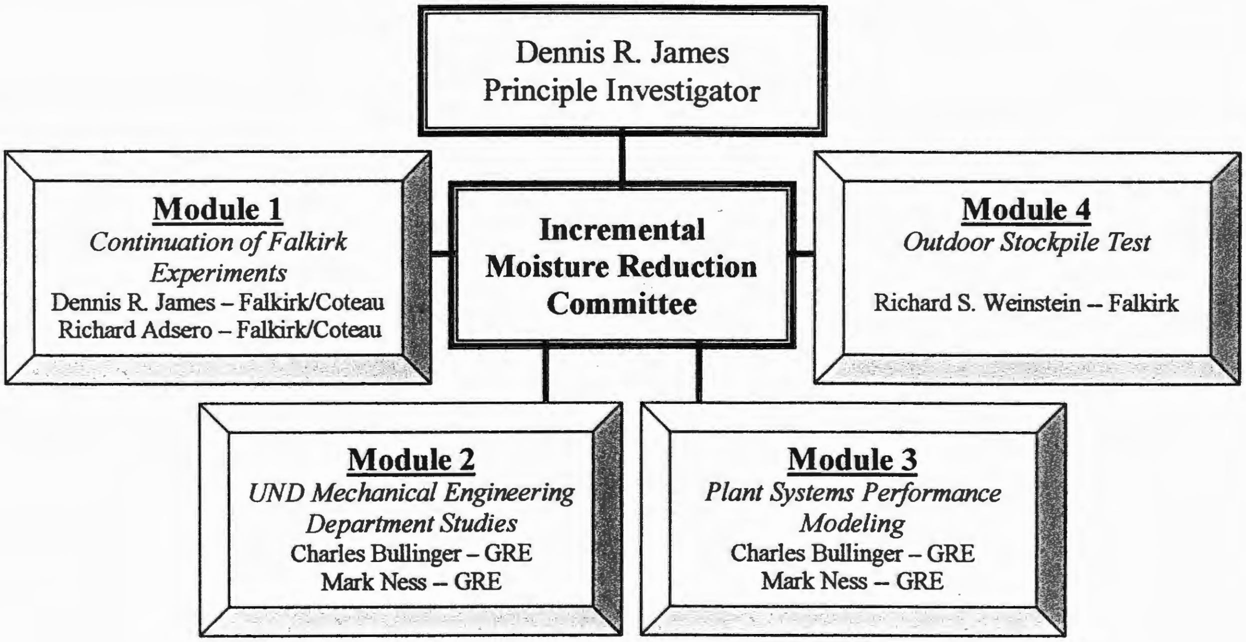
Reducing the total moisture content of lignite as little as five to six percent has a dramatic impact on the operational cost and efficiency of a power plant. If the total moisture of lignite were reduced from 38% to 32%, a power plant would save millions of dollars a year. A cost reduction of this magnitude will have a major effect on the cost of the electricity being generated and would make it more competitive in the regional electrical market. Improving the competitive position of the electricity generated in the state will result in increased power sales out-of-state and reduced costs to the in-state consumers.

Increasing the efficiency of a power plant and reducing the volume of its total emissions greatly reduces the amount of pollutants that are discharged by the power plant. Making more kilowatts of electricity per ton of coal has a large impact on the bottom line cost for the power producer, but there is also a significant reduction in pollutants that are generated. If the coal is used more efficiently and more kilowatts are made per ton of coal burned, there is a corresponding reduction for particulates, sulfur dioxide, and carbon dioxide created per kilowatt produced. In addition to decreasing pollutants by increasing the efficiency of the boiler, there are impacts to the downstream pollution control systems. Reducing the amount of steam in the exhaust of the power plant reduces the volume and velocity of the exhaust. By reducing the volume and speed of the gases electrostatic precipitators, bag houses, sulfur dioxide scrubbers, etc. can all operate more effectively on the exhaust gas. In other words, if there is less gas and it is traveling at a slower speed, the existing equipment can clean it better.

While the outcome of the proposed project is not certain, Falkirk, GRE, and Coteau are committed to maximizing the economic and environmental benefits to North Dakota. As such, they have chosen to partner with the Industrial Commission of North Dakota in this effort because of a demonstrated commitment to energy-related research and development.

MANAGEMENT

The proposed project will be managed and coordinated by Mr. Dennis R. James who will serve as the contact point for the Industrial Commission, Falkirk, GRE, and Coteau. 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:



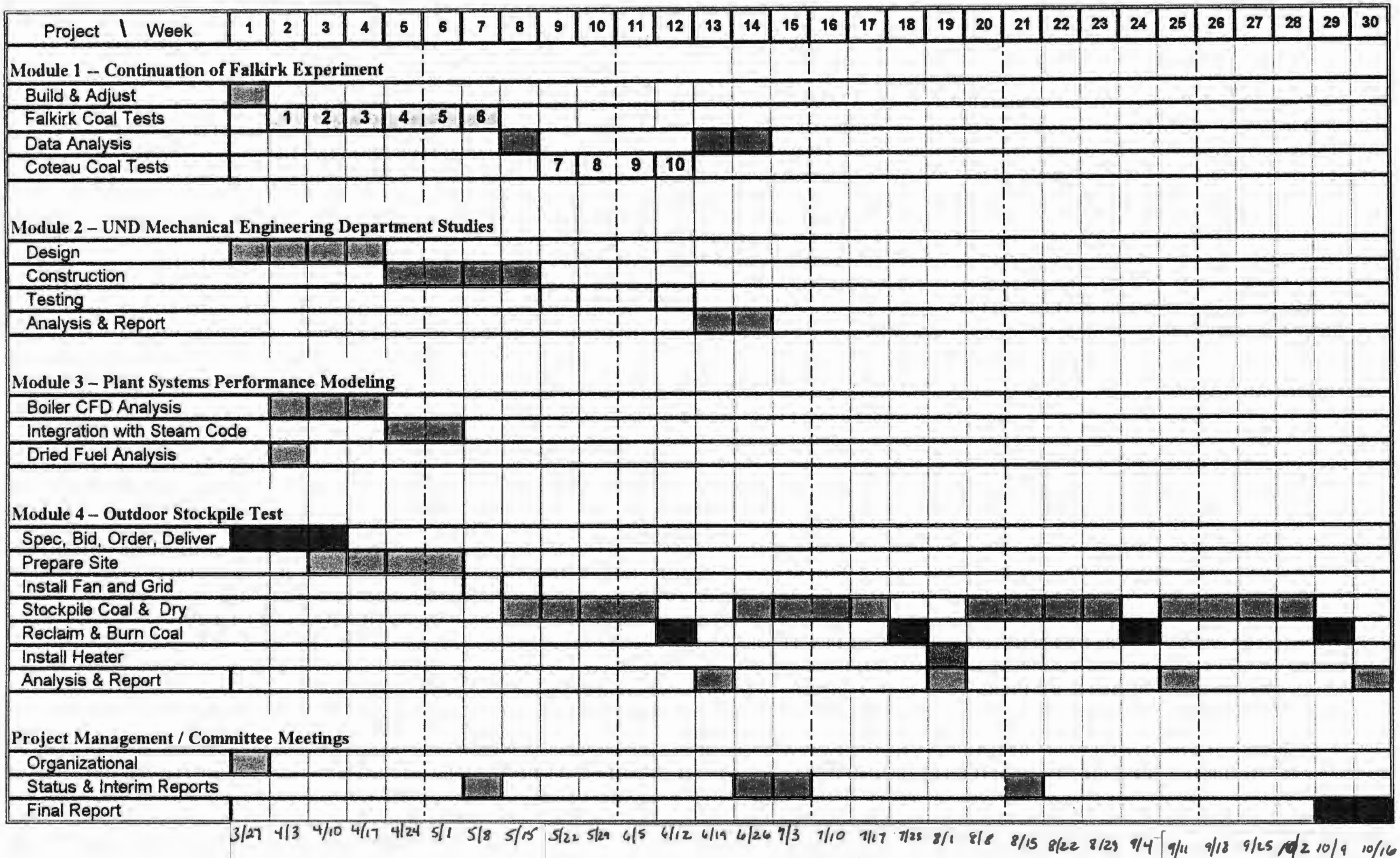
The Committee referenced in the above organizational chart is composed of the Key Personnel listed in the "Qualifications" section of this application. The committee will meet and otherwise communicate on a regular basis to keep everyone abreast of developments. These meetings and communications will serve as the basis for the interim reports. The final project report will be created as a joint effort of the committee. The Key Personnel are responsible for the work being proposed under each module of the project. The organizational chart lists the personnel that are specifically involved with each module.

TIMETABLE

Figure 5 Generalized Project Time Schedule on the following page shows the planned time schedule for Phase I of the project. This timetable is a week based schedule. After the initial week of organization and planning, work on each module will commence. The key personnel will meet and communicate on a regular basis. About every six weeks, the committee will meet and prepare an interim report of progress and findings to date.

It is anticipated that Module 4 will take longer to complete than the other modules. As such, the final report portions of the other modules will be in progress concurrent with the ongoing work on Module 4. The findings of the other modules may modify the direction of Module 4. Also the coal produced during Module 4 may be run through the power plant to test the models created in Module 3.

Figure 5 Generalized Project Time Schedule



BUDGET

Appendix D – Budget is a detailed listing of the estimated budget for Incremental Moisture Reduction Project Phase I. Appendix D lists a budget for each module, followed by a summary table. This summary table is shown below as Table 1.

Table 1 Budget Summary

	Total Project Cost Estimate
Module 1 -- Continuation of Falkirk's Experiments	$19,203.14
Module 2 -- UND Mechanical Engineering Department Studies	$14,730.00
Module 3 -- Plant Systems Performance Modeling	$28,080.00
Module 4 -- Outdoor Stockpile Test	$154,000.00
Contingency (10% of Total)	$21,601.31
Total Estimated Project Budget	**$237,614.45**

As shown in Table 1, the total estimated budget for the Incremental Moisture Reduction Project Phase I is $237,614.45. This includes equipment purchases, consultant time, and labor costs.

MATCHING FUNDS

The previously described Budget section and Appendix D – Budget details the estimated budget for Phase I of the Incremental Moisture Reduction Project. The Falkirk Mining Company, Great River Energy, and The Coteau Properties Company have agreed to provide a total contribution of $62,614.45. This contribution includes personnel, material purchases, laboratory analyses, and consultant costs. The applicants are requesting an additional $175,000.00 from the Industrial Commission of North Dakota through the Lignite Research Council.

The funds being requested under this grant application are for Phase I of the Incremental Moisture Reduction Project. Phase II of this project will be a demonstration scale plant. The nature, character, and cost of this demonstration scale plant are very tentative at this time. Completion of Phase I is important to define the design and concept for Phase II. Hence, Phase II of this project is planned to be a separate, standalone grant application; to be submitted later (after completion of Phase I).

Tax Liability

See Appendix B -- Letter affidavits stating that the following business entities owe no outstanding taxes to the State of North Dakota:

The Falkirk Mining Company

Great River Energy

The Coteau Properties Company

Confidential Information

---- None ----

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