ADVANCED HIGH-TEMPERATURE, HIGH-PRESSURE TRANSPORT REACTOR GASIFICATION

Comprehensive Final Technical Report

for the period September 30, 1998, through August 30, 2005
(including the annual report for January 1 through December 31, 2005)

Prepared for:

U.S. Department of Energy

National Energy Technology Laboratory
3610 Collins Ferry Road
PO Box 880, Mail Stop C04
Morgantown, WV 26507-0880

Cooperative Agreement No. DE-FC26-98FT40514
Performance Monitor: Ronald Breault

Prepared by:

Michael L. Swanson

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

06-EERC-03-01 March 2006

DOE DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DOE ACKNOWLEDGMENT

This report was prepared with the support of the U.S. Department of Energy (DOE), National Energy Technology Laboratory, Cooperative Agreement No. DE-FC26-98FT40514. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of the DOE.

EERC DISCLAIMER

LEGAL NOTICE This research report was prepared by the Energy & Environmental Research Center (EERC), an agency of the University of North Dakota, as an account of work sponsored by the U.S. Department of Energy. Because of the research nature of the work performed, neither the EERC nor any of its employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement or recommendation by the EERC.

ADVANCED HIGH-TEMPERATURE, HIGH-PRESSURE TRANSPORT REACTOR GASIFICATION

ABSTRACT

The transport reactor development unit (TRDU) was modified to accommodate oxygen-blown operation in support of a Vision 21-type energy plex that could produce power, chemicals, and fuel. These modifications consisted of changing the loop seal design from a J-leg to an L-valve configuration, thereby increasing the mixing zone length and residence time. In addition, the standpipe, dipleg, and L-valve diameters were increased to reduce slugging caused by bubble formation in the lightly fluidized sections of the solid return legs. A seal pot was added to the bottom of the dipleg so that the level of solids in the standpipe could be operated independently of the dipleg return leg. A separate coal feed nozzle was added that could inject the coal upward into the outlet of the mixing zone, thereby precluding any chance of the fresh coal feed back-mixing into the oxidizing zone of the mixing zone; however, difficulties with this coal feed configuration led to a switch back to the original downward configuration. Instrumentation to measure and control the flow of oxygen and steam to the burner and mix zone ports was added to allow the TRDU to be operated under full oxygen-blown conditions.

In total, ten test campaigns have been conducted under enriched-air or full oxygen-blown conditions. During these tests, 1515 hours of coal feed with 660 hours of air-blown gasification and 720 hours of enriched-air or oxygen-blown coal gasification were completed under this particular contract. During these tests, approximately 366 hours of operation with Wyodak, 123 hours with Navajo subbituminous coal, 143 hours with Illinois No. 6, 106 hours with SUFCo, 110 hours with Prater Creek, 48 hours with Calumet, and 134 hours with a Pittsburgh No. 8 bituminous coal were completed. In addition, 331 hours of operation on low-rank coals such as North Dakota lignite, Australian brown coal, and a 90:10 wt% mixture of lignite and wood waste were completed. Also included in these test campaigns was 50 hours of gasification on a petroleum coke from the Hunt Oil Refinery and an additional 73 hours of operation on a high-ash coal from India. Data from these tests indicate that while acceptable fuel gas heating value was achieved with these fuels, the transport gasifier performs better on the lower-rank feedstocks because of their higher char reactivity.

Comparable carbon conversions have been achieved at similar oxygen/coal ratios for both air-blown and oxygen-blown operation for each fuel; however, carbon conversion was lower for the less reactive feedstocks. While separation of fines from the feed coals is not needed with this technology, some testing has suggested that feedstocks with higher levels of fines have resulted in reduced carbon conversion, presumably due to the inability of the finer carbon particles to be captured by the cyclones. These data show that these low-rank feedstocks provided similar fuel gas heating values; however, even among the high-reactivity low-rank coals, the carbon conversion did appear to be lower for the fuels (brown coal in particular) that contained a significant amount of fines. The fuel gas under oxygen-blown operation has been higher in hydrogen and carbon dioxide concentration since the higher steam injection rate promotes the water–gas shift reaction to produce more CO_2 and H_2 at the expense of the CO and water vapor. However, the high water and CO_2

partial pressures have also significantly reduced the reaction of hydrogen sulfide with the calcium-based sorbents and thus the capture of sulfur in the circulating-bed material.

Since warm-gas cleanup is utilized, the unconverted steam and coal moisture injected into the gasifier will remain in the fuel gas entering the gas turbine. When the air-blown and oxygen-blown fuel gas heating values are compared for the wet product gas streams, it is apparent that only a slight improvement in product gas heating value entering the gas turbine is achieved with oxygen-blown operation. In order to keep the gas turbine firing temperature down to prevent thermal NO_x formation, typically large amounts of nitrogen or steam are injected into the gas turbine combustor such that the fuel gas heating is typically not much greater than 115 Btu/scf as-fired. In essence, the transport reactor has either injected the nitrogen with the oxidant (in the form of air) into the gasifier instead of directly into the gas turbine combustor in air-blown mode or has injected the steam directly into the gasifier instead of the gas turbine combustor in the oxygen-blown case. However, in a Vision 21 plant, where chemicals or fuel production are being considered and where potentially conventional cold-gas cleanup technology would be utilized to remove the water vapor from the fuel gas stream, significantly higher concentrations of desirable fuel gas constituents are achieved with oxygen-blown operation.

The TRDU and hot-gas filters have operated for over 2175 hours in gasification mode and over 2500 hours total with no major candle failures. The candles have exhibited no significant loss in candle permeability. The baseline "cleaned" filter differential pressure typically increased from 20 to approximately 80 inches H_2O over the course of most tests. The inlet particulate loading has ranged from approximately 3500 to 33,800 ppm, with the filter ash averaging between 20 to 70 wt% carbon with a low bulk density around 20 lb/ft^3. The average filter ash particle size has ranged from approximately 7 to 22 µm in size and was essentially representative of the coal ash from very early in the gasification test. The initial rapid recovery of the filter differential pressure along with the small size, the lack of cohesiveness seen in other filter ashes, and the low density of the ash had suggested that a high percentage of the filter cake would be reentrained back onto the filters after they are backpulsed. The large increase in filter baseline differential pressure also suggests that a thin but low-porosity (permeable) filter cake is remaining on the surface of the candle and is not being removed during backpulsing. The low bulk density and high flowability of the filter ash possibly suggests that the inlet ash is able to move or shift on the surface of the candle to reach some optimum (minimum) porosity, leading to low gas permeability across the candle.

Continuous measurement of mercury in the warm fuel gas has been another goal of the project. After considerable trial and error, a fuel gas-conditioning system and Hg continuous emission monitor (CEM) analyzer has been configured to allow the continuous measurement of mercury emissions. Sampling issues for both the wet-chemistry and Hg CEM techniques have been resolved, so that good agreement between the two techniques is being achieved. Wet-chemistry analysis has shown the mercury to essentially be in the elemental form. The EERC continues to utilize advanced scanning electron microscopy (SEM) techniques where appropriate to determine the chemistry of any bed material agglomeration or deposition samples. No high levels of reactive sulfide have been measured in any TRDU samples that would make the residual solids a hazardous waste.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

ADVANCED HIGH-TEMPERATURE, HIGH-PRESSURE TRANSPORT REACTOR GASIFICATION

1.0 OBJECTIVES

The objectives of the advanced high-temperature, high-pressure transport reactor gasification system with the transport reactor demonstration unit (TRDU) located at the Energy & Environmental Research Center (EERC) is to demonstrate and optimize the performance of the transport reactor gasification concept in a pilot-scale system prior to longer-term demonstration tests at the Power Systems Development Facility (PSDF). The primary focus of the experimental effort over the last 6 years has been to modify the TRDU and conduct oxygen-blown gasification testing including investigating the effects of coal type on gasification performance. A secondary objective of the project has been the testing of hot-gas filter element performance (particulate collection efficiency, filter pressure differential, filter cleanability, and durability) as a function of temperature and filter face velocity during relatively short-term operation (100–200 hours). The filter vessel is used in combination with the TRDU to evaluate the performance of selected hot-gas filter elements under gasification operating conditions. This work directly supports the PSDF utilizing the Kellogg Brown & Root (KBR) transport reactor located at Wilsonville, Alabama (1).

2.0 BACKGROUND INFORMATION

The U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) has a gasification program that has made gasification one of the centerpiece technologies being developed for future power, fuels, and chemicals production under the Vision 21 Program. In order to economically make fuels and chemicals from synthesis gas, the fuel should have a minimal amount of nitrogen in the fuel gas in order to minimize the size of the downstream unit operations required to produce the desired fuel or chemical slate.

The Gas Cleanup Program is intended to develop and demonstrate gas stream cleanup options for use in combustion- or gasification-based advanced power systems. One objective of the NETL gas cleanup program is to support the development and demonstration of barrier filters to control particulate matter. The goal is not only to meet current New Source Performance Standards (NSPS) with respect to particulate emissions, but also to protect high-efficiency gas turbines and control particulate emissions to low enough levels to meet more stringent regulatory requirements anticipated in the future. DOE NETL is investing significant resources in the PSDF under a Cooperative Agreement with Southern Company Services, Inc. (SCS). The Wilsonville facility will include three modules, including an advanced gasifier module, a gas cleanup module, and a combustor/turbine module. The gasifier module incorporates the KBR transport reactor technology for both gasification and combustion (1).

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 during operation. The Electric Power Research Institute (EPRI) was involved in establishing the program and operating objectives with the EERC project team.

The purpose of the previous program was to build a reactor system larger than the TRTU located in Houston, Texas, in support of the Wilsonville PSDF transport reactor train. The program was to address design and operation issues for the Wilsonville unit and also help develop information on the operation of the unit to decrease start-up costs.

The TRDU (design rate 240-lb/hr coal–limestone feed rate) provides an intermediate scale to the TRTU (up to 10-lb/hr coal–limestone feed rate) and the Wilsonville transport reactor (3400-lb/hr feed rate). Some of the design, construction, start-up, and operational issues for the Wilsonville transport train are being addressed during this project.

The four major design criteria that were established by EPRI were met (2): coal feed rate, operating pressure, carbon conversion, and high heating value of the product gas. Major accomplishments included showing that the TRDU performed well hydrodynamically, that it had the ability to switch from combustion mode to gasification mode easily and safely, that solids could be fed to and removed from the system, and that the J-leg/standpipe and cyclone performed according to their design specifications.

3.0 PROJECT DESCRIPTION

3.1 TRDU

The TRDU has an exit gas temperature of up to 980°C (1800°F), a gas flow rate of 325 scfm, and an operating pressure of 120–150 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 (which is an actual cyclone, unlike the disengager at the PSDF), and a primary cyclone and standpipe and dipleg under cyclone for recycling the bed material back to the mixing zone. 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 1090°C (2000°F). Table 1 summarizes the operational performance for the TRDU under the previous test program (3).

The premixed coal and limestone feed to the transport reactor can be admitted through three nozzles, which are at varying elevations. Two of these nozzles are located near the top of the mixing zone (gasification), and the remaining one is near the bottom of the mixing zone (combustion). During operation of the TRDU, feed is admitted through only one nozzle at a time. The coal feed is measured by an rpm-controlled metering auger. Oxidant is fed to the reactor through two pairs of nozzles at varying elevations within the mixing zone. For the combustion mode of operation, additional nozzles are provided in the riser for feeding secondary air. Hot solids from the standpipe are circulated into the mixing zone, where they come into contact with the nitrogen and the steam being injected into the J-leg. This feature enables spent char to contact steam prior to the fresh

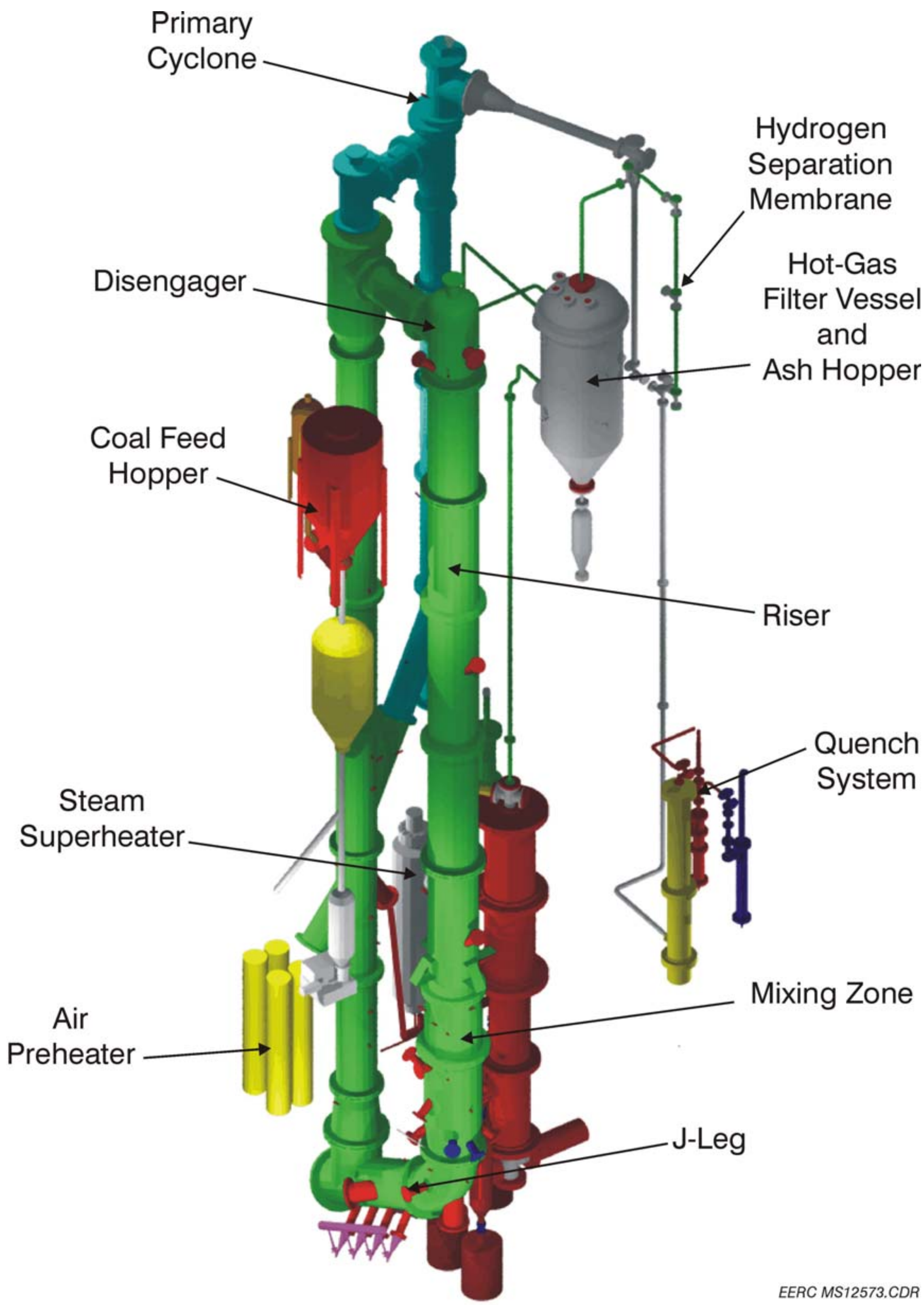

Figure 1. TRDU and hot-gas vessel in the EERC gasification tower.

Table 1. TRDU Design and Typical Actual Operating Conditions

Parameter	Design	P056 and P057	P056	P057
Conditions	Gasification	Gasification	Gasification	Gasification
Coal	Illinois No. 6	Wyodak	Illinois No. 6	SUFCo
Moisture Content, %	5	20	8.5	9.5
Pressure, bar	9.3	9.3	9.3	9.3
Steam:Coal Ratio, lb/lb coal	0.34	0.29	0.39	0.14 to 0.41
Air:Coal Ratio, lb/lb coal	4.0	2.69	2.59	3.34–3.45
Ca:S Mole Ratio, sorbent	1.5	2	2	2
Coal Feed Rate, lb/hr	198	276.6	232.5	220
J-Leg Zone, °C, avg.	9.931010e+13	8.00850841e+17	9.019359e+17	866–876
Mixing Zone, °C , avg.				920–950
Riser, °C, avg.				894–914
Standpipe, °C, avg.				828–860
Dipleg, °C, avg.				555–591
TRDU Outlet, °C, avg.				856–877
Carbon Conversion, %	>80	89	76	72–87
Carbon in Bed, %, Standpipe	20 to 40	6 to 15	6 to 15	5 to 20
Riser Velocity, ft/s	31.3	30	24	25–31
Standpipe Velocity, ft/s	0.1	0.4 to 0.5	0.45	0.4–0.45
Circulation Rate, lb/hr	30000	3000 to 6000	4000	2650–4200
HHV of Fuel Gas, Act.,	100	62–75	61113	52–75
Btu/scf,		105–117		93–130
Cor., Btu/scf				
Duration, hr	NA	179	41	118

coal feed. This staged gasification process is expected to enhance the process efficiency. Gasification or combustion and desulfurization reactions are carried out in the riser as coal, sorbent, and oxidant (with steam for gasification) flow up the reactor. The solids circulation into the mixing zone is controlled by the solids level in the standpipe and by the gas flow rates and distribution in the J-leg aeration nozzles.

The riser, disengager, standpipe, and cyclones are equipped with several internal and skin thermocouples. Nitrogen-purged pressure taps are also provided to record differential pressure across the riser, disengager, and the cyclones. The data acquisition and control system scans the data points every one-half second and saves the process data every 30 seconds. The bulk of entrained solids leaving the riser is separated from the gas stream in the disengager and circulated back to the riser via the standpipe. A solids stream can be withdrawn from the standpipe via an auger to maintain the system’s solids inventory. Gas exiting the disengager enters a primary cyclone. Solids from the primary cyclone were collected in a lock hopper for earlier tests through approximately Test P055. In tests after P055, the dipleg solids have been recirculated back to the standpipe through the dipleg crossover. Gas exiting this cyclone enters a jacketed-pipe heat exchanger before entering the hot-gas filter vessel (HGFV). The cleaned gases leaving the HGFV enter a quench system before being depressurized and vented to a flare.

The quench system uses a sieve tower and two direct-contact water scrubbers to act as heat sinks and remove impurities. All water and organic vapors are condensed in the first scrubber, with the second scrubber capturing entrained material and serving as a backup. The condensed liquid is separated from the gas stream in a cyclone that also serves as a reservoir. Liquid is pumped either to a shell-and-tube heat exchanger for reinfection into the scrubber or down to the product receiver barrels.

3.2 Hot-Gas Filter Vessel

This vessel is designed to handle all of the gas flow from the TRDU at its expected operating conditions. The vessel is approximately 48-in. ID and 185 in. long and is designed to handle gas flows of approximately 325 scfm at temperatures up to 980°C (1800°F) and 130 psig. The refractory has a 28-in. ID with a shroud diameter of approximately 22 in. The vessel is sized such that it could handle candle filters up to 1.5 m long; however, 1-m candles were utilized in the 1000°F (540°C) gasification tests. Candle filters are 2.375-in. OD with 4-in. center line-to-center line spacing. The filter design criteria are summarized in Table 2, and a schematic is given in Figure 2.

The total number of candles that can be mounted in the current geometry of the tube sheet is 19. This enables filter face velocities as low as 2.5 ft/min to be tested using 1-m candles. Tests consisted of 200-hr hot-gas filter tests under gasification conditions using the TRDU with the filter operating at temperatures of 540°–650°C (1000°–1200°F) and 120 psig. Higher face velocities would be achieved by using fewer candles. The test program performed the first filter test at 540°–650°C (1000°–1200°F), 120 psig, and 2.75 ft/min face velocity. All subsequent testing was performed after removing six candles to increase the face velocity to approximately 4.0 to 4.5 ft/min at the same operating temperature and pressure. The openings for the six removed candles were blanked off. This program has tested an Industrial Filter & Pump (IF&P) ceramic tube sheet and

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

Operating Conditions	Design	Actual
Inlet Gas Temperature	540°–980°C	520°–580°C
Operating Pressure	150 psig	120 psig
Volumetric Gas Flow	325 scfm	350 scfm
Number of Candles	19 (1 or 1.5 meter)	13 (1-meter)
Candle Spacing	4 in. ℄ to ℄	4 in. ℄ to ℄
Filter Face Velocity	2.5–10 ft/min	4.5 ft/min
Particulate Loading	<10,000 p.m.	< 7,000 p.m.
Temperature Drop Across HGFV	<30° C	25°C
Nitrogen Backpulse System Pressure	up to 800 psig	250 to 350 psig
Backpulse Valve Open Duration	up to 1-sec duration	½-sec duration

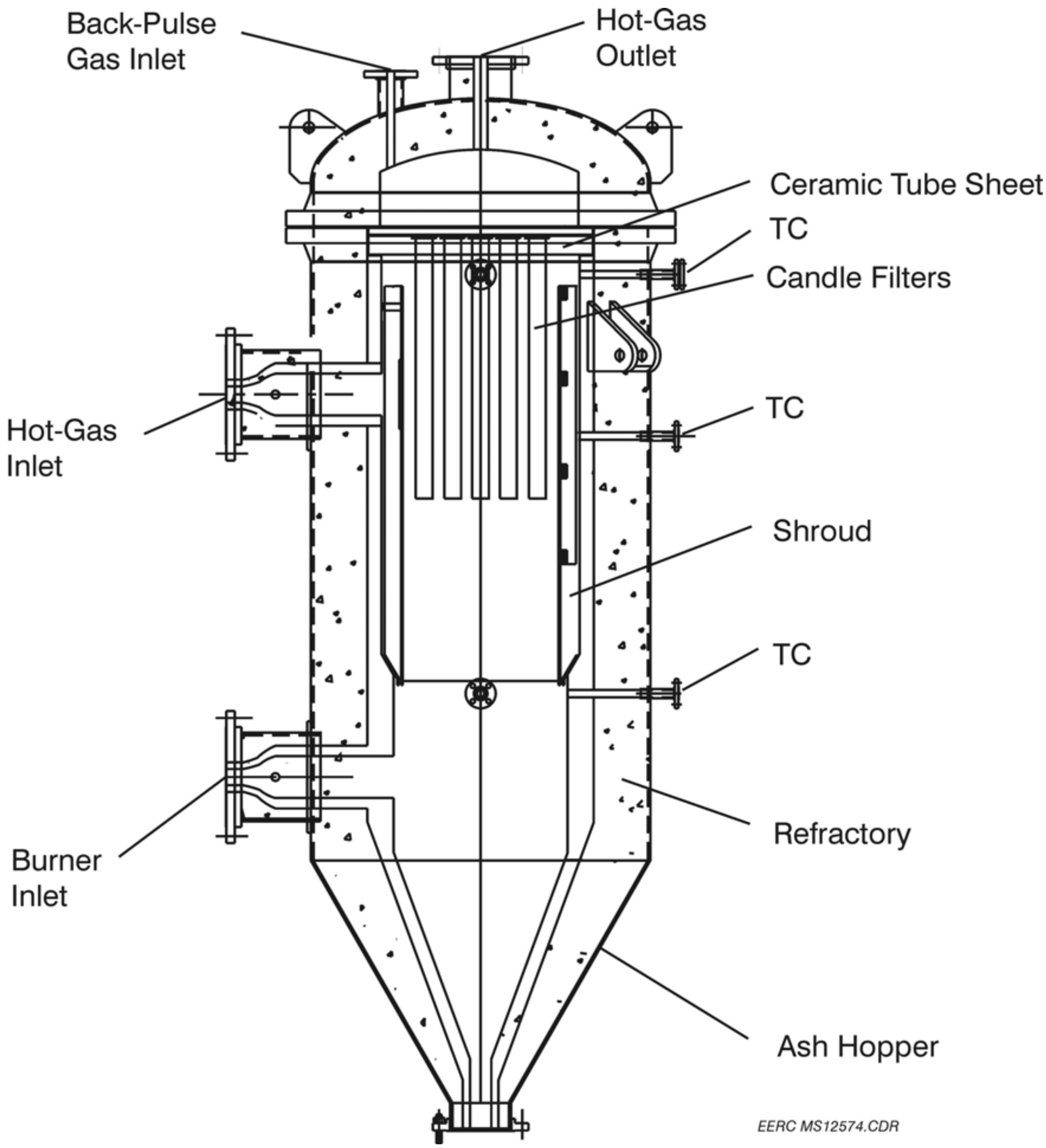

Figure 2. Schematic of the filter vessel design with internal refractory, tube sheet, and shroud.

Fibrosic candles, silicon carbon-coated ceramic fiber candles from the 3M Company, along with sintered metal (iron aluminide) and Vitropore silicon carbon ceramic candles from Pall Advanced Separation Systems Corporation. Later tests also utilized a metal tube sheet manufactured with expansion cones to allow for thermal stresses. Since the metal tube sheet was installed, candle filter fail-safes from Westinghouse Science and Technology Center have also been tested.

The ash letdown system consists of two sets of alternating high-temperature valves with a conical pressure vessel to act as a lock hopper. Additionally, a preheat natural gas burner attached to a lower inlet nozzle on the filter vessel can be used to preheat the filter vessel separately from the TRDU. The hot gas from the burner enters the vessel via a nozzle inlet separate from the dirty gas.

The high-pressure nitrogen backpulse system is capable of backpulsing up to four sets of four or five candle filters with ambient-temperature nitrogen in a time-controlled sequence. The pulse length and volume of nitrogen displaced into the filter vessel is controlled by regulating the pressure (up to 800 psig) of the nitrogen reservoir and the solenoid valves used to control the timing of the gas pulse. Figure 1 also shows the filter vessel location and process piping in the EERC gasifier tower. Since all the filter tests are to be completed in the 540°–650°C (1000°–1200°F) range, a length of heat exchanger was used to drop the gas temperature to the desired range. In addition, sample ports both upstream and downstream of the filter vessel have been utilized for obtaining particulate and hazardous air pollutant (HAP) samples.

4.0 ACCOMPLISHMENTS

4.1 TRDU Fuel Analysis

The fuels tested in the TRDU have been a Powder River Basin (PRB) subbituminous coal from the Wyodak seam at the Belle Ayr Mine in Gillette, Wyoming; an Illinois No. 6 bituminous coal from Seam 6 of the Creek Palm Mine near Mirressa, Illinois; a western bituminous coal mined from the Hiawatha seam at the SUFCo Mine in Salina, Utah; a bituminous coal from the Prater Creek Mine in eastern Kentucky; a bituminous coal from Mary Lee seam at the Calumet Mine in Alabama; a bituminous coal from Pittsburgh No. 8 seam from Consul's Bailey Mine; a petroleum coke from the Hunt Oil Refinery in Tuscaloosa, Alabama; a high-ash subbituminous coal from the Navajo Mine in the Four Corners region of New Mexico; and three different North Dakota lignites. Wood residue hog fuel was coal-fed with one of the lignites. Tables 3 and 4 shows the proximate, ultimate, and x-ray fluorescence (XRF) analysis of these fuels. In addition, through an intergovernment agreement between the Australian government and the U.S. government and separately through U.S. AID, three foreign coals (two different Australian brown coals and an as-received and washed high ash coal from India) have also been tested in the TRDU. Table 5 shows the proximate and ultimate analysis for these fuels also. Table 6 shows the XRF and loss on ignition (LOI) analyses for the Plum Run dolomite and the Montana and Longview limestones utilized in these tests. All fuels were mixed with calcium-based sorbents to provide a Ca/S molar ratio of approximately 1.5 to 2 on a sorbent-only basis for the fuels being gasified. Figure 3 shows the particle-size distribution for the coals tested on the TRDU. In general, the coal mean feed size is between approximately 300 to 500 μm which is larger than the circulating bed material mean size of 200 μm. Because of the friability of the brown coals, significantly more fines were present in the feed coal than other coals.

Table 3. Proximate, Ultimate, HHV, and XRF Analysis Results for TRDU Testing

	−10-mesh Wyodak Subbituminous Coal	−10-mesh Illinois No. 6 Bituminous Coal	−10-mesh SUFCo Bituminous Coal	−10-mesh Center Lignite Coal	−10-mesh Falkirk Lignite Coal	−10-mesh Freedom Lignite Coal	−1/8" Wood Hog Fuel
Proximate Analysis, as run, wt%							
Moisture	20.0	8.5	9.5	35.5	29.50	26.80	12.2
Volatile Matter	38.9	36.0	39.1	24.3	30.92	32.52	73.1
Fixed Carbon	36.4	44.8	43.8	25.3	27.89	32.48	11.1
Ash	4.7	10.7	7.6	14.87	11.69	8.2	3.5
Ultimate Analysis, MF,[1] wt%							
Carbon	69.06	69.27	77.10	56.72	58.64	62.61	48.36
Hydrogen	5.19	5.03	4.61	4.05	4.04	4.25	5.76
Nitrogen	0.84	1.1	1.29	0.80	0.81	0.96	0.62
Sulfur	0.44	3.55	0.36	1.2	1.06	0.94	0.16
Oxygen	18.63	9.34	8.29	19.68	18.87	20.05	41.07
Ash	5.85	11.7	8.4	23.1	16.58	11.20	4.0
Ash Composition, % as oxides							
Calcium, CaO	26.6	3.2	16.3	8.3	15.5	15.9	51.6
Magnesium, MgO	7.0	1.6	3.0	2.8	8.9	5.5	5.4
Sodium, Na_2O	1.3	1.1	4.6	1.8	0.7	6.0	3.5
Silica, SiO_2	27.8	53.9	38.3	48.3	41.3	34.6	22.7
Aluminum, Al_2O_3	13.1	21.2	9.3	14.2	12.8	12.6	2.7
Ferric, Fe_2O_3	5.5	13.6	6.1	6.8	4.5	6.6	2.2
Titanium, TiO_2	1.3	0.9	0.8	0.6	0.5	0.3	0.2
Phosphorus, P_2O_5	1.0	0.2	0.2	0.0	0.2	0.5	2.9
Potassium, K_2O	0.3	1.9	0.2	2.0	0.4	0.3	7.9
Sulfur, SO_3	16.0	2.5	21.1	2.2	14.3	17.6	0.9
High Heating Value							
Moisture-Free, Btu/lb	11,700	12,080	12,200	9446	9963	10,669	8,089
As-Received, Btu/lb	9750	11,300	11,040	6093	7024	7810	7,102

[1] Moisture-free.

Table 4. Proximate, Ultimate, HHV, and XRF Analysis Results for TRDU Testing

	−10-mesh Tuscaloosa Petroleum Coke	−10-mesh Prater Creek Bituminous Coal	−10-mesh Navajo Subbituminous	−10-mesh Pittsburgh No. 8 Bituminous Coal	−10-mesh Calumet Bituminous Coal
Proximate Analysis, as run, wt%					
Moisture	0.9	7.0	10.0	2.2	3.3
Volatile Matter	9.6	38.9	33.5	37.8	32.3
Fixed Carbon	88.5	47.5	35.5	52.6	49.1
Ash	1.0	6.6	21.0	7.4	15.7
Ultimate Analysis, MF, wt%					
Carbon	90.7	76.2	58.5	77.9	66.7
Hydrogen	3.9	4.8	4.5	5.3	4.3
Nitrogen	1.7	1.6	1.2	1.4	1.9
Sulfur	5.5	0.8	1.1	1.6	0.7
Oxygen	0.0	9.4	11.3	6.3	10.3
Ash	1.0	7.1	23.3	7.5	16.1
Ash Composition, % as oxides					
Calcium, CaO	11.9	1.8	3.5	3.3	0.8
Magnesium, MgO	5.1	1.2	1.4	0.9	2.2
Sodium, Na_2O	1.0	0.4	1.4	0.2	0.1
Silica, SiO_2	18.9	54.4	58.4	52.4	58.5
Aluminum, Al_2O_3	4.8	30.1	25.5	24.3	28.2
Ferric, Fe_2O_3	7.6	6.9	6.2	13.7	5.1
Titanium, TiO_2	0.0	1.0	1.2	1.0	1.4
Phosphorus, P_2O_5	0.1	0.3	0.1	0.5	0.3
Potassium, K_2O	0.7	0.8	0.5	1.6	2.5
Sulfur, SO_3	13.8	2.0	2.6	1.9	0.8
Vanadium, V_2O_5	30.2	ND	ND	ND	ND
Nickel, NiO	6.0	ND	ND	ND	ND
High Heating Value					
Moisture-Free, Btu/lb	12,080	13,813	9777	13,627	12,214
As-Received, Btu/lb	11,300	12,847	8880	13,327	11,809

Table 5. Proximate, Ultimate, HHV, and XRF Analyses of Australian Brown Coals and High-Ash Indian Subbituminous A Coals Utilized in Tests P075 and P077

	−10-mesh Dried Loy Yang Brown Coal	−10-mesh Dried Lochiel Brown Coal	−10-mesh Raw Indian Subbituminous A Coal	−10-mesh Washed Indian Subbituminous A Coal
Proximate Analysis, as run,				
wt%	15.0	18.0	4.7	9.0
Moisture	48.7	43.8	26.2	26.1
Volatile Matter	35.3	25.9	30.5	29.3
Fixed Carbon	0.9	12.3	38.6	35.5
Ash				
Ultimate Analysis, MF, wt%				
Carbon	65.4	56.1	46.2	44.9
Hydrogen	4.6	4.3	3.32	3.16
Nitrogen	0.8	0.7	1.1	1.1
Sulfur	0.4	3.6	0.55	0.61
Oxygen	27.7	20.4	8.32	11.2
Ash	1.1	15.0	40.5	39.1
Ash Composition, % as				
oxides	6.9	11.8	1.2	1.5
Calcium, CaO	13.2	10.4	0.6	0.6
Magnesium, MgO	10.3	9.1	0.4	0.5
Sodium, Na_2O	26.0	27.9	61.5	60.4
Silica, SiO_2	8.4	6.5	27.9	28.5
Aluminum, Al_2O_3	10.4	4.7	4.5	5.1
Ferric, Fe_2O_3	0.7	0.8	2.4	2.1
Titanium, TiO_2	0.1	0.0	0.6	0.1
Phosphorus, P_2O_5	1.4	0.4	1.0	1.1
Potassium, K_2O	22.7	28.4	0.0	0.0
Sulfur, SO_3	ND	ND	0.170	0.162
Mercury, µg/g	ND	ND		
Higher Heating Value				
MF, Btu/lb	11,112	9011	6864	7218
As-Received, Btu/lb	9445	7389	6555	6568

Table 7 shows the ASTM coal classification scheme. Except for the petroleum coke, coals that have been tested in the TRDU have ranged as high as a high-volatile B bituminous coals or lower. The transport reactor technology has been considered to be more suited to lower-rank coals that have a higher char reactivity; however, a number of higher-rank bituminous coals were also tested to determine their performance in a transport reactor.

Table 6. XRF Analyses of Plum Run Dolomite and Longview and Montana Limestones

	−35-mesh Plum Run Dolomite (PRD)	-35-mesh Longview Limestone (LVLS)	−35-mesh Montana Limestone (MLS)
Sorbent Composition, % as oxides			
Calcium, CaO	66.6	90.1	73.6
Magnesium, MgO	27.5	5.6	0.4
Sodium, Na_2O	0.3	0.0	0.0
Silicon, SiO_2	2.7	2.0	25.3
Aluminum, Al_2O_3	1.0	0.2	0.0
Ferric, Fe_2O_3	1.3	0.2	0.0
Titanium, TiO_2	0.0	0.0	0.0
Phosphorus, P_2O_5	0.0	0.0	0.0
Potassium, K_2O	0.3	0.3	0.3
Sulfur, SO_3	0.4	0.4	0.4
Loss on Ignition, as run	43.1	ND	36.6

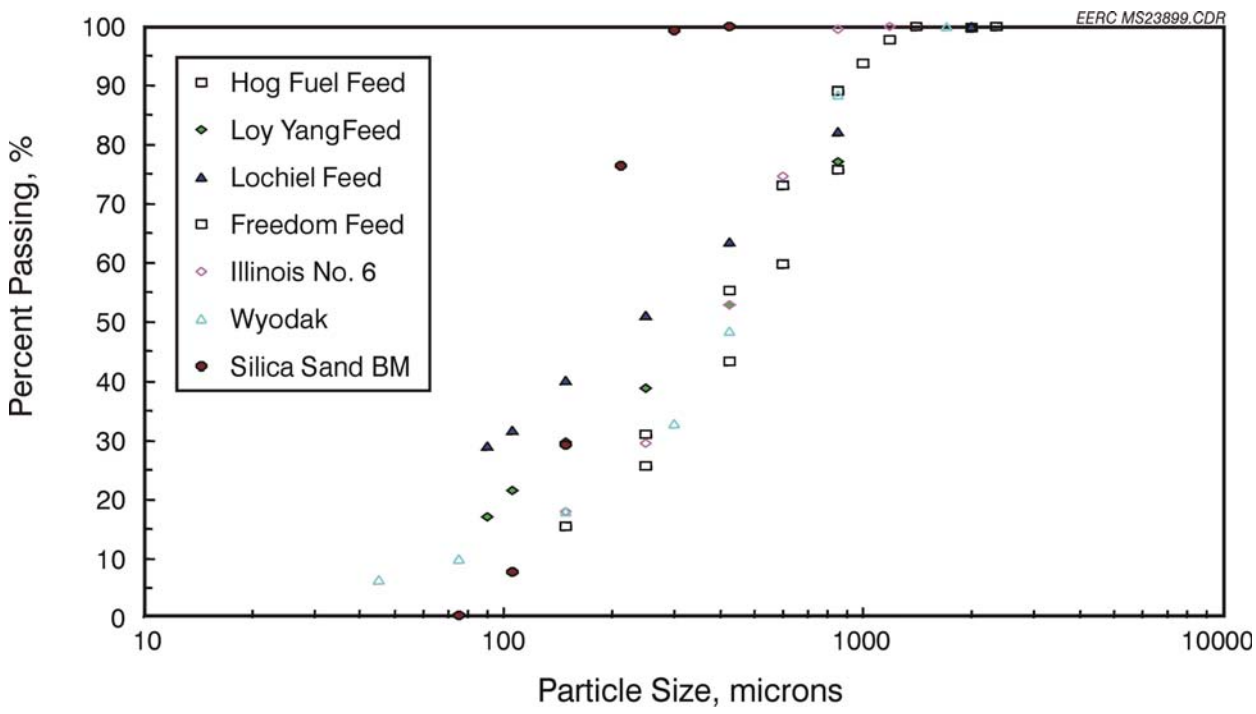

Figure 3. Particle-size distribution of feed coals tested in the TRDU.

Table 7. ASTM International Coal Classification Criteria

Class	Group	Fixed Carbon[a]	Volatile Matter[a]	Heating Value
Anthracitic	Metaanthracite	>98	<2	
	Anthracite	92–98	2–8	
	Semianthracite	86–92	8–14	
Bituminous	Low-volatile	78–86	14–22	
	Medium-volatile	69–86	22–31	
	High-volatile A	<69	>31	>14,000
	High-volatile B			13,000–14,000
	High-volatile C			10,500–13,000
Subbituminous	Subbituminous A			10,500–11,500
	Subbituminous B			9500–10,5000
	Subbituminous C			8300–9500
Lignitic	Lignite A			6300–8300
	Lignite B			<6300

Note: This classification system is based on ASTM Standard D 388–66, which is published annually by ASTM in its compilation of standards.

[a] The fixed carbon and volatile matter, reported as percentages, are determined on a dry, mineral-matter-free basis. The mineral matter is calculated from the ash content by the Parr formula: mineral matter = 1.08(percent ash + 0.55 [percent sulfur]).

[b] Calculated on mineral-matter-free coal with bed moisture content.

4.2 TRDU Testing with the J-Leg Loop Seal

As modifications to the TRDU were being contemplated and then designed, three additional air-blown and oxygen-enriched tests were completed utilizing the original J-leg configuration.

A TRDU test campaign was conducted during the weeks of March 1–11, 1999, that generated 138 hours of coal feed and 107 hours of operation in coal gasification mode with the system gases and fly ash passing through the filter vessel during the whole test campaign. These tests were terminated early because of deposition problems in the mixing zone with the SUFCo fuel and solids flow problems from both the disengager and primary cyclone cones back into the standpipe or dipleg with the petroleum coke test.

4.2.1 TRDU Gasification Tests P060 and P061

TRDU gasification Test P060 was an air-blown test conducted over the period of March 1 – 5, 1999, utilizing SUFCo coal. This test was to compare the gasifier performance after the TRDU had been modified by enlarging the diameter of the mixing zone to increase the solids residence time and decrease the gas velocity in the mixing zone. This test generated 56 hours on coal feed and 49 hours of gasification, which was shut down three times because of a buildup of deposits in the mixing zone. Operation during the first 2 days of testing were at 950°C (1742°F) and resulted in deposits preventing solids circulation within 9 hours of entering gasification. The longest test period of approximately 34 hours in gasification was achieved by dropping the operating temperatures 50°C (122°F) before another deposit forced a system shutdown. Table 8 shows all the average operating conditions from this test period.

TRDU Test P061 was a gasification test operated during the week of March 7–11, 1999, to test the ability of a transport reactor to gasify a near-term opportunity fuel such as petroleum coke. The Hunt Oil Refinery in Tuscaloosa, Alabama, was selected as the source because of its location near

Table 8. TRDU Tests P060 and P061 Operating Conditions

Parameter	P060	P061	P061
Condition	Air-blown gasification	Air-blown gasification	Enriched air gasification
Coal	SUFCo	Petcoke	Petcoke
Moisture Content, %	9.5	0.9	0.9
Pressure, psig	120	120	120
Steam:Coal Ratio, lb/lb coal	0.24	0.32	0.14
Air:Coal Ratio, lb/lb coal	2.9	2.8	NA
Ca:S Ratio, mole, sorbent only	2	1	1
Coal and Sorbent Feed Rate, lb/hr	272	335	520
J-Leg Zone, °C, avg.	820	873	984
Mixing Zone, °C , avg.	890	973	1088
Riser, °C , avg.	896	920	1017
Standpipe, °C , avg.	817	855	937
Dipleg, °C, avg.	673	668	714
TRDU Outlet, °C, avg.	849	869	980
Carbon Conversion, %	87	73	65
Carbon in Bed, %, standpipe	8–19	60	92.5
Riser Velocity, ft/sec	40–45	37.1	38.5
Standpipe Velocity, ft/sec	0.38–0.45	0.37	0.44
Calc. Circulation Rate, lb/hr	3000–4000	2565	2600
HHV of Fuel Gas, actual, Btu/scf	50–55	32	66
HHV of Fuel Gas, cor. Btu/scf	85–90	52	124
Duration, hr	49	24	26
Date (1998)	3/01–3/05	3/07–3/08	3/9–3/11

the PSDF in Wilsonville, Alabama. This fuel was tested under both air-blown and oxygen-enriched air-blown operation in the TRDU.

These operating conditions were interrupted twice because of solids plugging in the disengager solids drain back into the standpipe. The average operating conditions from these test conditions are also shown in Table 6. A small deposit in the burner gas entrance was found at the end of the test. This deposit was attributed to the low entrance velocity in the vicinity of the burner throat and the higher operating temperatures achieved with higher oxygen concentrations and less inert nitrogen associated with the air.

Table 9 shows the bulk chemical composition of SUFCo and petroleum coke steady-state solid samples obtained from the TRDU during the time period that these deposits formed. The SUFCo coal standpipe sample was approximately 200 µm in size, while the dipleg sample averaged 52 µm in size, and the filter ash was 15 µm in average size. The petroleum coke standpipe sample was approximately 500 µm in size and increasing throughout the test, while the dipleg material averaged 38 µm in size, and the filter ash averaged 9 µm.

4.2.2 TRDU Gasification Test P062

TRDU Test P062 was a gasification test operated on July 13 and 15, 1999, using a bituminous coal from the Calumet Mine in Alabama, and Longview Limestone from Alabama, which were selected because of their close proximity to the PSDF facility in Wilsonville. This test generated only 25 hours of coal feed and 10.5 hours of operation in coal gasification mode with the system gases and fly ash passing through the filter vessel during the whole test campaign. These tests were terminated early because of deposition and char agglomeration problems in the mixing zone with the Calumet fuel. Two instances of solids hangup in the disengager cyclone were also encountered during the heatup in combustion mode on Alabama bituminous coal. In both cases, the blockage cleared itself after coal feed was stopped and gas flow to the TRDU was reduced. The two tests with coal were very short because of the rapid buildup of deposits in the mixing zone. Compounding the operating problems was the buildup of char agglomerates in the mixing zone because of the higher-than-expected swelling properties of the bituminous coal. The operating temperature was approximately 1000°C (1832°F) in the mixing zone, but quickly dropped as deposit material covered the thermocouples. Coal feed was approximately 278 lb/hr with an air:coal ratio of 3.0 lb/lb coal and a steam:coal ratio of 0.27 lb/lb coal. Since the tests were so short, little satisfactory steady-state data were obtained.

4.2.3 TRDU Gasification Test P063

Another TRDU test campaign (TRDU Test P063) was conducted the week of August 29 – September 2, 1999, that generated approximately 90 hours of coal feed and slightly over 80 hours of gasification including 4 hours of enriched air gasification testing on the design Illinois No. 6 coal. Tests were conducted to examine the effects of air and steam distributions in the mixing zone, circulation rate, air/fuel and steam/fuel ratios on product gas heating value, and carbon conversion. Both air-blown and oxygen-enriched air-blown gasification tests were conducted during this test campaign. The range of average operating conditions obtained under the various test conditions of

Table 9. XRF Chemical Composition of TRDU Samples, Tests P060 and P061

Element	SUFCo Ash w/PRD	SUFCo Deposit	SUFCo Standpipe	SUFCo Dipleg	SUFCo Filter	Petcoke Ash /w PRD	Petcoke Deposit	Petcoke Standpipe	Petcoke Dipleg	Petcoke Filter
Si	23.3	87.6	76.2	46.4	21.4	3.1	28.9	8.8	2.4	3.3
Al	6.9	0.6	2.8	5.3	7.5	0.2	1.4	0.9	0.3	0.8
Fe	6.3	1.3	2.3	3.4	5.9	0.6	2.3	2.4	0.3	0.8
Ti	0.7	0.2	0.3	0.4	0.9	0.1	0.2	0.3	0.1	0.1
P	0.1	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0
Ca	33.6	5.5	9.6	24.3	36.5	44.3	40.7	27.5	46.5	46.4
Mg	13.5	3.2	4.1	12.8	12.8	22.9	19.8	12.3	21.3	24.0
Na	4.5	1.4	3.2	4.4	4.3	0.0	0.0	0.0	0.0	0.0
K	0.3	0.2	0.2	0.2	0.3	0.2	0.1	0.6	0.2	0.2
S	10.7	0.0	1.2	3.8	10.2	27.5	5.7	41.4	27.7	21.9
Ni	0.0	0.0	0.0	0.0	0.0	0.2	0.1	1.3	0.2	0.4
V	0.0	0.0	0.0	0.0	0.0	0.9	0.6	4.6	0.8	2.2
Total	99.9	100.1	100	100.1	100	100	99.8	100.1	99.8	100.1

Table 10. TRDU Test P063 Operating Conditions

Parameter	P063	P063	P063
Conditions	Air-blown gasification	Air-blown gasification	Enriched air gasification
Coal	Illinois No. 6	Illinois No. 6	Illinois No. 6
Moisture Content, %	8.5	8.5	8.5
Pressure, psig	120	120	120
Steam:Coal Ratio, lb/lb coal	0.23–0.54	0.31	0.46
Air:Coal Ratio, lb/lb coal	3.02–4.37	3.02	NA
O_2:Coal Ratio, lb/lb coal	0.70–1.01	0.7	0.76
Ca:S Ratio, mole, sorbent only	2	2	2
Coal and Sorbent Feed Rate, lb/hr	234–355	302	344
J-Leg Zone, °C, avg.	837–923	875	927
Mixing Zone, °C, avg.	928–1023	964	1039
Riser, °C, avg.	851–916	872	918
Standpipe, °C, avg.	820–896	829	882
Dipleg, °C, avg.	320–590	484	420
TRDU Outlet,°C, avg.	827–891	842	883
Carbon Conversion, %	71.6	68	62
Carbon in Bed, wt%, standpipe	1–7	3	3
Riser Velocity, ft/sec	26.1–38.2	27.7	33.8
Standpipe Velocity, ft/sec	0.25–0.31	0.25	0.26
Circulation Rate, lb/hr	2830–3800	3300	2575
HHV of Fuel Gas, actual, Btu/scf	40–56	56	64
HHV of Fuel Gas, corrected, Btu/scf	63–93	93	99
Duration, hr	80	4	4

reactor velocity, air:coal ratios, and circulation rates are shown in Table 10. Average operating conditions for the best air-blown test and the enriched air test are also shown in Table 10. Table 11 summarizes the bulk chemical composition of TRDU samples collected close to the time the mixing zone deposit was formed when the gasifier was being transitioned to the next highest oxygen enrichment condition. The hot-gas filter system was online for all but 4 hours of operation. These tests, especially the oxygen-enriched tests, indicated that significant modification of the TRDU to enhance circulation rate would be necessary before proceeding with plans to full oxygen-blown gasification tests on a transport reactor gasifier.

4.3 TRDU Modifications for Oxygen-Blown Transport Reactor Gasification Testing

4.3.1 Initial TRDU Modifications

After Test P063, the TRDU underwent a substantial modification in order to make improvements that would allow full oxygen-blown operation to occur. These modifications occurred over the period from the first quarter of 2000 until the first quarter of 2001.

Table 11. XRF Chemical Composition of TRDU Samples, Test P063

Element, wt%	Illinois No. 6 Coal Ash w/ 17 wt% PRD	Illinois No. 6 Mix Zone Deposit	Illinois No. 6 Standpipe	Illinois No. 6 Dipleg	Illinois No. 6 Filter
Si	23.0	26.2	19.6	17.2	14.8
Al	10.3	2.6	4.4	5.4	5.9
Fe	11.1	8.5	8.4	9.7	6.3
Ti	0.5	0.2	0.3	0.3	0.4
P	0.1	0.1	0.2	0.1	0.1
Ca	31.5	33.8	35.1	34.8	37.7
Mg	13.2	18.7	18.6	16.8	17.7
Na	0.4	0.0	0.0	0.0	0.0
K	1.5	0.5	1.0	1.1	0.9
S	8.5	9.3	12.3	14.7	14.3
Total	100.1	99.9	99.9	100.1	100.1

Specific needs for an oxygen-blown transport reactor were identified as:

1. Need for increased solids circulation: higher solids circulation dissipates the higher heat release generated by oxygen-blown operation.

2. A need for significantly higher steam flow rates and the need to mix the steam with the oxygen before it enters the gasifier and can contact circulating carbon in the bed material.

3. The need for a better gas seal for the dipleg solids return into the standpipe.

4. A coal feed nozzle that would inject the coal upward into the riser as compared to the original coal feed nozzle which would inject the coal feed at the top of mixing zone in a downward direction. There was concern that the downward-oriented coal feed nozzle was allowing fresh coal to back-mix into the partial oxidation region of the mixing zone, thereby combusting the fuel volatile matter instead of it just being volatilized and cracked in to the fuel gas.

Dr. Knowlton's recommendations are summarized as installing an L-valve as the standpipe loop seal design over the original J-leg or alternate Y-leg design. The J-leg had been shown to present some solids recirculation restrictions as actual solids recirculation rates were only about 1/10 of the design recirculation rate expected. This low solids recirculation rate is due to wall effects and to the large momentum change required to get the solids to turn the corner from the standpipe into the J-leg and flow back uphill through the J-leg to the mixing zone. The alternate choices were between an L-valve or a Y-leg with each loop seal having some advantages and disadvantages unique to that particular loop seal. A major advantage for the Y-leg included the minimization of aeration gas required to return the solids to the bottom of the mixing zone. A disadvantage of the Y-leg (at least in the TRDU design with a fairly wide spacing between the riser and the standpipe) would be fairly large bubbles accumulating on the upper side of the inclined Y-leg, and these bubbles could potentially inhibit solids circulation as the large bubbles would enter the vertical standpipe. Another disadvantage for the EERC transport reactor was the Y-leg would have to pass through an area currently occupied by a major structural beam requiring major structural modification of the building support structure.

The other potential loop seal design was an L-valve that would also increase solid circulation rates over the J-leg and reduce the amount of inert or recycled syngas injected to recirculate the solids back to the mixing zone. However, this design would probably still require significantly more gas being injected in this area to move the solids across the horizontal L-valve than would be required for a Y-leg loop seal. Another advantage would be the increased length on the mixing zone would add some additional residence time in the mixing zone, and construction would be simplified because of the use of conventional pipe tees instead of utilizing a specially constructed pipe-Y in the bottom of the mixing zone.

Other recommendations were to increase the standpipe diameter and dipleg diameter to minimize the effect of bubble size and friction effects with the wall on solids flowing down either the standpipe or dipleg. Another recommendation was to add a loop seal to the bottom of the dipleg so that the standpipe inventory could be operated independently of the level where the dipleg solids reentered the standpipe. Without a loop seal in the bottom of the dipleg, the standpipe inventory always had to operated at a level greater than the dipleg solids return height or a significant amount of gas would bypass up the dipleg, thereby severely spoiling the performance of the primary cyclone.

In addition, a simple atmospheric-pressure cold-flow system was constructed to determine the effects of different loop seals and mixing zone sizes on the amount of solids circulation, backmixing, and residence time in the mixing zone. The sizes investigated were approximately 87% of TRDU-scale equivalent mixing zone dimensions. Since the unit can only operate under atmospheric pressure and the same starting bed material was used for the TRDU, the particle-to-gas density ratio was not matched in these tests. Air and nitrogen flows were adjusted to match the relative distribution in the TRDU and to match the desired riser velocity (at atmospheric pressure and temperature). The mixing zone test sizes were selected to be equivalent to the original mixing zone diameter, a diameter 2 inches larger and another 4 inches larger than the original mixing zone. Cold-flow tests utilizing a 25-pound batch of red-colored FCC catalyst support material as a tracer were completed for each mixing zone configuration. The colored sand residence time tests were conducted using both burner air only and a combination of burner air and combustion air. From these tests, it was possible to measure residence time distributions passing through the mixing zone. These residence times were measured at 50, 65, and 75 seconds for the amount of time that the colored FCC material remained in the mixing zone. Based on these results, a diameter matching the medium diameter was selected for the TRDU design, and this residence time distribution was utilized in the calculation of the steam/carbon kinetics shown in Appendix A.

Based on the above recommendations and the results of the cold-flow testing, the L-leg loop seal design was selected as the best design given the building and budget constraints for the project. Figures 4 through 6 show the as-designed L-valve modification for the TRDU. The modifications consisted of constructing three new sections as shown in Figure 4. One section would be for the L-valve loop seal (Figure 5), and the other two sections would replace the J-leg elbow (also shown in Figure 6) and the bottom section of the TRDU mixing zone. In addition, as shown in Figure 6,

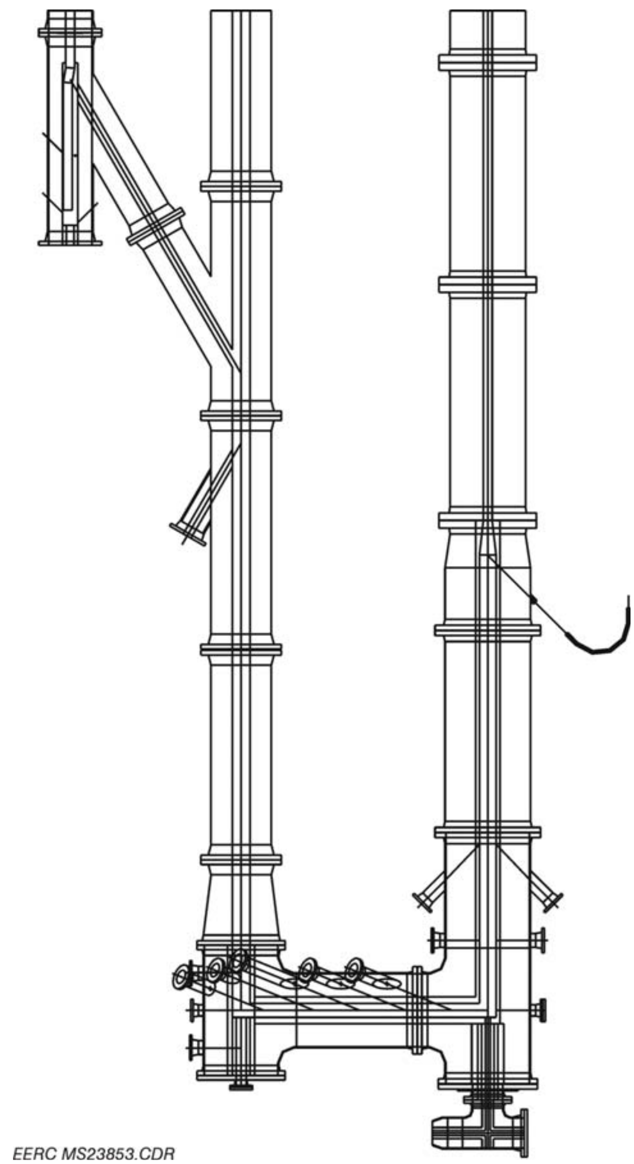

Figure 4. Schematic of TRDU modifications made for oxygen-blown operation.

Section Q on the bottom of the dipleg was modified to allow for a seal pot to be installed as the loop seal on the bottom dipleg. Other modifications included enlarging the standpipe and dipleg diameters by boring out the refractory in order to minimize wall effects on the flowing solids. The standpipe diameter was increased by 2.5 inches, and the dipleg diameter was increased by 0.625 inches, respectively. In addition to reducing wall effects, this increased diameter should reduce the bridging of the circulating solids across the bottom of the cyclone cones. This interrupts circulation of the bed material, and extended interruptions can lead to loss of bed material and eventually increased bed agglomeration and deposition. Instrumentation to measure and control the flow of oxygen and steam to the burner and mix zone ports was also added to allow the TRDU to be operated under full oxygen-blown conditions.

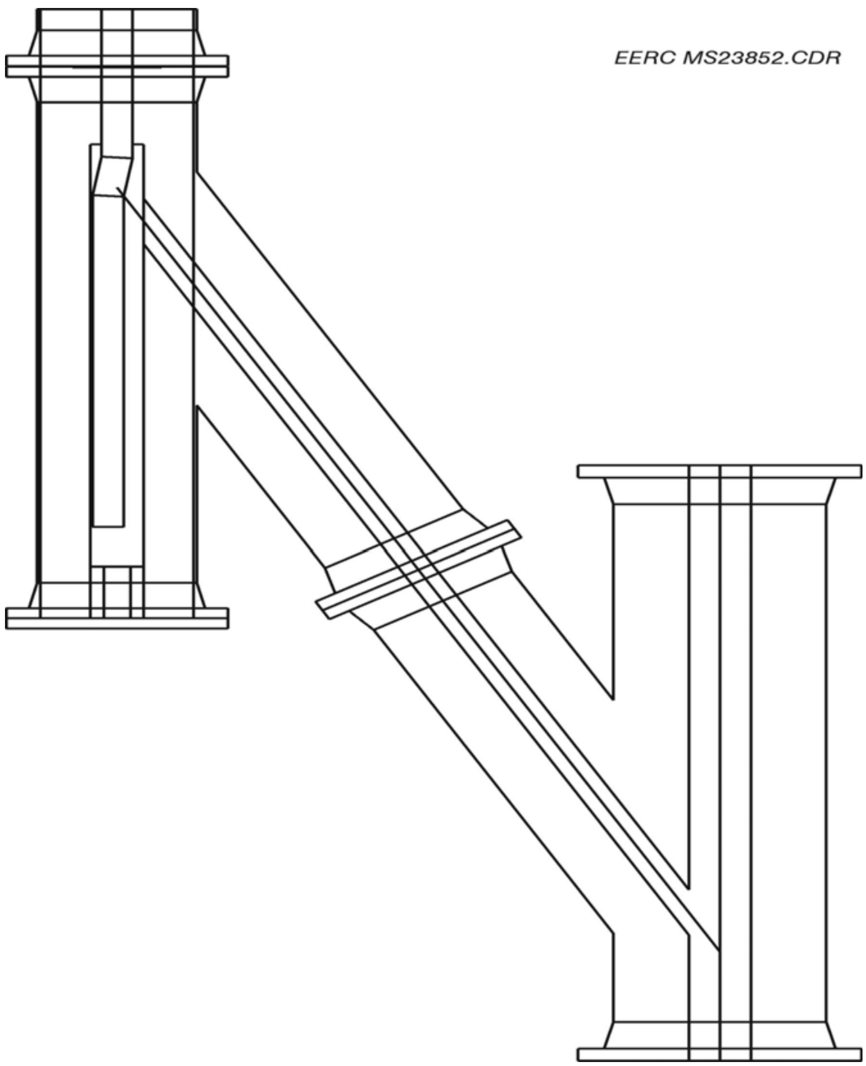

Figure 5. Drawing of L-valve and lower mixing zone modifications.

4.3.2 Additional TRDU Modifications

After Test P069, a thermal oxidizer was installed after the hot-gas filter system to combust the hot fuel gas from the TRDU and avoid the gas quench system with its numerous problematic and costly issues associated with the water scrubbers, circulating pumps, heat exchanger plugging, and wastewater disposal issues. Figure 7 shows a schematic of the thermal oxidizer built for the TRDU system. This thermal oxidizer was designed to handle all of the gas flow from the TRDU to combust this fuel gas between 1800° to 2000°F (982° to 1093°F) with a 2-second residence time. The thermal oxidizer is started and heated up on natural gas delivered down a central burner nozzle along with a substoichiometric amount of primary combustion air. Secondary air is swirled in around the primary burner and provides all of the combustion air to finish the combustion of the natural gas and all of the fuel gas from the TRDU. The hot fuel gas from the TRDU is then swirled around the

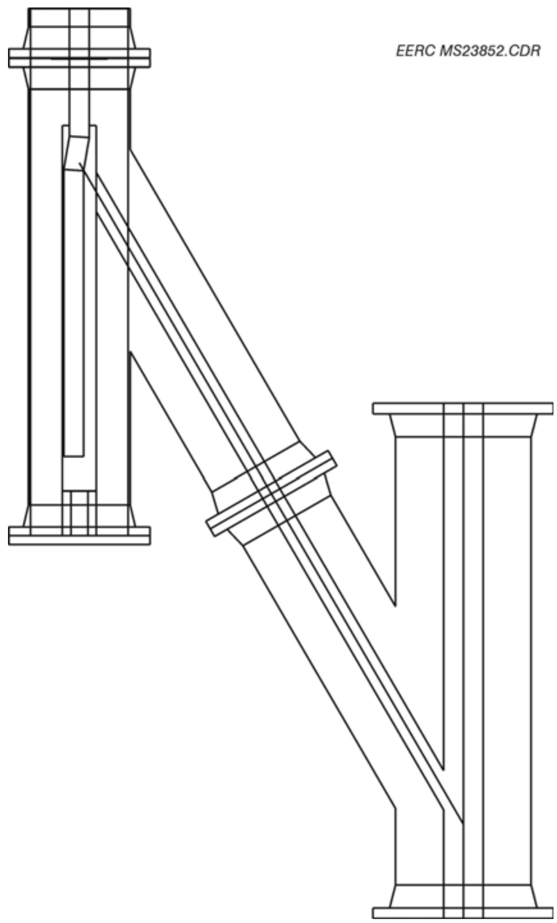

Figure 6. Drawing of seal pot loop seal on bottom of the dipleg.

outside of the secondary air to complete the combustion process. The flame safety system is set to add supplemental natural gas in order to maintain thermal oxidizer temperature; however, most tests have shown that the thermal oxidizer can be operated without any supplemental fuel. All extra air from the blower is added to the stack flue gas to cool the gas before it is discharged out the stack. No baghouse or particulate collection device is included downstream of the thermal oxidizer. Since there is no backup particulate control, the thermal oxidizer was installed such that the fuel gas flow can be diverted from the thermal oxidizer and sent to the quench system should a major filter failure result in a high dust loading to the thermal oxidizer. Collection of all the gaseous flow rates and gas emissions data including moisture concentration allows a material balance around the thermal oxidizer to be completed. This allows another measure of carbon conversion, sulfur retention, and fuel gas heating value to be calculated from the data collected.

4.4 Oxygen-Blown Results Utilizing the TRDU L-Valve Modification

In total, ten test campaigns have been conducted under enriched air or full oxygen-blown conditions. During these tests, 1515 hours of coal feed with 660 hours of air-blown gasification and

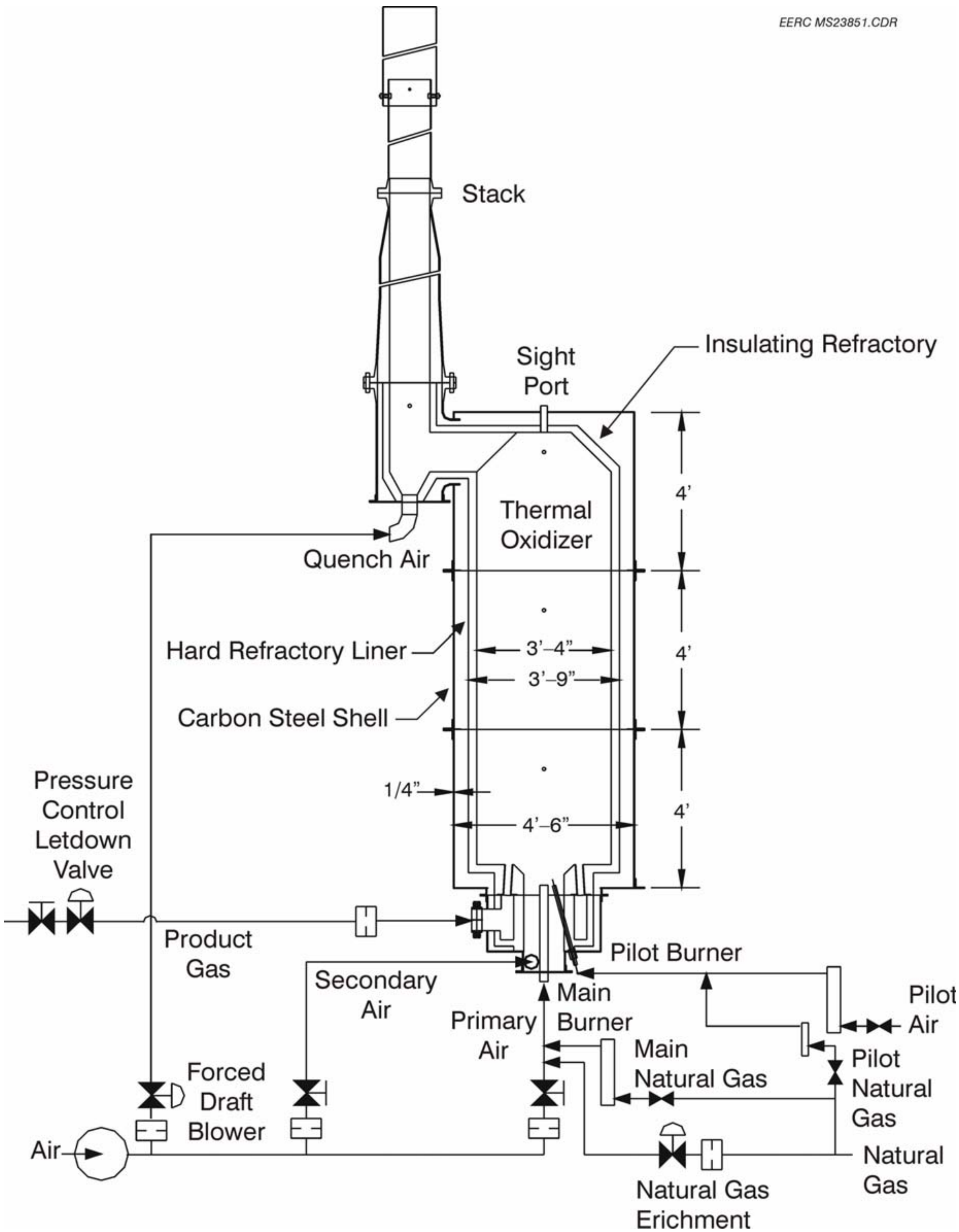

Figure 7. Schematic of the thermal oxidizer added to combust the TRDU fuel gas.

720 hours of enriched air or oxygen-blown gasification were completed. During these tests, approximately 366 hours of operation with Wyodak, 91 hours of operation with Navajo subbituminous coal, 135 hours of operation on Illinois No. 6, 108 hours on SUFCo, 110 hours on Prater Creek, 48 hours on Calumet, and 134 hours on a Pittsburgh No. 8 bituminous coal were completed. In addition, 287 hours of operation on low-rank coals such as North Dakota lignite, Australian brown coal, and a 90:10 wt% mixture of lignite and wood waste were completed. Also included in these test campaigns was 50 hours of gasification on a petroleum coke from the Hunt Oil Refinery. An additional 73 hours of gasification on a high ash Indian coal was completed.

Detailed operating and material balance information for all of the steady-state air and oxygen-blown tests is given in Appendix A. Elemental (H, C, N, S, O) material balances based on measured inputs are also given in Appendix A. This information was also utilized with a simple model based on thermogravimetric analysis (TGA) kinetics to estimate the amount of steam/carbon gasification and partial oxidation that is occurring with the circulating char (3–5). In general, these estimates showed that while partial oxidation of the recirculating carbon contributed significantly to the conversion of carbon, the conversion due to the steam–carbon reaction was small to moderate (depending on the char kinetics and the residence time distribution utilized). This implies that a large portion of the fuel gas heating value is being derived from the devolatilization and cracking of the fuel volatile matter.

4.4.1 TRDU Oxygen-Blown Shakedown Tests P066 and P067

4.4.1.1 TRDU Gasification Test P066

Test P066 was a shakedown test using the new TRDU L-valve loop seal and was accomplished during the weeks of January 23 – February 1, 2001, and that generated 125 hours and 137 hours of coal feed, respectively, with 109 and 121 hours of operation in coal gasification mode, respectively. These tests were to shake down the TRDU oxygen-blown modifications. These tests were completed at a full system pressure of 120 psig and were conducted while the steam flow was split between the L-valve nozzles and the burner and mix zone steam/oxygen ports. This resulted in fluctuating steam flows that were hard to control. This prevented the TRDU from operating in full oxygen-blown mode. Oxygen/air flow ratios up to 35% oxygen were achieved, but attempts at full oxygen-blown operation resulted in mixing zone deposition and agglomeration. A coal feed nozzle that pneumatically transported the coal directly into the bottom of the riser was tested; however, this testing resulted in extremely high tar concentrations in the fuel gas and difficulty in keeping the hot gas filter baseline differential pressure stable. The coal feed nozzle was switched back to its original downward configuration after 3 days of operation.

4.4.1.2 TRDU Gasification Test P067

Test P067, the second shakedown test using the new TRDU L-valve loop seal, was accomplished during the weeks of May 13–22, 2001. This test utilized Navajo subbituminous coal, Wyodak subbituminous coal, and Illinois No. 6 bituminous coal. This test generated 137 hours of coal feed with 59 hours of air-blown gasification and 62 hours of enriched and oxygen-blown gasification (121 hours in gasification total). This test was run at reduced pressure in order to utilize University of North Dakota (UND) steam as a second source of steam to the TRDU. This steam, which is only available at 130 psig, required the TRDU to operate at 100 psig. Table 12 shows some of the operating conditions from selected test periods on these three coals. Table 13 shows the actual and corrected product gas compositions for these same test periods.

4.4.2 TRDU Gasification Test P068

This test campaign was conducted as part of a test program conducted with the North Dakota Industrial Commission's Lignite Research Council to evaluate North Dakota lignite in a transport reactor (6). This test was the first to successfully operate the transport reactor in full oxygen-blown mode without bed material agglomeration and deposition problems. Results from these tests are shown in Appendix A along with the data from all of the other oxygen-blown tests. The TRDU was operated at average temperatures ranging from 792° to 828°C (1458° to 1522°F) at various air/fuel ratios and reactor velocities. Table 14 summarizes the range of operational performance for the TRDU during these test periods. Table 15 summarizes the optimum operating conditions achieved with each lignite. In general, similar actual and corrected fuel gas heating values were achieved with all three lignites. The actual dry product gas produced was 4.7% to 7.4% CO, 12.7% to 20.8% H_2, 20.8% to 29.7% CO_2, 1.9% to 3.1% CH_4, and 0.20% to 0.35% ethane with the balance being N_2 and other trace constituents. The moisture in the fuel gas exiting the transport reactor ranged from 45.9% to 55.7% under oxygen-blown conditions. Coal/sorbent feed rates ranged from 413 to 586 lb/hr, and the gasifier pressure averaged 100 psig. Calculated recirculation rates ranged from 950 to 7650 lb/hr.

The recirculating bed material particle size for Test P068 was approximately 150 to 300 µm while on the Montana limestone. The circulating bed material with the Falkirk lignite was approximately 180 µm and increased to approximately 400 µm while on the Freedom coal with the Montana limestone. After restarting the TRDU on fresh sand for the high-sodium Freedom lignite test with the Plum Run dolomite, the bed material particle size remained relatively constant at 150 µm. The particle-size distribution for the filter ash for all coals was approximately 15 µm but ranged between 8 µm up to almost 20 µm. Comparisons of particle-size distributions for selected standpipe and filter samples collected show there was no significant difference in particle-size distributions between air-blown and oxygen-blown operation.

Correction of the raw product gas stream is necessary because of the high level of dilution caused by the nitrogen purges in the system and by the high heat losses as a percentage of the coal feed experienced by a pilot-scale system. These corrections assume that the purges would either be small enough to be inconsequential, or when significant amounts of purge gas are required, a compressor would recycle syngas instead of injecting nitrogen. Heat losses were corrected from approximately 15% of the coal feed heat input to approximately 0.25% of the coal feed heat input. Comparing the corrected product gas compositions, the air-blown fuel gas composition would be 15%–17% H_2, 9%–12% CO, 2.0%–3.0% CH_4, and 15%–17% CO_2, as compared with a corrected fuel gas composition of 35%–39% H_2, 13%–14% CO, 4.5%–6.0% CH_4, and 38%–41% CO_2. The high hydrogen and carbon dioxide concentrations under oxygen-blown conditions are the result of the water-gas shift reaction (shown below) being driven to form the products on the right-hand side of the equation by the high steam partial pressure in the gasifier product gas stream:

$$H_2O + CO \rightleftharpoons H_2 + CO_2$$

Table 12. TRDU Gasification Efficiency for Test P067

Test	Navajo-12	Navajo-14	Wyodak-16	Wyodak-17	Illinois No. 6-22	Illinois No. 6-23
Gasifier Temp., °C	847	899	816	825	858	884
Coal/Sorbent Feed Rate, lb/hr	425	450	373	390	422	428
Air Flow, lb/hr	918	271	915	268	870	274
O_2 Flow, lb/hr	0	145	0	145	0	152
Steam Flow, lb/hr	336	335	332	369	408	504
Air:Coal Ratio, lb/lb	2.4	0.67	2.56	0.72	2.48	0.77
Steam:Coal Ratio, lb/lb	0.88	0.83	0.93	0.99	1.16	1.42
O_2:Coal Ratio, lb/lb	0.56	0.51	0.59	0.55	0.58	0.61
Recirculation Rate, lb/hr	4362	14,634	3612	3145	3844	4268
TRDU Throughout, lb/hr-ft^2	5726	6063	5360	5605	5243	5318
TRDU Throughout, MMBtu/hr-ft^2	50.4	53.4	52.3	54.6	59.3	60.1
TRDU Riser Velocity, ft/s	54.3	44.2	56.7	46.6	54.5	51.1
Carbon Conversion						
Solid Accountability	94.6	79.5	85	78.6	72.6	81.8
Gas Make	59.4	62.4	73.1	69.1	67.3	57.8

Table 13. Corrected TRDU Product Gas Compositions for Test P067

Test	Navajo-12	Navajo-14	Wyodak-16	Wyodak-17	Illinois No. 6-22	Illinois No. 6-23
Product Gas Composition, vol%						
H_2	5.48	11.19	7.63	16.79	3.55	11.7
CO	2.74	6.83	3.95	7.03	2.56	6.35
CH_4	1.59	3.61	1.68	2.94	1.54	3.94
CO_2	13.34	19.32	13.86	19.44	13.56	20.67
N_2	75.59	58.7	72.71	53.77	78.17	56.07
Total	99.12	99.65	99.83	99.97	99.38	98.73
Heating Value, Btu/scf	47	95	55	107	35	98
% N_2 in Feed	26.4	41.9	28.3	49.8	26.1	43.6
N_2-Free Heating Value, Btu/scf	59	126	69	152	45	140
Product Gas, vol%		Adjusted for 450,000 Btu/hr heat loss and N_2 purge free				
H_2	8.6	20.7	11.6	31.5	5.4	22.2
CO	4.3	12.7	6	13.2	3.9	12.1
CH_4	3.1	6.7	2.5	5.5	2.4	7.5
CO_2	16.3	28.3	17.2	30.4	16.9	33
N_2	67.7	31.6	62.7	19.5	71.4	25.3
Total	100	100	100	100	100	100
Heating Value, Btu/scf	73	176	83	200	54	187

Table 14. TRDU Range of Oxygen-Blown Operating Conditions for North Dakota Lignites

Parameter	P068	P068	P068
Conditions	Gasification	Gasification	Gasification
Coal	Center	Falkirk	Freedom
Moisture Content, %	35	36.2	28.3–33.8
Pressure, psig	100	100	85–100
Steam:Coal Ratio	0.80–1.01	0.79–0.95	1.05–1.43
O_2:Coal Ratio	0.41–0.51	0.40–0.48	0.49–0.61
Ca:S Ratio, mole (total including ash)	1.61	1.52	1.2–3.5
Coal and Sorbent Feed Rate, lb/hr	440–567	487–586	413–531
Avg. Mixing Zone Temp, °C , avg.	808–828	796–811	792–816
HHV of Fuel Gas, act., Btu/scf	79–128	112–121	90–118
HHV of Fuel Gas, cor., Btu/scf	220–239	211–236	214–232
Conversion, %	79–90	80–87	64–90
Carbon in Bed, %, standpipe	6–26	6–25	5–37
Riser Velocity, ft/s	41.6–45.0	50–53	48–51
Standpipe Velocity, ft/s	0.35	0.35	0.35
Circulation Rate, lb/hr	3250–7650	4000–5000	950–2550
Duration, hr	77	46	67

This high hydrogen and carbon dioxide product gas stream would make an excellent gas stream for hydrogen separation and for CO_2 separation and possible sequestration under a Vision 21 project. Table 16 shows the ash analysis from the lignite oxygen-blown gasification tests. These data suggest that even though the Freedom lignite was high in sodium, the bed material did not appear to be accumulating a lot of sodium. This presumably is due to a large majority of the sodium in the Freedom lignite being organically associated, which should result in the formation of fine sodium aerosol fume that will pass through the cyclones and condense on the filter ash and carbon.

4.4.3 TRDU Gasification Test P069

Another test campaign (P069) was conducted during the week of October 8–15, 2001. During this week, approximately 150 hours of coal feed and 143 hours of gasification, respectively, were achieved, with the system gases and fly ash passing through the filter vessel during the whole test campaign. Test P069 was terminated early because of a hot spot on one of the L-valve nozzles. This hot spot was the result of erosion of the soft insulating refractory around one of the downward-oriented L-valve nozzles. Table 17 shows selected operating data from this test. Table 18 shows a comparison of the fuel gas compositions for both air-blown and oxygen-blown operation. Appendix A shows all of the steady-state operating periods obtained for this test, including material balances.

Table 15. TRDU Optimum Oxygen-Blown Operating Conditions for North Dakota Lignites

Parameter	P068	P068	P068
Conditions	Gasification	Gasification	Gasification
Coal	Center-6	Falkirk-2	High-Na Freedom-3
Pressure, psig	100	100	85
Steam:Coal Ratio	1.01	0.92	1.05
O_2:Coal Ratio	0.5	0.47	0.49
% Sorbent in feed, wt%	8	10	20
Coal and Sorbent Feed Rate, lb/hr	457	502	531
Avg. Mixing Zone Temp., °C	812	8.11638e+14	8.09580713e+14
Avg. L-Valve Temp., °C	700		
Avg Riser Temp., °C	728		
Avg Standpipe Temp., °C	748		
Avg. Dipleg Temp., °C	440		
Conversion, %	85	85.3	81.5
Product Gas HHV (act.), Btu/scf	234	233	232
Prodcut Gas HHV (cor.), Btu/scf	–	–	–
Carbon in Bed, %, standpipe	10.7	12.2	10.4
Riser Velocity, ft/s	42.5	42.4	48.8
Standpipe Velocity, ft/s	0.35	0.35	0.35
Circulation Rate, lb/hr	5200	4000	947

4.4.4 TRDU Gasification Test P070

Test P070 was only scheduled for a week of operation from April 15 to 20, 2002. During this test, 118 hours of coal feed and 110 hours of gasification were completed, including 36 hours in air-blown gasification and 74 hours in enriched air and full oxygen-blown operation. This test utilized SUFCo and Illinois No. 6 bituminous coal with most of the testing completed on the SUFCo coal. Operation was very steady, with the best air- and oxygen-blown results for both feedstocks shown in Tables 19 and 20. All of the data from the identified steady-state periods are also shown in Appendix A.

Table 16. XRFA Analysis of Oxygen-Blown TRDU Samples Generated from North Dakota Lignite

		6/18/01				6/21/01	
	Falkirk	Standpipe	Dipleg	Filter	Freedom	Standpipe	Filter
Si	24.9	22.9	33.4	29.9	25.3	16.4	10.3
Al	8.8	6.1	5.3	11.5	14.2	4.9	6.4
Fe	7.8	4.9	5.3	9	7.5	5.1	4.6
Ti	0.5	0.4	0.4	0.6	0.6	0.3	0.4
P	0.1	0.1	0.1	0.1	0.3	0.1	0.2
Ca	34.8	56.5	47.9	35.8	20.8	42.7	47.1
Mg	4	3.9	2.6	6.2	8	25.0	26.5
Na	3.5	2.2	3.2	3.6	11.8	3.2	2.8
K	1.8	1.6	1.3	2	1.4	0.9	0.5
S	13.8	1.4	0.5	1.3	10.1	1.4	1.2
Total	100	100	100	100	100	100	100

Table 17. Corrected TRDU Product Gas Compositions for P069

Test	Wyodak	Wyodak
Product Gas Composition, vol%	Air	Oxygen
H_2	10.0	19.1
CO	5.7	11.0
CH_4	1.7	3.9
CO_2	13.5	24.2
N_2	79.0	45.4
Total	109.8	103.6
Heating Value, Btu/scf	68	137
% N_2 in Feed	28.6	64.1
N_2-Free Heating Value, Btu/scf	76	192
Product Gas, vol%	Corrected for Heat Losses and N_2 Purge Free	
H_2	13.7	35.2
CO	7.7	20.4
CH_4	2.3	7.2
CO_2	14.3	35.6
N_2	62.0	1.7
Total	100	100
Heating Value, Btu/scf	93	253

Table 18. TRDU Gasification Efficiency for Test P069

Test	Wyodak	Wyodak
Oxidant	Air	Oxygen
Gasifier Temp., °C	823	892
Coal/Sorbent Feed Rate, lb/hr	476	406
Air Flow, lb/hr	988	0
O_2 Flow, lb/hr	0	239
Steam Flow, lb/hr	269	364
Air:Coal Ratio, lb/lb	2.16	0
Steam:Coal Ratio, lb/lb	0.58	0.93
O_2:Coal Ratio, lb/lb	0.50	0.61
Recirculation Rate, lb/hr	1530	3665
TRDU Throughput, lb/hr-ft^2	6840	5835
TRDU Throughput, MMBtu/hr-ft^2	61.3	52.6
TRDU Riser Velocity, ft/s	54.8	44.0
Carbon Conversion		
Solid Accountability	79.4	95.5

Table 19. Corrected TRDU Product Gas Compositions for P070

Test	SUFCo	SUFCo	Illinois No. 6
Product Gas Composition, vol%	Air	Oxygen	Oxygen
H_2	10.7	15.8	14.7
CO	4.6	7.4	6.8
CH_4	1.9	3.8	3.2
CO_2	13.2	22.3	20.1
N_2	70.8	53.7	57.1
Total	101.2	103.0	101.9
Heating Value, Btu/scf	68	114	102
% N_2 in Dry Feed Cases	26.6	65.6	55.8
N_2-Free Heating Value, Btu/scf	88	189	162
Product Gas, vol%	Adjusted for 450,000 Btu/hr Heat Loss and N_2 Purge Free		
H_2	17.4	35.3	37.0
CO	7.5	16.5	17.1
CH_4	3.1	8.5	8.0
CO_2	16.2	37.1	34.5
N_2	55.8	2.6	3.4
Total	100	100	100
Heating Value, Btu/scf	112	254	257

Table 20. TRDU Gasification Efficiency for P070

Test	SUFCo	SUFCo	Illinois No. 6
Oxidant	Air	Oxygen	Oxygen
Gasifier Temp., °C	880	900	972
Coal/Sorbent Feed Rate, lb/hr	412	296	295
Air Flow, lb/hr	906	0	57
O_2 Flow, lb/hr	0	210	222
Steam Flow, lb/hr	287	454	483
Air:Coal Ratio, lb/lb	2.29	0	0.23
Steam:Coal Ratio, lb/lb	0.73	1.59	1.89
O_2:Coal Ratio, lb/lb	0.64	0.90	1.19
Recirculation Rate, lb/hr	4120	6740	4615
TRDU Throughout, lb/hr-ft^2	5920	4253	3665
TRDU Throughout, MMBtu/hr-ft^2	68.6	49.3	41.4
TRDU Riser Velocity, ft/s	57.1	57.2	61.4
Carbon Conversion			
Solid Accountability	76	83.0	81.0
Gas Make	77	56	57.4

4.4.5 TRDU Gasification Test P071

Test campaign P071 was run during the June 9–16, 2002, time period. This test had 107 hours of coal feed and 98 hours of gasification, including 18 hours of air-blown gasification and 80 hours of enriched air- or full oxygen-blown gasification. This test utilized Tuscaloosa petroleum coke and Prater Creek bituminous coal as feedstocks, with the petcoke sized to −30 mesh and the Prater Creek bituminous coal sized to the standard −10-mesh particle size. This test was ended prematurely when another hot spot on the riser vessel wall was detected. This hot spot was the result of too short of a ceramic plug being inserted into a downward pointing secondary air nozzle in the riser. Over the years of testing at the EERC, the high-velocity bed material was able to start eroding the soft insulating refractory behind the hard face refractory, creating a significant hollow pocket that would fill with hot-bed material. After this test, the EERC performed a through inspection of all the TRDU sections, paying particular attention to all nozzle penetrations. Any necessary refractory repairs were made, and either metal liner or ceramic plugs of the proper length were installed such that high-velocity bed material could not impact the softer insulating refractory. Tables 21 and 22 show the fuel gas compositions and the operating conditions achieved for these tests. All steady-state periods for this test campaign are given in Appendix A.

Table 21. Corrected TRDU Product Gas Compositions for Test P071

Test	Petcoke	Petcoke	Prater Creek
Product Gas Composition, vol%	Air	Oxygen	Oxygen
H_2	6.7	18.8	14.2
CO	5.6	9.9	7.8
CH_4	0.6	1.6	3.0
CO_2	12.0	20.1	15.8
N_2	74.0	50.2	61.4
H_2S, ppm	758	4798	1320
Total	98.8	100.6	102.3
Heating Value, Btu/scf	46	109	102
% N_2 in Feed	29.3	62.0	60.1
N_2-Free Heating Value, Btu/scf	64	194	161
Product Gas, vol%	Adjusted for 450,000 Btu/hr Heat Loss and N_2 Purge Free		
H_2	11.0	35.9	37.5
CO	9.2	18.8	20.7
CH_4	1.0	3.0	7.9
CO_2	15.5	31.3	31.2
N_2	63.3	11.0	2.7
Total	100	100	100
Heating Value, Btu/scf	76	207	269
Sulfur Retention %	88.6	49.9	30.0

Table 22. TRDU Gasification Efficiency for TRDU Test P071

Test	Petcoke	Petcoke	Prater Creek
Oxidant	Air	Oxygen	Oxygen
Gasifier Temp., °C	1020	965	980
Coal/Sorbent Feed Rate, lb/hr	289	241	329
Air Flow, lb/hr	1025	57	57
O_2 Flow, lb/hr	0	216	235
Steam Flow, lb/hr	261	456	473
Air:Coal Ratio, lb/lb	4.73	0.32	0.19
Steam:Coal Ratio, lb/lb	1.2	2.52	1.52
O_2:Coal Ratio, lb/lb	1.10	0.27	0.80
Recirculation Rate, lb/hr	2260	2730	5350
Operation Pressure, psig	100	80	80
TRDU Riser Velocity, ft/s	53.7	64.2	67.4
Carbon Conversion			
Solid Accountability	78.2	77.5	74.1
Noncondensible Gas Make	58.1	71.3	51.7
Thermal Oxidizer	75.8	68.1	81.8

4.4.6 TRDU Gasification Test P072

Test P072 was conducted during the weeks October 7–9, 2002, and October 21–25, 2002, with an 11-day interruption caused by a gasket failure on the filter vessel tube sheet that seals the tube sheet between the filter vessel flanges. This resulted in fuel gas leaking directly into the gasification tower and forced a system shutdown. The run was restarted after the filter was cooled and the filter gasket replaced. This test operated for 155 hours on coal feed with 145 hours in gasification, including 20 hours in air-blown gasification and 125 hours in enriched air- or full oxygen-blown gasification. This test utilized Illinois No. 6, Alabama bituminous coal from the Calumet Mine and, for a short period, the high-swelling Pittsburgh No. 8 bituminous coal. Tables 23 and 24 show the corrected and actual fuel gas composition for oxygen-blown testing and the operation conditions for these selected tests on these fuels. All steady-state data from this test campaign are given in Appendix A.

4.4.7 TRDU Gasification Test P073

TRDU Test P073 was conducted from the April 22 to April 30, 2003, time period. This test generated 135 hours of coal feed with 120 hours of gasification, including 75 hours of air-blown gasification and 45 hours of oxygen-blown gasification. This test utilized a high-swelling Pittsburgh No. 8 bituminous coal from the Blacksville Mine exclusively. While this test generated a significant number of hours, it was also subject to a much higher number of significant fluctuations in solids circulation possibly because of the swelling properties of this coal. It was speculated that a layer of sticky coal could build up on the wall opposite where the coal is injected and then spall off in large enough agglomerates to cause the fluctuations in the circulation rates. Because of these fluctuations, the amount of true steady-state data appears to be limited. Tables 25 and 26 show the product gas composition and TRDU operating conditions and efficiency results for the high-swelling Pittsburgh No. 8 bituminous coal from the Blacksville Mine in West Virginia. Table 27 shows the XRFA analysis from bed material and filter ash samples generated during the gasification of the Blacksville coal. Again, the data from all the identified steady-state periods are given in Appendix A.

4.4.8 TRDU Gasification Test P074

TRDU Test P074 was conducted during the week of September 22 through September 28, 2003. This test generated 81 hours of coal feed with 65 hours of gasification data. Of this testing, 48 hours was in air-blown operation, and 17 hours was in oxygen-blown operation. The first part of this test attempted to test Australian brown coal from the Loy Yang Mine; however, steady-state operation was difficult to obtain since this original 60% moisture coal could only be air-dried to approximately 35%–40% moisture before testing was started. This fuel proved to be very difficult to feed, so this testing was discontinued. The test was then completed on a 90 wt% Falkirk, North Dakota, lignite and 10 wt% hog fuel wood waste feedstock. This testing represented the bulk (44 hours) of the good steady-state operating results obtained during this test campaign. Tables 28 and 29 show some results from these gasification tests on the lignite/wood mixture in both air-blown and oxygen-blown operation. Table 30 shows the ash chemistry from various bed material and filter vessel samples taken during the testing of both the Falkirk lignite and the Falkirk lignite–10 wt% wood mixture. This table shows that after 2 days of operation on the Falkirk–wood mixture, potential

Table 23. Corrected TRDU Product Gas Compositions for P072

Test	Illinois No. 6	Illinois No. 6	Calumet
Product Gas Composition, vol%	Oxygen	Oxygen	Oxygen
H_2	12.6	11.1	16.8
CO	6.5	6.0	9.3
CH_4	3.3	2.1	3.5
CO_2	19.6	16.3	20.3
N_2	59.5	64.1	48.7
H_2S, ppm	2461	3291	1593
Total	101.5	99.6	98.5
Heating Value, Btu/scf	95	76.0	119
% N_2 in Noncondensible Feed	64.0	56.7	60.3
N_2-Free Heating Value, Btu/scf	176	120	219
Product Gas, vol%	Adjusted for 450,000 Btu/hr Heat Loss and N_2 Purge Free		
H_2	29.4	30.5	33.8
CO	15.2	16.6	18.7
CH_4	7.8	5.6	7.0
CO_2	33.1	31.4	31.1
N_2	14.5	15.8	9.5
Total	100	100	100
Heating Value, Btu/scf	223	210	241
Sulfur Retention %	73.2	55.0	31.0

Table 24. TRDU Operating Conditions and Gasification Efficiency Results for P072

Test	Illinois No. 6	Illinois No. 6	Calumet
Oxidant	Oxygen	Oxygen	Oxygen
Gasifier Temp., °C	934	1016	987
Coal/Sorbent Feed Rate, lb/hr	334	294	351
Air Flow, lb/hr	57	57	054
O_2 Flow, lb/hr	194	229	228
Steam Flow, lb/hr	416	438	434
Air:Coal Ratio, lb/lb	0.20	0.23	0.16
Steam:Coal Ratio, lb/lb	1.50	1.79	1.33
O_2:Coal Ratio, lb/lb	0.75	0.99	0.74
Recirculation Rate, lb/hr	4805	7315	6610
Operation Pressure, psig	85	85	85
TRDU Riser Velocity, ft/s	56	61.7	59.6
Carbon Conversion			
Solid Accountability	68.7	85.8	72.1
Noncondensible Gas Make	58.2	60.6	55.5
Thermal Oxidizer	74.3	82.2	74.3

Table 25. Corrected TRDU Product Gas Compositions for P073

Coal	−10 mesh Blacksville	−10 mesh Blacksville
Product Gas Composition, vol%	Air	Oxygen
H_2	6.3	16.2
CO	4.7	9.5
CH_4	1.8	4.1
CO_2	12.8	23.1
N_2	81.1	54.7
H_2S, ppm	892	2102
Total	106.7	107.6
Heating Value, Btu/scf	54	125
% N_2 in Noncondensible Feed	29.6	53.1
N_2 -Free Heating Value, Btu/scf	73	218
Product Gas, vol%	Adjusted for 450,000 Bur/hr Heat Loss and N_2 Purge Free	
H_2	13.7	31.0
CO	7.7	18.2
CH_4	2.3	7.8
CO_2	14.3	35.0
N_2	62.0	8.0
Total	100	100
Heating Value, Btu/scf	96	239
Sulfur Retention %	80.4	72.7

Table 26. TRDU Operating Conditions and Gasification Efficiency Results for P073

Test	−10 mesh Blacksville	−10 mesh Blacksville
Oxidant	Air	Oxygen
Gasifier Temp., °C	950	922
Coal/Sorbent Feed Rate, lb/hr	273	285
Air Flow, lb/hr	924	145
O_2 Flow, lb/hr	0	168
Steam Flow, lb/hr	167	290
Air:Coal Ratio, lb/lb	4.23	0.63
Steam:Coal Ratio, lb/lb	0.76	1.27
O_2:Coal Ratio, lb/lb	0.98	0.87
Recirculation Rate, lb/hr	13185	11265
Operation Pressure, psig	120	120
TRDU Riser Velocity, ft/s	48.2	34.3
Carbon Conversion		
Solid Accountability	74.5	73.4
Noncondensible Gas Make	57.3	64.6
Thermal Oxidizer	82.2	87.8

Table 27. XRFA of the Pittsburgh No. 8 Bituminous Coal Ashes

Element, wt%	P073 SP 12:20 04/23/03	P073 FV 12:25 04/23/03	P073 SP 07:00 04/24/03	P073 FV 7:15 04/24/03	P073 SP 19:18 04/29/03	P073 FV 19:25 04/29/03
Si	86.2	36.2	51.7	22.3	87.2	38.9
Al	0.9	5.8	3.3	8.0	1.0	7.4
Fe	1.7	5.3	5.1	8.5	1.7	6.7
Ti	0.1	0.3	0.2	0.4	0.1	0.3
P	0.0	0.1	0.1	0.1	0.0	0.1
Ca	5.8	30.3	19.2	35.8	4.9	25.8
Mg	3.6	14.4	10.9	16.5	3.2	12.3
Na	0.0	0.1	0.0	0.1	0.0	0.2
K	0.3	0.6	0.5	0.7	0.5	0.9
S	1.2	6.9	8.9	7.6	1.5	7.4
Total	99.8	100	99.9	100	100.1	100

Table 28. Corrected TRDU Product Gas Compositions for TRDU Test P074

Test	Falkirk	Falkirk	Falkirk–Wood	Falkirk–Wood
Product Gas Composition, vol%	Air	Oxygen	Air	Oxygen
H_2	8.3	18.8	7.2	15.7
CO	6.5	6.9	5.7	8.6
CH_4	1.1	2.7	1.2	2.5
CO_2	12.9	28.8	12.4	24.9
N_2	74.7	42.6	70.9	47.3
Total	103.4	99.9	97.4	99.0
Heating Value, Btu/scf	59	111	54	104
% N_2 in Feed	29.8	62.1	32.8	69.6
N_2 -Free Heating Value, Btu/scf	75	166	81	194
Product Gas, vol%	Adjusted for 450,000 Btu/hr Heat Loss and N_2 Purge Free			
H_2	16.9	34.8	18.5	34.1
CO	13.1	12.7	14.6	18.7
CH_4	2.2	5.1	3.1	5.4
CO_2	14.7	36.7	18.2	37.6
N_2	53.0	10.7	45.6	4.1
Total	100	100	100	100
Heating Value, Btu/scf	120	205	138	226

Table 29. TRDU Operating Conditions and Gasification Efficiency for TRDU Test P074

Test	Falkirk	Falkirk	Falkirk/Wood	Falkirk/Wood
Oxidant	Air	Oxygen	Oxygen	Oxygen
Gasifier Temp., °C	822	798	863	839
Coal/Sorbent Feed Rate, lb/hr	453	502	381	463
Air Flow, lb/hr	860	0	990	0
O_2 Flow, lb/hr	0	213	0	212
Steam Flow, lb/hr	95	416	121	341
Steam:Coal Ratio, lb/lb	0.21	0.92	0.35	0.82
O_2:MAF Coal Ratio, lb/lb	0.84	0.87	1.17	1.07
Recirculation Rate, lb/hr	2255	4005	9045	8550
TRDU Riser Velocity, ft/s	54.8	42.4	43.5	39.8
Carbon Conversion				
Solid Accountability	90.0	85.3	96.5	93.2

Table 30. XRFA of Falkirk Lignite and Falkirk–Wood Samples

Element, wt%	Falkirk SP	Falkirk FV	Falkirk–Wood SP	Falkirk–Wood FV
Si	22.9	29.9	69.5	35.7
Al	6.1	11.5	8	5.6
Fe	4.9	9	4.2	5.3
Ti	0.4	0.6	0.3	0.3
P	0.1	0.1	0	0.1
Ca	56.5	35.8	9.6	34
Mg	3.9	6.2	4.3	16.1
Na	2.2	3.6	2.5	1.6
K	1.6	2	1.6	1.4
S	1.4	1.3	0	0
Total	100	100	100	100.1

low melting species such as potassium were not building up in the bed material. Steady-state data from these tests are also given in Appendix A.

4.4.9 TRDU Gasification Test P075

TRDU Test P075 tested the thermally dried Australian brown coals from the Loy Yang and Lochiel Mines over the week of December 1, 2003, through December 4, 2003. This test generated 59 hours of coal feed and 46 hours of gasification, including 33 hours of air-blown gasification and 13 hours oxygen-blown gasification. Tables 31 and 32 summarize some results from the brown coal tests and compare them to previous tests conducted with the high-sodium North Dakota lignite from the Freedom Mine. Table 33 shows the ash chemistry from selected samples from the gasification

Table 31. Corrected TRDU Product Gas Compositions for TRDU Test P075 Utilizing Australian Brown Coal as Compared to North Dakota Lignite

Coal	Freedom	Freedom	Loy Yang	Loy Yang	Lochiel	Lochiel
Product Gas Composition, vol%	Air	Oxygen	Air	Oxygen	Air	Oxygen
H_2	7.7	17.3	7.4	9.3	6.3	13.8
CO	4.5	5.7	5	6.0	4.6	4.9
CH_4	1.1	2.2	1.7	3.1	1.5	3.5
CO_2	12.6	30.0	12.7	22.0	13.9	24.7
N_2	73.4	47.6	73.5	51.6	74.9	56.0
Total	99.3	102.8	100.3	98.0	101.2	102.9
Heating Value, Btu/scf	50	96	57	81	50	96
% N_2 in Dry Feed	35.3	62.7	32.0	74.0	32.8	74.8
N_2-Free Heating Value, Btu/scf	71	141	84	195	70	192
Product Gas, vol%	Adjusted for 450,000 Btu/hr Heat Loss and N_2 Purge Free					
H_2	19.1	33.9	17.9	25.8	13.1	33.2
CO	11.0	11.2	12.1	16.6	9.6	11.8
CH_4	2.6	4.2	4.1	8.6	3.1	8.4
CO_2	16.2	40.0	18.5	40.7	19.5	39.1
N_2	51.1	10.9	47.5	8.3	54.8	7.4
Total	100	100	100	100	100	100
Heating Value, Btu/scf	124	188	138	224	105	231

Table 32. TRDU Operating Conditions and Gasification Efficiency Results for P075 Utilizing Australian Brown Coal as Compared to North Dakota Lignite

Coal	Freedom	Freedom	Loy Yang	Loy Yang	Lochiel	Lochiel
Oxidant	Air	Oxygen	Air	Oxygen	Air	Oxygen
Gasifier Temp., °C	815	782	882	795	785	741
Coal/Sorbent Feed Rate,	354	469	267	443	479	482
lb/hr	758	0	766	0	1004	0
Air Flow, lb/hr	0	201	0	192	0	168
O_2 Flow, lb/hr	80	489	125	319	124	293
Steam Flow, lb/hr	0.24	1.3	0.46	0.72	0.31	0.61
Steam:Coal Ratio, lb/lb	0.96	0.97	0.78	0.51	0.86	0.50
O_2:maf Coal Ratio, lb/lb	2905	1225	11,880	2215	8305	11,225
Recirculation Rate, lb/hr	33.5	50.8	35.8	35.8	41.8	30.3
TRDU Riser Velocity, ft/s						
Carbon Conversion	84.3	80.9	77.3	83.0	72.0	74.4
Solid Accountability						

tests with the high-sodium Freedom lignite and the high-sodium Australian brown coals. All-steady state data are given in Appendix A.

4.4.10 TRDU Gasification Test P076

TRDU Test P076 tested as-received Wyodak subbituminoous coals from the Belle Ayr Mine over the period of June 1, 2004, through June 8, 2004. This test generated 180 hours of coal feed and 176 hours of gasification, including 101 hours of air-blown gasification and 75 hours oxygen-blown gasification. Tables 34 and 35 summarize some results from the Wyodak tests. Wyodak was selected for testing based on its excellent performance in the previous TRDU tests and in testing at the PSDF. These tests were conducted primarily to look at establishing a baseline for mercury emissions and measuring the performance of various Hg sorbents.

4.4.11 TRDU Gasification Test P077

TRDU Test P077 tested raw and washed subbituminous coals from India over the week of September 21, 2004, through September 25, 2004. This test generated 82 hours of coal feed and 72 hours of gasification, including 60 hours of air-blown gasification and 13 hours oxygen-blown gasification. Table 36 summarizes the range of operating conditions and results achieved with both Wyodak subbituminous coal and the high-ash Indian subbituminous coal tests conducted recently. Wyodak was selected as the comparison coal since it is the baseline coal for both the EERC and PSDF transport reactors and it is the closest in rank to the Indian coal tested.

Tables 37 and 38 summarize the identified steady-state periods which had the best performance for both the recent Wyodak and high-ash Indian coal tests. Typically, the best performance is a balance of fuel gas heating value and carbon conversion; however, with the low fuel gas heating values being achieved with the high-ash Indian coals, more of an emphasis was placed on fuel gas heating value at the expense of carbon conversion.

Table 33. XRFA of Selected Samples from Gasification of High-Sodium Low-Rank Coals

Element, wt%	Freedom SP	Freedom FV	Loy Yang SP	Loy Yang FV	Lochiel SP	Lochiel FV
Si	16.4	10.3	88.6	47.5	79.2	10.7
Al	4.9	6.4	4.3	5.4	4.2	6.2
Fe	5.1	4.6	2.1	6.4	2.3	6.4
Ti	0.3	0.4	0.1	0.3	0.2	0.7
P	0.1	0.2	0	0.1	0	0
Ca	42.7	47.1	2.4	13.3	7.2	30.6
Mg	25.0	26.5	0.8	12.5	2.3	25.3
Na	3.2	2.8	1.5	6.6	3.9	6.7
K	0.9	0.5	0.2	1.9	0.1	0.6
S	1.4	1.2	0	5.9	0	12.7
Total	100	100	100	99.9	99.4	99.9

Table 34. Corrected TRDU Product Gas Compositions for TRDU Test P076 Utilizing Wyodak PRB Subbituminous Coal

Coal	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak
Product Gas Composition, vol%	Air	Oxygen	Air	Oxygen	Air	Oxygen
H_2	6.6	15.8	7.5	15.5	8.1	15.6
CO	4.4	8.5	5.1	7.0	6.2	7.2
CH_4	1.1	2.9	1.5	2.9	1.6	2.8
CO_2	11.6	21.9	12.2	21.0	13.6	22.0
N_2	70.7	49.3	71.2	49.9	74.1	49.9
Total	94.4	98.4	97.5	96.3	103.6	97.8
Heating Value, Btu/scf	47	108	56	102	62	102
% N_2 in Dry Feed	33.9	71.4	34.1	71.6	31.9	72.5
N_2-Free Heating Value, Btu/scf	78	200	87	200	90	197
Product Gas, vol%	Adjusted for 450,000 Btu/hr Heat Loss					
H_2	17.8	34.0	17.6	35.5	17.7	34.6
CO	11.9	18.3	12.0	16.0	13.6	16.0
CH_4	3.0	6.2	3.5	6.6	3.5	6.2
CO_2	19.4	31.0	19.0	31.0	20.0	33.5
N_2	48.0	10.4	47.9	11.0	45.3	9.7
Total	100	100	100	100	100	100
Heating Value, Btu/scf	126	233	131	234	136	226

Tables 39 and 40 show ash analyses from samples taken at the end of each operating condition (air versus oxygen). These analyses show that the circulating standpipe material was still enriched in silica from the start-up sand. However, the filter ash seems to be very representative of the coal ash plus the small amount of dolomite being fed into the TRDU. This is very consistent with previous testing in which the filter ash chemistry was shown to be very representative of the coal/dolomite ash chemistry from within a few hours of starting up the gasifier. It typically takes a hundred hours or more to flush most of the silica sand from the circulating bed material.

Oxygen-blown operation requires the addition of considerable excess steam to maintain the reactor temperatures below the temperature where ash deposition and agglomeration of the circulating ash material become a problem. Figure 8 is a plot of both the corrected dry and wet product gas heating values and carbon conversion for the two subbituminous coals tested under both air- and oxygen-blown conditions. Carbon conversion seems to be primarily dependent on the ratio of weight oxygen fed to the weight of the maf coal fed regardless of what form the oxygen was fed (air versus oxygen). The oxygen-to-maf coal ratio was considerably higher for the high-ash Indian coal because of the higher gasifier operating temperature and the extra heat needed to bring all of the coal ash up to bed temperature. The corrected dry product gas heating value for the oxygen-blown test has a significantly higher HHV than air-blown operation (190–225 Btu/scf as compared to 90–120 Btu/scf). A comparison of the fuel gas heating values shows that the Indian coal had corrected heating values that were as high as 90 Btu/scf. This heating value would be marginal for

Table 35. TRDU Operating Conditions and Gasification Efficiency Results for P076 Utilizing Wyodak PRB Subbituminous Coal

Coal	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak
Oxidant	Air	Oxygen	Air	Oxygen	Air	Oxygen
Gasifier Temp., °C	890	886	844	848	868	869
Coal/Sorbent Feed Rate, lb/hr	285	334	325	325	363	337
Air Flow, lb/hr	906	0	933	0	986	0
O_2 Flow, lb/hr	0	241	0	216	0	213
Steam Flow, lb/hr	121	315	124	302	120	298
Steam:Coal Ratio, lb/lb	0.44	0.98	0.40	0.97	0.34	0.92
O_2:maf Coal Ratio, lb/lb	1.094	1.070	0.988	0.985	0.935	0.938
Recirculation Rate, lb/hr	3585	11,815	7280	11,780	6595	5640
TRDU Riser Velocity, ft/s	41.0	40.0	42	38	41	38
Carbon Conversion						
Solid Accountability	95.0	97	92	95	93	97

Table 36. TRDU Range of Operating Conditions for Air-Blown Operation

Coal Name Coal Type	Wyodak Subbituminous	As-Mined Indian Subbituminous	Washed Indian Subbituminous
Moisture Content, %	23	4.5	9
Pressure, psig	120	120	120
Steam–maf Coal Ratio	0.49–0.72	0.68–0.77	0.62–0.82
O_2–maf Coal Ratio	0.8–1.1	1.0–1.2	1.0–1.2
Ca–S Ratio, mole (sorbent only)	1.5	1.4	1.4
Coal and Sorbent Feed Rate, lb/hr	285–415	416–465	382–505
Avg. Mixing Zone Temp, °C , avg.	844–894	879–948	928–936
HHV of Fuel Gas, act., Btu/scf	47–66	41–43	33–50
HHV of Fuel Gas, cor., Btu/scf	126–140	80–89	84–90
Conversion, %	87–94.5	80–89	84–90
Carbon in Bed, %, Standpipe	1.6–5.0	1.1–2.5	1.7–2.5
Riser Velocity, ft/s	38.1–43.8	49.7–51.1	48.2–55.6
Standpipe Velocity, ft/s	0.20–0.25	0.20–0.22	0.21–0.22
Circulation Rate, lb/hr	3590–8840	2610–7520	3340–4350
Total Operating Hours	175.5	65*	

* Total for as-mined and washed Indian subbituminous.

operating a gas turbine without either enriched air operation or some supplemental fuel source. These lower heating values and carbon conversions as compared to the low-ash Wyodak coal are thought to be due to a lower char/steam reactivity and to the extra heat loss associated with heating all of the ash up to bed temperature. Typically, the lower heating value of the fuel gas stream achieved from air-blown and oxygen-blown gasifiers would have approximately the same heating value entering the gas turbine combustor since the high volume of steam addition needed in the oxygen-blown system acts like the nitrogen diluent that would enter the gas turbine combustor under air-blown operation. This high steam addition to the oxygen-blown transport reactor is necessary to prevent the formation of hot zones in the circulating bed material where bed material agglomeration and deposition can occur. Generally, the similar fuel gas heating values entering a gas turbine make it hard to justify the economics of an oxygen-blown transport reactor strictly for power production. However, in this case, some oxygen enrichment or oxygen operation may be necessary in order to achieve fuel gas heating values sufficient to guarantee operation of the gas turbine. In addition, concepts such as a Vision 21 plant in which a gasifier would be operated for both power and fuels or chemicals production could justify the higher capital and operating costs associated with an oxygen plant.

4.4.12 Conclusions of Gasification Testing

In total, eleven test campaigns utilizing the L-valve loop seal configuration have been conducted under enriched air- or full oxygen-blown conditions. During these tests, 1515 hours of coal feed with 660 hours of air-blown gasification and 720 hours of enriched air- or oxygen-blown gasification were completed. During these tests, approximately 366 hours of operation with Wyodak,

Table 37. TRDU Operating Conditions for Best-Case Gasification Performance

Test	Wyodak	Wyodak	Raw Indian	Raw Indian	Washed Indian	Washed Indian
Oxidant	Air	Oxygen	Air	Enriched Air	Air	Oxygen
Gasifier Temp, °C	848	848	936	946	936	895
Coal/Sorbent Feed Rate, lb/hr	359	325	448	451	441	461
Air Flow, lb/hr	968	0	1160	689	1087	0
O_2 Flow, lb/hr	0	216	0	101	0	249
Steam Flow, lb/hr	129	303	172	215	168	332
Steam:Coal Ratio, lb/lb	0.37	0.97	0.40	0.50	0.40	0.75
O_2/maf Coal Ratio, lb/lb	0.93	0.99	1.10	1.06	1.07	1.01
Recirculation Rate, lb/hr	8840	11,780	3280	6460	3780	4630
TRDU Riser Velocity, ft/s	43.5	37.5	50.6	46.4	48.2	41.1
Carbon Conversion	92.2	94.6	87.7	86.8	87.7	84.5

Table 38. Actual and Corrected TRDU Product Gas Compositions for Best-Case Steady-State Tests

Test	Wyodak	Wyodak	Raw Indian	Raw Indian	Washed Indian	Washed Indian
Oxidant	Air	Oxygen	Air	Enriched Air	Air	Oxygen
Product Gas Composition, vol%						
H_2	8.2	15.5	5.6	8.6	6.6	13.4
CO	5.4	7.0	4.1	5.6	4.5	7.3
CH_4	1.5	2.9	1.2	1.7	1.4	2.8
CO_2	11.7	21.0	12.8	17.8	13.6	22.6
N_2	71.2	49.9	73.9	65.0	76.2	55.9
Total	98.6	96.3	97.6	98.7	102.3	102.0
Heating Value, Btu/scf	59	102	44	63	50	95
% N_2 in Dry Feed	33.2	71.6	25.9	33.0	26.8	70.0
N_2-Free Heating Value, Btu/scf	91	200	57	87	62	179
Product Gas, vol%			Adjusted for 450,000 Btu/hr Heat Loss			
H_2	18.6	35.5	10.5	16.7	11.7	29.2
CO	12.3	16.0	7.7	10.9	8.0	15.9
CH_4	3.4	6.6	2.2	3.3	2.5	6.1
CO_2	17.4	31.0	15.8	23.8	16.0	32.9
N_2	48.3	11.0	63.8	45.3	61.8	15.9
Total	100	100	100	100	100	100
Heating Value, Btu/scf	135	234	81	123	90	208

Table 39. XRF Analysis of TRDU Samples Generated from the Raw High-Ash Indian Coal, %

	Raw Indian Coal Ash	Raw Indian – Air		Raw Indian – Enriched Air	
		Standpipe	Filter	Standpipe	Filter
Si	56.7	79.3	51.6	81.6	51.7
Al	29.1	12.6	27.5	10.6	27.8
Fe	6.2	3.4	6	3.2	6
Ti	2.8	0.6	2.2	0.5	2.3
P	0.5	0.1	0.5	0.1	0.5
Ca	1.7	1.8	6.6	2	6.3
Mg	0.7	0.8	3.5	0.8	3.1
Na	0.6	0.7	0.6	0.6	0.6
K	1.7	0.7	1.6	0.5	1.6
S	0	0	0	0	0
Total	100	100	100.1	99.9	99.9

Table 40. XRF Analysis of TRDU Samples Generated from Washed High-Ash Indian Coal, %

	Washed Indian Coal Ash	Washed Indian – Air		Washed Indian – Oxygen	
		Standpipe	Filter	Standpipe	Filter
Si	55.4	83.2	48.3	80.4	50.4
Al	29.6	8.9	25.7	11.6	27.1
Fe	7	3.2	5.6	3	5.4
Ti	2.5	0.4	2.1	0.6	2.3
P	0.1	0.1	0.6	0.2	0.6
Ca	2.1	2.1	10.1	2.1	9
Mg	0.7	1	5.5	1	3.1
Na	0.7	0.6	0.5	0.6	0.5
K	1.8	0.4	1.5	0.6	1.6
S	0	0	0	0	0
Total	99.9	99.9	99.9	100.1	100

123 hours of operation with Navajo subbituminous coal, 143 hours of operation on Illinois No. 6, 106 hours on SUFCo, 110 hours on Prater Creek, 48 hours on Calumet, and 134 hours on a Pittsburgh No. 8 bituminous coal were completed. In addition, 331 hours of operation on low-rank coals such as North Dakota lignite, Australian brown coal, and a 90:10 wt% mixture of lignite and wood waste were completed. Also included in these test campaigns was 50 hours of gasification on a petroleum coke from the Hunt Oil Refinery. An additional 73 hours of gasification on a high-ash Indian coal was generated.

Figures 8 and 9 show the product gas heating value and the carbon conversion measured as a function of the O_2/maf coal ratio for the various ranks of coal under both air-blown and oxygen-blown testing, respectively. In general, operation on the more reactive low-rank western coals has displayed higher carbon conversions and product gas heating values even when operating at lower reactor temperatures than comparable bituminous coal tests. From Figures 8 and 9 it is apparent that the transport gasifier performs better on the lower-rank feedstocks because of their higher char reactivity with the gasification reactions. Comparable carbon conversions have been achieved at similar oxygen/coal ratios for both air-blown and oxygen-blown operation. Figure 10 shows the operating results from the TRDU on the low-rank coals only as a function of the O_2/maf coal ratio. This figure shows that these low-rank feedstocks provided similar fuel gas heating values; however, even among the low-rank coals, there was still some variability in the carbon conversion. The carbon conversion was lower for the fuels (brown coal in particular) that contained a significant amount of fines. Appendix A contains all of the steady-state operating conditions and process performance data calculated for each steady-state period identified.

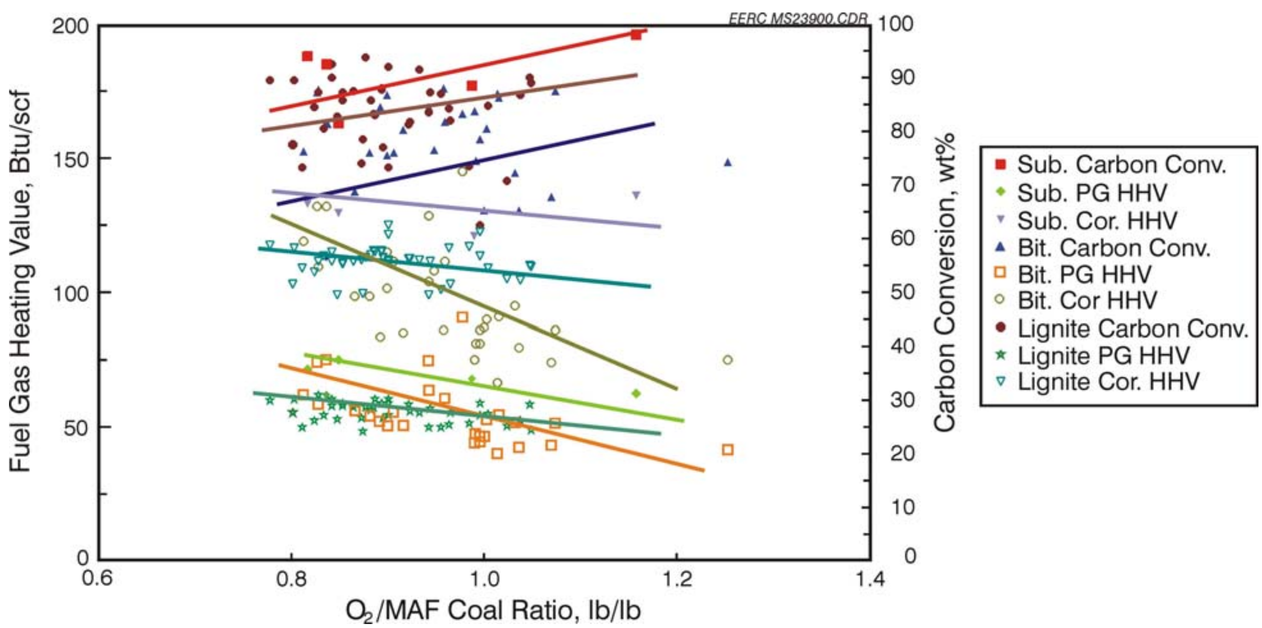

Figure 8. Effect of coal rank as a function of O_2/maf coal ratio on carbon conversion and fuel gas heating value under air-blown operation in the TRDU.

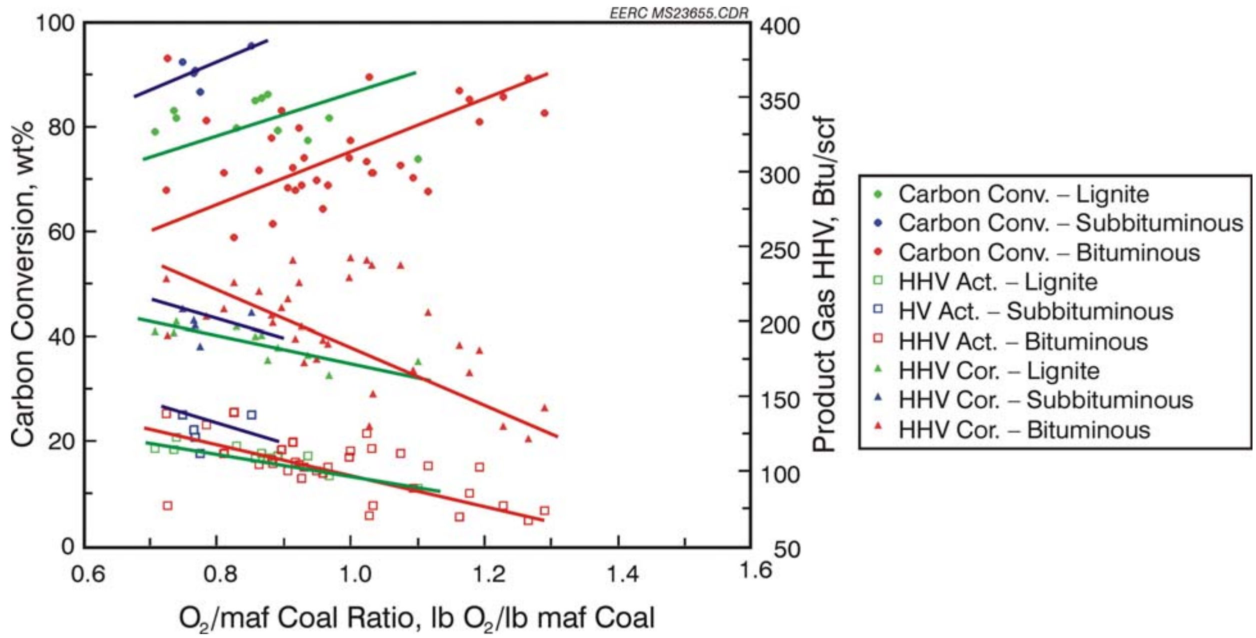

Figure 9. Effect of coal rank as a function of O_2/maf coal ratio under oxygen-blown operation in the TRDU.

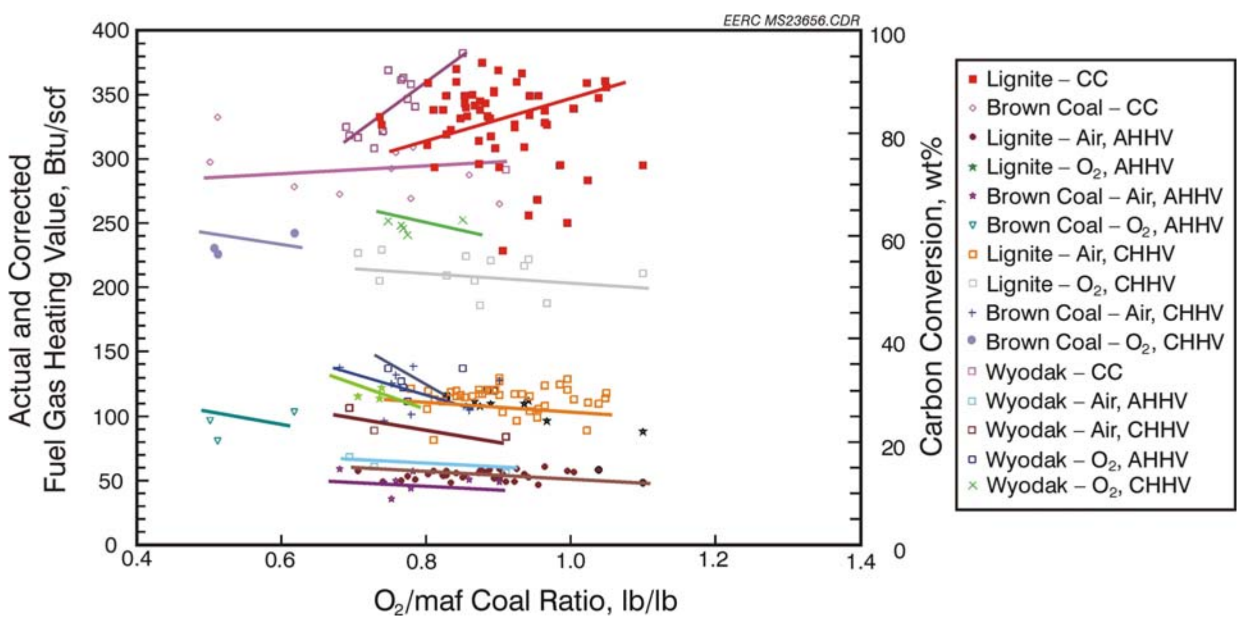

Figure 10. Effect of O_2/maf coal ratio on low-rank coal performance in a tranpsort gasifier (CC = carbon conversion, AHHV = actual higher heating value, CHHV = corrected higher heating value).

The more reactive lower-rank fuels had higher carbon conversions and corrected dry product gas heating values than the higher-rank bituminous coals. The bituminous coals were operated at higher oxygen/maf coal ratios than the lower-rank coals since they typically were operated at higher reactor temperatures in an effort to achieve the same level of steam gasification. For all fuels, carbon conversion increased and corrected dry product gas heating value decreased with an increasing oxygen/maf coal ratio. Appendix A contains all of the steady-state operating conditions and process performance data calculated for each steady-state period identified.

4.5 Hot-Gas Filter Vessel Operation

No major failures of these candles have occurred in over 2500 hours of testing with approximately 2175 hours in gasification mode. The HGFV has mostly been operated between 460° and 570°C (860° and 1058°F) at a face velocity of approximately 3.8 to 4.5 ft/min. Backpulse operating parameters were 270 to 400 psig reservoir pressure with either 1/4- or 1/2-second pulse valve opening times. The average particulate loading going into the HGFV has ranged from approximately 4500 up to 45,000 ppm with a d_{50} between 7 to 22 µm, depending on the fuel type, quantity of sorbent utilized for sulfur control, and whether solids were being recirculated from the dipleg back into the standpipe. A substantial increase in the "cleaned" filter baseline (from ~40 to >90 inches H_2O) has been observed in a few of the tests. This filter ash has averaged from 25 to 60 wt% carbon depending on the carbon conversion and has a low bulk density of approximately 20 lb/ft^3. The small size, the lack of the cohesiveness seen in other filter ashes, and the low density of the ash suggests that a high percentage of the filter cake will be reentrained back onto the filters after they are backpulsed. More details about the hot-gas filter performance have been given elsewhere (3, 7).

In gasification mode, the pulse frequency has been short, with pulses occurring every 8 to 15 minutes. This rapid pulsing is thought to be due to the high-carbon, low-density dust with a high aerodynamic drag being able to minimize the porosity of the filter cake on the surface of the candle. This results in a rapid rise in pressure drop across the filters. The data acquisition system on the TRDU has been programmed to save the filter vessel differential pressure and the filter outlet static pressure every 2 seconds whenever a backpulse sequence is started until 30 seconds after the last manifold is backpulsed.

Operation of the HGFV during the last two gasification tests P076 and P077 utilized ten 1.5-m Pall Advanced Separation iron aluminide candle filters exclusively. The HGFV was operated between 190° and 300°C (375° and 575°F) at a face velocity of approximately 2.2–3.2 ft/min. Backpulse operating parameters were approximately 360 psig backpulse reservoir pressure with a 0.5-s opening time. The average particulate loading going into the HGFV ranged from approximately 4500 up to 38,000 ppm, with a d_{50} between 9 and 12 µm with a top size 95% less than 40 µm (see Figure 11). Figure 11 also shows the particle-size distribution for these same samples for both the circulating bed material (standpipe) and filter ash along with the particle-size distribution of the feed coal. This figure shows that the coal had an average feed size of approximately 400–500 µm with less than 15 wt% being less than 100 µm. The circulating bed material was approximately 200 µm in size as compared to the 160-µm average size of the silica sand. The filter ash particle-size distribution (~10 µm for the raw Indian coal and slightly larger ~12 µm for the washed Indian coal)

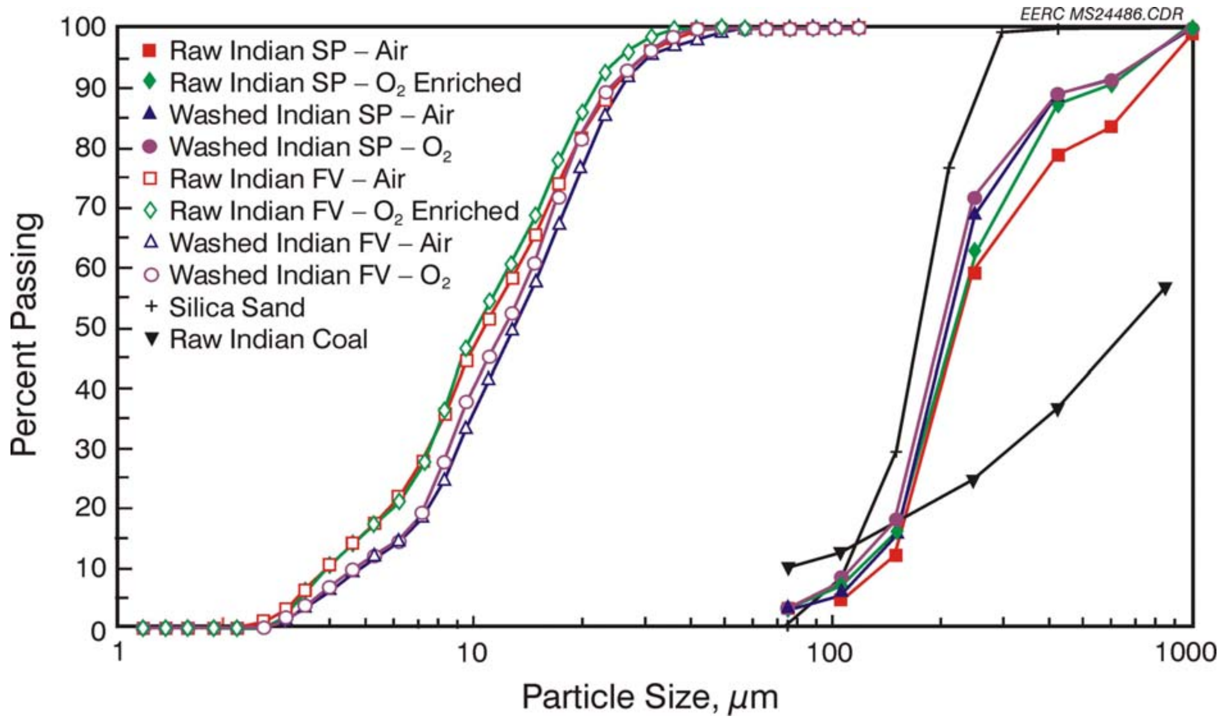

Figure 11. Particle-size distribution of high-ash Indian coal samples from a transport reactor.

were both below the filter particle-size distribution typically achieved with Wyodak subbituminous coal. The smaller particle-size distribution possibly could be due to the higher loadings of more dense ash particles into the cyclones, resulting in a better cyclone efficiency even for the less dense carbon particles in the circulating bed material. Outlet dust loadings were maintained at 1 ppmw or below, indicating good performance from the iron aluminide candle filters.

4.6 Measurement of Mercury in TRDU Fuel Gas

One goal of the transport reactor project has been to demonstrate the acceptable performance of mercury continuous emission monitors (CEMs) to measure mercury in actual coal-derived fuel gas. The EERC is attempting to evaluate the form of mercury (ionic, elemental, or particulate-bound) on the TRDU gasifier. Testing has involved both wet-chemistry methods and mercury CEMs. For the mercury CEMs, three different pretreatment systems could be used to determine which system gives the best results. The first uses a basic stannous chloride solution to convert all mercury to the elemental form and remove any gases such as HCl that may result in interferences. The second CEM uses an acid stannous chloride solution for conversion but has a heated alkali trap to remove interfering gases. The third system that could be used is a thermal system with dilution. Sampling on the TRDU facility has been done at one location on the outlet of the hot-gas filter system. The pressure at this point is approximately 116 psig. Wet-chemistry sampling has consisted of a modified EPA Method 29 multimetal trains to look for mercury in each sample. A detailed description of this method can be found at EPA's Web page: www.epa.gov/ttn/emc. In addition, three different types of mercury CEMs have been used to measure mercury continuously at this sampling location. The wet-chemistry samples were used to verify that the mercury CEM is giving good results. The EERC performs the wet-chemistry mercury analyses on-site so that the results can be obtained quickly for comparison purposes and quality control/quality assurance(QA/QC).

4.6.1 Description of Mercury CEM

4.6.1.1 Semtech Hg 2010 Instrument

The commercial Semtech Hg 2010 mercury analyzer is essentially a portable Zeeman-modulated cold-vapor atomic absorption spectrometer (CVAAS) that can monitor Hg^0 continuously. By using an online reduction unit, total mercury can be monitored continuously. In the reduction unit, a reducing solution ($SnCl_2$) is pumped to the sampling probe. The extracted gas sample and reducing solution are transported continuously through a mixing spiral to maximize the gas solution residence time and ensure complete conversion of Hg^{2+} to Hg^0. After conversion of all the mercury to Hg^0, the sample gas is transferred to a Peltier cooled gas–liquid separator. The conditioned dry gas is then analyzed by the instrument using CVAAS techniques. To minimize interferences from the presence of H_2S, hydrocarbons, and fine particulate in the flue gas sample, the analyzer uses Zeeman effect background correction by applying a modulated magnetic field to a mercury lamp.

4.6.1.2 OhioLumex RA-915+

The OhioLumex RA-915+ is a real-time continuous monitor for total and elemental mercury measurement. The instrument is based on differential Zeeman atomic absorption spectroscopy using high-frequency modulation of light polarization. A mercury lamp is placed in a permanent magnetic field which has the ability to slightly change the wavelength of the mercury light. This allows for background correction for such broadband absorbers as SO_2, moisture, and particulate matter. The Lumex has a multipass cell which provides an effective path length of 10 meters. The instrument does not use gold amalgamation preconcentration, which allows for a faster response time. In ambient air, a lower detection limit of 2 ng/m^3 can be achieved according to the manufacturer. OhioLumex provides a cell for thermal reduction of oxidized mercury to elemental mercury. No catalyst is used in the thermal decomposition cell.

The Lumex needs an external mercury supply such as a permeation device or a gas cylinder for calibration. The instrument does come with a small cell of fixed volume that contains saturated mercury vapor which can be used to check the calibration.

An earlier version of the OhioLumex instrument was evaluated during the first round of the U.S. Environmental Protection Agency (EPA) Environmental Technology Verification Program (8).

4.6.1.3 P S Analytical Sir Galahad and Tekran Model 2537

The P S Analytical and Tekran mercury CEMs are very similar in operation. Both instruments use a batch process where mercury is collected on a specialized gold trap and then desorbed into an atomic fluorescence (AF) analyzer. The primary difference between the two is the type of gold trap that is used. In both cases, the exact manufacturing technique is proprietary. The P S Analytical instrument was initially developed and used for the natural gas industry and the Tekran for ambient mercury measurements. For both instruments, between 0.5 and 2 L/min of flue gas (depending on mercury concentration) is pumped through a gold trap, which is maintained at a constant temperature. Once the mercury has been adsorbed on the gold trap, the trap is removed from the flue gas stream and flushed with argon. The mercury is then desorbed from the gold trap at 500°C using a heating coil. The mercury is then carried to the AF analyzer using argon as a carrier gas. Once the mercury has been desorbed from the trap, it is rapidly cooled with additional argon. To speed up the measurement process, a dual gold trap is used. As one trap is adsorbing mercury, the second trap is being desorbed. The approximate time for each measurement is 2–5 minutes. The operating mercury concentration range for AF-type mercury CEMs is up to 5 orders of magnitude. They can measure mercury concentrations from about 1 ng/m^3 to 150 $\mu g/m^3$, making these instruments ideal for measuring the low concentrations (<5 $\mu g/m^3$) often found in flue gas generated from coal-fired systems.

Both the Tekran and P S Analytical CEMs are calibrated using Hg^0 as the primary standard. The Hg^0 is contained in a closed vessel which is held in a thermostatic bath. The temperature of the mercury is monitored, and the amount of mercury is calculated using vapor pressure calculations. Currently, the calibration of the Tekran is more automated; however, the calibration of the P S Analytical CEM is also being automated. Typically, the calibration of the units has proven stable over a 24-hour period. The EERC has spent considerable effort to develop a sample conditioning procedure that provides representative results.

4.6.2 Hg Sampling Results

Since all of the mercury has been shown to be in the elemental form, it was hoped that very little sample conditioning would be required. However, sampling after the sample gas conditioning system utilized for the other gas analyzer indicated that no mercury was reaching the mercury CEM. Tests with water-filled impingers also exhibited issues with obtaining representative samples. Sample conditioning with basic stannous chloride solutions appeared to work over the short term; however, the reducing fuel gas would consume the reagents in the solution and affect the CEM readings. The sample conditioner was then set up with a peristaltic pump to pump fresh solution into the impingers and pump spent solution out of the impingers. This sample conditioning system has worked well in providing a fuel gas that continuously has worked well with the Hg CEM; however, this sample conditioning requires frequent human intervention to add fresh solution and remove the spent solution. It also generates a fair amount of waste material.

After resolving the sample conditioning issues, shakedown testing with four different types of analyzers (P S Analytical Sir Galahad, Semtech Hg 2010, Nippon DM6B, and the OhioLumex RA-915+), were tested. The light signal from the AA- based analyzers Semtech, Nippon, and OhioLumex appeared to be attenuated when the fuel gas was run through them. The Semtech and Nippon mercury analyzers were unsuccessful because some component of the fuel gas attenuated the signal to such a degree that no measurement could be made, while the OhioLumex appeared to trend the mercury emissions; however, a fourfold change in the factory calibration factor was required to the data to accurately trend the measured emissions. Further use of this analyzer may be warranted after consulting with OhioLumex to understand a scientific reason for the change in the calibration factor. After considerable testing and the addition the P S Analytical analyzer modification adopted during testing at the TECO coal gasification plant, the EERC has had good success measuring the mercury concentrations in the warm fuel gas. Based on these results, the EERC selected the P S Analytical Sir Galahad for further testing on the TRDU. This is the instrument that uses two gold traps in series to trap mercury. The first trap is exposed to the conditioned fuel gas sample at room temperature. After the sample is collected, the first trap is heated with an air purge to drive off the mercury and combust any collected organic material. This gas stream is passed through the second gold trap which captures the mercury. The second trap is then desorbed with an argon carrier gas, and the mercury is measured in the atomic fluorescence chamber.

The initial sample conditioner configuration consisted of an insulated sample line passing through the gasification tower wall to a area that was not explosion-rated. After passing through the wall, the flow was split. One line carried excess flow to a vent and was controlled with a needle valve. This line was used to maintain a flow rate high enough to ensure no condensation in the sample line. The second line was connected to a Teflon filter holder and a heated Teflon sample line. The filter was maintained at temperature with a heated muff set to 163°C (325°F). The flow through this line is also controlled with a needle valve. The sample line was connected to a set of stainless steel impingers. The first impinger was filled with a 20% NaOH/2% $SnCl_2$ solution to reduce all forms of mercury to the elemental state. This impinger was maintained at room temperature to prevent the solution from freezing. The second impinger was dry and maintained in an ice bath to remove moisture and other condensibles. The third and fourth impingers were dry and maintained in a cold bath of isopropanol and dry ice to ensure all heavier tars and oils were condensed. The last three impingers were filled with glass marbles to enhance heat transfer. A P S Analytical gold trap at room temperature was connected to the outlet of the last impinger. After the gold trap, the flow passed through a dry gas meter to measure the total dry sample volume.

The first several attempts to load the gold traps resulted in loadings that were too high for the P S Analytical Sir Galahad to measure. An acceptable sample volume of 0.10 ft^3 was obtained by continuing to half the total sample volume until the concentration was within the calibrated range of the PSA. The results are summarized in Table 41.

It appears there were problems with the first sample. The remaining samples are fairly consistent until the sample conditioning chemicals were consumed.

For the testing in April 2003, the sample conditioning equipment was modified to use a needle valve for pressure letdown before the Teflon-coated stainless steel impingers. The fuel gas and $SnCl_2$/NaOH solution were continuously filled with peristaltic pumps and mixed in a Teflon "T" just prior to entering the first impinger. The first impinger was left in water (not cooled). The second impinger was also in water and was only chilled by conduction from the next chamber in the impinger box. The remaining three impingers were chilled to roughly −6.7°C (20°F), −5°C (20°F [12°–23°F]) in a glycol bath. Liquids were removed from the second and third impingers with a second peristaltic pump. Most of the moisture was taken out in the second impinger.

Table 41. Initial Hg CEM Data Collected Utilizing the P S Analytical Sir Galahad Hg CEM

Sample	Date	Time	Sample Volume, ft^3	Hg Measured, pg	Hg Concentration, $\mu g/m^3$
1	10/23/02	5:45 pm	0.1	80,792.282	28.5
2	10/23/02	6:00 pm	0.1	41,906.1074	14.8
3	10/23/02	6:28 pm	0.05	17,585.792	12.4
4	10/23/02	6:57 pm	0.101	43,241.3843	15.1
5	10/23/02	7:12 pm	0.099	57,117.7956	20.4
6	10/23/02	7:12 pm	0.104	41,160.6491	14
7	10/23/02	7:12 pm	0.102	50,082.8335	17.3
8	10/23/02	7:26 pm	0.1	49,661.6426	17.5

For the test in September, a purged cabinet (for maintaining an explosion-proof rating with non-explosion-proof equipment) was installed on the seventh deck of the TRDU tower to hold the two peristaltic pumps, the supply and waste jugs for the $SnCl_2$ solution, and the chiller for the impingers. The configuration of the impingers was:

1. Gas and $SnCl_2$/NaOH solution in water at room temperature used to reduce oxidized mercury to elemental mercury.
2. Gas–liquid separator in water at room temperature used to remove condensibles.
3. Gas–liquid separator chilled to remove condensibles.

4. and 5. Chilled impingers to remove condensibles.

An unheated 1/4-inch Teflon line was used to transport the sample gas to the P S Analytical Sir Galahad mercury analyzer in the third-floor lab.

For the December 2003 sampling, the major changes for the sample conditioning system were to plumb a vent line for excess flow in after the pressure letdown valve but before the sample line leading to the Hg CEM. This was done to increase the gas flow through the pressure letdown valve to keep it warm and prevent plugging but to avoid bringing a large volume of gas that may contain traces of organics through the sample conditioner and reduce the chance that some might break through to the Hg CEM. In addition, a second 1/4-inch Teflon line was plumbed from the third-floor lab up to the impingers to allow spiking of elemental mercury into the impingers from the P S Analytical CAVKIT. The line was plumbed in upstream of the $SnCl_2$/NaOH line. A check valve and a shut-off valve were also plumbed in to prevent pressurized flow back to the CAVKIT. Five Teflon-lined stainless steel impingers were used. All were filled approximately 3/4 full with glass marbles to enhance heat transfer. The first impinger was used as a gas–liquid contactor. It was placed in cool water to help quench the fuel gas. The second impinger was used as a gas–liquid separator. It was placed in a water bath, which was somewhat cooled by contact with a chilled water bath. The fourth impinger was also used as a gas–liquid separator to remove any condensate. The third, fourth, and fifth impingers were in a chilled water bath that was maintained between −8° and −1°C (17° and 30°F).

On December 1, 2003, sampling of TRDU fuel gas began at 11:40 and continued until 16:30. The concentration varied throughout the day, ranging from 2.5 to 10 μg/m^3 (P S Analytical) as shown in Figure 12. On December 5, 2003, Figure 13 shows the Hg CEM and Method 29 data while both the Sir Galahad and the Lumex analyzers were used for sampling. The TRDU was switching between air-blown and oxygen-blown modes during the late morning. Two Method 29 samples were completed before 11:00. The measured concentrations from the CEMs are significantly higher than the Method 29 values. All CEM data were corrected for CO_2 removal.

Table 42 shows the wet-chemistry methods utilized to determine the total and speciated Hg found in the fuel. Except for the first test which was probably sampled for too long, thereby consuming all of the permanganate solution, the amount of mercury recovered in the KCl and 20% H_2O_2 solutions (i.e., oxidized forms of mercury) was very small. Essentially 90% or better of the mercury is in the elemental form in the fuel gas.

Some of the best data obtained on the monitoring and removal of mercury in the fuel gas was generated during Test P076 utilizing the baseline Wyodak subbituminous coal.

After the sample conditioning issues were resolved, with shakedown testing on three different types of analyzers (P S Analytical Sir Galahad, Semtech Hg 2010, and the OhioLumex RA-915+), the EERC selected the P S Analytical Sir Galahad for further testing on the TRDU. The light signal from the Semtech and OhioLumex both appeared to be attenuated when the fuel gas was run through them. The Semtech attenuated off-scale while the OhioLumex appeared to trend the mercury emissions; however, a fourfold change in the factory calibration factor was required to accurately trend the measured emissions. Further use of this analyzer may be warranted after consulting with OhioLumex to understand the change in the calibration factor. After considerable testing and adding the P S Analytical analyzer modification adopted during testing at the TECO coal gasification plant, the EERC has had good success measuring the mercury concentrations in the warm fuel gas. Figure 14 shows the Hg CEM measurements obtained with the P S Analytical Sir Galahad against those obtained utilizing the modified EPA Method 29 wet chemistry. This graph shows good agreement between the two methods. Figure 15 shows the results when the EERC-treated carbon/limestone mixture was injected in to the HGFV over a 2.5-hour period (10:00–12:30). The treated carbon was mixed with the limestone to make it more flowable and to allow the feeder to be operated at higher motor speeds. The baseline mercury CEM measurement dropped from approximately 26 μg/m^3 to approximately 18 μg/m^3 or a 30% reduction in the mercury (Hg^0) emissions. In-duct injection tests at higher temperatures around 350°C(662°F) appeared to have only a small effect on mercury emissions. This treated carbon feed rate was selected to give comparable feed rates for the treated carbon as utilized in other EERC-conducted pilot- and field-scale testing on combustion systems. These combustion tests showed that over 90% capture of Hg^0 was possible at similar sorbent feed rates on a volumetric basis as what was tested in the TRDU HGFV (5). This reduced performance of the treated activated carbon is probably affected by several variables, including the higher ash loading/carbon loading to the HGFV than combustion baghouses or electrostatic precipitators

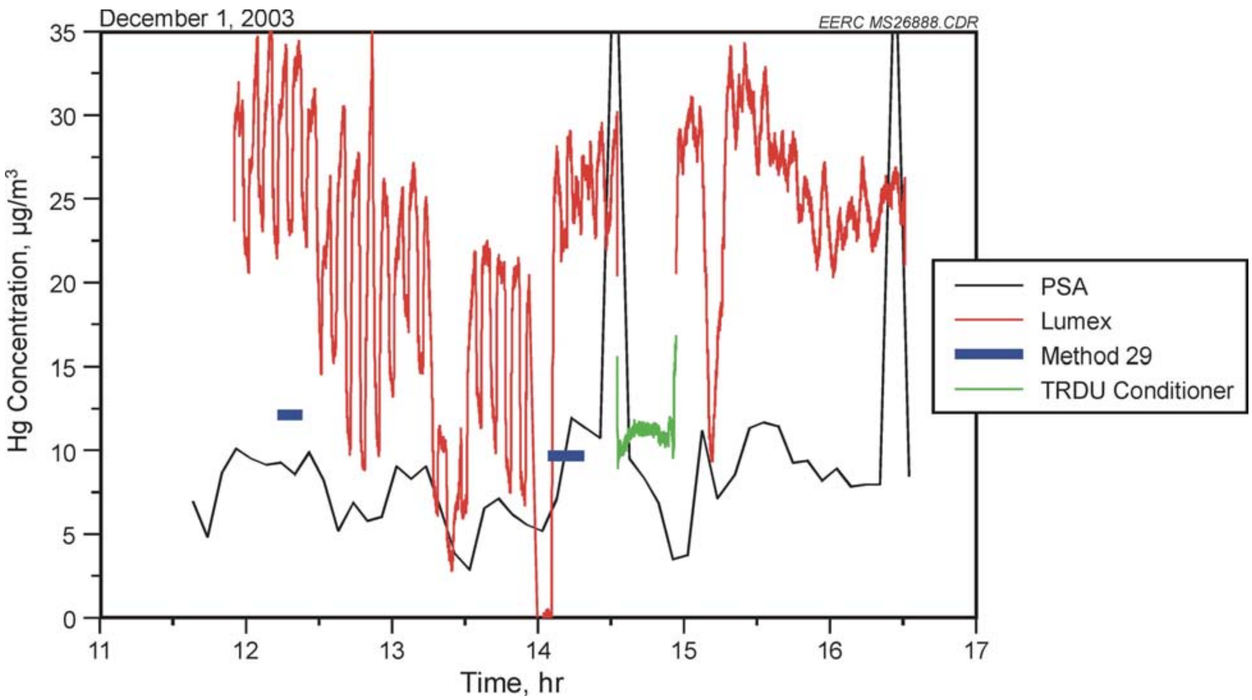

Figure 12. Comparison of Hg CEM and Method 29 data for Australian Lochiel brown coal.

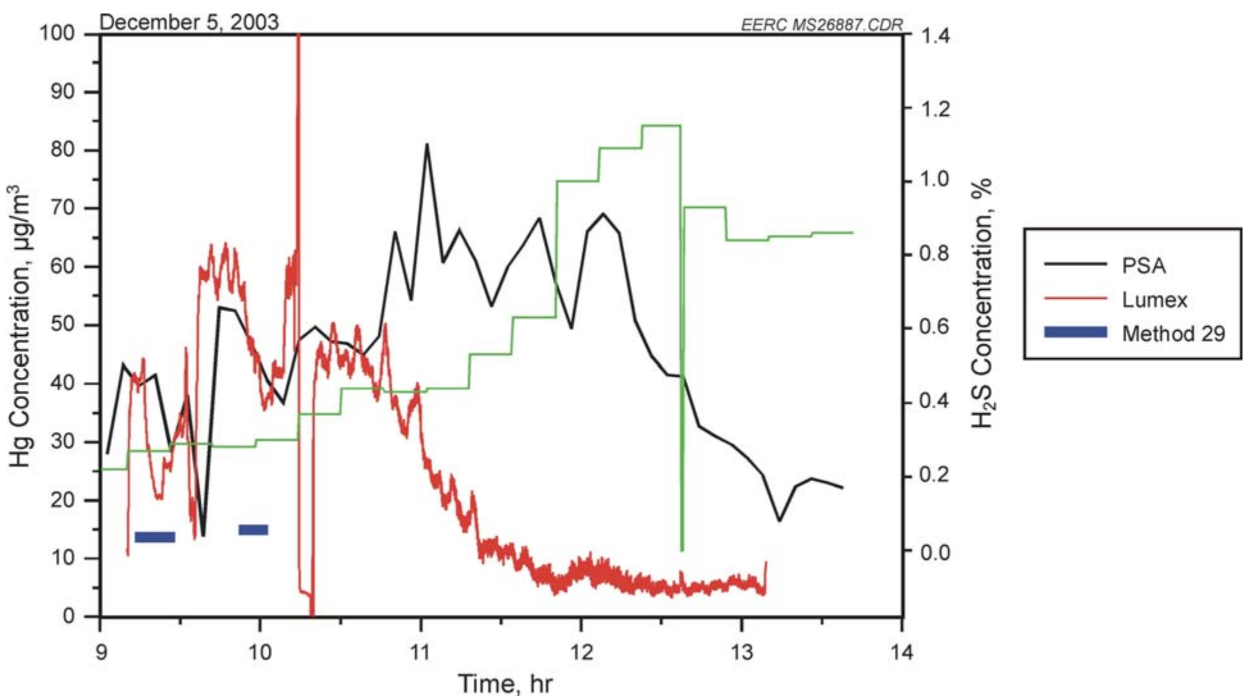

Figure 13. SEM micrograph of mixing zone deposit from gasification Test P060 on SUFCo coal showing Points 1–4.

Table 42. Results from Ontario Hydro/EPA Method 29 Data

Date	KCl Conc., µg/m^3	20% H_2O_2 Conc., µg/m^3	$KMnO_4$ Conc., µg/m^3	Total Conc., µg/m^3
37738	1.14	0.02	0.02	1.18
37738	0.4	0.26	3.17	3.84
37891	1.36	0	9.61	10.97
37955	NM*	0.7	11.42	12.14
37955	NM	0.32	9.35	9.67
37959	NM	0	13.85	13.7
37959	NM	0	14.86	14.86

* Not measured as part of Method 29 train, Ontario Hydro train only.

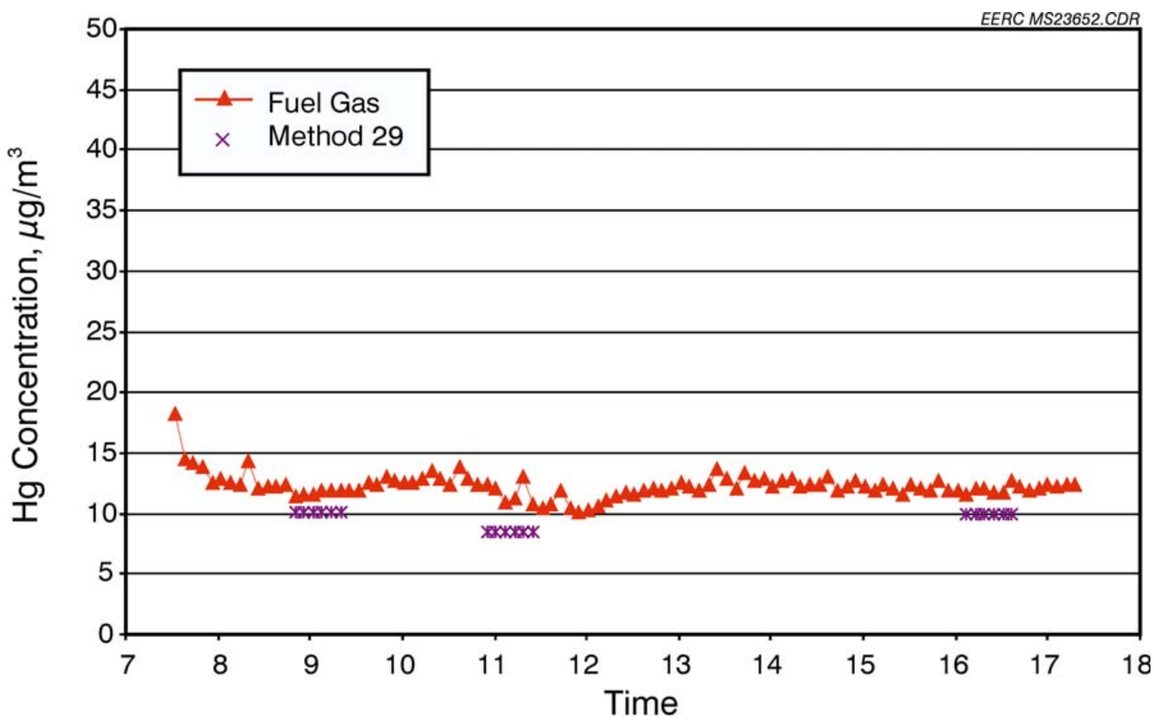

Figure 14. Comparison of Hg CEM with Method 29 wet-chemistry data on TRDU fuel gas.

(ESPs); the presence of different impurities such as H_2S, tars, and possibly NH_3; and the higher operating temperatures of the filter system as compared to the combustion systems.

Similar EERC-conducted combustion tests where the additive was added directly to the coal and nontreated carbon was fed into the baghouse or ESP had also exhibited mercury control greater than 90%. This type of test was also attempted with the TRDU under gasification conditions.

Figure 16 shows the results from this test where the active part of the additive was added to the coal starting at 9:30 in the morning; however, the addition of the additive alone did not appear to significantly change the mercury concentration in the fuel gas. At 4:12 in the afternoon, activated carbon feed was started from the feeder to the HGFV. This carbon was fed over a 3-hour and 40-minute period until a problem with the peristaltic pump delivering the basic stannous chloride solution to the sample conditioning traps failed, thereby terminating the test. The data shown in Figure 16 indicate that the presence of the additive together with the activated carbon injection was removing the mercury from approximately 24 $\mu g/m^3$ down to approximately 15 $\mu g/m^3$ (37.5% removal), and the trend still seemed to be dropping when the test was terminated.

A packed-bed system utilizing a slipstream of warm TRDU fuel gas was also constructed and tested. This packed-bed system was designed to run a slipstream of approximately 1000 scfh of fuel gas through a 3-inch-diameter and 15-inch-deep bed of sorbent. Three different tests utilizing a coarse EERC-treated activated carbon (F2BO and F2HO) were conducted. One additional test utilizing an amended silicate sorbent from ADA Technologies was also tested in the packed-bed contactors. Figures 17–19 show the breakthrough curves for these sorbents being tested at approximately 265°C (510°F). The one test with the EERC-treated carbon at a higher temperature exhibited very little mercury removal. Figures 17 and 18 show the breakthrough curve for the EERC-treated carbon with both a slow and fast heatup rate, respectively. There did not appear to be any major difference in the sorbent performance since both sorbents had breakthrough times of approximately 1.5 hours; however, the sorbent with the fast heatup time seemed to remove the mercury from the starting baseline of 26 $\mu g/m^3$ to less than 1 $\mu g/m^3$ while the slow-heatup sorbent only reduced mercury to approximately 2.5 $\mu g/m^3$. Tests with a smaller quantity of the ADA Technologies sorbent UP-EB-X015 mixed with silica sand were conducted to measure mercury breakthrough. The silica sand selected had a very high pressure drop (> 100 psid), resulting in a maximum fuel gas flow rate through the bed of 315 scfh. This test shown in Figure 19 indicates that the mercury level was dropped from approximately 28 $\mu g/m^3$ to approximately 3.5 $\mu g/m^3$ for approximately 0.5 hour.

The EERC has spent considerable effort to develop a sample-conditioning procedure that provides representative results. Since all of the mercury has been shown to be in the elemental form, it was hoped that very little sample conditioning would be required. However, sampling after the gas-conditioning system utilized for the other gas analyzer indicated that no mercury was reaching the mercury CEM. Tests with water-filled impingers also exhibited issues with obtaining representative samples. Sample conditioning with basic stannous chloride solutions appeared to work over the short term; however, the reducing fuel gas would consume the reagents in the solution and affect the CEM readings. The sample conditioner was then set up with a peristaltic pump to pump fresh solution into the impingers and pump spent solution out of the impingers. This sample-conditioning system has worked well in providing a fuel gas that works well with the Hg CEM; however, this sample conditioning requires frequent human intervention to add fresh solution and remove the spent solution. It also generates a fair amount of waste material that needs to be dealt with.

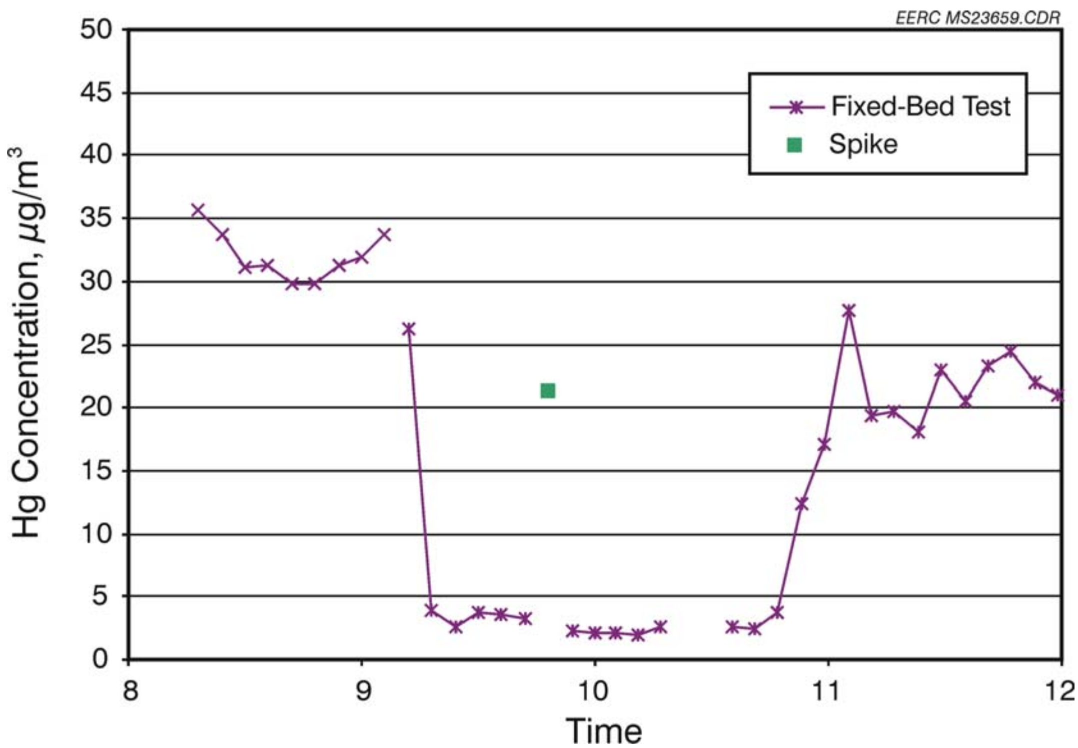

Figure 15. Effect of EERC-treated carbon injection on Hg removal in hot-gas filter vessel.

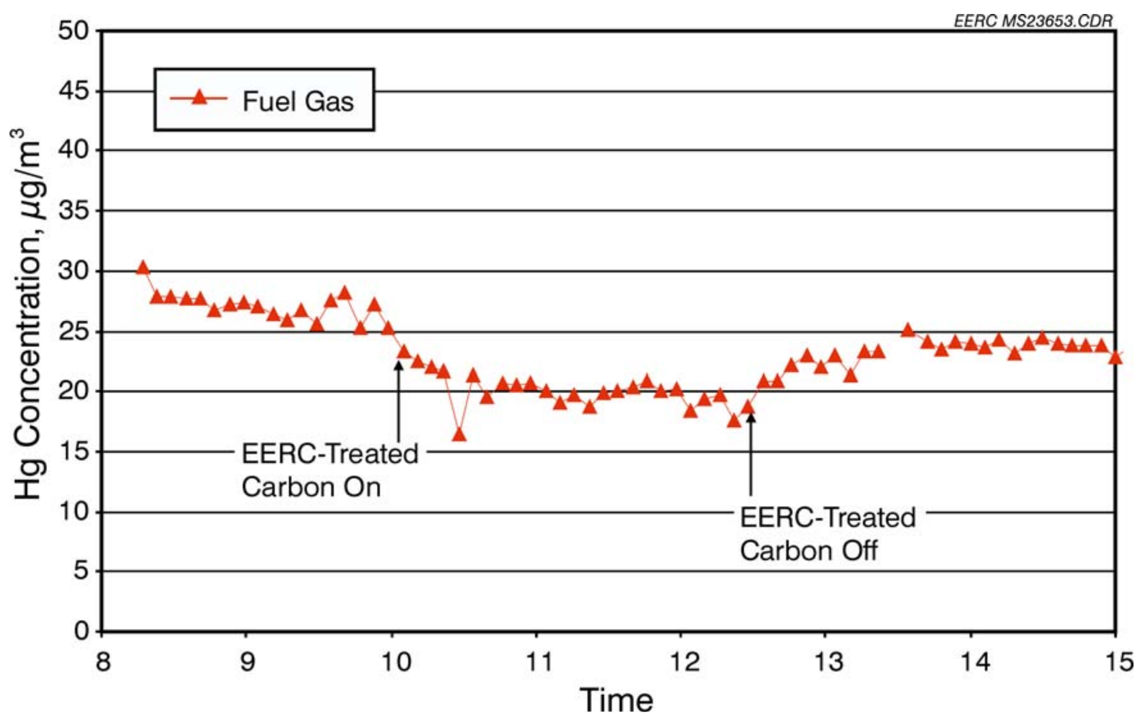

Figure 16. Effect of additive addition to Wyodak coal and activated carbon injection to hot-gas filter vessel on Hg removal.

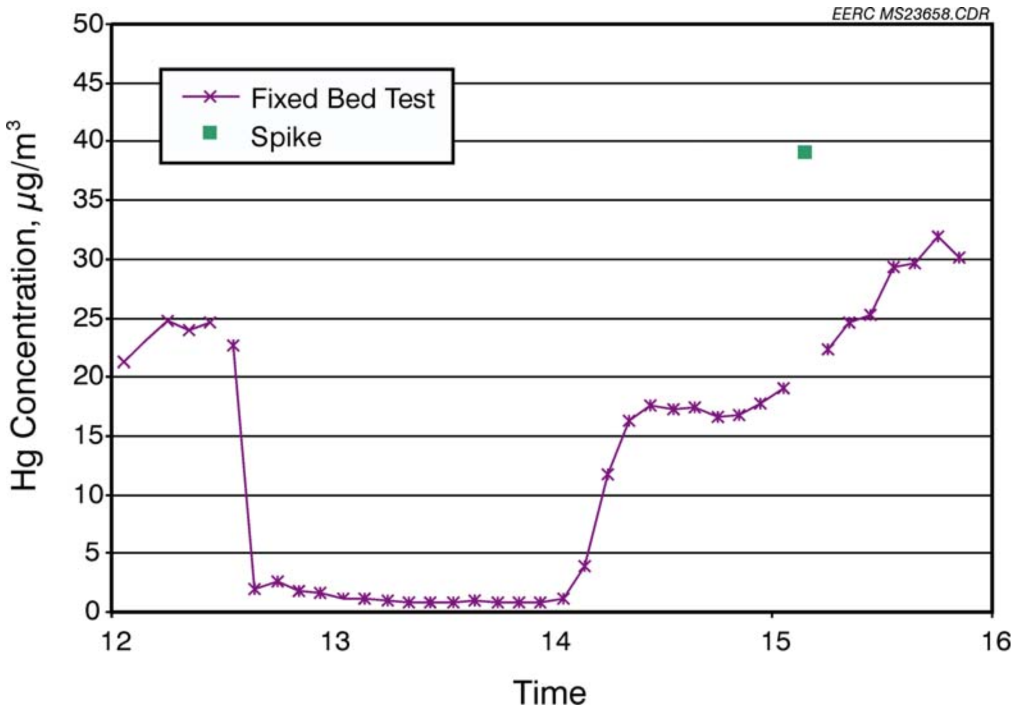

Figure 17. Packed-bed Hg sorbent removal with EERC-treated carbon at 265°C (510°F).

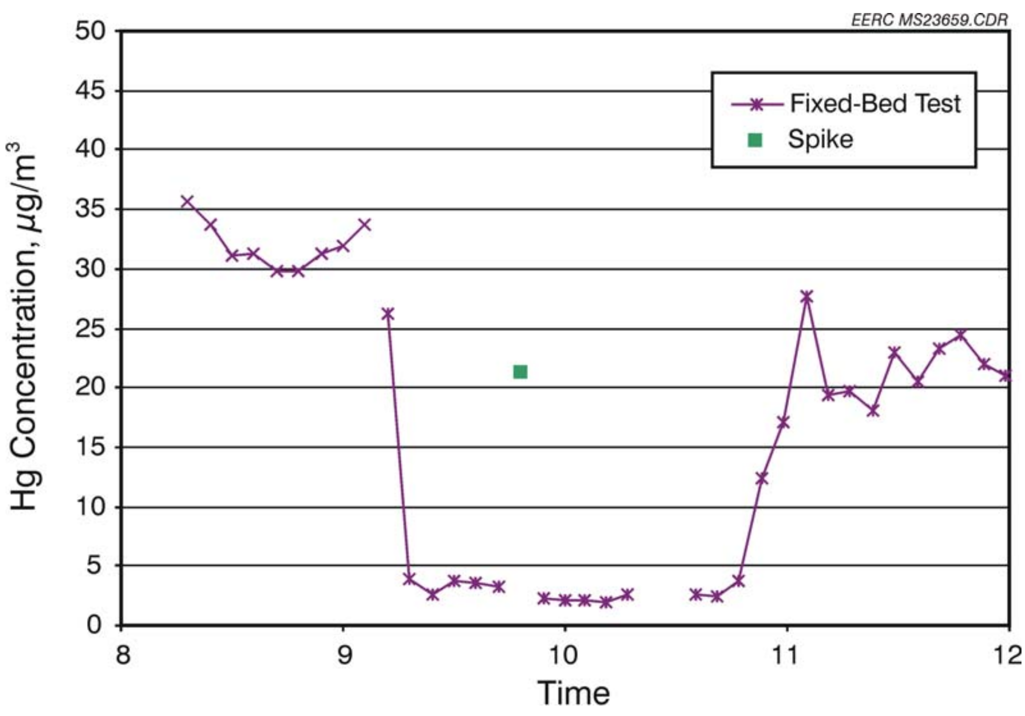

Figure 18. Hg removal with packed-bed test utilizing EERC-treated carbon at 265°C (510°F).

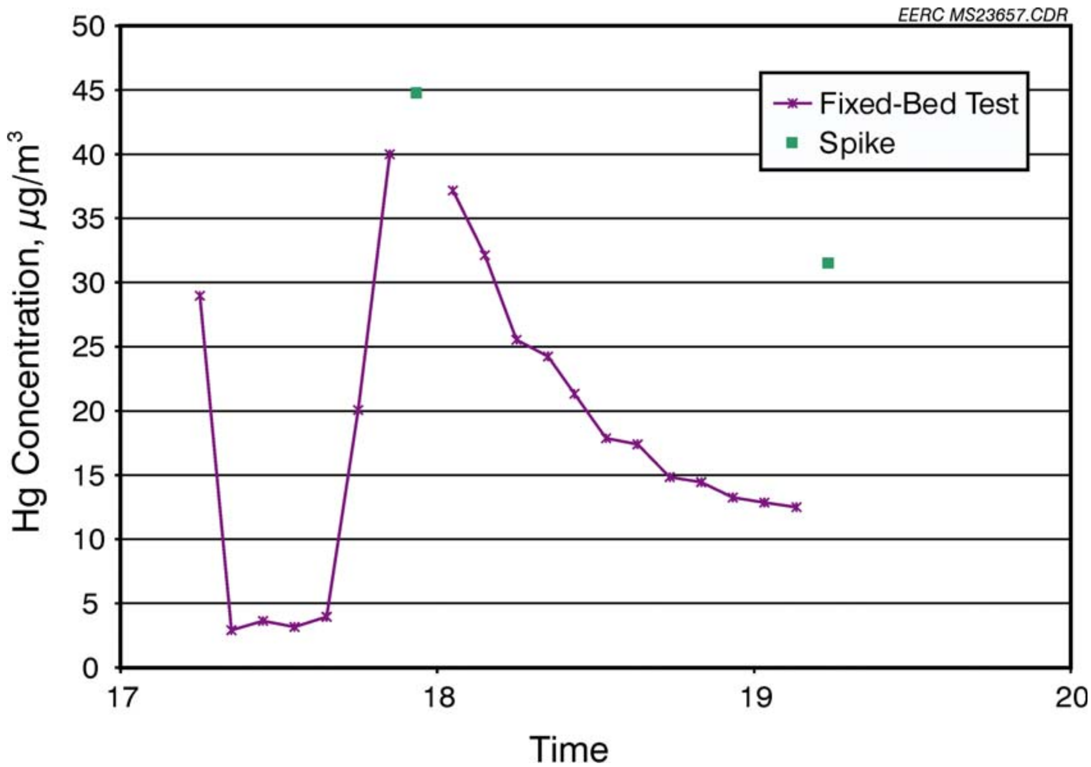

Figure 19. Hg removal test with packed-bed reactor utilizing ADA Technologies sorbent UP-EB-X015 at 260°C (500°F).

Figures 20–22 show the Hg CEM measurements with the P S Analytical Sir Galahad against those obtained utilizing the modified EPA Method 29 wet chemistry or at the outlet of the packed-bed slipstream test stand for the 3 days of operation on the Indian coal. These graphs shows that the mercury emissions for the Indian coal seemed to have lined out after a conditioning period at 15–20 µg/Nm^3 in air-blown mode and increased up to 40–50 µg/Nm^3 in oxygen-blown mode. The wet chemistry also showed that this mercury was almost exclusively elemental in nature with no oxide forms of mercury being detected.

A packed-bed system utilizing a slipstream of warm TRDU fuel gas was also tested. Figure 22 shows the results obtained while utilizing a coarse EERC-treated activated (F2ZO) carbon. This particular sorbent reduced the mercury emissions to less than 5 µg/Nm^3 for up to 4 hr at 215°C. The overall mercury removal was approximately 90% with a space velocity of 3060 hr^{-1}. This sorbent still had not exhibited a definitive breakthrough at the end of this test.

4.7 TRDU Deposit Formation

The TRDU was modified after Test P059 to increase the mixing zone diameter in an effort to operate at lower mixing zone velocities. Lower velocities result in longer residence times for the solid carbon and improved gasification kinetics. Lower velocities could also result in increased

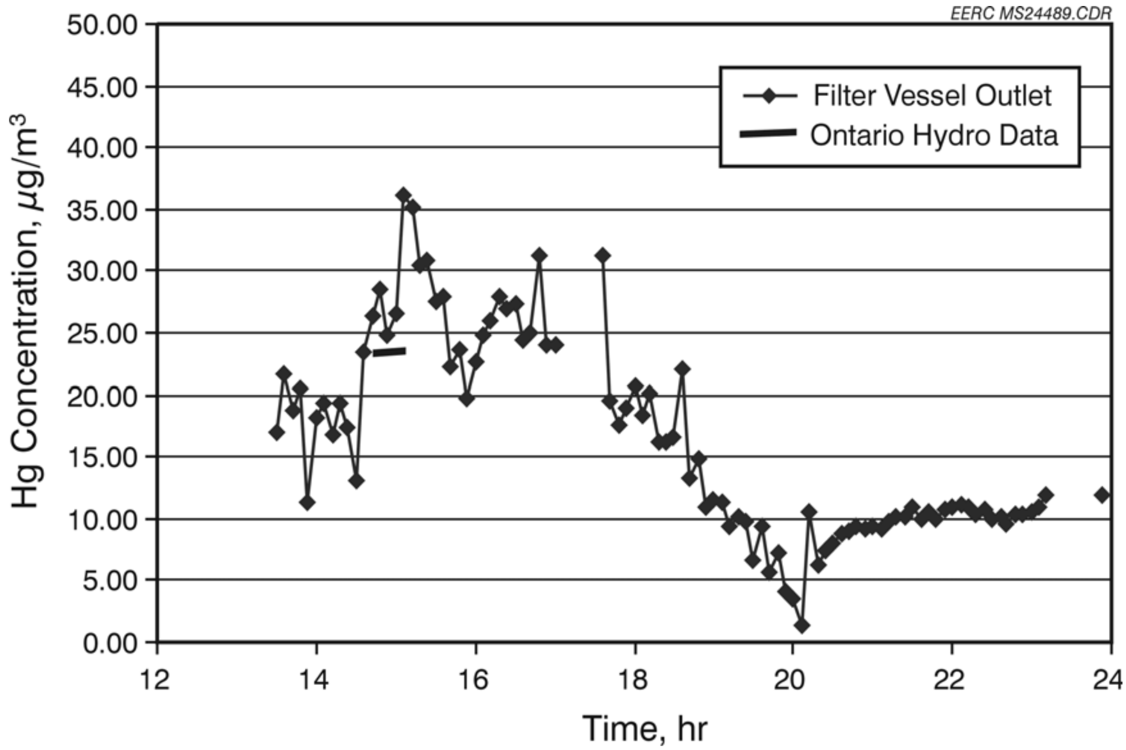

Figure 20. Hg CEM measurements, October 19.

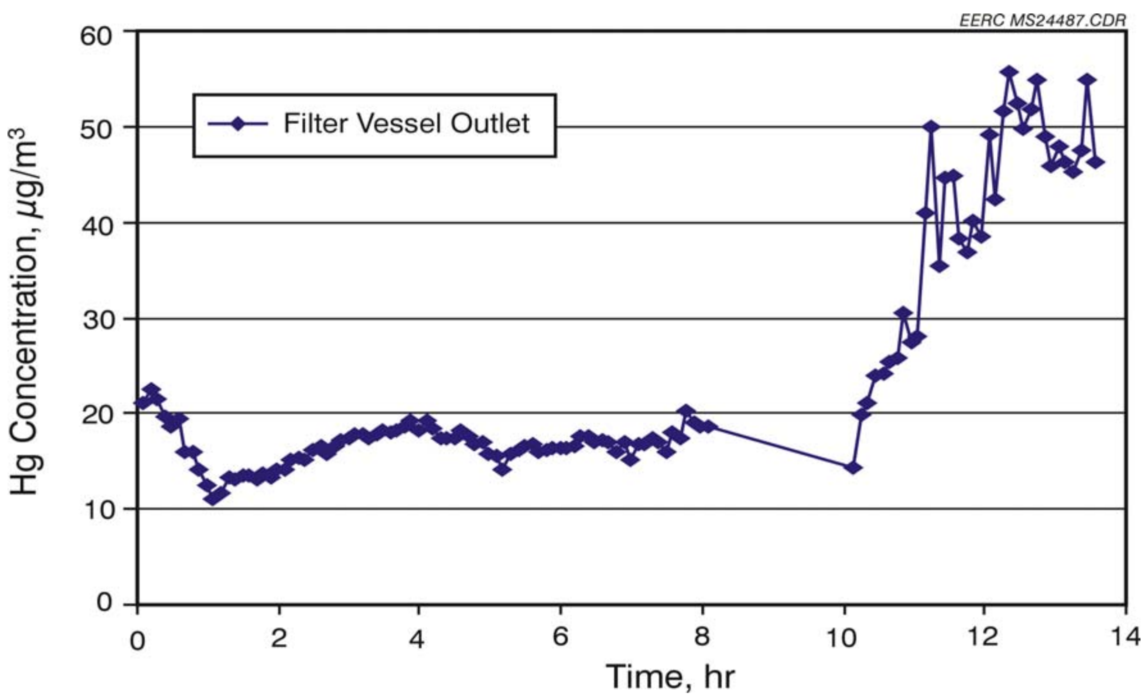

Figure 21. Hg CEM measurements, October 20.

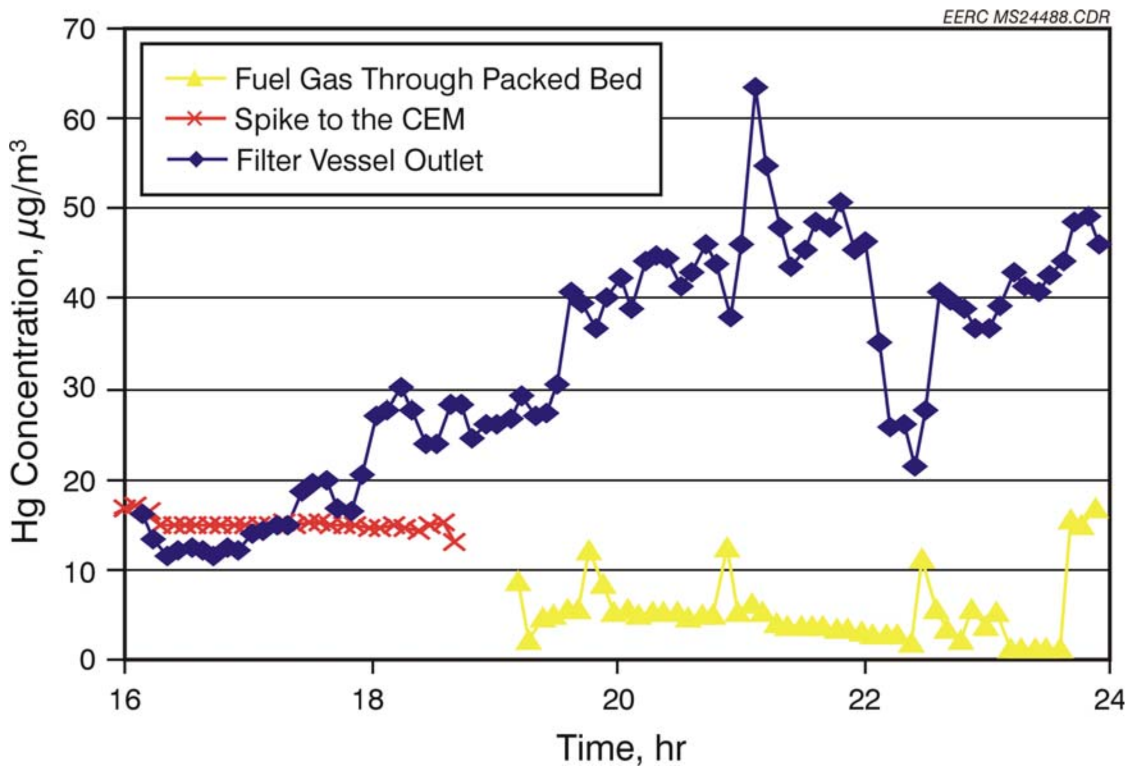

Figure 22. Hg CEM measurements, October 21.

occurrences of bed material agglomeration and deposition because of the presence of more localized "hot spots." Deposits formed in this larger-diameter mixing zone were analyzed with scanning electron microscopy (SEM) to determine the inorganic chemistry of the ash holding the individual bed particles together. This allows a better understanding of the glue chemistry such as low melting eutectics that will limit the bed temperature to prevent these sticky ash coatings from developing (9). Tables 43 through 47 summarize the SEM morphology data from the points analyzed in the SEM photomicrographs shown in Figures 23 through 43. These figures show the location of the points analyzed and exclude any points that were mostly bed material particles (i.e., high silica). These deposits were all formed utilizing the lower velocity mixing zone.

Deposition during these tests did appear to be more prevalent with the SUFCo coal (Test P060) than the previous test (Test P057), probably as a result of the larger-diameter mixing zone resulting in poorer gas–solid mixing. The ash chemistry of the sticky phase identified in the SEM photomicrographs (see Table 43 and Figures 25–27) are similar to the low melting point calcium-iron aluminosilicate phases identified in Test P057.

The petroleum coke gasification test (Test P061) had some deposition in the burner throat area, but this deposition was not enough to prevent TRDU operation. This deposit was highly sintered (see Table 44 and Figures 28–30) and was very hard. The sticky material appeared to be derived from partially sulfided calcium and magnesium compounds and unlike the combustion ash did not appear to contain any significant levels of vanadium. Whether the deposition would have

Table 43. SEM Morphology Analysis of TRDU Mixing Zone Deposit, SUFCo Coal, Test P060 (Figures 25–27)

SEM Point No.:	1	2	3	5	6	7	8	9		11
Description:	Neck	Neck	Neck	Fill	Fill	Neck	Fill	Fill	10	Fill
				Normal O_2-Free Element, wt%						
Na	2.3	1.7	2.9	2.9	2.2	4.2	1.5	4.2	3.1	3.4
Mg	1.8	2.9	0.9	4.5	10.0	2.6	3.2	3.8	1.3	0.5
Al	1.8	1.4	3.7	5.7	5.2	10.3	2.9	5.7	5.9	5.5
Si	33.5	34.4	35.0	58.4	55.4	58.6	50.9	62.8	62.3	60.2
P	0.1	0.1	0.2	0.2	0.1	0.5	0.3	0.2	0.0	0.0
S	0.1	0.1	0.5	0.1	0.2	0.2	0.7	0.2	0.0	0.5
Cl	0.2	0.2	0.0	0.0	0.2	0.2	0.4	0.1	0.2	0.1
K	1.1	0.7	3.0	0.5	0.2	0.8	0.2	0.5	0.6	0.5
Ca	4.7	4.9	2.3	18.8	21.2	17.6	26.8	15.7	18.7	23.3
Ti	0.1	0.1	0.8	0.5	0.1	0.3	0.1	0.8	0.7	1.0
Cr	0.0	0.2	0.2	0.1	0.0	0.2	0.0	0.1	0.0	0.0
Fe	54.2	52.5	50.5	6.8	4.4	4.4	12.2	6.0	5.5	4.7
Ba	0.0	0.6	0.2	1.0	0.6	0.0	0.7	0.0	1.3	0.3
V	0.2	0.0	0.0	0.1	0.3	0.0	0.1	0.0	0.3	0.1
Ni	0.1	0.2	0.0	0.5	0.0	0.1	0.0	0.0	0.3	0.0
Total	100	100	100	100	100	100	100	100	100	100

Table 44. SEM Morphology Analysis of TRDU Burner Deposit, Tuscaloosa Petroleum Coke, Test P061 (Figures 28–30)

SEM Point No.:	1	2	3	4	5	6	7	9	10	11	12	13
Description:	Fill	Fill	Fill	Part.	Part.	Fill	Fill	Part.	Fill	Part.	Band	Part.
Normal O_2-Free Element, wt%												
Na	0.1	0.0	0.0	0.1	0.0	0.3	0.2	0.1	0.1	0.0	0.3	0.2
Mg	13.2	11.5	15.7	13.7	13.2	12.6	15.3	5.2	13.2	1.9	9.9	14.2
Al	2.5	3.8	1.8	1.5	1.4	3.6	2.0	0.6	1.5	0.1	0.8	1.4
Si	48.5	51.0	46.6	50.2	46.3	50.8	46.7	77.3	45.3	5.5	29.0	44.7
P	0.2	0.0	0.0	0.1	0.1	0.0	0.2	0.3	0.1	0.2	0.0	0.1
S	5.9	3.6	5.4	3.7	8.5	3.8	4.8	3.2	7.4	39.6	19.9	7.8
Cl	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0
K	0.3	0.4	0.2	0.3	0.0	0.4	0.0	0.1	0.2	0.2	0.0	0.2
Ca	28.9	28.7	29.6	29.6	29.6	26.9	30.3	11.8	30.9	50.5	38.7	28.4
Ti	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0
Cr	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.4	0.1	0.1	0.0	0.0
Fe	0.1	0.6	0.3	0.5	0.6	0.5	0.1	0.0	1.0	1.6	0.7	2.2
Ba	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.7	0.0	0.3	0.2	0.0
V	0.5	0.2	0.1	0.0	0.0	0.5	0.3	0.0	0.0	0.0	0.5	0.3
Ni	0.0	0.2	0.0	0.4	0.0	0.6	0.0	0.2	0.0	0.0	0.0	0.3
Total	100	100	100	100	100	100	100	100	100	100	100	100

Table 45. SEM Morphology Analysis of TRDU Mixing Zone Outer Deposit, Calumet Coal, Test P062 (Figures 31–33)

SEM Point No.:	1	2	3	4	5	6	7	9	10
Description:	Layer	Neck	Fill	Fill	Fill	Fill	Layer	Fill	Fill
Normal O_2-Free Element, wt%									
Na	0.1	0.5	0.7	0.2	0.5	0.1	0.5	0.3	0.0
Mg	0.7	0.9	1.3	0.2	0.7	0.1	0.2	0.3	0.5
Al	34.8	8.4	15.4	4.6	11.7	5.0	18.5	2.3	5.4
Si	50.5	78.1	41.7	85.5	65.2	87.1	55.8	92.3	87.1
P	0.5	0.6	0.3	0.0	0.4	0.7	0.3	0.3	0.0
S	0.0	0.0	0.0	0.1	0.3	0.2	0.0	0.0	0.2
Cl	0.2	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.2
K	4.1	5.4	13.7	3.8	8.4	2.7	18.8	2.5	1.2
Ca	0.9	1.3	0.8	0.0	2.1	0.5	0.5	0.2	1.2
Ti	1.6	0.8	2.2	0.6	2.0	0.2	0.4	0.0	0.6
Mn	0.1	0.4	0.0	0.3	0.3	0.0	0.0	0.3	0.5
Fe	5.5	3.5	24.0	3.1	8.4	2.8	3.9	0.7	3.2
Ba	1.1	0.0	0.0	1.8	0.0	0.6	1.3	0.7	0.0
Total	100.1	99.9	100.1	100.2	100	100	100	99.9	100.1

Table 46. SEM Morphology Analysis of TRDU Mixing Zone Inner Deposit, Calumet Coal, Test P062 (Figures 34–36)

SEM Point No.:	1	3	5	6	7	9	10	12
Description:	Layer	Fill	Fill	Fill	Layer	Fill	Fill	Fill
Normal O_2-Free Element, wt%								
Na	0.6	0.4	0.6	0.1	0.4	0.4	0.4	0.5
Mg	0.5	1.1	0.4	0.3	1.0	0.5	2.9	1.0
Al	19.0	22.2	15.2	14.5	20.2	10.0	13.5	24.6
Si	58.7	62.1	69.8	72.6	64.1	79.7	63.6	58.4
P	0.5	0.8	0.3	0.3	0.6	0.1	1.0	0.2
S	0.0	0.2	0.0	0.3	0.0	0.0	0.0	0.2
Cl	0.3	0.0	0.1	0.0	0.0	0.3	0.1	0.1
K	12.3	4.7	8.9	7.2	6.0	4.9	4.2	4.2
Ca	0.5	0.9	0.7	0.0	0.5	0.1	7.4	0.5
Ti	0.8	1.4	0.8	0.8	1.6	0.3	1.0	1.3
Mn	0.3	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Fe	6.0	5.9	3.2	3.7	4.8	2.2	5.9	8.5
Ba	0.6	0.4	0.0	0.0	0.8	1.4	0.0	0.6
Total	100.1	100.1	100.1	99.9	100	99.9	100	100.1

Table 47. SEM Morphology Analysis of TRDU Mixing Zone Deposit, Illinois No. 6 Coal, Test P063 (Figures 37 and 38)

SEM Point No.:	XRFA	1	2	3	4	5	6	7	8	10	11	12
Description:	Bulk	Layer	Neck	Fill	Fill	Fill	Fill	Layer	Fill	Fill	Fill	Fill
Normal O_2-Free Element, wt%												
Na	0.0	0.1	0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0
Mg	18.7	17.0	12.0	10.7	13.6	9.0	13.9	0.7	9.1	14.3	3.0	19.7
Al	2.6	0.2	0.0	1.5	0.1	0.1	2.0	0.0	0.0	1.3	0.7	0.3
Si	26.2	0.4	0.2	33.5	0.3	0.5	24.4	0.0	4.7	3.6	7.8	6.3
P	0.1	0.2	0.0	0.1	0.2	0.4	0.4	0.2	0.0	0.3	0.1	0.0
S	9.3	32.3	37.4	0.1	33.2	37.3	16.5	42.9	38.4	33.0	30.9	32.1
Cl	ND[1]	0.0	0.0	0.0	0.0	0.4	1.4	0.0	0.0	0.2	0.0	0.1
K	0.5	0.0	0.0	0.4	0.0	0.0	0.5	0.0	0.1	0.0	0.1	0.1
Ca	33.8	44.0	47.8	53.3	21.7	49.9	31.3	41.8	45.6	19.4	11.3	36.2
Fe	8.5	3.0	2.7	0.4	30.5	1.9	9.5	14.4	2.1	27.7	45.9	5.2
Ba	ND	0.5	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ti	0.2	2.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.0
Total	99.9	100.1	100.1	100.1	100	100	99.9	100	100	99.9	100	100

[1] Not determined.

Table 47 (continued) (Figures 39 and 40).

SEM Point No.:	13	14	15	16	17	18	19	20	21	22	23	24	25
Description:	Layer	Neck	Fill	Fill	Fill	Fill	Layer	Fill	Fill	Fill	Fill	Fill	Layer
Normal O_2-Free Element, wt%													
Na	0.0	0.0	0.2	0.1	0.0	0.1	0.0	0.3	0.0	0.1	0.4	0.2	0.2
Mg	0.0	0.0	0.2	11.1	14.0	0.3	8.8	0.5	0.0	13.5	0.0	0.4	0.2
Al	0.0	0.0	0.2	0.2	2.8	0.1	0.5	0.0	0.0	1.5	0.0	0.0	0.0
Si	0.4	0.1	0.6	0.4	0.2	0.3	0.4	0.2	0.2	1.6	0.1	0.1	0.0
P	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0
S	37.4	38.4	40.8	37.4	36.3	39.1	37.8	42.6	41.7	35.2	37.2	39.5	38.2
Cl	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.1	0.0	0.0	0.0
K	0.0	0.1	15.1	0.3	0.0	0.0	0.2	0.0	0.0	0.2	0.2	0.0	0.3
Ca	16.5	0.4	16.6	37.1	44.8	7.9	36.9	45.7	0.8	44.9	0.2	38.9	0.2
Fe	44.8	60.9	26.2	13.3	1.5	51.6	14.9	10.1	57.1	2.0	61.2	20.9	61.1
Ba	0.2	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.6	0.4	0.0	0.0
Ti	0.4	0.1	0.0	0.1	0.5	0.0	0.3	0.2	0.0	0.3	0.2	0.0	0.0
Total	99.9	100	99.9	100	100	99.9	100	100	100	100	99.9	100	100

EERC MS17839.CDR

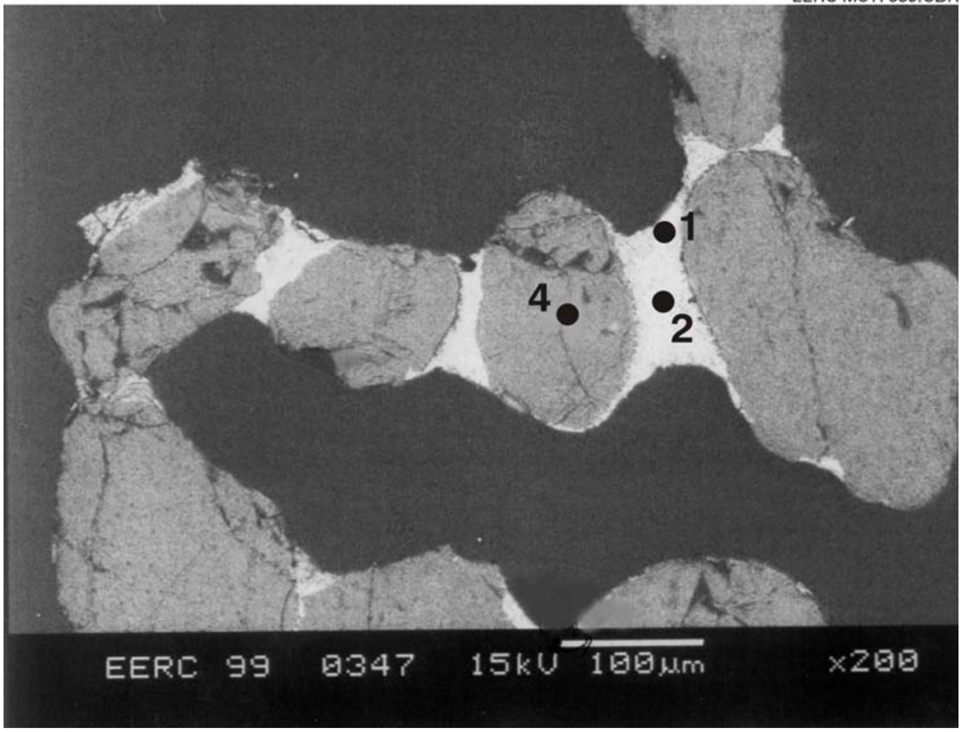

Figure 23. SEM micrograph of mixing zone deposit from gasification Test P060 on SUFCo coal showing Points 1–4.

EERC MS17838.CDR

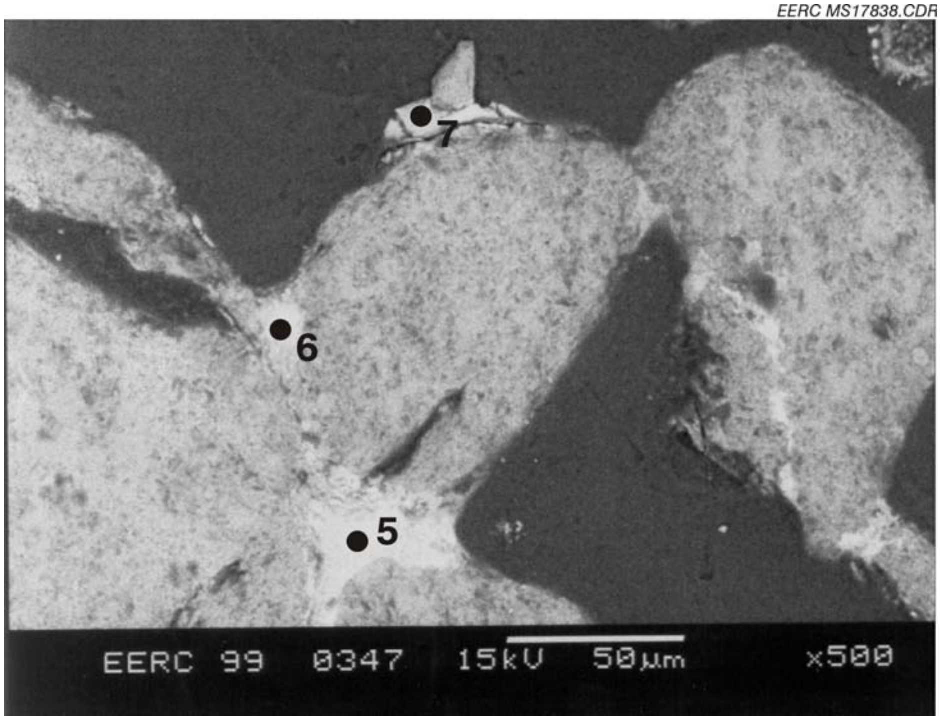

Figure 24. SEM micrograph of mixing zone deposit from gasification Test P060 on SUFCo coal showing Points 5–7.

EERC MS17837.CDR

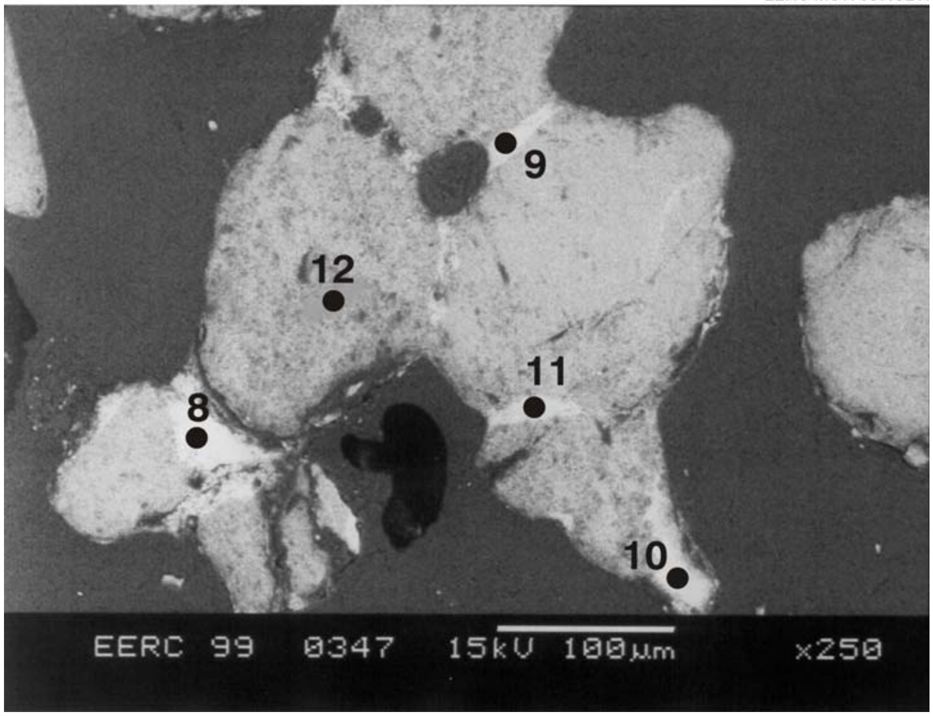

Figure 25. SEM micrograph of mixing zone deposit from gasification Test P060 on SUFCo coal showing Points 8–12.

EERC MS17835.CDR

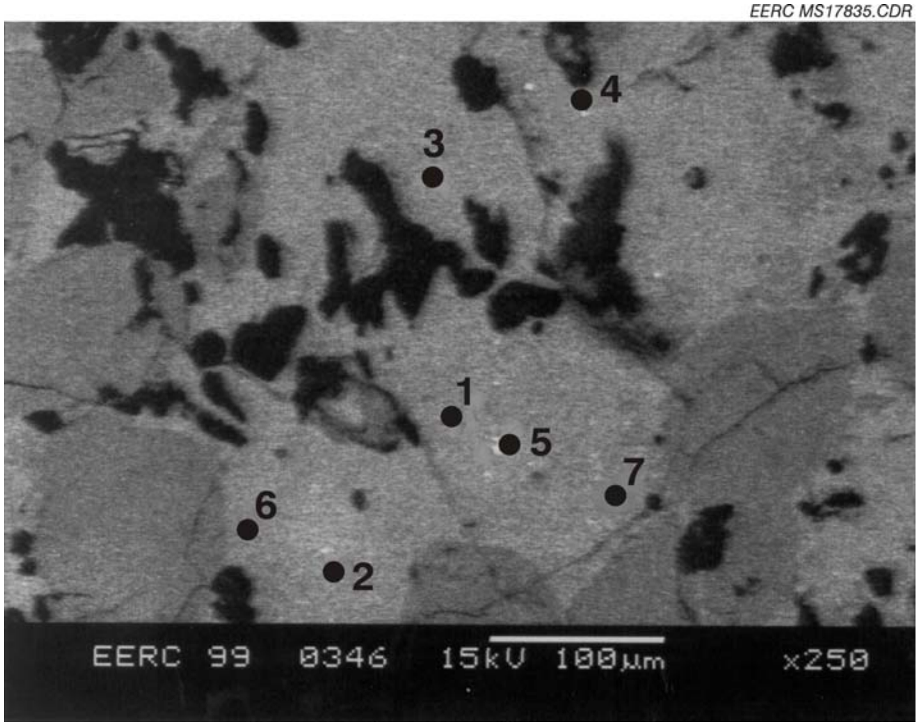

Figure 26. SEM micrograph of mixing zone deposit from gasification Test P061 on Tuscaloosa petcoke showing Points 1–7.

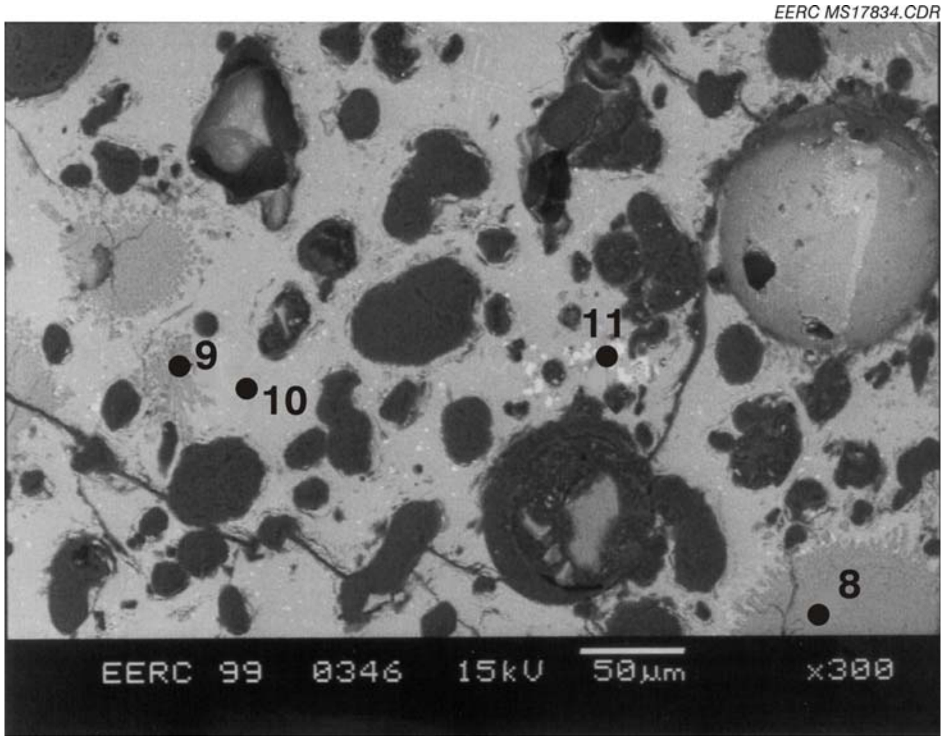

Figure 27. SEM micrograph of mixing zone deposit from gasification Test P061 on Tuscaloosa showing Points 8–11.

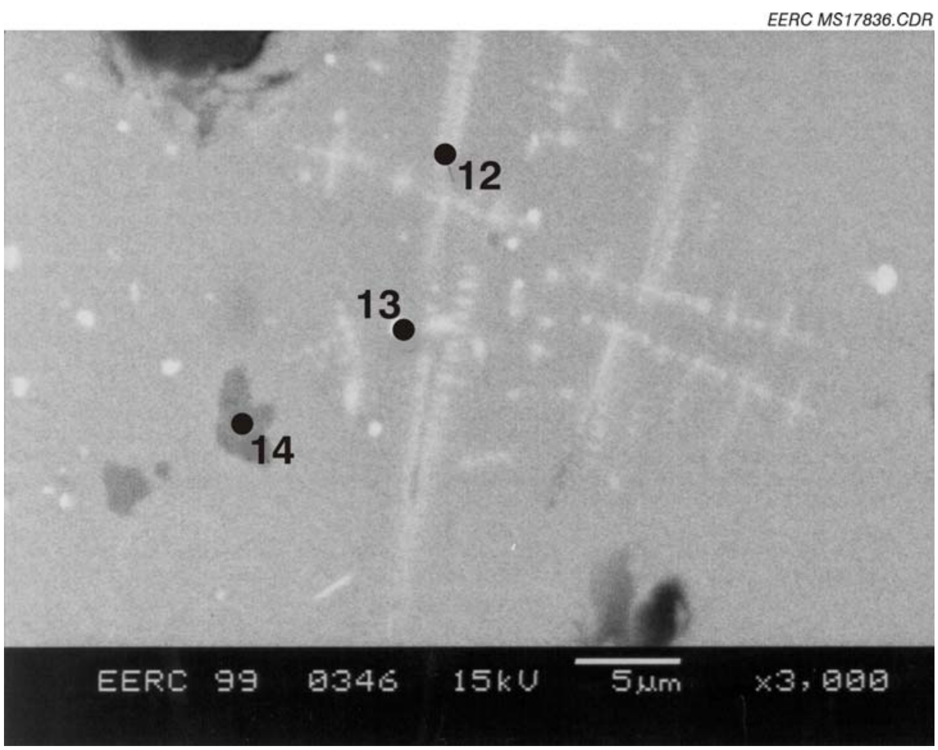

Figure 28. SEM micrograph of mixing zone deposit from gasification Test P061 on Tuscaloosa petcoke showing Points 12–14.

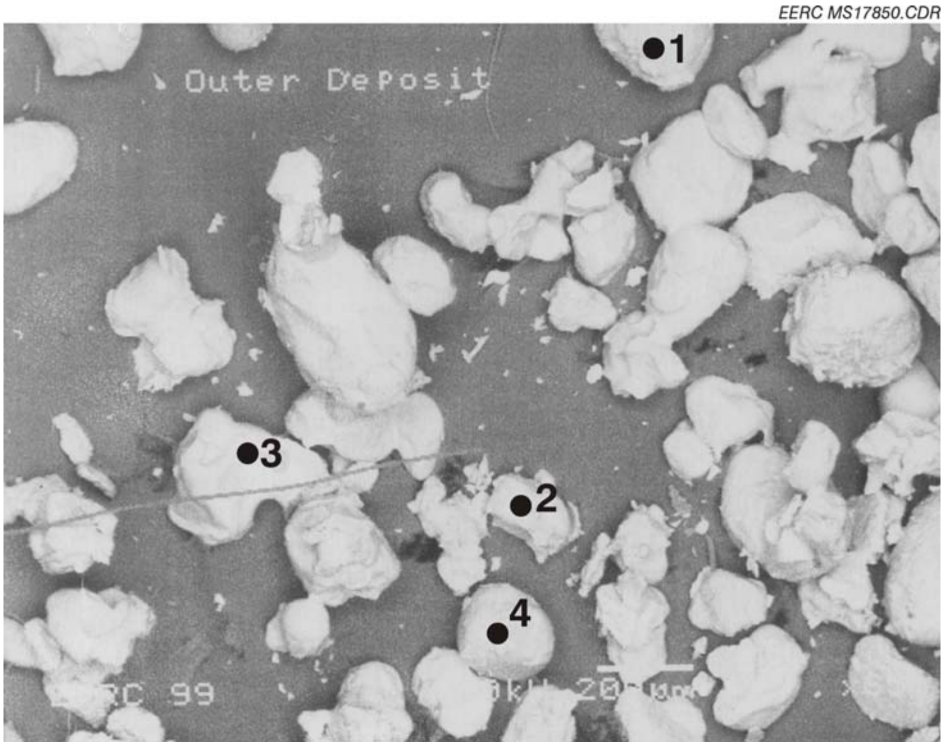

Figure 29. SEM micrograph of outer mixing zone deposit from gasification Test P062 on Calumet Mine bituminous coal showing Points 1–4.

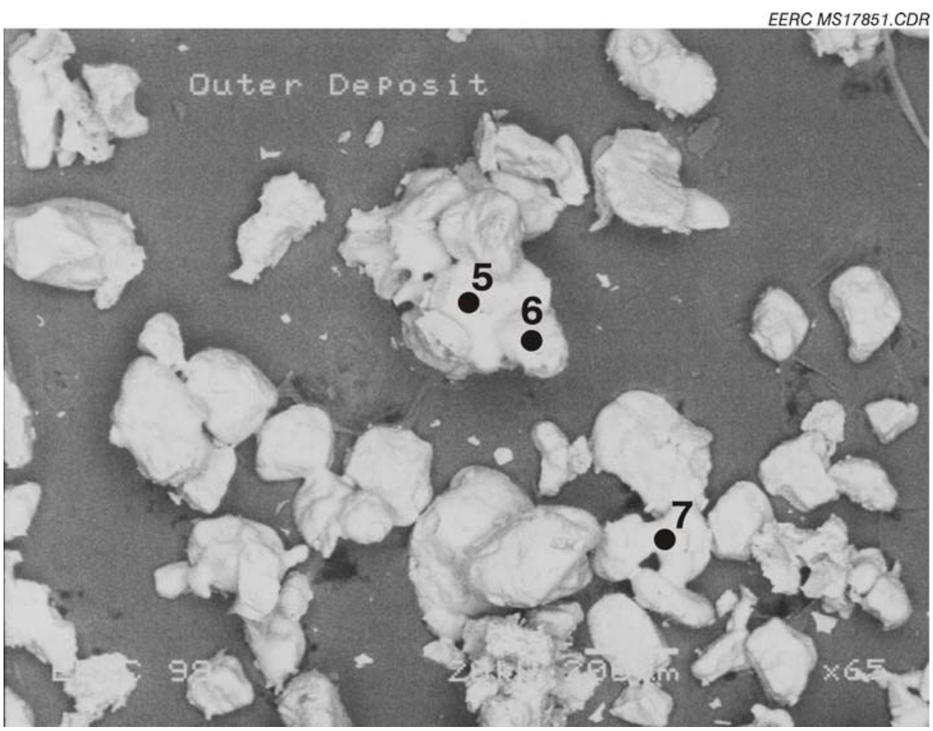

Figure 30. SEM micrograph of outer mixing zone deposit from gasification Test P062 on Calumet Mine bituminous coal showing Points 5–7.

continued to the point that it did interrupt steady TRDU operation or reached some maximum level where the increased burner velocity would keep the remaining throat opening clear is not known.

The short gasification test (Test P062) with the Alabama bituminous coal from Calumet Mine had substantial deposition in the mixing zone which was also compounded by the buildup of char agglomerates there. These agglomerates were the result of feeding coal that had more swelling properties than originally expected.

The buildup of these agglomerates in the mixing zone was leading to poor gas–solid mixing and probably to the presence of localized hot spots in the mixing zone. The SEM morphology analysis (Tables 45 and 46 and Figures 31–36) indicates that the melted sticky phase in the deposits was due to a low melting point potassium aluminosilicate, which was generated from the high levels of illite found in the starting coal. Illite has been shown to form low melting point compounds, especially under reducing conditions (10). No significant levels of sulfur were found in the deposit either at the oxidized inner layer or the carbon-rich outer layer, thereby suggesting that the formation of a low melting point sulfide compound was probably not the mechanism for deposit formation.

The Illinois No. 6 gasification test (Test P063) was operated successfully under air-blown operating conditions and the first attempt with oxygen-enriched air testing (26 mol%). It was not until a higher level of enriched air testing (33 mol%) was started that operating temperatures rose to over 1100°C (2012°F) and deposits formed very rapidly and terminated the test. Table 47 and Figures 37–40 show the SEM morphology of the mixing zone deposits. These deposits were very sintered and quite hard with low porosity because of a large portion of the deposit material melting. The deposit chemistry is very similar to the chemistry seen in the previous Illinois No. 6 gasification test (Test P056) in that a very high concentration of iron sulfide was observed in the deposit. During this test, it was also observed that even a small increase in the solid circulation rate could decrease the operating temperature by 30°C (86°F), suggesting that modifications to the TRDU that substantially increase circulation rate will allow the reactor temperature to be controlled even at higher oxygen levels.

Ash behavior in power systems can have a significant impact on the design and performance of advanced power systems. The EERC has focused significant effort on ash behavior in conventional power systems that can be applied to advanced power systems. This program utilized methods developed to better understand and mitigate adverse coal ash behavior in the EERC TRDU; however, these methods and observations can also be applied to other advanced power systems.

Although it is well established that sulfides readily break down in combustion environments, usually into oxides of iron, the mechanisms of sulfide formation in gasification are not well understood. Work by Benson and Sondreal (10) revealed that initial sulfidation of coal ash or bed material may have led to Ca–Mg-rich aluminosilicate deposits that formed in a pressurized circulating fluidized-bed gasifier. Volatile sulfide species can exist in the temperatures noted for the gasifier studied by Benson and Sondreal (10) and also in other gasification environments. Low melting point sulfides of Ca, Fe or, possibly, even Na are stable at temperatures less than 900°C (1652°F) in these environments, but the specific interaction of how the sulfides could lead to other silicate and oxide components becoming the “glue” material in a deposit is not understood.

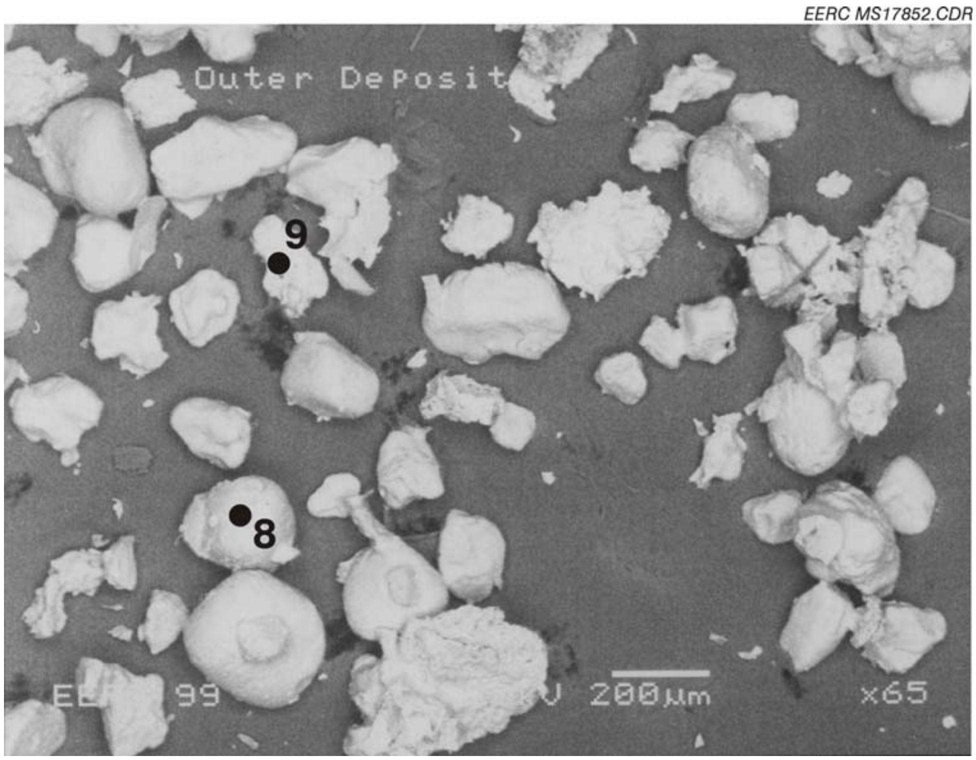

Figure 31. SEM micrograph of outer mixing zone deposit from gasification Test P062 on Calumet Mine bituminous coal showing Points 8 and 9.

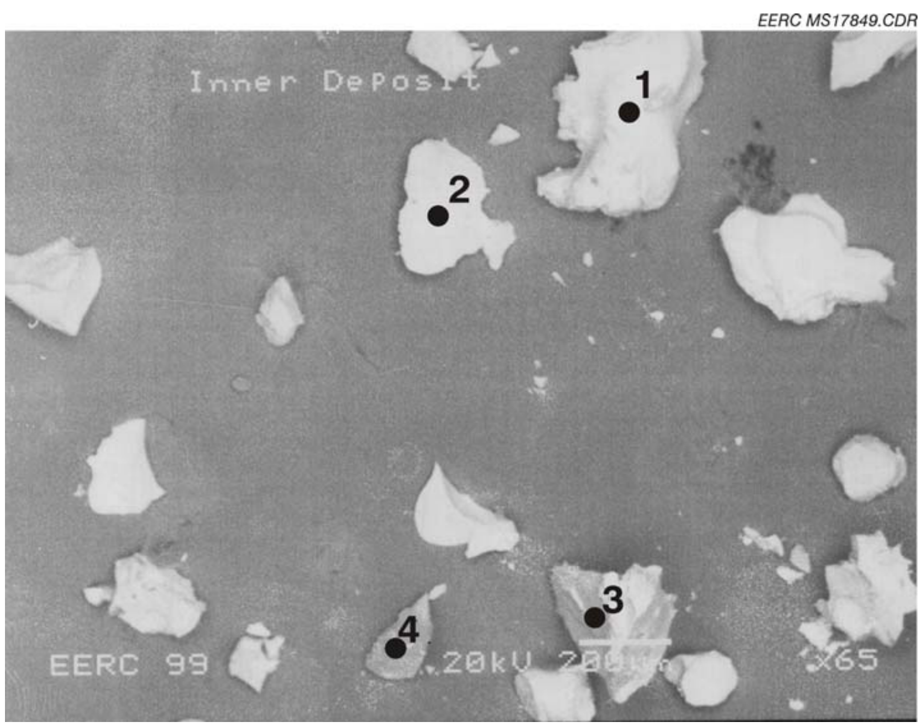

Figure 32. SEM micrograph of inner mixing zone deposit from gasification Test P062 on Calument Mine bituminous coal showing Points 1–4.

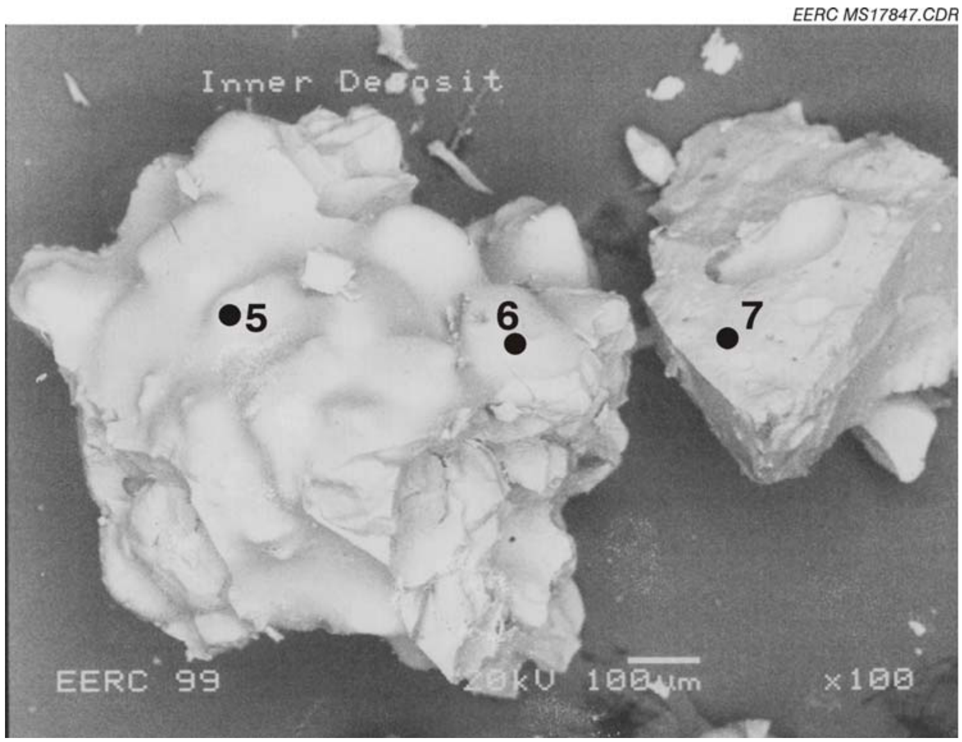

Figure 33. SEM micrograph of inner mixing zone deposit from gasification Test P062 on Calumet Mine bituminous coal showing Points 5–7.

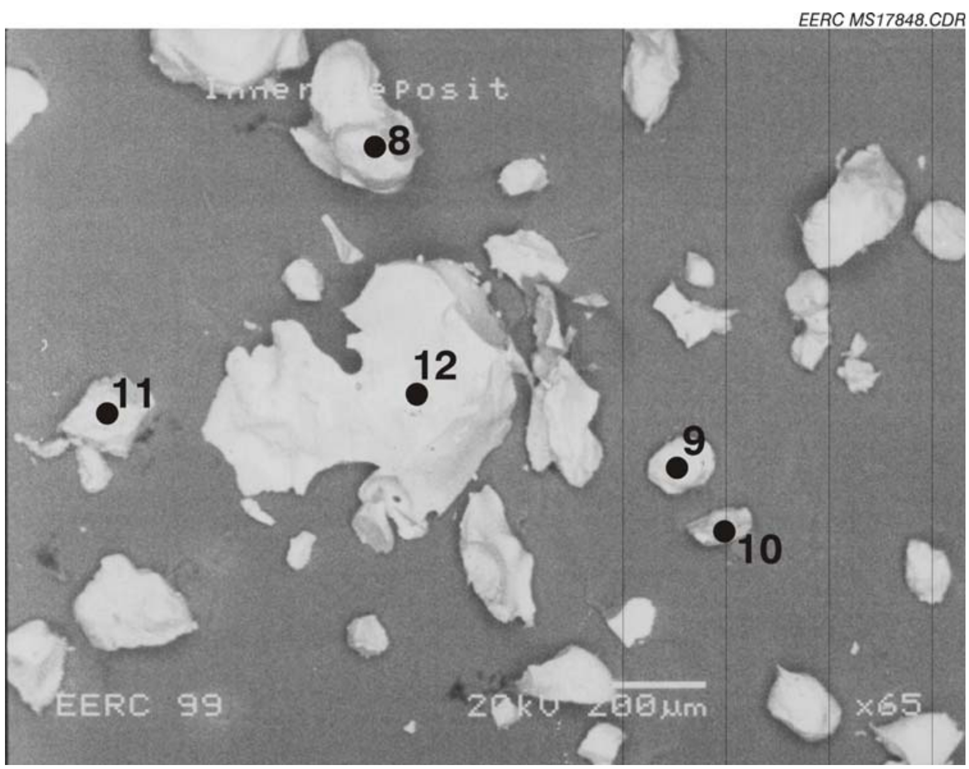

Figure 34. SEM micrograph of inner mixing zone deposit from gasification Test P062 on Calumet Mine bituminous coal showing Points 8–12.

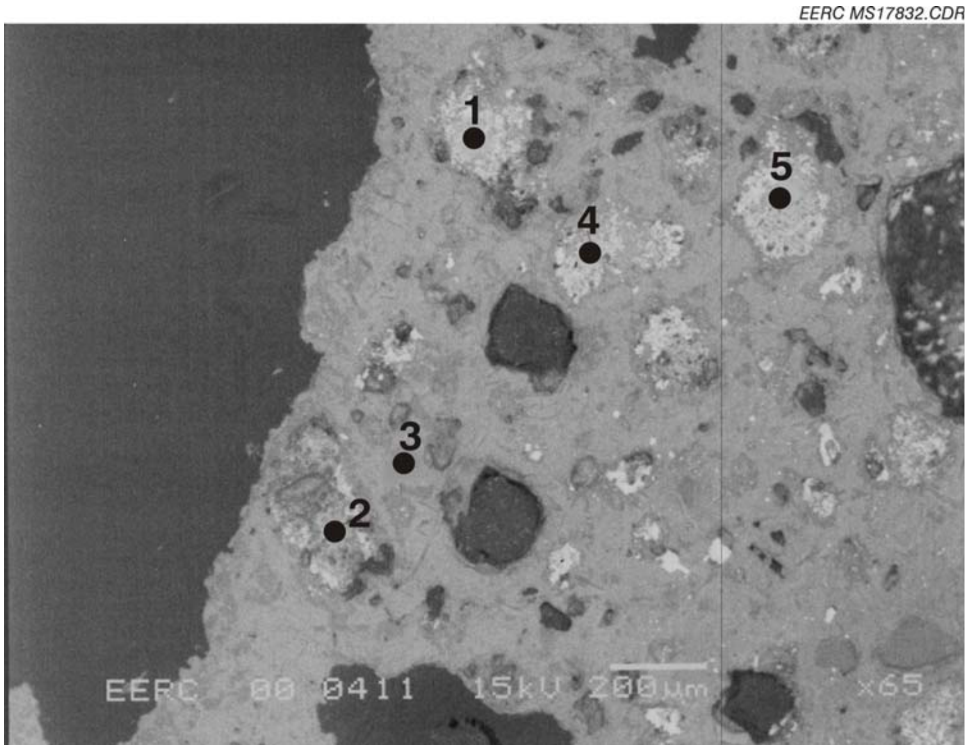

Figure 35. SEM micrograph of mixing zone deposit from gasification Test P063 on Illinois No. 6 bituminous coal showing Points 1–5.

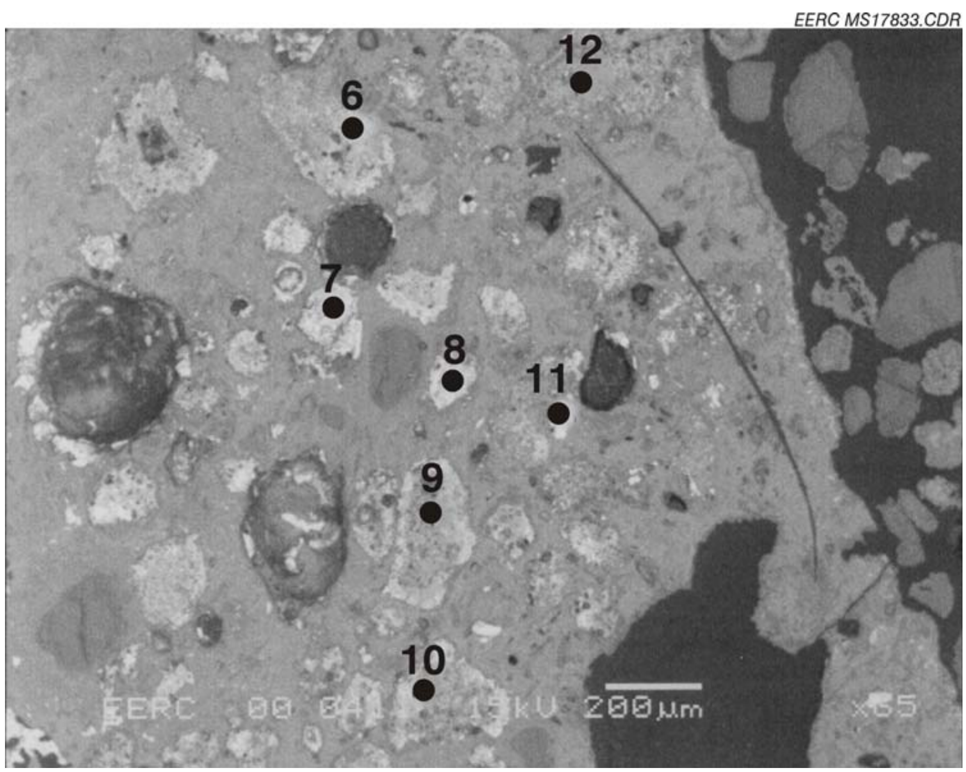

Figure 36. SEM micrograph of mixing zone deposit from gasification Test P063 on Illinois No. 6 bituminous coal showing Points 6–12.

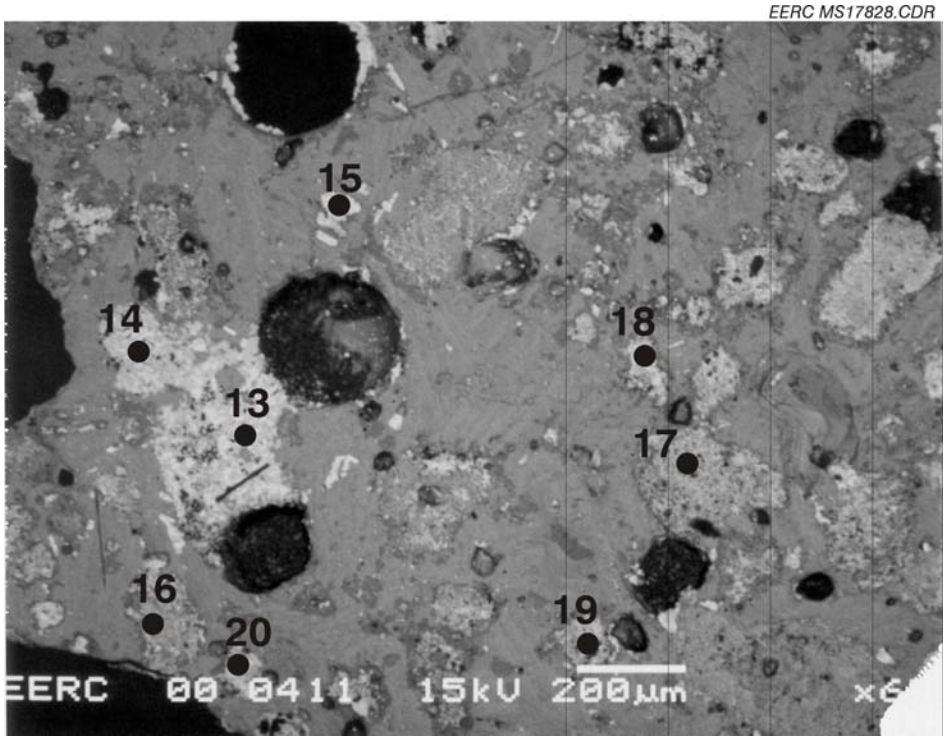

Figure 37. SEM micrograph of mixing zone deposit from gasification Test P063 on Illinois No. 6 bituminous coal showing Points 13–20.

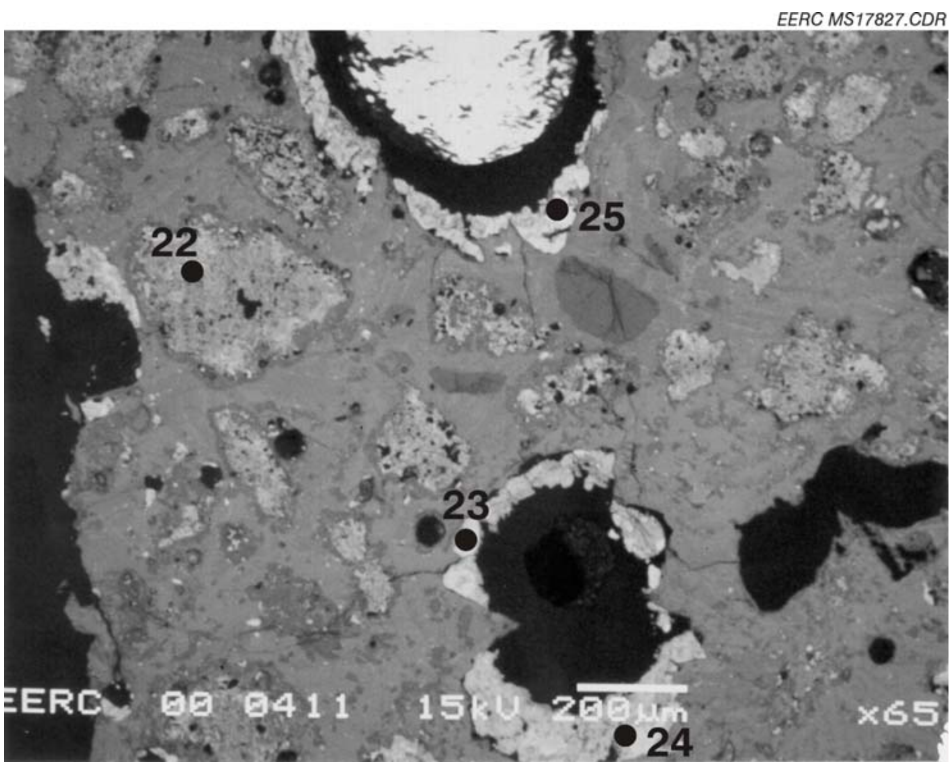

Figure 38. SEM micrograph of mixing zone deposit from gasification Test P063 on Illinois No. 6 bituminous coal showing Points 22–25.

Table 48. Maximum Reactive Sulfide Levels Determined for Various TRDU Samples

Sample Description	LASH Bed Material, µg/g	Filter Ash, µg/g
P067 Navajo	134	0.68
P071 Petcoke	42.8	<0.5
P071 Prater Creek	56.8	<0.5
P072 Illinois No. 6	1.5	<0.2
P073 Blacksville (Pitts. 8)	30	<0.2
P074 Falkirk–Wood	5.26	<0.4
P075 Loy Yang	<0.3	<0.5
P075 Lochiel	4.69	<0.4

Ash deposits were collected during runs of the TRDU gasifier, and the mechanisms of ash deposition were assessed, initially with a specific view toward the role of sulfides. Process information and deposits from the TRDU have provided deposits and process data with which to propose some deposition mechanisms. The interactions between sulfides and silicate or oxide materials can lead to potentially serious ash deposit formation, thereby adversely affecting system performance.

4.8 Determination of Reactive Sulfides in TRDU Samples

One potential issue for the utilization of calcium-based sorbents under reducing conditions is the formation of reactive sulfides in the solid materials removed from the gasifier. Reactive sulfide levels above 500 µg/g, as determined by EPA 376.2, are considered a hazardous waste that either must be disposed of or combusted to convert the sulfide species to a sulfate. North Dakota regulations require that hazardous wastes that are burned for energy recovery have a heating value of greater than 5000 Btu/lb or the energy recovery process can be considered "sham" recycling. The amount of carbon present in the limestone ash (LASH) bed material for all fuels tested (generally less than 20 wt% and in most cases approximately 10 wt%) indicate that the LASH by itself would not be recyclable because of the low heating value. The high carbon content of the filter ash material, typically greater than 40 wt%, suggests that this material would have enough heating value for recycling. Recent economic studies performed by Southern Company Services (SCS) on the transport reactor gasifier indicate that the most economic disposal option would be to landfill the ash without any treatment. However, should reactive sulfide levels limit this disposal, both the LASH bed material and the filter ash could be recycled to a fluid-bed combustor in an integrated commercial system. Mixing these fuels should provide a recycled stream that meets the 5000-Btu/lb requirement. Reactive sulfide tests were performed on various samples obtained from the TRDU while using the three different fuels tested under gasification conditions. Table 48 shows the reactive sulfide levels determined for these streams.

From these analyses, it appears that as the particle size gets smaller, less reactive sulfide is present in the solid material; thus no filter ash was measured with reactive sulfide levels above even 1 µg/g. The lower sulfur fuels provided LASH material that was still well below the allowable 500 µg/g reactive sulfide levels that make the material a hazardous waste, and even the high-sulfur fuels generated bed material that was still below the allowable 500 µg/g reactive sulfide limits. Other work performed at the EERC has shown that the combustion of these types of materials has been very successful in converting the reactive sulfide species to sulfates, thereby rendering them inert (see Appendix B).

4.9 TRDU Sulfur Capture Performance

The TRDU has shown a marked decrease in sulfur capture when the transport reactor has been operated in oxygen-blown mode. The H_2S concentration has ranged from 1200 to as high as 9000 ppm under full oxygen-blown operating conditions. The sulfur retention has ranged from 15% to 40% for the lower-sulfur coals and as high as 50% to 60% for the high-sulfur bituminous coals. This relatively low level of sulfur capture is the result of the high water and carbon dioxide partial pressures generated by oxygen-blown operation greatly reducing the equilibrium concentration of calcium sulfide that will form according to the reaction:

$$CaCO_3 + H_2S \rightleftharpoons CaS + CO_2 + H_2O$$

Sulfur retention data are given in the individual steady-state data presented in Appendix A.

5.0 CONCLUSIONS

The TRDU was modified to accommodate oxygen-blown operation in support of a Vision 21-type energy plex which could produce power, chemicals, and fuel. These modifications consisted of changing the loop seal design from a J-leg to an L-valve configuration, thereby increasing the mixing zone length and residence time. In addition, the standpipe, dipleg, and L-valve diameters were increased to reduce slugging caused by bubble formation in the lightly fluidized sections of the solid return legs. A seal pot was added to the bottom of the dipleg so that the level of solids in the standpipe could be operated independently of the dipleg return leg. A separate coal feed nozzle was added that could inject the coal upward into the outlet of the mixing zone, thereby precluding any chance of the fresh coal feed back-mixing into the oxidizing zone of the mixing zone; however, difficulties with this coal feed configuration led to a switch back to the original downward configuration. Instrumentation to measure and control the flow of oxygen and steam to the burner and mix zone ports was added to allow the TRDU to be operated under full oxygen-blown conditions.

In total, ten test campaigns have been conducted under enriched air- or full oxygen-blown conditions. During these tests, 1515 hours of coal feed with 660 hours of air-blown gasification and 720 hours of enriched air- or oxygen-blown coal gasification were completed. During these tests, approximately 366 hours of operation with Wyodak, 123 hours of operation with Navajo subbituminous coal, 143 hours of operation on Illinois No. 6, 106 hours on SUFCo, 110 hours on Prater Creek, 48 hours on Calumet, and 134 hours on a Pittsburgh No. 8 bituminous coals were completed. In addition, 331 hours of operation on low-rank coals such as North Dakota lignite, Australian brown coal, and a 90:10 wt% mixture of lignite and wood waste were completed. Also included in these test campaigns was 50 hours of gasification on a petroleum coke from the Hunt

Oil Refinery, and an additional 73 hours of operation on a high ash coal from India was completed. Data from these tests indicate that the transport gasifier performs better on the lower-rank feedstocks because of their higher char reactivity with the gasification reactions.

Comparable carbon conversions have been achieved at similar oxygen/coal ratios for both air-blown and oxygen-blown operation. While separation of fines from the feed coals is not needed with this technology, some testing has suggested that feedstocks with high levels of fines have resulted in reduced performance. These data show that these low-rank feedstocks provided similar fuel gas heating values; however, even among the high-reactivity low-rank coals, the carbon conversion did appear to lower for the fuels (brown coal in particular) that contained a significant amount of fines. The fuel gas under oxygen-blown operation has been high in hydrogen and carbon dioxide concentration since the high steam injection rate drives the water-gas shift reaction to produce more CO_2 and H_2 at the expense of the CO and water vapor. However, the high water and CO_2 partial pressures have also greatly retarded the reaction of hydrogen sulfide with the calcium-based sorbents.

Since warm gas cleanup is utilized, the unconverted steam and coal moisture injected into the gasifier will remain in the fuel gas entering the gas turbine. When the air-blown and oxygen-blown fuel gas heating values are compared for the wet product gas streams, it is apparent that only a slight improvement in product gas heating value entering the gas turbine is achieved with oxygen-blown operation. In order to keep the gas turbine firing temperature down to prevent thermal NO_x formation, typically large amounts of nitrogen or steam are injected into the gas turbine combustor such that the fuel gas heating is typically not much greater than 115 Btu/scf as-fired. In essence, the transport reactor has either injected the nitrogen with the oxidant (in the form of air) into the gasifier instead of directly into the gas turbine combustor in air-blown mode or has injected the steam directly into the gasifier instead of the gas turbine combustor in the oxygen-blown case. However, in a Vision 21 plant, where chemicals or fuel production are being considered and where potentially conventional cold-gas cleanup technology would be utilized to remove the water vapor from the fuel gas stream, significantly higher concentrations of desirable fuel gas constituents are achieved with oxygen-blown operation.

The TRDU and hot-gas filters have operated for over 2175 hours in gasification mode and over 2500 hours total with no major candle failures. The candles have exhibited no significant loss in candle permeability. The baseline “cleaned” filter differential pressure typically increased from 20 to approximately 80 inches H_2O over the course of most tests. The inlet particulate loading has ranged from approximately 3500 to 33,800 ppm with the filter ash averaging between 20 to 70 wt% carbon with a low bulk density around 20 lb/ft^3. The average filter ash particle size has ranged from approximately 7 to 22 µm in size and was essentially representative of the coal ash from very early in the gasification test. The initial rapid recovery of the filter differential pressure along with the small size, the lack of the cohesiveness seen in other filter ashes, and the low density of the ash had suggested that a high percentage of the filter cake would be reentrained back onto the filters after they are backpulsed. The large increase in filter baseline differential pressure also suggests that a thin but low porosity (permeable) filter cake is remaining on the surface of the candle and is not being removed during backpulsing. The low bulk density and high flowability of the filter ash possibly suggests that the inlet ash is able to move or sift on the surface of the candle to reach some optimum (minimum) porosity leading to low gas permeability across the candle.

Continuous measurement of mercury in the warm fuel gas has been another goal of the project. After considerable trial and error, a fuel gas conditioning system and Hg CEM analyzer has been configured to allow the continuous measurement of mercury emissions. Sampling issues for both the wet chemistry and Hg CEM techniques have been resolved, so that good agreement between the two techniques is being achieved. Wet-chemistry analysis has shown the mercury to essentially be in the elemental form. The EERC continues to utilize advanced SEM techniques where appropriate to determine the chemistry of any bed material agglomeration or deposition samples. No high levels of reactive sulfide have been measured in any TRDU samples that would make the residual solids a hazardous waste.

6.0 FUTURE PLANS

Future plans for operation of the TRDU include the design and construction of a new gas and particulate sampler for obtaining hot samples from the mixing zone and riser of the TRDU. Other future plans include testing of potential water-gas shift catalyst and membranes in order to maximize hydrogen production from future feedstocks. This testing will focus on demonstrating the transport gasifier as a significant hydrogen producer to help fuel the potential hydrogen economy. The EERC will continue aiming to integrate TRDU testing with potential partners focused on developing lower-cost synergistic multicontaminant control devices for warm-gas applications.

7.0 REFERENCES

1. Rush, R.E.; Moore, D.L.; Haq, Z.; Pinkston, T.E.; Vimalchand, P.; McClung, J.D.; Quandt, M.T. Status of the Advanced PFBC at the Power Systems Development Facility. In *Proceedings of the Coal-Fired Power Systems '94—Advances in IGCC and PFBC Review Meeting Vol. 1*; DOE/METC-94/1008 (DE94012252); June 1994; pp 127–137.

2. Ness, R.O. *Transport Reactor Demonstration Unit – Volume 1 Final Report*; 95-EERC-02-06, May 1995; 145 p.

3. Swanson, M.L.; Mann, M.D.; Sondreal, E.A. *Task 3.13 – Hot-Gas Filter Testing – Final Report*; 98-EERC-10-12 Oct 1998; 92 p.

4. Jacobsen, J.P. Char Reaction Kinetics in a Transport Gasifier. M.S. Thesis, University of North Dakota, 2001; 95 p.

5. Knutson, R.Z. Kinetic Modeling of a Transport Coal Gasifier. M.S. Thesis in Chemical Engineering, University of North Dakota, Aug 2001; 99 p.

6. Swanson, M.L. *Lignite Testing in an Advanced High-Temperature, High-Pressure Transport Reactor Gasifier – Final Report*; 2002-EERC-08-01, Aug 2002; 45 p.

7. Swanson, M.L.; Hajicek, D.R. Hot-Gas Filter Testing in an Advanced High-Temperature, High-Pressure Transport Reactor Gasifier. Presented at the 5th International Symposium on Gas Cleaning at High Temperature, DOE/NETL- 2003/1185, 2003, 15 p.

8. U.S. Environmental Protection Agency. www.epa.gov/etv/verifications/vcenter1-11.html (accessed July 2004).

9. Swanson, M.L. Modeling of Ash Properties in Advanced Coal-Based Power Systems. Ph.D Dissertation to the University of North Dakota, Aug 2000, 220 p.

10. Benson, S.A.; Sondreal, E.A. Impact of Low-Rank Coal Properties on Advanced Power Systems. In *Proceedings of 13th Annual Pittsburgh Coal Conference*; Chiang, S.-H., Ed.; 1996; Vol. 1, pp 484–498.

APPENDIX A

TRDU OXYGEN-BLOWN OPERATIONAL DATA WITH MODIFIED L-VALVE LOOP SEAL

Gas Compositions from TRDU Test
Test

Oxygen-blown lignite tests P068

		Center-1	Center-2	Center-3	Center-4	Center-5	Center-6	Center-7	Center-8	Falkirk-1	Falkirk-2	Falkirk-3	Falkirk-4	Freedom-1	Freedom-2	Freedom-3	HS Free-1	HS Free-2	HS Free-3	HS Free-4
		06/12/2001	06/14/2001	06/14/2001	06/14/2001	06/15/2001	06/15/2001	06/16/2001	06/16/2001	06/16/2001	06/17/2001	06/17/2001	06/18/2001	06/18/2001	06/19/2001	06/20/2001	06/20/2001	06/21/2001	06/21/2001	06/21/2001
Product Gas Comp, vol%		13:00-20:0C	06:00-10:0C	13:00-17:0C	20:00-24:0C	0:00-8:00	11:00-23:0C	0:00-7:00	8:00-12:00	15:00-24:0C	01:00-17:0C	18:00-23:0C	0:00-07:00	11:00-17:0C	0:00-10:00	12:30-14:0C	17:00-24:0C	0:00-5:00	06:00-13:0C	15:00-18:0C
	H2	8.2	6.7	6.4	13.5	12.7	18.5	19.5	20.8	19.8	18.8	18.3	19.5	9.3	8.6	16.5	17.3	20.2	19.9	20.0
	CO	3.2	3.4	2.9	4.8	4.7	6.1	6.6	7.4	7.0	6.9	6.8	6.9	4.7	4.7	4.8	5.7	7.1	6.8	6.6
	CH4	1.1	1.1	1.1	1.9	1.9	2.8	3.1	3.1	2.8	2.7	2.6	2.8	1.3	1.1	1.9	2.2	2.4	2.3	2.4
	CO2	14	14	14	21	21	28	29	29	29	29	33	29	16	15	26	30	29	29	30
	N2	73	74	76	57	57	43	41	39	40	43	44	43	73	72	50	48	43	44	44
	Total	99	99	100	98	97	99	99	99	99	100	105	100	104	102	99	103	101	101	103
	Ave Mol Wt	28	28	28	27	27	27	27	27	27	27	30	27	29	29	27	29	27	28	28
																		30.1	29.9	
Flow, scfh																				
	air in	10542	10500	11000	4250	4364	0	0	0	0	0	0	0	10999	11000	0	0	0	0	0
	oxygen in	0	0	0	1549	1549	2504	2563	2702	2570	2526	2474	2502	0	0	2412	2379	2488	2478	2449
	nitrogen in	4082	3991	4676	4063	4065	4123	4123	4146	4088	4140	4133	4198	4324	4340	5380	3998	4030	4062	4002
	product gas	19452	19044	20612	15627	15638	12503	13075	13768	13110	12611	12341	12920	21392	21419	13495	11623	12941	12668	12537
Product Gas, scfh																				
	H2	1593	1276	1311	2105	1989	2307	2554	2869	2601	2376	2263	2525	1989	1836	2228	2012	2610	2515	2502
	CO	628	644	606	745	740	768	858	1017	923	875	835	894	995	1007	652	666	921	864	825
	CH4	212	209	223	291	291	354	399	421	371	346	326	357	280	231	256	250	307	296	298
	CO2	2723	2731	2851	3254	3261	3550	3772	3971	3782	3631	4110	3693	3329	3269	3509	3489	3701	3610	3729
	N2	14155	14045	15579	8928	8920	5346	5424	5371	5291	5371	5400	5503	15623	15452	6748	5530	5581	5565	5548
	Total	19312	18905	20569	15322	15200	12324	13006	13650	12968	12598	12935	12970	22216	21794	13392	11947	13121	12850	12902
Heating Value, Btu/hr																				
	H2 (325)	517764	414683	426050	684111	646475	749711	829903	932507	845333	772172	735585	820485	646573	596573	724108	653881	848315	817244	813275
	CO (321)	201684	206624	194524	239276	237436	246427	275328	326603	296265	280940	268191	286995	319308	323148	209231	213785	295769	277330	264804
	CH4 (1014)	214995	212417	225726	294731	294939	358789	404371	427199	376207	350379	330364	361584	284158	234564	259995	253393	310996	300581	302558
	Total	934443	833723	846300	1218118	1178850	1354926	1509602	1686309	1517805	1403491	1334140	1469063	1250039	1154285	1193333	1121059	1455080	1395156	1380637
Heating Value, Btu/scf																				
	H2	27	22	21	44	41	60	63	68	64	61	60	64	30	28	54	56	66	65	65
	CO	10	11	9	15	15	20	21	24	23	22	22	22	15	15	16	18	23	22	21
	CH4	11	11	11	19	19	29	31	31	29	28	27	28	13	11	19	22	24	24	24
	Total	48	44	41	78	75	108	115	122	116	111	108	114	58	54	88	96	112	110	110
VALUES ADJUSTED FOR PURGE NITROGEN																				
Product Gas Comp, vol%																				
	H2	10.5%	8.6%	8.2%	18.7%	17.9%	28.1%	28.7%	30.2%	29.3%	28.1%	25.7%	28.8%	11.1%	10.5%	27.8%	25.3%	28.7%	28.6%	28.1%
	CO	4.1%	4.3%	3.8%	6.6%	6.6%	9.4%	9.7%	10.7%	10.4%	10.3%	9.5%	10.2%	5.6%	5.8%	8.1%	8.4%	10.1%	9.8%	9.3%
	CH4	1.4%	1.4%	1.4%	2.6%	2.6%	4.3%	4.5%	4.4%	4.2%	4.1%	3.7%	4.1%	1.6%	1.3%	3.2%	3.1%	3.4%	3.4%	3.4%
	CO2	17.9%	18.3%	17.9%	28.9%	29.3%	43.3%	42.5%	41.8%	42.6%	42.9%	46.7%	42.1%	18.6%	18.7%	43.8%	43.9%	40.7%	41.1%	41.9%
	N2	66.1%	67.4%	68.6%	43.2%	43.6%	14.9%	14.6%	12.9%	13.5%	14.6%	14.4%	14.9%	63.2%	63.7%	17.1%	19.3%	17.1%	17.1%	17.4%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	29	29	27	28	27	27	26	27	27	28	27	28	28	27	28	27	27	27
Heating Value, Btu/scf		61	56	53	108	106	165	170	177	171	166	152	167	70	66	149	141	160	159	155
Product Gas, scfh																				
	H2	1593	1276	1311	2105	1989	2307	2554	2869	2601	2376	2263	2525	1989	1836	2228	2012	2610	2515	2502
	CO	628	644	606	745	740	768	858	1017	923	875	835	894	995	1007	652	666	921	864	825
	CH4	212	209	223	291	291	354	399	421	371	346	326	357	280	231	256	250	307	296	298
	CO2	2723	2731	2851	3254	3261	3550	3772	3971	3782	3631	4110	3693	3329	3269	3509	3489	3701	3610	3729
	N2	10073	10054	10903	4865	4855	1223	1301	1225	1203	1231	1267	1305	11299	11112	1368	1532	1551	1503	1546
	Total	15230	14914	15893	11259	11135	8201	8883	9504	8880	8458	8802	8772	17892	17454	8012	7949	9091	8788	8900
FLUE GAS FLOWS ADJUSTED TO 450,000 BTU/HR HEAT LOSS																				
Gas created due to combustion of																				
Gas created due to combustion of		68	68	68	68	68	68	68	68	72	72	72	72	71	71	71	71	71	71	71
	CO2	1060	1060	1060	1060	1060	1060	1060	1060	1121	1121	1121	1121	1106	1106	1106	1106	1106	1106	1106
	N2	4487	4487	4487	4487	4487	1223	1301	1225	500	500	500	500	4679	4679	1368	1000	1551	1503	1546
Product Gas, scfh																				
	H2	1593	1276	1311	2105	1989	2307	2554	2869	2601	2376	2263	2525	1989	1836	2228	2012	2610	2515	2502
	CO	628	644	606	745	740	768	858	1017	923	875	835	894	995	1007	652	666	921	864	825
	CH4	212	209	223	291	291	354	399	421	371	346	326	357	280	231	256	250	307	296	298
	CO2	1663	1671	1790	2193	2200	2489	2712	2910	2661	2509	2988	2571	2223	2163	2403	2384	2595	2505	2623
	N2	5586	5567	6415	377	368	125	128	135	703	731	767	805	6620	6433	121	651	124	124	122
	Total	9682	9366	10345	5712	5587	6043	6650	7353	7259	6837	7180	7151	12107	11669	5660	5963	6558	6304	6371

		Oxygen-blown lignite tests P068																		
		Center-1	Center-2	Center-3	Center-4	Center-5	Center-6	Center-7	Center-8	Falkirk-1	Falkirk-2	Falkirk-3	Falkirk-4	Freedom-1	Freedom-2	Freedom-3	HS Free-1	HS Free-2	HS Free-3	HS Free-4
		06/12/2001	06/14/2001	06/14/2001	06/14/2001	06/15/2001	06/15/2001	06/16/2001	06/16/2001	06/16/2001	06/17/2001	06/17/2001	06/18/2001	06/18/2001	06/19/2001	06/20/2001	06/20/2001	06/21/2001	06/21/2001	06/21/2001
		13:00-20:0C	06:00-10:0C	13:00-17:0C	20:00-24:0C	0:00-8:00	11:00-23:0C	0:00-7:00	8:00-12:00	15:00-24:0C	01:00-17:0C	18:00-23:0C	0:00-07:00	11:00-17:0C	0:00-10:00	12:30-14:0C	17:00-24:0C	0:00-5:00	06:00-13:0C	15:00-18:0C
Product Gas, vol %																				
	H2	17	14	13	37	36	38	38	39	36	35	32	35	16	16	39	34	40	40	39
	CO	6.5	6.9	5.9	13.1	13.2	12.7	12.9	13.8	12.7	12.8	11.6	12.5	8.2	8.6	11.5	11.2	14.0	13.7	12.9
	CH4	2.2	2.2	2.2	5.1	5.2	5.9	6.0	5.7	5.1	5.1	4.5	5.0	2.3	2.0	4.5	4.2	4.7	4.7	4.7
	CO2	17	18	17	38	39	41	41	40	37	37	42	36	18	19	43	40	40	40	41
	N2	58	59	62	7	7	2	2	2	10	11	11	11	55	55	2	11	2	2	2
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		26	27	27	24	24	24	24	23	24	24	26	24	26	27	24	25	23	23	24
Heating Value, Btu/scf		97	89	82	213	211	224	227	229	209	205	186	205	103	99	211	188	222	221	217
	Gasifier Temp C	784	808	789	776	782	781	774	778	782	798	800	784	771	792	762	782	760	753	750
	Coal Feed Rate	374	337	445	445	440	457	567	571	534	502	487	586	480	456	413	469	504	531	499
	Air Flow (lb/hr)	807	803	842	325	334	0	0	0	0	0	0	0	842	842	0	0	0	0	0
	Steam Flow (lb/hr)	242	238	261	333	333	426	418	419	424	416	415	415	288	287	480	489	447	450	452
	O2 flow (lb/hr)	0	0	0	131	131	211	216	228	217	213	209	211	0	0	204	201	210	209	207
	Air/Coal Ratio (lb/lb)	2.34	2.59	2.06	0.79	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.16	2.28	0.00	0.00	0.00	0.00	0.00
	Steam/Coal Ratio (lb/lb)	0.70	0.77	0.64	0.81	0.82	1.01	0.80	0.80	0.88	0.92	0.95	0.79	0.74	0.78	1.43	1.30	1.11	1.06	1.13
	O2/Coal Ratio (lb/lb)	0.54	0.60	0.48	0.50	0.51	0.50	0.41	0.43	0.45	0.47	0.48	0.40	0.50	0.53	0.61	0.54	0.52	0.49	0.52
	O2/maf Coal Ratio (lb/lb)	0.92	1.02	0.81	0.86	0.88	0.86	0.71	0.74	0.83	0.87	0.88	0.74	0.91	0.95	1.10	0.97	0.94	0.89	0.94
	Recirc Rate (lb/hr)	1261	2827	2570	3256	4125	5193	7652	4583	4704	4003	4495	4965	2014	4168	2536	1226	1158	947	977
	Fraction Carbon in Coal	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38
	Fraction Sorbent in Coal	8%	8%	8%	8%	8%	8%	8%	8%	10%	10%	10%	10%	19%	19%	19%	20%	20%	20%	20%
	Coal Heating Value BTU/lb	6623	6623	6623	6623	6623	6623	6623	6623	6263	6263	6263	6263	6352	6352	6352	6352	6352	6352	6352
	Wt WAter (lb/hr)	326	302	400	481	523	487	587	523	520	448	511	520	326	312	559	491	460	451	566
	Wt LASH lb/hr	0	0	58	0	35	31	72	54	73	73	85	92	0	17	0	45	97	91	90
	Fraction C in LASH	16.1%	6.0%	13.0%	13.0%	12.1%	12.9%	19.0%	8.6%	15.6%	9.6%	10.1%	15.5%	0.0%	35.7%	7.5%	12.0%	24.8%	10.4%	6.8%
	WT filter ash lb/hr	33	28	36	52	41	39	49	55	53	48	40	46	154	55	73	47	64	56	57
	Fraction C in filter ash	0.43	0.46	0.51	0.53	0.52	0.55	0.62	0.62	0.47	0.37	0.35	0.40	0.41	0.54	0.46	0.40	0.49	0.43	0.50
	Wt dipleg lb/hr	0	0	0	0	0	0	0	0	0	6	0	8	8	31	0	27	0	0	0
	Fraction C in dipleg	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.5%	0.0%	10.2%	8.5%	33.6%	0.0%	8.4%	0.0%	0.0%	8.1%
	TRDU Throughput lb/hr-ft^	5151	4641	6129	6129	6060	6294	7809	7864	7195	6763	6561	7895	5820	5529	5008	5617	6036	6359	5976
	TRDU Throughput MMBtu/	34	31	41	41	40	42	52	52	45	42	41	49	37	35	32	36	38	40	38
	TRDU Riser Vel ft/s	48	48	51	45	45	43	42	42	42	42	42	43	52	53	50	51	49	49	49
	% Moisture As run	35	35	35	35	35	35	35	35	36	36	36	36	34	34	34	34	34	34	34
	Ultimate As run																			
	C	40	40	40	40	40	40	40	40	37	37	37	37	38	38	38	38	38	38	38
	H	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.6	6.6	6.6	6.6	6.2	6.2	6.2	6.2	6.2	6.2	6.2
	N	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	S	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
	O	44	44	44	44	44	44	44	44	44	44	44	44	40	40	40	40	40	40	40
	Ash	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	9.4	9.4	9.4	9.4	10.9	10.9	10.9	10.9	10.9	10.9	10.9
	Carbon Conversion																			
	Solid Accountability	90	90	85	83	85	85	79	82	80	85	86	83	57	67	74	82	64	79	77
	Gas Make	79	88	69	80	81	85	74	79	86	88	98	76	91	94	101	90	93	86	93
	Cold Gas Efficiency	41	40	31	44	43	48	43	48	50	50	51	45	53	50	56	48	58	52	56
	Cold Gas Eff cor	41	41	31	45	44	49	44	48	50	50	49	44	51	49	56	47	57	52	54
	Carbon Conv (calc)	74	81	79	86	85	88	84	83	94	89	90	88	111	100	57	88	86	87	94
	PG HHV (GC - Btu/scf)	50	45	42	81	79	114	122	128	121	116	112	118	60	58	111	100	118	116	117
	Hot Gas Eff (calc)	50	50	50	60	59	61	59	60	64	60	59	59	69	62	66	51	51	52	57
	Cold Gas Eff. (calc)	36	35	34	46	44	48	47	49	51	47	46	47	51	45	52	38	42	42	46
															0.97	0.97	0.97	0.97	0.97	0.97
															0	0	0	0	0	0
	H2S concetration (ppm)	1191	1401	1530	2158	2528	3524	3687	3561	3304	3493	2994	3039	1689	1596	967	2967	3218	3584	3709
	ulfur Retention (%)	46	31	38	34	21	16	26	25	31	25	35	43	75	75	89	75	72	71	68
	1-Lig, 2-Sub, 3-Bit, 4-Pet	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	TC416 thermocouple (402	606	663	688	682	708	719	711	690	665	674	690	666	621	698	612	604	576	552	539

Oxygen-blown lignite tests P068

	Center-1	Center-2	Center-3	Center-4	Center-5	Center-6	Center-7	Center-8	Falkirk-1	Falkirk-2	Falkirk-3	Falkirk-4	Freedom-1	Freedom-2	Freedom-3	HS Free-1	HS Free-2	HS Free-3	HS Free-4
	06/12/2001	06/14/2001	06/14/2001	06/14/2001	06/15/2001	06/15/2001	06/16/2001	06/16/2001	06/16/2001	06/17/2001	06/17/2001	06/18/2001	06/18/2001	06/19/2001	06/20/2001	06/20/2001	06/21/2001	06/21/2001	06/21/2001
	13:00-20:00	06:00-10:00	13:00-17:00	20:00-24:00	0:00-8:00	11:00-23:00	0:00-7:00	8:00-12:00	15:00-24:00	01:00-17:00	18:00-23:00	0:00-07:00	11:00-17:00	0:00-10:00	12:30-14:00	17:00-24:00	0:00-5:00	06:00-13:00	15:00-18:00
SUMMARY OF THE DRY PRODUCT GAS																			
TOTAL PRODUCT GAS, scf/hr -------->	20535	20008	20135	18977	18997	20408	20872	20123	20872	20872	20123	24134	22434	21524	20890	19894	19876	20128	20002
H2	7.1%	7.3%	8.1%	7.7%	7.7%	8.1%	8.1%	8.2%	8.7%	8.6%	8.3%	7.9%	7.7%	8.5%	8.7%	8.2%	8.5%	8.5%	8.5%
CO	4.4%	4.6%	4.7%	4.5%	4.5%	4.8%	4.9%	4.9%	5.0%	5.2%	5.2%	4.7%	4.6%	5.4%	5.4%	5.1%	5.4%	5.1%	5.4%
CH4	1.2%	1.1%	1.2%	1.1%	1.1%	1.1%	1.1%	1.1%	1.3%	1.4%	1.4%	1.3%	1.1%	1.1%	1.2%	1.1%	1.1%	1.1%	1.1%
CO2	13.3%	13.1%	13.0%	12.6%	12.4%	12.7%	12.7%	12.7%	12.9%	13.0%	13.4%	12.8%	12.6%	13.0%	13.2%	13.3%	13.1%	13.3%	13.0%
N2	74.4%	73.3%	72.7%	73.4%	73.8%	72.9%	72.8%	72.6%	71.3%	70.9%	71.4%	71.5%	72.1%	70.4%	69.9%	70.5%	70.1%	70.3%	70.2%
{ ppm } H2S	1088	1086	1078	1019	994	993	1017	901	800	800	800	446	875	935	946	906	852	941	917
SUMMARY OF THE ELEMENTAL AND MASS CLOSURE																			
#MOLES H	4%	5%	11%	-11%	-13%	10%	3%	-10%	0%	-1%	-12%	4%	7%	8%	-7%	-1%	5%	-27%	4%
#MOLES C	3%	-18%	2%	-12%	0%	-1%	-7%	-25%	-13%	-15%	-33%	1%	8%	6%	7%	5%	2%	-2%	10%
#MOLES O	0%	0%	3%	-8%	-8%	4%	-1%	-7%	-2%	-4%	-10%	-4%	0%	2%	-6%	-3%	1%	-18%	0%
#MOLES S	0%	-1%	0%	0%	0%	0%	0%	-1%	0%	-1%	-1%	0%	1%	1%	1%	1%	0%	0%	1%
#MOLES N	1%	1%	2%	2%	2%	3%	3%	3%	1%	1%	1%	1%	0%	1%	1%	1%	1%	1%	1%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	1%	1%	2%	1%	2%	2%	3%	3%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
SUMMARY OF CARBON UTILIZATION																			
High Kinetics																			
% CARBON LOST BY GASIFICATION { Total }	13%	15%	13%	14%	14%	13%	12%	17%	19%	19%	27%	5%	5%	7%	8%	10%	10%	10%	11%
% CARBON LOST BY COMBUSTION { Total }	73%	64%	66%	66%	72%	66%	67%	58%	60%	60%	50%	75%	81%	79%	81%	80%	74%	76%	81%
% Carbon Removed In Filter Ash { Total }	12%	14%	19%	16%	11%	19%	19%	23%	17%	17%	20%	18%	12%	12%	10%	8%	15%	12%	7%
% Carbon Removed In LASH { Total }	2%	7%	2%	4%	3%	2%	2%	2%	4%	4%	3%	1%	2%	1%	1%	1%	1%	3%	2%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analysis	6%	-34%	-4%	-24%	-11%	-10%	-12%	-44%	-25%	-25%	-67%	12%	15%	8%	6%	-0%	-2%	-6%	7%
Single-Pass CHAR Carbon Conversion { Gasification }	5.3%	7.7%	5.2%	5.8%	5.2%	5.0%	4.6%	8.8%	4.7%	4.7%	9.0%	4.0%	4.3%	7.4%	8.2%	12.4%	9.4%	9.0%	8.0%
Single-Pass CHAR Carbon Conversion { Combustion }	24%	24%	21%	22%	21%	20%	21%	23%	13%	13%	15%	37%	39%	45%	44%	49%	42%	41%	37%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3580	3358	3720	3333	3474	3905	3805	3424	3727	3745	3357	3757	3358	3176	3224	2825	3254	3348	3586
Low Kinetics																			
% CARBON LOST BY GASIFICATION { Total }	4%	5%	4%	4%	5%	4%	4%	5%	6%	6%	9%	2%	2%	2%	2%	3%	3%	3%	3%
% CARBON LOST BY COMBUSTION { Total }	80%	72%	73%	73%	80%	73%	73%	67%	69%	69%	63%	78%	84%	83%	86%	86%	80%	82%	88%
% Carbon Removed In Filter Ash { Total }	13%	16%	21%	18%	13%	21%	21%	26%	20%	20%	24%	19%	13%	13%	10%	9%	16%	13%	7%
% Carbon Removed In LASH { Total }	2%	7%	2%	5%	3%	2%	2%	2%	5%	5%	4%	1%	2%	2%	2%	2%	2%	3%	2%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analysis	2%	-19%	5%	-12%	0%	1%	-2%	-26%	-8%	-8%	-34%	15%	19%	13%	12%	7%	5%	1%	15%
Single-Pass CHAR Carbon Conversion { Gasification }	1.5%	2.0%	1.5%	1.7%	1.5%	1.4%	1.3%	2.3%	1.4%	1.4%	2.3%	1.2%	1.3%	2.0%	2.2%	3.1%	2.4%	2.3%	2.1%
Single-Pass CHAR Carbon Conversion { Combustion }	24%	24%	21%	22%	21%	20%	21%	23%	13%	13%	15%	37%	39%	45%	44%	49%	42%	41%	37%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3580	3358	3720	3333	3474	3905	3805	3424	3727	3745	3357	3757	3358	3176	3224	2825	3254	3348	3586
[H2O] { Inlet }	9.7%	9.9%	10.0%	9.6%	9.3%	8.8%	8.6%	8.9%	8.9%	8.9%	9.2%	9.1%	9.6%	10.1%	10.4%	10.8%	10.8%	10.7%	10.8%
[H2O] After Combustion { No WGS }	9.1%	9.3%	9.4%	9.0%	8.8%	8.3%	8.1%	8.3%	8.4%	8.4%	8.6%	8.6%	9.1%	9.5%	9.7%	10.1%	10.1%	10.0%	10.1%
[H2O] After Combustion { WGS }	5.2%	5.4%	5.5%	5.2%	5.1%	4.7%	4.6%	4.7%	4.7%	4.8%	4.8%	5.0%	5.4%	5.5%	5.6%	5.9%	5.9%	5.9%	6.0%
[H2O] After Steam-Gasification { WGS }	0.9%	0.7%	0.7%	0.8%	0.8%	0.6%	0.8%	0.5%	0.3%	0.3%	0.1%	2.0%	2.3%	2.0%	1.8%	1.8%	1.5%	1.5%	1.4%
SUMMARY OF THE SPREADSHEET RESULTS																			
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	85%	72%	78%	75%	85%	78%	76%	65%	74%	74%	62%	83%	88%	88%	90%	90%	84%	85%	92%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (C	83%	91%	77%	89%	86%	81%	86%	92%	87%	89%	96%	82%	80%	82%	83%	86%	82%	88%	83%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN)	84%	83%	85%	83%	86%	85%	84%	85%	88%	88%	87%	79%	59%	58%	58%	58%	62%	55%	59%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (L	-6%	-6%	-2%	-4%	-4%	-2%	-2%	-3%	-2%	-2%	-4%	0%	-1%	-2%	-3%	-3%	-2%	-3%	-2%
Heat Loss from TRDU { Btu/hr }	-1.5E+05	-1.3E+05	-4.8E+04	-9.0E+04	-8.3E+04	-4.4E+04	-4.6E+04	-6.8E+04	-5.9E+04	-5.6E+04	-8.1E+04	6.2E+03	-1.9E+04	-4.8E+04	-7.4E+04	-7.2E+04	-5.0E+04	-7.8E+04	-3.7E+04
HHV of Product Gas, 60 F w H2S w/o tar, Btu/scf	49	50	54	51	51	53	54	54	58	60	58	55	53	57	59	56	58	57	57
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Dry Corrected}	117	122	133	138	139	133	136	135	141	143	139	132	130	127	128	126	131	128	132
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet}	41	42	45	44	43	45	46	47	50	51	50	47	44	48	49	46	48	47	48
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet Corrected}	80	85	89	93	93	92	96	96	101	103	101	94	89	88	88	86	88	89	90
Gasifier Cold Gas Efficiency, % of coal HHV	41%	45%	41%	47%	46%	44%	47%	50%	49%	51%	52%	46%	44%	46%	47%	46%	46%	48%	46%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3580	3358	3720	3333	3474	3905	3805	3424	3727	3745	3357	3757	3358	3176	3224	2825	3254	3348	3586
COMPARISON OF SPREADSHEET RESULTS																			
delta T (°C)	178	145	101	94	74	62	63	88	117	124	110	118	150	94	150	178	184	201	211
Average Mixing Zone T (°C)	784	808	789	776	782	781	774	778	782	798	800	784	771	792	762	782	760	753	750
Average Low T (°C)	606	663	688	682	708	719	711	690	665	674	690	666	621	698	612	604	576	552	539
Air in (scfh)	10,542	10,500	11,000	4,250	4,364	0	0	0	0	0	0	0	10,999	11,000	0	0	0	0	0
Oxygen in (scfh)	0	0	0	1,549	1,549	2,504	2,563	2,702	2,570	2,526	2,474	2,502	0	0	2,412	2,379	2,488	2,478	2,449
Nitrogen in (scfh)	4,082	3,991	4,676	4,063	4,065	4,123	4,123	4,146	4,088	4,140	4,133	4,198	4,324	4,340	5,380	3,998	4,030	4,062	4,002
Product Gas (scfh)	19,452	19,044	20,612	15,627	15,638	12,503	13,075	13,768	13,110	12,611	12,341	12,920	21,392	21,419	13,495	11,623	12,941	12,668	12,537
Coal Feed Rate (lb/hr)	374	337	445	445	440	457	567	571	534	502	487	586	480	456	413	469	504	531	499
Air Flow (lb/hr)	807	803	842	325	334	0	0	0	0	0	0	0	842	842	0	0	0	0	0
Steam Flow (lb/hr)	242	238	261	333	333	426	418	419	424	416	415	415	288	287	480	489	447	450	452
Air/Coal Ratio (lb/lb)	2.34	2.59	2.06	0.79	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.16	2.28	0.00	0.00	0.00	0.00	0.00
Steam/Coal Ratio (lb/lb)	0.70	0.77	0.64	0.81	0.82	1.01	0.80	0.80	0.88	0.92	0.95	0.79	0.74	0.78	1.43	1.30	1.11	1.06	1.13
O2/Coal Ratio (lb/lb)	0.54	0.60	0.48	0.50	0.51	0.50	0.41	0.43	0.45	0.47	0.48	0.40	0.50	0.53	0.61	0.54	0.52	0.49	0.52
Fraction Carbon in Coal	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.37	0.37	0.37	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Bed Recycle Rate, lb/hr {by heat balance around burner}	3,580	3,358	3,720	3,333	3,474	3,905	3,805	3,424	3,727	3,745	3,357	3,757	3,358	3,176	3,224	2,825	3,254	3,348	3,586
Bed Recycle Rate,lb/hr {Calculated}	1,261	2,827	2,570	3,256	4,125	5,193	7,652	4,583	4,704	4,003	4,495	4,965	2,014	4,168	2,536	1,226	1,158	947	977

Gas Compositions from TRDU Test		P069										
Test		Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak	Wyodak
		10/09/2001	10/10/2001	10/10/2001	10/10/2001	10/11/2001	10/12/2001	11/12/2001	10/13/2001	10/13/2001	10/14/2001	10/14/2001
Product Gas Comp, vol%		04:38-07:00	12:00 - 10:0	14:00-18:25	18:25-01:00	02:00-8:00	12:00-20:00	22:00-03:00	04:00-15:00	16:00-03:00	03:00-18:00	22:00-08:00
	H2	8.6	8.7	15.2	14.8	17.4	10.0	16.1	19.3	19.4	20.0	19.1
	CO	4.0	4.4	6.5	5.9	6.8	5.7	7.1	7.8	8.7	10.4	11.0
	CH4	1.5	1.8	2.9	2.8	3.2	1.7	2.7	3.4	3.6	3.8	3.9
	CO2	14	14	20	20	24	14	19	24	24	24	24
	N2	81	81	62	64	54	70	61	49	48	44	45
	Total	109	110	106	107	105	101	106	104	103	103	104
	Ave Mol Wt	31	30	29	29	28	28	28	27	27	27	27
Flow, scfh												
	air in	9999	10961	3199	3084	0	12906	3200	0	0	0	0
	oxygen in	0	0	1695	1614	2219	0	1750	2400	2513	2798	2835
	nitrogen in	3904	4823	4908	5011	4991	5193	5118	5110	5091	5097	5080
	product gas	18578	21083	15866	15488	12900	25142	16356	14076	14543	15932	15718
Product Gas, scfh												
	H2	1600	1834	2412	2289	2250	2504	2628	2718	2814	3188	3004
	CO	745	932	1033	912	873	1421	1153	1101	1270	1657	1735
	CH4	279	371	457	440	415	427	440	474	516	605	611
	CO2	2638	2907	3153	3025	3071	3402	3162	3360	3477	3868	3813
	N2	15078	17119	9788	9835	6993	17524	9908	6961	6960	7069	7133
	Total	20339	23164	16842	16501	13603	25278	17292	14614	15037	16388	16296
Heating Value, Btu/hr												
	H2 (325)	519859	596122	783780	743966	731172	813847	854233	883375	914573	1036098	976206
	CO (321)	239138	299130	331553	292830	280339	455988	370144	353339	407543	531874	557021
	CH4 (1014)	282571	376256	463338	446017	421195	433398	446136	481002	523504	613892	619990
	Total	1041568	1271507	1578672	1482813	1432706	1703232	1670514	1717715	1845620	2181864	2153217
Heating Value, Btu/scf												
	H2	28	28	49	48	57	32	52	63	63	65	62
	CO	13	14	21	19	22	18	23	25	28	33	35
	CH4	15	18	29	29	33	17	27	34	36	39	39
	Total	56	60	100	96	111	68	102	122	127	137	137
VALUES ADJUSTED FOR PURGE NITROGEN												
Product Gas Comp, vol%												
	H2	9.7%	10.0%	20.2%	19.9%	26.1%	12.5%	21.6%	28.6%	28.3%	28.2%	26.8%
	CO	4.5%	5.1%	8.7%	7.9%	10.1%	7.1%	9.5%	11.6%	12.8%	14.7%	15.5%
	CH4	1.7%	2.0%	3.8%	3.8%	4.8%	2.1%	3.6%	5.0%	5.2%	5.4%	5.5%
	CO2	16.1%	15.9%	26.4%	26.3%	35.7%	16.9%	26.0%	35.4%	35.0%	34.3%	34.0%
	N2	68.0%	67.0%	40.9%	42.0%	23.2%	61.4%	39.4%	19.5%	18.8%	17.5%	18.3%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	28	27	27	26	27	26	26	26	25	26
Heating Value, Btu/scf		63	69	132	129	166	85	137	181	186	193	192
Product Gas, scfh												
	H2	1600	1834	2412	2289	2250	2504	2628	2718	2814	3188	3004
	CO	745	932	1033	912	873	1421	1153	1101	1270	1657	1735
	CH4	279	371	457	440	415	427	440	474	516	605	611
	CO2	2638	2907	3153	3025	3071	3402	3162	3360	3477	3868	3813
	N2	11174	12296	4880	4824	2002	12331	4790	1851	1869	1972	2053
	Total	16435	18341	11934	11490	8612	20085	12174	9504	9946	11291	11216
FLUE GAS FLOWS ADJUSTED TO 450,000 BTU/HR HEAT LOSS												
Gas created due to combustion of												
Gas created due to combustion of		50	50	50	50	50	50	50	50	50	50	50
	CO2	779	779	779	779	779	779	779	779	779	779	779
	N2	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299
Product Gas, scfh												
	H2	1600	1834	2412	2289	2250	2504	2628	2718	2814	3188	3004
	CO	745	932	1033	912	873	1421	1153	1101	1270	1657	1735
	CH4	279	371	457	440	415	427	440	474	516	605	611
	CO2	1859	2128	2373	2245	2292	2622	2382	2580	2698	3089	3034
	N2	7875	8998	1581	1525	111	9032	1492	120	126	140	142
	Total	12357	14263	7856	7412	5941	16007	8096	6994	7423	8679	8526

		P069 Wyodak 10/09/2001 04:38-07:00	Wyodak 10/10/2001 12:00 - 10:0	Wyodak 10/10/2001 14:00-18:25	Wyodak 10/10/2001 18:25-01:00	Wyodak 10/11/2001 02:00-8:00	Wyodak 10/12/2001 12:00-20:00	Wyodak 11/12/2001 22:00-03:00	Wyodak 10/13/2001 04:00-15:00	Wyodak 10/13/2001 16:00-03:00	Wyodak 10/14/2001 03:00-18:00	Wyodak 10/14/2001 22:00-08:00
Product Gas, vol %												
	H2	13	13	31	31	38	16	33	39	38	37	35
	CO	6.0	6.5	13.1	12.3	14.7	8.9	14.2	15.7	17.1	19.1	20.4
	CH4	2.3	2.6	5.8	5.9	7.0	2.7	5.4	6.8	7.0	7.0	7.2
	CO2	15	15	30	30	39	16	29	37	36	36	36
	N2	64	63	20	21	2	56	18	2	2	2	2
	Total	100	100	100	100	100	100	100	100	100	100	100
		27	27	24	24	23	26	24	23	23	23	24
Heating Value, Btu/scf		84	89	201	200	241	106	206	246	249	251	253
	Gasifier Temp C	804	823	835	832	828	804	823	827	840	865	892
	Coal Feed Rate	281	385	390	400	349	476	376	381	400	456	406
	Air Flow (lb/hr)	765	839	245	236	0	988	245	0	0	0	0
	Steam Flow (lb/hr)	297	288	325	341	392	269	342	405	361	365	364
	O2 flow (lb/hr)	0	0	143	136	187	0	148	203	212	236	239
	Air/Coal Ratio (lb/lb)	2.84	2.27	0.65	0.61	0.00	2.16	0.68	0.00	0.00	0.00	0.00
	Steam/Coal Ratio (lb/lb)	1.10	0.78	0.87	0.89	1.17	0.59	0.95	1.11	0.94	0.83	0.93
	O2/Coal Ratio (lb/lb)	0.66	0.53	0.53	0.50	0.56	0.50	0.57	0.55	0.55	0.54	0.61
	O2/maf Coal Ratio (lb/lb)	0.91	0.73	0.74	0.69	0.78	0.69	0.79	0.77	0.77	0.75	0.85
	Recirc Rate (lb/hr)	2700	2750	3010	3675	3140	1530	1340	1790	2780	3045	3665
	Fraction Carbon in Coal	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
	Fraction Sorbent in Coal	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
	Coal Heating Value BTU/lb	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010
	Wt WAter (lb/hr)	414	365	397	521	418	357	388	436	351	386	368
	Wt LASH lb/hr	0	0	0	0	0	0	0	0	0	11	0
	Fraction C in LASH	12.5%	5.9%	13.4%	21.0%	12.8%	41.2%	24.3%	18.7%	13.7%	9.3%	6.8%
	WT filter ash lb/hr	87	79	63	65	39	75	48	34	38	35	31
	Fraction C in filter ash	0.48	0.61	0.67	0.64	0.66	0.70	0.64	0.57	0.56	0.52	0.33
	Wt dipleg lb/hr	20	8	3	0	0	16	0	0	0	0	0
	Fraction C in dipleg	1.8%	5.5%	9.4%	0.0%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%
	TRDU Throughput lb/hr-ft^:	4038	5533	5605	5749	5016	6841	5404	5475	5749	6553	5835
	TRDU Throughput MMBtu/	36	50	50	52	45	62	49	49	52	59	53
	TRDU Riser Vel ft/s	46	51	42	42	40	55	43	42	41	43	44
	% Moisture As run	23	23	23	23	23	23	23	23	23	23	23
	Ultimate As run											
	C	58	58	58	58	58	58	58	58	58	58	58
	H	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
	N	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	S	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	O	30	30	30	30	30	30	30	30	30	30	30
	Ash	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	Carbon Conversion											
	Solid Accountability	73	77	80	81	87	79	85	91	90	92	95
	Gas Make	74	62	68	62	71	63	72	74	75	76	86
	Cold Gas Efficiency	47	42	50	46	50	42	54	54	55	57	64
	Cold Gas Eff cor	43	38	47	43	47	41	51	52	53	55	61
	Carbon Conv (calc)	68	60	73	68	67	79	76	82	80	83	96
	PG HHV (GC - Btu/scf)	59	63	106	102	118	71	108	130	134	144	141
	Hot Gas Eff (calc)	48	44	55	52	50	59	59	62	60	62	71
	Cold Gas Eff. (calc)	34	33	45	41	40	46	48	51	51	53	60
		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
		0	0	0	0	0	0	0	0	0	0	0
	H2S concetration (ppm)	262	424	766	776	854	500	683	868	891	1009	1020
	ulfur Retention (%)	58	43	24	27	23	35	27	22	21	14	4
	1-Lig, 2-Sub, 3-Bit, 4-Pet	2	2	2	2	2	2	2	2	2	2	2
	TC416 thermocouple (402	658	679	668	661	646	639	638	639	683	718	764

	P069 Wyodak 10/09/2001 04:38-07:0C	Wyodak 10/10/2001 12:00 - 10:C	Wyodak 10/10/2001 14:00-18:25	Wyodak 10/10/2001 18:25-01:0C	Wyodak 10/11/2001 02:00-8:00	Wyodak 10/12/2001 12:00-20:0C	Wyodak 11/12/2001 22:00-03:0C	Wyodak 10/13/2001 04:00-15:0C	Wyodak 10/13/2001 16:00-03:0C	Wyodak 10/14/2001 03:00-18:0C	Wyodak 10/14/2001 22:00-08:00
SUMMARY OF THE DRY PRODUCT GAS											
TOTAL PRODUCT GAS, scf/hr ------->	20567	21242	20711	20299	21443	19993	19680	19002	20689	19603	18772
H2	9.0%	9.1%	8.3%	7.4%	8.7%	8.3%	7.8%	8.2%	8.7%	8.3%	7.2%
CO	5.4%	5.2%	5.3%	4.9%	5.3%	4.6%	4.0%	3.7%	5.9%	6.5%	5.7%
CH4	1.2%	1.1%	1.0%	1.0%	1.1%	1.0%	0.9%	1.0%	1.3%	1.1%	1.0%
CO2	12.9%	12.7%	12.5%	12.9%	12.8%	12.5%	12.0%	12.2%	13.8%	12.9%	13.0%
N2	69.8%	70.3%	71.2%	72.3%	70.2%	71.3%	72.8%	72.2%	74.0%	74.7%	75.8%
{ppm} H2S	815	978	840	797	694	866	773	886	229	627	662
SUMMARY OF THE ELEMENTAL AND MASS CLOSURE											
#MOLES H	8%	11%	2%	-9%	6%	10%	11%	10%	18%	10%	24%
#MOLES C	13%	14%	2%	4%	13%	5%	2%	3%	15%	13%	2%
#MOLES O	3%	4%	0%	-8%	1%	3%	4%	5%	10%	5%	14%
#MOLES S	2%	2%	0%	1%	2%	1%	0%	1%	2%	2%	0%
#MOLES N	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%
SUMMARY OF CARBON UTILIZATION											
High Kinetics											
% CARBON LOST BY GASIFICATION {Total}	6%	5%	8%	10%	7%	6%	5%	3%	13%	14%	23%
% CARBON LOST BY COMBUSTION {Total}	82%	82%	84%	77%	84%	76%	76%	69%	75%	73%	68%
% Carbon Removed In Filter Ash {Total}	10%	13%	7%	13%	9%	18%	16%	28%	7%	8%	5%
% Carbon Removed In LASH {Total}	3%	1%	0%	0%	0%	0%	4%	0%	5%	5%	4%
Char Carbon Accounted For {Comb + S.Gasif + Filter + LASH}	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analy	18%	21%	-4%	-9%	14%	6%	4%	3%	8%	4%	-31%
Single-Pass CHAR Carbon Conversion {Gasification}	4.6%	3.8%	10.2%	16.9%	6.8%	5.6%	5.5%	2.9%	5.4%	5.5%	11.5%
Single-Pass CHAR Carbon Conversion {Combustion}	40%	39%	51%	56%	45%	43%	47%	37%	23%	22%	25%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	4452	4538	3788	3523	4238	3937	3280	4202	3729	3659	3260
Low Kinetics											
% CARBON LOST BY GASIFICATION {Total}	2%	1%	2%	3%	2%	2%	1%	1%	4%	4%	7%
% CARBON LOST BY COMBUSTION {Total}	85%	84%	89%	83%	88%	79%	79%	70%	83%	81%	82%
% Carbon Removed In Filter Ash {Total}	10%	14%	8%	14%	9%	19%	16%	28%	7%	8%	6%
% Carbon Removed In LASH {Total}	3%	1%	1%	0%	1%	1%	4%	0%	6%	6%	5%
Char Carbon Accounted For {Comb + S.Gasif + Filter + LASH}	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analy	21%	23%	3%	-0%	19%	10%	7%	5%	17%	14%	-8%
Single-Pass CHAR Carbon Conversion {Gasification}	1.3%	1.1%	2.5%	3.9%	1.8%	1.5%	1.6%	0.9%	1.5%	1.6%	2.8%
Single-Pass CHAR Carbon Conversion {Combustion}	40%	39%	51%	56%	45%	43%	47%	37%	23%	22%	25%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	4452	4538	3788	3523	4238	3937	3280	4202	3729	3659	3260
[H2O] {Inlet}	10.6%	10.3%	10.3%	10.4%	10.1%	10.6%	10.7%	11.0%	10.4%	10.8%	11.0%
[H2O] After Combustion {No WGS}	9.9%	9.7%	9.6%	9.6%	9.5%	10.0%	10.1%	10.4%	9.7%	10.1%	10.2%
[H2O] After Combustion {WGS}	5.8%	5.7%	5.6%	5.5%	5.5%	6.0%	6.2%	6.3%	5.6%	5.9%	5.9%
[H2O] After Steam-Gasification {WGS}	2.0%	2.1%	1.7%	1.5%	1.8%	2.2%	2.8%	2.6%	0.8%	0.7%	0.4%
SUMMARY OF THE SPREADSHEET RESULTS											
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	90%	89%	92%	86%	92%	83%	82%	73%	89%	88%	88%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (	77%	75%	90%	82%	80%	77%	80%	70%	75%	75%	86%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN)	66%	60%	58%	63%	70%	61%	61%	61%	93%	79%	73%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (	-1%	-1%	-4%	-3%	-1%	-2%	-1%	-3%	-3%	-2%	-6%
Heat Loss from TRDU {Btu/hr}	-3.5E+04	-1.7E+04	-9.4E+04	-6.1E+04	-2.9E+04	-4.2E+04	-2.7E+04	-6.7E+04	-8.0E+04	-6.0E+04	-1.3E+05
HHV of Product Gas, 60 F w H2S w/o tar, Btu/scf	60	59	55	50	58	53	49	50	58	57	50
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Dry Corrected}	134	135	124	115	129	131	136	133	125	131	119
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet}	49	49	46	41	48	44	41	40	46	45	41
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet Corrected}	90	91	86	77	88	86	88	81	81	82	75
Gasifier Cold Gas Efficiency, % of coal HHV	44%	44%	50%	42%	45%	42%	43%	39%	41%	41%	43%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	4452	4538	3788	3523	4238	3937	3280	4202	3729	3659	3260
COMPARISON OF SPREADSHEET RESULTS											
delta T (°C)	146	144	167	171	182	165	185	188	157	147	128
Average Mixing Zone T (°C)	804	823	835	832	828	804	823	827	840	865	892
Average Low T (°C)	658	679	668	661	646	639	638	639	683	718	764
Air in (scfh)	9,999	10,961	3,199	3,084	0	12,906	3,200	0	0	0	0
Oxygen in (scfh)	0	0	1,695	1,614	2,219	0	1,750	2,400	2,513	2,798	2,835
Nitrogen in (scfh)	3,904	4,823	4,908	5,011	4,991	5,193	5,118	5,110	5,091	5,097	5,080
Product Gas (scfh)	18,578	21,083	15,866	15,488	12,900	25,142	16,356	14,076	14,543	15,932	15,718
Coal Feed Rate (lb/hr)	281	385	390	400	349	476	376	381	400	456	406
Air Flow (lb/hr)	765	839	245	236	0	988	245	0	0	0	0
Steam Flow (lb/hr)	297	288	325	341	392	269	342	405	361	365	364
Air/Coal Ratio (lb/lb)	2.84	2.27	0.65	0.61	0.00	2.16	0.68	0.00	0.00	0.00	0.00
Steam/Coal Ratio (lb/lb)	1.10	0.78	0.87	0.89	1.17	0.59	0.95	1.11	0.94	0.83	0.93
O2/Coal Ratio (lb/lb)	0.66	0.53	0.53	0.50	0.56	0.50	0.57	0.55	0.55	0.54	0.61
Fraction Carbon in Coal	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Bed Recycle Rate, lb/hr {by heat balance around burner}	4,452	4,538	3,788	3,523	4,238	3,937	3,280	4,202	3,729	3,659	3,260
Bed Recycle Rate,lb/hr {Calculated}	2,700	2,750	3,010	3,675	3,140	1,530	1,340	1,790	2,780	3,045	3,665

Gas Compositions from TRDU Test		P070																			
Test		SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	SUFCo	Illinois No. 6	Illinois No. 6	Illinois No. 6
		04/15/2002	04/15/2002	04/15/2002	04/16/2002	04/16/2002	04/16/2002	04/16/2002	04/17/2002	04/17/2002	04/17/2002	04/17/2002	04/18/2002	04/18/2002	04/18/2002	04/19/2002	04/19/2002	04/20/2002	04/20/2002	04/20/2002	04/20/2002
Product Gas Comp, vol%		16:00-18:00	18:00-20:00	20:00-24:00	0:00-05:00	05:00-10:00	11:00-16:00	18:00-20:00	0:00-5:00	07:00-12:00	12:00-18:00	20:00-23:00	0:00-07:00	08:00-11:00	12:00-13:45	12:00-16:30	18:00-04:30	05:00-07:00	07:30-13:30	13:30-14:45	17:00-19:00
	H2	8.4	7.7	8.3	10.7	10.4	9.6	17.6	15.7	18.8	15.6	14.7	18.6	19.3	19.6	15.7	14.9	15.8	14.1	14.7	8.7
	CO	4.1	3.9	4.3	4.6	4.6	5.1	4.0	5.7	6.9	7.9	7.1	7.8	8.0	8.1	6.4	7.0	7.4	7.2	6.8	5.5
	CH4	1.6	1.7	1.8	1.9	1.8	1.7	1.9	2.8	3.5	3.8	3.5	4.5	4.9	4.9	3.9	3.6	3.8	3.4	3.2	2.3
	CO2	13	14	13	13	13	13	13	16	21	21	19	24	24	24	22	23	22	28	20	22
	N2	75	76	74	71	73	72	74	66	62	65	62	48	49	49	57	56	56	59	62	65
	Total	102	103	101	101	102	101	110	106	112	113	106	103	106	105	105	104	105	111	107	104
	Ave Mol Wt	28	29	28	27	28	28	28	28	29	31	28	27	28	28	28	29	28	31	29	30
Flow, scfh																					
	air in	11405	11799	11801	11851	12299	13247	10000	5759	4147	4038	2964	0	0	0	0	0	0	750	749	730
	oxygen in	0	0	0	0	0	0	214	1141	1464	1501	1540	2217	2260	2171	2490	2501	2499	2496	2638	2572
	nitrogen in	4322	4293	4283	4303	4227	4526	4731	4832	4678	4904	4570	4577	4565	4609	5041	4974	4769	4260	4285	4522
	product gas	17575	18424	18744	19158	19672	20990	16599	15056	14163	13881	13363	11520	11798	11610	10993	10828	10636	10289	9746	11762
Product Gas, scfh																					
	H2	1476	1353	1529	2006	1992	1888	3694	2606	2831	2209	2040	2485	2223	2312	1726	1613	1680	1451	1433	1023
	CO	721	685	792	862	881	1003	840	946	1039	1119	986	1042	922	956	704	758	787	741	663	647
	CH4	281	299	332	356	345	334	399	465	527	538	486	601	564	578	429	390	404	350	312	271
	CO2	2320	2496	2395	2474	2395	2557	2813	2623	3147	2988	2651	3261	2799	2843	2408	2469	2372	2829	1959	2599
	N2	13111	13339	13542	13270	13890	14105	15428	10906	9259	9163	8550	6414	5645	5746	6266	6064	5924	6071	6042	7669
	Total	17909	18172	18590	18969	19503	19888	23173	17545	16803	16018	14713	13804	12153	12435	11532	11294	11167	11441	10408	12209
Heating Value, Btu/hr																					
	H2 (325)	479790	439808	497000	651809	647544	613760	1200620	846961	919925	718048	663146	807787	722574	751552	560928	524349	546142	471496	465600	332576
	CO (321)	231301	220018	254313	276768	282888	322047	269510	303711	333476	359152	316353	334580	295826	306768	225844	243307	252640	237801	212729	207661
	CH4 (1014)	285132	302953	336283	361114	349674	339102	404391	471277	534339	545717	492623	609749	572368	586210	434737	395268	409814	354725	316228	274318
	Total	996223	962779	1087597	1289691	1280106	1274909	1874520	1621950	1787741	1622917	1472122	1752116	1590769	1644529	1221509	1162923	1208596	1064022	994557	814555
Heating Value, Btu/scf																					
	H2	27	25	27	35	34	31	57	51	61	51	48	60	63	64	51	48	51	46	48	28
	CO	13	13	14	15	15	16	13	18	22	25	23	25	26	26	21	22	24	23	22	18
	CH4	16	17	18	19	18	17	19	28	35	39	35	46	50	50	40	37	39	34	32	23
	Total	57	55	59	69	67	65	89	98	119	115	106	131	138	139	111	107	114	103	102	69
VALUES ADJUSTED FOR PURGE NITROGEN																					
Product Gas Comp, vol%																					
	H2	10.9%	9.8%	10.7%	13.7%	13.1%	12.1%	19.8%	20.3%	23.6%	19.5%	20.8%	26.9%	29.3%	29.4%	26.6%	25.5%	26.3%	20.2%	23.4%	13.3%
	CO	5.3%	4.9%	5.5%	5.9%	5.8%	6.4%	4.5%	7.4%	8.7%	9.9%	10.0%	11.3%	12.2%	12.1%	10.8%	12.0%	12.3%	10.3%	10.8%	8.4%
	CH4	2.1%	2.2%	2.3%	2.4%	2.3%	2.1%	2.1%	3.6%	4.4%	4.7%	5.0%	6.5%	7.5%	7.3%	6.6%	6.2%	6.3%	4.9%	5.1%	3.5%
	CO2	17.1%	18.0%	16.8%	16.8%	15.8%	16.3%	15.1%	20.5%	26.3%	26.4%	27.0%	35.3%	36.9%	36.1%	37.1%	39.1%	37.1%	39.4%	32.0%	33.8%
	N2	64.7%	65.1%	64.7%	61.2%	63.1%	63.1%	58.5%	48.2%	37.0%	39.6%	37.2%	20.0%	14.1%	15.0%	18.9%	17.2%	18.1%	25.2%	28.7%	40.9%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	28	28	27	27	27	25	26	26	27	26	26	25	25	26	27	26	28	26	30
Heating Value, Btu/scf		73	70	76	88	84	81	101	127	149	143	150	190	210	209	188	184	189	148	162	106
Product Gas, scfh																					
	H2	1476	1353	1529	2006	1992	1888	3694	2606	2831	2209	2040	2485	2223	2312	1726	1613	1680	1451	1433	1023
	CO	721	685	792	862	881	1003	840	946	1039	1119	986	1042	922	956	704	758	787	741	663	647
	CH4	281	299	332	356	345	334	399	465	527	538	486	601	564	578	429	390	404	350	312	271
	CO2	2320	2496	2395	2474	2395	2557	2813	2623	3147	2988	2651	3261	2799	2843	2408	2469	2372	2829	1959	2599
	N2	8789	9017	9249	8987	9587	9878	10902	6175	4427	4485	3646	1844	1068	1181	1225	1090	1155	1811	1757	3147
	Total	13587	13850	14297	14686	15200	15661	18647	12814	11971	11340	9809	9234	7576	7870	6491	6320	6398	7181	6123	7687
FLUE GAS FLOWS ADJUSTED TO 450,000 BTU/HR HEAT LOSS																					
Gas created due to combustion of																					
Gas created due to combustion of		39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	40	40	40
	CO2	605	605	605	605	605	605	605	605	605	605	605	605	605	605	605	605	605	622	622	622
	N2	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2562	2630	2630	2630
Product Gas, scfh																					
	H2	1476	1353	1529	2006	1992	1888	3694	2606	2831	2209	2040	2485	2223	2312	1726	1613	1680	1451	1433	1023
	CO	721	685	792	862	881	1003	840	946	1039	1119	986	1042	922	956	704	758	787	741	663	647
	CH4	281	299	332	356	345	334	399	465	527	538	486	601	564	578	429	390	404	350	312	271
	CO2	1714	1890	1790	1869	1789	1952	2207	2017	2541	2383	2046	2655	2194	2238	1802	1863	1766	2208	1337	1978
	N2	6227	6455	6687	6425	7025	7316	0	11	57	73	75	77	111	113	125	125	125	125	132	129
	Total	10419	10683	11130	11518	12032	12494	7140	6045	6995	6323	5633	6861	6014	6197	4785	4750	4763	4874	3876	4047

		P070 SUFCo 04/15/2002 16:00-18:00	SUFCo 04/15/2002 18:00-20:00	SUFCo 04/15/2002 20:00-24:00	SUFCo 04/16/2002 0:00-05:00	SUFCo 04/16/2002 05:00-10:00	SUFCo 04/16/2002 11:00-16:00	SUFCo 04/16/2002 18:00-20:00	SUFCo 04/17/2002 0:00-5:00	SUFCo 04/17/2002 07:00-12:00	SUFCo 04/17/2002 12:00-18:00	SUFCo 04/17/2002 20:00-23:00	SUFCo 04/18/2002 0:00-07:00	SUFCo 04/18/2002 08:00-11:00	SUFCo 04/18/2002 12:00-13:45	SUFCo 04/19/2002 12:00-16:30	SUFCo 04/19/2002 18:00-04:30	SUFCo 04/20/2002 05:00-07:00	Illinois No. 6 04/20/2002 07:30-13:30	Illinois No. 6 04/20/2002 13:30-14:45	Illinois No. 6 04/20/2002 17:00-19:00
Product Gas, vol %																					
	H2	14	13	14	17	17	15	52	43	41	35	36	36	37	37	36	34	35	30	37	25
	CO	6.9	6.4	7.1	7.5	7.3	8.0	11.8	15.7	14.9	17.7	17.5	15.2	15.3	15.4	14.7	16.0	16.5	15.2	17.1	16.0
	CH4	2.7	2.8	3.0	3.1	2.9	2.7	5.6	7.7	7.5	8.5	8.6	8.8	9.4	9.3	9.0	8.2	8.5	7.2	8.0	6.7
	CO2	17	18	16	16	15	16	31	33	36	38	36	39	37	36	38	39	37	45	35	49
	N2	60	60	60	56	58	59	0	0	1	1	1	1	2	2	3	3	3	3	3	3
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		27	27	27	26	26	26	19	21	22	24	23	24	23	23	24	24	24	27	23	28
Heating Value, Btu/scf		96	90	98	112	106	102	263	268	256	257	261	255	265	265	255	245	254	218	257	201
	Gasifier Temp C	900	903	898	880	885	918	856	886	894	908	906	893	885	897	867	896	900	944	972	972
	Coal Feed Rate	258	290	313	412	313	318	327	357	332	298	276	300	331	279	326	301	296	220	295	295
	Air Flow (lb/hr)	873	903	903	907	941	1014	765	441	317	309	227	0	0	0	0	0	0	57	57	56
	Steam Flow (lb/hr)	287	287	288	287	288	288	351	382	383	382	385	434	430	452	460	459	454	457	463	458
	O2 flow (lb/hr)	0	0	0	0	0	0	18	96	124	127	130	187	191	183	210	211	211	211	223	217
	Air/Coal Ratio (lb/lb)	3.52	3.24	3.01	2.29	3.13	3.32	2.44	1.29	1.00	1.08	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.23	0.23
	Steam/Coal Ratio (lb/lb)	1.16	1.03	0.96	0.73	0.96	0.94	1.12	1.11	1.20	1.34	1.45	1.51	1.35	1.69	1.47	1.59	1.60	2.50	1.89	1.87
	O2/Coal Ratio (lb/lb)	0.82	0.75	0.70	0.53	0.73	0.77	0.62	0.58	0.62	0.69	0.69	0.65	0.60	0.68	0.67	0.73	0.74	1.23	0.96	0.94
	O2/maf Coal Ratio (lb/lb)	0.98	0.91	0.84	0.64	0.88	0.93	0.75	0.70	0.75	0.84	0.83	0.78	0.72	0.83	0.81	0.88	0.90	1.52	1.19	1.16
	Recirc Rate (lb/hr)	1395	2080	1990	4120	5555	4440	1540	2835	2060	1610	1745	3800	5870	2040	6780	4995	6740	5490	4615	4235
	Fraction Carbon in Coal	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.63	0.63	0.63
	Fraction Sorbent in Coal	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	17%	17%	17%
	Coal Heating Value BTU/lb	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11600	11300	11300	11300
	Wt WAter (lb/hr)	251	263	267	273	281	299	366	332	312	306	295	360	369	368	436	429	422	408	386	466
	Wt LASH lb/hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	13	0	0	0	0
	Fraction C in LASH	7.8%	7.8%	7.8%	12.7%	5.8%	13.0%	8.8%	11.2%	21.3%	32.6%	22.5%	15.7%	28.4%	27.8%	19.4%	4.1%	6.5%	0.8%	0.5%	0.7%
	WT filter ash lb/hr	50	95	180	105	87	91	340	101	89	89	104	61	80	154	100	88	62	96	85	68
	Fraction C in filter ash	0.33	0.60	0.68	0.63	0.66	0.52	0.61	0.65	0.56	0.60	0.59	0.63	0.65	0.50	0.62	0.50	0.55	0.39	0.35	0.30
	Wt dipleg lb/hr	0	0	86	0	115	0	0	44	73	45	35	28	82	0	0	0	0	0	0	0
	Fraction C in dipleg	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	23.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	TRDU Throughput lb/hr-ft^	3708	4168	4498	5921	4498	4570	4699	5131	4771	4283	3966	4311	4757	4010	4685	4326	4254	2734	3665	3665
	TRDU Throughput MMBtu/	43	48	52	69	52	53	55	60	55	50	46	50	55	47	54	50	49	31	41	41
	TRDU Riser Vel ft/s	55	57	57	57	59	63	56	53	51	51	49	46	45	47	54	56	57	60	61	61
	% Moisture As run	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	9	9	9
	Ultimate As run																				
	C	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	63	63	63
	H	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.6	5.6	5.6
	N	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.0	1.0	1.0
	S	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	3.2	3.2	3.2
	O	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	Ash	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	10.7	10.7	10.7
	Carbon Conversion																				
	Solid Accountability	90	71	41	76	73	78	6	72	78	73	67	81	68	59	71	78	83	68	81	87
	Gas Make	60	56	53	42	54	57	58	53	66	73	70	77	61	73	51	56	56	103	57	69
	Cold Gas Efficiency	35	31	31	28	37	36	57	43	54	55	51	54	46	56	35	36	38	57	38	31
	Cold Gas Eff cor	35	30	31	28	37	36	51	41	48	49	48	52	43	53	34	35	37	52	36	29
	Carbon Conv (calc)	82	82	74	77	77	84	74	78	95	105	100	111	107	123	102	104	113	142	148	122
	PG HHV (GC - Btu/scf)	58	56	60	70	68	66	90	99	122	117	108	134	142	143	114	109	115	107	115	70
	Hot Gas Eff (calc)	59	54	53	60	61	62	74	66	74	76	76	82	81	96	74	71	80	72	70	54
	Cold Gas Eff. (calc)	43	40	40	47	48	48	60	55	63	64	63	70	70	82	63	59	67	58	56	41
		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	H2S concetration (ppm)	228	223	315	213	307	273	339	323	404	701	784	600	716	786	599	796	792	2070	2000	2368
	ulfur Retention (%)	59	64	51	74	50	55	42	60	51	11	-5	29	34	11	46	24	24	69	79	70
	1-Lig, 2-Sub, 3-Bit, 4-Pet	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	TC416 thermocouple (402	773	810	810	815	833	860	777	803	793	794	795	795	792	747	802	828	843	884	905	908

	P070 SUFCo 04/15/2002 16:00-18:00	SUFCo 04/15/2002 18:00-20:00	SUFCo 04/15/2002 20:00-24:00	SUFCo 04/16/2002 00:00-05:00	SUFCo 04/16/2002 05:00-10:00	SUFCo 04/16/2002 11:00-16:00	SUFCo 04/16/2002 18:00-20:00	SUFCo 04/17/2002 00:00-5:00	SUFCo 04/17/2002 07:00-12:00	SUFCo 04/17/2002 12:00-18:00	SUFCo 04/17/2002 20:00-23:00	SUFCo 04/18/2002 00:00-07:00	SUFCo 04/18/2002 08:00-11:00	SUFCo 04/18/2002 12:00-13:45	SUFCo 04/19/2002 12:00-16:30	SUFCo 04/19/2002 18:00-04:30	SUFCo 04/20/2002 05:00-07:00	Illinois No. 6 04/20/2002 07:30-13:30	Illinois No. 6 04/20/2002 13:30-14:45	Illinois No. 6 04/20/2002 17:00-19:00
SUMMARY OF THE DRY PRODUCT GAS																				
TOTAL PRODUCT GAS, scf/hr ------- >	19854	20016	19648	19933	20444	17923	19671	17967	16294	17122	19698	18767	21443	20103	15394	13158	22080	18264	17012	16402
H2	8.1%	8.4%	8.3%	8.5%	8.5%	8.7%	9.2%	8.9%	7.8%	8.5%	8.6%	11.1%	5.5%	4.0%	11.2%	12.9%	8.1%	8.0%	8.7%	9.7%
CO	6.1%	6.1%	5.9%	5.5%	5.7%	4.9%	5.2%	5.0%	4.3%	4.5%	5.3%	6.9%	2.7%	2.3%	6.8%	7.5%	6.8%	6.4%	7.8%	6.9%
CH4	1.1%	1.2%	1.1%	1.1%	1.1%	1.0%	1.1%	1.0%	0.9%	1.0%	1.0%	4.1%	2.0%	1.6%	3.6%	3.7%	1.4%	1.6%	1.8%	2.1%
CO2	12.9%	12.7%	12.8%	13.1%	13.0%	13.3%	13.5%	13.7%	13.7%	13.5%	13.4%	18.4%	13.3%	13.3%	19.3%	20.9%	12.3%	9.6%	11.6%	11.4%
N2	74.5%	73.9%	74.0%	74.1%	73.8%	74.0%	72.9%	73.8%	76.2%	75.7%	75.4%	59.4%	75.6%	77.5%	58.7%	54.9%	69.4%	73.1%	71.1%	69.4%
{ ppm } H2S	630	664	704	698	774	771	905	1058	1019	1064	1029	1500	1800	1700	1900	2100	550	100	113	100
SUMMARY OF THE ELEMENTAL AND MASS CLOSURE																				
#MOLES H	27%	23%	25%	19%	24%	-6%	0%	3%	7%	7%	12%	12%	20%	19%	9%	22%	-4%	-149%	4%	13%
#MOLES C	11%	5%	2%	13%	-5%	7%	12%	8%	-1%	-1%	-1%	1%	33%	-2%	10%	24%	25%	8%	28%	27%
#MOLES O	16%	14%	15%	11%	14%	-4%	-1%	0%	3%	3%	6%	1%	7%	2%	-2%	7%	-13%	-75%	-1%	14%
#MOLES S	1%	1%	0%	2%	0%	1%	2%	1%	0%	0%	1%	0%	6%	0%	2%	4%	13%	4%	15%	15%
#MOLES N	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	2%	0%	1%	1%	0%	1%	1%	0%	0%	0%
SUMMARY OF CARBON UTILIZATION																				
High Kinetics																				
% CARBON LOST BY GASIFICATION { Total }	21%	19%	20%	17%	19%	17%	15%	17%	19%	13%	17%	23%	18%	14%	27%	18%	19%	24%	24%	19%
% CARBON LOST BY COMBUSTION { Total }	71%	68%	65%	71%	71%	69%	73%	69%	70%	65%	69%	45%	73%	50%	51%	54%	76%	74%	69%	68%
% Carbon Removed In Filter Ash { Total }	5%	10%	11%	10%	8%	11%	9%	12%	9%	15%	12%	25%	6%	36%	16%	24%	2%	2%	6%	12%
% Carbon Removed In LASH { Total }	2%	3%	4%	2%	2%	3%	3%	3%	3%	7%	2%	7%	3%	0%	5%	5%	3%	0%	1%	0%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analys	-8%	-11%	-21%	-1%	-26%	-11%	2%	-7%	-26%	-14%	-19%	-21%	15%	-25%	-15%	23%	18%	-17%	11%	7%
Single-Pass CHAR Carbon Conversion { Gasification }	9.7%	8.2%	9.5%	6.2%	7.6%	6.2%	5.0%	5.8%	6.4%	4.3%	6.8%	3.6%	4.9%	8.1%	38.8%	13.9%	13.2%	15.5%	14.0%	14.9%
Single-Pass CHAR Carbon Conversion { Combustion }	25%	23%	24%	20%	22%	20%	19%	19%	19%	18%	22%	7%	16%	22%	42%	30%	35%	32%	28%	35%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3344	3566	3482	4001	3861	3702	4113	3767	3487	3738	3671	12675	6244	4376	1619	1803	3557	3008	3349	3136
Low Kinetics																				
% CARBON LOST BY GASIFICATION { Total }	6%	6%	6%	5%	6%	5%	5%	5%	6%	4%	5%	7%	5%	4%	8%	5%	5%	7%	7%	5%
% CARBON LOST BY COMBUSTION { Total }	85%	79%	77%	81%	82%	79%	82%	78%	81%	71%	79%	55%	84%	55%	65%	62%	89%	91%	84%	80%
% Carbon Removed In Filter Ash { Total }	6%	12%	13%	11%	9%	12%	11%	14%	10%	16%	14%	30%	7%	40%	21%	28%	2%	2%	7%	14%
% Carbon Removed In LASH { Total }	3%	4%	4%	3%	3%	3%	3%	3%	3%	8%	3%	8%	3%	0%	6%	5%	3%	0%	1%	0%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analys	9%	5%	-3%	11%	-8%	3%	13%	6%	-9%	-3%	-4%	-0%	27%	-12%	9%	33%	30%	5%	28%	21%
Single-Pass CHAR Carbon Conversion { Gasification }	2.5%	2.1%	2.4%	1.7%	2.0%	1.7%	1.4%	1.6%	1.8%	1.3%	1.8%	0.9%	1.3%	2.0%	8.9%	3.7%	3.2%	3.7%	3.3%	3.6%
Single-Pass CHAR Carbon Conversion { Combustion }	25%	23%	24%	20%	22%	20%	19%	19%	19%	18%	22%	7%	16%	22%	42%	30%	35%	32%	28%	35%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3344	3566	3482	4001	3861	3702	4113	3767	3487	3738	3671	12675	6244	4376	1619	1803	3557	3008	3349	3136
[H2O] { Inlet }	10.7%	10.6%	10.8%	10.6%	9.3%	9.4%	9.1%	10.0%	10.7%	10.3%	9.1%	32.7%	27.3%	26.5%	38.1%	52.0%	8.9%	8.8%	10.7%	9.8%
[H2O] After Combustion { No WGS }	10.0%	9.9%	10.0%	10.0%	8.7%	8.8%	8.5%	9.4%	10.0%	9.7%	8.5%	30.2%	25.9%	25.2%	35.2%	49.1%	8.3%	8.2%	10.0%	9.0%
[H2O] After Combustion { WGS }	5.8%	5.8%	5.8%	5.8%	4.9%	5.0%	4.7%	5.4%	5.9%	5.7%	4.8%	22.0%	19.8%	19.2%	26.6%	41.2%	4.6%	4.6%	5.7%	4.9%
[H2O] After Steam-Gasification { WGS }	0.5%	0.5%	0.4%	0.5%	0.4%	0.5%	0.5%	0.5%	0.5%	0.7%	0.5%	0.0%	0.3%	0.6%	1.1%	4.3%	0.6%	0.5%	0.3%	0.5%
SUMMARY OF THE SPREADSHEET RESULTS																				
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	92%	85%	82%	88%	87%	86%	88%	85%	86%	75%	83%	63%	93%	56%	76%	78%	96%	98%	94%	89%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (C	81%	80%	81%	75%	93%	79%	77%	78%	87%	77%	86%	61%	59%	57%	66%	53%	71%	90%	66%	61%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN)	77%	76%	74%	75%	67%	71%	68%	62%	57%	60%	59%	54%	12%	17%	38%	49%	17%	78%	85%	87%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (	-2%	-2%	-3%	-2%	-6%	-4%	-3%	-3%	-8%	-4%	-5%	-6%	-5%	-4%	-5%	-0%	-3%	-6%	-3%	-6%
Heat Loss from TRDU { Btu/hr }	-5.0E+04	-4.6E+04	-6.6E+04	-5.4E+04	-1.3E+05	-9.7E+04	-6.6E+04	-7.6E+04	-1.4E+05	-8.7E+04	-1.0E+05	-2.9E+05	-1.7E+05	-1.5E+05	-1.8E+05	-1.9E+04	-9.4E+04	-1.2E+05	-8.8E+04	-1.7E+05
HHV of Product Gas, 60 F w H2S w/o tar, Btu/scf	56	58	56	55	56	54	56	54	47	51	53	101	48	38	96	104	64	63	71	75
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Dry Corrected}	131	134	131	130	127	134	132	134	133	140	125	258	98	84	264	264	119	144	139	136
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet}	45	46	45	44	47	44	47	44	39	41	44	72	35	28	66	59	58	57	61	63
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet Corrected}	84	86	83	82	88	86	87	86	82	86	84	129	57	47	117	91	100	114	106	102
Gasifier Cold Gas Efficiency, % of coal HHV	44%	45%	44%	41%	51%	43%	43%	42%	43%	41%	45%	37%	28%	22%	38%	31%	41%	59%	42%	42%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3344	3566	3482	4001	3861	3702	4113	3767	3487	3738	3671	12675	6244	4376	1619	1803	3557	3008	3349	3136
COMPARISON OF SPREADSHEET RESULTS																				
delta T (°C)	127	93	88	65	52	58	79	83	101	114	111	98	93	150	65	68	57	60	67	64
Average Mixing Zone T (°C)	900	903	898	880	885	918	856	886	894	908	906	893	885	897	867	896	900	944	972	972
Average Low T (°C)	773	810	810	815	833	860	777	803	793	794	795	795	792	747	802	828	843	884	905	908
Air in (scfh)	11,405	11,799	11,801	11,851	12,299	13,247	10,000	5,759	4,147	4,038	2,964	0	0	0	0	0	0	750	749	730
Oxygen in (scfh)	0	0	0	0	0	0	214	1,141	1,464	1,501	1,540	2,217	2,260	2,171	2,490	2,501	2,499	2,496	2,638	2,572
Nitrogen in (scfh)	4,322	4,293	4,283	4,303	4,227	4,526	4,731	4,832	4,678	4,904	4,570	4,577	4,565	4,609	5,041	4,974	4,769	4,260	4,285	4,522
Product Gas (scfh)	17,575	18,424	18,744	19,158	19,672	20,990	16,599	15,056	14,163	13,881	13,363	11,520	11,798	11,610	10,993	10,828	10,636	10,289	9,746	11,762
Coal Feed Rate (lb/hr)	258	290	313	412	313	318	327	357	332	298	276	300	331	279	326	301	296	220	295	295
Air Flow (lb/hr)	873	903	903	907	941	1014	765	441	317	309	227	0	0	0	0	0	0	57	57	56
Steam Flow (lb/hr)	287	287	288	287	288	288	351	382	383	382	385	434	430	452	460	459	454	457	463	458
Air/Coal Ratio (lb/lb)	3.52	3.24	3.01	2.29	3.13	3.32	2.44	1.29	1.00	1.08	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.23	0.23
Steam/Coal Ratio (lb/lb)	1.16	1.03	0.96	0.73	0.96	0.94	1.12	1.11	1.20	1.34	1.45	1.51	1.35	1.69	1.47	1.59	1.60	2.50	1.89	1.87
O2/Coal Ratio (lb/lb)	0.82	0.75	0.70	0.53	0.73	0.77	0.62	0.58	0.62	0.69	0.69	0.65	0.60	0.68	0.67	0.73	0.74	1.23	0.96	0.94
Fraction Carbon in Coal	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.63	0.63	0.63
Bed Recycle Rate, lb/hr {by heat balance around burner}	3,344	3,566	3,482	4,001	3,861	3,702	4,113	3,767	3,487	3,738	3,671	12,675	6,244	4,376	1,619	1,803	3,557	3,008	3,349	3,136
Bed Recycle Rate,lb/hr {Calculated}	1,395	2,080	1,990	4,120	5,555	4,440	1,540	2,835	2,060	1,610	1,745	3,800	5,870	2,040	6,780	4,995	6,740	5,490	4,615	4,235

Gas Compositions from TRDU Test		P071								
Test		Pet Coke	Pet Coke	Pet Coke	Prater Creel	Prater Creel	Prater Creel	rater Creek	'rater Creek	'rater Creek
		06/10/2002	06/13/2002	06/13/2002	06/14/2002	06/14/2002	06/14/2002	06/15/2002	06/15/2002	06/15/2002
Product Gas Comp, vol%		16:00-20:00	10:00-14:00	16:00-20:00	5:00-7:39	09:00-19:00	20:00-04:00	04:00-12:00	13:00-20:00	20:00-01:00
	H2	6.7	19.0	18.8	13.9	14.8	14.2	14.7	14.2	14.1
	CO	5.6	9.2	9.9	7.8	7.2	7.4	7.6	7.8	7.7
	CH4	0.6	1.6	1.6	3.3	3.4	3.2	3.4	3.0	2.9
	CO2	12	22	20	17	17	18	18	16	15
	N2	74	49	50	58	59	62	61	61	62
	Total	99	101	101	100	102	105	104	102	102
	Ave Mol Wt	28	27	26	27	27	28	28	27	27
Flow, scfh										
	air in	13400	0	750	750	750	750	750	750	750
	oxygen in	0	2606	2562	2493	2492	2497	2514	2791	2649
	nitrogen in	5548	5823	5403	5445	5480	5487	5482	5323	5388
	product gas	20983	11601	12152	11970	12422	12163	12704	13606	13180
Product Gas, scfh										
	H2	1412	2205	2288	1660	1840	1728	1861	1935	1854
	CO	1179	1066	1198	935	892	902	966	1065	1008
	CH4	130	180	191	393	420	387	429	408	384
	CO2	2436	2541	2446	2078	2096	2188	2246	2152	2036
	N2	15576	5709	6104	6922	7379	7559	7726	8357	8181
	Total	20734	11700	12227	11988	12626	12765	13228	13917	13463
Heating Value, Btu/hr										
	H2 (325)	458955	716714	743669	539576	597905	561721	604892	628781	602673
	CO (321)	378541	342217	384617	300088	286301	289702	309938	341966	323647
	CH4 (1014)	131917	182327	193457	398112	425744	392201	435423	413881	388898
	Total	969414	1241257	1321743	1237776	1309950	1243624	1350253	1384629	1315218
Heating Value, Btu/scf										
	H2	22	62	61	45	48	46	48	46	46
	CO	18	29	32	25	23	24	24	25	25
	CH4	6	16	16	33	34	32	34	30	30
	Total	46	107	109	103	105	102	106	102	100
VALUES ADJUSTED FOR PURGE NITROGEN										
Product Gas Comp, vol%										
	H2	9.3%	37.5%	33.5%	25.4%	25.7%	23.7%	24.0%	22.5%	23.0%
	CO	7.8%	18.1%	17.6%	14.3%	12.5%	12.4%	12.5%	12.4%	12.5%
	CH4	0.9%	3.1%	2.8%	6.0%	5.9%	5.3%	5.5%	4.7%	4.7%
	CO2	16.0%	43.2%	35.8%	31.8%	29.3%	30.1%	29.0%	25.0%	25.2%
	N2	66.0%	-1.9%	10.3%	22.6%	26.6%	28.5%	29.0%	35.3%	34.6%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	25	25	26	25	26	26	26	25
Heating Value, Btu/scf		64	211	194	189	183	171	174	161	163
Product Gas, scfh										
	H2	1412	2205	2288	1660	1840	1728	1861	1935	1854
	CO	1179	1066	1198	935	892	902	966	1065	1008
	CH4	130	180	191	393	420	387	429	408	384
	CO2	2436	2541	2446	2078	2096	2188	2246	2152	2036
	N2	10028	-114	701	1477	1899	2072	2244	3034	2793
	Total	15186	5877	6824	6543	7146	7278	7746	8594	8075
FLUE GAS FLOWS ADJUSTED TO 450,000 BTU/HR HEAT LOSS										
Gas created due to combustion of										
Gas created due to combustion of		29	29	29	35	35	35	35	35	35
	CO2	451	451	451	547	547	547	547	547	547
	N2	1907	1907	1907	2313	2313	2313	2313	2313	2313
Product Gas, scfh										
	H2	1412	2205	2288	1660	1840	1728	1861	1935	1854
	CO	1179	1066	1198	935	892	902	966	1065	1008
	CH4	130	180	191	393	420	387	429	408	384
	CO2	1985	2090	1996	1531	1549	1641	1699	1606	1490
	N2	8121	130	721	717	717	717	718	732	725
	Total	12828	5671	6393	5236	5418	5376	5674	5746	5461

		P071								
		Pet Coke	Pet Coke	Pet Coke	Prater Creel	Prater Creel	Prater Creel	rater Creek	rater Creek	rater Creek
		06/10/2002	06/13/2002	06/13/2002	06/14/2002	06/14/2002	06/14/2002	06/15/2002	06/15/2002	06/15/2002
		16:00-20:00	10:00-14:00	16:00-20:00	5:00-7:39	09:00-19:00	20:00-04:00	04:00-12:00	13:00-20:00	20:00-01:00
Product Gas, vol %										
	H2	11	39	36	32	34	32	33	34	34
	CO	9.2	18.8	18.7	17.9	16.5	16.8	17.0	18.5	18.5
	CH4	1.0	3.2	3.0	7.5	7.8	7.2	7.6	7.1	7.0
	CO2	16	37	31	29	29	31	30	28	27
	N2	63	2	11	14	13	13	13	13	13
	Total	100	100	100	100	100	100	100	100	100
		27	23	23	24	23	24	23	23	23
Heating Value, Btu/scf		76	219	207	236	242	231	238	241	241
	Gasifier Temp C	1020	943	965	974	955	960	955	980	973
	Coal Feed Rate	289	208	241	247	312	286	303	329	308
	Air Flow (lb/hr)	1025	0	57	57	57	57	57	57	57
	Steam Flow (lb/hr)	261	456	456	456	456	456	456	473	467
	O2 flow (lb/hr)	0	220	216	210	210	211	212	236	224
	Air/Coal Ratio (lb/lb)	4.73	0.00	0.32	0.25	0.20	0.21	0.20	0.19	0.20
	Steam/Coal Ratio (lb/lb)	1.20	2.92	2.52	1.96	1.56	1.70	1.60	1.53	1.61
	O2/Coal Ratio (lb/lb)	1.10	1.41	1.27	0.96	0.76	0.83	0.79	0.80	0.82
	O2/maf Coal Ratio (lb/lb)	1.12	1.44	1.29	1.12	0.88	0.97	0.92	0.93	0.95
	Recirc Rate (lb/hr)	2261	3900	2729	2152	3800	6105	5322	5352	5022
	Fraction Carbon in Coal	0.90	0.90	0.90	0.71	0.71	0.71	0.71	0.71	0.71
	Fraction Sorbent in Coal	25%	25%	25%	6%	6%	6%	6%	6%	6%
	Coal Heating Value BTU/lb	15584	15584	15584	12847	12847	12847	12847	12847	12847
	Wt WAter (lb/hr)	214	370	388	424	440	430	412	442	428
	Wt LASH lb/hr	0	0	0	0	0	18	0	0	0
	Fraction C in LASH	11.6%	28.2%	32.8%	9.2%	9.5%	4.9%	7.2%	10.9%	10.6%
	WT filter ash lb/hr	141	69	77	88	129	90	101	91	97
	Fraction C in filter ash	0.30	0.44	0.48	0.59	0.62	0.64	0.65	0.62	0.64
	Wt dipleg lb/hr	0	0	0	10	0	4	0	0	0
	Fraction C in dipleg	15.5%	0.0%	30.3%	19.0%	9.0%	8.2%	0.0%	0.0%	0.0%
	TRDU Throughput lb/hr-ft^2	3245	2339	2706	3477	4388	4023	4265	4634	4330
	TRDU Throughput MMBtu/	51	36	42	45	56	52	55	60	56
	TRDU Riser Vel ft/s	54	62	64	65	64	65	65	67	67
	% Moisture As run	1	1	1	7	7	7	7	7	7
	Ultimate As run									
	C	90	90	90	71	71	71	71	71	71
	H	4.0	4.0	4.0	5.2	5.2	5.2	5.2	5.2	5.2
	N	1.7	1.7	1.7	1.5	1.5	1.5	1.5	1.5	1.5
	S	5.4	5.4	5.4	0.7	0.7	0.7	0.7	0.7	0.7
	O	-2	-2	-2	15	15	15	15	15	15
	Ash	1.0	1.0	1.0	6.6	6.6	6.6	6.6	6.6	6.6
	Carbon Conversion									
	Solid Accountability	78	78	77	68	61	69	68	74	70
	Gas Make	58	81	71	65	51	57	56	52	52
	Cold Gas Efficiency	28	51	47	42	35	38	38	36	36
	Cold Gas Eff cor	29	51	47	41	35	36	37	35	35
	Carbon Conv (calc)	129	124	107	150	147	146	134	126	126
	PG HHV (GC - Btu/scf)	46	107	109	104	106	103	104	102	98
	Hot Gas Eff (calc)	44	65	58	73	72	75	69	65	65
	Cold Gas Eff. (calc)	31	54	49	60	60	61	57	54	53
		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
		0	0	0	0	0	0	0	0	0
	H2S concetration (ppm)	758	4620	4798	1776	1613	1484	1416	1320	1259
	ulfur Retention (%)	89	47	50	-10	18	19	24	30	31
	1-Lig, 2-Sub, 3-Bit, 4-Pet	4	4	4	3	3	3	3	3	3
	TC416 thermocouple (402	904	839	880	880	879	897	888	910	903

	P071								
	Pet Coke	Pet Coke	Pet Coke	Prater Cree	Prater Cree	Prater Cree	rater Creek	rater Creek	rater Creek
	06/10/2002	06/13/2002	06/13/2002	06/14/2002	06/14/2002	06/14/2002	06/15/2002	06/15/2002	06/15/2002
	16:00-20:0C	10:00-14:0C	16:00-20:0C	5:00-7:39	09:00-19:0C	20:00-04:0C	04:00-12:0C	13:00-20:0C	20:00-01:0C
SUMMARY OF THE DRY PRODUCT GAS									
TOTAL PRODUCT GAS, scf/hr ------->	17833	22587	17399	14596	14389	12957	17085	17895	17203
H2	8.6%	7.6%	16.8%	14.3%	11.1%	18.0%	7.7%	7.4%	6.5%
CO	7.2%	4.0%	7.0%	5.2%	3.9%	5.2%	8.1%	8.7%	6.7%
CH4	1.7%	1.7%	2.9%	2.9%	2.8%	3.2%	2.4%	2.2%	1.6%
CO2	12.0%	13.9%	19.4%	18.8%	20.1%	23.1%	10.6%	9.8%	10.2%
N2	70.2%	72.7%	53.8%	57.3%	60.6%	49.8%	70.6%	70.6%	74.1%
{ppm} H2S	115	800	1300	1300	600	1000	50	50	50
SUMMARY OF THE ELEMENTAL AND MASS CLOSURE									
#MOLES H	-3%	-5%	3%	22%	8%	11%	0%	3%	16%
#MOLES C	9%	12%	-4%	27%	18%	10%	16%	19%	31%
#MOLES O	-3%	-11%	-1%	9%	0%	5%	-5%	-3%	4%
#MOLES S	5%	7%	-2%	14%	9%	5%	11%	14%	22%
#MOLES N	0%	0%	0%	0%	-1%	-1%	0%	0%	0%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	0%	0%	0%	0%	0%	0%	0%	0%	0%
SUMMARY OF CARBON UTILIZATION									
High Kinetics									
% CARBON LOST BY GASIFICATION {Total}	17%	9%	6%	3%	2%	2%	3%	18%	2%
% CARBON LOST BY COMBUSTION {Total}	69%	74%	68%	56%	60%	69%	72%	64%	80%
% Carbon Removed In Filter Ash {Total}	14%	12%	24%	38%	38%	21%	23%	15%	18%
% Carbon Removed In LASH {Total}	0%	5%	2%	3%	0%	8%	1%	3%	0%
Char Carbon Accounted For {Comb + S.Gasif + Filter + LASH}	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analy	-7%	13%	13%	43%	25%	28%	24%	16%	32%
Single-Pass CHAR Carbon Conversion {Gasification}	16.2%	7.0%	2.7%	1.0%	0.3%	0.3%	4.3%	4.6%	3.1%
Single-Pass CHAR Carbon Conversion {Combustion}	39%	36%	23%	16%	9%	9%	48%	14%	60%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	2872	2578	3927	3700	8874	7966	3217	2771	5221
Low Kinetics									
% CARBON LOST BY GASIFICATION {Total}	5%	3%	2%	1%	1%	1%	0%	1%	0%
% CARBON LOST BY COMBUSTION {Total}	79%	79%	71%	57%	61%	69%	75%	77%	82%
% Carbon Removed In Filter Ash {Total}	16%	13%	25%	39%	38%	21%	24%	18%	18%
% Carbon Removed In LASH {Total}	0%	5%	2%	3%	0%	8%	1%	4%	0%
Char Carbon Accounted For {Comb + S.Gasif + Filter + LASH}	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analy	7%	19%	17%	44%	26%	29%	27%	30%	33%
Single-Pass CHAR Carbon Conversion {Gasification}	3.9%	2.0%	0.9%	0.4%	0.1%	0.1%	0.2%	0.2%	0.2%
Single-Pass CHAR Carbon Conversion {Combustion}	39%	36%	23%	16%	9%	9%	48%	14%	60%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	2872	2578	3927	3700	8874	7966	3217	2771	5221
[H2O] {Inlet}	9.1%	26.9%	39.8%	48.0%	49.7%	58.8%	9.4%	6.6%	9.0%
[H2O] After Combustion {No WGS}	8.4%	25.6%	37.5%	46.1%	47.6%	56.4%	8.9%	6.2%	8.5%
[H2O] After Combustion {WGS}	4.5%	19.7%	29.7%	39.9%	40.6%	49.5%	5.8%	3.9%	5.5%
[H2O] After Steam-Gasification {WGS}	0.7%	4.4%	4.0%	11.9%	6.3%	9.8%	5.0%	2.4%	4.8%
SUMMARY OF THE SPREADSHEET RESULTS									
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	85%	85%	77%	77%	72%	79%	82%	85%	88%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (	76%	73%	81%	49%	53%	68%	66%	66%	57%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN)	82%	-30%	-54%	-4%	49%	6%	91%	91%	91%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (	-8%	-4%	-6%	2%	-6%	-6%	-4%	-4%	-4%
Heat Loss from TRDU {Btu/hr}	-1.9E+05	-1.2E+05	-2.0E+05	7.8E+04	-2.4E+05	-1.8E+05	-1.2E+05	-1.2E+05	-1.3E+05
HHV of Product Gas, 60 F w H2S w/o tar, Btu/scf	68	55	107	94	78	109	76	75	59
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Dry Corrected}	126	105	254	254	233	245	137	137	114
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet}	60	41	74	55	42	55	70	71	54
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet Corrected}	102	63	122	87	64	77	119	124	95
Gasifier Cold Gas Efficiency, % of coal HHV	47%	38%	54%	31%	28%	43%	44%	44%	33%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	2872	2578	3927	3700	8874	7966	3217	2771	5221
COMPARISON OF SPREADSHEET RESULTS									
delta T (°C)	116	104	85	94	76	63	67	70	70
Average Mixing Zone T (°C)	1020	943	965	974	955	960	955	980	973
Average Low T (°C)	904	839	880	880	879	897	888	910	903
Air in (scfh)	13,400	0	750	750	750	750	750	750	750
Oxygen in (scfh)	0	2,606	2,562	2,493	2,492	2,497	2,514	2,791	2,649
Nitrogen in (scfh)	5,548	5,823	5,403	5,445	5,480	5,487	5,482	5,323	5,388
Product Gas (scfh)	20,983	11,601	12,152	11,970	12,422	12,163	12,704	13,606	13,180
Coal Feed Rate (lb/hr)	289	208	241	247	312	286	303	329	308
Air Flow (lb/hr)	1025	0	57	57	57	57	57	57	57
Steam Flow (lb/hr)	261	456	456	456	456	456	456	473	467
Air/Coal Ratio (lb/lb)	4.73	0.00	0.32	0.25	0.20	0.21	0.20	0.19	0.20
Steam/Coal Ratio (lb/lb)	1.20	2.92	2.52	1.96	1.56	1.70	1.60	1.53	1.61
O2/Coal Ratio (lb/lb)	1.10	1.41	1.27	0.96	0.76	0.83	0.79	0.80	0.82
Fraction Carbon in Coal	0.90	0.90	0.90	0.71	0.71	0.71	0.71	0.71	0.71
Bed Recycle Rate, lb/hr {by heat balance around burner}	2,872	2,578	3,927	3,700	8,874	7,966	3,217	2,771	5,221
Bed Recycle Rate,lb/hr {Calculated}	2,261	3,900	2,729	2,152	3,800	6,105	5,322	5,352	5,022

		P072a						P072B														
		Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Pittsburgh N	Pittsburgh N	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet
		10/08/2002	10/08/2002	10/08/2002	10/09/2002	10/09/2002	10/09/2002	10/21/2002	10/21/2002	10/22/2002	10/22/2002	10/22/2002	10/23/2002	10/23/2002	10/23/2002	10/23/2002	10/24/2002	10/24/2002	10/24/2002	10/24/2002	10/24/2002	10/25/2002
		01:00-05:00	06:00-09:00	16:00-20:00	22:00-04:00	14:00-19:00	20:00-21:30	09:34-13:33	17:30-01:35	01:35-11:00	11:00-15:00	17:30-20:00	02:00-04:00	05:30-08:00	13:00-16:00	16:00-20:00	00:00-04:00	05:00-08:00	10:00-16:00	16:00-20:00	20:00-24:00	00:00-04:00
Product Gas, vol %																						
	H2	5	6	12	29	31	27	28	28	31	33	26	28	29	30	30	33	32	32	32	32	33
	CO	3.6	3.8	6.2	15.2	15.3	14.2	15.7	15.1	16.6	13.8	12.1	13.3	14.1	14.5	14.8	18.3	16.5	17.7	16.8	17.5	18.2
	CH4	1.3	1.4	3.0	7.8	6.1	5.6	5.6	5.0	5.6	4.6	4.5	6.5	6.6	7.8	7.7	6.8	6.3	7.1	6.5	6.3	6.0
	CO2	10	10	17	33	33	39	34	35	31	32	40	36	35	34	34	30	33	31	32	32	31
	N2	80	79	63	15	15	14	16	17	16	17	18	17	15	13	14	12	13	13	12	12	12
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		28	28	27	25	25	27	25	26	24	24	27	26	25	25	25	23	24	24	24	24	24
Heating Value, Btu/scf		42	47	88	223	210	189	199	191	210	197	171	199	207	224	223	235	220	232	224	225	227
	Gasifier Temp C	964	974	941	934	990	969	1011	1028	1016	1030	1035	957	953	940	949	987	989	982	987	1006	1015
	Coal Feed Rate	269	253	306	334	281	289	283	279	294	382	255	244	281	311	305	351	322	293	305	300	327
	Air Flow (lb/hr)	899	899	421	57	57	54	57	57	57	63	68	68	68	54	54	54	54	54	54	54	54
	Steam Flow (lb/hr)	262	262	416	416	425	422	436	436	438	439	438	437	435	441	440	434	435	438	437	437	435
	O2 flow (lb/hr)	0	0	118	194	209	188	232	223	229	211	190	184	186	188	194	228	210	214	216	229	232
	Air/Coal Ratio (lb/lb)	4.03	4.28	1.65	0.21	0.25	0.22	0.24	0.25	0.23	0.18	0.31	0.30	0.26	0.19	0.19	0.16	0.18	0.20	0.19	0.19	0.18
	Steam/Coal Ratio (lb/lb)	1.18	1.25	1.64	1.50	1.82	1.76	1.86	1.88	1.79	1.28	1.98	1.93	1.67	1.53	1.55	1.33	1.45	1.61	1.54	1.57	1.43
	O2/Coal Ratio (lb/lb)	0.93	0.99	0.85	0.75	0.95	0.84	1.04	1.02	0.99	0.66	0.93	0.88	0.77	0.69	0.73	0.74	0.74	0.83	0.80	0.87	0.80
	O2/maf Coal Ratio (lb/lb)	1.16	1.23	1.05	0.93	1.18	1.03	1.29	1.27	1.23	0.73	1.03	1.09	0.96	0.86	0.91	0.91	0.92	1.03	1.00	1.07	1.00
	Recirc Rate (lb/hr)	1910	2162	2005	4804	4510	3829	8464	8272	7314	6842	5954	6623	6323	4595	6375	6613	5768	6289	6578	6463	6794
	Fraction Carbon in Coal	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.76	0.76	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
	Fraction Sorbent in Coal	17%	17%	17%	17%	17%	17%	17%	17%	17%	10%	13%	7%	7%	7%	7%	7%	7%	7%	7%	7%	7%
	Coal Heating Value BTU/lb	11300	11300	11300	11300	11300	11300	11300	11300	11300	13327	13327	12214	12214	12214	12214	12214	12214	12214	12214	12214	12214
	Wt WAter (lb/hr)	236	232	429	371	378	371	390	394	401	375	357	349	351	347	347	371	354	348	357	363	369
	Wt LASH lb/hr	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	62	4	0	0	0
	Fraction C in LASH	1.0%	3.9%	3.6%	4.7%	1.0%	0.4%	1.2%	0.3%	0.9%	0.2%	0.5%	2.5%	3.0%	3.7%	3.2%	2.6%	2.1%	5.1%	4.8%	4.3%	4.3%
	WT filter ash lb/hr	62	67	120	119	73	183	59	64	61	95	56	88	109	91	107	109	76	98	93	97	86
	Fraction C in filter ash	0.34	0.29	0.30	0.46	0.30	0.24	0.44	0.24	0.36	0.19	0.32	0.51	0.57	0.61	0.56	0.56	0.52	0.53	0.53	0.53	0.53
	Wt dipleg lb/hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fraction C in dipleg																					
	TRDU Throughput lb/hr-ft^2	3336	3147	3807	4152	3496	3593	3518	3464	3658	5151	3316	3390	3905	4323	4239	4887	4476	4079	4246	4170	4546
	TRDU Throughput MMBtu/t	38	36	43	47	40	41	40	39	41	69	44	41	48	53	52	60	55	50	52	51	56
	TRDU Riser Vel ft/s	67	68	65	56	60	59	62	62	62	62	62	59	58	58	59	60	60	59	59	60	60
	% Moisture As run	9	9	9	9	9	9	9	9	9	2	2	3	3	3	3	3	3	3	3	3	3
	Ultimate As run																					
	C	63	63	63	63	63	63	63	63	63	76	76	67	67	67	67	67	67	67	67	67	67
	H	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.4	5.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
	N	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.4	1.4	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	S	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6	1.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	O	16	16	16	16	16	16	16	16	16	8	8	10	10	10	10	10	10	10	10	10	10
	Ash	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	10.7	7.3	7.3	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
	Carbon Conversion																					
	Solid Accountability	85	85	77	69	85	71	83	89	86	93	90	70	64	72	68	72	80	71	74	73	77
	Gas Make	49	50	46	58	67	68	63	62	61	34	57	68	63	56	55	55	55	61	60	63	58
	Cold Gas Efficiency	18	21	22	35	38	33	34	31	35	20	26	35	34	32	31	35	31	38	35	36	34
	Cold Gas Eff cor	18	21	22	35	39	33	34	31	35	20	27	35	34	32	32	35	32	38	35	38	36
	Carbon Conv (calc)	38	61	81	103	108	99	103	107	94	93	99	93	126	97	93	105	107	130	122	125	127
	PG HHV (GC - Btu/scf)	23	26	46	96	85	76	73	66	76	76	70	88	99	104	99	120	104	115	109	112	113
	Hot Gas Eff (calc)	21	36	45	62	63	50	65	66	64	64	56	59	82	67	65	77	74	85	85	88	91
	Cold Gas Eff. (calc)	11	21	31	50	50	38	49	49	49	48	41	46	65	54	52	64	60	69	69	72	75
		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97										
		0	0	0	0	0	0	0	0	0	0	0										
	H2S concetration (ppm)	0	157	1112	2461	3420	3241	3009	3447	3291	3462	2809	1664	1665	1708	1594	1593	1636	1802	1487	1498	1475
	ulfur Retention (%)	100	96	84	73	54	58	58	51	55	35	23	2	15	22	26	31	26	12	29	26	32
	1-Lig, 2-Sub, 3-Bit, 4-Pet	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
	TC416 thermocouple (402-	807	837	807	815	895	885	938	953	935	951	952	887	884	869	880	912	913	906	909	923	935

Gas Compositions from TRDU Test		P072a						P072B														
Test		Illinois No. 6	Ilinois No. 6	Ilinois No. 6	Ilinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Illinois No. 6	Pittsburgh N	Pittsburgh N	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet	Calumet
		10/08/2002	10/08/2002	10/08/2002	10/09/2002	10/09/2002	10/09/2002	10/21/2002	10/21/2002	10/22/2002	10/22/2002	10/22/2002	10/23/2002	10/23/2002	10/23/2002	10/23/2002	10/24/2002	10/24/2002	10/24/2002	10/24/2002	10/24/2002	10/25/2002
Product Gas Comp, vol%		01:00-05:00	06:00-09:00	16:00-20:00	22:00-04:00	14:00-19:00	20:00-21:30	09:34-13:33	17:30-01:35	01:35-11:00	11:00-15:00	17:30-20:00	02:00-04:00	05:30-08:00	13:00-16:00	16:00-20:00	00:00-04:00	05:00-08:00	10:00-16:00	16:00-20:00	20:00-24:00	00:00-04:00
	H2	2.9	3.4	6.1	12.6	12.4	10.7	10.4	9.8	11.1	12.6	10.9	12.3	13.9	14.1	13.4	16.8	14.9	15.7	15.5	16.0	16.5
	CO	2.0	2.1	3.2	6.5	6.2	5.7	5.7	5.2	6.0	5.4	5.0	5.9	6.7	6.8	6.6	9.3	7.8	8.7	8.2	8.7	9.1
	CH4	0.7	0.8	1.6	3.3	2.5	2.2	2.0	1.7	2.1	1.8	1.9	2.9	3.2	3.6	3.4	3.5	3.0	3.5	3.2	3.1	3.0
	CO2	9	8	13	20	19	21	18	17	16	17	21	21	22	21	20	20	20	20	21	21	20
	N2	85	85	78	59	59	62	64	65	64	64	59	56	53	54	54	49	51	52	51	48	47
	Total	100	100	102	102	99	102	100	99	100	101	98	98	98	99	98	99	97	101	98	97	96
	Ave Mol Wt	28	28	29	28	27	29	28	28	27	27	28	27	27	27	27	26	26	27	26	26	26
Flow, scfh																						
	air in	11750	11750	5500	750	750	700	750	750	750	818	890	890	890	700	700	700	700	700	700	700	700
	oxygen in	0	0	1400	2300	2475	2228	2743	2646	2716	2501	2250	2177	2201	2229	2303	2698	2488	2534	2553	2711	2748
	nitrogen in	5503	5487	5519	5423	5034	5462	5385	4924	4577	4445	4365	4441	4494	5109	5126	5156	5182	5183	5149	5146	5168
	product gas	19874	19502	13540	11443	11952	11717	12302	12446	12670	11854	11273	11018	11089	10945	10965	11718	11174	10976	11265	11461	11653
Product Gas, scfh																						
	H2	566	667	819	1439	1478	1258	1279	1217	1404	1496	1228	1350	1538	1544	1474	1963	1668	1726	1749	1836	1919
	CO	401	410	439	745	741	667	706	647	764	634	566	650	741	740	723	1089	869	956	921	995	1058
	CH4	147	154	211	380	295	261	251	217	260	211	211	320	349	395	376	407	334	384	356	356	351
	CO2	1749	1652	1789	2244	2243	2472	2155	2115	2068	2010	2366	2325	2398	2321	2228	2380	2288	2239	2343	2382	2368
	N2	16944	16606	10549	6807	7029	7288	7922	8136	8119	7577	6642	6200	5866	5865	5969	5705	5719	5750	5709	5547	5507
	Total	19808	19489	13806	11615	11787	11947	12314	12332	12614	11929	11013	10844	10892	10866	10770	11543	10879	11056	11079	11116	11203
Heating Value, Btu/hr																						
	H2 (325)	184079	216769	266222	467831	480500	408996	415801	395609	456232	486200	398994	438646	499846	501892	478951	637899	542181	561110	568573	596696	623735
	CO (321)	128864	131466	140817	239117	237869	214017	226666	207755	245237	203578	181662	208666	237771	237493	231953	349441	279052	306873	295794	319324	339636
	CH4 (1014)	149124	156226	214175	385213	299347	264956	254470	219599	263363	213959	213764	323989	354181	400631	381365	412307	338774	389531	360958	361415	355654
	Total	462067	504461	621214	1092161	1017716	887969	896937	822963	964832	903737	794420	971302	1091798	1140017	1092269	1399647	1160007	1257515	1225324	1277435	1319024
Heating Value, Btu/scf																						
	H2	9	11	20	41	40	35	34	32	36	41	35	40	45	46	44	54	49	51	50	52	54
	CO	6	7	10	21	20	18	18	17	19	17	16	19	21	22	21	30	25	28	26	28	29
	CH4	8	8	16	34	25	23	21	18	21	18	19	29	32	37	35	35	30	35	32	32	31
	Total	23	26	46	95	85	76	73	66	76	76	70	88	98	104	100	119	104	115	109	111	113
VALUES ADJUSTED FOR PURGE NITROGEN																						
Product Gas Comp, vol%																						
	H2	4.0%	4.8%	9.9%	23.2%	21.9%	19.4%	18.5%	16.4%	17.5%	20.0%	18.5%	21.1%	24.0%	26.8%	26.1%	30.7%	29.3%	29.4%	29.5%	30.8%	31.8%
	CO	2.8%	2.9%	5.3%	12.0%	11.0%	10.3%	10.2%	8.7%	9.5%	8.5%	8.5%	10.2%	11.6%	12.9%	12.8%	17.0%	15.3%	16.3%	15.5%	16.7%	17.5%
	CH4	1.0%	1.1%	2.5%	6.1%	4.4%	4.0%	3.6%	2.9%	3.2%	2.8%	3.2%	5.0%	5.5%	6.9%	6.7%	6.4%	5.9%	6.5%	6.0%	6.0%	5.8%
	CO2	12.2%	11.8%	21.6%	36.2%	33.2%	38.1%	31.1%	28.5%	25.7%	26.9%	35.6%	36.3%	37.5%	40.3%	39.5%	37.3%	40.2%	38.1%	39.5%	39.9%	39.2%
	N2	80.0%	79.4%	60.7%	22.4%	29.5%	28.2%	36.6%	43.4%	44.1%	41.9%	34.3%	27.5%	21.4%	13.1%	14.9%	8.6%	9.4%	9.7%	9.4%	6.7%	5.6%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	29	29	29	27	27	29	28	28	27	27	29	28	27	27	27	25	26	26	26	26	25
Heating Value, Btu/scf		32	36	75	176	151	137	129	111	120	121	119	152	171	198	194	219	204	214	207	214	219
Product Gas, scfh																						
	H2	566	667	819	1439	1478	1258	1279	1217	1404	1496	1228	1350	1538	1544	1474	1963	1668	1726	1749	1836	1919
	CO	401	410	439	745	741	667	706	647	764	634	566	650	741	740	723	1089	869	956	921	995	1058
	CH4	147	154	211	380	295	261	251	217	260	211	211	320	349	395	376	407	334	384	356	356	351
	CO2	1749	1652	1789	2244	2243	2472	2155	2115	2068	2010	2366	2325	2398	2321	2228	2380	2288	2239	2343	2382	2368
	N2	11441	11119	5030	1384	1995	1826	2537	3212	3542	3132	2277	1759	1372	756	843	549	537	567	560	401	339
	Total	14305	14002	8287	6192	6753	6485	6929	7408	8037	7484	6648	6403	6398	5757	5644	6387	5697	5873	5930	5970	6035
FLUE GAS FLOWS ADJUSTED TO 450,000 BTU/HR HEAT LOSS																						
Gas created due to combustion of																						
Gas created due to combustion of		40	40	40	40	40	40	40	40	40	34	34	37	37	37	37	37	37	37	37	37	37
	CO2	622	622	622	622	622	622	622	622	622	527	527	575	575	575	575	575	575	575	575	575	575
	N2	2630	2630	2630	2630	2630	2630	2630	2630	2630	2230	2230	2433	2433	2433	2433	2433	2433	2433	2433	2433	2433
Product Gas, scfh																						
	H2	566	667	819	1439	1478	1258	1279	1217	1404	1496	1228	1350	1538	1544	1474	1963	1668	1726	1749	1836	1919
	CO	401	410	439	745	741	667	706	647	764	634	566	650	741	740	723	1089	869	956	921	995	1058
	CH4	147	154	211	380	295	261	251	217	260	211	211	320	349	395	376	407	334	384	356	356	351
	CO2	1127	1030	1167	1622	1622	1851	1534	1493	1446	1483	1839	1750	1823	1746	1653	1805	1713	1664	1768	1807	1793
	N2	8811	8489	4415	708	716	664	730	725	728	771	816	812	813	664	668	688	677	680	681	689	690
	Total	11053	10750	7051	4894	4853	4702	4500	4299	4602	4596	4659	4881	5265	5090	4894	5951	5262	5410	5476	5682	5811

	P072a Illinois No. 6 10/08/2002 01:00-05:00	Illinois No. 6 10/08/2002 06:00-09:00	Illinois No. 6 10/08/2002 16:00-20:00	Illinois No. 6 10/09/2002 22:00-04:00	Illinois No. 6 10/09/2002 14:00-19:00	Illinois No. 6 10/09/2002 20:00-21:30	P072B Illinois No. 6 10/21/2002 09:34-13:33	Illinois No. 6 10/21/2002 17:30-01:35	Illinois No. 6 10/22/2002 01:35-11:00	Pittsburgh N 10/22/2002 11:00-15:00	Pittsburgh N 10/22/2002 17:30-20:00	Calumet 10/23/2002 02:00-04:00	Calumet 10/23/2002 05:30-08:00	Calumet 10/23/2002 13:00-16:00	Calumet 10/23/2002 16:00-20:00	Calumet 10/24/2002 00:00-04:00	Calumet 10/24/2002 05:00-08:00	Calumet 10/24/2002 10:00-16:00	Calumet 10/24/2002 16:00-20:00	Calumet 10/24/2002 20:00-24:00	Calumet 10/25/2002 00:00-04:00
SUMMARY OF THE DRY PRODUCT GAS																					
TOTAL PRODUCT GAS, scf/hr ------->	17441	17017	16711	17333	24750	13598	13743	20060	21625	20115	19360	18540	15360	16040	14830	16735	16280	16120	16510	16390	16310
H2	5.2%	6.7%	6.2%	6.0%	5.3%	7.9%	7.3%	4.1%	5.5%	5.3%	5.3%	4.3%	5.4%	6.0%	6.3%	5.9%	5.0%	5.7%	6.6%	6.3%	4.5%
CO	7.0%	6.4%	6.4%	6.2%	5.4%	6.6%	6.8%	4.2%	5.7%	6.0%	5.8%	4.8%	4.9%	5.8%	5.4%	5.7%	4.9%	5.3%	5.3%	5.3%	4.1%
CH4	1.6%	1.8%	1.6%	1.2%	1.6%	1.5%	1.4%	1.3%	1.6%	1.4%	1.4%	1.2%	1.3%	1.8%	1.6%	1.4%	1.2%	1.2%	1.6%	1.5%	1.5%
CO2	8.6%	10.2%	9.8%	9.7%	8.9%	11.7%	11.9%	11.6%	10.8%	10.9%	10.3%	11.0%	10.7%	10.9%	11.2%	11.1%	11.9%	11.6%	11.4%	11.3%	12.2%
N2	77.0%	74.0%	75.2%	74.9%	78.5%	73.8%	73.4%	79.1%	77.2%	76.9%	77.0%	77.9%	77.2%	74.5%	73.9%	73.8%	75.0%	73.9%	72.9%	73.0%	78.9%
{ ppm } H2S	50	50	50	50	20	1750	400	300	300	300	300	300	300	300	300	300	300	300	300	300	300
SUMMARY OF THE ELEMENTAL AND MASS CLOSURE																					
#MOLES H	13%	11%	19%	21%	-135%	4%	7%	-10%	-20%	-50%	-252%	-17%	-22%	19%	31%	21%	-2%	32%	20%	45%	12%
#MOLES C	16%	17%	14%	9%	20%	17%	6%	22%	18%	18%	17%	-8%	7%	11%	16%	21%	24%	-7%	23%	18%	7%
#MOLES O	5%	6%	10%	12%	-82%	-2%	-2%	-9%	-16%	-31%	-142%	-9%	-10%	11%	18%	14%	-4%	17%	15%	27%	7%
#MOLES S	12%	12%	10%	6%	14%	1%	0%	2%	1%	1%	1%	-1%	0%	1%	1%	1%	2%	0%	2%	1%	0%
#MOLES N	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SUMMARY OF CARBON UTILIZATION																					
High Kinetics																					
% CARBON LOST BY GASIFICATION { Total }	14%	4%	9%	2%	10%	14%	23%	20%	19%	20%	22%	27%	19%	15%	18%	29%	30%	27%	31%	30%	20%
% CARBON LOST BY COMBUSTION { Total }	61%	75%	66%	70%	74%	61%	54%	65%	62%	60%	63%	55%	55%	55%	58%	61%	57%	44%	59%	55%	57%
% Carbon Removed In Filter Ash { Total }	22%	21%	24%	27%	14%	23%	20%	10%	13%	17%	9%	13%	26%	27%	21%	9%	12%	11%	11%	14%	23%
% Carbon Removed In LASH { Total }	2%	0%	0%	0%	2%	2%	4%	5%	6%	3%	6%	4%	0%	2%	3%	0%	1%	17%	0%	0%	0%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analysi	2%	15%	5%	-1%	17%	3%	-21%	-16%	-8%	-14%	-13%	-81%	-33%	-13%	-11%	-33%	-33%	-72%	-31%	-38%	-38%
Single-Pass CHAR Carbon Conversion { Gasification }	4.2%	3.6%	3.1%	6.2%	12.4%	8.6%	9.1%	9.3%	13.2%	9.4%	11.8%	56.8%	6.5%	5.3%	6.3%	12.1%	13.0%	16.8%	10.6%	11.2%	7.1%
Single-Pass CHAR Carbon Conversion { Combustion }	16%	43%	18%	65%	47%	27%	18%	24%	30%	22%	25%	54%	16%	16%	17%	21%	19%	21%	17%	17%	17%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3832	4566	5384	4336	1682	2302	2178	3005	2349	3171	2390	1284	3370	3423	3031	3115	2835	2617	3252	3206	3148
Low Kinetics																					
% CARBON LOST BY GASIFICATION { Total }	1%	0%	1%	0%	1%	1%	2%	2%	2%	2%	2%	6%	2%	1%	1%	4%	4%	4%	4%	4%	2%
% CARBON LOST BY COMBUSTION { Total }	71%	78%	72%	72%	81%	70%	68%	80%	75%	74%	79%	71%	66%	64%	69%	83%	78%	59%	81%	76%	69%
% Carbon Removed In Filter Ash { Total }	26%	22%	27%	28%	16%	27%	25%	12%	16%	21%	11%	17%	32%	32%	26%	13%	16%	15%	15%	20%	29%
% Carbon Removed In LASH { Total }	2%	0%	0%	0%	2%	2%	5%	6%	7%	4%	8%	6%	0%	3%	4%	0%	1%	22%	0%	0%	0%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analysi	15%	18%	13%	1%	25%	16%	5%	5%	10%	7%	10%	-41%	-10%	3%	8%	1%	4%	-31%	5%	-0%	-13%
Single-Pass CHAR Carbon Conversion { Gasification }	0.3%	0.2%	0.2%	0.5%	0.9%	0.6%	0.6%	0.8%	1.2%	0.8%	1.0%	9.3%	0.5%	0.3%	0.4%	1.2%	1.3%	1.9%	1.0%	1.1%	0.5%
Single-Pass CHAR Carbon Conversion { Combustion }	16%	43%	18%	65%	47%	27%	18%	24%	30%	22%	25%	54%	16%	16%	17%	21%	19%	21%	17%	17%	17%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3832	4566	5384	4336	1682	2302	2178	3005	2349	3171	2390	1284	3370	3423	3031	3115	2835	2617	3252	3206	3148
[H2O] { Inlet }	3.9%	11.4%	11.4%	10.9%	6.3%	14.1%	14.0%	8.5%	7.1%	7.6%	7.9%	8.0%	9.5%	10.4%	13.3%	11.8%	11.9%	12.1%	14.9%	12.0%	12.1%
[H2O] After Combustion { No WGS }	3.7%	10.7%	10.8%	10.2%	6.0%	13.3%	13.1%	7.9%	6.7%	7.1%	7.4%	7.3%	8.9%	9.7%	12.4%	10.9%	11.0%	11.2%	13.8%	11.1%	11.3%
[H2O] After Combustion { WGS }	2.1%	7.2%	7.3%	6.6%	3.7%	9.2%	9.1%	4.8%	3.9%	4.2%	4.5%	4.1%	5.6%	6.3%	8.5%	6.9%	7.0%	7.0%	9.2%	7.0%	7.4%
[H2O] After Steam-Gasification { WGS }	1.4%	5.7%	3.7%	5.3%	3.0%	4.8%	3.3%	1.9%	1.9%	1.4%	2.0%	1.2%	1.9%	2.6%	3.1%	0.9%	0.9%	0.6%	0.9%	0.7%	2.3%
SUMMARY OF THE SPREADSHEET RESULTS																					
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	76%	82%	77%	73%	87%	77%	73%	83%	80%	78%	84%	69%	66%	68%	74%	88%	83%	53%	86%	81%	69%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (C	60%	65%	62%	63%	66%	58%	66%	59%	61%	59%	66%	76%	57%	55%	56%	66%	59%	58%	62%	61%	61%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN)	90%	90%	90%	89%	95%	71%	93%	94%	94%	95%	94%	93%	94%	95%	95%	94%	95%	95%	94%	94%	94%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (L	-5%	-6%	-6%	-7%	-0%	-2%	-3%	-9%	-4%	-6%	-4%	-9%	-9%	-7%	-6%	-9%	-8%	-8%	-8%	-8%	-11%
Heat Loss from TRDU { Btu/hr }	-1.4E+05	-1.6E+05	-1.5E+05	-1.7E+05	-1.2E+04	-4.8E+04	-7.0E+04	-2.7E+05	-1.4E+05	-1.9E+05	-1.2E+05	-1.9E+05	-2.1E+05	-1.9E+05	-1.5E+05	-2.2E+05	-2.2E+05	-2.0E+05	-2.0E+05	-2.0E+05	-2.8E+05
HHV of Product Gas, 60 F w H2S w/o tar, Btu/scf	56	61	57	52	51	62	59	40	52	50	50	42	47	57	55	53	45	49	56	54	42
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Dry Corrected}	116	116	113	100	115	126	120	73	97	91	100	80	91	104	105	92	80	85	96	95	77
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet}	52	54	50	46	48	53	51	35	47	45	45	37	40	49	46	45	38	41	46	46	36
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet Corrected}	101	93	88	78	102	94	92	58	81	74	83	65	68	80	77	70	60	64	70	72	57
Gasifier Cold Gas Efficiency, % of coal HHV	36%	39%	37%	35%	39%	35%	37%	26%	32%	30%	34%	34%	29%	31%	31%	34%	26%	28%	34%	33%	27%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3832	4566	5384	4336	1682	2302	2178	3005	2349	3171	2390	1284	3370	3423	3031	3115	2835	2617	3252	3206	3148
COMPARISON OF SPREADSHEET RESULTS																					
delta T (°C)	157	137	134	119	95	84	73	75	81	79	83	70	69	71	69	75	76	76	78	83	80
Average Mixing Zone T (°C)	964	974	941	934	990	969	1011	1028	1016	1030	1035	957	953	940	949	987	989	982	987	1006	1015
Average Low T (°C)	807	837	807	815	895	885	938	953	935	951	952	887	884	869	880	912	913	906	909	923	935
Air in (scfh)	11,750	11,750	5,500	750	750	700	750	750	750	818	890	890	890	700	700	700	700	700	700	700	700
Oxygen in (scfh)	0	0	1,400	2,300	2,475	2,228	2,743	2,646	2,716	2,501	2,250	2,177	2,201	2,229	2,303	2,698	2,488	2,534	2,553	2,711	2,748
Nitrogen in (scfh)	5,503	5,487	5,519	5,423	5,034	5,462	5,385	4,924	4,577	4,445	4,365	4,441	4,494	5,109	5,126	5,156	5,182	5,183	5,149	5,146	5,168
Product Gas (scfh)	19,874	19,502	13,540	11,443	11,952	11,717	12,302	12,446	12,670	11,854	11,273	11,018	11,089	10,945	10,965	11,718	11,174	10,976	11,265	11,461	11,653
Coal Feed Rate (lb/hr)	269	253	306	334	281	289	283	279	294	382	255	244	281	311	305	351	322	293	305	300	327
Air Flow (lb/hr)	899	899	421	57	57	54	57	57	57	63	68	68	68	54	54	54	54	54	54	54	54
Steam Flow (lb/hr)	262	262	416	416	425	422	436	436	438	439	438	437	435	441	440	434	435	438	437	437	435
Air/Coal Ratio (lb/lb)	4.03	4.28	1.65	0.21	0.25	0.22	0.24	0.25	0.23	0.18	0.31	0.30	0.26	0.19	0.19	0.16	0.18	0.20	0.19	0.19	0.18
Steam/Coal Ratio (lb/lb)	1.18	1.25	1.64	1.50	1.82	1.76	1.86	1.88	1.79	1.28	1.98	1.93	1.67	1.53	1.55	1.33	1.45	1.61	1.54	1.57	1.43
O2/Coal Ratio (lb/lb)	0.93	0.99	0.85	0.75	0.95	0.84	1.04	1.02	0.99	0.66	0.93	0.88	0.77	0.69	0.73	0.74	0.74	0.83	0.80	0.87	0.80
Fraction Carbon in Coal	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.76	0.76	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Bed Recycle Rate, lb/hr {by heat balance around burner}	3,832	4,566	5,384	4,336	1,682	2,302	2,178	3,005	2,349	3,171	2,390	1,284	3,370	3,423	3,031	3,115	2,835	2,617	3,252	3,206	3,148
Bed Recycle Rate,lb/hr {Calculated}	1,910	2,162	2,005	4,804	4,510	3,829	8,464	8,272	7,314	6,842	5,954	6,623	6,323	4,595	6,375	6,613	5,768	6,289	6,578	6,463	6,794

Gas Compositions from TRDU Test Test		P073 Blacksville 04/23/2003 07:00-12:00	Blacksville 04/24/2003 01:00-09:00	P074 Falkirk/wooc 09/26/2003 21:15-24:15	Falkirk/wooc 09/27/2003 02:00-03:10	Falkirk/wooc 09/27/2003 03:10-05:10	Falkirk/wooc 09/27/2003 05:10-08:10	Falkirk/wooc 09/27/2003 08:10-11:25	Falkirk/wooc 09/27/2003 11:25-14:25	Falkirk/wooc 09/27/2003 14:25-17:00	Falkirk/wooc 09/27/2003 17:00-19:30	Falkirk/wooc 09/27/2003 19:30-21:50	Falkirk/wooc 09/27/2003 21:50-23:00	Falkirk/wooc 09/28/2003 06:23-08:53	Falkirk/wooc 09/28/2003 08:53-11:23	Falkirk/wooc 09/28/2003 11:23-13:53	Falkirk/wooc 09/28/2003 13:53-16:30	Falkirk/wooc 09/27/2003 16:30-19:00
Product Gas Comp, vol%																		
	H2	6.3	16.2	7.1	5.8	5.9	6.5	7.2	6.5	6.8	6.6	7.3	5.6	14.5	15.0	15.7	15.4	15.3
	CO	4.7	9.5	3.1	4.4	4.5	5.3	5.7	5.6	5.6	5.5	5.5	5.0	7.4	8.0	8.6	8.7	8.7
	CH4	1.8	4.1	0.4	0.8	0.9	1.1	1.2	1.1	1.1	1.1	1.2	1.1	2.2	2.4	2.5	2.7	2.8
	CO2	13	23	12	12	13	13	12	13	13	13	13	12	26	25	25	28	27
	N2	81	55	77	74	73	72	71	74	72	72	71	73	51	48	47	50	48
	Total	107	108	100	97	97	98	97	100	98	97	98	96	101	98	99	104	102
	Ave Mol Wt	30	29	28	28	28	28	27	28	27	27	27	27	28	27	27	29	29
Flow, scfh																		
	air in	12076	1141	10931	11379	12197	12952	12949	12951	13133	13263	13296	13199	0	0	0	0	0
	oxygen in	0	1996	0	0	0	0	0	0	0	0	231	506	2758	2858	2868	2903	2966
	nitrogen in	5069	5001	6205	6367	6389	6360	6332	6323	6385	6387	6554	6573	6550	6455	6564	6528	6766
	product gas	15543	9609	16737	18310	20096	21468	20666	20314	21298	21612	22958	23869	13643	13579	14458	14458	13163
Product Gas, scfh																		
	H2	979	1557	1188	1062	1186	1395	1488	1320	1448	1426	1676	1337	1978	2037	2270	2227	2014
	CO	731	913	519	806	904	1138	1178	1138	1193	1189	1263	1193	1010	1086	1243	1258	1145
	CH4	280	394	67	146	181	236	248	223	234	238	275	263	300	326	361	390	369
	CO2	1990	2220	2042	2270	2532	2748	2563	2661	2662	2702	2870	2793	3493	3381	3600	4005	3567
	N2	12606	5256	12921	13531	14710	15478	14652	15012	15271	15453	16346	17305	6931	6518	6839	7186	6371
	Total	16585	10340	16737	17816	19513	20996	20129	20355	20808	21007	22430	22890	13711	13348	14313	15065	13466
Heating Value, Btu/hr																		
	H2 (325)	318250	505929	386206	345144	385341	453512	483584	429133	470686	463577	544679	434416	642926	661976	737719	723623	654530
	CO (321)	234503	293035	166550	258610	290287	365235	378126	365164	382853	381560	405323	383097	324076	348709	399128	403769	367603
	CH4 (1014)	283697	399496	67885	148531	183396	239454	251464	226582	237558	241060	279353	266235	304348	330459	366510	395831	373724
	Total	836450	1198460	620641	752285	859024	1058201	1113174	1020880	1091097	1086198	1229355	1083748	1271350	1341144	1503357	1523223	1395857
Heating Value, Btu/scf																		
	H2	20	53	23	19	19	21	23	21	22	21	24	18	47	49	51	50	50
	CO	15	30	10	14	14	17	18	18	18	18	18	16	24	26	28	28	28
	CH4	18	42	4	8	9	11	12	11	11	11	12	11	22	24	25	27	28
	Total	54	125	37	41	43	49	54	50	51	50	54	45	93	99	104	105	106
VALUES ADJUSTED FOR PURGE NITROGEN																		
Product Gas Comp, vol%																		
	H2	8.5%	29.2%	11.3%	9.3%	9.0%	9.5%	10.8%	9.4%	10.0%	9.8%	10.6%	8.2%	27.6%	29.5%	29.3%	26.1%	28.0%
	CO	6.3%	17.1%	4.9%	7.0%	6.9%	7.8%	8.5%	8.1%	8.3%	8.1%	8.0%	7.3%	14.1%	15.8%	16.0%	14.7%	15.9%
	CH4	2.4%	7.4%	0.6%	1.3%	1.4%	1.6%	1.8%	1.6%	1.6%	1.6%	1.7%	1.6%	4.2%	4.7%	4.7%	4.6%	5.1%
	CO2	17.3%	41.6%	19.4%	19.8%	19.3%	18.8%	18.6%	19.0%	18.5%	18.5%	18.1%	17.1%	48.8%	49.1%	46.5%	46.9%	49.6%
	N2	65.4%	4.8%	63.8%	62.6%	63.4%	62.3%	60.3%	61.9%	61.6%	62.0%	61.7%	65.8%	5.3%	0.9%	3.5%	7.7%	1.4%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	26	28	29	29	28	28	28	28	28	28	28	28	28	27	28	28
Heating Value, Btu/scf		73	224	59	66	65	72	81	73	76	74	77	66	178	195	194	178	194
Product Gas, scfh																		
	H2	979	1557	1188	1062	1186	1395	1488	1320	1448	1426	1676	1337	1978	2037	2270	2227	2014
	CO	731	913	519	806	904	1138	1178	1138	1193	1189	1263	1193	1010	1086	1243	1258	1145
	CH4	280	394	67	146	181	236	248	223	234	238	275	263	300	326	361	390	369
	CO2	1990	2220	2042	2270	2532	2748	2563	2661	2662	2702	2870	2793	3493	3381	3600	4005	3567
	N2	7537	255	6716	7164	8321	9118	8320	8689	8886	9066	9792	10732	381	63	275	658	100
	Total	11516	5339	10532	11449	13124	14636	13797	14032	14423	14620	15876	16317	7161	6893	7749	8537	7195
FLUE GAS FLOWS ADJUSTED TO 450,000 BTU/HR HEAT LOSS																		
Gas created due to combustion of																		
Gas created due to combustion of		30	30	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
	CO2	463	463	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099	1099
	N2	1959	1959	4652	4652	4652	4652	4652	4652	4652	4652	4652	4652	0	0	0	0	0
Product Gas, scfh																		
	H2	979	1557	1188	1062	1186	1395	1488	1320	1448	1426	1676	1337	1978	2037	2270	2227	2014
	CO	731	913	519	806	904	1138	1178	1138	1193	1189	1263	1193	1010	1086	1243	1258	1145
	CH4	280	394	67	146	181	236	248	223	234	238	275	263	300	326	361	390	369
	CO2	1527	1757	943	1171	1433	1649	1463	1562	1563	1602	1771	1693	2393	2282	2501	2906	2468
	N2	5578	1001	2064	2512	3670	4467	3668	4037	4234	4414	5140	6080	381	63	275	658	100
	Total	9094	5622	4781	5698	7373	8885	8046	8281	8672	8869	10125	10566	6062	5794	6650	7438	6096

	P073		P074														
	Blacksville	Blacksville	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc	Falkirk/wooc
	04/23/2003	04/24/2003	09/26/2003	09/27/2003	09/27/2003	09/27/2003	09/27/2003	09/27/2003	09/27/2003	09/27/2003	09/27/2003	09/27/2003	09/28/2003	09/28/2003	09/28/2003	09/28/2003	09/27/2003
	07:00-12:00	01:00-09:00	21:15-24:15	02:00-03:10	03:10-05:10	05:10-08:10	08:10-11:25	11:25-14:25	14:25-17:00	17:00-19:30	19:30-21:50	21:50-23:00	06:23-08:53	08:53-11:23	11:23-13:53	13:53-16:30	16:30-19:00
Product Gas, vol %																	
H2	11	28	25	19	16	16	19	16	17	16	17	13	33	35	34	30	33
CO	8.0	16.2	10.9	14.1	12.3	12.8	14.6	13.7	13.8	13.4	12.5	11.3	16.7	18.7	18.7	16.9	18.8
CH4	3.1	7.0	1.4	2.6	2.5	2.7	3.1	2.7	2.7	2.7	2.7	2.5	5.0	5.6	5.4	5.2	6.0
CO2	17	31	20	21	19	19	18	19	18	18	18	16	40	39	38	39	41
N2	61	18	43	44	50	50	46	49	49	50	51	58	6	1	4	9	2
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	28	25	25	26	27	27	26	27	26	26	26	27	25	24	24	26	25
Heating Value, Btu/scf	92	213	130	132	117	119	138	123	126	122	121	103	210	231	226	205	229
Gasifier Temp C	950	922	860	845	840	853	863	861	857	852	844	842	837	855	839	850	839
Coal Feed Rate	273	285	305	263	335	431	381	421	417	455	462	396	474	439	463	457	501
Air Flow (lb/hr)	924	87	836	871	933	991	991	991	1005	1015	1017	1010	0	0	0	0	0
Steam Flow (lb/hr)	167	290	121	121	121	121	121	120	121	121	133	223	338	336	341	338	340
O2 flow (lb/hr)	0	169	0	0	0	0	0	0	0	0	20	43	233	241	242	245	250
Air/Coal Ratio (lb/lb)	4.23	0.38	3.05	3.68	3.10	2.55	2.89	2.62	2.68	2.48	2.45	2.83	0.00	0.00	0.00	0.00	0.00
Steam/Coal Ratio (lb/lb)	0.76	1.27	0.44	0.51	0.40	0.31	0.35	0.32	0.32	0.30	0.32	0.63	0.79	0.85	0.82	0.82	0.75
O2/Coal Ratio (lb/lb)	0.98	0.83	0.71	0.85	0.72	0.59	0.67	0.61	0.62	0.57	0.61	0.78	0.55	0.61	0.58	0.60	0.56
O2/maf Coal Ratio (lb/lb)	1.13	0.96	1.24	1.49	1.26	1.04	1.17	1.06	1.09	1.01	1.08	1.36	0.96	1.07	1.02	1.04	0.97
Recirc Rate (lb/hr)	13185	11265	14787	11420	10602	10098	9045	9310	8222	7094	7638	7055	8714	8552	8655	8238	8605
Fraction Carbon in Coal	0.73	0.73	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Fraction Sorbent in Coal	20%	20%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Coal Heating Value BTU/lb	15170	15170	6389	6389	6389	6389	6389	6389	6389	6389	6389	6389	6389	6389	6389	6389	6389
Wt WAter (lb/hr)	219	258	137	147	158	151	175	185	189	188	187	205	287	279	298	310	308
Wt LASH lb/hr	1	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fraction C in LASH	1.3%	14.9%		0.7%	1.3%	1.0%	0.2%	0.6%	0.9%	1.3%	1.2%	0.2%			1.9%		
WT filter ash lb/hr	104	91	70	80	91	103	85	86	89	92	94	94	108	78	96	106	115
Fraction C in filter ash	0.39	0.45	0.05	0.05	0.06	0.07	0.05	0.05	0.07	0.10	0.11	0.13	0.11	0.11	0.11	0.10	0.13
Wt dipleg lb/hr	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fraction C in dipleg		5.2%			0.3%						0.0%		0.2%		0.0%		
TRDU Throughput lb/hr-ft^2	3269	3413	4109	3543	4513	5807	5133	5672	5618	6130	6225	5335	6386	5915	6238	6157	6750
TRDU Throughput MMBtu/	50	52	26	23	29	37	33	36	36	39	40	34	41	38	40	39	43
TRDU Riser Vel ft/s			36	38	41	44	44	43	45	45	47	52	39	40	40	40	40
% Moisture As run	6	6	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Ultimate As run																	
C	73	73	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
H	4.9	4.9	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
N	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
S	2.7	2.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
O	5	5	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Ash	7.6	7.6	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Carbon Conversion																	
Solid Accountability	75	73	97	96	95	95	96	97	96	94	93	91	93	94	93	93	91
Gas Make	57	65	77	110	97	86	94	86	88	81	86	96	91	98	101	111	91
Cold Gas Efficiency	27	37	35	48	43	42	49	42	44	40	45	46	47	52	56	60	50
Cold Gas Eff cor	25	35	35	50	45	43	51	42	46	42	46	48	47	53	56	58	48
Carbon Conv (calc)	66	105	58	71	69	78	72	67	72	67	72	73	107	94	103	97	102
PG HHV (GC - Btu/scf)	54	127	37	42	40	50	54	54	58	65	55	70	95	101	106	103	108
Hot Gas Eff (calc)	36	62	49	57	53	65	64	59	68	70	65	84	85	78	89	75	82
Cold Gas Eff. (calc)	28	54	35	42	40	51	51	47	55	58	53	71	73	68	77	65	72
H2S concetration (ppm)	892	2102	454	831	878	729	644	709	680	746	808	771	2240	2257	2270	2482	2428
ulfur Retention (%)	80	73	77	47	52	67	68	69	68	68	63	58	41	36	35	28	42
1-Lig, 2-Sub, 3-Bit, 4-Pet	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TC416 thermocouple (402	800	781	835	824	814	831	843	843	836	828	819	818	795	812	794	802	792

	P073 Blacksville 04/23/2003 07:00-12:0C	Blacksville 04/24/2003 01:00-09:0C	P074 Falkirk/wooc 09/26/2003 21:15-24:15	Falkirk/wooc 09/27/2003 02:00-03:1C	Falkirk/wooc 09/27/2003 03:10-05:1C	Falkirk/wooc 09/27/2003 05:10-08:1C	Falkirk/wooc 09/27/2003 08:10-11:25	Falkirk/wooc 09/27/2003 11:25-14:25	Falkirk/wooc 09/27/2003 14:25-17:0C	Falkirk/wooc 09/27/2003 17:00-19:3C	Falkirk/wooc 09/27/2003 19:30-21:5C	Falkirk/wooc 09/27/2003 21:50-23:0C	Falkirk/wooc 09/28/2003 06:23-08:53	Falkirk/wooc 09/28/2003 08:53-11:23	Falkirk/wooc 09/28/2003 11:23-13:53	Falkirk/wooc 09/28/2003 13:53-16:3C	Falkirk/wooc 09/27/2003 16:30-19:0C
SUMMARY OF THE DRY PRODUCT GAS																	
TOTAL PRODUCT GAS, scf/hr ------- >	15160	15915	16955	15785	15915	16955	19327	14517	15163	20590	21750	19340	19530	20500	19452	19044	20612
H2	4.8%	5.2%	7.7%	11.4%	5.6%	8.8%	3.6%	11.7%	14.1%	3.9%	5.6%	5.9%	7.7%	6.5%	8.2%	6.7%	6.4%
CO	2.7%	3.0%	6.3%	10.7%	3.8%	9.0%	2.6%	6.4%	7.3%	3.9%	5.7%	7.3%	9.3%	4.5%	3.2%	3.4%	2.9%
CH4	1.8%	1.8%	1.8%	1.9%	1.6%	1.7%	1.5%	3.9%	3.8%	0.7%	0.9%	1.0%	1.1%	1.4%	1.1%	1.1%	1.1%
CO2	13.3%	12.9%	13.2%	13.7%	10.9%	12.1%	13.6%	20.7%	23.6%	11.1%	11.3%	11.2%	11.1%	10.0%	14.0%	14.3%	13.8%
N2	77.2%	77.0%	73.4%	68.0%	77.1%	67.8%	78.2%	56.1%	51.2%	84.0%	78.3%	74.0%	68.2%	75.0%	72.8%	73.8%	75.6%
{ ppm } H2S	300	300	300	300	300	300	2100	4500	4000	68	86	104	177	177	1191	1401	1530
SUMMARY OF THE ELEMENTAL AND MASS CLOSURE																	
#MOLES H	2%	13%	20%	13%	13%	17%	24%	17%	10%	4%	8%	-3%	-21%	-56%	6%	10%	5%
#MOLES C	2%	18%	26%	19%	22%	20%	27%	21%	-13%	-1%	15%	-6%	0%	12%	9%	0%	15%
#MOLES O	1%	8%	14%	13%	13%	12%	9%	9%	1%	-3%	4%	-2%	-8%	-25%	2%	2%	-1%
#MOLES S	0%	1%	2%	1%	1%	1%	2%	2%	-1%	0%	1%	0%	0%	4%	1%	0%	2%
#MOLES N	0%	0%	0%	0%	0%	0%	1%	0%	-1%	0%	0%	0%	0%	0%	1%	1%	1%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%
SUMMARY OF CARBON UTILIZATION																	
High Kinetics																	
% CARBON LOST BY GASIFICATION { Total }	18%	10%	16%	19%	10%	16%	1%	1%	2%	8%	11%	10%	11%	11%	9%	5%	8%
% CARBON LOST BY COMBUSTION { Total }	52%	68%	68%	65%	68%	68%	63%	73%	58%	54%	55%	42%	38%	61%	80%	85%	75%
% Carbon Removed In Filter Ash { Total }	23%	17%	13%	13%	17%	13%	37%	26%	40%	11%	11%	5%	2%	26%	11%	10%	12%
% Carbon Removed In LASH { Total }	7%	6%	3%	2%	6%	3%	0%	0%	0%	27%	23%	43%	49%	1%	0%	0%	5%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analys	-44%	-8%	-8%	-19%	-7%	-8%	26%	30%	-2%	-13%	-4%	-29%	-29%	-14%	6%	-0%	11%
Single-Pass CHAR Carbon Conversion { Gasification }	6.5%	6.8%	18.4%	17.5%	6.8%	17.7%	0.9%	1.0%	2.8%	1.0%	1.3%	1.8%	2.4%	13.7%	4.6%	5.9%	2.8%
Single-Pass CHAR Carbon Conversion { Combustion }	16%	32%	44%	37%	33%	43%	49%	35%	46%	6%	7%	7%	8%	42%	29%	50%	21%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3355	3197	2900	3608	3166	3016	5254	8256	4589	2003	2588	1954	2387	3017	2229	2658	4013
Low Kinetics																	
% CARBON LOST BY GASIFICATION { Total }	2%	1%	2%	3%	1%	2%	0%	0%	0%	2%	4%	4%	7%	1%	3%	2%	3%
% CARBON LOST BY COMBUSTION { Total }	63%	74%	79%	78%	74%	79%	63%	74%	59%	58%	60%	45%	40%	68%	85%	88%	79%
% Carbon Removed In Filter Ash { Total }	27%	19%	15%	16%	19%	15%	37%	26%	41%	11%	11%	5%	2%	29%	12%	11%	13%
% Carbon Removed In LASH { Total }	8%	6%	3%	3%	6%	3%	0%	0%	0%	29%	25%	46%	51%	1%	0%	0%	5%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analys	-20%	2%	7%	1%	2%	7%	26%	31%	-0%	-5%	3%	-20%	-23%	-2%	11%	3%	16%
Single-Pass CHAR Carbon Conversion { Gasification }	0.5%	0.5%	2.3%	2.5%	0.5%	2.3%	0.0%	0.0%	0.1%	0.2%	0.5%	0.6%	1.4%	1.5%	1.5%	1.8%	0.9%
Single-Pass CHAR Carbon Conversion { Combustion }	16%	32%	44%	37%	33%	43%	49%	35%	46%	6%	7%	7%	8%	42%	29%	50%	21%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3355	3197	2900	3608	3166	3016	5254	8256	4589	2003	2588	1954	2387	3017	2229	2658	4013
[H2O] { Inlet }	17.2%	16.7%	16.3%	18.2%	16.6%	16.9%	32.8%	49.8%	53.9%	9.9%	9.7%	10.9%	11.0%	7.9%	23.6%	23.4%	23.5%
[H2O] After Combustion { No WGS }	16.1%	15.6%	14.8%	16.3%	15.5%	15.3%	31.8%	47.4%	51.0%	9.6%	9.2%	10.2%	9.9%	7.4%	22.5%	22.3%	22.4%
[H2O] After Combustion { WGS }	11.3%	11.0%	9.6%	10.3%	10.9%	9.9%	27.5%	41.1%	43.8%	7.9%	6.7%	7.5%	6.2%	4.3%	16.7%	16.4%	16.7%
[H2O] After Steam-Gasification { WGS }	2.7%	5.7%	2.0%	0.6%	5.8%	1.8%	26.5%	37.2%	38.6%	3.8%	0.9%	0.9%	0.0%	2.1%	4.2%	6.5%	2.5%
SUMMARY OF THE SPREADSHEET RESULTS																	
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	59%	76%	83%	82%	76%	83%	74%	83%	61%	60%	66%	41%	38%	69%	90%	90%	85%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (	56%	57%	56%	62%	53%	62%	45%	60%	73%	58%	49%	45%	34%	57%	81%	90%	69%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN)	95%	95%	96%	96%	95%	95%	64%	43%	46%	99%	99%	99%	99%	84%	45%	30%	37%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (	-12%	-10%	-8%	-9%	-9%	-7%	-2%	-5%	-5%	-5%	-4%	-5%	-2%	-6%	-5%	-6%	-2%
Heat Loss from TRDU { Btu/hr }	-3.0E+05	-2.6E+05	-2.7E+05	-2.9E+05	-2.4E+05	-2.3E+05	-9.0E+04	-1.9E+05	-1.9E+05	-1.3E+05	-1.3E+05	-1.8E+05	-1.4E+05	-1.9E+05	-1.1E+05	-1.2E+05	-5.3E+04
HHV of Product Gas, 60 F w H2S w/o tar, Btu/scf	43	45	62	86	47	75	37	102	110	31	45	53	68	50	49	45	42
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Dry Corrected}	74	81	117	163	86	133	72	249	243	61	93	97	123	92	118	111	105
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet}	34	36	49	68	37	61	25	59	63	28	41	47	58	46	36	33	30
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet Corrected}	51	56	79	108	57	94	37	89	91	51	76	78	95	78	63	60	53
Gasifier Cold Gas Efficiency, % of coal HHV	25%	26%	30%	39%	28%	37%	18%	36%	42%	24%	25%	25%	22%	33%	41%	41%	31%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	3355	3197	2900	3608	3166	3016	5254	8256	4589	2003	2588	1954	2387	3017	2229	2658	4013
COMPARISON OF SPREADSHEET RESULTS																	
delta T (°C)	150	141	25	21	26	22	20	18	21	24	25	24	42	43	45	48	47
Average Mixing Zone T (°C)	950	922	860	845	840	853	863	861	857	852	844	842	837	855	839	850	839
Average Low T (°C)	800	781	835	824	814	831	843	843	836	828	819	818	795	812	794	802	792
Air in (scfh)	12,076	1,141	10,931	11,379	12,197	12,952	12,949	12,951	13,133	13,263	13,296	13,199	0	0	0	0	0
Oxygen in (scfh)	0	1,996	0	0	0	0	0	0	0	0	231	506	2,758	2,858	2,868	2,903	2,966
Nitrogen in (scfh)	5,069	5,001	6,205	6,367	6,389	6,360	6,332	6,323	6,385	6,387	6,554	6,573	6,550	6,455	6,564	6,528	6,766
Product Gas (scfh)	15,543	9,609	16,737	18,310	20,096	21,468	20,666	20,314	21,298	21,612	22,958	23,869	13,643	13,579	14,458	14,458	13,163
Coal Feed Rate (lb/hr)	273	285	305	263	335	431	381	421	417	455	462	396	474	439	463	457	501
Air Flow (lb/hr)	924	87	836	871	933	991	991	991	1005	1015	1017	1010	0	0	0	0	0
Steam Flow (lb/hr)	167	290	121	121	121	121	121	120	121	121	133	223	338	336	341	338	340
Air/Coal Ratio (lb/lb)	4.23	0.38	3.05	3.68	3.10	2.55	2.89	2.62	2.68	2.48	2.45	2.83	0.00	0.00	0.00	0.00	0.00
Steam/Coal Ratio (lb/lb)	0.76	1.27	0.44	0.51	0.40	0.31	0.35	0.32	0.32	0.30	0.32	0.63	0.79	0.85	0.82	0.82	0.75
O2/Coal Ratio (lb/lb)	0.98	0.83	0.71	0.85	0.72	0.59	0.67	0.61	0.62	0.57	0.61	0.78	0.55	0.61	0.58	0.60	0.56
Fraction Carbon in Coal	0.73	0.73	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Bed Recycle Rate, lb/hr {by heat balance around burner}	3,355	3,197	2,900	3,608	3,166	3,016	5,254	8,256	4,589	2,003	2,588	1,954	2,387	3,017	2,229	2,658	4,013
Bed Recycle Rate,lb/hr {Calculated}	13,185	11,265	14,787	11,420	10,602	10,098	9,045	9,310	8,222	7,094	7,638	7,055	8,714	8,552	8,655	8,238	8,605

Gas Compositions from TRDU Test		P075										
Test		Loy Yang	Loy Yang	Loy Yang	Loy Yang	Loy Yang	Lochiel w/d	Lochiel w/d	Lochiel w/d	Lochiel w/d	Lochiel w/d	Lochiel wo/c
		12/01/2003	12/01/2003	12/01/2003	12/02/2003	12/03/2003	12/03/2003	12/04/2003	12/05/2003	12/05/2003	12/05/2003	12/05/2003
Product Gas Comp, vol%		13:20-16:00	16:00-19:20	19:20-22:00	00:35-00:50	18:45-20:45	23:00-23:20	20:11-24:11	02:30-04:40	04:40-06:40	06:40-08:40	11:30-13:30
	H2	6.6	7.4	7.0	12.5	9.3	7.5	4.3	6.1	6.3	5.6	13.8
	CO	4.4	5.0	5.3	8.3	6.0	3.5	3.3	4.4	4.6	4.7	4.9
	CH4	1.4	1.7	1.9	3.5	3.1	0.8	1.1	1.5	1.5	1.5	3.5
	CO2	12	13	12	18	22	19	14	14	14	13	25
	N2	74	74	72	58	58	78	79	74	75	75	56
	Total	99	100	99	100	98	109	101	100	101	99	103
	Ave Mol Wt	28	28	28	27	28	32	29	28	29	28	29
Flow, scfh												
	air in	10010	10010	10057	0	0	0	10036	11657	13127	13005	0
	oxygen in	0	0	0	2128	2281	1911	0	0	0	0	1994
	nitrogen in	4813	4714	4733	4959	6485	6420	6674	6260	6212	6336	5951
	product gas	14211	14532	15367	9786	10045	11210	16041	18290	21089	23089	11247
Product Gas, scfh												
	H2	938	1075	1076	1223	934	841	690	1116	1329	1293	1552
	CO	625	727	814	812	603	392	529	805	970	1085	551
	CH4	199	247	292	343	311	90	176	274	316	346	394
	CO2	1762	1846	1890	1732	2210	2164	2198	2542	2931	2955	2778
	N2	10474	10681	11080	5715	5786	8721	12608	13535	15796	17201	6298
	Total	13998	14576	15152	9825	9844	12208	16201	18272	21342	22881	11573
Heating Value, Btu/hr												
	H2 (325)	304826	349495	349599	397556	303610	273244	224173	362599	431797	420220	504428
	CO (321)	200716	233239	261439	260728	193467	125944	169922	258328	311400	348344	176904
	CH4 (1014)	201739	250503	296061	347305	315755	90936	178921	278191	320764	351184	399156
	Total	707281	833236	907099	1005590	812831	490124	573017	899118	1063961	1119747	1080488
Heating Value, Btu/scf												
	H2	21	24	23	41	30	24	14	20	20	18	45
	CO	14	16	17	27	19	11	11	14	15	15	16
	CH4	14	17	19	35	31	8	11	15	15	15	35
	Total	50	57	59	103	81	44	36	49	50	48	96
VALUES ADJUSTED FOR PURGE NITROGEN												
Product Gas Comp, vol%												
	H2	10.2%	10.9%	10.3%	25.1%	20.5%	14.5%	7.2%	9.3%	8.8%	7.8%	27.6%
	CO	6.8%	7.4%	7.8%	16.7%	13.2%	6.8%	5.6%	6.7%	6.4%	6.6%	9.8%
	CH4	2.2%	2.5%	2.8%	7.0%	6.8%	1.5%	1.9%	2.3%	2.1%	2.1%	7.0%
	CO2	19.2%	18.7%	18.1%	35.6%	48.5%	37.4%	23.1%	21.2%	19.4%	17.9%	49.4%
	N2	61.6%	60.5%	60.9%	15.5%	11.0%	39.8%	62.3%	60.6%	63.3%	65.7%	6.2%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	28	28	26	30	30	30	29	29	29	28
Heating Value, Btu/scf		77	84	87	207	178	85	60	75	70	68	192
Product Gas, scfh												
	H2	938	1075	1076	1223	934	841	690	1116	1329	1293	1552
	CO	625	727	814	812	603	392	529	805	970	1085	551
	CH4	199	247	292	343	311	90	176	274	316	346	394
	CO2	1762	1846	1890	1732	2210	2164	2198	2542	2931	2955	2778
	N2	5661	5967	6347	756	500	2301	5934	7275	9584	10865	347
	Total	9185	9862	10419	4866	4558	5788	9527	12012	15130	16545	5622
FLUE GAS FLOWS ADJUSTED TO 450,000 BTU/HR HEAT LOSS												
Gas created due to combustion of												
Gas created due to combustion of		47	47	47	47	47	61	61	61	61	61	61
	CO2	735	735	735	735	735	950	950	950	950	950	950
	N2	3110	3110	3110	0	0	0	4022	4022	4022	4022	0
Product Gas, scfh												
	H2	938	1075	1076	1223	934	841	690	1116	1329	1293	1552
	CO	625	727	814	812	603	392	529	805	970	1085	551
	CH4	199	247	292	343	311	90	176	274	316	346	394
	CO2	1027	1111	1155	997	1475	1213	1247	1592	1981	2005	1828
	N2	2550	2857	3237	756	300	2301	1912	3252	5562	6843	347
	Total	5340	6017	6574	4131	3623	4837	4555	7039	10157	11573	4672

		P075										
		Loy Yang	Loy Yang	Loy Yang	Loy Yang	Loy Yang	Lochiel w/d	Lochiel w/d	Lochiel w/d	Lochiel w/d	Lochiel w/d	Lochiel wo/c
		12/01/2003	12/01/2003	12/01/2003	12/02/2003	12/03/2003	12/03/2003	12/04/2003	12/05/2003	12/05/2003	12/05/2003	12/05/2003
		13:20-16:00	16:00-19:20	19:20-22:00	00:35-00:50	18:45-20:45	23:00-23:20	20:11-24:11	02:30-04:40	04:40-06:40	06:40-08:40	11:30-13:30
Product Gas, vol %												
	H2	18	18	16	30	26	17	15	16	13	11	33
	CO	11.7	12.1	12.4	19.7	16.6	8.1	11.6	11.4	9.6	9.4	11.8
	CH4	3.7	4.1	4.4	8.3	8.6	1.9	3.9	3.9	3.1	3.0	8.4
	CO2	19	19	18	24	41	25	27	23	20	17	39
	N2	48	48	49	18	8	48	42	46	55	59	7
	Total	100	100	100	100	100	100	100	100	100	100	100
		26	26	26	23	27	27	28	27	27	28	25
Heating Value, Btu/scf		132	138	138	243	224	101	126	128	105	97	231
	Gasifier Temp C	893	882	865	877	795	661	753	781	785	785	741
	Coal Feed Rate	275	267	308	342	443	367	419	406	479	550	482
	Air Flow (lb/hr)	766	766	770	0	0	0	768	892	1004	995	0
	Steam Flow (lb/hr)	126	125	139	311	319	324	124	124	124	167	293
	O2 flow (lb/hr)	0	0	0	180	193	161	0	0	0	0	168
	Air/Coal Ratio (lb/lb)	2.79	2.87	2.50	0.00	0.00	0.00	2.26	2.71	2.59	2.23	0.00
	Steam/Coal Ratio (lb/lb)	0.46	0.47	0.45	0.91	0.72	1.09	0.37	0.38	0.32	0.37	0.61
	O2/Coal Ratio (lb/lb)	0.65	0.66	0.58	0.53	0.43	0.54	0.52	0.63	0.60	0.52	0.35
	O2/maf Coal Ratio (lb/lb)	0.76	0.78	0.68	0.62	0.51	0.78	0.75	0.90	0.86	0.74	0.50
	Recirc Rate (lb/hr)	10136	11879	11930	12295	2214	2657	8720	7729	8307	8015	11224
	Fraction Carbon in Coal	0.56	0.56	0.56	0.56	0.56	0.46	0.46	0.46	0.46	0.46	0.46
	Fraction Sorbent in Coal	0%	0%	0%	0%	0%	19%	19%	19%	19%	19%	0%
	Coal Heating Value BTU/lb	9556	9556	9556	9556	9556	7389	7389	7389	7389	7389	7389
	Wt WAter (lb/hr)	186	174	186	200	347	270	206	221	218	227	305
	Wt LASH lb/hr	0	0	0	0	0	0	0	0	0	0	0
	Fraction C in LASH	1.5%	2.2%	4.4%	0.0%	7.0%	8.6%	4.1%	3.2%	1.4%	4.9%	8.9%
	WT filter ash lb/hr	61	48	69	70	61	123	118	128	138	108	94
	Fraction C in filter ash	0.60	0.71	0.81	0.84	0.69	0.36	0.36	0.40	0.36	0.38	0.60
	Wt dipleg lb/hr						0					
	Fraction C in dipleg						4.2%					
	TRDU Throughput lb/hr-ft^	4117	3997	4611	5120	6632	4450	5081	4923	5808	6669	7216
	TRDU Throughput MMBtu/	39	38	44	49	63	33	38	36	43	49	53
	TRDU Riser Vel ft/s	36	36	38	34	36	35	34	37	42	45	30
	% Moisture As run	14	14	14	14	14	18	18	18	18	18	18
	Ultimate As run											
	C	56	56	56	56	56	46	46	46	46	46	46
	H	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	N	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6
	S	0.3	0.3	0.3	0.3	0.3	3.0	3.0	3.0	3.0	3.0	3.0
	O	36	36	36	36	36	33	33	33	33	33	33
	Ash	1.0	1.0	1.0	1.0	1.0	12.3	12.3	12.3	12.3	12.3	12.3
	Carbon Conversion											
	Solid Accountability	76	77	68	70	83	67	73	66	72	80	74
	Gas Make	53	59	55	47	40	57	55	71	70	64	53
	Cold Gas Efficiency	27	33	30	31	19	24	23	37	38	34	31
	Cold Gas Eff cor	27	33	31	31	19	22	23	37	37	34	30
	Carbon Conv (calc)	72	64	73	81	106	84	69	127	141	105	101
	PG HHV (GC - Btu/scf)	50	79	79	104	82	45	38	52	53	51	104
	Hot Gas Eff (calc)	48	59	67	62	63	42	31	66	74	55	56
	Cold Gas Eff. (calc)	37	49	56	53	52	30	23	52	59	44	49
	H2S concetration (ppm)	313	276	310	587	515	3750	2190	1976	1722	1970	9013
	ulfur Retention (%)	60	63	62	58	71	60	70	69	73	71	40
	1-Lig, 2-Sub, 3-Bit, 4-Pet	1	1	1	1	1	1	1	1	1	1	1
	TC416 thermocouple (402	823	822	810	800	652	423	697	735	748	756	701

P075

	Loy Yang 12/01/2003 13:20-16:0C	Loy Yang 12/01/2003 16:00-19:2C	Loy Yang 12/01/2003 19:20-22:0C	Loy Yang 12/02/2003 00:35-00:5C	Loy Yang 12/03/2003 18:45-20:45	Lochiel w/d 12/03/2003 23:00-23:2C	Lochiel w/d 12/04/2003 20:11-24:11	Lochiel w/d 12/05/2003 02:30-04:4C	Lochiel w/d 12/05/2003 04:40-06:4C	Lochiel w/d 12/05/2003 06:40-08:4C	Lochiel wo/c 12/05/2003 11:30-13:3C
SUMMARY OF THE DRY PRODUCT GAS											
TOTAL PRODUCT GAS, scf/hr ------->	15627	15638	12503	13075	13768	13110	12611	12341	12920	21392	21419
H2	13.5%	12.7%	18.5%	19.5%	20.8%	19.8%	18.8%	18.3%	19.5%	9.3%	8.6%
CO	4.8%	4.7%	6.1%	6.6%	7.4%	7.0%	6.9%	6.8%	6.9%	4.7%	4.7%
CH4	1.9%	1.9%	2.8%	3.1%	3.1%	2.8%	2.7%	2.6%	2.8%	1.3%	1.1%
CO2	20.8%	20.9%	28.4%	28.9%	28.8%	28.9%	28.8%	33.3%	28.6%	15.6%	15.3%
N2	57.1%	57.0%	42.8%	41.5%	39.0%	40.4%	42.6%	43.8%	42.6%	73.0%	72.1%
{ppm} H2S	2158	2528	3524	3687	3561	3304	3493	2994	3039	1689	1596
SUMMARY OF THE ELEMENTAL AND MASS CLOSURE											
#MOLES H	-5%	-12%	7%	-2%	5%	4%	13%	5%	7%	12%	15%
#MOLES C	1%	1%	-2%	5%	2%	-7%	-2%	-8%	7%	-30%	-25%
#MOLES O	-7%	-13%	2%	-6%	0%	-1%	7%	-4%	2%	5%	5%
#MOLES S	0%	0%	-1%	1%	0%	-1%	-1%	-1%	1%	-1%	-1%
#MOLES N	0%	0%	0%	0%	0%	0%	0%	-1%	0%	1%	1%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
SUMMARY OF CARBON UTILIZATION											
High Kinetics											
% CARBON LOST BY GASIFICATION {Total}	7%	7%	8%	9%	4%	8%	6%	7%	8%	3%	20%
% CARBON LOST BY COMBUSTION {Total}	75%	76%	76%	67%	74%	71%	78%	78%	71%	61%	56%
% Carbon Removed In Filter Ash {Total}	18%	14%	14%	17%	20%	15%	11%	9%	11%	36%	15%
% Carbon Removed In LASH {Total}	0%	3%	3%	8%	3%	7%	5%	6%	9%	0%	9%
Char Carbon Accounted For {Comb + S.Gasif + Filter + LASH}	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analys	7%	6%	8%	14%	18%	5%	8%	7%	16%	-20%	-39%
Single-Pass CHAR Carbon Conversion {Gasification}	1.5%	1.3%	1.0%	0.9%	1.1%	1.8%	2.5%	2.4%	1.9%	2.4%	3.1%
Single-Pass CHAR Carbon Conversion {Combustion}	14%	12%	9%	6%	17%	13%	23%	20%	14%	32%	8%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	6107	8031	10660	10566	8607	5780	5385	5907	5509	3387	3870
Low Kinetics											
% CARBON LOST BY GASIFICATION {Total}	2%	2%	3%	3%	1%	3%	2%	2%	3%	1%	7%
% CARBON LOST BY COMBUSTION {Total}	79%	80%	80%	71%	76%	75%	81%	82%	75%	62%	65%
% Carbon Removed In Filter Ash {Total}	19%	15%	15%	18%	20%	15%	12%	10%	12%	36%	18%
% Carbon Removed In LASH {Total}	0%	3%	3%	8%	3%	7%	5%	6%	10%	0%	10%
Char Carbon Accounted For {Comb + S.Gasif + Filter + LASH}	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analys	11%	11%	12%	19%	20%	10%	12%	12%	21%	-17%	-20%
Single-Pass CHAR Carbon Conversion {Gasification}	0.5%	0.4%	0.3%	0.3%	0.4%	0.6%	0.8%	0.7%	0.6%	0.8%	1.0%
Single-Pass CHAR Carbon Conversion {Combustion}	14%	12%	9%	6%	17%	13%	23%	20%	14%	32%	8%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	6107	8031	10660	10566	8607	5780	5385	5907	5509	3387	3870
[H2O] {Inlet}	37.9%	37.7%	53.5%	52.7%	52.4%	53.4%	52.9%	53.8%	52.6%	25.9%	25.7%
[H2O] After Combustion {No WGS}	35.6%	35.4%	49.8%	49.1%	48.7%	49.6%	49.2%	49.9%	49.0%	24.7%	24.5%
[H2O] After Combustion {WGS}	27.7%	27.5%	40.3%	39.4%	38.7%	39.9%	39.4%	40.1%	39.4%	18.9%	18.7%
[H2O] After Steam-Gasification {WGS}	1.9%	1.0%	0.5%	0.2%	2.8%	1.6%	3.5%	2.4%	1.6%	6.2%	0.3%
SUMMARY OF THE SPREADSHEET RESULTS											
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	84%	85%	85%	79%	82%	80%	86%	87%	83%	59%	68%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (	82%	84%	86%	74%	79%	87%	87%	93%	76%	89%	94%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN)	32%	19%	15%	25%	24%	30%	26%	39%	43%	75%	75%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (	-8%	-8%	-9%	-5%	-6%	-6%	-7%	-7%	-3%	0%	1%
Heat Loss from TRDU {Btu/hr}	-2.0E+05	-2.1E+05	-2.5E+05	-1.7E+05	-2.0E+05	-1.8E+05	-1.9E+05	-1.9E+05	-1.1E+05	5.3E+03	1.6E+04
HHV of Product Gas, 60 F w H2S w/o tar, Btu/scf	80	79	111	117	125	118	113	104	114	57	54
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Dry Corrected	226	224	228	230	232	230	229	209	230	131	125
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet}	51	50	60	63	69	64	61	57	61	42	40
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf {Wet Corrected	87	86	83	86	93	88	84	79	83	72	70
Gasifier Cold Gas Efficiency, % of coal HHV	45%	45%	49%	43%	48%	51%	50%	46%	44%	49%	48%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	6107	8031	10660	10566	8607	5780	5385	5907	5509	3387	3870
COMPARISON OF SPREADSHEET RESULTS											
delta T (°C)	70	60	55	77	143	238	56	46	37	29	40
Average Mixing Zone T (°C)	893	882	865	877	795	661	753	781	785	785	741
Average Low T (°C)	823	822	810	800	652	423	697	735	748	756	701
Air in (scfh)	10,010	10,010	10,057	0	0	0	10,036	11,657	13,127	13,005	0
Oxygen in (scfh)	0	0	0	2,128	2,281	1,911	0	0	0	0	1,994
Nitrogen in (scfh)	4,813	4,714	4,733	4,959	6,485	6,420	6,674	6,260	6,212	6,336	5,951
Product Gas (scfh)	14,211	14,532	15,367	9,786	10,045	11,210	16,041	18,290	21,089	23,089	11,247
Coal Feed Rate (lb/hr)	275	267	308	342	443	367	419	406	479	550	482
Air Flow (lb/hr)	766	766	770	0	0	0	768	892	1004	995	0
Steam Flow (lb/hr)	126	125	139	311	319	324	124	124	124	167	293
Air/Coal Ratio (lb/lb)	2.79	2.87	2.50	0.00	0.00	0.00	2.26	2.71	2.59	2.23	0.00
Steam/Coal Ratio (lb/lb)	0.46	0.47	0.45	0.91	0.72	1.09	0.37	0.38	0.32	0.37	0.61
O2/Coal Ratio (lb/lb)	0.65	0.66	0.58	0.53	0.43	0.54	0.52	0.63	0.60	0.52	0.35
Fraction Carbon in Coal	0.56	0.56	0.56	0.56	0.56	0.46	0.46	0.46	0.46	0.46	0.46
Bed Recycle Rate, lb/hr {by heat balance around burner}	6,107	8,031	10,660	10,566	8,607	5,780	5,385	5,907	5,509	3,387	3,870
Bed Recycle Rate,lb/hr {Calculated}	10,136	11,879	11,930	12,295	2,214	2,657	8,720	7,729	8,307	8,015	11,224

10-Dec-04	RUN NUMBER --->	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
Balancing Was Performed On The Following :		06/01/2004	06/02/2004	06/02/2004	06/02/2004	06/02/2004	06/03/2004	06/03/2004	06/03/2004	06/04/2004	06/04/2004	06/04/2004	06/04/2004	06/05/2004	06/05/2004	06/06/2004	06/06/2004	06/06/2004	06/06/2004	06/07/2004	06/07/2004	06/07/2004	06/08/2004	06/08/2004
O - H2OOUT, N - Dry Product Gas, C - Conversion, H - N/A		06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001
Balanced by Difference :	Type of Coal --->	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
Data for the	Test	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
Spreadsheet		06/01/2004	06/02/2004	06/02/2004	06/02/2004	06/02/2004	06/03/2004	06/03/2004	06/03/2004	06/04/2004	06/04/2004	06/04/2004	06/04/2004	06/05/2004	06/05/2004	06/06/2004	06/06/2004	06/06/2004	06/06/2004	06/07/2004	06/07/2004	06/07/2004	06/08/2004	06/08/2004
Calculations	Product Gas Comp, vol%	22:00-02:00	04:00-10:00	12:00-16:00	17:00-20:00	20:00-00:30	06:30-14:30	14:30-18:00	21:30-02:00	05:00-08:00	09:30-13:30	15:00-17:00	17:30-01:30	10:30-13:30	13:30-18:45	00:00-07:00	13:30-17:30	17:30-21:30	21:30-01:30	06:00-09:30	09:30-17:30	21:00-23:59	00:00-04:30	14:00-21:00
	H2	6.6	7.5	8.2	8.8	8.1	7.9	8.6	8.3	8.2	7.9	6.9	8.1	8.0	7.7	15.6	15.3	16.9	15.6	16.3	15.5	16.2	16.1	15.8
	CO	4.4	5.1	5.4	6.4	6.2	5.4	6.2	6.1	6.1	5.6	5.0	5.5	5.2	5.5	7.2	5.8	6.9	6.9	7.3	7.0	8.5	8.2	8.5
	CH4	1.1	1.5	1.5	1.7	1.6	1.5	1.6	1.6	1.6	1.5	1.3	1.5	1.4	1.4	2.8	3.0	3.1	2.9	3.0	2.9	2.5	2.4	2.9
	CO2	12	12	12	13	14	12	13	13	12	12	12	12	11	12	22	20	21	22	21	21	22	22	22
	N2	71	71	69	72	74	71	72	75	71	70	72	70	68	70	50	49	50	50	48	50	48	49	49
	Total	94	98	96	101	104	98	101	104	99	96	97	96	94	96	98	93	98	97	96	96	97	98	98
	Ave Mol Wt	26	27	26	28	29	27	28	29	27	27	27	26	26	27	26	25	26	26	26	26	26	26	27
Flow, scfh																								
	air in	11834	12197	12649	13141	12885	11674	12010	12028	13025	12409	11987	11714	11972	12008	0	0	0	0	0	0	0	0	0
	oxygen in	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2521	2429	2451	2492	2499	2553	2770	2701	2850
	nitrogen in	6062	6298	6293	6100	6023	6384	6363	6347	5734	6358	6096	6274	6452	6407	6639	6672	6213	6107	6188	6425	6206	6196	6604
	product gas	17697	18901	19195	18852	17462	16477	16225	15770	16595	16610	15221	15824	16954	17844	11361	10835	10854	11077	10422	10439	10134	9978	10405
Product Gas, scfh																								
	H2	1168	1418	1574	1659	1414	1302	1395	1309	1361	1312	1050	1282	1356	1374	1772	1658	1834	1728	1699	1618	1642	1606	1644
	CO	779	964	1037	1207	1083	890	1006	962	1012	930	761	870	882	981	818	628	749	764	761	731	861	818	884
	CH4	195	284	288	320	279	247	260	252	266	249	198	237	237	250	318	325	336	321	313	303	253	239	302
	CO2	2053	2306	2246	2394	2375	1994	2028	2097	1958	1960	1766	1820	1882	2052	2499	2113	2323	2437	2230	2192	2260	2225	2279
	N2	12512	13458	13283	13517	12939	11765	11747	11764	11782	11544	10913	11014	11597	12473	5669	5331	5405	5505	5023	5209	4844	4859	5130
	Total	16706	18428	18427	19097	18091	16197	16436	16385	16379	15995	14688	15223	15954	17130	11077	10055	10648	10756	10026	10053	9860	9749	10239
Heating Value, Btu/hr																								
	H2 (325)	379601	460712	511547	539167	459687	423047	453489	425396	442257	426462	341331	416567	440804	446546	576003	538770	596156	561604	552105	525865	533555	522099	534297
	CO (321)	249952	309428	332726	387295	347529	285612	322910	308792	324947	298581	244297	279373	282996	315036	262575	201726	240405	245344	244219	234564	276506	262641	283900
	CH4 (1014)	197392	287484	291956	324971	283303	250615	263234	255852	269237	252638	200643	240683	240679	253313	322562	329601	341185	325730	317037	306969	256897	242825	305969
	Total	826945	1057624	1136229	1251433	1090519	959274	1039633	990041	1036441	977681	786271	936623	964479	1014895	1161140	1070097	1177746	1132679	1113361	1067398	1066958	1027564	1124167
Heating Value, Btu/scf																								
	H2	21	24	27	29	26	26	28	27	27	26	22	26	26	25	51	50	55	51	53	50	53	52	51
	CO	14	16	17	21	20	17	20	20	20	18	16	18	17	18	23	19	22	22	23	22	27	26	27
	CH4	11	15	15	17	16	15	16	16	16	15	13	15	14	14	28	30	31	29	30	29	25	24	29
	Total	47	56	59	66	62	58	64	63	62	59	52	59	57	57	102	99	109	102	107	102	105	103	108
VALUES ADJUSTED FOR PURGE NITROGEN																								
Product Gas Comp, vol%																								
	H2	11.0%	11.7%	13.0%	12.8%	11.7%	13.3%	13.9%	13.0%	12.8%	13.6%	12.2%	14.3%	14.3%	12.8%	30.0%	31.7%	31.9%	30.0%	30.9%	30.3%	29.8%	29.8%	29.3%
	CO	7.3%	7.9%	8.5%	9.3%	9.0%	9.1%	10.0%	9.6%	9.5%	9.7%	8.9%	9.7%	9.3%	9.2%	13.8%	12.0%	13.0%	13.3%	13.8%	13.7%	15.6%	15.2%	15.8%
	CH4	1.8%	2.3%	2.4%	2.5%	2.3%	2.5%	2.6%	2.5%	2.5%	2.6%	2.3%	2.7%	2.5%	2.3%	5.4%	6.2%	5.9%	5.6%	5.7%	5.7%	4.6%	4.4%	5.4%
	CO2	19.3%	19.0%	18.5%	18.4%	19.7%	20.3%	20.1%	20.9%	18.4%	20.3%	20.5%	20.3%	19.8%	19.1%	42.3%	40.4%	40.4%	42.4%	40.5%	41.0%	41.0%	41.3%	40.6%
	N2	60.6%	59.0%	57.6%	57.1%	57.3%	54.8%	53.4%	54.0%	56.8%	53.8%	56.1%	53.0%	54.1%	56.6%	8.5%	9.6%	8.7%	8.7%	9.1%	9.4%	9.1%	9.3%	8.9%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	28	27	27	28	27	27	28	27	27	28	27	27	27	26	25	25	26	26	26	26	26	26
Heating Value, Btu/scf		78	87	94	96	90	98	103	99	97	101	92	105	102	95	197	205	205	197	202	200	193	191	200
Product Gas, scfh																								
	H2	1168	1418	1574	1659	1414	1302	1395	1309	1361	1312	1050	1282	1356	1374	1772	1658	1834	1728	1699	1618	1642	1606	1644
	CO	779	964	1037	1207	1083	890	1006	962	1012	930	761	870	882	981	818	628	749	764	761	731	861	818	884
	CH4	195	284	288	320	279	247	260	252	266	249	198	237	237	250	318	325	336	321	313	303	253	239	302
	CO2	2053	2306	2246	2394	2375	1994	2028	2097	1958	1960	1766	1820	1882	2052	2499	2113	2323	2437	2230	2192	2260	2225	2279
	N2	6450	7160	6990	7417	6916	5381	5384	5417	6048	5186	4817	4740	5145	6066	500	500	500	500	500	500	500	500	500
	Total	10644	12130	12134	12997	12068	9813	10073	10038	10645	9637	8592	8949	9502	10723	5908	5224	5742	5750	5503	5344	5516	5389	5609
FLUE GAS FLOWS ADJUSTED TO 320,000 BTU/HR HEAT LOSS																								
Gas created due to combustion of																								
Gas created due to combustion of		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	CO2	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779
	N2	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	0	0	0	0	0	0	0	0	0
Product Gas, scfh																								
	H2	1168	1418	1574	1659	1414	1302	1395	1309	1361	1312	1050	1282	1356	1374	1772	1658	1834	1728	1699	1618	1642	1606	1644
	CO	779	964	1037	1207	1083	890	1006	962	1012	930	761	870	882	981	818	628	749	764	761	731	861	818	884
	CH4	195	284	288	320	279	247	260	252	266	249	198	237	237	250	318	325	336	321	313	303	253	239	302
	CO2	1273	1526	1466	1615	1595	1214	1249	1318	1179	1181	986	1040	1102	1273	1720	1333	1543	1657	1451	1413	1480	1446	1499
	N2	3151	3861	3691	4118	3618	2082	2085	2119	2750	1887	1519	1441	1846	2767	500	500	500	500	500	500	500	500	500
	Total	6566	8052	8056	8919	7990	5735	5995	5960	6567	5559	4514	4871	5424	6645	5128	4445	4963	4971	4723	4564	4737	4610	4829
Product Gas, vol %																								
	H2	18	18	20	19	18	23	23	22	21	24	23	26	25	21	35	37	37	35	36	36	35	35	34
	CO	11.9	12.0	12.9	13.5	13.6	15.5	16.8	16.1	15.4	16.7	16.9	17.9	16.3	14.8	16.0	14.1	15.1	15.4	16.1	16.0	18.2	17.7	18.3
	CH4	3.0	3.5	3.6	3.6	3.5	4.3	4.3	4.2	4.0	4.5	4.4	4.9	4.4	3.8	6.2	7.3	6.8	6.5	6.6	6.6	5.3	5.2	6.2
	CO2	19	19	18	18	20	21	21	22	18	21	22	21	20	19	34	30	31	33	31	31	31	31	31
	N2	48	48	46	46	45	36	35	36	42	34	34	30	34	42	10	11	10	10	11	11	11	11	10
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		26	26	25	26	26	25	25	25	25	25	25	24	24	25	24	22	23	24	23	23	23	23	23
Heating Value, Btu/scf		126	131	141	140	136	167	173	166	158	176	174	192	178	153	226	241	237	228	236	234	225	223	233
	Gasifier Temp C	890	844	844	845	868	854	849	856	859	867	894	863	859	854	869	858	826	841	851	848	890	885	886
	Coal Feed Rate	285	325	358	416	363	343	358	349	342	354	299	329	341	323	337	341	377	312	342	325	359	374	334
	Air Flow (lb/hr)	906	933	968	1006	966	893	919	920	997	950	917	896	916	919	0	0	0	0	0	0	0	0	0

10-Dec-04

Balancing Was Performed On The Following :

O - H2OOUT, N - Dry Product Gas, C - Conversion, H - N/A

Balanced by Difference :

	RUN NUMBER --->	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
		06/01/2004	06/02/2004	06/02/2004	06/02/2004	06/02/2004	06/03/2004	06/03/2004	06/03/2004	06/04/2004	06/04/2004	06/04/2004	06/04/2004	06/05/2004	06/05/2004	06/06/2004	06/06/2004	06/06/2004	06/06/2004	06/07/2004	06/07/2004	06/07/2004	06/08/2004	06/08/2004
		06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001
	Type of Coal --->	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
Data for the Spreadsheet Calculations	Test	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
		06/01/2004	06/02/2004	06/02/2004	06/02/2004	06/02/2004	06/03/2004	06/03/2004	06/03/2004	06/04/2004	06/04/2004	06/04/2004	06/04/2004	06/05/2004	06/05/2004	06/06/2004	06/06/2004	06/06/2004	06/06/2004	06/07/2004	06/07/2004	06/07/2004	06/08/2004	06/08/2004
		22:00-02:00	04:00-10:00	12:00-16:00	17:00-20:00	20:00-00:30	06:30-14:30	14:30-18:00	21:30-02:00	05:00-08:00	09:30-13:30	15:00-17:00	17:30-01:30	10:30-13:30	13:30-18:45	00:00-07:00	13:30-17:30	17:30-21:30	21:30-01:30	06:00-09:30	09:30-17:30	21:00-23:59	00:00-04:30	14:00-21:00
Product Gas Comp, vol%																								
	H2	6.6	7.5	8.2	8.8	8.1	7.9	8.6	8.3	8.2	7.9	6.9	8.1	8.0	7.7	15.6	15.3	16.9	15.6	16.3	15.5	16.2	16.1	15.8
	CO	4.4	5.1	5.4	6.4	6.2	5.4	6.2	6.1	6.1	5.6	5.0	5.5	5.2	5.5	7.2	5.8	6.9	6.9	7.3	7.0	8.5	8.2	8.5
	CH4	1.1	1.5	1.5	1.7	1.6	1.5	1.6	1.6	1.6	1.5	1.3	1.5	1.4	1.4	2.8	3.0	3.1	2.9	3.0	2.9	2.5	2.4	2.9
	CO2	12	12	12	13	14	12	13	13	12	12	12	12	11	12	22	20	21	22	21	21	22	22	22
	N2	71	71	69	72	74	71	72	75	71	70	72	70	68	70	50	49	50	50	48	50	48	49	49
	Total	94	98	96	101	104	98	101	104	99	96	97	96	94	96	98	93	98	97	96	96	97	98	98
	Ave Mol Wt	26	27	26	28	29	27	28	29	27	27	27	26	26	27	26	25	26	26	26	26	26	26	27
Flow, scfh																								
	air in	11834	12197	12649	13141	12885	11674	12010	12028	13025	12409	11987	11714	11972	12008	0	0	0	0	0	0	0	0	0
	oxygen in	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2521	2429	2451	2492	2499	2553	2770	2701	2850
	nitrogen in	6062	6298	6293	6100	6023	6384	6363	6347	5734	6358	6096	6274	6452	6407	6639	6672	6213	6107	6188	6425	6206	6196	6604
	product gas	17697	18901	19195	18852	17462	16477	16225	15770	16595	16610	15221	15824	16954	17844	11361	10835	10854	11077	10422	10439	10134	9978	10405
Product Gas, scfh																								
	H2	1168	1418	1574	1659	1414	1302	1395	1309	1361	1312	1050	1282	1356	1374	1772	1658	1834	1728	1699	1618	1642	1606	1644
	CO	779	964	1037	1207	1083	890	1006	962	1012	930	761	870	882	981	818	628	749	764	761	731	861	818	884
	CH4	195	284	288	320	279	247	260	252	266	249	198	237	237	250	318	325	336	321	313	303	253	239	302
	CO2	2053	2306	2246	2394	2375	1994	2028	2097	1958	1960	1766	1820	1882	2052	2499	2113	2323	2437	2230	2192	2260	2225	2279
	N2	12512	13458	13283	13517	12939	11765	11747	11764	11782	11544	10913	11014	11597	12473	5669	5331	5405	5505	5023	5209	4844	4859	5130
	Total	16706	18428	18427	19097	18091	16197	16436	16385	16379	15995	14688	15223	15954	17130	11077	10055	10648	10756	10026	10053	9860	9749	10239
Heating Value, Btu/hr																								
	H2 (325)	379601	460712	511547	539167	459687	423047	453489	425396	442257	426462	341331	416567	440804	446546	576003	538770	596156	561604	552105	525865	533555	522099	534297
	CO (321)	249952	309428	332726	387295	347529	285612	322910	308792	324947	298581	244297	279373	282996	315036	262575	201726	240405	245344	244219	234564	276506	262641	283900
	CH4 (1014)	197392	287484	291956	324971	283303	250615	263234	255852	269237	252638	200643	240683	240679	253313	322562	329601	341185	325730	317037	306969	256897	242825	305969
	Total	826945	1057624	1136229	1251433	1090519	959274	1039633	990041	1036441	977681	786271	936623	964479	1014895	1161140	1070097	1177746	1132679	1113361	1067398	1066958	1027564	1124167
Heating Value, Btu/scf																								
	H2	21	24	27	29	26	26	28	27	27	26	22	26	26	25	51	50	55	51	53	50	53	52	51
	CO	14	16	17	21	20	17	20	20	20	18	16	18	17	18	23	19	22	22	23	22	27	26	27
	CH4	11	15	15	17	16	15	16	16	16	15	13	15	14	14	28	30	31	29	30	29	25	24	29
	Total	47	56	59	66	62	58	64	63	62	59	52	59	57	57	102	99	109	102	107	102	105	103	108
VALUES ADJUSTED FOR PURGE NITROGEN																								
Product Gas Comp, vol%																								
	H2	11.0%	11.7%	13.0%	12.8%	11.7%	13.3%	13.9%	13.0%	12.8%	13.6%	12.2%	14.3%	14.3%	12.8%	30.0%	31.7%	31.9%	30.0%	30.9%	30.3%	29.8%	29.8%	29.3%
	CO	7.3%	7.9%	8.5%	9.3%	9.0%	9.1%	10.0%	9.6%	9.5%	9.7%	8.9%	9.7%	9.3%	9.2%	13.8%	12.0%	13.0%	13.3%	13.8%	13.7%	15.6%	15.2%	15.8%
	CH4	1.8%	2.3%	2.4%	2.5%	2.3%	2.5%	2.6%	2.5%	2.5%	2.6%	2.3%	2.7%	2.5%	2.3%	5.4%	6.2%	5.9%	5.6%	5.7%	5.7%	4.6%	4.4%	5.4%
	CO2	19.3%	19.0%	18.5%	18.4%	19.7%	20.3%	20.1%	20.9%	18.4%	20.3%	20.5%	20.3%	19.8%	19.1%	42.3%	40.4%	40.4%	42.4%	40.5%	41.0%	41.0%	41.3%	40.6%
	N2	60.6%	59.0%	57.6%	57.1%	57.3%	54.8%	53.4%	54.0%	56.8%	53.8%	56.1%	53.0%	54.1%	56.6%	8.5%	9.6%	8.7%	8.7%	9.1%	9.4%	9.1%	9.3%	8.9%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	28	26	27	27	28	27	27	28	27	27	28	27	27	27	26	25	25	26	26	26	26	26	26
Heating Value, Btu/scf		78	87	94	96	90	98	103	99	97	101	92	105	102	95	197	205	205	197	202	200	193	191	200
Product Gas, scfh																								
	H2	1168	1418	1574	1659	1414	1302	1395	1309	1361	1312	1050	1282	1356	1374	1772	1658	1834	1728	1699	1618	1642	1606	1644
	CO	779	964	1037	1207	1083	890	1006	962	1012	930	761	870	882	981	818	628	749	764	761	731	861	818	884
	CH4	195	284	288	320	279	247	260	252	266	249	198	237	237	250	318	325	336	321	313	303	253	239	302
	CO2	2053	2306	2246	2394	2375	1994	2028	2097	1958	1960	1766	1820	1882	2052	2499	2113	2323	2437	2230	2192	2260	2225	2279
	N2	6450	7160	6990	7417	6916	5381	5384	5417	6048	5186	4817	4740	5145	6066	500	500	500	500	500	500	500	500	500
	Total	10644	12130	12134	12997	12068	9813	10073	10038	10645	9637	8592	8949	9502	10723	5908	5224	5742	5750	5503	5344	5516	5389	5609
FLUE GAS FLOWS ADJUSTED TO 320,000 BTU/HR HEAT LOSS																								
Gas created due to combustion of																								
Gas created due to combustion of		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	CO2	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779	779
	N2	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	3299	0	0	0	0	0	0	0	0	0
Product Gas, scfh																								
	H2	1168	1418	1574	1659	1414	1302	1395	1309	1361	1312	1050	1282	1356	1374	1772	1658	1834	1728	1699	1618	1642	1606	1644
	CO	779	964	1037	1207	1083	890	1006	962	1012	930	761	870	882	981	818	628	749	764	761	731	861	818	884
	CH4	195	284	288	320	279	247	260	252	266	249	198	237	237	250	318	325	336	321	313	303	253	239	302
	CO2	1273	1526	1466	1615	1595	1214	1249	1318	1179	1181	986	1040	1102	1273	1720	1333	1543	1657	1451	1413	1480	1446	1499
	N2	3151	3861	3691	4118	3618	2082	2085	2119	2750	1887	1519	1441	1846	2767	500	500	500	500	500	500	500	500	500
	Total	6566	8052	8056	8919	7990	5735	5995	5960	6567	5559	4514	4871	5424	6645	5128	4445	4963	4971	4723	4564	4737	4610	4829
Product Gas, vol %																								
	H2	18	18	20	19	18	23	23	22	21	24	23	26	25	21	35	37	37	35	36	36	35	35	34
	CO	11.9	12.0	12.9	13.5	13.6	15.5	16.8	16.1	15.4	16.7	16.9	17.9	16.3	14.8	16.0	14.1	15.1	15.4	16.1	16.0	18.2	17.7	18.3
	CH4	3.0	3.5	3.6	3.6	3.5	4.3	4.3	4.2	4.0	4.5	4.4	4.9	4.4	3.8	6.2	7.3	6.8	6.5	6.6	6.6	5.3	5.2	6.2
	CO2	19	19	18	18	20	21	21	22	18	21	22	21	20	19	34	30	31	33	31	31	31	31	31
	N2	48	48	46	46	45	36	35	36	42	34	34	30	34	42	10	11	10	10	11	11	11	11	10
	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
		26	26	25	26	26	25	25	25	25	25	25	24	24	25	24	22	23	24	23	23	23	23	23
Heating Value, Btu/scf		126	131	141	140	136	167	173	166	158	176	174	192	178	153	226	241	237	228	236	234	225	223	233
	Gasifier Temp C	890	844	844	845	868	854	849	856	859	867	894	863	859	854	869	858	826	841	851	848	890	885	886
	Coal Feed Rate	285	325	358	416	363	343	358	349	342	354	299	329	341	323	337	341	377	312	342	325	359	374	334
	Air Flow (lb/hr)	906	933	968	1006	986	893	919	920	997	950	917	896	916	919	0	0	0	0	0	0	0	0	0

10-Dec-04	RUN NUMBER ——>	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
Balancing Was Performed On The Following :		06/01/2004	06/02/2004	06/02/2004	06/02/2004	06/02/2004	06/03/2004	06/03/2004	06/03/2004	06/04/2004	06/04/2004	06/04/2004	06/04/2004	06/05/2004	06/05/2004	06/06/2004	06/06/2004	06/06/2004	06/06/2004	06/07/2004	06/07/2004	06/07/2004	06/08/2004	06/08/2004
O - H2OOUT, N - Dry Product Gas, C - Conversion, H - N/A		06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001
Balanced by Difference :	Type of Coal ——>	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
	Steam Flow (lb/hr)	121	124	129	144	120	127	172	139	120	120	124	120	120	132	298	298	298	298	298	302	310	310	315
	O2 Flow (lb/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	213	205	207	210	211	216	234	228	241
	Air/Coal Ratio (lb/lb)	3.31	2.99	2.82	2.52	2.83	2.71	2.67	2.75	3.04	2.79	3.20	2.84	2.80	2.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Steam/Coal Ratio (lb/lb)	0.44	0.40	0.37	0.36	0.34	0.38	0.50	0.41	0.37	0.35	0.43	0.38	0.37	0.43	0.92	0.91	0.82	1.00	0.91	0.97	0.90	0.86	0.98
	O2/Coal Ratio (lb/lb)	0.77	0.69	0.65	0.58	0.66	0.63	0.62	0.64	0.70	0.65	0.74	0.66	0.65	0.69	0.66	0.63	0.57	0.70	0.64	0.69	0.68	0.64	0.75
	O2/maf Coal (lb/lb)	1.0935577	0.9883816	0.9305252	0.8319363	0.9348303	0.8963561	0.8835171	0.9076596	1.0030131	0.9231845	1.0558308	0.9377009	0.9246286	0.9790912	0.9381637	0.8933237	0.815338	1.0016803	0.9163805	0.9851518	0.9676561	0.905709	1.070124
	Recirc Rate (lb/hr)	3586	7277	8841	7714	6594	5647	6278	7033	7553	6565	4844	5594	5703	5356	5537	4831	9754	11393	10741	11778	11454	12540	11813
	Fraction Carbon in Coal	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
	Fraction Sorbent in Coal	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
	Coal Heating Value BTU/lb	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010	9010
	Smoothing of LASH																							
	[illegible]	225	234	251	254	253	249	245	249	240	255	247	252	254	253	360	467	351	338	470	510	402	396	541
	Wt LASH lb/hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fraction C in LASH	0.7%	1.6%	2.0%	2.0%	2.1%	1.8%	1.9%	3.3%	4.2%	5.0%	2.1%	2.0%	1.5%	1.9%	1.2%	1.0%	1.2%	1.3%	1.4%	1.8%	0.3%	0.3%	0.4%
	WT filter ash lb/hr	30	41	38	38	39	34	59	37	32	32	33	38	44	32	30	31	34	30	32	36	29	28	22
	Fraction C in filter ash	0.29	0.35	0.40	0.39	0.36	0.40	0.43	0.39	0.38	0.34	0.32	0.34	0.35	0.35	0.20	0.38	0.37	0.34	0.34	0.26	0.17	0.19	0.28
	Wt dipleg lb/hr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fraction C in dipleg																							
	TRDU Throughput lb/hr-ft^2	4096	4671	5145	5978	5217	4929	5145	5016	4915	5067	4297	4728	4901	4642	4843	4901	5418	4484	4915	4671	5159	5375	4800
	TRDU Throughput MMBtu/hr-ft^2	37	42	46	54	47	44	46	45	44	46	39	43	44	42	44	44	49	40	44	42	46	48	43
	TRDU Riser Vel ft/s	41	42	44	44	41	38	39	38	39	40	38	38	40	42	38	37	36	37	37	38	39	39	40
	% Moisture As run	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
	Ultimate As run																							
	C	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
	H	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
	N	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	S	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	O	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
	Ash	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
	Carbon Conversion																							
	Solid Accountability	95	92	92	94	93	93	87	93	94	94	94	93	92	94	97	94	94	94	94	95	97	97	97
	Gas Make	60	62	57	54	58	52	52	54	54	50	52	51	50	58	61	51	51	64	55	56	53	50	59
	Stoichiometric Invar	0.65	0.61	0.60	0.51	0.55	0.54	0.55	0.54	0.67	0.58	0.65	0.61	0.60	0.62	-0.30	-0.33	-0.33	-0.30	-0.32	-0.31	-0.29	-0.29	-0.30
	Is	0.90	0.99	1.05	1.06	0.97	1.02	1.04	0.99	1.06	1.03	0.96	1.06	1.06	1.02	1.06	1.17	1.15	1.07	1.12	1.10	1.04	1.03	1.08
	Cold Gas Efficiency	32	37	35	35	36	32	34	34	35	31	29	32	31	35	39	34	34	35	36	37	33	31	38
	Cold Gas Eff cor	34	38	37	35	35	32	34	33	35	32	30	33	33	36	40	36	36	42	38	38	34	32	39
	Carbon Conv (calc)	76	81	82	85	83	68	72	74	71	70	78	66	67	72	78	99	98	106	109	111	104	101	122
	PG HHV (GC - Btu/scf)		66		63	64	64	66	63	61	60	52	65	59	58	99		113	105	109	105	106	105	109
	Hot Gas Eff (calc)		56		52	51	49	48	46	46	46	49	48	90	81	78		83	65	74	75	66	65	78
	Cold Gas Eff. (calc)		48		44	43	41	40	39	39	38	39	40	82	72	71		75	57	67	68	58	57	71
	H2S concetration (ppm)	300	364	340	420	416	323	391	406	362	386	343	337	333	340	263	600	645	608	630	603	683	694	631
	ulfur Retention (%)	54	48	55	54	51	62	57	55	57	56	57	60	60	54	78	53	55	47	53	53	53	55	52
	[illegible]	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	[illegible]	804	788	805	796	809	789	791	797	801	802	818	788	787	784	786	773	763	784	788	786	830	827	824

10-Dec-04	RUN NUMBER ——>	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
Balancing Was Performed On The Following :		06/01/2004	06/02/2004	06/02/2004	06/02/2004	06/02/2004	06/03/2004	06/03/2004	06/03/2004	06/04/2004	06/04/2004	06/04/2004	06/04/2004	06/05/2004	06/05/2004	06/06/2004	06/06/2004	06/06/2004	06/06/2004	06/07/2004	06/07/2004	06/07/2004	06/08/2004	06/08/2004
O - H2OOUT, N - Dry Product Gas, C - Conversion, H - N/A		06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001
Balanced by Difference :	Type of Coal ——>	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
{S, Ca, Mg, Ash}	Type of Sorbent ——>	Lime Stone	Lime Stone	Lime Stone	Lime Stone	Lime Stone	Lime Stone	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite	Dolomite
Balanced Product - Product Gas) / (Product Gas) (Dry)		0%	0%	0%	0%	0%	0%	49%	53%	46%	47%	50%	46%	41%	33%	39%	41%	39%	33%	46%	45%	54%	53%	54%
SUMMARY OF THE {RAW} DRY PRODUCT GAS																								
TOTAL PRODUCT GAS, scf/hr ——>		17697	18901	19195	18852	17462	16477	16225	15770	16595	16610	15221	15824	16954	17644	11361	10835	10854	11077	10422	10439	10134	9978	10405
	H2	6.6%	7.5%	8.2%	8.8%	8.1%	7.9%	8.6%	8.3%	8.2%	7.9%	6.9%	8.1%	8.0%	7.7%	15.6%	15.3%	16.9%	15.6%	16.3%	15.5%	16.2%	16.1%	15.8%
BEFORE	CO	4.4%	5.1%	5.4%	6.4%	6.2%	5.4%	6.2%	6.1%	6.1%	5.6%	5.0%	5.5%	5.2%	5.5%	7.2%	5.8%	6.9%	6.9%	7.3%	7.0%	8.5%	8.2%	8.5%
	CH4	1.1%	1.5%	1.5%	1.7%	1.6%	1.5%	1.6%	1.6%	1.6%	1.5%	1.3%	1.5%	1.4%	1.4%	2.8%	3.0%	3.1%	2.9%	3.0%	2.9%	2.5%	2.4%	2.9%
BALANCING	CO2	11.6%	12.2%	11.7%	12.7%	13.6%	12.1%	12.5%	13.3%	11.8%	11.8%	11.6%	11.5%	11.1%	11.5%	22.0%	19.5%	21.4%	22.0%	21.4%	21.0%	22.3%	22.3%	21.9%
	N2	70.7%	71.2%	69.2%	71.7%	74.1%	71.4%	72.4%	74.6%	71.0%	69.5%	71.7%	69.6%	68.4%	69.9%	49.9%	49.2%	49.8%	49.7%	48.2%	49.9%	47.8%	48.7%	49.3%
{ppm}	H2S	300	364	340	420	416	323	391	406	362	386	343	337	333	340	263	600	645	608	630	603	683	694	631
SUMMARY OF THE {BALANCED} DRY PRODUCT GAS																								
TOTAL PRODUCT GAS, scf/hr ——>		17735	18946	19241	18903	17507	16518	24194	24080	24276	24389	22882	23450	23866	23802	15774	15293	15070	14734	15217	15169	15561	15316	16051
	H2	6.6%	7.5%	8.2%	8.8%	8.1%	7.9%	8.6%	8.3%	8.2%	7.9%	6.9%	8.1%	8.0%	7.7%	15.6%	15.3%	16.9%	15.6%	16.3%	15.5%	16.2%	16.1%	15.8%
AFTER	CO	4.4%	5.1%	5.4%	6.4%	6.2%	5.4%	6.2%	6.1%	6.1%	5.6%	5.0%	5.5%	5.2%	5.5%	7.2%	5.8%	6.9%	6.9%	7.3%	7.0%	8.5%	8.2%	8.5%
	CH4	1.1%	1.5%	1.5%	1.7%	1.6%	1.5%	1.6%	1.6%	1.6%	1.5%	1.3%	1.5%	1.4%	1.4%	2.8%	3.0%	3.1%	2.9%	3.0%	2.9%	2.5%	2.4%	2.9%
BALANCING	CO2	11.6%	12.2%	11.7%	12.7%	13.6%	12.1%	12.5%	13.3%	11.8%	11.8%	11.6%	11.5%	11.1%	11.5%	22.0%	19.5%	21.4%	22.0%	21.4%	21.0%	22.3%	22.3%	21.9%
	N2	70.7%	71.2%	69.2%	71.7%	74.1%	71.4%	72.4%	74.6%	71.0%	69.5%	71.7%	69.6%	68.4%	69.9%	49.9%	49.2%	49.8%	49.7%	48.2%	49.9%	47.8%	48.7%	49.3%
{ppm}	H2S	300	364	340	420	416	323	391	406	362	386	343	337	333	340	263	600	645	608	630	603	683	694	631
SUMMARY OF THE {RAW} Elemental and Mass Closure																								
	#MOLES H	-11%	-11%	-12%	1%	-10%	-9%	6%	-2%	-10%	-12%	-12%	-15%	-15%	-14%	0%	-22%	5%	2%	-22%	-30%	-1%	2%	-32%
	#MOLES C	30%	28%	33%	41%	36%	40%	36%	41%	39%	42%	40%	40%	39%	34%	34%	39%	42%	28%	37%	36%	43%	46%	37%
BEFORE	#MOLES O	-4%	-6%	-5%	2%	-4%	-2%	9%	3%	4%	-1%	1%	-2%	-3%	-5%	1%	-11%	7%	4%	-11%	-16%	4%	6%	-15%
	#MOLES S	16%	15%	18%	22%	19%	21%	26%	30%	28%	31%	29%	28%	27%	23%	14%	29%	29%	21%	28%	27%	33%	35%	29%
BALANCING	#MOLES N	0%	0%	0%	0%	0%	0%	33%	35%	32%	32%	33%	33%	29%	25%	28%	29%	28%	25%	32%	31%	35%	35%	35%
	#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

10-Dec-04 RUN NUMBER ---->	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
Balancing Was Performed On The Following :	06/01/2004	06/02/2004	06/02/2004	06/02/2004	06/02/2004	06/03/2004	06/03/2004	06/03/2004	06/04/2004	06/04/2004	06/04/2004	06/04/2004	06/05/2004	06/05/2004	06/06/2004	06/06/2004	06/06/2004	06/06/2004	06/07/2004	06/07/2004	06/07/2004	06/08/2004	06/08/2004
O - H2OOUT, N - Dry Product Gas, C - Conversion, H - N/A	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001	06/13/2001
Balanced by Difference : Type of Coal ---->	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
MASS, #	0%	0%	0%	0%	0%	0%	29%	31%	28%	29%	30%	29%	26%	23%	22%	22%	21%	19%	24%	24%	27%	26%	27%
SUMMARY OF CARBON REMOVALS																							
Fast Kinetics																							
% CARBON LOST BY GASIFICATION (Total)	8%	3%	2%	4%	5%	5%	4%	3%	6%	8%	5%	4%	5%	4%	10%	6%	5%	4%	5%	5%	7%	7%	7%
% CARBON LOST BY COMBUSTION (Total)	86%	87%	87%	87%	87%	85%	79%	87%	87%	85%	88%	87%	84%	88%	86%	84%	86%	88%	88%	88%	90%	89%	89%
% Carbon Removed In Filter Ash (Total)	6%	10%	10%	10%	9%	9%	16%	10%	8%	7%	7%	9%	11%	8%	4%	8%	9%	7%	8%	7%	3%	3%	4%
% Carbon Removed In LASH (Total)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Char Carbon Accounted For (Comb + S Gasif + Filter + LASH)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles (Basis: Recycle Rate, Ultimate Analysis, 4x%C's)	6%	20%	25%	32%	22%	25%	21%	25%	17%	22%	11%	22%	21%	21%	21%	24%	34%	20%	25%	20%	20%	26%	12%
Single-Pass CHAR Carbon Conversion (Gasification)	11.4%	2.8%	2.3%	2.7%	4.6%	4.6%	4.8%	5.4%	4.8%	6.9%	13.9%	8.0%	7.0%	6.2%	6.6%	6.0%	2.5%	2.8%	3.7%	3.4%	5.8%	5.4%	5.5%
Single-Pass CHAR Carbon Conversion (Combustion)	54%	45%	48%	39%	47%	42%	48%	58%	42%	43%	69%	63%	53%	58%	37%	39%	31%	37%	40%	35%	42%	41%	42%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	5001	10820	13560	11579	9301	7547	6607	6533	7727	6018	4517	4865	5260	5519	6491	6118	9100	10114	8987	9347	10124	10194	10113
Slow Kinetics - Mann, et.al.																							
% CARBON LOST BY GASIFICATION (Total)	2%	1%	1%	1%	1%	1%	1%	1%	2%	2%	1%	1%	1%	1%	3%	2%	1%	1%	1%	1%	2%	2%	2%
% CARBON LOST BY COMBUSTION (Total)	92%	89%	89%	89%	90%	89%	82%	89%	90%	90%	91%	90%	88%	91%	93%	89%	89%	91%	91%	92%	95%	95%	94%
% Carbon Removed In Filter Ash (Total)	6%	10%	11%	10%	9%	10%	17%	10%	8%	8%	8%	9%	11%	8%	4%	9%	9%	7%	8%	7%	3%	4%	4%
% Carbon Removed In LASH (Total)	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Char Carbon Accounted For (Comb + S Gasif + Filter + LASH)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles (Basis: Recycle Rate, Ultimate Analysis, 4x%C's)	12%	21%	26%	34%	25%	28%	23%	27%	21%	26%	15%	25%	24%	23%	27%	28%	36%	22%	28%	23%	25%	30%	17%
Single-Pass CHAR Carbon Conversion (Gasification)	2.7%	0.7%	0.6%	0.7%	1.1%	1.2%	1.2%	1.4%	1.2%	1.7%	3.1%	2.0%	1.7%	1.6%	1.6%	1.5%	0.7%	0.8%	0.9%	0.9%	1.4%	1.3%	1.3%
Single-Pass CHAR Carbon Conversion (Combustion)	54%	45%	48%	39%	47%	42%	48%	58%	42%	43%	69%	63%	53%	58%	37%	39%	31%	37%	40%	35%	42%	41%	42%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	5001	10820	13560	11579	9301	7547	6607	6533	7727	6018	4517	4865	5260	5519	6491	6118	9100	10114	8987	9347	10124	10194	10113
[H2O] (Inlet)	13.9%	13.8%	14.1%	15.9%	14.3%	15.6%	15.5%	12.9%	11.1%	11.1%	11.8%	11.5%	11.3%	12.3%	37.2%	37.4%	38.4%	38.5%	38.3%	38.0%	38.6%	38.8%	37.9%
[H2O] After Combustion (No WGS)	12.8%	12.8%	13.1%	14.7%	13.1%	14.4%	14.6%	12.1%	10.4%	10.4%	11.0%	10.8%	10.6%	11.6%	34.3%	34.6%	35.6%	35.6%	35.3%	35.0%	35.1%	35.3%	34.5%
[H2O] After Combustion (WGS)	7.7%	7.8%	8.0%	9.1%	7.8%	8.9%	9.7%	7.6%	6.2%	6.2%	6.7%	6.6%	6.4%	7.2%	25.4%	25.9%	26.8%	26.6%	26.4%	26.2%	25.6%	26.0%	25.1%
[H2O] After Steam-Gasification (WGS)	1.5%	2.0%	2.3%	1.6%	1.4%	1.6%	2.8%	3.0%	1.4%	1.3%	2.8%	2.9%	2.2%	2.9%	1.4%	2.3%	2.5%	2.6%	2.7%	2.0%	1.0%	1.1%	1.2%
SUMMARY OF THE SPREADSHEET RESULTS																							
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	95%	92%	92%	94%	93%	93%	87%	93%	94%	94%	94%	93%	92%	94%	97%	94%	94%	94%	94%	95%	97%	97%	97%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (Coal IN)	64%	64%	59%	53%	56%	53%	77%	79%	80%	77%	81%	78%	75%	80%	87%	78%	72%	88%	83%	85%	84%	78%	92%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H2S) / (S IN) (molar)	52%	47%	59%	54%	53%	61%	36%	34%	36%	32%	33%	39%	39%	36%	69%	29%	36%	28%	29%	28%	26%	29%	25%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (LHVmaf)	-11%	-10%	-9%	-7%	-10%	-9%	-1%	-2%	-5%	-3%	-4%	-2%	-3%	-3%	-7%	-7%	-6%	-10%	-8%	-10%	-8%	-7%	-11%
Heat Loss from TRDU (Btu/hr)	-2.8E+005	-2.8E+005	-2.8E+005	-2.7E+005	-3.2E+005	-2.7E+005	-4.0E+004	-6.5E+004	-1.6E+005	-8.4E+004	-1.2E+005	-7.4E+004	-6.2E+004	-1.0E+005	-2.2E+005	-2.2E+005	-2.2E+005	-2.9E+005	-2.4E+005	-2.9E+005	-2.7E+005	-2.4E+005	-3.3E+005
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf	49	57	62	66	60	59	63	60	63	61	54	61	60	59	105	106	110	105	111	106	108	105	110
HHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf (Dry Corrected)	90	102	105	104	95	101	124	119	118	119	108	123	121	118	238	253	250	241	247	246	235	233	243
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf (Wet)	40	47	50	51	47	46	55	54	56	55	47	55	54	53	78	76	78	76	80	76	78	75	79
LHV of Product Gas, 60 F, w H2S w/o tar, Btu/scf (Wet Corrected)	63	73	74	72	67	67	95	96	95	97	85	100	97	94	133	129	130	127	134	128	127	122	131
Gasifier Cold Gas Efficiency, % of coal HHV	33%	35%	35%	32%	31%	30%	45%	44%	48%	45%	43%	46%	45%	46%	52%	51%	47%	53%	52%	52%	50%	46%	56%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	5001	10820	13560	11579	9301	7547	6607	6533	7727	6018	4517	4865	5260	5519	6491	6118	9100	10114	8987	9347	10124	10194	10113
ADJUSTMENTS TO STREAM FLOWS AND TROUBLE SHOOTING																							
X. s. Sorbent (Ca - S IN) / (S IN) (molar)	207%	207%	207%	207%	207%	207%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
If No then Sorbent is not in Excess																							
Fraction of Carbon in LASH (Original)	0.7%	1.6%	2.0%	2.0%	2.1%	1.6%	1.9%	3.3%	4.2%	5.0%	2.1%	2.0%	1.5%	1.9%	1.2%	1.0%	1.2%	1.3%	1.4%	1.6%	0.3%	0.3%	0.4%
Fraction of Carbon in LASH (Modified)	4.7%	2.6%	2.0%	3.0%	3.1%	3.8%	3.9%	3.3%	4.2%	5.0%	4.1%	4.0%	4.5%	3.9%	5.2%	5.0%	4.2%	3.3%	3.4%	3.8%	3.3%	3.3%	3.4%
If No then there is not enough carbon in the Bed	NO	NO		NO	NO	NO	NO				NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
CO2/CO Mass Ratio Leaving Combustion Zone (No WGS)	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.5	0.5	0.5
CO2/CO Mass Ratio Leaving Combustion Zone (WGS)	1.6	1.9	1.9	2.0	1.6	1.9	2.3	2.0	1.7	1.7	1.5	1.8	1.8	1.9	3.2	3.5	4.0	3.7	3.5	3.5	2.8	2.9	2.8
(Balanced Product - Product Gas) / (Product Gas) (Dry)	0%	0%	0%	0%	0%	0%	49%	53%	46%	47%	50%	48%	41%	33%	39%	41%	39%	33%	46%	45%	54%	53%	54%
If No then Product gas has been adjusted too much							NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
(Balanced H2O - H2O) / (H2O) (Quenched)	-11%	-15%	-12%	0%	-12%	-7%	-28%	-46%	-39%	-48%	-41%	-48%	-44%	-44%	-28%	-38%	-17%	-19%	-42%	-44%	-28%	-25%	-46%
If No then the water has been adjusted too much							NO	NO	NO	NO	NO	NO	NO	NO	NO	NO			NO	NO	NO		NO
(Balanced Carbon Conversion) - ("UN-Balanced" Carbon Conversion), Prod	-0%	-0%	-0%	-0%	-0%	-0%	25%	27%	25%	24%	27%	25%	21%	20%	24%	22%	20%	22%	26%	26%	29%	27%	32%
If No then the Carbon Conversion has changed dramatically							NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sum of Spreadsheet Checkers Must be Zero --->	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
If No then there is error in the spreadsheet and debugging is required							NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Kp' - Kp Inventory Check Must be Zero --->	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arrhenius "A"	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500
Arrhenius "E"	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300
Type of Coal ---->	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
COMPARISON OF CERTAIN SPREADSHEET RESULTS																							
delta T (°C)	86	46	39	49	59	65	58	59	58	65	76	75	72	70	83	86	63	57	63	62	60	58	62
Average Mixing Zone T (°C)	890	844	844	845	868	854	849	856	859	887	894	863	859	854	869	858	826	841	851	848	890	885	886
Average Low T (°C)	804	798	805	796	809	789	791	797	801	802	818	788	787	784	786	773	763	784	788	786	830	827	824
Air in (scfh)	11,834	12,197	12,649	13,141	12,885	11,674	12,010	12,028	13,025	12,409	11,987	11,714	11,972	12,008	0	0	0	0	0	0	0	0	0
Oxygen in (scfh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,521	2,429	2,451	2,492	2,499	2,553	2,770	2,701	2,850
Nitrogen in (scfh)	6,062	6,298	6,293	6,100	6,023	6,384	6,363	6,347	5,734	6,358	6,096	6,274	6,452	6,407	6,639	6,672	6,213	6,107	6,188	6,425	6,206	6,196	6,604
Product Gas (scfh)	17,697	18,901	19,196	18,852	17,462	16,477	16,225	15,770	16,595	16,610	15,221	15,824	16,954	17,844	11,361	10,835	10,854	11,077	10,422	10,439	10,134	9,978	10,406
Coal Feed Rate (lb/hr)	285	325	358	416	363	343	358	349	342	354	299	329	341	323	337	341	377	312	342	325	359	374	334
Air Flow (lb/hr)	906	933	968	1006	986	893	919	920	997	950	917	896	916	919	0	0	0	0	0	0	0	0	0
Steam Flow (lb/hr)	121	124	129	144	120	127	172	139	120	120	124	120	120	132	298	298	298	298	298	302	310	310	315
Air/Coal Ratio (lb/lb)	3.31	2.99	2.62	2.52	2.83	2.71	2.67	2.75	3.04	2.79	3.20	2.84	2.80	2.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Steam/Coal Ratio (lb/lb)	0.44	0.40	0.37	0.36	0.34	0.38	0.50	0.41	0.37	0.35	0.43	0.38	0.37	0.43	0.92	0.91	0.82	1.00	0.91	0.97	0.90	0.86	0.98

10-Dec-04	RUN NUMBER ——>	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
Balancing Was Performed On The Following : O - H2OOUT, N - Dry Product Gas, C - Conversion, H - N/A		06/01/2004 06/13/2001	06/02/2004 06/13/2001	06/02/2004 06/13/2001	06/02/2004 06/13/2001	06/02/2004 06/13/2001	06/03/2004 06/13/2001	06/03/2004 06/13/2001	06/03/2004 06/13/2001	06/04/2004 06/13/2001	06/04/2004 06/13/2001	06/04/2004 06/13/2001	06/04/2004 06/13/2001
Balanced by Difference :	Type of Coal ——>	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
O2/Coal Ratio (lb/lb)		0.77	0.69	0.65	0.58	0.66	0.63	0.62	0.64	0.70	0.65	0.74	0.66
Fraction Carbon in Coal		0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Bed Recycle Rate, lb/hr (by heat balance)		5,001	10,820	13,560	11,579	9,301	7,547	6,807	6,533	7,727	6,018	4,517	4,685
Bed Recycle Rate, lb/hr (Calc from dp's)		3,588	7,277	8,841	7,714	6,594	5,647	6,278	7,033	7,553	6,565	4,844	5,594

10-Dec-04	RUN NUMBER ——>	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d	Wyodak w/d
Balancing Was Performed On The Following : O - H2OOUT, N - Dry Product Gas, C - Conversion, H - N/A		06/05/2004 06/13/2001	06/05/2004 06/13/2001	06/06/2004 06/13/2001	06/06/2004 06/13/2001	06/06/2004 06/13/2001	06/06/2004 06/13/2001	06/07/2004 06/13/2001	06/07/2004 06/13/2001	06/07/2004 06/13/2001	06/08/2004 06/13/2001	06/08/2004 06/13/2001
Balanced by Difference :	Type of Coal ——>	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit	Subbit
O2/Coal Ratio (lb/lb)		0.65	0.69	0.68	0.63	0.67	0.70	0.64	0.60	0.68	0.64	0.75
Fraction Carbon in Coal		0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Bed Recycle Rate, lb/hr (by heat balance)		5,260	5,519	6,491	6,118	9,100	10,114	8,587	9,347	10,124	10,194	10,113
Bed Recycle Rate, lb/hr (Calc from dp's)		5,703	5,356	5,537	4,831	9,754	11,393	10,741	11,778	11,454	12,540	11,813

Data for the Spreadsheet Calculations

Test		Indian w/d 10/19/2004 15:00-18:00	Indian w/d 10/19/2004 19:00-21:30	Indian w/d 10/20/2004 02:00-07:00	Indian w/d 10/20/2004 09:00-11:00	Indian w/d 10/20/2004 14:43-19:00	Indian w/d 10/20/2004 22:00-23:47	Indian w/d 10/21/2004 01:00-04:48	Indian w/d 10/21/2004 10:00-12:15	Indian w/d 10/21/2004 20:00-22:00	Indian w/d 10/21/2004 23:00-02:00	Indian w/d 10/22/2004 02:00-05:00
Product Gas Comp, vol%												
	H2	5.4	5.5	5.6	5.5	8.6	6.6	5.6	4.4	13.1	11.4	13.4
	CO	3.3	3.7	4.0	4.1	5.6	4.5	3.2	3.3	5.5	5.3	7.3
	CH4	1.3	1.2	1.2	1.2	1.7	1.4	1.0	0.8	3.3	2.8	2.8
	CO2	13	13	13	15	18	14	12	12	21	22	23
	N2	74	74	74	75	65	76	75	78	59	60	56
	Total	97	98	98	101	99	102	96	98	102	102	102
	Ave Mol Wt	28	28	28	29	28	29	27	28	28	29	28
Flow, scfh												
	air in	13501	14453	15161	14838	8999	14203	13842	15112	0	0	0
	oxygen in	0	0	0	0	1194	0	0	0	2247	2529	2951
	nitrogen in	5149	5249	5312	5395	5020	5196	6204	6238	6552	6985	6894
	product gas	22898	23757	24730	23764	19358	23511	24476	24697	13557	13294	14180
Product Gas, scfh												
	H2	1236	1307	1385	1307	1665	1552	1371	1087	1776	1516	1900
	CO	756	879	989	974	1084	1058	783	815	746	705	1035
	CH4	298	285	297	285	329	329	245	198	447	372	397
	CO2	2954	3136	3165	3541	3446	3197	2864	2865	2888	2938	3205
	N2	16990	17580	18275	17823	12583	17915	18333	19190	7972	7976	7927
	Total	22234	23187	24112	23930	19106	24052	23595	24154	13828	13507	14464
Heating Value, Btu/hr												
	H2 (325)	401860	424656	450086	424782	541056	504311	445463	353167	577189	492543	617539
	CO (321)	242559	282162	317533	312758	347979	339616	251417	261615	239349	226171	332280
	CH4 (1014)	301841	289075	300915	289160	333693	333762	248187	200342	453644	377443	402599
	Total	946260	995893	1068534	1026700	1222729	1177690	945067	815124	1270182	1096157	1352418
Heating Value, Btu/scf												
	H2	18	18	18	18	28	21	18	14	43	37	44
	CO	11	12	13	13	18	14	10	11	18	17	23
	CH4	13	12	12	12	17	14	10	8	33	28	28
	Total	41	42	43	43	63	50	39	33	94	82	95
VALUES ADJUSTED FOR PURGE NITROGEN												
Product Gas Comp, vol%												
	H2	7.2%	7.3%	7.4%	7.1%	11.8%	8.2%	7.9%	6.1%	24.4%	23.2%	25.1%
	CO	4.4%	4.9%	5.3%	5.3%	7.7%	5.6%	4.5%	4.5%	10.2%	10.8%	13.7%
	CH4	1.7%	1.6%	1.6%	1.5%	2.3%	1.7%	1.4%	1.1%	6.1%	5.7%	5.2%
	CO2	17.3%	17.5%	16.8%	19.1%	24.5%	17.0%	16.5%	16.0%	39.7%	45.0%	42.3%
	N2	69.3%	68.7%	69.0%	67.1%	53.7%	67.5%	69.7%	72.3%	19.5%	15.2%	13.6%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Ave Mol Wt	29	29	29	29	29	28	28	29	27	28	28
Heating Value, Btu/scf		55	56	57	55	87	62	54	45	175	168	179
Product Gas, scfh												
	H2	1236	1307	1385	1307	1665	1552	1371	1087	1776	1516	1900
	CO	756	879	989	974	1084	1058	783	815	746	705	1035
	CH4	298	285	297	285	329	329	245	198	447	372	397
	CO2	2954	3136	3165	3541	3446	3197	2864	2865	2888	2938	3205
	N2	11841	12331	12963	12428	7563	12719	12129	12952	1420	991	1033
	Total	17085	17938	18800	18535	14086	18856	17391	17916	7276	6522	7570
FLUE GAS FLOWS ADJUSTED TO 320,000 BTU/HR HEAT LOSS												
Gas created due to combustion of												
Gas created due to combustion of		69	69	69	69	69	69	69	69	69	69	69
	CO2	1071	1071	1071	1071	1071	1069	1069	1069	1069	1069	1069
	N2	4534	4534	4534	4534	3045	4525	4525	4525	0	0	0
Product Gas, scfh												
	H2	1236	1307	1385	1307	1665	1552	1371	1087	1776	1516	1900
	CO	756	879	989	974	1084	1058	783	815	746	705	1035
	CH4	298	285	297	285	329	329	245	198	447	372	397
	CO2	1882	2065	2094	2469	2374	2128	1794	1796	1818	1869	2135
	N2	7307	7797	8430	7894	4517	8194	7604	8427	1420	991	1033
	Total	11480	12333	13194	12930	9970	13262	11797	12321	6207	5452	6500
Product Gas, vol %												
	H2	11	11	11	10	17	12	12	9	29	28	29
	CO	6.6	7.1	7.5	7.5	10.9	8.0	6.6	6.6	12.0	12.9	15.9
	CH4	2.6	2.3	2.2	2.2	3.3	2.5	2.1	1.6	7.2	6.8	6.1
	CO2	16	17	16	19	24	16	15	15	29	34	33
	N2	64	63	64	61	45	62	65	68	23	18	16
	Total	100	100	100	100	100	100	100	100	100	100	100
		28	28	28	28	27	27	27	28	24	25	25
Heating Value, Btu/scf		82	81	81	79	123	89	80	66	205	201	208
	Gasifier Temp C	879	896	936	948	946	936	928	934	856	860	895
	Coal Feed Rate	419	465	448	416	451	441	382	505	416	433	461
	Air Flow (lb/hr)	1033	1106	1160	1135	689	1087	1059	1156	0	0	0
	Steam Flow (lb/hr)	175	172	172	172	215	168	168	168	327	330	332
	Oxygen Flow (lb/hr)	0	0	0	0	101	0	0	0	190	214	249
	Air/Coal Ratio (lb/lb)	2.57	2.48	2.70	2.84	1.59	2.57	2.89	2.39	0.00	0.00	0.00
	Steam/Coal Ratio (lb/lb)	0.44	0.39	0.40	0.43	0.50	0.40	0.46	0.35	0.82	0.79	0.75
	O2/Coal Ratio (lb/lb)	0.60	0.57	0.63	0.66	0.60	0.59	0.67	0.55	0.48	0.51	0.56
	O2/maf Coal (lb/lb)	1.04960934	1.01246687	1.10236548	1.16187072	1.06063201	1.07178419	1.20587233	0.9958557	0.85596557	0.9255662	1.01441307
	Recirc Rate (lb/hr)	6485	7520	3282	2605	6456	3773	4347	3338	2446	1689	4624
	Fraction Carbon in Coal	0.44	0.44	0.44	0.44	0.44	0.41	0.41	0.41	0.41	0.41	0.41

Fraction Sorbent in Coal	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Coal Heating Value BTU/lb	6555	6555	6555	6555	6555	6568	6568	6568	6568	6568	6568
WT filter ash lb/hr	187	184	179	177	190	137	200	146	129	110	141
Fraction C in filter ash	0.19	0.16	0.13	0.11	0.13	0.16	0.12	0.14	0.28	0.28	0.20
Wt dipleg lb/hr	0	0	0	0	0	0	0	0	0	0	0
Fraction C in dipleg									2.3%		
TRDU Throughput lb/hr-ft^2	6022	6683	6438	5978	6481	6338	5490	7257	5978	6223	6625
TRDU Throughput MMBtu/h	39	44	42	39	42	42	36	48	39	41	44
TRDU Riser Vel ft/s	50	51	51	50	46	48	49	56	38	39	41
% Moisture As run	5	5	5	5	5	9	9	9	9	9	9
Ultimate As run											
C	44	44	44	44	44	41	41	41	41	41	41
H	3.7	3.7	3.7	3.7	3.7	3.9	3.9	3.9	3.9	3.9	3.9
N	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
S	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6
O	12	12	12	12	12	18	18	18	18	18	18
Ash	38.6	38.6	38.6	38.6	38.6	35.5	35.5	35.5	35.5	35.5	35.5
Carbon Conversion											
Solid Accountability	80	81	88	89	87	88	84	90	78	82	84
Gas Make	71	68	73	85	80	83	81	61	78	74	80
H2S conectration (ppm)	595	504	570	700	850	660	504	398	1318	1292	1246
ulfur Retention (%)	46	57	48	34	39	45	49	69	33	38	40
1-Lig, 2-Sub, 3-Bit, 4-Pet											
TC416 thermocouple (402-C	857	869	890	895	888	876	868	872	776	771	839
Calculate or Specify BEDRATE, "C" or "S"	S	S	S	S	S	S	S	S	S	S	S
If Spedified, Multiplier for Recirculation Rate	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40

Balanced Product - Product Gas) / (Product Gas) {Dry}	-3%	-1%	-1%	4%	5%	1%	-3%	-0%	-1%	5%	1%
SUMMARY OF THE {RAW} DRY PRODUCT GAS											
TOTAL PRODUCT GAS, scf/hr -------- >	22898	23757	24730	23764	19358	23511	24476	24697	13557	13294	14180
H2	5.4%	5.5%	5.6%	5.5%	8.6%	6.6%	5.6%	4.4%	13.1%	11.4%	13.4%
BEFORE CO	2.7%	3.0%	3.3%	3.4%	4.5%	3.7%	2.8%	2.4%	4.2%	3.6%	5.1%
CH4	0.8%	0.8%	0.7%	0.7%	1.1%	0.9%	0.7%	0.5%	2.1%	1.8%	1.8%
BALANCING CO2	12.9%	13.2%	12.8%	14.9%	17.8%	13.6%	11.7%	11.6%	21.3%	22.1%	22.6%
N2	75.0%	75.0%	75.0%	75.0%	65.0%	75.0%	75.0%	75.0%	60.0%	60.0%	60.0%
{ ppm } H2S	595	504	570	700	850	660	504	398	1318	1292	1246
SUMMARY OF THE {BALANCED} DRY PRODUCT GAS											
TOTAL PRODUCT GAS, scf/hr ------- >	22308	23583	24367	24665	20304	23799	23754	24597	13449	13927	14337
H2	5.4%	5.5%	5.6%	5.5%	8.6%	6.6%	5.6%	4.4%	13.1%	11.4%	13.4%
AFTER CO	2.7%	3.0%	3.3%	3.4%	4.5%	3.7%	2.8%	2.4%	4.2%	3.6%	5.1%
CH4	0.8%	0.8%	0.7%	0.7%	1.1%	0.9%	0.7%	0.5%	2.1%	1.8%	1.8%
BALANCING CO2	12.9%	13.2%	12.8%	14.9%	17.8%	13.6%	11.7%	11.6%	21.3%	22.1%	22.6%
N2	75.0%	75.0%	75.0%	75.0%	65.0%	75.0%	75.0%	75.0%	60.0%	60.0%	60.0%
{ ppm } H2S	595	504	570	700	850	660	504	398	1318	1292	1246
SUMMARY OF THE {RAW} Elemental and Mass Closure											
#MOLES H	-4%	-5%	-1%	2%	1%	0%	-9%	11%	14%	10%	11%
#MOLES C	10%	18%	17%	8%	10%	10%	-7%	30%	7%	14%	14%
BEFORE #MOLES O	-12%	-13%	-8%	-13%	-10%	-4%	-5%	4%	5%	4%	8%
#MOLES S	2%	5%	4%	4%	5%	3%	-3%	7%	1%	6%	4%
BALANCING #MOLES N	-3%	-1%	-1%	4%	5%	1%	-3%	0%	-1%	5%	1%
#MOLES Ca	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
#MOLES Mg	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
MASS, #	-2%	0%	-1%	4%	4%	1%	-3%	0%	0%	3%	1%

SUMMARY OF CARBON REMOVALS

Fast Kinetics

% CARBON LOST BY GASIFICATION { Total }	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%
% CARBON LOST BY COMBUSTION { Total }	76%	67%	81%	67%	81%	86%	81%	85%	46%	74%	80%
% Carbon Removed In Filter Ash { Total }	19%	31%	19%	33%	19%	14%	19%	15%	54%	26%	15%
% Carbon Removed In LASH { Total }	2%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analysis, 4x%	-6%	52%	34%	66%	30%	14%	6%	31%	59%	29%	-4%

Single-Pass CHAR Carbon Conversion { Gasification }	5.7%	6.3%	23.1%	31.8%	14.5%	20.5%	16.4%	22.2%	10.0%	15.0%	9.9%
Single-Pass CHAR Carbon Conversion { Combustion }	63%	100%	100%	100%	100%	100%	100%	100%	100%	100%	61%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	9079	10528	4595	3647	9038	5282	6086	4673	3424	2365	6474

Slow Kinetics - Mann et. al.

% CARBON LOST BY GASIFICATION { Total }	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%
% CARBON LOST BY COMBUSTION { Total }	77%	67%	81%	67%	81%	86%	81%	85%	46%	74%	82%
% Carbon Removed In Filter Ash { Total }	19%	31%	19%	33%	19%	14%	19%	15%	54%	26%	15%
% Carbon Removed In LASH { Total }	2%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Char Carbon Accounted For { Comb + S.Gasif + Filter + LASH }	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% Coal Carbon From Volatiles {Basis: Recycle Rate, Ultimate Analysis, 4x%	-4%	52%	34%	66%	30%	14%	6%	31%	59%	29%	-2%

Single-Pass CHAR Carbon Conversion { Gasification }	3.1%	2.3%	4.2%	5.2%	2.3%	3.4%	3.8%	6.6%	13.9%	25.0%	6.4%
Single-Pass CHAR Carbon Conversion { Combustion }	63%	100%	100%	100%	100%	100%	100%	100%	100%	100%	61%
Bed Recycle Rate from Comb Zone nrg-Balance, lb/hr	9079	10528	4595	3647	9038	5282	6086	4673	3424	2365	6474

[H2O] { Inlet }	15.5%	14.7%	14.2%	14.4%	21.4%	14.5%	14.1%	13.4%	40.3%	38.9%	38.3%
[H2O] After Combustion { No WGS }	14.5%	13.6%	13.1%	13.2%	19.4%	13.4%	13.1%	12.4%	37.5%	36.0%	34.8%
[H2O] After Combustion { WGS }	9.3%	8.5%	7.9%	7.9%	12.4%	8.2%	8.1%	7.4%	29.1%	27.3%	25.4%
[H2O] After Steam Gasification { WGS }	3.1%	8.2%	7.6%	7.7%	12.0%	7.9%	7.8%	7.2%	28.6%	26.8%	3.8%
SUMMARY OF THE											

SPREADSHEET RESULTS											
Carbon Conversion (Coal IN - Filter/LASH) / (Coal IN)	78%	84%	88%	89%	87%	88%	82%	90%	78%	82%	85%
Carbon Conversion (Coal IN - [1 - Balanced Product]) / (Coal IN	66%	65%	69%	84%	80%	78%	86%	59%	70%	71%	71%
% Sulfur On Sorbent, CHAR, & ASH (S IN - H_2S) / (S IN) {mo	46%	56%	47%	31%	34%	44%	43%	68%	33%	34%	41%
Heat Loss from Mass & Energy Balances (H IN - H Out) / (LHVm	-12%	-11%	-11%	-11%	-12%	-9%	-14%	-9%	-9%	-13%	-16%
Heat Loss from TRDU { Btu/hr }	-3.5E+005	-3.5E+005	-3.4E+005	-3.1E+005	-3.7E+005	-2.6E+005	-3.1E+005	-3.0E+005	-2.6E+005	-3.6E+005	-4.7E+005
HHV of Product Gas, 60 F w H_2S w/o tar, Btu/scf	36	37	37	36	55	43	36	29	77	68	76
HHV of Product Gas, 60 F, w H_2S w/o tar, Btu/scf {Dry Corrected}	78	76	75	73	136	88	81	63	235	212	220
LHV of Product Gas, 60 F, w H_2S w/o tar, Btu/scf {Wet}	30	31	32	33	47	37	30	24	51	45	49
LHV of Product Gas, 60 F, w H_2S w/o tar, Btu/scf {Wet Corrected}	56	57	56	59	95	65	57	43	92	82	85
Gasifier Cold Gas Efficiency, % of coal HHV	25%	25%	27%	29%	33%	34%	36%	21%	37%	32%	35%
Bed Recycle Rate from Comb Zone mg-Balance, lb/hr	9079	10528	4595	3647	9038	5282	6086	4673	3424	2365	6474
ADJUSTMENTS TO STREAM FLOWS AND TROUBLE SHOOTING											
X. s. Sorbent (Ca - S IN) / (S IN) {molar}	33%	33%	33%	33%	33%	26%	26%	26%	26%	26%	26%
If No then Sorbent is not in Excess											
Fraction of Carbon in LASH (Original)	2.5%	0.6%	2.2%	1.1%	1.2%	2.4%	1.7%	2.5%	0.9%	3.8%	3.8%
Fraction of Carbon in LASH (Modified)	2.5%	0.6%	2.2%	1.1%	1.2%	2.4%	1.7%	2.5%	0.9%	3.8%	3.8%
If No then there is not enough carbon in the Bed											
CO_2/CO Mass Ratio Leaving Combustion Zone (No WGS)	0.5	0.5	0.4	0.3	0.3	0.4	0.4	0.4	0.6	0.6	0.5
CO_2/CO Mass Ratio Leaving Combustion Zone (WGS)	1.9	1.7	1.3	1.3	1.5	1.4	1.5	1.3	4.0	3.6	2.7
(Balanced Product - Product Gas) / (Product Gas) {Dry}	-3%	-1%	-1%	4%	5%	1%	-3%	-0%	-1%	5%	1%
If No then Product gas has been adjusted too much											
(Balanced H_2O - H_2O) / (H_2O) {Quenched}	-22%	-27%	-18%	-38%	-31%	-13%	-8%	9%	12%	2%	17%
If No then the water has been adjusted too much											
(Balanced Carbon Conversion) - ("UN-Balanced" Carbon Conversion).	-2%	-1%	-1%	3%	4%	1%	-3%	-1%	-1%	3%	0%
If No then the Carbon Conversion has changed dramatically											
Sum of Spreadsheet Checkers Must be Zero ---->	1	1	0	1	1	0	0	0	0	0	0
If No then there is error in the spreadsheet and debugging is required											
Kp' - Kp Inventory Check Must be Zero ---->	0	0	0	0	0	0	0	0	0	0	0
Arrhenius "A"	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500	32,500
Arrhenius "E"	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300	31,300

COMPARISON OF CERTAIN SPREADSHEET RESULTS											
delta T (°C)	22	27	46	53	58	60	60	62	80	89	56
Average Mixing Zone T (°C)	879	896	936	948	946	936	928	934	856	860	895
Average Low T (°C)	857	869	890	895	888	876	868	872	776	771	839
Air in (scfh)	13,501	14,453	15,161	14,838	8,999	14,203	13,842	15,112	0	0	0
Oxygen in (scfh)	0	0	0	0	1,194	0	0	0	2,247	2,529	2,951
Nitrogen in (scfh)	5,149	5,249	5,312	5,395	5,020	5,196	6,204	6,238	6,552	6,985	6,894
Product Gas (scfh)	22,898	23,757	24,730	23,764	19,358	23,511	24,476	24,697	13,557	13,294	14,180
Coal Feed Rate (lb/hr)	419	465	448	416	451	441	382	505	416	433	461
Air Flow (lb/hr)	1033	1106	1160	1135	689	1087	1059	1156	0	0	0
Steam Flow (lb/hr)	175	172	172	172	215	168	168	168	327	330	332
Air/Coal Ratio (lb/lb)	2.57	2.48	2.70	2.84	1.59	2.57	2.89	2.39	0.00	0.00	0.00
Steam/Coal Ratio (lb/lb)	0.44	0.39	0.40	0.43	0.50	0.40	0.46	0.35	0.82	0.79	0.75
O_2/Coal Ratio (lb/lb)	0.60	0.57	0.63	0.66	0.60	0.59	0.67	0.55	0.48	0.51	0.56
Fraction Carbon in Coal {Swany's}	0.44	0.44	0.44	0.44	0.44	0.41	0.41	0.41	0.41	0.41	0.41
Bed Recycle Rate, lb/hr {Everett's}	9,079	10,528	4,595	3,647	9,038	5,282	6,086	4,673	3,424	2,365	6,474
Bed Recycle Rate,lb/hr {Swany's}	6,485	7,520	3,282	2,605	6,456	3,773	4,347	3,338	2,446	1,689	4,624

APPENDIX B

RESULTS FROM EERC HAZARDOUS WASTE TREATABILITY STUDY

January 12, 2001

Mr. Curt Erickson, Program Manager
North Dakota Department of Health
Division of Waste Management
PO Box 5520
1200 Missouri Avenue, Room 302
Bismarck, ND 58506-5520

Dear Mr. Erickson:

Subject: EERC Report on EERC Hazardous Waste Treatability Study

Based upon previous conversations and correspondence with the North Dakota Department of Health, a hazardous waste treatability study was performed on waste generated at the University of North Dakota (UND) Energy & Environmental Research Center (EERC). This study was completed November 28, 2000. The enclosed report provides the details of the study successfully performed at the EERC within the guidelines of Section 33-24-02-04.6 of the North Dakota Administrative Code. As follows Subsection i, a report on the study is enclosed. As stated in Subsection j, representative samples of all waste materials generated by this study were analyzed and determined to be not hazardous waste. The City of Grand Forks has been contacted and has agreed to accept the waste at the landfill.

If there are any questions, please feel free to contact me at (701) 777-5172. You can also fax me at (701) 777-5181 or e-mail at dhajicek@undeerc.org. Thank you.

Sincerely,

Douglas R. Hajicek, PE
Manager, Advanced Power Systems

DRH/drh

Enclosure

c: John Hendrikson, EERC
Mike Swanson, EERC
Ken Grohs, EERC

Subsection i

Name: University of North Dakota (UND) Energy & Environmental Research Center (EERC)
Mailing Address: PO Box 9018
Grand Forks, ND 58202-9018
Shipping Address: 15 North 23rd Street
Grand Forks, ND 58203
Identification Number: NDD000819227

TREATABILITY STUDIES CONDUCTED

Materials were generated by the Transport Reactor Development Unit (TRDU), a research gasification system located at the Energy & Environmental Research Center (EERC) during Test No. PO63 conducted in September 1999. A brief description of the TRDU is contained in Appendix A. The Illinois No. 6 bituminous coal used during this test resulted in the generation of solids with high sulfide concentrations. The product analyses are shown in Table 1. During this test, there was 824 lb of bed material, 1596 lb of dipleg material, and 7313 lb of filter vessel material collected. Based upon the composite samples obtained from each of these product streams, they each, respectively, had sulfide concentrations of 4980 μg/g, 3530 μg/g, and 2650 μg/g.

TABLE 1

TRDU Product Analyses

	Bed Material	Dip Leg	Filter Vessel
Proximate Analysis, wt%			
Moisture	0.0	0.1	0.4
Volatile Matter	2.7	2.1	7.0
Fixed Carbon (ind.)	0.0	0.0	20.8
Ash	97.3	97.8	71.8
Heating Value, Btu/lb	0	864	5473
Sulfides, μg/g	4980	3530	2650

Treatment of these materials was in the EERC circulating fluidized-bed (CFB) combustor. The CFB is a research combustion system, and a brief description is contained in Appendix B. A CFB-type system would be well suited for the economical and environmental disposal of the solid product streams that would be generated by a commercial transport gasification system. This solid fuel by-product is a low-Btu small-sized material that would be difficult to burn in a pulverized-coal-fired system and could only be burnt in a bubbling fluidized bed at very low velocities, thus requiring a much larger system compared to a CFB combustor. Operational CFB combustion data will allow for a more optimized design of a commercial CFB system. Steam or steam and electrical power would be produced by the combustion of these solids.

The first test conducted on November 19–20, 2000, was terminated early because of operational difficulties encountered. A normal start-up procedure was used, with initial heatup on natural gas to about 800°F and then switching over to coal for final heatup to about 1550°F. The more reactive Wyodak subbituminous coal was needed to heat up the system to full operational temperatures, because of limitations with the natural gas preheat system, before introducing the relatively low-Btu test fuel that would not likely ignite at the low temperatures. Several indications pointed to the lack of good bed material circulation being established even at the start of this test. The most likely explanation is that the silica sand bed material (~600-μm average size) that was selected for use in this CFB test is suspected to be slightly oversized for this combination of fluidizing velocity and particularly for the extremely fine size of this fuel. Normal fuel feed size for the CFB is minus 1/4 inch (6.35 mm), while this material was mostly less than 0.1 mm. The unexpected lack of good circulation resulted in the majority of the fuel being burned at the top of the combustor while the lower portions of the combustor continually dropped off in temperature. Several corrective adjustments were made (by redistributing the combustion air into the combustor and external heat exchanger), but a recovery could not be achieved. As a result of high temperatures, there were deposits formed at the entrance into the primary cyclone and also at the bottom of the primary cyclone where solids normally flow down the downcomer into the external heat exchanger and then back to the combustor. The system was shut down and allowed to cool down for cleaning and a subsequent restart.

A much smaller than normal silica sand (~150 μm average size) was selected for the restart. There was some concern about being able to retain this size material in the system, but no problems with excessive carryover into the baghouse were encountered. The operational conditions for both tests are shown in Table 2. The second test was divided into three test periods based upon average combustor temperatures. It is suspected that during Period 2 more of the fuel feed material was from the lower-Btu TRDU bed material and dipleg material than the filter vessel material. This did result in lower average bed temperatures (~1400°F) and required a minimal addition of the start-up coal (~5 lb/hr) to help ensure that sufficient bed temperatures could be maintained to successfully oxidize the sulfides present in the feed material. The average oxygen content of the flue gas during Test Period 2 was 10% or greater. Test Periods 1 and 3 are very similar, with average bed temperatures of 1520°F and oxygen content at about 2% to 3%. The overall fuel feed rate for Test Periods 1–3 was 402 lb/hr. Test conditions for the second test are shown in Figures 1–3. Figures 1 and 2 show combustor and downcomer and external heat exchanger temperatures, respectively. Figure 3 shows sulfur dioxide emissions obtained during Test 2.

There was no limestone addition for sulfur capture during any of the testing. Based upon visual observations, the sulfur dioxide emissions were somewhat greater than 1000 ppm and much less then 5000 ppm for the November 20 test during the brief, less than 45 minutes, high-temperature portion of this test. Levels greater than 1000 ppm were not set to be automatically

TABLE 2

CFB Operating Conditions

		Period 1	Period 2	Period 3
Date	11/20	11/27–28	11/28	11/28
Start Time	09:45 AM	11:00 PM	08:30 AM	02:30 PM
Stop Time	10:30 AM	07:30 AM	02:00 PM	10:00 PM
Average Temperatures, °F				
Combustor	1714	1519	1402	1520
Downcomer	1230	1525	1402	1519
External Heat Exchanger	707	1491	1382	1529
Combustion Air, scfm	309	406	416	405
Fuel Feed Rate, lb/hr	216	451	396	361
Velocities, ft/sec				
Combustor	9.7	13.0	12.6	13.0
External Heat Exchanger	2.4	2.0	2.0	2.0
Gas Emissions				
Oxygen, %	3.7	1.9	10.0	3.1
Nitrogen oxides, ppm	430	48	99	69
Sulfur Dioxide, ppm	>1000	645	52	437
Sulfur Dioxide, lb/hr	>3.6	2.8	0.3	2.1
Solid Emissions, lb/hr				
Bed Material	0	21	173	40
Secondary Cyclone	0	89	113	259
Baghouse	61	51	40	45

recorded by the data acquisition system. The system can be manually switched over to the 5000 ppm range if required. It had been planned to add limestone if sulfur dioxide emissions exceeded 5000 ppm for any sustained periods. For the flue gas flow rate at which this test was conducted, a sulfur dioxide emission of 5000 ppm would produce 18.2 lb/hr of sulfur dioxide, less than the 18.3 lb/hr limit for the EERC. Solids addition and removal rates are shown in Tables 3 and 4, respectively.

Representative samples were obtained for the November 20 test, from the low-temperature Test Period 2, and from composites of Test Periods 1 and 3. Test results for the sulfide content of these sample are shown in Appendix C. All samples were successfully treated, resulting in sulfide contents of less than 0.2 µg/g. Based upon these results, all of the treated materials will be disposed of in the Grand Forks city landfill.

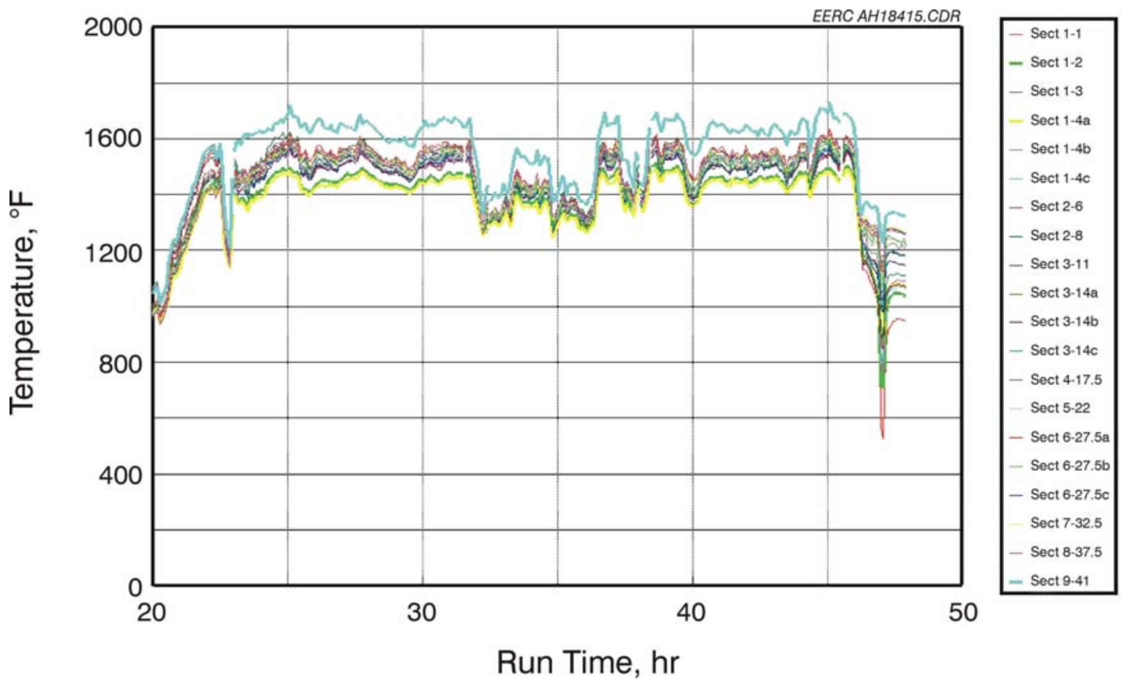

Figure 1. Combustor and downcomer temperatures.

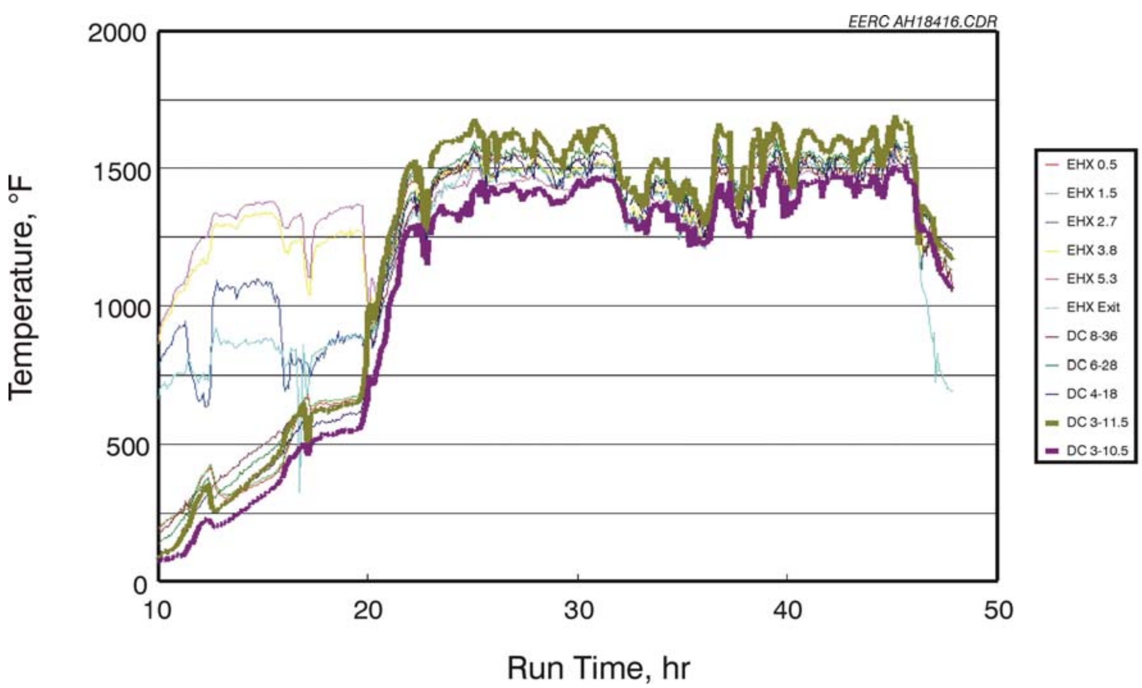

Figure 2. External heat exchanger temperatures.

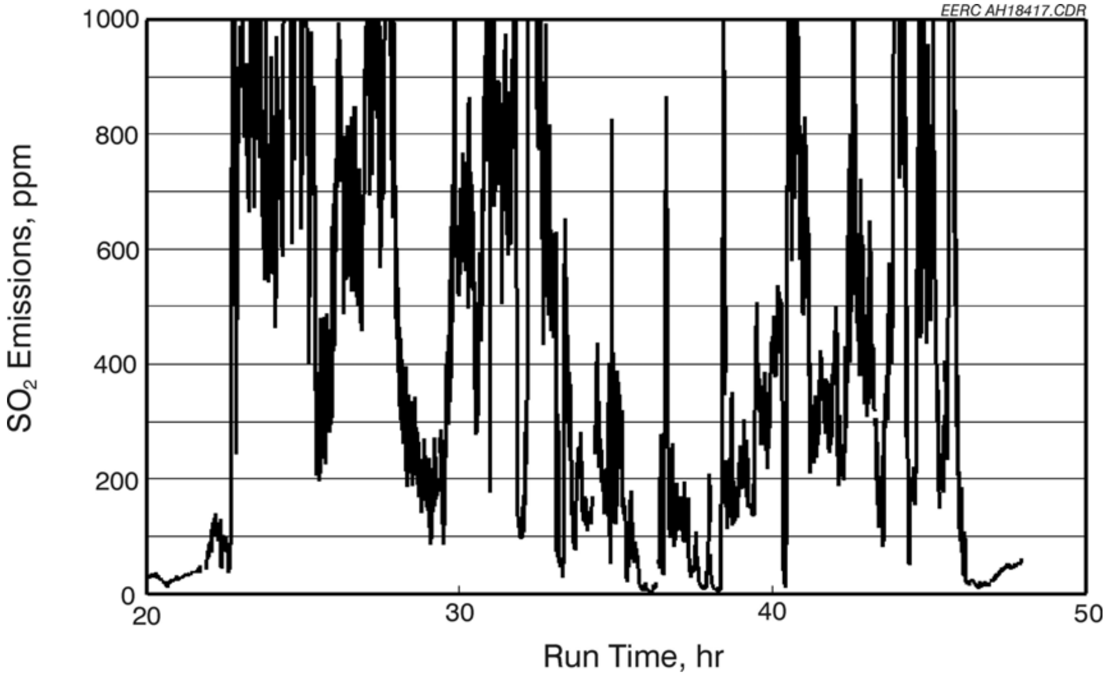

Figure 3. Sulfur dioxide emissions obtained during Test 2.

TABLE 3

CFB Solids Addition

Fuel Feed Rate					
Start Date	Start Time	Stop Time	Hopper Net, lb	Hopper Feed Rate, lb/hr	Period Feed Rate, lb/hr
11/20/1900	09:45 AM	10:30 AM	162	216	216
Period 1					
11/27/1900	11:00 PM	01:50 AM	2080	734	
11/28/1900	01:50 AM	07:15 AM	1640	303	451
Period 2					
11/28/1900	07:15 AM	01:10 PM	2344	396	396
Period 3					
11/28/1900	01:10 PM	07:15 PM	2352	387	
11/28/1900	07:15 PM	10:00 PM	836	304	361
Totals/Averages			9252	402	402

Bed Material Added (Silica Sand)	
Date	Amount, lb
11/20/1900	1200
11/27/1900	800
Total	2000

TABLE 4

CFB Solids Removal

Bed Material Removed			
Date	Barrel	Drain Location	Weight, lb
11/20/1900	1	Combustor	635
11/20/1900	2	Combustor	310
11/20/1900	1	Downcomer	326
Total			1271
11/28/1900	1	Combustor	483
11/28/1900	2	Combustor	508
11/28/1900	3	Combustor	496
11/28/1900	4	Combustor	416
11/28/1900	1	Downcomer	668
Total			2571

Secondary Cyclone Ash Material Captured			
Date	Barrel	Drain Location	Weight, lb
11/28/1900	1	Cyclone	528
11/28/1900	2	Cyclone	380
11/28/1900	3	Cyclone	408
11/28/1900	4	Cyclone	526
11/28/1900	5	Cyclone	530
11/28/1900	6	Cyclone	637
Total			3009

Baghouse Ash Material Captured			
Date	Barrel	Drain Location	Weight, lb
11/20/1900	1	Baghouse	46
11/28/1900	1	Baghouse	208
11/28/1900	2	Baghouse	229
11/28/1900	3	Baghouse	219
11/28/1900	4	Baghouse	166
11/28/1900	5	Baghouse	236
Total			1058

Total Solid Material Collected	Weight, lb
11/20/1900	1317
11/28/1900	6638
Total	7955

In conclusion, a CFB system is well suited for the successful conversion of this type of material into a nonhazardous waste for disposal in both an economic and environmental manner. This test provided a couple of basic data points demonstrating the CFB's potential for use in this process. Detailed design data for an optimized design would require a much more complete test matrix. Test variables would include parameters like bed material size, fluidizing velocities, average combustor bed temperatures, excess air, and limestone addition for better sulfur capture. No further testing is planned at this time. Additional testing is dependent upon approval from the North Dakota Department of Health and obtaining additional funding for this type of research. Use of the EERC CFB system for conversion of high sulfide materials to nonhazardous waste will be normally more expensive then shipping to an off-site licenced disposal facility. This is due to a number of reasons. Usually only a relatively small amount of material is being disposed of, which only allows the use of a research facility for a short period of time. A thorough research program would require much more extensive characterization of the feed and product streams as compared to simple disposal.

APPENDIX A

THE EERC TRANSPORT REACTOR DEVELOPMENT UNIT

The transport reactor development unit (TRDU) is a 200–300-lb/hr pressurized circulating fluid-bed gasifier. 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 A-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.

The hot-gas filter vessel (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. 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 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. 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.

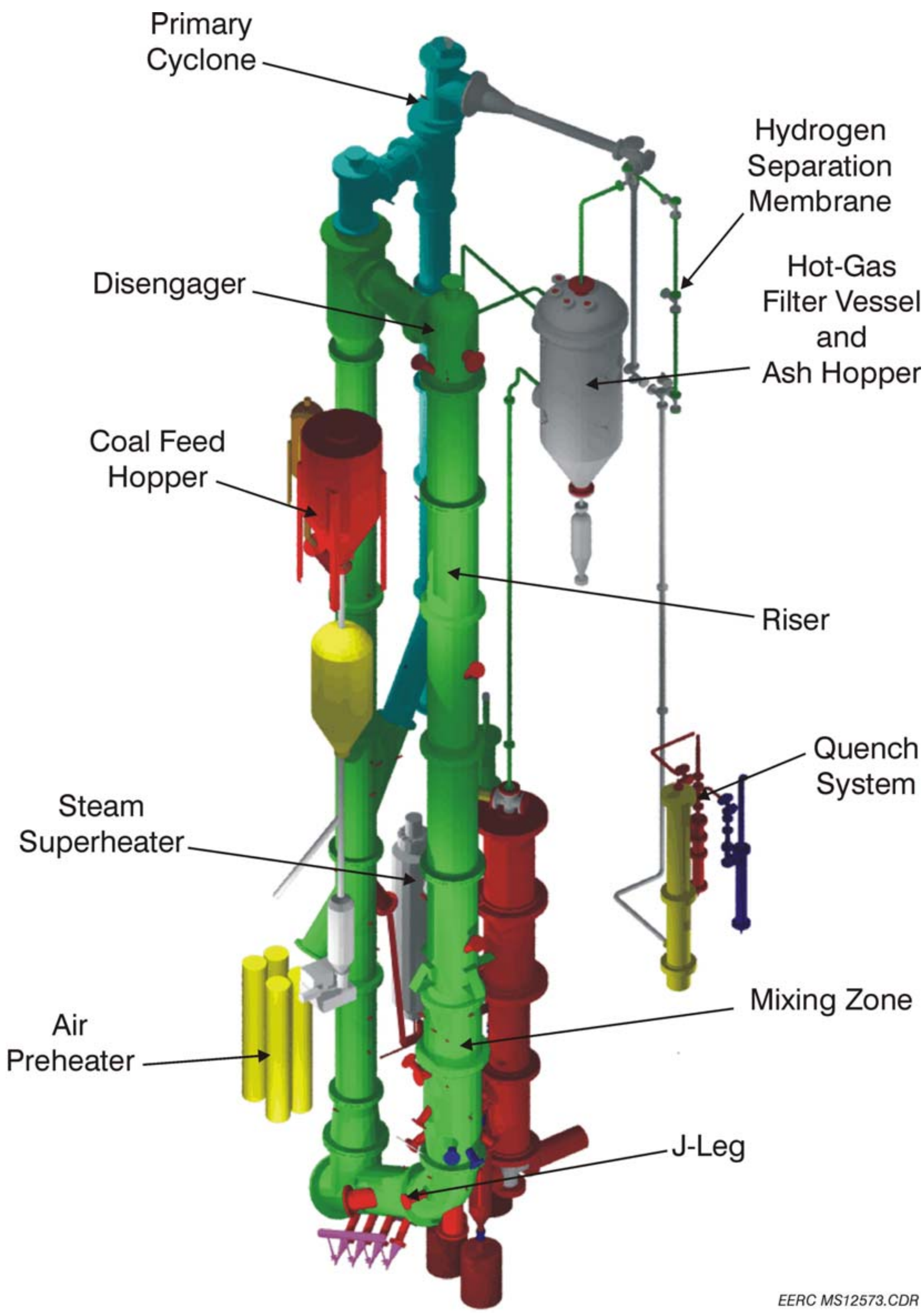

Figure A-1. TRDU with HGFV in EERC gasification tower.

APPENDIX B

DESCRIPTION OF THE CIRCULATING FLUIDIZED-BED COMBUSTION SYSTEM

A schematic of the overall circulating fluidized-bed combustion (CFBC) system is shown in Figure B-1. The overall system is divided up into the following subsystems:

- Combustion Air System
- Flue Gas System
- Flue Gas Recirculation System
- Ash-Fouling Section
- Fuel and Sorbent System
- Combustor
- Solids Recirculation System
- Natural Gas-Fired Preheater
- Combustor Heat Exchange System
- External Heat Exchange System
- Flue Gas Cooling Water System

A forced-draft blower supplies combustion air and secondary air to the combustor. The combustion air heat exchanger is a shell and tube heat exchanger that uses hot flue gas to preheat the combustion air before it enters the combustor. Total combustion air flow is controlled by the amount of bypass through the combustion air bypass valve located directly after the combustion air heat exchanger. The secondary combustion air control valve determines the ratio of combustion air which enters the test furnace above the distributor plate to the amount of

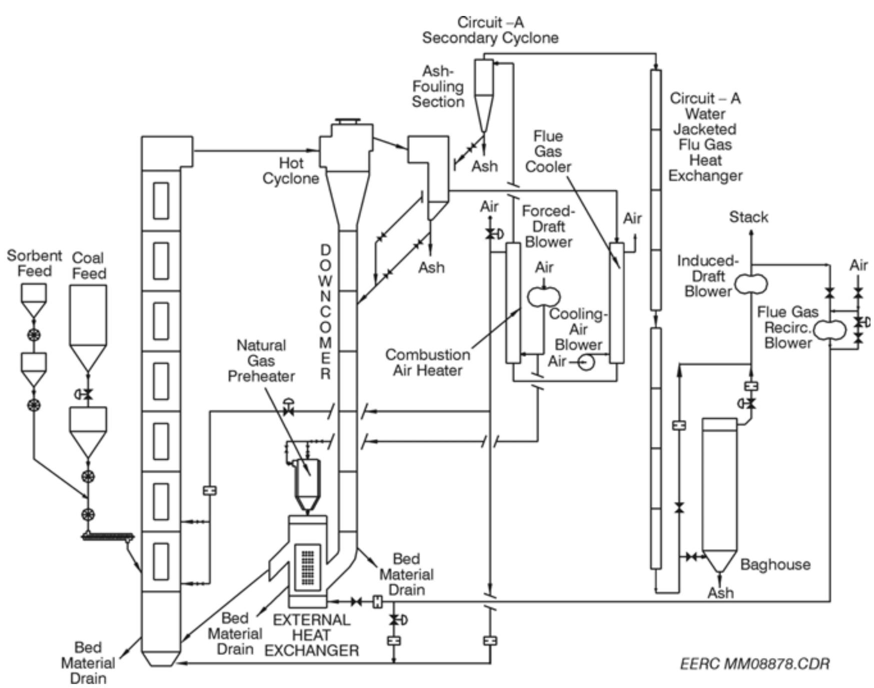

Figure B-1. Schematic of CFB pilot plant.

combustion air introduced into the combustor plenum below the distributor plate. The secondary combustion air can be introduced through manifolds at two different levels, located 5' 9" and 10' 6" above the distributor plate in Sections 2 and 3, respectively, of the combustor. Four 3-inch manual gate valves at each level are used to select where overfire air is introduced into the combustor.

Flue gas exits the top of the combustor, then flows through a refractory-lined primary cyclone with an inside diameter of 25 inches, the ash-fouling section, an air-cooled flue gas cooler, the combustion air heater, an 18-inch stainless steel secondary cyclone, eight water-jacketed flue gas heat exchangers, and through either the flue gas bypass or the baghouse. Temperatures and pressures are monitored throughout the flue gas system. Flue gas is drawn through the induced-draft (ID) blower where it finally enters a stack for release to the atmosphere. Flue gas flow is controlled by the amount of air allowed into the ID blower through the ID fan bypass valve. The ID fan bypass valve is computer-controlled and continually adjusted to maintain −2-inch pressure at the inlet of the primary cyclone.

The flue gas recirculation blower is used to supply either air or flue gas to the external heat exchanger (EHX) and to supply flue gas to the combustor for flue gas recirculation testing. Manual gate valves located upstream of the blower allow either air or flue gas to enter the blower.

Primary and secondary combustion air, flue gas recirculation, and flue gas flow rates are measured using orifice plates. Instrumentation is interfaced with the data acquisition/control system to record and display the flow rates. Orifice differential and static pressures are also monitored with magnehelic pressure gages.

The ash-fouling section is located at the exit of the 25-inch primary cyclone. Two air-cooled stainless steel probes maintained at 1000°F are present in the ash-fouling section to detect potential ash deposition or slagging. A hopper attached to the bottom of the ash-fouling section is connected to the downcomer via a drain leg containing two pneumatically actuated gate valves for ash recirculation. Three pneumatically actuated gate valves are used to allow the solids collected downstream by the secondary cyclone to be either routed back into the downcomer or to a collection barrel located on the ground floor. The length of time that any of these five pneumatic valves are open or closed is controlled with the data acquisition/control system.

The fuel storage hopper has a capacity of about 3000 pounds, which is transferred to a permanent feed hopper in approximately 600-pound increments. A gate valve is used to recharge the fuel feed hopper. The fuel feed hopper is suspended from a load cell; approximate fuel feed rates are calculated from the weight loss of the hopper over time. At the bottom of the weigh hopper, a rotary valve with an electronic speed controller is used to control the fuel feed rate.

The combustor is a series of refractory-lined sections bolted together. Each section has 2 inches of hard, abrasion-resistant refractory used in combination with 7 inches of insulating refractory. The bottom plenum section has the primary combustion air entrance and a bed material drain. The first combustor section (Section 1) has the solids recirculation return from the EHX. A removable stainless steel nozzle distributor plate is installed between the plenum and first combustor section. The next seven sections (Sections 2–8) each have two doorways on opposite sides for the installation of either blank refractory doors or heat exchanger panels. At this time, twelve of the possible fourteen heat exchanger panels are installed in the combustor, two each in Sections 2, 3, 4, 7, and 8, and one each in Sections 5 and 6. Section 2 has the entrance for gravity feed of fuel and sorbent and the first set of secondary combustion air ports. Section 3 has the second set of four secondary combustion air ports. Section 9, the combustor exit, connects to the primary refractory-lined cyclone. Thermocouple and pressure taps are present in all of the combustor sections. All pressure taps are continuously purged with air to keep them open for accurate pressure measurements.

The refractory-lined components of the solids recirculation system include the primary cyclone, the downcomer, and the EHX. Solids that are captured by the primary cyclone drop into the downcomer and travel downward into the EHX. Thermocouples monitor the temperature at the entrance and exit of the primary cyclone. The EHX has a plenum section into which either air or flue gas can be introduced. A removable stainless steel distributor plate is installed between the plenum and the main body of the EHX. The natural gas-fired preheater, described later, is attached to the top section of the EHX. Sixteen U-shaped stainless steel water-cooled heat exchanger tubes are installed in a removable refractory-lined door in the EHX. Thermocouple and pressure taps are distributed along the sections of the downcomer and in the EHX.

The preheater combustion chamber is constructed with inner and outer stainless steel shells. The natural gas-fired burner is bolted to the top of the preheater and fires downward. To maintain an acceptable operational temperature on the inside surface of the preheater, air is circulated through a baffled cooling jacket. Cooling air enters at the top of the preheater and flows downward, where it combines with the combustion gases at the bottom of the preheater transition cone. Preheater combustion air and the cooling jacket air are supplied by the forced-draft (FD) blower. A butterfly valve in the 4-inch supply line from the FD blower and a gate valve between the preheater and the EHX isolate the system when it is not being used. There are butterfly valves in the combustion air and cooling air lines for control purposes. There are also orifice plates in each line with magnehelics to monitor the flow rates. The flow of natural gas to the main and pilot burners are controlled with flowmeters located in the control room. A flame safety system is located in the control room to shut off the flow of natural gas to the preheater if 1) a flame is not present in the preheater, 2) combustion air is not being supplied to the preheater or cooling jacket, or 3) the combustion air pressure is greater than the natural gas pressure supplied to the preheater.

The rate of water flow to the combustor heat exchangers (CHX) is measured individually for each door by flowmeters and controlled by globe valves installed above the flowmeters in the CHX panel boards. Total flow is measured with an in-line turbine flowmeter, which includes a bypass to allow for maintenance or repair during operation. An air system is connected to the inlet manifolds of each of the heat exchange panels. Air is used to cool the heat exchanger panels during operation prior to the introduction of water. Each inlet manifold has a selector switch to allow for the proper distribution of either air or water through the manifold into the heat exchanger tubes of the panels.

There are sixteen heat exchange coils installed in the external heat exchanger door. Each U-shaped heat exchanger is constructed out of 1-inch stainless steel pipe with ½-inch stainless steel tubing at each end. Each of eight circuits have a flowmeter and flow control valve mounted in a panel board to monitor and control the flow of water. Total flow is measured with an in-line turbine flowmeter, installed with a bypass to allow for maintenance or repair during operation.

Three different configurations are used: two using a single tube, four with two tubes in series, and two with three heat exchanger tubes connected in series. A thermocouple is located in the exit of each circuit to measure the water exit temperature.

APPENDIX C

COPIES OF ANALYSES AND DATA SHEETS

Final Results

November 1, 1999

Set Number: 49910

Fund#: 4506

PI: Mike Swanson

Contact Person: M. Swanson

Request Date: Monday, November 01, 1999

Due Date: Monday, November 15, 1999

Set Description: Ash Samples for Sulfide

Sample **49910-01**

49910-01	**PO62 L ash hopper 7/13/99 time2200**	
Sulfide		124 µg/g
49910-02	**PO63 Stand pipe 0645 8/31/99**	
Sulfide		4980 µg/g
49910-03	**PO63 Dipleg 0645 8/31/99**	
Sulfide		3530 µg/g
49910-04	**PO63 Filter 0645 8/31/99**	
Sulfide		2650 µg/g

Distribution 35 Date 11-1-99

Final Results

November 4, 1999

Set Number: 49911

Fund#: 4506

PI: Mike Swanson

Contact Person: M. Swanson

Request Date: Thursday, November 04, 1999

Due Date: Thursday, November 18, 1999

Set Description: Ash Samples for Sulfide

Sample **49911-01**

49911-01	**PO63 Filter 0645 8/31/99**		
	Sulfide	1820	µg/g
49911-02	**PO63 Filter 1335 8/30/99**		
	Sulfide	349	µg/g
49911-03	**PO63 Standpipe 1335 8/30/99**		
	Sulfide	333	µg/g
49911-04	**PO63 Standpipe 1505 8/31/99**		
	Sulfide	1660	µg/g
49911-05	**PO63 Filter 1505 8/31/99 BBL#24**		
	Sulfide	425	µg/g

Distribution 3/4 Date 11-4-99

ANALYTICAL RESEARCH LAB - Final Results

December 4, 2000

Set Number: 50154
Fund#: 4506
PI: Mike Swanson
Contact Person: M. Swanson

Request Date: Monday, December 04, 2000
Due Date: Monday, December 18, 2000
Set Description: Ash Samples for Sulfide

Sample **50154-01**

50154-01	**11/20/00 BBL#1 Bed Material**	
Sulfide		< 0.1 μg/g
50154-02	**11/20/00 BBL#1 BH Ash**	
Sulfide		< 0.2 μg/g
50154-03	**11/28/00 Cyclone Ash Composite**	
Sulfide		< 0.2 μg/g
50154-04	**11/28/00 BH Ash Composite**	
Sulfide		< 0.2 μg/g
50154-05	**11/28/00 Bed Material Composite**	
Sulfide		0.26 μg/g
50154-06	**11/28/00 BBL#3 BH Ash (low temp)**	
Sulfide		< 0.2 μg/g
50154-07	**11/28/00 BBL#3 Cyclone Ash (low temp)**	
Sulfide		< 0.2 μg/g

Distribution 35 Date 12-4-00

CFBC DATA SHEET 6 - COAL, SORBENT AND BED MATERIAL RECORD (Page 1 of 3)

Run No. CFB-NDI-0100

COAL HOPPERS

Start Date	Start Time	Start Name	Hopper Letter	Stop Date	Stop Time	Stop Name	Gross (lbs)	Tare (lbs)	Net (lbs)	
11-19							2692	1826	866	WYODAK
							3434	3272	162	FYA
							~~3[illegible]~~			
							~~3272~~			~~FYA~~
11-27			B				1826	1138		wyodak
	2300	~~0150~~		11/28	0150		3272	1192	2080	FYA
11/28	0150				0715		2812	1172	1640	
	0715						3794	1450 ~~1[illegible]~~	2344	
	1310		I	11-28	1915		3334	982	2352	
	1915		B				1980	1144	836	

CFBC DATA SHEET 8 - ASH INVENTORY RECORD (Page 1 of 3)

Run No. CFB-ND1-0100

BAGHOUSE (BH - 11250)

Bbl. No.	Test No.	Start			Stop			Gross (lbs)	Tare (lbs)	Net (lbs)
		Date	Time	Name	Date	Time	Name			
1					11-20-00			86	40	46
1		11-27			11-27			248	40	208
2			0		11-28	0725		272	43	229
3			0725		11-28	1310		268	49	219
4			1310		11-28	1730		206	40	166
5			1730		11-28	EOR		264	28	236

CFBC DATA SHEET 8 - ASH INVENTORY RECORD (Page 2 of 3)

Run No. CFB-ND1-100

18" CYCLONE (C - 11290)

Bbl. No.	Test No.	Start Date	Start Time	Start Name	Stop Date	Stop Time	Stop Name	Gross (lbs)	Tare (lbs)	Net (lbs)
1					11-28	/				528
2		11-28	0600		11-28	0915		420	40	380
3		11-28	0915		11-28	1315		456	48	408
4		11-28	1315		11-28	1730		566	40	526
5		11-28	1730		11-28	2045		574	44	530
6		11-28	2045		11-28	E.O.R		368	31	637

Run No. CFB-ND1-0100

BED MATERIAL (BED - 11270)

Bbl. No.	Test No.	Start Date	Start Time	Start Name	Stop Date	Stop Time	Stop Name	Gross (lbs)	Tare (lbs)	Net (lbs)
1		11-20			11-20	←				635
2		11-20			11-20	←				310
1		11-28			11-28			532	49	483
2		11-28			11-28			556	48	508
3		11-28			11-28			546	50	496
4		11-28			11-28			466	50	416
				DOWN COMER						
1		11-20	←		11-20	←				326
1		11-28			11-28			718	50	668