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
World-Wide Web Server Address: http://www.eerc.und.nodak.edu

January 2, 1998

State of North Dakota
The Industrial Commission
State Capitol
Bismarck, ND 58505
Attn: Lignite Research Program

Dear Lignite Research Program:

Subject: EERC Proposal No. 98-0062

Please find enclosed the proposal entitled "Lignite Testing in the High-Temperature Advanced Furnace."

The University of North Dakota Energy & Environmental Research Center (EERC) is requesting funding to perform two pilot-scale tests of lignite in an advanced pilot-scale slagging combustor and to perform bench-scale tests of the resistance of new refractories to lignite corrosion. These tests will prove that the use of lignite fuel does not present any special problems in the operation of a very high-efficiency power system being developed by a team led by the United Technologies Research Center (UTRC) under the U.S. Department of Energy Combustion 2000 high-performance power system program. The UTRC system will be up to 50% more efficient than today's pulverized coal-fired systems and will subsequently reduce CO_2, sulfur, and nitrogen oxide emissions and produce power at a 10% lower cost. The system is designed to be used as a retrofit to a typical pulverized coal-burning plant. The EERC has constructed a pilot-scale slagging combustor system and a bench-scale system for testing some key subsystems and materials that will be used in the UTRC plant. However, without the requested funds, no testing will be performed using a lignite coal.

The successful use of lignite in this system will benefit North Dakota because it will prove to power utilities the viability of lignite as a fuel in this type of high-efficiency power plant. This will also prove that even if legislation forcing a reduction in CO_2 emissions is passed, a switch to natural gas is not necessary, and that lignite fuels can still be fired in a retrofitted plant without the purchase of CO_2 credits.

If you have any questions, please feel free to call me at (701) 777-5159, fax at (701) 777-5181, or e-mail at jhurley@eerc.und.nodak.edu.

Sincerely,

Ed Steadman for

John P. Hurley
Senior Research Manager

Approved by:

Carl A Fox 1/2/98

Dr. Carl A. Fox, Director
Office of Research and Program Development

JPH/djs

Enclosure

c: Gerald Groenewold, EERC
Steve Benson, EERC
Mike Jones, EERC
John Hendrickson, EERC

Energy & Environmental Research Center

LIGNITE TESTING IN THE HIGH-TEMPERATURE ADVANCED FURNACE

Prepared for:

State of North Dakota
The Industrial Commission
State Capitol
Bismarck, ND 58505
ATTN: Lignite Research Program

Prepared by:

John P. Hurley
Greg F. Weber

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

John P. Hurley, Project Manager

Dr. Carl A. Fox, Director
Office of Research and Program Development

December 30, 1997
$262,510 – Base amount
$53,252 – Option amount

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIGNITE TESTING IN THE HIGH-TEMPERATURE ADVANCED FURNACE

ABSTRACT

Under the Combustion 2000 Program, the Department of Energy is partially funding the development of a high-performance power system to be at least 35% more efficient while emitting less SO_x and NO_x or particulate than today's systems. The United Technologies Research Center (UTRC) is the prime contractor for one of the two main efforts. The heart of the UTRC system is a high-temperature advanced furnace (HITAF) that uses heat exchangers to produce clean air at 2600°F and 250 psi to turn an aeroderivative turbine. Overall system design is like a typical pulverized coal-fired boiler system's, except that it is a combined cycle and ceramics and alloys are used to carry the high-temperature air, making it especially suitable as a boiler retrofit technology.

The University of North Dakota Energy & Environmental Research Center (EERC) is a major subcontractor on the UTRC team. The Phase 2 Program involves detailed plant and cycle design and testing of key subsystems and materials at the pilot scale. Phase 2 is a $35 million program running over 5½ years. The EERC performs lab- and bench-scale determinations of the corrosion resistance of the refractory and structural materials, develops methods to improve corrosion resistance, and constructs and operates a 2.5 million Btu/hr slagging combustor system for materials and subsystem testing.

Because lignites are not tested in the existing project, we request funding from the North Dakota Industrial Commission (NDIC) to fire a lignite in the EERC pilot-scale system. The EERC will use the funding to perform two pilot-scale tests of lignite in the EERC slagging combustor and to perform bench-scale tests of slag corrosion with advanced refractories to prove that the use of lignite fuel does not present any special problems in the operation of the HITAF. The NDIC project is assumed to run from April 1, 1998, to June 30, 1998. Cost to NDIC is $262,510, with an option for trace element sampling for an additional $53,252.

LIGNITE TESTING IN THE HIGH-TEMPERATURE ADVANCED FURNACE

PROJECT SUMMARY

The U.S. Department of Energy (DOE) projects that from 1995 to 2015, worldwide use of electricity will double to approach 20 trillion kilowatt hours. This growth comes during a time of concern over global warming, thought by many policy makers to be caused primarily by increases in CO_2 emissions through the use of fossil fuels. Government regulations now being negotiated in global treaties may force electric utilities to reduce CO_2 emissions or be forced to buy CO_2 credits from nations producing less CO_2 per capita. Unless coal-fired power plants are made more efficient, utilities may be forced to turn to more expensive fuels to avoid buying the credits.

In 1991, DOE started the Combustion 2000 Program, which is designed to work with industry in the development of an ambitious high-efficiency coal-fired power plant technology called the High-Performance Power System or HIPPS concept. This type of plant will use a combined cycle involving a typical steam cycle along with an indirectly fired turbine cycle using very high temperature but low pressure air as the working fluid. The goals for the HIPPS system are 47% efficiency, with only 1/10 of the particulate, SO_x, and NO_x emissions allowed under the New Source Performance Standards, while reducing the cost of electricity by 10%. The University of North Dakota (UND) Energy & Environmental Research Center (EERC) is working with a team led by United Technologies Research Center (UTRC) in the development of this system.

The heart of the HIPPS system is a high-temperature advanced furnace (HITAF) which will use heat exchangers to produce clean air at 2600°F and 250 psi to turn an aeroderivative turbine. The overall system design is very similar to that of a typical pulverized coal-fired boiler system, except that ceramics and alloys are used to carry the very high-temperature air. This design makes it especially suitable as a boiler retrofit technology. In addition, UTRC has calculated that with the use of a gas-fired duct heater, efficiencies of 55% can be achieved, leading to reductions in CO_2 emissions of 40%, as compared to today's coal-fired systems.

The program is currently in Phase 2, which is a $35 million program running over 5½ years, of which 20% is cost-shared by UTRC, the subcontractors including the EERC, and the contributions of Northern States Power Company, Minnesota Power, and Minnkota Power Cooperative through their participation in a utility advisory board. The UND EERC role is to perform laboratory- and bench-scale determinations of the corrosion resistance of the refractory and structural materials, develop methods to improve corrosion resistance, and construct and operate a 2.5 million Btu/hr slagging combustor system for materials and subsystem testing. However, with the existing funding, no tests are being planned with a lignite.

Because there are no plans to use lignites under the existing project, we request funding from the North Dakota Industrial Commission (NDIC) to fire a lignite in the EERC pilot-scale HITAF to test the subsystems and materials being developed for the UTRC Combustion 2000 HIPPS system. The purpose of the tests will be to prove to lignite-burning utilities that it will not be necessary to switch to natural gas firing or purchase CO_2 credits if CO_2 emission restrictions are legislated. Instead, existing lignite-burning boilers can be upgraded with a HIPPS retrofit to increase efficiency by 35% to 50% and reduce CO_2 emissions by as much as 40%.

PROJECT DESCRIPTION

The objective of the proposed scope of work is to evaluate the performance of key HITAF technologies while lignite is fired. Specific technical issues of interest include the performance of the large radiant air heater (LRAH) panel, the performance of the convective air heater (CAH) tube bank, and the general impact of lignite firing on overall operation of the pilot-scale slagging furnace system. Some limited sampling will be completed to characterize flue gas emissions (sulfur dioxide, nitrogen species, carbon dioxide, and particulate); evaluate pulse-jet baghouse performance; and document fuel, slag, and ash properties. The proposed scope of work consists of one primary task and an optional task. Trace element sampling is proposed as an option for consideration.

Task 1 – Evaluation of HITAF Performance While Lignite is Fired

Task 1 assumes the completion of two nonconsecutive weeks of pilot-scale HITAF system operation. Each week of operation will consist of nominally 24 hours of natural gas firing to preheat the furnace and a maximum of 85 hours of lignite firing at a single operating condition. Conditions during the second week will be modified based on first-week observations and may include increases in firing rate or use of a different lignite. Slagging furnace operation will be evaluated based on furnace temperature (flue gas and refractory) and pressure measurements and on-line flue gas instrumentation readings (oxygen, carbon monoxide, carbon dioxide, nitrogen species, and sulfur dioxide). A nominal lignite firing rate of 2 MMBtu/hr at an air-to-fuel ratio of about 1.2 is anticipated to achieve furnace gas temperatures of 2700° to 2800°F near the furnace wall. Fuel selection will be based on availability and properties such as ash fusion temperature. A final selection will be made in concurrence with the NDIC technical project monitor.

Special emphasis will be placed on the collection of data to document the performance of the LRAH panel located in the furnace wall. Performance of the LRAH panel will be evaluated relative to radiant heat-transfer from the furnace to a hot air stream and the impact of slag on the ceramic bricks protecting the high-temperature alloy heat-transfer surfaces. Temperature measurements will be made to document the surface temperatures of the ceramic bricks and alloy heat-transfer surfaces as well as bulk inlet and outlet cooling air temperatures. Comparisons will be made with similar data generated during bituminous and subbituminous coal firing. The impact of slag on the ceramic bricks will be evaluated based on observations before and after each week of operation. Photographs will be taken to document observations.

Furnace exit, slag tap, and slag screen operating temperatures will be selected based on ash fusion data for the specific lignite fuel selected. These system temperatures are generally controlled at 200°F above the fluid temperature of the slag under oxidizing conditions. Although the design and operation of these components are specific to the scale and design of the slagging furnace, evaluating their performance is important to determining the impact of lignite firing on the relative performance of the HITAF concept when compared to bituminous and subbituminous coals. The required flue gas recirculation rate in the dilution/quench zone will depend on the slag screen exit temperature. The flue gas recirculation rate will be controlled to achieve a flue gas temperature of 1800°F entering the CAH tube bank.

Performance of the CAH tube bank will be evaluated relative to heat transfer from the flue gas to a hot air stream and the impact of ash deposition on the ceramic and metal tube surfaces. Temperature measurements will be made to document the surface temperatures of the metal heat-transfer surfaces as well as bulk inlet and outlet cooling air temperatures. Comparisons will be made with similar data generated as a result of bituminous and subbituminous coal firing. Heat recovery from the CAH tube bank is integral to the preheating of cooling air for the LRAH panel in the furnace. The EERC expects that it will be necessary to periodically remove ash deposits from the CAH tube surfaces to avoid excessive heat-transfer degradation. Therefore, data concerning deposition rate on the heat-transfer surfaces will not be available. One approach worth considering to 2 weeks of operation might be to avoid CAH tube cleaning during the first week of operation, documenting performance degradation and ash deposition rate as a function of time. However, the duration of the operating period while firing lignite might be quite short (<24 hours) without CAH tube cleaning. During the second week, a routine cleaning/sootblowing schedule would be implemented based on data and observations from the first week. In any case, ash deposits collected during both weeks of observation will be characterized to determine chemical composition and relative strength. Specific analyses to be completed include x-ray fluorescence (XRF), scanning electron microscopy (SEM) point count, and SEM morphology. Acquiring this information is important because the firing characteristics of the HITAF concept represent a firing condition different from either pulverized coal (pc) or cyclone firing. Flame intensity and furnace temperature are greater than pc-firing yet less intense with higher air-to-fuel ratios than cyclone-firing.

Flue gas composition (sulfur dioxide, nitrogen species, carbon dioxide, carbon monoxide, oxygen, and particulate) will be measured and reported. Gas-phase constituents will be monitored continuously using on-line instrumentation at the exit of the furnace and pulse-jet baghouse. Gas phase constituent data will be reported on a lb/MMBtu and concentration basis. Particulate sampling will be completed at the inlet and outlet of the baghouse during 1 week of slagging furnace system operation. Sampling at the inlet of the baghouse will document mass loading and particle-size distribution. Sampling at the outlet of the baghouse will document mass and fine particulate emissions. Particulate emissions will be reported on a lb/MMBtu and mass per unit volume basis.

Composite samples of coal, slag, and baghouse ash will be collected for routine analyses. One composite coal sample will be analyzed for each week of operation. Analyses will include ultimate, proximate, Btu, dry sieve, ash fusion (oxidizing), XRF, computer-controlled scanning electron microscopy (CCSEM), and ash viscosity. Analysis of slag will involve one composite sample for each week of operation and include ash fusion, ash viscosity, and XRF. One baghouse ash composite sample will be characterized for each week of operation. Analyses will include Malvern particle size, loss on ignition, CCSEM, and XRF. Composite samples of ash from other locations in the system will also be collected. Analysis of these samples will depend on system performance observations and initial data analysis.

A detailed test plan documenting test objectives, planned operating conditions, data to be collected, sampling requirements, and sample analyses to be completed will be prepared in advance for each week of HITAF operation. This experiment operating specification (EOS) will be reviewed with the NDIC technical project monitor prior to each week of operation.

In addition to the pilot-scale tests, bench-scale tests of the relative corrosivity of lignite slag will be performed with the EERC dynamic slag application furnace (DSAF). The DSAF is an electric furnace capable of reaching 3000°F. It is used to heat blocks of refractories while slag is dripped over them. With a lignite slag collected from a utility boiler system, preferably a cyclone unit, dynamic (flowing) slag corrosion tests will be performed on at least two refractories under two test conditions, either different temperatures or slag flow rates depending on the first test, for periods of up to 150 hours. The refractory recession will be measured as well as the depth of penetration into the refractory by cross-sectioning the blocks and analyzing them in an SEM.

The results of Task 1 will be documented in a detailed project report. The report will contain a system description and document operating conditions, the performance of the LRAH panel and CAH tube bank, flue gas emissions, and observations specific to lignite firing impacts on HITAF performance relative to data available for bituminous and subbituminous coals. Data will be presented in tabular and/or graphical formats. Also, graphs showing the results of the bench scale refractory corrosion tests will be prepared. Conclusions based on the data will be summarized as well as recommendations for further work, if warranted. Project results will also be summarized in a presentation prepared for a Lignite Council program review meeting if requested.

Task 2 – Trace Element Sampling (optional)

Task 2 (optional) addresses trace element sampling. Development and comparison of the data are necessary to determine if the HITAF concept results in any significant change in the distribution or speciation of trace elements which might influence their fate in the environment or the performance of control technologies. Although the emphasis will be on mercury (Hg), other trace elements of interest include arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), and selenium (Se). In addition, chlorine (Cl_2) and hydrochloric acid (HCl) measurements will be made because of their importance relative to Hg speciation. Development of this information is necessary because the HITAF concept represents a firing condition different from either pc or cyclone firing. Flame intensity and furnace temperature are greater in the HITAF than typical pc firing yet less intense with higher air-to-fuel ratios than cyclone firing.

The pilot-scale slagging furnace system also offers an opportunity to evaluate trace element speciation, distribution, and emissions from a dynamic slagging system firing lignite. The trace element sampling approach selected will make use of both the Ontario Hydro and the EPA Method 29 sample trains. The Ontario Hydro sampling method has been shown to effectively speciate Hg, while EPA Method 29 only provides a total Hg value. However, the Ontario Hydro sampling method is not a proven multimetals sample train whereas EPA Method 29 is an approved method for multimetals sampling. Therefore, the proposed scope of work will require the use of both the Ontario Hydro method and EPA Method 29 in order to obtain Hg speciation and multimetals data.

Flue gas trace element sampling will occur simultaneously at the inlet and outlet of the pulse-jet baghouse during the second week of HITAF operation. Simultaneous sampling will occur twice at each sample location using matched pairs of both the Ontario Hydro and EPA Method 29 sample trains. The result will be eight complete data sets, four inlet and four outlet, during a single day of

HITAF operation. Composite samples of coal and baghouse ash will be collected for trace element analyses during the daylong sampling effort. Composite samples of slag and ash from other locations in the system will also be collected at the conclusion of the weeklong operating period. Analysis of one of these samples will depend on the results of the sampling train data and the baghouse ash data. Two sampling periods will be completed at the baghouse outlet using EPA Method 26A to determine Cl_2 and HCl concentrations in the flue gas. Sample preparation methods to be used will include coal digestion, mixed-acid digestion, filtering, Hg prep, and IC (ion chromatography) prep. Analytical methods to be used will include hydride, GFAA (graphite furnace atomic absorption), CVGAA (cold-vapor generation atomic absorption), and IC.

The data generated as a result of Task 2 will be compared with field data and pilot-scale data already existing in the EERC Center for Air Toxic Metals (CATM) database. Emissions and collection efficiency data will be presented in tabular and/or graphical formats with conclusions supported by statistical analysis of the data where appropriate. If Task 2 is selected, the results will be included in the final project report along with Task 1 results. In addition, the trace element data will be added to the CATM database.

STANDARDS OF SUCCESS

The use of lignite as a fuel to fire the HITAF will be deemed a success if three criteria are met. First, the LRAH must produce clean pressurized air at 1700°F while the system is fired to a flame temperature of no more than 2850°F. Second, the CAH must produce clean pressurized air at 1300°F with a convective pass gas temperature of no more than 1850°F. Third, the castable alumina refractory must be corroded by lignite slag at a rate of less than 0.3 millimeter/hour at a temperature of 2730°F during bench-scale testing.

BACKGROUND

DOE projects that from 1995 to 2015, worldwide use of electricity will double to approach 20 trillion kilowatt hours. This growth comes during a time of concern over global warming, thought by many policy makers to be caused primarily by increases in CO_2 emissions through the use of fossil fuels. Government regulations now being negotiated in global treaties may force electric utilities to reduce CO_2 emissions or be forced to buy CO_2 credits from nations producing less CO_2 per capita. Unless coal-fired power plants are made more efficient, utilities may be forced to turn to more expensive fuels to avoid buying the credits.

In 1991, DOE started a program that takes a two-pronged approach at increasing coal-fired power plant efficiency while decreasing emissions of particulates and sulfur and nitrogen oxides. Called the Combustion 2000 Program, it is designed to promote the development of two types of advanced power plants. The more near-term technology is to be the Low-Emission Boiler System or LEBS. It is a single cycle, ultrasupercritical plant designed to achieve efficiencies of 42% on a higher heating value (HHV) basis. The more ambitious technology is named the High-Performance Power System or HIPPS concept. This type of plant will use a combined cycle involving a typical steam cycle along with an indirectly fired turbine cycle using very high temperature but low pressure air as the working fluid. The goals for the HIPPS system are 47% efficiency, with only 1/10 of the particulate, SO_x, and NO_x emissions allowed under the New Source Performance Standards, while reducing the cost of electricity by 10%. Two teams are working on the HIPPS technology: one led by Foster Wheeler and the other by UTRC.

The heart of the UTRC system is an HITAF that uses heat exchangers to produce clean air at 2600°F and 250 psi to turn an aeroderivative turbine. The overall system design is very similar to that of a typical pulverized coal-fired boiler system, except that ceramics and alloys are used to carry the very high-temperature air. This design makes it especially suitable as a boiler retrofit technology.

In addition, UTRC has calculated that with the use of a gas-fired duct heater, efficiencies of 55% can be achieved, leading to reductions in CO_2 emissions of 40% as compared to today's coal-fired systems.

The UND EERC is a major subcontractor on the UTRC team. Currently, the program is in Phase 2, which involves detailed plant and cycle design, as well as testing of key subsystems and materials at the pilot scale. Phase 2 is a $35 million program running over 5½ years, of which 20% is cost-shared by UTRC, the subcontractors including the EERC, and the contributions of Northern States Power Company, Minnesota Power, and Minnkota Power Cooperative through their participation in a utility advisory board. The other subcontractors on the UTRC team are ABB/Combustion Engineering, Fluor Daniel, Pratt and Whitney, Physical Sciences Incorporated, Reaction Engineering International, and Bechtel. The EERC role is to perform laboratory- and bench-scale determinations of the corrosion resistance of the refractory and structural materials, develop methods to improve corrosion resistance, and construct and operate a 2.5 million Btu/hr slagging combustor system for materials and subsystem testing.

Major EERC accomplishments in the project as of December 1997 are the development of a castable refractory that is much more resistant to molten slag corrosion than commercially available refractories and the design, construction, and initial operation of the 2.5 million Btu/hr slagging combustor system. Early tests have shown that the furnace system works very well except for some solvable problems with slag freezing at the slag tap. Tests have also shown that the UTRC design for the high-temperature air heater is sound, it can withstand temperatures of over 1900°F, and the experimental castable refractory is as resistant to flowing slag corrosion as fusion cast bricks costing 10 times as much. However, all of the tests to date have been performed with an Illinois No. 6 bituminous coal and a Powder River Basin coal. With the existing funding, no tests have been planned with a lignite.

Because there are no plans to use lignites under the existing project, we request funding from the North Dakota Industrial Commission to fire a lignite in the EERC pilot-scale HITAF to test the subsystems and materials being developed for the UTRC Combustion 2000 HIPPS system. The funds will be highly leveraged since they will contribute to the $6.9 million activity at the EERC and the $35 million overall UTRC project. The purpose of the tests will be to prove to lignite-burning utilities that it will not be necessary to switch to natural gas firing or purchase CO_2 credits if CO_2 emission restrictions are legislated. Instead, existing lignite-burning boilers can be upgraded with a HIPPS retrofit to increase efficiency by 35% to 50% and reduce CO_2 emissions by as much as 40%.

Specific issues of concern in lignite firing of this system are the luminosity of the lignite flame and the corrosivity of the slag toward the refractory and heat exchanger surfaces. We intend to test the hypothesis that because of the higher moisture content and the vaporization of organically associated elements, the lignite flame can be more luminous than other coal flames for a given temperature, thus offsetting the typically lower temperature of a lignite flame. In addition, higher sodium slag can be very corrosive to refractories, especially when they are not cooled. Therefore, we also intend to test the hypothesis that because the refractory developed by the EERC for this system does not contain silica, it will be as resistant to lignite slag corrosion as it is to corrosion by other coal slags.

THE EERC HIGH-TEMPERATURE ADVANCED FURNACE

The EERC pilot-scale HITAF is a slagging design intended to be as fuel-flexible as possible. It is pictured in Figure 1, with a schematic of the system shown in Figure 2. The HITAF is designed for a maximum furnace exit temperature of 2900°F, but is typically run at 2750°F at the exit in order to maintain desired slag flow while extending the furnace lifetime. It has a nominal firing rate of 2.5 million Btu/hr and a range of 2.0 to 3.0 million Btu/hr using a single burner. The design is based

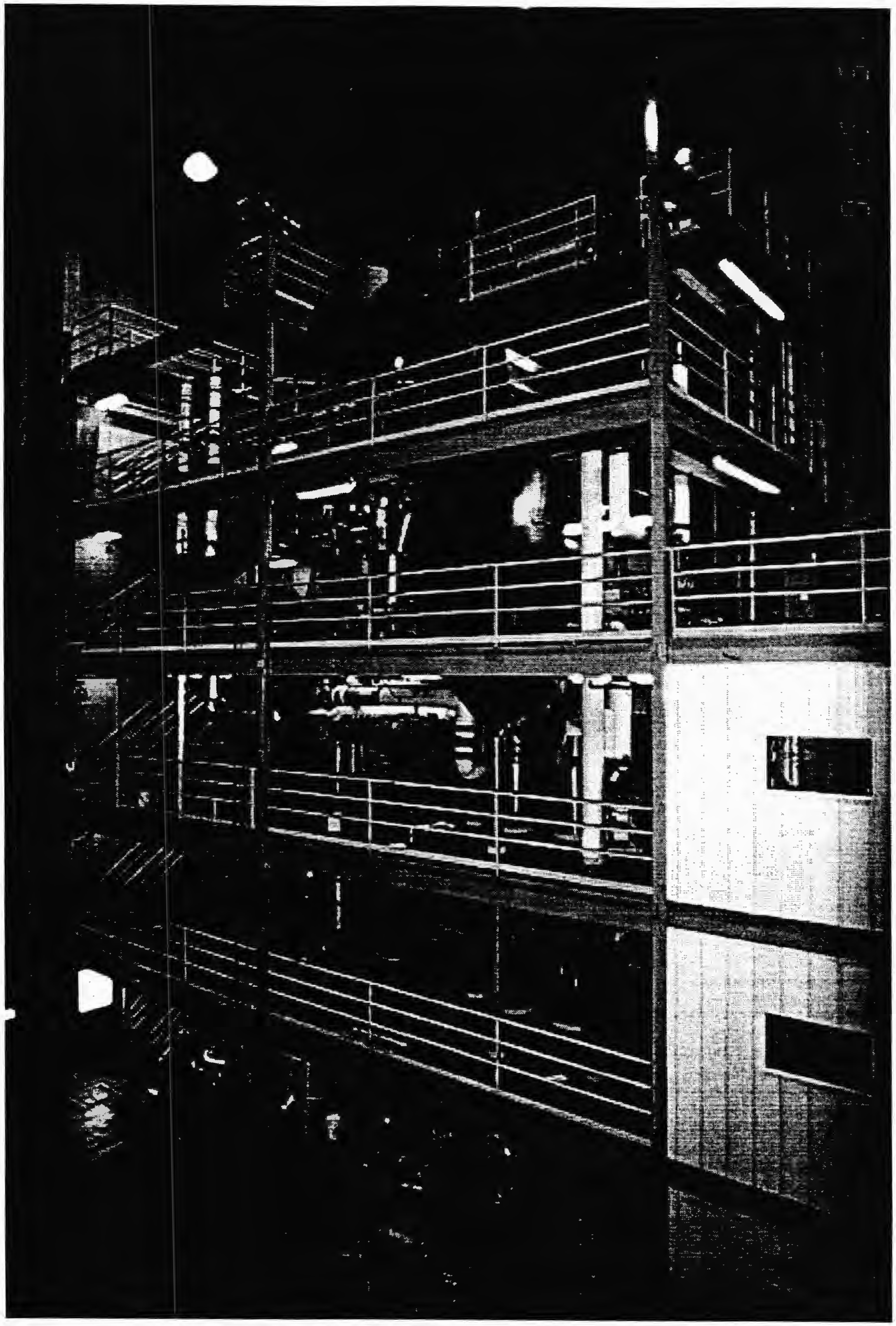

Figure 1. Photograph illustrating the EERC HITAF system.

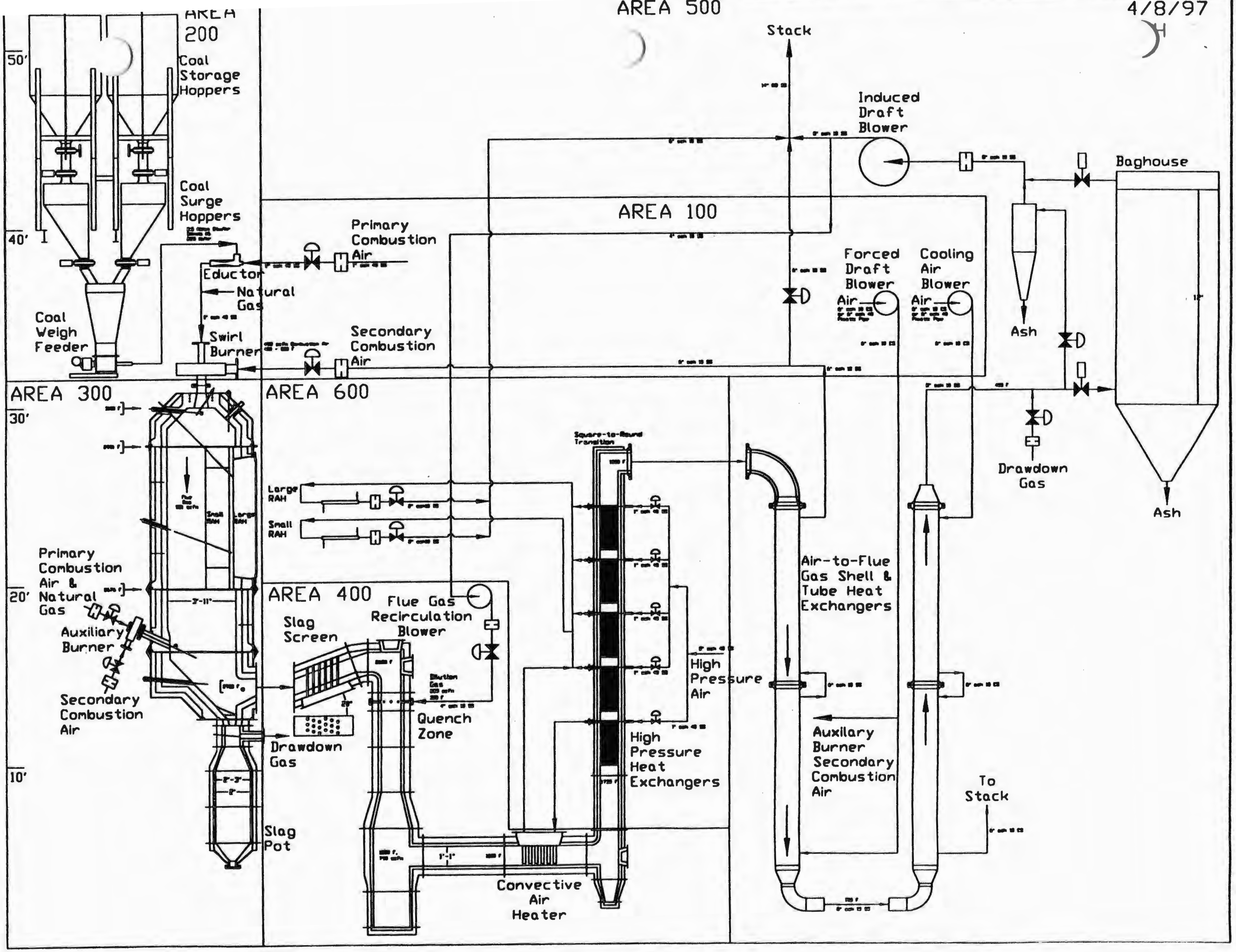

Figure 2. Schematic of the EERC HITAF system.

on a bituminous coal (Illinois No. 6) and a nominal furnace residence time of 3.5 s. Resulting flue gas flow rates range from roughly 425 to 640 scfm, with a nominal value of 530 scfm based on 20% excess air. Firing a lignite will increase the flue gas volume, decreasing residence time to roughly 2.7 s. However, the high volatility of the low-rank fuels will result in high combustion efficiency (>99%). The EERC oriented the furnace vertically (downfired) and based the burner design on a swirl burner currently used on two EERC pilot-scale pulverized coal (pc)-fired units that are fired at 600,000 Btu/hr (633,000 kJ/hr). The furnace dimensions are 47-in. (119-cm) inside diameter (ID) by roughly 18 ft (5.5 m) in length. It is lined with three layers of refractory totaling 12 in. thick. The inner layer is composed of an alumina castable, developed by the EERC in cooperation with the Plibrico Company, that has been shown in laboratory tests to be extremely resistant to slag corrosion.

A key design feature of the furnace is accessibility for installation and testing of one LRAH test panel and one SRAH panel. The panels are designed for testing material lifetimes and heat exchange coefficients. The LRAH is 1 × 6 ft. This size was based on manufacturing constraints identified by UTRC, which designed and built the panels. The large panel contains three vertically oriented tubes made of an oxide dispersion-strengthened alloy. The tubes are protected from slag corrosion protected by alumina refractory plates. The SRAH is constructed with a variety of refractory plates and is designed only for testing material lifetimes.

Air to be heated by the LRAH panel is provided by an existing EERC air compressor system having a maximum delivery rate of 510 scfm and a maximum stable delivery pressure of 275 psig. It is heated from 1300°F to as much as 1800°F as it passes through the LRAH, although in initial tests we have only gone to 1650°F as determined by a thermocouple at the exit from the LRAH. However, since some cooling is anticipated between the furnace and the exit of the LRAH, additional thermocouples will be installed to better measure the highest temperatures reached.

Backup cooling air is available from a smaller compressor at a maximum delivery rate of 300 scfm and pressure of <100 psig. A tie-in to an existing nitrogen system was also installed as a backup to the existing air compressor system to prevent the panel from overheating in the event of a power outage.

As the hot combustion gases leave the combustor, they pass through a slag screen to remove the entrained ash as a nonleachable slag and reduce deposition on the CAH. Other design criteria specific to the pilot-scale slag screen include 1) a simple design, permitting modifications if necessary using readily available, inexpensive materials; 2) matching duct dimensions and flue gas flow rates to maintain turbulent flow conditions; 3) minimizing the potential for plugging as the result of slag deposit growth on tube surfaces or the sloped floor; 4) limiting differential pressure across the slag screen to 2 in. W.C. (4 mm Hg); and 5) limiting heat losses to ensure desired slag flow from the slag screen to the furnace slag tap. Initial tests with the slag screen show that it removes approximately 65% of the particulate matter from the gas stream.

As the hot combustion gas leaves the slag screen, it is quenched with recirculated flue gas to 1850°F in order to reduce the stickiness of the ash to reduce deposition on the CAH. This is the only region in the furnace where hard ash deposits form, but they are easily removed by knocking them into a hopper at the bottom of the quench zone. The gases then pass over the CAH which is used to heat air from 1000° to 1300°F. The hot combustion gases then flow through a series of heat exchangers and, finally, a baghouse on the way to the system stack.

QUALIFICATIONS

The UND 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, emissions control technologies, ash use and disposal, analytical methods, groundwater, waste-to-energy systems, and advanced environmental control systems. The main EERC facilities—with 169,000 square feet of laboratory, pilot plant, and office space—are located on the southeast corner of the UND campus. High-severity processes can be developed from conceptual ideas through proof-of-concept demonstration in the flexible EERC reactor systems. Laboratory- and pilot-scale combustors and gasifiers with capacities of up to 4.0 million Btu/hr, as well as diesel and gas turbine simulators, are available for evaluating new fuels and assessing new emission control technologies. Testing equipment is also available for full-scale sampling and measuring of system flow and temperature. Analytical techniques and instrumentation are available for the characterization of solid, liquid, and gaseous materials.

The EERC has conducted extensive research on the engineering aspects and environmental effects of carbon-based fuels combustion and gasification. Specific program areas include ash and slag chemistry, trace metals in fuels, inorganic transformations, ash deposition, coal combustion chemistry, corrosion/erosion mechanisms, fuels evaluation, fluidized-bed combustion, gas turbines, diesels, slurry combustion, SO_x control, NO_x control, particulate control, hot-gas cleanup, clean coal technologies, advanced power systems, process development, gasification/combined-cycle systems research, waste-to-energy conversion, and synthetic fuels investigations.

The project will be managed by Dr. John Hurley. Dr. Hurley has 14 years of experience as a scientist working to improve power system efficiencies through fundamental understanding of the coal combustion and ash formation phenomena. He is also the project manager of the $6.9 million Combustion 2000 program at the EERC. Mr. Greg Weber will be the principal investigator. A senior research advisor at the EERC, Mr. Weber has responsibility for administrative and technical review of projects related to emission control (NO_x, SO_x, air toxics) for conventional as well as advanced power systems and pilot-scale research and development activities related to combustion and gasification technology.

VALUE TO NORTH DAKOTA

The UTRC Combustion 2000 program is attempting to develop a high-efficiency power system that is 35%–50% more efficient, reducing CO_2 emissions by up to 40% while reducing sulfur and nitrogen oxide emissions and producing power at a 10% lower cost than today's systems. The system is designed to be used as a retrofit to a typical pc plant. The EERC has constructed a pilot-scale slagging combustor system and a bench-scale system for testing some key subsystems and materials that will be used in the UTRC plant. However, no testing is currently planned using a lignite coal.

The EERC will use the NDIC funding requested in this proposal to perform two pilot-scale tests of lignite in the EERC slagging combustor and to perform bench-scale tests of materials corrosion to prove that the use of lignite fuel does not present any special problems in the operation of the UTRC system. This will benefit North Dakota because it will prove to power utilities the viability of lignite as a fuel in this type of high-efficiency power plant. This will also prove that even if legislation forcing a reduction in CO_2 emissions is passed, a switch to natural gas would not be necessary since lignite fuels could still be fired in a retrofitted plant without the purchase of CO_2 credits.

TIMETABLE

If we have funding by the first of April 1998 and can get the fuel selected and delivered within 2 weeks, we could complete the first week of operation in late April and the second week of operation in late May (Table 1). In that case, all of the analytical work should be completed in June, and the reports could be prepared and sent out in July.

TABLE 1

Project Time Line

	April		May	June	July
Fuel Selected and Delivered	X				
First Week of Lignite Firing		X			
Second Week of Lignite Firing			X		
Analytical Work				X	
Final Report					X

BUDGET

This proposal requests a base amount of $262,510 with an option for trace element sampling for an additional $53,252, for a total request of $315,762 from NDIC to allow testing a North Dakota lignite to prove its ability in an HITAF. If successful, this will ensure a continued market for North Dakota lignite in a strict regulatory environment. A detailed budget and budget notes follow on page 20.

MATCHING FUNDS

NDIC is asked to contribute funding to a $35 million program running over 5½ years to prove lignite does not present any special problems in operation of the HITAF. Of the $35 million, 20% is cost-shared by UTRC, the subcontractors including the EERC, and the contributions of Northern States Power Company, Minnesota Power, and Minnkota Power Cooperative through their participation in a utility advisory board. The other subcontractors on the UTRC team are ABB/Combustion Engineering, Fluor Daniel, Pratt and Whitney, Physical Sciences Incorporated, Reaction Engineering International, and Bechtel.

TAX LIABILITY

The EERC does not have an outstanding tax liability to the state of North Dakota or any of its political subdivisions.

CONFIDENTIAL

None.

SUMMARY BUDGET

EVALUATION OF LIGNITE PERFORMANCE IN THE COMBUSTION 2000
SLAGGING FURNACE SYSTEM
NORTH DAKOTA INDUSTRIAL COMMISSION
PROPOSED START DATE: 4/1/98
EERC PROPOSAL #98-0062 02-Jan-98

	TASK 1 HOURS	TASK 1 $ COST	(OPTIONAL) TASK 2 HOURS	(OPTIONAL) TASK 2 $ COST	TOTAL HOURS	TOTAL $ COST
TOTAL DIRECT LABOR	3856	$78,578	426	$11,724	4282	$90,302
FRINGE BENEFITS - % OF DIRECT LABOR	52%	$40,861		$6,096		$46,957
TOTAL LABOR		$119,439		$17,820		$137,259
OTHER DIRECT COSTS						
TRAVEL		$570		$0		$570
SUPPLIES		$12,000		$0		$12,000
EQUIPMENT > $750		$0		$0		$0
COMMUNICATIONS - PHONES & POSTAGE		$200		$100		$300
OFFICE (PROJECT SPECIFIC SUPPLIES)		$1,075		$100		$1,175
REPAIRS		$10,000		$0		$10,000
DATA PROCESSING - SOFTWARE		$500		$100		$600
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)		$1,100		$0		$1,100
FEES (ANALYTICAL/OTHER)		$25,577		$16,459		$42,036
TOTAL OTHER DIRECT COST		$51,022		$16,759		$67,781
TOTAL DIRECT COST		$170,461		$34,579		$205,040
INDIRECT COST - % OF MTDC	54%	$92,049		$18,673		$110,722
TOTAL ESTIMATED COST		$262,510		$53,252		$315,762

NOTE: Due to limitations within the University's accounting system, the system does not provide for accumulating and reporting expenses at a detail or task level. Thus costs will be accumulated and reported as shown in the total column. The detail budget is presented for proposal evaluation purposes only.

DETAIL BUDGET

VALUATION OF LIGNITE PERFORMANCE IN THE COMBUSTION 200(GGING FURNACE SYSTEM
NORTH DAKOTA INDUSTRIAL COMMISSION
PROPOSED START DATE: 4/1/98
EERC PROPOSAL #98-0062 02-Jan-98

LABOR	LABOR CATEGORY	HOURLY RATE	TASK 1 HOURS	TASK 1 $ COST	(OPTIONAL) TASK 2 HOURS	(OPTIONAL) TASK 2 $ COST	TOTAL HOURS	TOTAL $ COST
J. HURLEY	PROJECT MANAGER	$34.27	200	$6,854	0	$0	200	$6,854
G. WEBER	PRINCIPAL INVESTIGATOR	$38.38	250	$9,595	100	$3,838	350	$13,433
---------------	SENIOR MANAGEMENT	$40.12	104	$4,172	20	$802	124	$4,974
---------------	QUALITY CONTROL MANAGER	$21.21	26	$551	5	$106	31	$657
---------------	RESEARCH SCIENTIST/ENGINEER	$27.85	736	$20,498	199	$5,542	935	$26,040
---------------	RESEARCH TECHNICIAN	$14.58	2324	$33,884	62	$904	2386	$34,788
---------------	TECHNICAL SUPPORT SERVICES	$10.40	216	$2,246	40	$416	256	$2,662
			3856	$77,800	426	$11,608	4282	$89,408
ESCALATION ABOVE CURRENT BASE		1%		$778		$116		$894
TOTAL DIRECT LABOR				$78,578		$11,724		$90,302
FRINGE BENEFITS - % OF DIRECT LABOR		52%		$40,861		$6,096		$46,957
TOTAL LABOR				$119,439		$17,820		$137,259
<u>OTHER DIRECT COSTS</u>								
TRAVEL				$570		$0		$570
SUPPLIES				$12,000		$0		$12,000
EQUIPMENT > $750				$0		$0		$0
COMMUNICATIONS - PHONES & POSTAGE				$200		$100		$300
OFFICE (PROJECT SPECIFIC SUPPLIES)				$1,075		$100		$1,175
REPAIRS				$10,000		$0		$10,000
DATA PROCESSING - SOFTWARE				$500		$100		$600
GENERAL (FREIGHT, FOOD, MEMBERSHIPS, ETC.)				$1,100		$0		$1,100
SHOPS/OPS SUPPORT				$3,168		$0		$3,168
GRAPHICS				$1,333		$1,333		$2,666
NATURAL MATERIALS ANALYTICAL RES. LAB.				$7,005		$0		$7,005
COAL & MATERIALS RESEARCH LAB				$8,687		$63		$8,750
ANALYTICAL RESEARCH LAB.				$0		$12,304		$12,304
PARTICULATE ANALYSIS				$1,142		$2,759		$3,901
COAL PREP. AND MAINTENANCE				$4,242		$0		$4,242
TOTAL OTHER DIRECT COST				$51,022		$16,759		$67,781
TOTAL DIRECT COST				$170,461		$34,579		$205,040
INDIRECT COST - % OF MTDC		54%		$92,049		$18,673		$110,722
TOTAL ESTIMATED COST				$262,510		$53,252		$315,762

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

Background

The EERC is an independently organized multidisciplinary research center within the University of North Dakota. 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 based 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 for this proposal has been prepared based on a specific start date; this start date is indicated at the top of the EERC detail 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. Financial reporting will be at the total project level.

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 salaries are estimated based on the scope of work and prior experience on projects of similar scope. Technical and administrative salaries are charged based on direct hourly effort on the project. Costs for general support services, such as grants and contracts administration, accounting, personnel, purchasing and receiving, as well as clerical support of these functions, are included in the indirect cost of the EERC.

Fringe benefits are estimated based on 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 on 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 based on UND travel policies, which include estimated GSA daily meal rates. Travel includes scheduled meetings and conference participation as indicated in the scope of work.

Communications

Monthly telephone services and fax telephone lines are included in indirect cost. Direct project cost includes long-distance telephone including fax-related long-distance calls; postage for regular, air, and express mail; and other data or document transportation costs.

Office

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: special research notebooks, binders, and other project organizational materials; duplicating, printing, special covers or paper, and binding of reports; project data forms, transparencies or other presentation materials; literature searches and technical information procurement, including subscriptions; manuals, computer diskettes, memory chips, laser printer paper, and toner cartridges; and other miscellaneous supplies required to complete the project.

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, and glassware and/or other project items such as: nuts, bolts, and piping necessary for pilot plant operations.

Fees

Laboratory and analytical fees are established and approved at the beginning of each fiscal year and are charged based on a per sample or hourly charge depending on the analytical services performed. Additionally, laboratory analyses may be performed outside the University when necessary.

Engineering support fees are based on an established per hour rate for drafting services related to the production of drawings as part of EERC's quality assurance/quality control program for complying with piping and pressure vessel codes.

Graphic services fees are based on an established per hour rate for overall graphics production such as report figures, 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

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 workshops and conferences may include such items as food (some of which may exceed the institutional established limits), room amenities (e.g., place cards, music, banners, floral arrangements), speaker gifts, security, interpreters, technical tour transportation, and room and equipment rental necessary to conduct workshops and conferences.

Indirect Cost

The indirect cost rate included in this proposal is the rate which became effective July 1, 1995. Indirect cost is calculated on modified total direct costs (MTDC). MTDC is defined as total direct costs less individual items of equipment in excess of $750 and subcontracts/subgrants in excess of the first $25,000 of each award.