Energy & Environmental Research Center

LIGNITE TESTING IN AN ADVANCED HIGH-TEMPERATURE, HIGH-PRESSURE TRANSPORT REACTOR GASIFIER

EERC Proposal No. 99-0101

Submitted to:

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LIGNITE TESTING IN AN ADVANCED HIGH-TEMPERATURE, HIGH-PRESSURE TRANSPORT REACTOR GASIFIER

ABSTRACT

Today, coal supplies over 55% of the electricity consumed in the United States and will continue to do so well into the next century. One of the technologies being developed for advanced electric power-generating systems is integrated gasification combined cycle (IGCC). Kellogg Brown & Root (KBR) is developing a transport reactor gasifier, which functions as a circulating fluid-bed gasifier while operating in the pneumatic transport regime of solid-particle flow. This gasifier concept provides excellent gas–solid contacting of relatively small particles to promote high gasification rates and also provides the highest coal throughput per unit cross-sectional area of any other gasifier, thereby reducing capital cost of the gasification island.

In support of the KBR development efforts, the EERC has developed an extensive database of transport reactor development unit (TRDU) operation on a Powder River Basin subbituminous coal and two bituminous coals, an eastern high-sulfur Illinois No. 6 and a western low-sulfur Utah coal from the SUFCo mine. A hot-gas filter operations database on these fuels has also been developed. In total, the EERC has generated 960 hours of coal gasification data, with another 200 hours of coal combustion including 70 hours of combustion testing on a petroleum coke. Acceptable product gas quality in the 105- to 128-Btu/scf range has been demonstrated (after correction for issues associated with the operation of an air-blown pilot-scale system). Because lignites are not being tested in the existing project, the EERC is requesting funds from the North Dakota Industrial Commission (NDIC) to perform two pilot-scale gasification tests of lignite in the TRDU (one under combustion/air-blown and one under oxygen-blown conditions). The NDIC project is assumed to run from September 1, 1999, to December 31, 2000, and the cost to NDIC is $249,970.

LIGNITE TESTING IN AN ADVANCED HIGH-TEMPERATURE, HIGH-PRESSURE TRANSPORT REACTOR GASIFIER

1.0 PROJECT SUMMARY

Today coal supplies over 55% of the electricity consumed in the United States and will continue to do so well into the next century. One of the technologies being developed for advanced coal-based electric power-generating systems is an integrated gasification combined cycle (IGCC), which converts coal to a combustible gas, cleans the gas of pollutants, and combusts it in a gas turbine to generate electricity. The hot exhaust from the gas turbine is used to generate steam to generate more electricity from a steam turbine cycle. The use of advanced hot-gas particulate and sulfur control technologies together with the combined power generation cycles make IGCC one of the cleanest and most efficient ways available to generate electric power from coal. One of the strategic objectives for U.S. Department of Energy (DOE) IGCC research and development program is to develop and demonstrate advanced gasifiers and second-generation pressurized fluidized-bed combustion (PFBC) systems. Another objective is to develop advanced hot-gas cleanup and trace contaminant control technologies.

Specific program goals for baseload IGCC systems include attaining a net electric system efficiency of greater than 45%, reducing SO_2 and NO_x emissions to 1/10 of New Source Performance Standards (NSPS), maintaining air toxic emissions below 1990 Clean Air Act Amendment (CAAA) levels, and achieving a capital cost of less than $1200/kW while producing electricity at 80% of the cost of a conventional pulverized coal (pc) power plant (1).

One of the more recent gasification concepts to be investigated by a team headed by KBR is that of the transport reactor gasifier, which functions as a circulating fluid-bed gasifier while operating in the pneumatic transport regime of solid-particle flow. This gasifier concept provides excellent solid–gas contacting of relatively small particles to promote high gasification rates and also provides the highest coal throughput per unit cross-sectional area of any other gasifier, thereby reducing capital cost of the gasification island.

Another goal of the DOE IGCC product line is to convert carbonaceous fuel to valuable fuels or chemicals in addition to directly converting such fuels into electricity. IGCC is unique in that it has high fuel flexibility (i.e., coal liquids, wastes, or other opportunity fuels can be gasified) and it can produce value-added coproducts such a syngas for chemicals production, or high-value components such as hydrogen can be concentrated with gas separation membranes or similar technologies. As low-cost air separation concepts are being developed, the economics of an oxygen-blown system become more favorable with an air-blown IGCC system for power production. Oxygen-blown gasifiers are essential for chemicals production in order to reduce the amount of inert N_2 processed in subsequent unit operations.

The Energy & Environmental Research Center (EERC) is currently in Year 1 of a 3-year, $2.5 million program to operate a transport reactor gasifier under both air-blown and oxygen-blown conditions. Oxygen-blown testing is not scheduled to begin until the spring of 2000 after modification of the transport reactor loop seal (currently a J-leg) has been completed to allow for better mixing and higher solids recirculation rates. This modification is needed to dissipate the higher heat release rates that occur under oxygen-blown conditions while providing longer residence times for more complete carbon conversion. Current plans are to test higher-rank coals and other opportunity fuels such as petroleum coke and biomass or refuse-derived fuels (RDF) with the existing funding, but no tests are planned under the current DOE funding with a lignite fuel. Because there are no plans to use lignites under the existing project, the EERC is requesting funding from the North Dakota Industrial Commission (NDIC) to gasify a lignite in the EERC pilot-scale transport reactor development unit (TRDU). The advantages of the advanced transport reactor IGCC for electricity and fuel or chemicals production from lignite can be demonstrated through gasification tests at the EERC and include:

- Testing in an advanced high-efficiency power system (7000 Btu/kWh), which will ultimately result in less CO_2 emissions/global warming impact per unit of power output.
- Low sulfur emissions – > 95% inherent sulfur capture with Ca-based bed material. Higher sulfur capture is possible using hot-gas desulfurization technology currently under development. No wet scrubber process is necessary.
- Very low (<< 1 wt%) tar production – no organic byproduct to deal with.
- Transport reactor gasifier can handle coal fines – no coal fines separation necessary.
- High fuel reactivity results in higher conversion of lignite to fuel gas at temperatures low enough to prevent ash sintering problems.
- Use of hot- or warm-gas cleanup before combustion in a gas turbine results in little negative impact on cycle efficiency from high-moisture fuels.
- Oxygen-blown operation generates a nitrogen-free syngas suitable for chemicals or energy production.
- Transport reactors are used extensively in the petrochemical industry as fluid catalytic crackers and have operated at a commercial scale. SCS has exhibited strong commercial interest in the transport reactor technology developed by KBR. SCS has 20% cost share in a $125 million transport reactor "proof-of-concept" project at the SCS site in Wilsonville, Alabama. KBR, EPRI, SCS, and the EERC supplied 20% cost share for an over $3 million pilot-scale project at the EERC.

- Transport reactors are the highest throughput per unit cross-sectional area gasifier available—SCS estimates $880/kW total plant cost for air-blown operation. Lower capital costs are projected for oxygen-blown operation using oxygen separation membranes currently under development to produce syngas for chemicals and electricity.
- The successful use of lignite in this system will benefit the North Dakota lignite industry by demonstrating the technical and economic viability of lignite as a fuel in this type of high-efficiency IGCC power plant, thereby providing lignite-based options to electricity generators for their future power expansions.

2.0 PROJECT DESCRIPTION

The objective of the proposed scope of work is to evaluate the performance of lignite fuels in a highly efficient advanced transport reactor IGCC system. Specific technical issues include determining the effects of TRDU operating conditions on carbon conversion and product gas yields and quality while monitoring for the increased ash agglomeration and deposition potential of the lignite fuels. Variable operating conditions include air or oxygen:coal, steam:coal, sorbent:coal ratios and the operating temperature of the mixing zone of the gasifier. Obtaining a comparison of the cost of electricity from the lignite-fired transport gasifier versus a gas-fired combined cycle is also an important objective of this work.

Task 1 – Evaluation of Air-Blown TRDU Performance Using ND Lignite

Task 1 is broken into two subtasks, with Task 1.1 performing 50 hours of pressurized circulating fluid-bed combustor (PCFBC) testing and Task 1.2 performing 150 hours of air-blown gasification testing. Task 1 assumes the completion of two consecutive weeks of pilot-scale TRDU system operation, with the first 50 hours of operation devoted to operating the TRDU as a PCFBC to evaluate the combustion efficiency, emissions, and ash deposition tendencies under PCFBC operating conditions both in the TRDU and with the hot-gas filter system. Hot-gas filtering is accomplished at the maximum system limit of 1200°F and a filter face velocity of 4 ft/ min.

After completion of Task 1.1, the TRDU will be shut down for a system inspection and conversion of auxiliary equipment from combustion to gasification mode, which takes approximately a day to complete. The TRDU would then be reheated on gas and coal until transitioned to gasification for a 150-hour air-blown gasification test. The hot-gas filter system will be operated at 1000°F and a filter face velocity of 4 ft/min (Task 1.2) for the gasification test. Start-up typically consists of nominally 8 to 12 hours of natural gas firing to preheat the reactor and filter system followed by the desired operation period.

Fuel selection will be based on availability and ash deposition properties such as ash composition and ash fusion temperature. A final selection will be made in concurrence with the NDIC technical project monitor.

Any ash deposits collected during the first test period 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. Fuel gas composition (carbon dioxide, carbon monoxide, hydrogen, hydrogen sulfide, and methane along with other trace species) will be measured by on-line gas chromatography and reported with the fuel gas quantity to determine conversion efficiency. The gas-phase constituents—carbon monoxide, carbon dioxide, hydrogen, hydrogen sulfide, and oxygen—will also be monitored continuously using on-line instrumentation at the exit of the TRDU quench system. Gas-phase constituent data will be reported on a concentration basis and a heating value basis. Particulate sampling will be completed at the inlet and outlet of the hot-gas filter system during both combustion and gasification testing periods. Sampling at the inlet of the hot-gas filter system will document mass loading and particle-size distribution. Sampling at the outlet of the hot-gas filter system will document the collection efficiency of the ceramic filters and show whether acceptable turbine inlet levels are achieved. Particulate emissions will be reported on a mass per unit volume and parts per million by weight basis.

Composite samples of coal, bed material, and hot-gas filter ash will be collected for routine analyses. One composite coal sample will be analyzed for each period of operation. Analyses will include ultimate, proximate, Btu, dry-sieve, ash fusion (reducing), and XRF. Samples of limestone ash (LASH) bed material will be taken every 4 hours and analyzed for loss on ignition (LOI) and particle size along with selected XRF analysis. Hot-gas filter samples will also be collected every 4 hours and analyzed for LOI and particle size along with selected XRF. Samples of ash from other locations in the system such as the dipleg 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 period of TRDU operation. This experiment operating specification (EOS) will be reviewed with the NDIC technical project monitor prior to each period of operation. Special emphasis will be placed on the collection of data to determine the performance of the TRDU mixing zone at various temperatures and velocities with regard to product gas quality and ash deposition properties under reducing conditions. Deliverables include a pretest kickoff meeting to familiarize all involved parties with the TRDU and its capabilities. The initial test plan will be developed at this meeting. Deliverables also include a detailed report summarizing the test data and discussion of the operational, thermal, and environmental performance of the system within 3 months of the test completion date. A review meeting will be held at the EERC to present these results.

Task 2 – Oxygen-Blown TRDU Operation Using a ND lignite

Under the current DOE program, the TRDU loop seal will be modified from a J-leg to either a L-valve or a Y-leg, depending on cold-flow modeling currently under way at FETC–Morgantown. The current DOE program will pay for the loop seal modifications and two oxygen-blown gasification tests. It is expected to take 9 months to complete the loop seal modifications and the two DOE-funded oxygen-blown gasification tests. This will result in a minimum 9-month delay between the completion of the first air-blown gasification test and the second oxygen-blown gasification test. The lignite test should be conducted after the loop seal modifications and both 200-hour gasification tests have been completed in order to reduce the project risk to NDIC from system operation under the new configuration.

For budgeting purposes, it was assumed the TRDU would be heated on natural gas for 12 hours until transitioned to air-blown gasification for approximately 24 hours. This will allow a direct comparison between the air-blown data generated with the current J-leg loop seal and those generated with the new loop seal. After each subsequent 24-hour period, the oxygen concentration would be increased approximately 16% until either an upper temperature limit is reached in the mixing zone or full 100% oxygen-blown gasification conditions are achieved, with the test being continued until the desired 200-hour test period is completed. This oxygen-blown gasification test would be completed with the hot-gas filter system operating at 1000°F and a filter face velocity of 4 ft/min. An upper limit on operating temperature in the mixing zone would be selected on the basis of any ash deposition observations made during the previous air-blown gasification test and would be made in concurrence with the NDIC technical project monitor.

Conditions during the Task 2 period of operation will be modified on the basis of Task 1 observations and may include changes in sorbents or even the use of a different lignite. Ash deposits collected during the second test period will be characterized to determine chemical composition and relative strength. Specific analyses to be completed include XRF, SEM point count, and SEM morphology. Fuel gas composition (carbon dioxide, carbon monoxide, hydrogen, hydrogen sulfide, and methane along with other minor species) will be measured by on-line gas chromatography and reported with the fuel gas quantity to determine a conversion efficiency. The gas-phase constituents—carbon monoxide, carbon dioxide, hydrogen, hydrogen sulfide, and oxygen—will also be monitored continuously using on-line instrumentation at the exit of the TRDU quench system. Gas-phase constituent data will be reported on a concentration basis and a heating value basis. Particulate sampling will be completed at the inlet and outlet of the hot-gas filter system during both air-blown and oxygen-blown gasification testing periods. Sampling at the inlet of the hot-gas filter system will document mass loading and particle-size distribution. Sampling at the outlet of the hot-gas filter system will document the collection efficiency of the ceramic filters and show whether acceptable turbine inlet levels are achieved. Particulate emissions will be reported on a mass per unit volume and parts per million by weight basis.

Composite samples of coal, bed material, and hot-gas filter ash will be collected for routine analysis. One composite coal sample will be analyzed for each period of operation. Analyses will include ultimate, proximate, Btu, dry-sieve, ash fusion (reducing), and XRF. Samples of LASH bed material will be taken every 4 hours and analyzed for LOI and particle size along with selected XRF analysis. Hot-gas filter samples will also be collected every 4 hours and analyzed for LOI and particle size along with XRF. Samples of ash from other locations in the system such as the dipleg will also be collected. Analysis of these samples will depend on system performance observations and initial data analysis.

Again, a detailed EOS will be prepared for each period of TRDU operation and reviewed with the NDIC technical project monitor prior to each test period. Special emphasis will be placed on the collection of data to determine the performance of the TRDU mixing zone at various temperatures and velocities with regard to product gas quality and ash deposition properties under reducing conditions. Deliverables will include a Task 2 pretest meeting to familiarize all involved parties with the recent results from the TRDU loop seal changes and operation in an oxygen-blown mode. This will enable an initial Task 2 test plan to be developed at this meeting. Deliverables also include a detailed report summarizing the Task 2 test data and discussing the technical feasibility of oxygen-blown IGCC within 3 months of the test completion date. A final review meeting will be held at the EERC to present the results from the test and results from the modeling and economic projections of Tasks 3 and 4.

Task 3 – Gas Turbine Combustion Modeling

As part of the cost share in this program, GE will perform, at its expense, extensive computer modeling to determine the suitability of a transport reactor fuel gas to fire a GE frame gas turbine in a combined cycle system. This modeling will use the fuel gas flow rate, composition, temperature, and pressure from the TRDU tests after adjustment to a commercial-scale IGCC plant as inputs for the model. Output from the model will include pollutant emission rates, peak firing temperatures, gas turbine output, and load-following capability.

Task 4 – Economic Projections for Transport Reactor Gasifiers

Another part of the project cost share consists of Great River Energy performing at its expense an economic assessment for a transport reactor IGCC system operating on lignite as compared to a natural gas combined cycle system. This analysis will determine the natural gas fuel price at which this IGCC technology is competitive. Deliverables for Tasks 3 and 4 would include a summary of their findings at the review meetings and a written summary included in the final project report.

3.0 STANDARDS OF SUCCESS

The use of lignite as a fuel to the TRDU will be deemed a success if four criteria are met. First, the TRDU must exhibit stable operation without significant ash deposition or agglomeration for over 100 hours of operation. Second, the fuel gas must exceed 120 Btu/scf (after correction for nitrogen purges and heat loss) for air-blown operation and over 240 Btu/scf for oxygen-blown operation with carbon conversion exceeding 85% in either case. Third, the system emissions should be at least 10% of NSPS for a new commercial-scale power system. Fourth, the hot-gas filter system should show stable operation with only a small increase in filter baseline differential pressure (~40 inches water increase over the duration of the test). The technical advantages of firing a lignite in a transport gasifier will have been demonstrated if these criteria are met.

4.0 BACKGROUND

In September 1990, DOE entered into a cooperative agreement with SCS to design, construct, and operate a 50-tpd proof-of-concept integrated semiworks for the long-term testing of hot-gas cleanup under pressurized gasification and combustion conditions. Gas generators for this facility were selected that would also further develop high-efficiency advanced new power system technology. This resulted in the selection of the KBR transport reactor and the Foster Wheeler second-generation PFBC as the coal-based power systems to be installed at the SCS Power Systems Development Facility (PSDF) site near Wilsonville, Alabama.

In order to minimize the scaleup issues, the EERC entered into a subcontract to construct and operate a TRDU in 1992. The TRDU was built and operated at the EERC under Contract No. C-92-000276 with SCS. KBR designed and procured the reactor and provided valuable on-site personnel for start-up and operation. EPRI was involved in establishing the program and operating objectives with the EERC project team. The TRDU (200–350-lb/hr coal–limestone feed rate) provides an intermediate scale between the KBR 10-lb/hr transport reactor test unit (TRTU) and the 50-tpd PSDF reactor. Some of the design, construction, start-up, and operational issues for the Wilsonville transport train were addressed during this project's 2.5-year duration (2, 3).

In December 1994, a new project was started to improve the operation of the TRDU and add a hot-gas filter system. The objectives for that project were to evaluate the performance of hot-gas filter elements as a function of particulate collection efficiency, filter pressure differential, filter cleanability, and durability during relatively short-term operation (100–200 hr). A hot-gas filter system was used in combination with the TRDU to evaluate the performance of selected hot-gas filter elements under gasification operating conditions. During this 4-year project, seven test campaigns have been conducted. During these tests, 700 hours of gasification and 800 total hours of coal feed with Wyodak subbituminous coal, 41 hours of gasification on Illinois No. 6 bituminous coal, and 118 hours of gasification on SUFCo bituminous coal were completed. In addition, 70 hours of combustion on a petroleum coke were also completed, with the system gases and fly ash passing through the filter vessel during all of the test campaigns.

The TRDU was operated at an average temperature of 1607°F for the Wyodak coal tests and up to 1740°F for the bituminous coal tests. Coal feed rates ranged from 220 up to 320 lb/hr depending on the coal type and operating conditions, while the gasifier pressure averaged 120 psig. The raw moisture-free product gas produced was 6%–10% CO, 6–10% H_2, 9%–11% CO_2, 1.0%–2.5% CH_4, with the balance being N_2 and other trace constituents. The H_2S concentration averaged 50 to 400 ppm. Correction of the fuel gas concentrations for nitrogen purges and the high system heat loss as a percentage of the coal feed demonstrated that heating values ranging between 105 and 130 Btu/scf can be achieved. Factors that affect the TRDU product gas quality appeared to be circulation rate, coal type, temperature, and air:coal and steam:coal ratios. A decrease in circulation rate improves the product gas quality by increasing the solid residence time in the gasification zones of the TRDU; however, lower circulation rate tests were more prone to deposition and agglomeration problems as a result of inadequate gas–solid mixing in the mixing zone. The less reactive bituminous fuels were gasified at higher temperatures to produce a product gas quality similar to that obtained with the Wyodak fuel. Higher operating temperatures increase carbon conversion for the TRDU but again at the risk of increased ash deposition. Higher steam:coal ratios result in improved product gas quality with increased hydrogen and carbon dioxide formation from the water–gas shift reaction, but data also showed that additional CO was produced via the steam–carbon reaction.

The deposits that formed were generally in the mixing zone where the air first enters the TRDU through the burner inlet and comes into contact with the carbon-containing bed material circulating through the J-leg. If the gas–solid mixing is not adequate, localized hot spots can occur. As a result, some of the coal ash can form a sticky layer around bed material particles and start to "glue" impacting particles together in the form of deposits or agglomerates.

The objectives of the current DOE project, Advanced High-Temperature, High-Pressure Transport Reactor Gasification, at the EERC is to demonstrate acceptable hydrodynamic and gasification performance of the TRDU under a variety of operating conditions using a wide range of fuels. The current objectives are focused on understanding and improving the operation of the transport reactor gasifier itself under both air-blown and oxygen-blown conditions. A secondary objective of the program is to demonstrate acceptable performance of hot-gas filter elements on the hot dust-laden fuel gas stream coming from the pilot-scale TRDU system prior to long-term demonstration tests at the PSDF. Approximately $6 million have been spent to date on the TRDU concept at the EERC since its inception. The fuels to be tested in the current DOE program include a petroleum residual product, two bituminous coals, and an opportunity fuel such as biomass or RDF, but does not include a lignite, thereby necessitating NDIC funding to ensure that a lignite is tested under both the air- and oxygen-blown conditions.

The EERC Transport Reactor Development Unit

The TRDU is a 200–300-lb/hr pressurized circulating fluid-bed gasifier similar to the gasifier being tested at the SCS PSDF site. The TRDU has an exit gas temperature of up to 2000°F, a gas flow rate of up to 350 scfm, and an operating pressure of 120 psig. The TRDU system can be divided into three sections: the coal feed section, the TRDU, and the product recovery section. The TRDU proper, as shown in Figure 1, consists of a riser reactor with an expanded mixing zone at the bottom, a disengager, and a primary cyclone and standpipe. The standpipe is connected to the mixing section of the riser by a J-leg transfer line. All of the components in the system are refractory-lined and designed mechanically for 150 psig and an internal temperature of 2000°F. Detailed design criteria and a comparison to actual operating conditions on the design coal are given in Table 1.

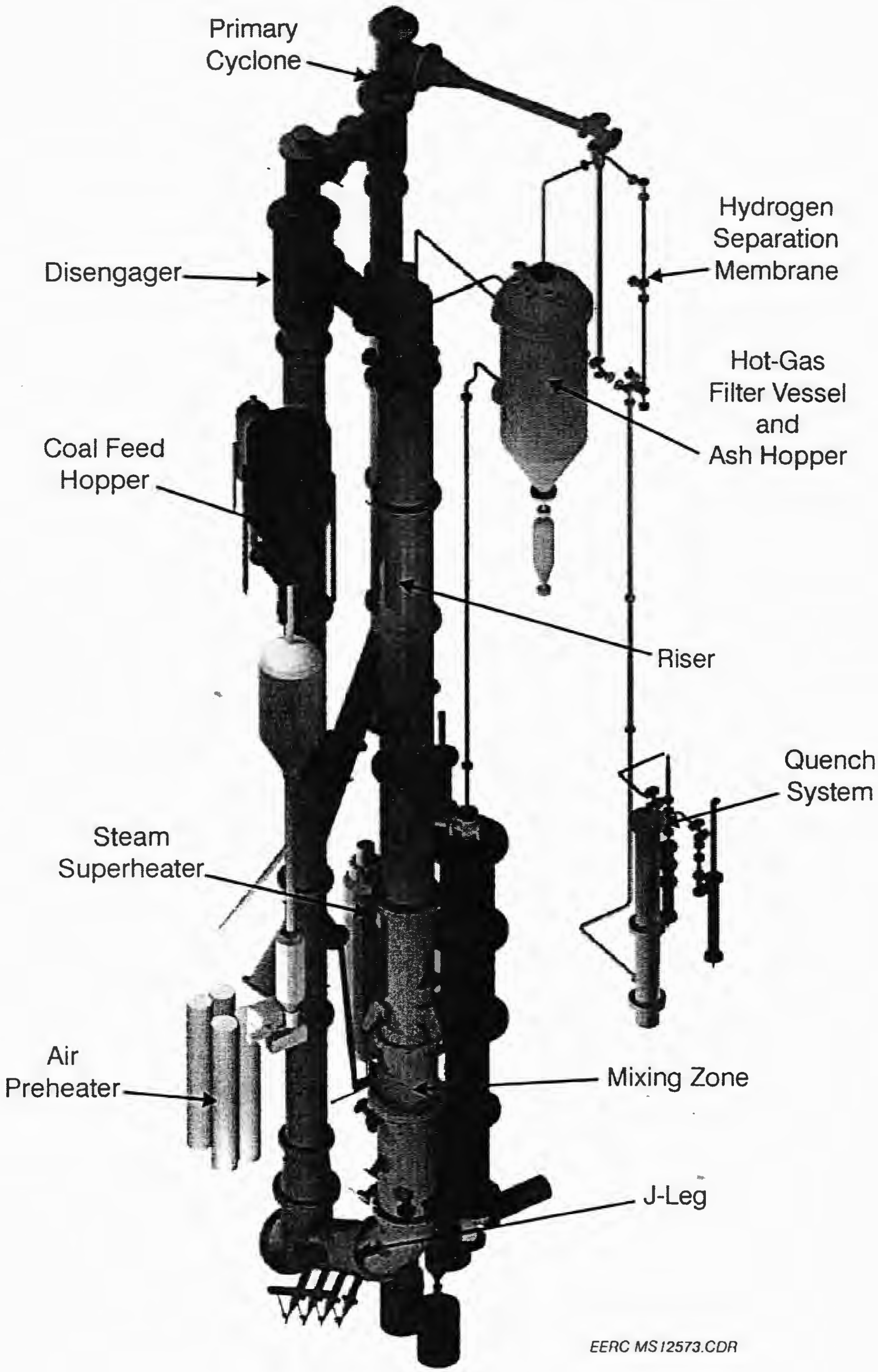

Figure 1. TRDU with HGFV in EERC gasification tower.

Table 1. Summary of TRDU Design and Operation on the Design Coal

Parameter	Design	Actual
Coal	Illinois No. 6	Illinois No. 6
Moisture Content, %	5	8.5
Pressure, psig	120	120*
Steam:Coal Ratio	0.34	0.39
Air:Coal Ratio	4.0	2.6
Ca:S Ratio, mole	1.5	2.0
Air Inlet Temperature, °F	800	650
Steam Preheat, °F	1000	650
Coal Feed Rate, lb/hr	198	232
Gasifier Temperature, maximum °F	2000	1750
ΔT, maximum °F	32	180
Conversion, %	>80	89
HHV[1] of Fuel Gas, Btu/scf	100	113
Heat Loss as Coal Feed, %	19.5	14
Riser Velocity, ft/s	40	25
Heat Loss, Btu/hr	252,000	300,000
Standpipe Superficial Velocity, ft/s	0.1	0.38

[1] Higher heating value.

Detailed descriptions of the TRDU and hot-gas filter vessel HGFV design has been given in other reports (4, 5).

The HGFV is designed to handle all of the gas flow from the TRDU at its nominal operating conditions. This vessel has a 48-in. inner diameter and is 185 in. long, with a refractory inside diameter of 28 in. and a shroud diameter of 24 in. The filter design criteria and its average operating conditions are summarized in Table 2. Filter vessel design capabilities include operation at elevated temperatures (to 1750°F) and pressures (up to 150 psig), with the initial test program operating in

Table 2. Design Criteria and Operating Conditions for the Pilot-Scale Hot-Gas Filter Vessel

Operating Conditions	**Design**	**Actual**
Inlet Gas Temperature	1000°–1800°F	860°–1200°F
Operating Pressure	8.6–11.4 bar	9.3 bar
Volumetric Gas Flow	350 scfm	280 – 375 scfm
Number of Candles	19 (1.5-meter)	13 (1-meter)
Candle Spacing	4 in. ℄ to ℄	4 in. ℄ to ℄
Filter Face Velocity	2.5–10 ft/min	4.0 ft/min
Particulate Loading	<10,000 ppm	< 38,000 ppm
Temperature Drop Across HGFV	< 55°F	45°F
Nitrogen Backpulse System Pressure	up to 800 psig	up to 380 psig
Backpulse Valve Open Duration	up to 1-s duration	½-s duration

the 1000°–1200°F range. The HGFV can operate with filter face velocities in the range of 2.5 to 10 ft/min. Up to nineteen 1.5-meter candles can be installed in the filter vessel, but 1.0-meter candles have been used to date. An existing heat exchanger limits the current hot-gas filter system to operation between 800° and 1200°F. An unheated nitrogen backpulse system was constructed to test the effects of backpulsing parameters on candle performance and cleanability. The nitrogen backpulse system was constructed to backpulse up to four sets of four- or five-candle filters in a time-controlled or differential pressure-controlled sequence.

Sample ports for obtaining particulate and hazardous air pollutant samples were added to the piping system so that a high-pressure and high-temperature sampling system (HPHTSS) can be used to extract dust-laden flue gas isokinetically from the TRDU's reducing environment. Details of the HPHTSS are given elsewhere (5). In the past year, a switch to a metal tube sheet as opposed to a ceramic tube sheet was made to provide better filter seal performance and reliability.

5.0 QUALIFICATIONS

The University of North Dakota (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 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.

Project manager Michael Swanson and the EERC technical support team have many years of experience with related projects. Resumes are included in Appendix A.

6.0 VALUE TO NORTH DAKOTA

The goals of the KBR IGCC transport reactor gasification project include the development of a high-efficiency power system with a net electric system efficiency approaching 50%, SO_2 and NO_x emissions at 1/10 of NSPS, air toxic emissions below 1990 CAAA levels, and a capital cost of less than $900/kW that produces electricity at 80% of the cost of a conventional pc power plant. Demonstrating that the highly reactive lignite fuels will produce a quality product gas without ash-related problems during the operation of an advanced power system such as a transport reactor IGCC will help market North Dakota's low-cost lignite reserves as a viable fuel for future advanced power generating and chemical coproduction. The high reactivity of the lignite provides a market advantage against other coals for this type of IGCC system, and the impact of high moisture is minimized. These systems also offer the best potential competition to natural gas-fired turbines. IGCC systems are being developed and promoted under DOE's Vision 21 program, which should help facilitate market acceptance and accelerate implementation of IGCC by today's generating companies.

7.0 TIMETABLE

If funding is in place by September 1, 1999, and a lignite fuel can be selected and delivered within a few weeks, we could complete the first air-blown gasification test by mid to late October, 1999. The second oxygen-blown test would be completed after the TRDU loop seal modifications and subsequent two 200-hour oxygen-blown gasification tests are completed, which would delay the second test approximately 9 months until the mid to late summer of 2000. All of the analytical work for each test period should be completed within 2 months of the test completion. This would enable a detailed Task 1 report summarizing all test data to be completed around the end of December, 1999. The detailed Task 2 report summarizing all the Task 2 test data would be completed around late October, 2000. The final report including all modeling and economic assessment results would be finished by the end of December, 2000. Table 3 outlines the project schedule.

Table 3. Project Time Line

	October 1999	December 1999	July 2000	October 2000	December 2000
First Lignite Gasification Test	X				
Analytical Work and Task 1 Detailed Report		X			
Second Lignite Gasification Test			X		
Analytical Work and Task 2 Detailed Report				X	
Final Report					X

8.0 MANAGEMENT

The project will be managed by Michael Swanson. Mr. Swanson has 17 years of experience as an engineer working in the area of high-temperature, high-pressure advanced power generation and hot-gas cleanup. He is also the project manager of the current DOE-funded $2.5 million Advanced High-Temperature, High-Pressure Transport Gasification project. Mr. Swanson has responsibility for administrative and technical review of projects related to transport reactor gasifier performance and hot-gas filter operation and provides technical expertise in all gasification projects at the EERC. Dr. Michael D. Mann (EERC Senior Research Advisor) will provide technical assistance and advice. Resumes are in Appendix A.

9.0 BUDGET

This proposal requests a base amount of $249,970 from NDIC to allow testing of a North Dakota lignite in a transport reactor gasifier. These tests will prove the viability of lignite as a fuel for an advanced high-efficiency transport reactor IGCC system. If successful, this will ensure a continued market for North Dakota lignite in a highly competitive deregulated power-generating market, which will also be facing a strict regulatory environment. Once we have NDIC's commitment, we will submit the proposal to DOE requesting approval of its share of the funding. For inclusion in the proposal to DOE, the EERC needs a letter of commitment, purchase order, or signed contract from NDIC and a short overview of NDIC.

A detailed budget and budget notes follow the body of the proposal.

10.0 MATCHING FUNDS

Based on preliminary discussions with several interested parties, this proposal assumes approximately $260,000 in industrial support will be received from several organizations. These organizations include Otter Tail Power, NSP, Great River Energy, Minnesota Power, GE, SCS, KBR, and Dakota Gasification. These organizations have all expressed an interest in participating in a review board to evaluate the viability of the transport reactor IGCC concept for commercial development. These groups were assumed to provide $10,000 per year of in-kind support in the form of travel and the performance of an engineering review at scheduled meetings. GE has also offered to perform, at no cost to the project, a series of computer models to evaluate the performance of a transport reactor fuel gas in a GE frame gas turbine. Great River Energy has offered to perform an economic assessment of a lignite-fueled transport reactor IGCC as compared to a natural gas-fired combined cycle plant. When NDIC makes a decision to fund this project, the EERC will request approval for one-third of the project costs from the EERC–DOE Jointly Sponsored Research Program. NDIC would be providing one-third of the total project costs, with one-third from the other commercial sponsors.

11.0 TAX LIABILITY

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

12.0 CONFIDENTIAL INFORMATION

The EERC has an agreement with KBR to keep all detailed design information on the construction of the TRDU confidential. The EERC is permitted to release operating data such as temperatures, pressures, flows, velocities, gas compositions, and the solids material balance information to other public and private organizations such as DOE, SCS, and various hot-gas filter vendors.

13.0 REFERENCES

1. From U.S. DOE Integrated Gasification Combined Cycle Technology Strategic Objectives Web site at http://www.fe.doe.gov/coal_power/igcc_so.html.

2. Ness, R.O. *Transport Reactor Demonstration Unit, Volume 1 – Final Report*; EERC Publication No. 95-EERC-02-06, May 1995; 150 p.

3. Ness, R.O. Transport Reactor Demonstration Unit. In *Proceedings of the Coal-Fired Power Systems '93—Advances in IGCC and PFBC Review Meeting*; DOE/METC-93/6131 (DE93000289), June 1993; pp. 357–358.

4. Swanson, M.L.; Ness, R.O.; Mann, M.D.; Haley, J.S. Hot-Gas Filter Testing with the Transport Reactor Demonstration Unit. In *Proceedings pf the Advanced Coal-Fired Power Systems '95 Review Meeting*; DOE/METC-95/1018 (DE95009732), June 1995; Vol. 1, pp. 87–97.

5. Swanson, M.L.; Mann, M.D.; Sondreal, E. *Hot-Gas Filter Testing in a Transport Reactor Development Unit*; final report for the period Dec. 1994 to Sept. 1998.