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EVALUATION OF CONTINUOUS OXYDESULFURIZATION PROCESSES

Final Technical Report, September 1979—July 1981

By
J. F. Jones
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July 1981

Work Performed Under Contract No. AC01-79ET14292

TRW
Defense and Space Systems Group
Redondo Beach, California

U. S. DEPARTMENT OF ENERGY

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FINAL TECHNICAL REPORT

SEPTEMBER 1979 - JULY 1981

by

J.F. JONES AND D.M. WEVER

JULY 1981

FOR

U.S. DEPARTMENT OF ENERGY

PITTSBURGH ENERGY TECHNOLOGY CENTER

CONTRACT DE-AC01 - 79ET14292

TRW
DEFENSE AND SPACE SYSTEMS GROUP

ABSTRACT

Three processes developed by Pittsburgh Energy Technology Center (PETC), Ledgemont Laboratories, and Ames Laboratories for the oxydesulfurization of coal were evaluated in continuous processing equipment designed, built, and/or adapted for the purpose at the DOE-owned Multi-Use Fuels and Energy Processes Test Plant (MEP) located at TRW's Capistrano Test Site in California. The three processes differed primarily in the chemical additives (none, sodium carbonate, or ammonia), fed to the 20% to 40% coal/water slurries, and in the oxygen content of the feed gas stream. Temperature, pressure, residence time, flow rates, slurry concentration and stirrer speed were the other primary independent variables. The amount of organic sulfur removed, total sulfur removed and the BTU recovery were the primary dependent variables. Evaluation of the data presented was not part of the test effort.

TABLE OF CONTENTS

	<u>PAGE</u>
ABSTRACT.....	ii
TABLE OF CONTENTS.....	iii
LIST OF FIGURES.....	v
LIST OF TABLES.....	vi
ACKNOWLEDGEMENTS.....	vii
1. INTRODUCTION.....	1
2. PROCESS TEST EQUIPMENT.....	3
2.1 Coal Slurry Preparation System.....	3
2.2 High Pressure Reactor System.....	6
2.3 Slurry Disposal System.....	10
3. COAL SELECTION AND CHARACTERIZATION.....	14
4. SYSTEM SHAKEDOWN.....	21
4.1 Planned Test Plant Operation.....	21
4.2 Shakedown Tests.....	24
5. TEST OPERATIONS.....	30
5.1 Test Conditions.....	30
5.2 Data Management.....	30
5.2.1 <u>Instrumentation</u>	30
5.2.2 <u>Sample Analyses</u>	34
5.3 Data Collection and Reduction.....	35
5.4 Data Reporting.....	36
5.5 Operational Problems.....	37
5.5.1 <u>Ames Process Foaming</u>	37
5.5.2 <u>Sulfur Input/Output Problem on PETC Process</u>	39
5.5.3 <u>Exotherm in Kennecott Process</u>	40

TABLE OF CONTENTS
(CONT.)

6. EXPERIMENTAL TEST DATA FOR OXYDESULFURIZATION PROCESS EVALUATIONS..	41
APPENDIX A - EQUIPMENT CALIBRATION.....	83
APPENDIX B - PROCESS INPUT/OUTPUT DATA SUMMARIES.....	88

LIST OF FIGURES

Figures

	<u>PAGE</u>
1 Schematic Diagram of Coal Slurry Preparation System.....	4
2 Schematic Diagram of High Pressure Reactor System.....	7
3 MEP Process Equipment.....	11
4 Control Panel for Gas Supply System.....	12
5 Photograph of Reactor Interior with Baffle Installed.....	25
6 Photograph of Baffles.....	26
7 Photograph of Reactor Top-Flange with Titanium Impeller.....	29
Shaft Guide.	

LIST OF TABLES

Tables

	<u>PAGE</u>
1 Coals Employed in Oxydesulfurization Processes Evaluations.....	15
2 Proximate, Ultimate and Sulfur Forms Analyses for Illinois..... No. 6 Coal.	16
3 Proximate, Ultimate and Sulfur Forms Analyses for Western..... Kentucky No. 9 Coal.	17
4 Proximate, Ultimate and Sulfur Forms Analyses for Lucas..... No. 5 Coal.	18
5 Proximate, Ultimate and Sulfur Forms Analyses for Pittsburg Coal...	19
6 Proximate, Ultimate and Sulfur Forms Analyses for Lower..... Kittanning Coal.	20
7 Shakedown Test Matrix.....	27
8 Test Conditions for Illinois No. 6 Coal.....	31
9 Test Conditions for Western Kentucky No. 9 Coal Bed.....	32
10 Test Conditions for Lucas No. 5 Coal.....	33

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1. INTRODUCTION

This document summarizes work performed by TRW for the U.S. Department of Energy under DOE Contract No. DE-AC01-79ET14292, titled "Evaluation of Performance During Continuous Operation of the Chemical Desulfurization Processes Known under the Title of 'Oxydesulfurization'." The work was conducted from 1 October 1979 through 31 March 1981. The objective of this project was to evaluate the performance, during continuous operation, of the oxydesulfurization processes developed at Pittsburgh Energy Technology Center (PETC), Ledgemont Laboratories, and Ames Laboratory at Iowa State University. These processes treat aqueous coal slurries with oxygen (either as pure gas, mixed with gaseous nitrogen, or as air) to oxidize the pyritic sulfur and a portion of the organic sulfur in coal to soluble sulfates. The Ledgemont* process and the Ames process also employ ammonia and sodium carbonate, respectively, as additives in the aqueous coal slurries.

Previous studies by the developers of the processes indicate that two competing reactions occur. In addition to oxidizing the sulfur, the processes also oxidize some of the carbon in the coal matrix thus reducing the heating value of the coal. Therefore, each of the processes has been evaluated in terms of the sulfur removed and the coal heating value retained.

The Department of Energy (DOE) owned Multi-Use Fuel and Energy Process Test Plant (MEP) located at TRW's Capistrano Test Site was used to conduct the evaluation tests. The test stand was designed and built in 1975-1977 to evaluate another oxydesulfurization process. However, because the test

*Also known as the Kennecott Process.

conditions for this project required reactor operating pressures above the original capabilities of the MEP, an additional bank of high-pressure reactors were designed and implemented.

Upon completion of the plant modification, a short test effort was conducted to demonstrate the operating capabilities of the modified reactor system and the process plant as a whole. This was followed by a series of process evaluation tests using operating conditions and coal samples which were specified by the DOE.

Feed and processed coal slurries and vent gases were sampled and analyzed to obtain data necessary to evaluate the processes. Sufficient data, weights and chemical analyses, have been generated to determine material balances around the reactor system. However, the calculation of material balances and assessment of the data is outside the scope of this effort.

The remainder of this report discusses the selection and preparation of the coal samples used, the process equipment and its operation, the material sampling and analyses procedures, the process evaluation testing, and presents tabulations of the acquired test data.

2. PROCESS TEST EQUIPMENT

The process evaluation tests were conducted using the DOE-owned Multi-Use Fuel and Energy Process Test Plant (MEP) located at the TRW Capistrano Test Site near San Clemente, CA. Because the test conditions for these evaluations required operating pressures exceeding the original capabilities of the test plant, a new reactor section was designed and installed. Other minor plumbing changes were also made to enable the use of existing test plant equipment.

After modification, the process equipment consisted of a coal slurry preparation system, a high pressure reactor, and gas handling and sparging system, and a slurry disposal system. The following is a description of each of these systems, the capabilities of the process plant, and the hardware related changes implemented during the process test operations to overcome problems and to meet the objectives of the effort.

2.1 COAL SLURRY PREPARATION SYSTEM

The coal slurry was prepared using existing MEP equipment. The major pieces of equipment for this system consist of a liquid storage tank T-7, a coal storage tank T-1, a weigh belt feeder A-3, a slurry mix tank T-2, a slurry feed tank R-2, and two pumps, P-13 and P-1. A schematic flow diagram of this system is shown in Figure 1.

Coal slurry is prepared by mixing 100-mesh top-size coal with de-ionized (DI) water. The DI water is stored in the 15,000 gallon liquid storage tank T-7. During slurry preparation, pump P-13 is used to transfer a prescribed amount of DI water to the slurry mix tank T-2. A volume displacement, vane type water meter is used to measure the amount transferred.

Figure 1. Schematic Diagram of Coal Slurry Preparation System.

The coals to be used for testing were ground to the desired 100-mesh X 0 and loaded into Tote bins by Solomon Chem-Grind Company of Springfield, IL. The bins were sealed and shipped to TRW. Each of these Tote bins are 42"X42"X96"(H) providing approximately 112 cubic feet of storage space. This is sufficient to hold approximately 3500 pounds of coal. Each bin is equipped with a 12-inch diameter port at the top for coal loading and a 34"X14"(H) door on the side of the bin near the bottom for coal discharge. The bins are air-tight and are equipped with gas inlet fittings to enable a slight pressurization with nitrogen.

Prior to slurry preparation, a bin of the coal to be tested is hoisted to the top level of the process test stand, and the coal is transferred to the coal storage tank T-1. During slurry preparation, the coal is gravity-fed from T-1 to a weigh belt feeder A-3. A vibrating discharge unit at the bottom of T-1 prevents solids bridging or packing during this transfer. The coal is metered by A-3 and discharged into the mix tank T-2. The coal is maintained under a nitrogen blanket from the time the coal is ground and placed into the steel transfer bins through its mixing with the DI water in the mix tank.

The coal is first contacted and wetted with the DI water in mix tank T-2. The operation is conducted at atmospheric pressure and ambient temperature. The mix tank is equipped with three variable speed mixers to promote coal wetting and to prevent coal settling. Upon completion of the mixing operation, the coal slurry is transferred from the mix tank T-2 to the slurry storage tank R-2 using a slurry pump P-1. The residual coal in the coal storage tank T-1 is discharged through the weigh belt feeder into a portable steel storage bin when a change in coal feedstock is dictated by the test matrix.

2.2 HIGH PRESSURE REACTOR SYSTEM

The major pieces of equipment in the high pressure reactor system consist of a 200-gallon slurry storage tank R-2, a positive displacement slurry feed pump P-17, three one-gallon top-stirred autoclaves (R-3, R-4, and R-5), a gas handling subsystem, and treated product collection subsystem. A schematic flow diagram of the entire system is shown in Figure 2.

The existing MEP process plumbing was modified to include a pump-around loop from the bottom of R-2 through a slurry recirculating pump P-6 then returning to R-2 to provide a pressurized supply of slurry to the suction side of the reactor feed pump P-17. Plumbing was also installed from the pump discharge side of the pump-around loop to a belt filter S-1 and to the waste storage tank T-9 to enable R-2 to be emptied of unused slurry. A slurry sample port and a slurry feed line to the high pressure slurry feed pump P-17 are also connected to the pump-around loop downstream of the recirculation pump P-6. The top of R-2 is equipped with ports which can be opened to permit the addition of sodium carbonate, ammonium hydroxide, or additional DI water as needed.

A Milton Roy, Model MR 1-32-59SM, positive displacement pump (P-17) meters (volumetrically) the coal slurry to the reactors. It has an adjustable flow rate from less than 0.7 gallons per hour to 6.0 gallons per hour against head pressures up to 1175 psi. To preclude the settling of the coal from the slurry (creating variations in solids concentration in the slurry feed material), the pump inlet is close-coupled with the R-2 pump-around loop. The pump discharge line was sized to maximize the velocity of the slurry flowing through the line to prevent line plugging.

Figure 2. Schematic Diagram of High Pressure Reactor System

Each of the three reactors (R-3, R-4, R-5) are 3.8ℓ, top-stirred pressure vessels fabricated of Grade 2 titanium. Each is electrically heated, and the rotational speed of the stirring shaft is changed by replacing the drive pulley. Shaft speeds up to 3000 RPM and operating pressures up to 1500 at 300°C are possible for the gas circulation/dispersion shaft/impeller system. The slurry inlet is through a dip tube whose exit is near the bottom of the vessels, while the discharge is by overflow into a stand-pipe providing a retained slurry volume of 2.7ℓ (during flow) for each reactor. The introduction of the slurry feed via a dip tube insures mixing of the slurry feed with reactor contents prior to exiting through the discharge port. The downleg inlet dip tube also provides a liquid seal to prevent gas flow from one reactor to another.

The slurry flows from the R-2 pump-around loop through the slurry feed pump P-17, through each autoclave in series, through a water-cooled heat exchanger C-4 and finally into one of four product receivers (T-15, T-16, T-30, or T-31). T-15 is used to collect product for a prescribed duration. The output slurry flow rate is then determined from the weight of the product collected and the collection time. Slurry sample tanks T-23, T-24, and T-25 are used to obtain slurry samples from each reactor at the end of each test.

Air, oxygen, or nitrogen can be fed through flow orifices into the bottom of each reactor. The sparging gas exits the top of each reactor and passes through a water-cooled condenser (C-1, C-2, or C-3) followed by a liquid-gas separator (T-20, T-21, or T-22). The condensate is returned to the reactor via its slurry feed line. The cooled gas then flows through an individual gas sampling container (T-26, T-27, or T-28)

and into an exhaust manifold which is also equipped with a total gas sampling container (T-29). The gas is then expanded to atmospheric pressure through the back pressure regulator BR-1. The wet test meter GM-1 downstream of the regulator measures the quantity of gas exiting the system.

The oxygen and nitrogen were procured in commercial compressed gas cylinders. A leased air compressor was installed to supply compressed air at pressures to 1175 psig. The air and nitrogen supply share a common feed manifold. The gas flow rate of either nitrogen or air is controlled to reactors R-3, R-4, R-5 by control valves V-43, V-45, and V-47, respectively. The flow rate to each reactor is measured by the pressure drop across an orifice meter (O-2, O-4, O-6, respectively) as measured by differential pressure gauges PI-9, PI-13, and PI-17, respectively.

Oxygen feed gas is introduced into each reactor through a separate, but similar, manifold. Flow rate control and measurement are accomplished in the same manner. The control valves are V-52, V-54, and V-56. The orifice meters are O-1, O-3, and O-5. The differential pressure gauges are PI-7, PI-11, and PI-15. Having separate feed manifolds for oxygen and nitrogen permit feeding both of these gases to the reactor simultaneously.

System operating pressure is controlled by the back pressure regulator BR-1 and measured by pressure gauge PI-4. Gas inlet flow rate is maintained by control valves and measured by orifice meters described in the preceeding two paragraphs. Gas outlet is measured using the wet test meter GM-1. Sample tanks T-26 through T-29 are used to obtain output gas samples for analyses.

Slurry input is measured and controlled by the slurry feed pump P-17. Slurry output is measured by weighing the material collected in product tank T-15 for a specified time. Slurry samples from each reactor were collected in slurry sample tanks T-23, T-24, and T-25 until a procedure change discussed later was initiated. Samples of input slurry are withdrawn from valve R4-57 on the R-2 pump-around loop.

Reactor operating temperatures are controlled by heater controllers HC-1, HC-2, and HC-3. Thermocouples TC-9, TC-11, and TC-13 are used to measure slurry temperature in R-3, R-4, and R-5, respectively.

A personnel shield was built to house the equipment containing hot feed or processed slurry at elevated pressures: reactors, condensers, slurry heat exchanger, and product collectors. Even though the process equipment was designed to permit personnel access during operation, additional personnel protection was deemed prudent. Figure 3 shows the process equipment on the MEP. The condensers, reactors, slurry heat exchangers, and product collectors are shown inside the open protective shield.

Figure 4 shows the control panel on the operator side of the protective shield. This panel contains the controls for the gas supply, the various pressure gauges, and the gas sample tanks. The reactor temperature controllers, the reactor stirrer RPM indicators, the output gas meter readout, and the temperature recorder are on a separate control panel.

2.3 SLURRY DISPOSAL SYSTEM

The ancillary plumbing involving the product collectors (T-15 and

Figure 3. MCP Process Equipment.

Figure 4. Control Panel for Gas Supply System.

T-16 and T-30 and T-31), pump P-4, and the flush water feed valve V-27 as shown in Figure 2 were installed for flushing and draining the product collectors of slurry. The slurry and flush water are pumped to either the filter S-1 or to the 15,000-gallon waste disposal tank T-9. Appendix A describes the operating equipment calibrations in detail.

3. COAL SELECTION AND CHARACTERIZATION

One coal sample from each of five preselected coal seams were obtained for use in evaluating the oxydesulfurization processes: Illinois No. 6, Western Kentucky No. 9, Lucas No. 5, Pittsburgh, and Lower Kittanning. The coal samples obtained by the TRW subcontractor for coal preparation, Solomon Grind-Chem Company, are identified in Table 1 by the mine, the mine location, and the company operating the mine.

Prior to grinding each coal, Solomon Grind-Chem shipped a 25-pound grab sample of each to the DOE. There, the samples were crushed to 3/8" X 0 and portions of each were sent to Warner Laboratories for ultimate, proximate, chlorine, sulfur forms, and major-elements-in-ash analyses. The results are shown in Tables 2 through 6.

Solomon Grind-Chem Company ground each coal to 100 mesh X 0, loaded each ground coal type into three Tote bins, and shipped the loaded and sealed Tote bins to TRW's Capistrano Test Site. Upon receipt, one bin of each coal was opened and five thief samples extracted (from the top center and each top corner of the bin approximately ten inches below the surface). Approximately four lbs of total sample were taken from each coal. This amount was riffled to 100-gram samples. These samples were used to determine particle size distribution of each sample. The results of these determinations are also shown in Tables 2 through 6.

During the preparation of the coal slurries for test operations, samples of the coal from the slurry being fed were obtained and sent to Warner Laboratories for ultimate, proximate, and sulfur forms analyses. The results are shown in Tables 2 through 6.

Table 1. Coals Selected For Oxydesulfurization Processes Evaluations.

<u>Coal Seam</u>	<u>Mine</u>	<u>Mine Location</u>	<u>Coal Company</u>
Illinois No. 6	River King Mine	St. Clair County, Illinois	Peabody Coal Co.
Western Kentucky No. 9	Hamilton Mine No. 1	Union County, Kentucky	Island Creek Coal Co.
Lucas No. 5	Lovilia No. 4 Mine	Monroe County, Iowa	Lovilia Coal Co.
Pittsburg	Franklin Mine	Harrison County, Ohio	Consolidation Coal Co.
Lower Kittanning	C. H. Snyder Mine	Armstrong County, PA	Allegheny River Mining Co.

Table 2. Proximate, Ultimate and Sulfur Forms
Analyses* for Illinois No. 6 Coal

Sample Source	DOE	DOE	Top of Bin	Slurry Prep	Slurry Prep
Sample Date	3-21-80	3-21-80	4-8-80	9-4-80	9-4-80
Coal Analyses, W/W % (MF)					
Total Sulfur, as S	3.29	4.65		3.62	3.69
Organic Sulfur, as S	2.34	2.49		2.21	2.21
Pyritic Sulfur, as S	0.95	2.16		1.40	1.47
Sulfate Sulfur, as S	0.00	0.00		0.01	0.01
Ash	13.00	10.23		12.06	11.91
Carbon Content, as C	68.71	70.25		69.03	69.15
Hydrogen Content, as H	4.81	5.04		4.54	4.51
Nitrogen Content, as N	1.07	1.16		1.27	1.29
Oxygen Content, as O	9.12	8.62		9.43	9.45
Chlorine Content, as Cl	0.08	0.12			
Heating Value, BTU/lb (MF)	12395	12757		12495	12542
Major Elements in Ash, W/W %					
Silica	53.27	42.19			
Al ₂ O ₃	20.74	17.35			
Fe ₂ O ₃	11.44	28.88			
TiO ₂	1.33	1.05			
CaO	2.80	2.06			
MgO	1.92	1.18			
Na ₂ O	1.00	0.96			
K ₂ O	2.65	1.76			
Sulfites	1.65	1.86			
Coal Particle Size, % Retained					
100 mesh			0.88		
150 mesh			1.41		
200 mesh			3.53		
325 mesh			48.42		
Pan			45.77		

*Reference information and documentation only. Calculations should be based on actual Run data.

Table 3. Proximate Ultimate and Sulfur Forms Analyses*
for Western Kentucky No. 9 Coal.

Sample Source	DOE	DOE	Top of Bin	Slurry Prep
Sample Date	3-21-80	3-21-80	4-8-80	10-25-80
Coal Analyses, W/W % (MF)				
Total Sulfur, as S	3.22	3.01		3.06
Organic Sulfur, as S	1.59	1.73		1.25
Pyritic Sulfur, as S	1.64	1.28		1.77
Sulfate Sulfur, as S	0.00	0.00		0.04
Ash	18.06	13.51		21.72
Carbon Content, as C	65.52	69.48		62.44
Hydrogen Content, as H	4.62	4.85		4.38
Nitrogen Content, as N	1.24	1.38		1.28
Oxygen Content, as O	7.35	7.77		7.13
Chlorine Content, as Cl	0.19	0.19		N/A
Heating Value, BTU/lb (MF)	11801	12548		11270
Major Elements in Ash, W/W %				
Silica	50.71	52.42		
Al ₂ O ₃	18.48	19.99		
Fe ₂ O ₃	13.44	13.73		
TiO ₂	1.33	1.33		
CaO	6.72	3.64		
MgO	1.43	1.29		
Na ₂ O	1.02	0.94		
K ₂ O	2.89	2.89		
Sulfites	2.16	1.86		
Coal Particle Size, % Retained				
100 mesh			0.55	
150 mesh			0.83	
200 mesh			2.68	
325 mesh			58.67	
Pan			37.27	

*Reference information and documentation only. Calculations should be based on actual Run data.

Table 4. Proximate, Ultimate and Sulfur Forms Analyses
for Lucas No. 5 Coal.

Sample Source	DOE	DOE	Top of Bin	Slurry Prep
Sample Date	3-21-80	3-21-80	4-8-80	11-24-80
Coal Analyses, W/W % (MF)				
Total Sulfur, as S	2.35	2.57		1.94
Organic Sulfur, as S	0.97	1.02		0.73
Pyritic Sulfur, as S	1.37	1.54		1.20
Sulfate Sulfur, as S	0.01	0.01		0.01
Ash	8.14	7.07		8.70
Carbon Content, as C	73.17	73.70		72.93
Hydrogen Content, as H	5.26	5.15		5.34
Nitrogen Content, as N	1.37	1.37		1.25
Oxygen Content, as O	9.71	10.15		9.84
Chlorine Content, as Cl	0.04	0.04		N/A
Heating Value, BTU/lb (MF)	13098	13337		13142
Major Elements in Ash, W/W %				
Silica	34.73	34.52		
Al ₂ O ₃	11.87	9.81		
Fe ₂ O ₃	28.74	31.03		
TiO ₂	0.83	0.48		
CaO	13.01	14.55		
MgO	0.66	0.48		
Na ₂ O	0.71	0.70		
K ₂ O	0.90	0.70		
Sulfites	2.76	2.98		
Coal Particle Size, % Retained				
100 mesh			0.16	
150 mesh			0.48	
200 mesh			1.76	
325			34.25	
Pan			63.35	

*Reference information and documentation only. Calculations
should be based on actual Run data.

Table 5. Proximate, Ultimate and Sulfur Forms
Analyses for Pittsburgh Coal.

Sample Source	DOE	DOE	Top of Bin
Sample Date	3-21-80	3-21-80	4-8-80
Coal Analyses, W/W % (MF)			
Total Sulfur, as S	2.36	2.26	
Organic Sulfur, as S	1.20	1.12	
Pyritic Sulfur, as S	1.16	1.14	
Sulfate Sulfur, as S	0.00	0.00	
Ash	8.22	8.36	
Carbon Content, as C	75.12	75.56	
Hydrogen Content, as H	5.04	5.10	
Nitrogen Content, as N	1.27	1.36	
Oxygen Content, as O	7.99	7.37	
Chlorine Content, as Cl	0.05	0.06	
Heating Value, BTU/lb (MF)	13503	13467	
Major Elements in Ash, W/W %			
Silica	48.37	50.07	
Al ₂ O ₃	23.76	24.32	
Fe ₂ O ₃	22.02	19.16	
TiO ₂	1.27	1.23	
CaO	0.49	0.45	
MgO	0.58	0.53	
Na ₂ O	0.61	0.54	
K ₂ O	1.69	1.69	
Sulfites	0.18	0.21	
Coal Particle Size, % Retained			
100 mesh			0.13
150 mesh			0.53
200 mesh			2.26
325 mesh			52.96
Pan			44.12

Table 6. Proximate, Ultimate and Sulfur Forms Analyses
for Lower Kittanning Coal.

Sample Source	DOE	DOE	Top of Bin
Sample Date	3-21-80	3-21-80	4-8-80
Coal Analyses, W/W % (MF)			
Total Sulfur, as S	5.34	6.49	
Organic Sulfur, as S	2.21	1.72	
Pyritic Sulfur, as S	3.13	4.77	
Sulfate Sulfur, as S	0.00	0.00	
Ash	12.58	13.13	
Carbon Content, as C	71.55	71.33	
Hydrogen Content, as H	4.91	4.84	
Nitrogen Content, as N	1.05	1.09	
Oxygen Content, as O	4.57	3.14	
Chlorine Content, as Cl	0.15	0.20	
Heating Value, BTU/lb (MF)	13170	13084	
Major Elements in Ash, W/W %			
Silica	34.09	25.57	
Al ₂ O ₃	19.61	15.08	
Fe ₂ O ₃	40.03	53.47	
TiO ₂	1.33	1.33	
CaO	1.01	0.90	
MgO	0.46	0.33	
Na ₂ O	0.38	0.30	
K ₂ O	1.37	0.92	
Sulfites	1.40	0.61	
Coal Particle Size, % Retained			
100 mesh			0.22
150 mesh			0.70
200 mesh			2.63
325 mesh			74.00
Pan			22.40

4. SYSTEM SHAKEDOWN

This section contains information on the proposed operation, on the shakedown runs completed, and a discussion of the results and equipment modifications made as a result of shakedown testing.

4.1 PLANNED TEST PLANT OPERATION

The three continuous stirred, one-gallon, titanium reactors were designed and fabricated for small throughputs. The system was designed to allow a slurry residence time independent of gas flow rate, but to provide a series slurry flow approaching the performance of a plug-flow reactor (without the limitations of plug-flow reactor). Materials of construction were picked for safe, long service (in the heated, slurry contacted zones) based on a series of metal compatibility tests run by TRW on an earlier oxydesulfurization test program.

Further, the system provided for air and oxygen sparging rates of at least 2500 SLH* and 500 SLH, respectively. Temperature control was provided for up to 250°C. Stirring rates were capable of up to 3000 RPM. Slurry feed rates were provided for retention times of 30 to 120 minutes. The pressure capability of the system was designed for safe operation (at the maximum temperature) for greater than 1000 psig with air, and 300 psig with pure oxygen.

The reactor system was designed and operated to evaluate the oxydesulfurization processes in a continuous mode. However, the system was flushed

*NOTE: Throughout this report, SLH are normalized to the "standard engineering" temperature of 20°C rather than the "scientific standard" of 0°C.

with water and shut down after each evaluation test run to permit safe removal of the sample containers, to send them to the lab for analyses, and to install clean sample containers. Therefore, the reactor system was at ambient temperature and pressure and the liquid volume of the reactors was full of water at the start of each test.

The preliminary time lines for a typical test requiring a 60-minute slurry retention time indicated that approximately 2.0 hours would be needed to reach steady state condition, approximately three hours would be needed to feed three reactor volumes of slurry after reaching steady state, and two hours for taking samples and completing system shutdown. Total run time would be approximately 7.0 hours. It was, therefore, originally planned that two such test runs would be completed in two eight-hour shifts.

The times to reach steady state and for completing system shutdown would be the same for tests requiring 30- to 120-minute slurry retention times. Only the time required to process three reactor volumes of slurry would change: 1.5 hours for the shorter retention time and six hours for the longest retention time runs. Therefore, the total run times for these runs would be 5.5 hours, and ten hours, respectively. A 30-minute retention time run could be paired with a 120-minute retention time run, and both of them originally were planned to be completed in a two-shift day.

The above operational planning was based on batch operation information provided by the process developers and from previous experience gained during the operation of the test plant with coal-water slurries at lower temperatures and pressure. The batch process information gave

little data relevant to continuous operation. This ultimately led to unplanned modifications in the operational sequence and to hardware modifications not originally envisaged. For example, serious slurry foaming occurs in continuous process testing of the Ames Process which was not observed at batch scale. A major exotherm occurs during continuous operation of the Ledgemont Process with greater than 30% slurry concentration which was not previously reported. Finally, segregation of coal by density and particle size occurs in the continuous process, but it is not of importance in batch testing. Many of the unexpected items were discovered during the shakedown testing.

4.2 SHAKEDOWN TESTS

A series of tests was planned and carried out (see Table 7) to evaluate the effects of flow rate, temperature, pressure, etc., on the system. The tests were run with air only; the first test with water and air only. Temperatures and pressures were started low and then increased to near maximum target value during each test series. Slurry feed rate was varied from a low rate to the maximum required in the actual test plan.

The results of the shakedown tests provided several pieces of important information. Both the pressure and temperature controlled in a very stable mode throughout the range required by the test plan. No plugging of lines or other mechanical flow malfunctions were noted.

Two problem areas were identified. The first was an input/output coal solids deviation. Evaluation of samples of coal slurry from all three reactors showed that solids content was varying $\pm 35\%$ compared with the solids content of the first reactor (R-3). The problem appeared to be one of coal settling. As a result, 316 stainless steel baffles (Figures 5 and 6) were installed in each reactor to improve mixing efficiency.

Another problem was the very high rate of wear on the bearings in the mixers. The mixers were custom made of titanium (housings, shafts, and impellers) and used graphite bearings. At the 2400 RPM shaft speed specified by the process developers, the bearing life was only 4-8 hours running time. The manufacturer of the units, Autoclave Engineers, Inc., supplied several other bearing materials which were installed and tried with the same negative results. With the concurrence of the DOE Project Officer, the shaft speed was reduced to 1900 RPM; however, the

Figure 5. Photograph of Reactor Interior with Baffle Installed.

Figure 6. Photograph of Baffles

Table 7. SHAKEDOWN TEST MATRIX

TEST NO.	TEMP °C	PRESS.	% COAL	FLOW SLURRY Kg/HR	RATE GAS SLPH	TEST GAS	TEST DATE (1980)	REMARKS
F.C. 1	*	*	0	6.0GPH	1300	AIR	6-18	*TEST STARTED WITH TEMP @ R.T. AND PRESS @ 300 AND INCREASED AS DIRECTED BY TEST ENG.
F.C. 2	150	300	0	8.7	700	AIR	6-19	
F.C. 3	R.T.	600	40	1.0GPH	375	AIR	7-14	STARTED SLURRY PUMP CALS WITH SLURRY - HAD PROBLEMS WITH PUMP CHECK VALVES
F.C. 4	200	985	40	11.6	1450	AIR	7-17	
F.C. 5	200	985	40	2.4	1450	AIR	7-23	INSTALLED REBUILT WET TEST METER
F.C. 6	R.T.	985	20	4.3GPH	1300	AIR	7-24	
F.C. 7	R.T.	985	20	9.8	1300	AIR	7-28	REPLACED BUSHING IN ALL REACTOR MIXERS. INSTALLED MIXING BAFFLE PLATES IN REACTORS.
F.C. 8	R.T.	985	20	9.8	1300	AIR	8-11	
							8-15	MIXER BUSHING BAD. BROKEN IMPELLER IN R-5.
							8-18	MIXER ENCAPSULATED MAGNET ASSEM. ON R-4 AND R-5 WORN THROUGH. CHANGE MIXER SPEED TO 1900 RPM.
							8-19	INSTALLED MIXER SHAFT RETAINERS.
							8-27	RECV. 316SS MIXERS.

performance was still unacceptable. As the bearings wore out, the shaft would start to whip or wobble causing the impeller to strike the overflow pipe. A titanium guide, or wobble limiter, was made from titanium and welded in-place on the feed pipe (See Figure 7). Although this helped, it did not solve the problem. The titanium stirrer assemblies were returned to the manufacturer who supplied three stainless steel equivalent models. These stainless stirrers were installed, checked out, and used for the balance of the program. The titanium impellers were retained, however.

With the new baffles and the new stirrers in place, the coal settling problem was reduced but not eliminated. It is clear that as the coal progressed through the three reactors under varying conditions, that not only would the density change (removal of pyrites), but also the particle size, wettability, etc., would vary. No single stirrer speed assured 100% throughput in each reactor. As a result, it can be seen in the tabulated run data that discrepancies exist between input and output flow rates.

Figure 7. Photograph of Reactor Top-Flange with Titanium Impeller Shaft Guide.

5. TEST OPERATIONS

This section deals with the operation of the test plant during pre-selected test conditions, provides a record of operating conditions encountered, and addresses the changes made to obtain the required operational data.

5.1 TEST CONDITIONS

The experimental test conditions were preselected by the DOE in conjunction with the process developers. The test conditions for the first three coals selected for evaluation are presented in Tables 8 through 10. All conditions were within the capability of the system.

5.2 DATA MANAGEMENT

Data was provided by various digital and analog readouts and by sample analyses as described below. The data were divided into two major categories defined as instrumentation and sample analyses.

5.2.1 Instrumentation

- o Temperatures - critical temperatures as measured by calibrated thermocouples were recorded on a strip chart recorder and displayed on a digital readout. Other temperatures of lesser importance were recorded on the strip chart only. Temperatures felt to be critical to data measurement were: slurry input temperature, feed gas temperature at the orifice, exhaust gas temperature at the gas meter, and the temperature of the reactors.

Other temperatures used for reference were the heat exchangers input and output, gas/liquid separators for each reactor, and the final slurry cooler output temperature.

TABLE 8. TEST CONDITIONS FOR ILLINOIS NO. 6 COAL

Test No.	Process	Slurry	Additive	Additive	Retent.	Slurry	Press.	Gas	Gas Flow Rate, SLPH			Reactor		
		Conc.				Conc., M			Time	Feed	Rate, GPH	psig	R3	R4
1	PETC	20	--	--	30	4.3	985	AIR	978	978	978	220	220	220
2	PETC	20	--	--	60	2.2	985	AIR	489	489	489	180	180	180
3	PETC	20	--	--	60	2.2	985	AIR	489	489	489	200	200	200
4	PETC	20	--	--	90	1.4	985	AIR	329	329	329	220	220	220
5	PETC	20	--	--	90	1.4	985	AIR	329	329	329	180	180	180
6	PETC	20	--	--	120	1.1	985	AIR	245	245	245	180	180	180
7	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	100	85	70	150	150	150
8	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	150	130	105	150	150	150
9	AMES	20	NaCO ₃	0.3	120	1.1	253	O ₂	70	70	70	150	150	150
10	AMES	20	NaCO ₃	0.3	120	1.1	600	O ₂ /N ₂	128 148	100 122	0 100	150	150	150
11	AMES	20	NaCO ₃	0.3	120	1.1	600	AIR	610	610	120	150	150	150
12	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	100	85	70	150	150	150
13	KENN	40	NH ₃	3.0	120	1.1	300	O ₂	164	164	164	130	130	130
14	KENN	40	NH ₃	3.0	60	2.2	300	O ₂	328	328	328	160	160	160
15	KENN	40	NH ₃	3.0	60	2.2	300	O ₂	328	328	328	190	190	190
16	KENN	20	NH ₃	3.0	120	1.1	300	O ₂	76	76	76	130	130	130
17	KENN	20	NH ₃	3.0	60	2.2	300	O ₂	152	152	152	160	160	160
18	KENN	20	NH ₃	3.0	30	4.3	300	O ₂	304	304	304	190	190	190

TABLE 9. TEST CONDITIONS FOR WESTERN KENTUCKY NO. 9 BED COAL

Test No.	Process	Slurry Conc. Wt. %	Additive	Additive Conc., M	Retent. Time, Min.	Slurry Feed Rate, GPH	Press. psig	Gas	Gas Flow Rate, SLPH			Reactor Temperature, °C		
									R3	R4	R5	R3	R4	R5
19	PETC	20	--	--	30	4.3	985	AIR	1178	1178	1178	180	180	180
20	PETC	20	--	--	60	2.2	985	AIR	589	589	589	180	180	180
21	PETC	20	--	--	60	2.2	985	AIR	539	589	589	170	170	170
22	PETC	20	--	--	90	1.4	985	AIR	393	393	393	180	180	180
23	PETC	20	--	--	90	1.4	985	AIR	393	393	393	170	170	170
24	PETC	20	--	--	120	1.1	985	AIR	295	295	295	160	160	160
25	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	100	85	70	150	150	150
26	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	150	130	105	150	150	150
27	AMES	20	NaCO ₃	0.3	120	1.1	253	O ₂	70	70	70	150	150	150
28	AMES	20	NaCO ₃	0.3	120	1.1	600	O ₂ /N ₂	128 148	100 122	0 100	150	150	150
29	AMES	20	NaCO ₃	0.3	120	1.1	600	AIR	610	610	610	150	150	150
30	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	105	85	70	150	150	150
31	KENN	40	NH ₃	3.0	120	1.1	300	O ₂	164	164	164	130	130	130
32	KENN	40	NH ₃	3.0	60	2.2	300	O ₂	328	328	328	160	160	160
33	KENN	40	NH ₃	3.0	60	2.2	300	O ₂	328	328	328	190	190	190
34	KENN	20	NH ₃	3.0	120	1.1	300	O ₂	76	76	76	130	130	130
35	KENN	20	NH ₃	3.0	60	2.2	300	O ₂	152	152	152	160	160	160
36	KENN	20	NH ₃	3.0	30	4.3	300	O ₂	304	304	304	190	190	190

TABLE 10. TEST CONDITIONS FOR LUCAS NO. 5 COAL

Test No.	Process	Slurry Conc. Wt. %	Additive	Additive Conc., M	Retent. Time, Min.	Slurry Feed Rate, GPH	Press. psig	Gas	Gas Flow Rate, SLPH			Reactor Temperature, °C		
									R3	R4	R5	R3	R4	R5
37	PETC	20	--	--	30	4.3	985	AIR	662	662	662	190	190	190
38	PETC	20	--	--	60	2.2	985	AIR	331	331	331	180	180	180
39	PETC	20	--	--	60	2.2	985	AIR	331	331	331	170	170	170
40	PETC	20	--	--	90	1.4	985	AIR	221	221	221	190	190	190
41	PETC	20	--	--	90	1.4	985	AIR	221	221	221	180	180	180
42	PETC	20	--	--	117.5	1.1	985	AIR	170	170	170	170	170	170
43	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	70	70	70	150	150	150
44	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	130	100	70	150	150	150
45	AMES	20	NaCO ₃	0.3	120	1.1	253	O ₂	70	70	70	150	150	150
46	AMES	20	NaCO ₃	0.3	120	1.1	600	O ₂ /N ₂	102 118	100 130	0 103	150	150	150
47	AMES	20	NaCO ₃	0.3	120	1.1	600	AIR	485	485	120	150	150	150
48	AMES	20	NaCO ₃	0.3	60	2.2	253	O ₂	70	70	70	150	150	150
49	KENN	40	NH ₃	3.0	120	1.1	300	O ₂	164	164	164	130	130	130
50	KENN	40	NH ₃	3.0	60	2.2	300	O ₂	328	328	328	160	160	160
51	KENN	40	NH ₃	3.0	60	1.1	300	O ₂	328	328	328	190	190	190
52	KENN	20	NH ₃	3.0	120	1.1	300	O ₂	76	76	76	130	130	130
53	KENN	20	NH ₃	3.0	60	2.2	300	O ₂	152	152	152	160	160	160
54	KENN	20	NH ₃	3.0	30	4.3	300	O ₂	304	304	304	190	190	190

- Pressures - process pressures were read from gauges and hand recorded. These pressures were: the ΔP across each gas inlet orifice meter, the system pressure, and the pressure at the gas meter.
- Stirrer RPM was read from indicating magnetic-electronic meters and were calibrated using a strobe tachometer. The indicating meters provided the operators with a relative reference to stirrer rate.
- Slurry feed rate was measured by both pre- and post-test. An integrated stroke control on the feed pump provided the set point.
- Slurry Output was measured in a designated output tank.
- Gas Flow In was measured by calibrated orifice meters.
- Gas Flow Out was measured with a calibrated wet test gas meter.

5.2.2 Sample Analyses

- Slurry - representative samples of input (R-2) and output (R-3, R-4, R-5, and eventually T-15) were collected in special sample containers during steady state operation after at least three reactor volumes had passed through the system. The solid samples were subjected to analyses for:
 - 1) Slurry concentration (% solids)
 - 2) Proximate analysis
 - 3) Ultimate analysis
 - 4) Sulfur Forms analysis
- Filtrates from the slurry were analyzed for:
 - 1) Sulfate content (as sulfur)

- 2) Carbonate and bicarbonate (as carbon)
 - 3) Additive content (carbonate or ammonia)
 - 4) pH
- Gas - representative samples of flowing gases were taken under the same conditions described above for the slurry. Purged sample bombs were used for sampling the off-gases from R-3, R-4, R-5, and System Output. These samples were analyzed for CO, CO₂, N₂, O₂, and C₁-C₃ hydrocarbons. A special combined sample was used for analysis of SO_x.

5.3 DATA COLLECTION AND REDUCTION

Operational data were collected, reduced, and are reported in Section 6, Test Data. The operational data were recorded and reduced in different ways. A description of the methods used is presented below.

It is first necessary to understand the term "steady state". Steady state" is the point at which valid samples may be taken; time to achieve "steady state" is defined as the time it takes for the entire volume of the three reactors to be replaced three times (three times the specified retention time) as measured from the time at which constant temperature and pressure are achieved. This time ensures that the original water has been displaced, and that the products leaving the system are representative of the process under continuous flow conditions at the specified flow rates, temperatures, pressure, and retention times.

The data were collected and reduced as follows:

- Reactor Pressure, psig - Pressure was read from gauges and recorded on the run data sheet every 15 minutes for runs with steady state times of 90, 180, 270 minutes, and every 20

minutes for runs with 360 minutes steady state time. The average pressure over the steady state time is reported.

- Reactor Temperature, °C - Temperature was measured by thermocouple and recorded on strip chart. Digital readings were recorded in the same way as the pressure readings. The temperature readings presented in the data were averaged over the entire steady state time.
- Slurry Feed Rate, Kg/hr - Three data points were taken for each of both pre- and post-slurry calibrations. The "Pre- and Post-" data were averaged to provide the run slurry feed rate shown.
- Slurry Retention Time, Min. (correction to actual operating conditions)

$$= \frac{483.3 \times \text{Feed Density, g/cc}^*}{\text{Feed Rate Kg/min}}$$

5.4 DATA REPORTING

Data was reported for all runs successfully completed. All of the data is presented in a standard format shown in Section 6. The data was used to calculate the section on the data sheet headed "Process Performance". The calculations are described below:

- BTU Recovery, % = $\frac{\text{Product Coal (BTU/lb)} \times \% \text{ wt recovery}}{\text{Starting Coal (BTU/lb)}} \times 100$
- Organic Sulfur Removed, % = $\left[\frac{\% \text{ organic S initial} - \% \text{ final}}{\% \text{ initial}} \times 100 \right]$
- Pyritic Sulfur Removed, % = $\left[\quad \right]$

*Feed slurry density in g/cc was measured on actual sets of a number of coal slurries with no additions, with 0.3M Na₂CO₃ additive and with 3.0M NH₄OH additive: the results of individual tests were averaged.

- Carbon Removed, % = []

- Hydrogen Removed, % = []

all are calculated as $\frac{\% \text{ initial} - \% \text{ final}}{\% \text{ initial}} \times 100$

- Oxygen Added, %

- Ash Added, %

both are calculated as $\frac{\% \text{ final} - \% \text{ initial}}{\% \text{ initial}} \times 100$

Note that the ash content actually decreased in nearly all cases giving rise to the negative results (shown by parentheses), which can be read as Ash Removed, %, if sign is changed to positive.

5.5 OPERATIONAL PROBLEMS

During test evaluation runs, unexpected problems were encountered. The following information is provided to identify the problems and to document the findings and the disposition of the problems.

5.5.1 Ames Process Foaming

Three initial run attempts were aborted when the filter in the gas exit line plugged. Disassembly each time revealed the filter to be filled with slurry being transported through the vent lines from the product collectors. Six out of eight test runs evaluating the Ames Process resulted in plugged filters. Post-test evidence indicated that the slurry was foaming in the reactors. This foam was being transported from reactor R-5 to the product collectors. When the collector became full of foam, the foam was then transported through the collector vent line to the filter.

Post-test examination of the gas sample containers showed them to be clean. No slurry or foam had been transported through them. It was concluded that the condensate from the condensers was knocking down

the foam trying to escape from the reactors through the reactor gas exit lines. In an attempt to contain the foam in the reactors, the vent line from the collectors was rerouted to the vapor space of reactor R-5. The first test run ended with a plugged slurry line from reactor R-5 to the collector. It is believed that either the foam will support the slurry flow from the reactor or the coal drops out of the foam and forms a plug in the line. The vent line was returned to its original route.

A water scrubber (T-17) was then installed in this collector vent line. The scrubber was constructed from a five-gallon vessel. The gas exit line from the product collectors was connected to a dip tube installed in the top of the vessel and extending $\frac{2}{3}$ the distance to bottom. The gas exited the top of the vessel into a line going to the filter. The vessel was partially filled with water, thus creating a "bubbler" scrubber.

The entrance line to the common gas sample cylinder was also revised so that all the vent gases from the reactors, after passing through their individual gas sample collectors, was routed through the liquid collector tank vent manifold and the new scrubber. This set-up resulted in delaying the plugged filter situation, but did not prevent it. Foam reformed on top of the water and was subsequently transported to the filter. The use of 10% sulfuric acid in place of the water did not help. Anti-foams (silicone types from Union Carbide Corp.) were also tried in the scrubber; these were also of no apparent help (probably because there was not good mixing in the tank). The final disposition of the problem was to limit further Ames Process runs to those of shorter residence times and lower gas flow rates.

5.5.2 Sulfur Input/Output Problem on PETC Process

The results of the sulfur forms analyses of the coal from the slurry samples from Runs 1, 2, and 3A do not show a sequential decrease in sulfur content as the slurry flows through the system. In fact, the sulfur content of the coal from the reactor slurry samples is generally higher than that in the coal from the feed slurry.

The ash content of the coal from the slurry samples follows the same pattern. These data indicate that the heavier coal particles (those containing more ash and pyrite) are having more difficulty rising to the overflow discharge port in the reactor. The lighter coal particles are discharged more easily. Therefore, even at steady state conditions, the average density of the coal near the bottom of the reactor is higher than that of the coal near the slurry surface. Because the reactor slurry samples were taken from the bottom of the reactors, the samples were not representative of the slurry in the entire reactor, nor were they representative of the slurry being discharged from the reactor.

Discussions relating to this problem, between DOE and TRW representatives, led to the following recommendations:

- The analyses of the coal from individual reactor samples do not provide useful data for this program for reasons stated above.
- To improve the data, the slurry sampling and analyses plan was revised.
- Slurry overflow output from reactor R-5 was to be sampled at the end of steady state and submitted for filtrate and coal analyses.

- Coal from reactor slurry samples taken during the other test runs was to be saved for possible future analyses.
- Filtrates from all reactor slurry samples would be analyzed.
- Process evaluation testing would be completed using three of the five coals. Illinois No. 6 would be the first coal, Kentucky No. 9 the second, and Lucas No. 5 the third.

5.5.3 Exotherm in Kennecott Process

Operational difficulties were encountered during test runs evaluating the Kennecott process with the Illinois No. 6 coal. The exotherm from the coal-oxygen reaction during the tests using a 40% slurry was too great to permit adequate control of reactor temperatures. The slurry concentration was reduced to 30% to enable temperature control. The tests requiring a 20% slurry were conducted without any problems.

As a result of this unexpected problem, it was decided that all subsequent tests be run such that those tests indicated as 40% be changed to 30% coal weight in the slurry, and those indicated as 20% be changed to 15%.

6. EXPERIMENTAL TEST DATA FOR OXYDESULFUR- IZATION PROCESS EVALUATIONS

All test data collected for Oxydesulfurization Process evaluations have been tabulated and uniformly reported in the following pages of this section. Process input/output data obtained in the evaluation studies have been summarized in Appendix B.

Note: All Test Nos. refer to those in Tables 8-10.

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 1
DATE 8-11-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 18.2
ADDITIVE: None
REACTOR PRESSURE, PSIG: 985
REACTOR TEMPERATURE, C: R-3 202

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 25
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 2500
R-4 214 R-5 229

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	21.1	--	--	--	20.0
GAS, STD LITERS/HR	--	980	975	982	2598
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.2	18.7	29.1	18.1	--
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.28	4.17	4.82	3.89	--
ORGANIC SULFUR, AS S	2.12	1.84	1.94	2.16	--
PYRITIC SULFUR, AS S	1.13	2.30	2.86	1.70	--
SULFATE SULFUR, AS S	0.03	0.03	0.03	0.03	--
MOISTURE	9.39	8.21	8.00	7.14	--
ASH	11.37	12.73	13.62	11.52	--
CARBON CONTENT, AS C	69.84	66.24	66.05	66.02	--
HYDROGEN CONTENT, AS H	4.97	4.65	4.43	4.26	--
NITROGEN CONTENT, AS N	1.12	1.08	1.11	1.10	--
OXYGEN CONTENT, AS O	9.43	11.12	9.98	13.21	--
HEAT CONTENT, BTU/LB	12616	11921	11875	11490	--
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.219	0.215	0.258	0.180	--
SULFATE CONTENT, AS SO4	0.085	0.156	0.209	0.339	--
CARBONATE CONTENT, AS CO3	0.002	0	0	0	--
BICARBONATE CONTENT, AS HCO3	0.025	0	0	0	--
AMMONIA CONTENT, AS NH3	--	--	--	--	--
pH	8.5	7.4	7.4	3.4	--
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT	--	0.25	--	0.52	0.25
CO2 CONTENT	--	4.08	--	12.52	6.54
N2 CONTENT	--	87.29	--	83.16	84.94
O2 CONTENT	--	8.38	--	3.80	8.26
SOx CONTENT, AS SO2	--	--	--	--	0
C1-C3 CONTENT	--	0	--	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %	--	--	--	--	85.9**
ORGANIC SULFUR REMOVED, %	--	13.2	(5.43)	(11.3)	(1.89)**
PYRITIC SULFUR REMOVED, %	--	(103.5)	(24.3)	40.6	(50.44)**
CARBON REMOVED, %	--	5.15	0.29	0.05	5.47**
HYDROGEN REMOVED, %	--	6.44	4.73	3.83	14.3**
OXYGEN ADDED, %	--	17.9	(11.4)	32.4	40.1**
ASH ADDED, %	--	12.0	7.00	(15.4)	1.32**

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

**SYSTEM PERFORMANCE CALCULATIONS BASED ON ANALYSES OF FEED AND R-5 MATERIAL

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 2
DATE 8-28-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 15.5
ADDITIVE:
REACTOR PRESSURE, PSIG: 988
REACTOR TEMPERATURE, C: R-3 181
FEED GAS: Air
SLURRY RETENTION TIME, MIN: 58
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900
R-4 185 R-5 186

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.8				9.8
GAS, STD LITERS/HR		483	481	490	1242
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	15.5	16.0	16.1	15.6	12.0
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.35	3.94	3.89	3.27	2.66
ORGANIC SULFUR, AS S	2.11	1.98	1.91	1.83	2.08
PYRITIC SULFUR, AS S	1.23	1.93	1.96	1.43	0.56
SULFATE SULFUR, AS S	0.01	0.03	0.02	0.02	0.02
MOISTURE	3.74	4.70	4.88	6.04	3.73
ASH	11.21	12.22	12.46	11.66	10.26
CARBON CONTENT, AS C	69.65	66.54	65.36	65.35	66.85
HYDROGEN CONTENT, AS H	5.08	4.68	4.29	4.17	4.41
NITROGEN CONTENT, AS N	1.31	1.21	1.16	1.15	1.22
OXYGEN CONTENT, AS O	9.39	11.40	12.84	14.40	14.60
HEAT CONTENT, BTU/LB	12594	11880	11484	11298	11476
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.124	0.225	0.148	0.183	0.289
SULFATE CONTENT, AS SO4	0.089	0.268	0.397	0.513	0.353
CARBONATE CONTENT, AS CO3	0.004	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.021	0	0	0	0
AMMONIA CONTENT, AS NH3					
pH	8.9	6.2	2.8	2.3	2.4
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		0.33		0.36	0.26
CO2 CONTENT		5.00		6.45	4.06
N2 CONTENT		92.89		91.39	94.43
O2 CONTENT		1.77		1.80	1.28
SOx CONTENT, AS SO2					0
C1-C3 CONTENT		0		0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %		--	--	--	78.5
ORGANIC SULFUR REMOVED, %		6.16	3.54	4.19	1.42
PYRITIC SULFUR REMOVED, %		(56.9)	(1.55)	27.0	54.5
CARBON REMOVED, %		4.47	1.77	0.02	4.02
HYDROGEN REMOVED, %		7.87	8.33	2.80	13.2
OXYGEN ADDED, %		21.4	12.6	12.1	55.5
ASH ADDED, %		9.01	1.96	(6.42)	(8.47)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 3A
DATE 8-29-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 15.4
ADDITIVE:
REACTOR PRESSURE, PSIG: 985
REACTOR TEMPERATURE, C: R-3 201

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 58
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900
R-4 203 R-5 204

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.8				6.5
GAS, STD LITERS/HR		479	477	486	1165
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WTZ	15.4	13.2	--	14.5	17.2
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.36	4.84	5.02	3.35	2.53
ORGANIC SULFUR, AS S	2.14	1.93	1.91	1.90	1.97
PYRITIC SULFUR, AS S	1.20	2.90	3.10	1.44	0.58
SULFATE SULFUR, AS S	0.02	0.01	0.01	0.01	0.01
MOISTURE	4.08	5.90	6.68	7.96	9.01
ASH	11.24	13.72	14.39	11.68	10.99
CARBON CONTENT, AS C	69.57	65.09	63.77	65.07	64.87
HYDROGEN CONTENT, AS H	5.19	4.30	4.07	4.33	4.25
NITROGEN CONTENT, AS N	1.29	1.16	1.13	1.23	1.17
OXYGEN CONTENT, AS O	9.35	10.90	11.62	14.35	15.90
HEAT CONTENT, BTU/LB	12656	11606	11100	11199	11153
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.143	0.207	0.212	0.190	0.222
SULFATE CONTENT, AS SO4	0.095	0.095	0.224	0.372	.736
CARBONATE CONTENT, AS CO3	.0035	0	0	0	0
BICARBONATE CONTENT, AS HCO3	.0218	0	0	0	0
AMMONIA CONTENT, AS NH3					
pH	8.2	4.2	2.9	2.3	2.4
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		0.38	0.39	0.39	0.38
CO2 CONTENT		6.83	8.02	8.04	7.61
N2 CONTENT		91.35	90.33	90.36	90.73
O2 CONTENT		1.45	1.26	1.21	1.27
SOx CONTENT, AS SO2					0.0
C1-C3 CONTENT		0.0	0.0	0.0	0.0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					72.7
ORGANIC SULFUR REMOVED, %		9.81	1.04	0.52	7.94
PYRITIC SULFUR REMOVED, %		(141.7)	(6.90)	53.5	51.7
CARBON REMOVED, %		6.44	2.03	(2.04)	6.76
HYDROGEN REMOVED, %		17.1	5.35	(6.39)	18.1
OXYGEN ADDED, %		16.6	6.61	23.5	70.1
ASH ADDED, %		22.1	4.88	(18.8)	(2.22)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 3C
DATE 9-16-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 18.4
ADDITIVE:
REACTOR PRESSURE, PSIG: 987
REACTOR TEMPERATURE, °C: R-3 201 R-4 202 R-5 204
FEED GAS: Air
SLURRY RETENTION TIME, MIN: 53
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	9.7				9.6
GAS, STD LITERS/HR		477	475	484	1543
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.4	19.3	19.8	19.4	17.9
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.42				3.03
ORGANIC SULFUR, AS S	2.09				2.11
PYRITIC SULFUR, AS S	1.37				0.92
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	2.74				4.85
ASH	11.39				9.98
CARBON CONTENT, AS C	69.74				67.43
HYDROGEN CONTENT, AS H	5.09				4.39
NITROGEN CONTENT, AS N	1.30				1.31
OXYGEN CONTENT, AS O	9.02				13.85
HEAT CONTENT, BTU/LB	12656				11670
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.776	0.549	0.594	0.682	.333
SULFATE CONTENT, AS SO4	0.045	0.151	0.269	0.401	.672
CARBONATE CONTENT, AS CO3	0.001	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.066	0.049			0
AMMONIA CONTENT, AS NH3					
pH	8.5	7.0	3.8	3.0	2.5
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.00	0.34	0.36	0.38
CO2 CONTENT		0.07	6.09	7.39	6.58
N2 CONTENT		80.75	85.04	83.99	81.42
O2 CONTENT		1.52	1.24	1.61	4.46
SOx CONTENT, AS SO2		0	0	0	TR
C1-C3 CONTENT		0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, % 88.8
ORGANIC SULFUR REMOVED, % (0.96)
PYRITIC SULFUR REMOVED, % 32.8
CARBON REMOVED, % 3.3
HYDROGEN REMOVED, % 13.8
OXYGEN ADDED, % 53.5
ASH ADDED, % (12.4)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 4
DATE 9-5-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 18.5
ADDITIVE: None
REACTOR PRESSURE, PSIG: 1000
REACTOR TEMPERATURE, C: R-3 224

FEED GAS: Compressed Air
SLURRY RETENTION TIME, MIN: N/A
ADDITIVE CONC., MOLAR: --
AGITATOR SPEED, RPM: 1900
R-4 224 R-5 221

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	N/A				N/A
GAS, STD LITERS/HR		329	336	327	998
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WTZ	18.5	18.48	17.28	14.99	14.02
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.20	3.78	2.85	2.87	2.24
ORGANIC SULFUR, AS S	2.08	1.97	1.75	2.15	1.68
PYRITIC SULFUR, AS S	1.25	1.79	0.94	0.70	0.31
SULFATE SULFUR, AS S	0.01	0.02	0.16	0.02	0.26
MOISTURE	4.21	3.80	5.08	5.20	5.90
ASH	11.44	13.31	11.57	12.09	10.76
CARBON CONTENT, AS C	69.55	64.64	64.03	61.43	62.20
HYDROGEN CONTENT, AS H	5.18	4.12	3.54	3.08	3.21
NITROGEN CONTENT, AS N	1.32	1.20	1.21	1.23	1.30
OXYGEN CONTENT, AS O	9.16	12.94	16.80	19.29	20.29
HEAT CONTENT, BTU/LB	12662	11188	10540	9888	10083
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	.420	.287	.418	.440	.904
SULFATE CONTENT, AS SO4	0.063	.405	.455	.708	1.33
CARBONATE CONTENT, AS CO3	0.000				
BICARBONATE CONTENT, AS HCO3	0.390				
AMMONIA CONTENT, AS NH3					
pH	8.0	3.4	1.9	1.6	2.8
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		.42	.45	.49	.38
CO2 CONTENT		11.42	15.25	16.77	12.09
N2 CONTENT		86.90	83.24	81.50	86.63
O2 CONTENT		1.23	1.10	1.13	.91
SOx CONTENT, AS SO2					TR
C1-C3 CONTENT				0.08	
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %	--	--	--	--	--
ORGANIC SULFUR REMOVED, %	5.29	11.2	(22.9)		19.2
PYRITIC SULFUR REMOVED, %	(43.2)	47.5	25.5		75.2
CARBON REMOVED, %	7.06	0.94	4.06		10.6
HYDROGEN REMOVED, %	20.5	14.1	13.0		38.0
OXYGEN ADDED, %	41.3	29.8	14.8		121.5
ASH ADDED, %	16.3	(13.1)	4.49		(5.94)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 5A
DATE 9-10-80

TEST CONDITIONS

COAL: Illinois No.6
SLURRY CONC, W/WZ SOLIDS: 18.1
ADDITIVE:
REACTOR PRESSURE, PSIG: 981
REACTOR TEMPERATURE, C: R-3 181

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 84
ADDITIVE CONC., MOLAR:
AGITATOR SPEED; RPM: 1900
R-4 183 R-5 184

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	6.0				6.1
GAS, STD LITERS/HR		323	329	321	954
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.1	18.4	18.6	18.9	18.8
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.41				3.06
ORGANIC SULFUR, AS S	2.19				2.02
PYRITIC SULFUR, AS S	1.21				1.04
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	2.34				3.51
ASH	11.29				10.41
CARBON CONTENT, AS C	69.83				67.64
HYDROGEN CONTENT, AS H	5.17				4.62
NITROGEN CONTENT, AS N	1.26				1.22
OXYGEN CONTENT, AS O	9.03				13.05
HEAT CONTENT, BTU/LB	12629				11852
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.271	0.265	0.171	0.244	0.175
SULFATE CONTENT, AS SO4	0.073	0.106	0.261	0.409	0.234
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0	0	0	0	0
AMMONIA CONTENT, AS NH3					
pH	<4.0	<4.0	<4.0	<4.0	<4.0
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.18	0.15	0.20	0.20
CO2 CONTENT		3.81	3.50	4.18	3.88
N2 CONTENT		94.68	95.34	94.22	94.76
O2 CONTENT		1.32	1.01	1.40	1.15
SOx CONTENT, AS SO2					TR
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					99.1
ORGANIC SULFUR REMOVED, %					7.80
PYRITIC SULFUR REMOVED, %					14.0
CARBON REMOVED, %					3.14
HYDROGEN REMOVED, %					10.6
OXYGEN ADDED, %					44.5
ASH ADDED, %					(7.79)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 6
DATE 9-2-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/W% SOLIDS: 15.4
ADDITIVE: None
REACTOR PRESSURE, PSIG: 985
REACTOR TEMPERATURE, C: R-3 180

FEED GAS: Compressed Air
SLURRY RETENTION TIME, MIN: N/A
ADDITIVE CONC., MOLAR: --
AGITATOR SPEED; RPM: 1900
R-4 181 R-5 183

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	N/A				N/A
GAS, STD LITERS/HR		240	251	244	591
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	15.36	14.80	13.78	14.54	13.12
<u>COAL ANALYSES (W/W% MF COAL)</u>					
TOTAL SULFUR, AS S	3.30	3.53	2.96	2.75	2.06
ORGANIC SULFUR, AS S	2.22	2.09	1.88	1.76	1.70
PYRITIC SULFUR, AS S	1.07	1.43	1.07	0.98	.35
SULFATE SULFUR, AS S	.01	.01	.01	.01	.01
MOISTURE	3.81	1.81	2.38	7.60	3.79
ASH	11.11	11.32	11.81	11.44	11.18
CARBON CONTENT, AS C	69.63	64.77	63.35	61.67	62.99
HYDROGEN CONTENT, AS H	5.40	4.89	4.18	3.66	3.84
NITROGEN CONTENT, AS N	1.21	1.14	1.18	1.17	1.18
OXYGEN CONTENT, AS O	9.35	14.36	16.52	19.31	18.76
HEAT CONTENT, BTU/LB	12673	11346	10685	10182	10192
<u>FILTRATE ANALYSES (W/W%)</u>					
CARBON CONTENT, AS C*	.187	.318	.294	.262	.858
SULFATE CONTENT, AS SO4	.0856	.4492	.6946	.8660	.9554
CARBONATE CONTENT, AS CO3	.001				
BICARBONATE CONTENT, AS HCO3	.013				
AMMONIA CONTENT, AS NH3					
pH	8.4	2.3	2.0	1.9	2.1
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		.42	.46	.47	.45
CO2 CONTENT		10.63	13.73	13.41	12.48
N2 CONTENT		87.10	83.56	83.86	84.97
O2 CONTENT		1.86	2.24	2.26	2.10
SOx CONTENT, AS SO2					TR
C1-C3 CONTENT		0.0	0.0	0.0	0.0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %		--	--	--	--
ORGANIC SULFUR REMOVED, %		5.86	10.0	6.38	23.4
PYRITIC SULFUR REMOVED, %		(33.6)	25.2	8.41	67.3
CARBON REMOVED, %		6.98	2.19	2.65	9.54
HYDROGEN REMOVED, %		9.44	14.5	12.4	28.9
OXYGEN ADDED, %		53.6	13.1	16.9	100.6
ASH ADDED, %		1.89	4.33	(3.13)	0.63

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 6A
DATE 9-11-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/W% SOLIDS: 17.9
ADDITIVE:
REACTOR PRESSURE, PSIG: 998
REACTOR TEMPERATURE, C: R-3 180

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 116
ADDITIVE CONC., MOLAR:
AGITATOR SPEED; RPM: 1900
R-4 180 R-5 181

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	4.4				4.8
GAS, STD LITERS/HR		244	256	248	902
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	17.9	18.6	18.5	17.4	18.1
<u>COAL ANALYSES (W/W% MF COAL)</u>					
TOTAL SULFUR, AS S	3.35				2.81
ORGANIC SULFUR, AS S	2.06				1.89
PYRITIC SULFUR, AS S	1.29				0.91
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	2.02				2.40
ASH	11.17				10.16
CARBON CONTENT, AS C	69.21				66.79
HYDROGEN CONTENT, AS H	5.19				4.34
NITROGEN CONTENT, AS N	1.32				1.29
OXYGEN CONTENT, AS O	9.75				14.60
HEAT CONTENT, BTU/LB	12337				11568
<u>FILTRATE ANALYSES (W/W%)</u>					
CARBON CONTENT, AS C*	0.127	0.124	0.182	0.197	0.140
SULFATE CONTENT, AS SO4	0.073	0.168	0.399	0.377	0.457
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.098	0.146	0.063	0.067	0.057
AMMONIA CONTENT, AS NH3					
pH	8.2	--	6.9	--	--
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.29	0.27	0.29	0.29
CO2 CONTENT		6.91	6.43	7.59	6.28
N2 CONTENT		91.44	91.73	90.64	91.99
O2 CONTENT		1.46	1.56	1.48	1.44
SOx CONTENT, AS SO2					TR
C1-C3 CONTENT		0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, % 103.2
ORGANIC SULFUR REMOVED, % 8.25
PYRITIC SULFUR REMOVED, % 29.5
CARBON REMOVED, % 3.50
HYDROGEN REMOVED, % 16.4
OXYGEN ADDED, % 49.7
ASH ADDED, % (9.04)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 7A
DATE 9-17-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 19.0
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 250
REACTOR TEMPERATURE, C: R-3 148

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 60
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED, RPM: 1900
R-4 150 R-5 154

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	8.7				9.2
GAS, STD LITERS/HR		91	88	57	225
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	19.0	18.3	20.2	19.3	17.9
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.39	3.56	3.26	3.43	2.74
ORGANIC SULFUR, AS S	2.08	2.15	2.11	2.05	2.06
PYRITIC SULFUR, AS S	1.30	1.39	1.13	1.34	0.68
SULFATE SULFUR, AS S	0.01	0.01	0.02	0.03	0.01
MOISTURE	2.52	3.05	3.51	3.63	4.60
ASH	12.09	14.19	14.17	16.68	16.26
CARBON CONTENT, AS C	68.83	66.26	66.23	63.87	64.43
HYDROGEN CONTENT, AS H	5.03	4.64	4.58	4.35	4.68
NITROGEN CONTENT, AS N	1.28	1.29	1.25	1.20	1.27
OXYGEN CONTENT, AS O	9.37	10.05	10.52	10.47	10.61
HEAT CONTENT, BTU/LB	12405	11937	11681	11257	11402
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.378	0.532	0.930	0.555	0.354
SULFATE CONTENT, AS SO ₄	0.066	0.221	0.653	0.707	0.299
CARBONATE CONTENT, AS CO ₃	1.65	.296	.044	.380	.127
BICARBONATE CONTENT, AS HCO ₃	1.22	1.38	2.73	1.24	.701
AMMONIA CONTENT, AS NH ₃					
pH	10.8	8.9	8.3	9.0	8.9
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.87	1.12	1.17	0.82
CO ₂ CONTENT		10.40	10.83	11.32	9.96
N ₂ CONTENT		71.54	73.32	70.92	72.12
O ₂ CONTENT		9.29	9.88	11.23	14.14
SO _x CONTENT, AS SO ₂					TR
C1-C3 CONTENT		0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, %	--	--	--	91.6
ORGANIC SULFUR REMOVED, %	(3.37)	1.86	2.84	0.96
PYRITIC SULFUR REMOVED, %	(6.92)	18.7	(18.6)	47.7
CARBON REMOVED, %	3.73	0.05	3.56	6.39
HYDROGEN REMOVED, %	7.75	1.29	5.02	6.96
OXYGEN ADDED, %	7.26	4.68	(0.48)	13.2
ASH ADDED, %	17.4	(0.14)	17.7	34.5

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 8A
DATE 9-29-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 17.0
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 250
REACTOR TEMPERATURE, C: R-3 150

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 57
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED, RPM: 1900
R-4 153 R-5 153

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	9.2				7.5
GAS, STD LITERS/HR		141	132	81	348
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WTZ	17.0				12.0
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.28				2.62
ORGANIC SULFUR, AS S	2.51				2.29
PYRITIC SULFUR, AS S	0.74				0.31
SULFATE SULFUR, AS S	0.02				0.02
MOISTURE	1.60				2.85
ASH	11.56				13.78
CARBON CONTENT, AS C	69.32				65.44
HYDROGEN CONTENT, AS H	5.01				4.50
NITROGEN CONTENT, AS N	1.28				1.20
OXYGEN CONTENT, AS O	9.55				12.46
HEAT CONTENT, BTU/LB	12557				11361
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.451	2.29	1.30	1.42	0.922
SULFATE CONTENT, AS SO ₄	0.081	0.195	0.310	0.146	1.82
CARBONATE CONTENT, AS CO ₃	1.44	0.017	0.059	0	0.084
BICARBONATE CONTENT, AS HCO ₃	0.159	0.624	0.489	0.217	1.22
AMMONIA CONTENT, AS NH ₃					
pH	10.6	8.3	8.7	8.0	9.0
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		1.88	1.94	1.92	1.83
CO ₂ CONTENT		27.21	27.75	28.84	16.15
N ₂ CONTENT		18.22	15.43	13.42	44.19
O ₂ CONTENT		52.58	56.80	55.81	37.84
SO _x CONTENT, AS SO ₂					TR
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					52.1
ORGANIC SULFUR REMOVED, %					8.76
PYRITIC SULFUR REMOVED, %					58.1
CARBON REMOVED, %					5.60
HYDROGEN REMOVED, %					10.2
OXYGEN ADDED, %					30.5
ASH ADDED, %					19.2

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 9F
DATE 10-1-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 17.2
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 275
REACTOR TEMPERATURE, C: R-3 154

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 104
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED; RPM: 1900
R-4 151 R-5 153

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	5.0				5.5
GAS, STD LITERS/HR		68	76	57	173

SLURRY ANALYSES

SOLIDS CONTENT, WT%	17.2	16.6		12.8	9.6
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COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S	3.32				2.50
ORGANIC SULFUR, AS S	2.28				2.05
PYRITIC SULFUR, AS S	1.03				0.39
SULFATE SULFUR, AS S	0.01				0.06
MOISTURE	2.35				3.92
ASH	11.77				14.65
CARBON CONTENT, AS C	68.60				63.95
HYDROGEN CONTENT, AS H	4.96				4.30
NITROGEN CONTENT, AS N	1.18				1.23
OXYGEN CONTENT, AS O	10.17				13.38
HEAT CONTENT, BTU/LB	12469				11212

FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*	0.538	0.778		0.953	0.904
SULFATE CONTENT, AS SO ₄	0.311	0.454		0.537	0.443
CARBONATE CONTENT, AS CO ₃	1.54	0.131		0.086	0.055
BICARBONATE CONTENT, AS HCO ₃	0.238	1.69		0.944	0.820
AMMONIA CONTENT, AS NH ₃					
pH	10.6	8.6	--	8.8	8.9

GAS ANALYSES (MOLE%)

CO CONTENT		0.33	1.04	1.06	0.31
CO ₂ CONTENT		14.46	17.53	21.75	14.67
N ₂ CONTENT		77.29	52.97	50.33	77.89
O ₂ CONTENT		7.86	28.42	26.86	7.14
SO _x CONTENT, AS SO ₂					TR
C1-C3 CONTENT		0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, %		55.2
ORGANIC SULFUR REMOVED, %		10.1
PYRITIC SULFUR REMOVED, %		62.1
CARBON REMOVED, %		6.77
HYDROGEN REMOVED, %		13.3
OXYGEN ADDED, %		31.6
ASH ADDED, %		24.5

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 13
DATE 10-19-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 27.5
ADDITIVE: NH3
REACTOR PRESSURE, PSIG: 296
REACTOR TEMPERATURE, C: R-3 138 R-4 129 R-5 131
FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 112
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1900

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	4.6				3.1
GAS, STD LITERS/HR		159	164	191	371
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WTZ	27.5	31.2	24.5	33.0	30.1
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.47				2.29
ORGANIC SULFUR, AS S	2.15				1.89
PYRITIC SULFUR, AS S	1.31				0.39
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	1.54				3.01
ASH	11.29				9.50
CARBON CONTENT, AS C	69.09				64.66
HYDROGEN CONTENT, AS H	4.92				4.38
NITROGEN CONTENT, AS N	1.43				3.83
OXYGEN CONTENT, AS O	9.79				15.34
HEAT CONTENT, BTU/LB	12534				11067
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.443	1.01	0.893	1.48	0.469
SULFATE CONTENT, AS SO4	0.079	1.17	1.29	1.98	1.20
CARBONATE CONTENT, AS CO3					
BICARBONATE CONTENT, AS HCO3					
AMMONIA CONTENT, AS NH3	5.08	5.01	2.12	2.37	0.002
pH					
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		0.73	0.78	0.74	0.74
CO2 CONTENT		8.75	10.59	11.45	8.64
N2 CONTENT		0	0	0	0
O2 CONTENT		90.51	88.63	87.80	90.60
SOx CONTENT, AS SO2					TR
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					65.1
ORGANIC SULFUR REMOVED, %					12.1
PYRITIC SULFUR REMOVED, %					70.2
CARBON REMOVED, %					6.41
HYDROGEN REMOVED, %					11.0
OXYGEN ADDED, %					56.7
ASH ADDED, %					(15.9)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 14
DATE 10-8-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 35.6
ADDITIVE: Ammonia
REACTOR PRESSURE, PSIG: 320
REACTOR TEMPERATURE, C: R-3 155

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 58
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1900
R-4 199 R-5 191

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

FEED	R-3	R-4	R-5	SYSTEM OUTPUT
9.1				11.03
	341	354	328	498

SLURRY ANALYSES

SOLIDS CONTENT, WTZ

35.6	34.2	34.4	36.3	29.1
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COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S

3.46				2.57
------	--	--	--	------

ORGANIC SULFUR, AS S

2.15				2.08
------	--	--	--	------

PYRITIC SULFUR, AS S

1.30				0.45
------	--	--	--	------

SULFATE SULFUR, AS S

0.01				0.04
------	--	--	--	------

MOISTURE

1.87				3.31
------	--	--	--	------

ASH

11.34				10.39
-------	--	--	--	-------

CARBON CONTENT, AS C

69.36				63.22
-------	--	--	--	-------

HYDROGEN CONTENT, AS H

4.94				3.93
------	--	--	--	------

NITROGEN CONTENT, AS N

1.48				4.50
------	--	--	--	------

OXYGEN CONTENT, AS O

9.42				15.39
------	--	--	--	-------

HEAT CONTENT, BTU/LB

12576				10825
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FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*

1.10	1.34	1.52	1.18	1.07
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SULFATE CONTENT, AS SO4

0.084	0.926	1.40	1.52	1.51
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CARBONATE CONTENT, AS CO3

BICARBONATE CONTENT, AS HCO3

2.79	2.82	1.55	0.34	0.01
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AMMONIA CONTENT, AS NH3

pH

GAS ANALYSES (MOLEZ)

CO CONTENT

	2.27	2.26	3.56	2.29
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CO2 CONTENT

	50.01	60.77	80.35	52.57
--	-------	-------	-------	-------

N2 CONTENT

	1.52	1.32	1.30	1.27
--	------	------	------	------

O2 CONTENT

	46.20	35.71	14.79	43.86
--	-------	-------	-------	-------

SOx CONTENT, AS SO2

				0
--	--	--	--	---

C1-C3 CONTENT

	0	0	0	0
--	---	---	---	---

PROCESS PERFORMANCE

BTU RECOVERY, %

				85.3
--	--	--	--	------

ORGANIC SULFUR REMOVED, %

				3.26
--	--	--	--	------

PYRITIC SULFUR REMOVED, %

				65.4
--	--	--	--	------

CARBON REMOVED, %

				8.85
--	--	--	--	------

HYDROGEN REMOVED, %

				20.4
--	--	--	--	------

OXYGEN ADDED, %

				63.4
--	--	--	--	------

ASH ADDED, %

				(8.38)
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*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 14C
DATE 10-15-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 28.2
ADDITIVE: NH3
REACTOR PRESSURE, PSIG: 300
REACTOR TEMPERATURE, C: R-3 155

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 59
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1900
R-4 191 R-5 159

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.1				9.1
GAS, STD LITERS/HR		249	260	229	410
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	28.2	19.2	28.3	25.6	24.0
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.41				2.21
ORGANIC SULFUR, AS S	2.05				1.72
PYRITIC SULFUR, AS S	1.35				0.46
SULFATE SULFUR, AS S	0.01				0.03
MOISTURE	1.79				2.55
ASH	11.48				11.16
CARBON CONTENT, AS C	69.59				62.71
HYDROGEN CONTENT, AS H	5.03				4.03
NITROGEN CONTENT, AS N	1.47				4.92
OXYGEN CONTENT, AS O	9.02				14.97
HEAT CONTENT, BTU/LB	12534				10778
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.305	0.367	0.613	0.440	0.226
SULFATE CONTENT, AS SO4	0.056	0.355	0.630	0.476	1.27
CARBONATE CONTENT, AS CO3					
BICARBONATE CONTENT, AS HCO3					
AMMONIA CONTENT, AS NH3	3.22	2.43	0.906	0.339	0.004
pH					
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		2.63	1.63	2.00	1.90
CO2 CONTENT		49.05	33.24	33.20	28.77
N2 CONTENT		1.75	1.09	1.12	1.18
O2 CONTENT		46.57	64.04	63.12	68.16
SOx CONTENT, AS SO2					0
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					82.2
ORGANIC SULFUR REMOVED, %					16.1
PYRITIC SULFUR REMOVED, %					65.9
CARBON REMOVED, %					9.89
HYDROGEN REMOVED, %					19.9
OXYGEN ADDED, %					66.0
ASH ADDED, %					(2.79)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 15
DATE 10-7-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 36.0
ADDITIVE: Ammonia
REACTOR PRESSURE, PSIG: 295
REACTOR TEMPERATURE, C: R-3 159

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 55
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1900
R-4 194 R-5 202

<u>MATERIAL FLOW MEASUREMENTS</u>	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	9.6				18.6
GAS, STD LITERS/HR		338	337	303	444
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	36.0	33.5	32.6	27.2	21.8
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.48				2.47
ORGANIC SULFUR, AS S	2.21				1.83
PYRITIC SULFUR, AS S	1.26				0.63
SULFATE SULFUR, AS S	0.02				0.01
MOISTURE	1.45				4.13
ASH	11.31				10.39
CARBON CONTENT, AS C	69.01				64.68
HYDROGEN CONTENT, AS H	4.93				3.95
NITROGEN CONTENT, AS N	1.38				4.36
OXYGEN CONTENT, AS O	9.90				14.15
HEAT CONTENT, BTU/LB	12510				10917
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.165	0.236	0.135	0.283	0.256
SULFATE CONTENT, AS SO4	0.061	0.778	1.36	0.695	0.917
CARBONATE CONTENT, AS CO3					
BICARBONATE CONTENT, AS HCO3					
AMMONIA CONTENT, AS NH3	3.12	1.06	1.28	0.836	0.003
pH					
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		3.43	4.97	2.70	3.36
CO2 CONTENT		81.87	70.98	85.03	77.58
N2 CONTENT		0.51	1.20	0.38	0.53
O2 CONTENT		14.20	22.85	11.89	18.53
SOx CONTENT, AS SO2					TR
Cl-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					91.4
ORGANIC SULFUR REMOVED, %					17.2
PYRITIC SULFUR REMOVED, %					50.0
CARBON REMOVED, %					6.27
HYDROGEN REMOVED, %					19.9
OXYGEN ADDED, %					42.9
ASH ADDED, %					(8.13)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 16
DATE 10-17-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 20.4
ADDITIVE: NH₃
REACTOR PRESSURE, PSIG: 310
REACTOR TEMPERATURE, C: R-3 127

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 102
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED; RPM: 1900
R-4 132 R-5 128

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	4.9				4.6
GAS, STD LITERS/HR		79	80	95	151

SLURRY ANALYSES

SOLIDS CONTENT, WT%	20.4	16.0	16.3	10.9	18.6
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.41				2.28
ORGANIC SULFUR, AS S	2.52				1.92
PYRITIC SULFUR, AS S	0.87				0.33
SULFATE SULFUR, AS S	0.01				0.03
MOISTURE	2.66				4.63
ASH	11.61				11.75
CARBON CONTENT, AS C	69.54				64.62
HYDROGEN CONTENT, AS H	4.92				4.29
NITROGEN CONTENT, AS N	1.37				4.67
OXYGEN CONTENT, AS O	9.16				12.40
HEAT CONTENT, BTU/LB	12031				11248

FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*	0.124	0.374	0.618	0.364	0.669
SULFATE CONTENT, AS SO ₄	0.063	0.483	0.603	0.378	0.685
CARBONATE CONTENT, AS CO ₃					
BICARBONATE CONTENT, AS HCO ₃					
AMMONIA CONTENT, AS NH ₃	0.686	2.16	2.02	0.650	0.430

pH

GAS ANALYSES (MOLEZ)

CO CONTENT	0.86	0.74	0.81		
CO ₂ CONTENT	0	0	0		
N ₂ CONTENT	2.37	2.04	2.62		
O ₂ CONTENT	96.60	88.95	96.62		
SO _x CONTENT, AS SO ₂					0
C1-C3 CONTENT	0	0	0		0

PROCESS PERFORMANCE

BTU RECOVERY, %	80.0
ORGANIC SULFUR REMOVED, %	23.8
PYRITIC SULFUR REMOVED, %	62.1
CARBON REMOVED, %	7.08
HYDROGEN REMOVED, %	12.8
OXYGEN ADDED, %	35.4
ASH ADDED, %	1.21

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 17
DATE 10-16-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 18.9
ADDITIVE: NH₃
REACTOR PRESSURE, PSIG: 290
REACTOR TEMPERATURE, C: R-3 159

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 65
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED; RPM: 1900
R-4 161 R-5 158

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	7.7				6.8
GAS, STD LITERS/HR		150	154	180	190
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WTZ	18.9	13.9	15.3	17.7	20.3
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.49				2.23
ORGANIC SULFUR, AS S	2.35				1.95
PYRITIC SULFUR, AS S	1.12				0.24
SULFATE SULFUR, AS S	0.02				0.04
MOISTURE	1.95				4.24
ASH	11.65				10.52
CARBON CONTENT, AS C	69.48				63.40
HYDROGEN CONTENT, AS H	4.91				4.11
NITROGEN CONTENT, AS N	1.38				6.16
OXYGEN CONTENT, AS O	9.10				13.58
HEAT CONTENT, BTU/LB	12552				10793
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.383	0.444	0.678	1.10	0.623
SULFATE CONTENT, AS SO ₄	0.045	0.514	0.348	0.844	0.872
CARBONATE CONTENT, AS CO ₃					
BICARBONATE CONTENT, AS HCO ₃					
AMMONIA CONTENT, AS NH ₃	3.35	2.73	0.869	0.246	0.006
pH					
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		1.94	1.54	1.94	1.87
CO ₂ CONTENT		12.83	6.87	12.99	13.78
N ₂ CONTENT		2.24	2.28	2.27	2.09
O ₂ CONTENT		83.00	89.31	82.79	82.27
SO _x CONTENT, AS SO ₂					0
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					81.6
ORGANIC SULFUR REMOVED, %					17.0
PYRITIC SULFUR REMOVED, %					78.6
CARBON REMOVED, %					8.75
HYDROGEN REMOVED, %					16.3
OXYGEN ADDED, %					49.2
ASH ADDED, %					(9.70)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 18
DATE 10-20-80

TEST CONDITIONS

COAL: Illinois No. 6
SLURRY CONC, W/WZ SOLIDS: 18.6
ADDITIVE: NH3
REACTOR PRESSURE, PSIG: 297
REACTOR TEMPERATURE, C: R-3 189

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 28
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1900
R-4 198 R-5 194

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

FEED	R-3	R-4	R-5	SYSTEM OUTPUT
17.6				18.6
	315	294	280	390

SLURRY ANALYSES

SOLIDS CONTENT, WT%

18.6	15.2	19.3	14.9	12.6
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COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S

3.28				2.16
------	--	--	--	------

ORGANIC SULFUR, AS S

2.09				1.81
------	--	--	--	------

PYRITIC SULFUR, AS S

1.16				0.31
------	--	--	--	------

SULFATE SULFUR, AS S

0.02				0.04
------	--	--	--	------

MOISTURE

2.12				8.07
------	--	--	--	------

ASH

11.55				12.65
-------	--	--	--	-------

CARBON CONTENT, AS C

69.67				62.19
-------	--	--	--	-------

HYDROGEN CONTENT, AS H

5.02				3.67
------	--	--	--	------

NITROGEN CONTENT, AS N

1.46				6.45
------	--	--	--	------

OXYGEN CONTENT, AS O

9.03				12.88
------	--	--	--	-------

HEAT CONTENT, BTU/LB

12663				10405
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FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*

0.289	0.334	0.397	0.368	0.446
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SULFATE CONTENT, AS SO4

0.055	0.387	0.398	0.264	0.773
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CARBONATE CONTENT, AS CO3

BICARBONATE CONTENT, AS HCO3

AMMONIA CONTENT, AS NH3

2.48	0.434	0.617	0.0430	
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pH

GAS ANALYSES (MOLEZ)

CO CONTENT

2.42	1.31	2.14	2.36
------	------	------	------

CO2 CONTENT

25.26	13.60	22.96	27.2
-------	-------	-------	------

N2 CONTENT

5.06	4.16	5.19	5.38
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O2 CONTENT

67.26	80.98	69.72	65.10
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SOx CONTENT, AS SO2

			TR
--	--	--	----

C1-C3 CONTENT

0	0	0	0
---	---	---	---

PROCESS PERFORMANCE

BTU RECOVERY, %

			58.8
--	--	--	------

ORGANIC SULFUR REMOVED, %

			13.4
--	--	--	------

PYRITIC SULFUR REMOVED, %

			97.3
--	--	--	------

CARBON REMOVED, %

			10.7
--	--	--	------

HYDROGEN REMOVED, %

			26.9
--	--	--	------

OXYGEN ADDED, %

			42.6
--	--	--	------

ASH ADDED, %

			(9.52)
--	--	--	--------

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 19
DATE 10-29 80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS: 18.3
ADDITIVE: None
REACTOR PRESSURE, PSIG: 980
REACTOR TEMPERATURE, C: R-3 176

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 31
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: R-4 185 R-5 184

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	16.5				17.5
GAS, STD LITERS/HR		1103	1081	1174	4253
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.3	20.1	18.4	--	18.9
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.06				2.21
ORGANIC SULFUR, AS S	1.25				1.21
PYRITIC SULFUR, AS S	1.77				0.63
SULFATE SULFUR, AS S	0.04				0.36
MOISTURE	2.12				2.12
ASH	21.72				20.25
CARBON CONTENT, AS C	62.44				58.98
HYDROGEN CONTENT, AS H	4.38				3.78
NITROGEN CONTENT, AS N	1.28				1.27
OXYGEN CONTENT, AS O	7.13				13.52
HEAT CONTENT, BTU/LB	11270				10143
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.162	0.200	0.194	0.489	0.217
SULFATE CONTENT, AS SO4	0.160	0.317	0.591	0.977	0.709
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.006	0.002	0	0	0
AMMONIA CONTENT, AS NH3					
pH	7.5	5.9	2.5	2.7	2.1
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		0.31	0.33	0.38	0.30
CO2 CONTENT		6.04	5.59	5.99	5.78
N2 CONTENT		83.39	85.96	85.75	85.86
O2 CONTENT		7.97	8.11	7.88	8.06
SOx CONTENT, AS SO2					TR
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					98.6
ORGANIC SULFUR REMOVED, %					3.20
PYRITIC SULFUR REMOVED, %					64.4
CARBON REMOVED, %					5.54
HYDROGEN REMOVED, %					13.7
OXYGEN ADDED, %					89.6
ASH ADDED, %					(6.77)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 20
DATE 10-23-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 19.1
ADDITIVE: None
REACTOR PRESSURE, PSIG: 998
REACTOR TEMPERATURE, C: R-3 180

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 66
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900
R-4 181 R-5 183

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	7.8				8.1
GAS, STD LITERS/HR		592	549	592	2005
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	19.1	21.5	21.8	24.6	20.6
<u>COAL ANALYSES (W/W% MF COAL)</u>					
TOTAL SULFUR, AS S	3.30				2.35
ORGANIC SULFUR, AS S	1.58				1.45
PYRITIC SULFUR, AS S	1.66				0.29
SULFATE SULFUR, AS S	0.06				0.61
MOISTURE	1.99				3.17
ASH	22.13				21.19
CARBON CONTENT, AS C	61.74				57.57
HYDROGEN CONTENT, AS H	4.28				3.42
NITROGEN CONTENT, AS N	1.16				1.13
OXYGEN CONTENT, AS O	7.40				14.33
HEAT CONTENT, BTU/LB	11206				9742
<u>FILTRATE ANALYSES (W/W%)</u>					
CARBON CONTENT, AS C*	0.159	0.480	0.531	0.276	0.256
SULFATE CONTENT, AS SO4	0.135	0.457	0.738	0.473	0.365
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.003	0	0	0	0
AMMONIA CONTENT, AS NH3					
pH	5.8	3.5	2.5	2.6	2.1
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.210	0.334	0.372	0.221
CO2 CONTENT		5.19	6.43	6.49	4.08
N2 CONTENT		90.61	88.40	87.90	90.50
O2 CONTENT		4.56	4.86	5.23	4.08
SOx CONTENT, AS SO2					TR
Cl-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					97.3
ORGANIC SULFUR REMOVED, %					8.23
PYRITIC SULFUR REMOVED, %					82.5
CARBON REMOVED, %					6.75
HYDROGEN REMOVED, %					20.1
OXYGEN ADDED, %					93.6
ASH ADDED, %					(4.25)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 21
DATE 10-29-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 18.5
ADDITIVE: None
REACTOR PRESSURE, PSIG: 1009
REACTOR TEMPERATURE, C: R-3 169

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 62
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900
R-4 168 R-5 170

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.3				8.9
GAS, STD LITERS/HR		505	512	584	2035
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.5	19.3	18.7	21.4	17.9
<u>COAL ANALYSES (W/W% MF COAL)</u>					
TOTAL SULFUR, AS S	3.22	3.85	3.04	2.43	2.20
ORGANIC SULFUR, AS S	1.43	1.61	1.41	1.50	1.44
PYRITIC SULFUR, AS S	1.78	1.81	1.14	0.59	0.29
SULFATE SULFUR, AS S	0.02	0.44	0.49	0.35	0.47
MOISTURE	1.78	2.47	2.36	2.20	2.62
ASH	21.99	23.28	22.26	20.70	20.51
CARBON CONTENT, AS C	62.23	58.63	58.37	58.77	59.16
HYDROGEN CONTENT, AS H	4.37	4.04	3.82	3.75	3.98
NITROGEN CONTENT, AS N	1.32	1.28	1.25	1.23	1.24
OXYGEN CONTENT, AS O	6.86	8.91	11.26	13.11	12.92
HEAT CONTENT, BTU/LB	11321	10377	10166	10055	10205
<u>FILTRATE ANALYSES (W/W%)</u>					
CARBON CONTENT, AS C*	0.254	0.169	0.261	0.360	0.212
SULFATE CONTENT, AS SO4	0.139	0.396	0.584	0.826	0.484
CARBONATE CONTENT, AS CO3	0	--	--	--	--
BICARBONATE CONTENT, AS HCO3	.015	--	--	--	--
AMMONIA CONTENT, AS NH3					
pH	7.4	3.4	2.3	2.3	2.1
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0	0.24	0.76	0.23
CO2 CONTENT		3.06	4.26	3.13	4.45
N2 CONTENT		83.54	84.63	83.24	84.69
O2 CONTENT		13.46	10.87	12.87	10.63
SOx CONTENT, AS SO2					TR
U1-U3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %		--	--	--	93.5
ORGANIC SULFUR REMOVED, %		(12.6)	12.4	(6.38)	(0.70)
PYRITIC SULFUR REMOVED, %		(1.68)	37.0	48.2	83.7
CARBON REMOVED, %		5.78	0.44	(0.69)	4.93
HYDROGEN REMOVED, %		7.55	5.45	1.83	8.92
OXYGEN ADDED, %		29.9	26.4	14.1	88.3
ASH ADDED, %		5.87	(4.38)	(7.01)	(6.73)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 21A
DATE 10-30-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS:
ADDITIVE: None
REACTOR PRESSURE, PSIG: 990
REACTOR TEMPERATURE, C: R-3 171

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 60
ADDITIVE CONC., MOLAR:
AGITATOR SPEED; RPM: 1200
R-4 165 R-5 169

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.5				9.0
GAS, STD LITERS/HR		581	538	581	2023
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.35	19.15	18.61	18.88	19.31
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.15	4.15	3.08	2.68	2.31
ORGANIC SULFUR, AS S	1.28	1.18	1.30	1.33	1.59
PYRITIC SULFUR, AS S	1.85	2.24	1.27	0.88	0.35
SULFATE SULFUR, AS S	0.01	0.72	0.52	0.47	0.37
MOISTURE	1.30	2.67	2.64	2.54	2.96
ASH	21.77	23.84	22.31	21.07	20.61
CARBON CONTENT, AS C	62.39	58.39	58.65	58.17	59.24
HYDROGEN CONTENT, AS H	4.50	4.10	3.89	3.73	3.74
NITROGEN CONTENT, AS N	1.31	1.27	1.22	1.20	1.25
OXYGEN CONTENT, AS O	6.88	8.25	10.85	13.14	12.85
HEAT CONTENT, BTU/LB	11162	10322	10202	10077	10112
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.279	0.182	0.332	0.317	0.184
SULFATE CONTENT, AS SO4	0.149	0.235	0.677	0.669	0.506
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.002	0	0	0	0
AMMONIA CONTENT, AS NH3					
pH	5.1	3.8	3.1	3.0	2.9
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		0.25	0.25	0.28	0.27
CO2 CONTENT		5.79	5.54	6.16	5.37
N2 CONTENT		86.5	87.4	85.6	86.2
O2 CONTENT		7.49	6.83	7.94	8.15
SOx CONTENT, AS SO2					
Cl-C3 CONTENT					
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %		--	--	--	100.9
ORGANIC SULFUR REMOVED, %		7.81	(10.2)	(2.31)	(24.2)
PYRITIC SULFUR REMOVED, %		(21.1)	43.3	30.1	81.1
CARBON REMOVED, %		6.41	(0.45)	0.82	5.05
HYDROGEN REMOVED, %		8.89	5.12	4.11	16.9
OXYGEN ADDED, %		19.9	31.5	21.1	86.8
ASH ADDED, %		9.51	(6.42)	(5.56)	(5.33)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 22
DATE 10-23-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 18.8
ADDITIVE: None
REACTOR PRESSURE, PSIG: 987
REACTOR TEMPERATURE, C: R-3 178

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 82
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900
R-4 179 R-5 182

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	6.2				6.5
GAS, STD LITERS/HR		393	396	392	1482

SLURRY ANALYSES

SOLIDS CONTENT, WT%	18.8	18.9	20.0		21.0
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COAL ANALYSES (W/W% MF COAL)

TOTAL SULFUR, AS S	3.02				2.26
ORGANIC SULFUR, AS S	1.17				1.62
PYRITIC SULFUR, AS S	1.84				0.63
SULFATE SULFUR, AS S	0.02				0.02
MOISTURE	1.55				3.99
ASH	21.98				20.84
CARBON CONTENT, AS C	62.26				58.51
HYDROGEN CONTENT, AS H	4.43				3.43
NITROGEN CONTENT, AS N	1.37				1.29
OXYGEN CONTENT, AS O	6.93				13.67
HEAT CONTENT, BTU/LB	11267				9946

FILTRATE ANALYSES (W/W%)

CARBON CONTENT, AS C*	0.142	0.176	0.237	0.221	0.354
SULFATE CONTENT, AS SO4	0.142	0.309	0.767	0.655	0.516
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.003	0	0	0	0
AMMONIA CONTENT, AS NH3					
pH	5.0	3.4	2.3	2.2	2.0

GAS ANALYSES (MOLE%)

CO CONTENT		0.39	0.29	0.32	0.40
CO2 CONTENT		7.46	7.00	7.32	7.28
N2 CONTENT		89.49	89.86	88.50	88.62
O2 CONTENT		3.66	2.85	3.90	3.69
SOx CONTENT, AS SO2					0
CI-C3 CONTENT		0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, %		103.4
ORGANIC SULFUR REMOVED, %		(38.5)
PYRITIC SULFUR REMOVED, %		65.8
CARBON REMOVED, %		6.02
HYDROGEN REMOVED, %		22.6
OXYGEN ADDED, %		97.3
ASH ADDED, %		(5.19)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 23
DATE 10-28-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS: 18.6
ADDITIVE: None
REACTOR PRESSURE, PSIG: 992
REACTOR TEMPERATURE, C: R-3 170

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 81
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900
R-4 169 R-5 171

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	6.3				6.8
GAS, STD LITERS/HR		389	392	388	1535
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.6	19.4	18.8	22.6	19.7
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	3.18				2.24
ORGANIC SULFUR, AS S	1.28				1.43
PYRITIC SULFUR, AS S	1.86				0.38
SULFATE SULFUR, AS S	0.03				0.42
MOISTURE	2.46				3.85
ASH	21.91				20.75
CARBON CONTENT, AS C	62.33				59.32
HYDROGEN CONTENT, AS H	4.38				3.74
NITROGEN CONTENT, AS N	1.34				1.32
OXYGEN CONTENT, AS O	6.86				12.63
HEAT CONTENT, BTU/LB	11265				10108
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.470	0.177	0.257	0.283	0.371
SULFATE CONTENT, AS SO4	0.135	0.404	0.605	0.697	0.776
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.004	0	0	0	0
AMMONIA CONTENT, AS NH3					
pH	6.9	2.8	2.2	2.3	2.1
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.31	0.31	0.33	0.31
CO2 CONTENT		6.34	6.42	6.29	6.39
N2 CONTENT		88.00	88.00	87.80	88.00
O2 CONTENT		5.37	5.31	5.61	5.34
SOx CONTENT, AS SO2					
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					102.5
ORGANIC SULFUR REMOVED, %					(11.7)
PYRITIC SULFUR REMOVED, %					79.6
CARBON REMOVED, %					4.83
HYDROGEN REMOVED, %					14.6
OXYGEN ADDED, %					84.1
ASH ADDED, %					(5.29)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 24
DATE 10-24-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 18.7
ADDITIVE: None
REACTOR PRESSURE, PSIG: 978
REACTOR TEMPERATURE, C: R-3 158

FEED GAS: Air
SLURRY RETENTION TIME, MIN: 103
ADDITIVE CONC., MOLAR:
AGITATOR SPEED, RPM: 1900
R-4 165 R-5 164

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	5.0				4.9
GAS, STD LITERS/HR		296	300	287	1018

SLURRY ANALYSES

SOLIDS CONTENT, WT%	18.7	21.2	20.9	18.1	20.2
---------------------	------	------	------	------	------

COAL ANALYSES (W/W% MF COAL)

TOTAL SULFUR, AS S	3.21				2.45
ORGANIC SULFUR, AS S	1.40				1.69
PYRITIC SULFUR, AS S	1.75				0.45
SULFATE SULFUR, AS S	0.06				0.32
MOISTURE	1.42				2.23
ASH	22.00				21.11
CARBON CONTENT, AS C	60.85				58.82
HYDROGEN CONTENT, AS H	4.40				3.80
NITROGEN CONTENT, AS N	1.35				1.26
OXYGEN CONTENT, AS O	8.19				12.56
HEAT CONTENT, BTU/LB	11204				10099

FILTRATE ANALYSES (W/W%)

CARBON CONTENT, AS C*	0.227	0.334	0.265	0.403	0.221
SULFATE CONTENT, AS SO ₄	0.179	0.494	0.605	0.870	0.332
CARBONATE CONTENT, AS CO ₃	0	0	0	0	0
BICARBONATE CONTENT, AS HCO ₃	0.003	0	0	0	0
AMMONIA CONTENT, AS NH ₃					
pH	6.5	5.7	3.5	2.4	2.2

GAS ANALYSES (MOLE%)

CO CONTENT	0.49	0.24	0	0.32
CO ₂ CONTENT	27.01	6.10	3.00	8.52
N ₂ CONTENT	62.04	89.13	91.90	91.16
O ₂ CONTENT				
SO _x CONTENT, AS SO ₂				0
C1-C3 CONTENT	0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, %	95.4
ORGANIC SULFUR REMOVED, %	(20.7)
PYRITIC SULFUR REMOVED, %	74.3
CARBON REMOVED, %	3.34
HYDROGEN REMOVED, %	13.6
OXYGEN ADDED, %	53.4
ASH ADDED, %	(4.05)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 25
DATE 10-31-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 18.2
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 260
REACTOR TEMPERATURE, C: R-3 144

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 54
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED; RPM: 1200
R-4 153 R-5 147

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

FEED	R-3	R-4	R-5	SYSTEM OUTPUT
9.5				8.0
	98	90	55	188

SLURRY ANALYSES

SOLIDS CONTENT, WT%

18.2	18.9	20.8	16.8	13.0
------	------	------	------	------

COAL ANALYSES (W/W% MF COAL)

TOTAL SULFUR, AS S

3.13				1.77
------	--	--	--	------

ORGANIC SULFUR, AS S

1.28				1.20
------	--	--	--	------

PYRITIC SULFUR, AS S

1.83				0.55
------	--	--	--	------

SULFATE SULFUR, AS S

0.02				0.02
------	--	--	--	------

MOISTURE

2.00				6.21
------	--	--	--	------

ASH

22.66				22.35
-------	--	--	--	-------

CARBON CONTENT, AS C

61.83				59.47
-------	--	--	--	-------

HYDROGEN CONTENT, AS H

4.34				3.83
------	--	--	--	------

NITROGEN CONTENT, AS N

1.37				1.41
------	--	--	--	------

OXYGEN CONTENT, AS O

6.67				11.18
------	--	--	--	-------

HEAT CONTENT, BTU/LB

11150				10320
-------	--	--	--	-------

FILTRATE ANALYSES (W/W%)

CARBON CONTENT, AS C*

0.367	0.400	0.605	0.763	0.830
-------	-------	-------	-------	-------

SULFATE CONTENT, AS SO₄

0.397	0.640	1.18	0.904	1.34
-------	-------	------	-------	------

CARBONATE CONTENT, AS CO₃

1.51	0	0.013	0.023	0.015
------	---	-------	-------	-------

BICARBONATE CONTENT, AS HCO₃

0.194	1.42	1.48	1.38	1.33
-------	------	------	------	------

AMMONIA CONTENT, AS NH₃

--	--	--	--	--

pH

10.2	8.0	8.1	8.3	8.0
------	-----	-----	-----	-----

GAS ANALYSES (MOLE%)

CO CONTENT

	0.32	0.31	0.33	0.33
--	------	------	------	------

CO₂ CONTENT

	8.20	8.64	8.25	8.28
--	------	------	------	------

N₂ CONTENT

	2.73	2.64	2.89	2.64
--	------	------	------	------

O₂ CONTENT

	88.70	88.40	88.53	88.70
--	-------	-------	-------	-------

SO_x CONTENT, AS SO₂

				0
--	--	--	--	---

C1-C3 CONTENT

	0	0	0	0
--	---	---	---	---

PROCESS PERFORMANCE

BTU RECOVERY, %

				55.7
--	--	--	--	------

ORGANIC SULFUR REMOVED, %

				6.25
--	--	--	--	------

PYRITIC SULFUR REMOVED, %

				69.9
--	--	--	--	------

CARBON REMOVED, %

				3.82
--	--	--	--	------

HYDROGEN REMOVED, %

				11.8
--	--	--	--	------

OXYGEN ADDED, %

				67.6
--	--	--	--	------

ASH ADDED, %

				(1.37)
--	--	--	--	--------

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 26A
DATE 11-6-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS: 17.7
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 250
REACTOR TEMPERATURE, C: R-3 154

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 69
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED; RPM: 1200
R-4 156 R-5 151

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	7.51				7.71
GAS, STD LITERS/HR		159	144	00	119
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	17.74	18.63		20.99	16.78
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	2.82				1.76
ORGANIC SULFUR, AS S	1.22				1.09
PYRITIC SULFUR, AS S	1.59				0.66
SULFATE SULFUR, AS S	0.01				0.02
MOISTURE	2.23				5.28
ASH	22.72				23.80
CARBON CONTENT, AS C	61.96				59.06
HYDROGEN CONTENT, AS H	4.33				3.79
NITROGEN CONTENT, AS N	1.37				1.38
OXYGEN CONTENT, AS O	6.79				10.21
HEAT CONTENT, BTU/LB	11144				10264
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.345	0.324	--	0.538	.731
SULFATE CONTENT, AS SO ₄	0.226	0.734	--	--	.913
CARBONATE CONTENT, AS CO ₃	1.49	0.199	--	0.096	0.077
BICARBONATE CONTENT, AS HCO ₃	0.428	2.22	--	1.27	.864
AMMONIA CONTENT, AS NH ₃					
pH	2.60	8.53	--	8.70	8.62
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.137	0.51	0.59	0.571
CO ₂ CONTENT		3.18	15.10	20.9	10.0
N ₂ CONTENT		4.14	4.20	3.61	3.94
O ₂ CONTENT		92.6	80.2	74.9	79.5
SO _x CONTENT, AS SO ₂					0
C1-C3 CONTENT					
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					89.4
ORGANIC SULFUR REMOVED, %					10.7
PYRITIC SULFUR REMOVED, %					58.5
CARBON REMOVED, %					4.68
HYDROGEN REMOVED, %					12.5
OXYGEN ADDED, %					30.4
ASH ADDED, %					4.75

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 27
DATE 11-4-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 18.1
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 250
REACTOR TEMPERATURE, C: R-3 150

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 119
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED; RPM: 1200
R-4 150 R-5 154

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	4.4				6.9
GAS, STD LITERS/HR		72	81	51	67
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	18.1	18.3	18.7	18.9	14.4
<u>COAL ANALYSES (W/W% MF COAL)</u>					
TOTAL SULFUR, AS S	3.00				1.75
ORGANIC SULFUR, AS S	1.23				1.15
PYRITIC SULFUR, AS S	1.75				0.58
SULFATE SULFUR, AS S	0.02				0.02
MOISTURE	2.31				4.06
ASH	22.36				21.29
CARBON CONTENT, AS C	61.71				60.46
HYDROGEN CONTENT, AS H	4.23				3.79
NITROGEN CONTENT, AS N	1.37				1.39
OXYGEN CONTENT, AS O	7.33				11.33
HEAT CONTENT, BTU/LB	11146				10427
<u>FILTRATE ANALYSES (W/W%)</u>					
CARBON CONTENT, AS C*	0.467	0.538	0.631	0.772	0.859
SULFATE CONTENT, AS SO ₄	0.144	1.02	0.646	0.655	0.773
CARBONATE CONTENT, AS CO ₃	1.61	0.087	0.087	0.045	0.030
BICARBONATE CONTENT, AS HCO ₃	0.571	2.55	1.71	1.21	1.29
AMMONIA CONTENT, AS NH ₃					
pH	10.3	8.4	8.5	8.6	8.3
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.68	0.70	0.78	0.82
CO ₂ CONTENT		22.20	23.30	23.10	24.12
N ₂ CONTENT		3.47	3.40	3.49	3.51
O ₂ CONTENT		73.70	72.70	72.60	71.55
SO _x CONTENT, AS SO ₂					0
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					116.7
ORGANIC SULFUR REMOVED, %					6.50
PYRITIC SULFUR REMOVED, %					66.9
CARBON REMOVED, %					2.02
HYDROGEN REMOVED, %					10.4
OXYGEN ADDED, %					54.6
ASH ADDED, %					(4.79)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 30
DATE 11-10-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS: 18
ADDITIVE: NaCO₃
REACTOR PRESSURE, PSIG: 260
REACTOR TEMPERATURE, C: R-3 152 R-4 152 R-5 153

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 62
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED; RPM: 1200

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.5				8.3
GAS, STD LITERS/HR		107	98	70	117
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WTZ	--	17.94	--	16.95	13.4
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S					1.64
ORGANIC SULFUR, AS S					1.37
PYRITIC SULFUR, AS S					.26
SULFATE SULFUR, AS S					.01
MOISTURE					2.14
ASH					27.24
CARBON CONTENT, AS C					55.94
HYDROGEN CONTENT, AS H					3.64
NITROGEN CONTENT, AS N					1.30
OXYGEN CONTENT, AS O					10.24
HEAT CONTENT, BTU/LB					9634
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	--	0.501	--	.734	.872
SULFATE CONTENT, AS SO ₄	--	0.740	--	.770	.993
CARBONATE CONTENT, AS CO ₃	--	0.102	--	0	.057
BICARBONATE CONTENT, AS HCO ₃	--	1.86	--	0.922	1.31
AMMONIA CONTENT, AS NH ₃					
pH	--	8.6	--	7.9	9.0
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		.95	0.87	.69	.90
CO ₂ CONTENT		21.0	20.3	16.8	20.6
N ₂ CONTENT		3.10	3.05	3.03	3.15
O ₂ CONTENT		75.0	75.8	79.5	75.4
SO _x CONTENT, AS SO ₂					
C1-C3 CONTENT					

PROCESS PERFORMANCE

BTU RECOVERY, %
ORGANIC SULFUR REMOVED, %
PYRITIC SULFUR REMOVED, %
CARBON REMOVED, %
HYDROGEN REMOVED, %
OXYGEN ADDED, %
ASH ADDED, %

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 31B
DATE 11-20-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 29.2
ADDITIVE: NH₃
REACTOR PRESSURE, PSIG: 295
REACTOR TEMPERATURE, C: R-3 133

FEED GAS,: Oxygen
SLURRY RETENTION TIME, MIN: 118
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1200
R-4 134 R-5 136

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	4.4				5.6
GAS, STD LITERS/HR		161	166	177	212
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	29.17	27.30	25.71	29.00	31.08
<u>COAL ANALYSES (W/W% MF COAL)</u>					
TOTAL SULFUR, AS S	3.32				1.83
ORGANIC SULFUR, AS S	1.81				1.16
PYRITIC SULFUR, AS S	1.47				0.64
SULFATE SULFUR, AS S	0.04				0.03
MOISTURE	2.32				5.10
ASH	22.97				21.11
CARBON CONTENT, AS C	61.36				58.49
HYDROGEN CONTENT, AS H	4.40				3.91
NITROGEN CONTENT, AS N	1.32				3.54
OXYGEN CONTENT, AS O	6.63				11.13
HEAT CONTENT, BTU/LB	11094				10183
<u>FILTRATE ANALYSES (W/W%)</u>					
CARBON CONTENT, AS C*	0.248	0.200	0.462	0.353	0.717
SULFATE CONTENT, AS SO ₄	0.334	1.22	1.61	0.724	0.893
CARBONATE CONTENT, AS CO ₃	--	--	--	--	--
BICARBONATE CONTENT, AS HCO ₃	--	--	--	--	--
AMMONIA CONTENT, AS NH ₃	3.59	2.83	3.99	1.08	.853
pH					
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		2.07	2.86	2.14	0.703
CO ₂ CONTENT		11.26	13.5	11.2	7.80
N ₂ CONTENT		2.56	2.91	2.61	1.90
O ₂ CONTENT		84.11	80.7	84.0	89.6
SO _x CONTENT, AS SO ₂					0
C1-C3 CONTENT		0	0	0	0
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					124.5
ORGANIC SULFUR REMOVED, %					35.9
PYRITIC SULFUR REMOVED, %					56.5
CARBON REMOVED, %					4.68
HYDROGEN REMOVED, %					11.1
OXYGEN ADDED, %					67.9
ASH ADDED, %					(8.10)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 32
DATE 11-18-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS: 29.3
ADDITIVE: NH₃
REACTOR PRESSURE, PSIG: 300
REACTOR TEMPERATURE, C: R-3 159

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN:
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED; RPM: 1900
R-4 162 R-5 170

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

FEED	R-3	R-4	R-5	SYSTEM OUTPUT
7.6				9.4
	330	324	280	653

SLURRY ANALYSES

SOLIDS CONTENT, WT%

29.31	26.96	27.26	26.21	29.35
-------	-------	-------	-------	-------

COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S

3.35				1.58
------	--	--	--	------

ORGANIC SULFUR, AS S

1.32				1.29
------	--	--	--	------

PYRITIC SULFUR, AS S

1.98				0.26
------	--	--	--	------

SULFATE SULFUR, AS S

0.06				0.02
------	--	--	--	------

MOISTURE

2.46				6.21
------	--	--	--	------

ASH

22.90				19.94
-------	--	--	--	-------

CARBON CONTENT, AS C

61.65				56.74
-------	--	--	--	-------

HYDROGEN CONTENT, AS H

4.44				3.62
------	--	--	--	------

NITROGEN CONTENT, AS N

1.21				4.04
------	--	--	--	------

OXYGEN CONTENT, AS O

6.44				14.08
------	--	--	--	-------

HEAT CONTENT, BTU/LB

11081				9578
-------	--	--	--	------

FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*

0.206	0.339	0.436	0.616	0.497
-------	-------	-------	-------	-------

SULFATE CONTENT, AS SO₄

0.388	0.995	1.16	1.38	0.931
-------	-------	------	------	-------

CARBONATE CONTENT, AS CO₃

0	0	0	0	0
---	---	---	---	---

BICARBONATE CONTENT, AS HCO₃

0	0	0	0	0
---	---	---	---	---

AMMONIA CONTENT, AS NH₃

0.822	3.03	1.47	3.77	3.56
-------	------	------	------	------

pH

GAS ANALYSES (MOLEZ)

CO CONTENT

	2.05	1.84	1.46	2.01
--	------	------	------	------

CO₂ CONTENT

	24.13	27.2	16.97	27.76
--	-------	------	-------	-------

N₂ CONTENT

	1.57	.352	2.82	0
--	------	------	------	---

O₂ CONTENT

	77.75	70.63	78.7	70.2
--	-------	-------	------	------

SO_x CONTENT, AS SO₂

				0
--	--	--	--	---

Cl-C3 CONTENT

	0	0	0	0
--	---	---	---	---

PROCESS PERFORMANCE

BTU RECOVERY, %

				107.8
--	--	--	--	-------

ORGANIC SULFUR REMOVED, %

				2.27
--	--	--	--	------

PYRITIC SULFUR REMOVED, %

				86.9
--	--	--	--	------

CARBON REMOVED, %

				8.00
--	--	--	--	------

HYDROGEN REMOVED, %

				18.5
--	--	--	--	------

OXYGEN ADDED, %

				118.6
--	--	--	--	-------

ASH ADDED, %

				(12.9)
--	--	--	--	--------

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 33
DATE 11-24-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 30.2
ADDITIVE: NH3
REACTOR PRESSURE, PSIG: 295
REACTOR TEMPERATURE, C: R-3 191

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 61
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1900
R-4 190 R-5 199

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	8.5				13.6
GAS, STD LITERS/HR		337	331	286	482

SLURRY ANALYSES

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
SOLIDS CONTENT, WT%	30.24	26.65	27.99	24.75	20.65
COAL ANALYSES (W/W% MF COAL)					
TOTAL SULFUR, AS S	3.28				1.93
ORGANIC SULFUR, AS S	1.33				1.16
PYRITIC SULFUR, AS S	1.93				0.74
SULFATE SULFUR, AS S	0.02				0.03
MOISTURE	1.52				3.64
ASH	22.87				22.88
CARBON CONTENT, AS C	60.98				55.51
HYDROGEN CONTENT, AS H	4.45				3.62
NITROGEN CONTENT, AS N	1.23				4.45
OXYGEN CONTENT, AS O	7.20				11.61
HEAT CONTENT, BTU/LB	10972				9185

FILTRATE ANALYSES (W/W%)

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
CARBON CONTENT, AS C*	0.220	0.346	0.565	0.365	0.592
SULFATE CONTENT, AS SO4	0.291	0.693	0.868	0.688	0.301
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0	0	0	0	0
AMMONIA CONTENT, AS NH3	2.36	0.476	1.10	0.359	0.888

GAS ANALYSES (MOLE%)

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
CO CONTENT			2.27	1.67	2.62
CO2 CONTENT			73.9	69.94	41.3
N2 CONTENT			.612	.491	1.45
O2 CONTENT			23.2	27.9	54.6
SOx CONTENT, AS SO2					0
C1-C3 CONTENT		0	0	0	0

PROCESS PERFORMANCE

	SYSTEM OUTPUT
BTU RECOVERY, %	91.5
ORGANIC SULFUR REMOVED, %	12.8
PYRITIC SULFUR REMOVED, %	61.7
CARBON REMOVED, %	8.97
HYDROGEN REMOVED, %	18.7
OXYGEN ADDED, %	61.3
ASH ADDED, %	0.04

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 34
DATE 11-14-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS: 23.6
ADDITIVE: NH3
REACTOR PRESSURE, PSIG: 293
REACTOR TEMPERATURE, C: R-3 128

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 108
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1200
R-4 127 R-5 130

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

FEED	R-3	R-4	R-5	SYSTEM OUTPUT
4.7				6.3
	76	75	86	114

SLURRY ANALYSES

SOLIDS CONTENT, WTZ

23.57	16.31	20.90	22.61	23.95
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COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S

3.17				1.89
------	--	--	--	------

ORGANIC SULFUR, AS S

1.06				.90
------	--	--	--	-----

PYRITIC SULFUR, AS S

2.09				.94
------	--	--	--	-----

SULFATE SULFUR, AS S

0.01				.04
------	--	--	--	-----

MOISTURE

2.03				2.79
------	--	--	--	------

ASH

22.30				22.25
-------	--	--	--	-------

CARBON CONTENT, AS C

62.17				57.99
-------	--	--	--	-------

HYDROGEN CONTENT, AS H

4.42				3.95
------	--	--	--	------

NITROGEN CONTENT, AS N

1.50				4.10
------	--	--	--	------

OXYGEN CONTENT, AS O

6.45				9.83
------	--	--	--	------

HEAT CONTENT, BTU/LB

11172				10060
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FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*

0.284	0.156	0.301	0.295	0.819
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SULFATE CONTENT, AS SO4

0.224	0.688	1.15	0.496	3.27
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CARBONATE CONTENT, AS CO3

--	--	--	--	--
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BICARBONATE CONTENT, AS HCO3

--	--	--	--	--
----	----	----	----	----

AMMONIA CONTENT, AS NH3

2.59	2.10	1.20	2.74	3.38
------	------	------	------	------

pH

GAS ANALYSES (MOLEZ)

CO CONTENT

	1.11	1.19	1.15
--	------	------	------

CO2 CONTENT

	0.28	0.37	2.89
--	------	------	------

N2 CONTENT

	3.10	3.40	4.21
--	------	------	------

O2 CONTENT

	95.52	95.06	91.7
--	-------	-------	------

SOx CONTENT, AS SO2

--	--	--	--

C1-C3 CONTENT

0	0	0	0
---	---	---	---

PROCESS PERFORMANCE

BTU RECOVERY, %

	122.6
--	-------

ORGANIC SULFUR REMOVED, %

	15.1
--	------

PYRITIC SULFUR REMOVED, %

	55.0
--	------

CARBON REMOVED, %

	6.72
--	------

HYDROGEN REMOVED, %

	10.6
--	------

OXYGEN ADDED, %

	52.4
--	------

ASH ADDED, %

	(0.22)
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*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 35
DATE 11-13-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/WZ SOLIDS: 24.6
ADDITIVE: NH₃
REACTOR PRESSURE, PSIG: 301
REACTOR TEMPERATURE, C: R-3 155

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 60
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1200
R-4 159 R-5 162

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

SLURRY ANALYSES

SOLIDS CONTENT, WTZ

COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S

ORGANIC SULFUR, AS S

PYRITIC SULFUR, AS S

SULFATE SULFUR, AS S

MOISTURE

ASH

CARBON CONTENT, AS C

HYDROGEN CONTENT, AS H

NITROGEN CONTENT, AS N

OXYGEN CONTENT, AS O

HEAT CONTENT, BTU/LB

FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*

SULFATE CONTENT, AS SO₄CARBONATE CONTENT, AS CO₃BICARBONATE CONTENT, AS HCO₃AMMONIA CONTENT, AS NH₃

pH

GAS ANALYSES (MOLEZ)

CO CONTENT

CO₂ CONTENTN₂ CONTENTO₂ CONTENTSO_x CONTENT, AS SO₂

C1-C3 CONTENT

PROCESS PERFORMANCE

BTU RECOVERY, %

ORGANIC SULFUR REMOVED, %

PYRITIC SULFUR REMOVED, %

CARBON REMOVED, %

HYDROGEN REMOVED, %

OXYGEN ADDED, %

ASH ADDED, %

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 36
DATE 11-17-80

TEST CONDITIONS

COAL: Kentucky No. 9
SLURRY CONC, W/W% SOLIDS: 23.4
ADDITIVE: NH₃
REACTOR PRESSURE, PSIG: 300
REACTOR TEMPERATURE, C: R-3 185 R-4 193 R-5 195

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 30
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1200

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	16.9				17.0
GAS, STD LITERS/HR		318	291	251	371

SLURRY ANALYSES

SOLIDS CONTENT, WT%	23.76	22.32	21.84	22.31	23.33
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COAL ANALYSES (W/W% MF COAL)

TOTAL SULFUR, AS S	3.24				1.93
ORGANIC SULFUR, AS S	1.01				0.83
PYRITIC SULFUR, AS S	2.19				1.06
SULFATE SULFUR, AS S	0.04				0.03
MOISTURE	1.10				2.28
ASH	22.81				22.70
CARBON CONTENT, AS C	61.10				56.61
HYDROGEN CONTENT, AS H	4.38				3.60
NITROGEN CONTENT, AS N	1.48				5.01
OXYGEN CONTENT, AS O	6.99				10.15
HEAT CONTENT, BTU/LB	10994				9517

FILTRATE ANALYSES (W/W%)

CARBON CONTENT, AS C*	0.191	0.415	0.391	0.421	0.656
SULFATE CONTENT, AS SO ₄	0.277	0.578	0.656	0.470	0.978
CARBONATE CONTENT, AS CO ₃	--	--	--	--	--
BICARBONATE CONTENT, AS HCO ₃	--	--	--	--	--
AMMONIA CONTENT, AS NH ₃	3.33	2.11	2.05	1.74	2.36

pH

GAS ANALYSES (MOLE%)

CO CONTENT	0.88	2.39	1.24	0.82
CO ₂ CONTENT	14.08	43.73	34.16	21.03
N ₂ CONTENT	3.75	6.02	3.64	3.25
O ₂ CONTENT	81.29	47.85	60.86	74.9
SO _x CONTENT, AS SO ₂				TR
C1-C3 CONTENT	0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, %	86.6
ORGANIC SULFUR REMOVED, %	17.8
PYRITIC SULFUR REMOVED, %	51.6
CARBON REMOVED, %	7.35
HYDROGEN REMOVED, %	17.8
OXYGEN ADDED, %	45.2
ASH ADDED, %	(0.48)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 37
DATE 11-25-80

TEST CONDITIONS

COAL: Lucas No. 5
SLURRY CONC, W/WZ SOLIDS: 13.4
ADDITIVE: None
REACTOR PRESSURE, PSIG: 994
REACTOR TEMPERATURE, C: R-3 183
FEED GAS: Compressed Air
SLURRY RETENTION TIME, MIN: 34
ADDITIVE CONC., MOLAR: None
AGITATOR SPEED, RPM: 1200
R-4 185 R-5 190

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

FEED	R-3	R-4	R-5	SYSTEM OUTPUT
14.9				18.1
	658	659	682	2450

SLURRY ANALYSES

SOLIDS CONTENT, WT%

13.35	13.61	14.32	10.65	12.75
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COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S

1.94				1.43
------	--	--	--	------

ORGANIC SULFUR, AS S

0.73				1.06
------	--	--	--	------

PYRITIC SULFUR, AS S

1.20				0.35
------	--	--	--	------

SULFATE SULFUR, AS S

0.01				0.01
------	--	--	--	------

MOISTURE

2.28				2.97
------	--	--	--	------

ASH

8.70				6.72
------	--	--	--	------

CARBON CONTENT, AS C

72.93				71.05
-------	--	--	--	-------

HYDROGEN CONTENT, AS H

5.34				4.96
------	--	--	--	------

NITROGEN CONTENT, AS N

1.25				1.59
------	--	--	--	------

OXYGEN CONTENT, AS O

9.84				14.25
------	--	--	--	-------

HEAT CONTENT, BTU/LB

13142				12281
-------	--	--	--	-------

FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*

0.314	0.344	0.242	0.332	0.481
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SULFATE CONTENT, AS SO4

0.078	0.128	0.277	0.129	0.725
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CARBONATE CONTENT, AS CO3

0	0	0	0	0
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BICARBONATE CONTENT, AS HCO3

.024	.070	0.63	0	0
------	------	------	---	---

AMMONIA CONTENT, AS NH3

--	--	--	--	--

pH

8.0	7.2	6.7	4.0	3.7
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GAS ANALYSES (MOLE%)

CO CONTENT

	0	0	0	0
--	---	---	---	---

CO2 CONTENT

	1.50	1.44	0	1.48
--	------	------	---	------

N2 CONTENT

	82.3	82.4	81.9	82.3
--	------	------	------	------

O2 CONTENT

	16.2	16.1	18.1	16.1
--	------	------	------	------

SOx CONTENT, AS SO2

				0.0
--	--	--	--	-----

Cl-C3 CONTENT

PROCESS PERFORMANCE

BTU RECOVERY, %

				108.4
--	--	--	--	-------

ORGANIC SULFUR REMOVED, %

				(45.2)
--	--	--	--	--------

PYRITIC SULFUR REMOVED, %

				70.8
--	--	--	--	------

CARBON REMOVED, %

				2.58
--	--	--	--	------

HYDROGEN REMOVED, %

				7.11
--	--	--	--	------

OXYGEN ADDED, %

				44.8
--	--	--	--	------

ASH ADDED, %

				(22.8)
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*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 38
DATE 11-26-80

TEST CONDITIONS

COAL: Lucas No. 5
SLURRY CONC, W/WZ SOLIDS: 13.3
ADDITIVE: None
REACTOR PRESSURE, PSIG: 1016
REACTOR TEMPERATURE, C: R-3 183

FEED GAS: Compressed Air
SLURRY RETENTION TIME, MIN: 65
ADDITIVE CONC., MOLAR: None
AGITATOR SPEED, RPM: 1200
R-4 176 R-5 179

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	7.8				14.2
GAS, STD LITERS/HR		335	318	333	1152
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WTZ	13.25	13.58	14.16	14.09	13.35
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	2.01				1.51
ORGANIC SULFUR, AS S	1.21				1.12
PYRITIC SULFUR, AS S	0.79				0.38
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	2.23				3.50
ASH	9.03				7.19
CARBON CONTENT, AS C	72.34				70.09
HYDROGEN CONTENT, AS H	5.62				4.46
NITROGEN CONTENT, AS N	1.45				1.54
OXYGEN CONTENT, AS O	9.56				15.20
HEAT CONTENT, BTU/LB	12758				12178
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C	0.394	0.413	0.465	0.376	0.488
SULFATE CONTENT, AS SO4	0.055	0.174	0.231	0.247	0.270
CARBONATE CONTENT, AS CO3	0	0	0	0	0
BICARBONATE CONTENT, AS HCO3	0.061	0	0.021	0	0
AMMONIA CONTENT, AS NH3					
pH	6.8	4.0	4.9	3.5	3.4
<u>GAS ANALYSES (MOLEZ)</u>					
CO CONTENT		0.161	0.194	0.307	0.182
CO2 CONTENT		3.89	4.31	6.10	4.29
N2 CONTENT		86.7	87.3	90.3	87.4
O2 CONTENT		9.20	8.23	3.34	8.17
SOx CONTENT, AS SO2					0
C1-C3 CONTENT					
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					175.2
ORGANIC SULFUR REMOVED, %					7.44
PYRITIC SULFUR REMOVED, %					51.9
CARBON REMOVED, %					3.11
HYDROGEN REMOVED, %					20.6
OXYGEN ADDED, %					59.0
ASH ADDED, %					(20.4)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 43
DATE 12-1-80

TEST CONDITIONS

COAL: Lucas No. 5
SLURRY CONC, W/WZ SOLIDS: 13.0
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 250
REACTOR TEMPERATURE, C: R-3 147

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 61
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED, RPM: 1200
R-4 147 R-5 152

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.39				9.53
GAS, STD LITERS/HR		74.2	81.5	55.2	138
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	13.04	14.14	10.58	15.36	13.11
<u>COAL ANALYSES (W/WZ MF COAL)</u>					
TOTAL SULFUR, AS S	1.83				1.33
ORGANIC SULFUR, AS S	1.12				1.08
PYRITIC SULFUR, AS S	0.70				0.24
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	3.47				3.70
ASH	10.46				13.75
CARBON CONTENT, AS C	71.77				67.96
HYDROGEN CONTENT, AS H	5.17				4.68
NITROGEN CONTENT, AS N	1.40				1.49
OXYGEN CONTENT, AS O	9.37				10.80
HEAT CONTENT, BTU/LB	12929				11886
<u>FILTRATE ANALYSES (W/WZ)</u>					
CARBON CONTENT, AS C*	0.563	0.486	0.622	0.603	0.739
SULFATE CONTENT, AS SO ₄	0.063	0.229	0.387	0.683	0.649
CARBONATE CONTENT, AS CO ₃	1.42	0.136	0.101	0.115	0.120
BICARBONATE CONTENT, AS HCO ₃	0.183	1.90	1.47	1.97	1.42
AMMONIA CONTENT, AS NH ₃	0	0	0	0	0
pH	10.4	8.6	8.8	8.6	8.4
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.675	0.494	0.683	0.460
CO ₂ CONTENT		10.6	10.6	10.0	6.11
N ₂ CONTENT		76.1	75.9	76.0	74.4
O ₂ CONTENT		12.6	13.0	13.3	19.1
SO _x CONTENT, AS SO ₂					0.0
C1-C3 CONTENT					
<u>PROCESS PERFORMANCE</u>					
BTU RECOVERY, %					104.9
ORGANIC SULFUR REMOVED, %					3.57
PYRITIC SULFUR REMOVED, %					65.7
CARBON REMOVED, %					5.31
HYDROGEN REMOVED, %					9.48
OXYGEN ADDED, %					15.3
ASH ADDED, %					31.5

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 44
DATE 12-2-80

TEST CONDITIONS

COAL: Lucas No. 5
SLURRY CONC, W/W% SOLIDS: 12.9
ADDITIVE: Na₂CO₃
REACTOR PRESSURE, PSIG: 250
REACTOR TEMPERATURE, C: R-3 148

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 60
ADDITIVE CONC., MOLAR: 0.3
AGITATOR SPEED, RPM: 1200
R-4 150 R-5 153

<u>MATERIAL FLOW MEASUREMENTS</u>	<u>FEED</u>	<u>R-3</u>	<u>R-4</u>	<u>R-5</u>	<u>SYSTEM OUTPUT</u>
COAL SLURRY, KG/HR	8.6				9.4
GAS, STD LITERS/HR		128	112	48	159
<u>SLURRY ANALYSES</u>					
SOLIDS CONTENT, WT%	12.89	14.04	10.83	12.65	11.24
<u>COAL ANALYSES (W/W% MF COAL)</u>					
TOTAL SULFUR, AS S	1.88				1.22
ORGANIC SULFUR, AS S	1.33				0.94
PYRITIC SULFUR, AS S	0.55				0.27
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	3.27				3.57
ASH	10.04				13.05
CARBON CONTENT, AS C	70.96				68.54
HYDROGEN CONTENT, AS H	5.01				4.58
NITROGEN CONTENT, AS N	1.51				1.47
OXYGEN CONTENT, AS O	10.59				11.15
HEAT CONTENT, BTU/LB	12991				11948
<u>FILTRATE ANALYSES (W/W%)</u>					
CARBON CONTENT, AS C*	0.450	0.364	0.520	0.385	1.29
SULFATE CONTENT, AS SO ₄	0.085	0.258	0.434	0.333	0.787
CARBONATE CONTENT, AS CO ₃	1.36	0.247	0.094	0.088	0.106
BICARBONATE CONTENT, AS HCO ₃	0.189	1.78	1.52	0.966	1.74
AMMONIA CONTENT, AS NH ₃	0	0	0	0	0
pH	10.5	8.9	8.5	8.8	8.7
<u>GAS ANALYSES (MOLE%)</u>					
CO CONTENT		0.20	0.197	0.23	0.27
CO ₂ CONTENT		5.71	15.33	16.20	15.09
N ₂ CONTENT		76.44	68.94	67.09	68.73
O ₂ CONTENT		17.65	15.54	16.48	15.91
SO _x CONTENT, AS SO ₂					0.0
C1-C3 CONTENT					

PROCESS PERFORMANCE

BTU RECOVERY, %	88.4
ORGANIC SULFUR REMOVED, %	29.3
PYRITIC SULFUR REMOVED, %	50.0
CARBON REMOVED, %	3.41
HYDROGEN REMOVED, %	8.58
OXYGEN ADDED, %	5.29
ASH ADDED, %	30.0

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 50
DATE 12-5-80

TEST CONDITIONS

COAL: Lucas No. 5
SLURRY CONC, W/WZ SOLIDS: 27.2
ADDITIVE: NH₃
REACTOR PRESSURE, PSIG: 300
REACTOR TEMPERATURE, C: R-3 155 R-4 171 R-5 158

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 59
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED; RPM: 1200

MATERIAL FLOW MEASUREMENTS

	FEED	R-3	R-4	R-5	SYSTEM OUTPUT
COAL SLURRY, KG/HR	8.7				10.2
GAS, STD LITERS/HR		344	323	299	586

SLURRY ANALYSES

SOLIDS CONTENT, WT%	27.19	24.98	24.50	22.77	28.82
COAL ANALYSES (W/WZ MF COAL)					
TOTAL SULFUR, AS S	2.05				1.08
ORGANIC SULFUR, AS S	0.73				0.82
PYRITIC SULFUR, AS S	1.31				0.25
SULFATE SULFUR, AS S	0.01				0.01
MOISTURE	4.74				13.48
ASH	8.31				7.74
CARBON CONTENT, AS C	73.48				67.61
HYDROGEN CONTENT, AS H	5.26				4.02
NITROGEN CONTENT, AS N	1.87				5.25
OXYGEN CONTENT, AS O	9.04				14.30
HEAT CONTENT, BTU/LB	13264				11358

FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*	0.250	0.653	0.952	0.770	0.999
SULFATE CONTENT, AS SO ₄	0.125	0.515	0.850	0.476	0.969
CARBONATE CONTENT, AS CO ₃	0	0	0	0	0
BICARBONATE CONTENT, AS HCO ₃	0	0	0	0	0
AMMONIA CONTENT, AS NH ₃	5.18	2.19	3.07	4.83	3.81

pH

GAS ANALYSES (MOLEZ)

CO CONTENT	1.52	1.31	2.06	1.53
CO ₂ CONTENT	63.00	53.16	76.45	62.81
N ₂ CONTENT	17.52	25.48	6.03	16.14
O ₂ CONTENT	17.96	20.05	15.47	19.52
SO _x CONTENT, AS SO ₂				0.0
C1-C3 CONTENT	0	0	0	0

PROCESS PERFORMANCE

BTU RECOVERY, %	106.4
ORGANIC SULFUR REMOVED, %	(12.3)
PYRITIC SULFUR REMOVED, %	80.9
CARBON REMOVED, %	8.00
HYDROGEN REMOVED, %	23.6
OXYGEN ADDED, %	58.2
ASH ADDED, %	(6.86)

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO₃ AND CO₃

OXYDESULFURIZATION PROCESS TEST DATA SHEET

TEST NO. 51
DATE 12-8-80

TEST CONDITIONS

COAL: Lucas No. 5
SLURRY CONC, W/WZ SOLIDS: 26.1
ADDITIVE: NH3
REACTOR PRESSURE, PSIG: 316
REACTOR TEMPERATURE, C: R-3 184

FEED GAS: Oxygen
SLURRY RETENTION TIME, MIN: 116
ADDITIVE CONC., MOLAR: 3.0
AGITATOR SPEED, RPM: 1200
R-4 189 R-5 192

MATERIAL FLOW MEASUREMENTS

COAL SLURRY, KG/HR
GAS, STD LITERS/HR

FEED	R-3	R-4	R-5	SYSTEM OUTPUT
4.4	352	330	298	4.6

SLURRY ANALYSES

SOLIDS CONTENT, WT%

26.05	21.17	16.95	18.38	19.63
-------	-------	-------	-------	-------

COAL ANALYSES (W/WZ MF COAL)

TOTAL SULFUR, AS S

2.05				0.81
------	--	--	--	------

ORGANIC SULFUR, AS S

0.16				0.57
------	--	--	--	------

PYRITIC SULFUR, AS S

1.88				0.23
------	--	--	--	------

SULFATE SULFUR, AS S

0.01				0.01
------	--	--	--	------

MOISTURE

2.34				6.22
------	--	--	--	------

ASH

8.27				8.93
------	--	--	--	------

CARBON CONTENT, AS C

72.98				61.68
-------	--	--	--	-------

HYDROGEN CONTENT, AS H

5.39				3.30
------	--	--	--	------

NITROGEN CONTENT, AS N

1.82				5.96
------	--	--	--	------

OXYGEN CONTENT, AS O

9.49				19.32
------	--	--	--	-------

HEAT CONTENT, BTU/LB

13315				9934
-------	--	--	--	------

FILTRATE ANALYSES (W/WZ)

CARBON CONTENT, AS C*

0.170	0.406	0.664	0.620	1.21
-------	-------	-------	-------	------

SULFATE CONTENT, AS SO4

0.120	0.895	1.09	0.579	1.77
-------	-------	------	-------	------

CARBONATE CONTENT, AS CO3

0	0	0	0	0
---	---	---	---	---

BICARBONATE CONTENT, AS HCO3

0	0	0	0	0
---	---	---	---	---

AMMONIA CONTENT, AS NH3

3.53	2.47	3.92	2.29	1.78
------	------	------	------	------

pH

GAS ANALYSES (MOLE%)

CO CONTENT

0.0	3.28	2.86	1.01
-----	------	------	------

CO2 CONTENT

34.48	20.33	55.10	19.65
-------	-------	-------	-------

N2 CONTENT

3.82	32.25	20.01	50.16
------	-------	-------	-------

O2 CONTENT

61.67	44.18	22.03	29.18
-------	-------	-------	-------

SOx CONTENT, AS SO2

			0.0
--	--	--	-----

C1-C3 CONTENT

0	0	0	0
---	---	---	---

PROCESS PERFORMANCE

BTU RECOVERY, %

			58.8
--	--	--	------

ORGANIC SULFUR REMOVED, %

			(256.3)
--	--	--	---------

PYRITIC SULFUR REMOVED, %

			87.8
--	--	--	------

CARBON REMOVED, %

			15.5
--	--	--	------

HYDROGEN REMOVED, %

			38.8
--	--	--	------

OXYGEN ADDED, %

			103.6
--	--	--	-------

ASH ADDED, %

			7.98
--	--	--	------

*CARBON CONTENT VALUE INCLUDES CARBON FROM HCO3 AND CO3

APPENDIX A - EQUIPMENT CALIBRATION

A-1 SLURRY FEED PUMP CALIBRATION

To facilitate calibration of the slurry feed pump, the pump discharge is disconnected from the slurry feed line to the reactor and connected to a 18.9 ℓ tank which has a 1500 psig operating pressure rating. This tank is equipped with a pressurization and pressure control system similar to that used to pressurize and control the pressure of the reactor system. The tank is installed on a scale so that weight data could be obtained as a function of time.

The Milton Roy pump is a piston type, positive displacement pump which the literature describes as "polar-crank controlled". The pumping rate is changed by adjusting the stroke length. Flow direction is controlled by check valves at the inlet and at the outlet of the pump. The pump was delivered with standard double-check valves for slurry service installed. While it would pump water, the pump would not pump coal slurry. After two modifications of the plumbing from the R-2 pump-around loop to the pump inlet and several tests to assure that the pump inlet was not being starved, it was determined that the check valve design was not proper for this application. As a result of discussions with the pump supplier, several other designs were tested prior to determining that the double-check valve design with tantalum carbide trim appeared to work properly. Calibration curves were obtained for water, 20% slurry, and 40% slurry at 300, 600, and 1000 psig.

The calibration curves appeared to remain valid for the shakedown test runs. However, the data from the first process evaluation test

indicated that a problem still existed. The coal slurry feed rate for this test as determined by the feed pump setting and the calibration curve was 17.4 Kg per hour. The system output flow rate was measured by weight change at 20.0 Kg per hour. The magnitude of the inconsistency dictated a review of the pump calibration data. The lines connecting the pump outlet to the collection tank for calibration testing were thought to be flexible enough to not affect weighing accuracy. Further investigation indicated otherwise. The calibration test set-up was modified with flexible connection lines, and the pump calibration tests were re-run. The coal slurry feed rate for the first process evaluation test as determined by the revised calibration data is 21.1 Kg per hour. The difference between the value and the measured system output flow rate of 20.0 Kg per hour is within the data scatter of the pump calibration data. To assure the best data possible, the practice was implemented of obtaining slurry input flow rate data using the pump calibration equipment before and after each process evaluation test. This practice was employed on test number 2 and all subsequent tests. The slurry feed rates reported for those tests are the average of the pre-test and post-test feed rate calibration data.

This added calibration required an extra two to three hours for each test, which meant that run times for tests requiring 60-minute retention times in the reactors were extended to nine or ten hours per run. The times required for the 30- and 120-minute retention time runs were approximately eight and twelve hours, respectively. The number of runs possible in each two-shift day was essentially reduced from two to one. However, this revised, longer test procedure proved to be

essential since data from subsequent runs indicated that the pumping rate curve shifted from day-to-day.

The observed pumping variation was likely caused by the check valves operating intermittently. The agreement obtained between the pre-test and the post-test calibration data suggested that whatever the cause, test-to-test variations could be compensated for by adjusting the pump flow rate during the pre-test calibration. Variations within a test did not appear likely. However, to assure that this was true, an ultrasonic flow rate meter from Dynasonics, Inc. (Ultrasonic Doppler Flowmeter Series 500 Model No. UFT-501-HF-S-X) was procured and installed.

A-2 CALIBRATION OF DI WATER FLOW METER AND COAL WEIGH BELT FEEDER

To assure preparation of proper feed slurry composition, the DI water flow meter and the coal feed weigh belt were calibrated. The accuracy of the water flow meter was determined by measuring known amounts of fluid at various flow rates. The meter was found to be accurate within 0.5%.

The manufacturers of the weigh belt feeder provided the equipment and procedure for calibrating this unit. The results of the calibration essentially duplicated the results of the calibration conducted prior to shutting down the test stand in February 1978, i.e., it is accurate within 2% over the full range of flow rates. All slurry compositions were confirmed by laboratory analyses.

A-3 CALIBRATION OF LIQUID LEVEL IN SLURRY FEED TANK R2

The slurry feed tank R2 is equipped with instrumentation to measure the volume of liquid in the tank. Recalibration of the water depth meter was performed by filling the tank with water and incrementally discharging

portions of the water into a catch tank on scales. The weight of each increment of water collected was converted to volume and plotted against the meter reading.

However, the meter does not measure the changes in tank content when the slurry level is below the bottom of the cylindrical section of the tank. The lower conical section of the tank holds approximately 66 gallons. A method was employed of measuring the liquid level in the cone using a dip stick and a calibration curve for correlating the dip stick measurement to a liquid volume. The procedure used to develop the calibration curve was the same as that used for establishing the calibration curve for the cylindrical section.

A-4 CALIBRATION OF INPUT AND OUTPUT GAS FLOW METERS

The instrument selected to measure the output gas flow from the reactor system is a Wet Test Meter, Model AL21-1, manufactured by Singer American. This is the only meter found that can measure flow rates of the gas compositions expected with the accuracy and flow rate range capabilities that were needed. This meter also can be modified for use in oxygen service. The meter was modified to provide a remote readout capability so that the meter could be installed inside the protective shield, while the readout was located on an exterior instrument panel. Calibration of the Wet Test Meter (in the flow rate ranges required) was accomplished in the TRW Metrology gas calibration laboratory.

Orifice meters are used to measure the input gas flow into each reactor. For safety reasons, a separate gas feed manifold and, therefore, separate orifice meters are used to supply oxygen and air to the reactors. Since orifice meters capable of measuring the required gas flow rates at

the pressures required are not available, internally designed and fabricated meters were utilized.

The pre-calibrated Wet Test Meter was used to calibrate each orifice. The temperature of the gas at the orifice and at the Wet Test Meter was measured and recorded during the calibration. The pressure just downstream of the orifice and at the Wet Test Meter was also recorded, as well as the ΔP across the orifice.

In establishing the orifice flow rates vs ΔP , the two temperatures were used to correct to 20°C. The correction for the Wet Test Meter was $\frac{273}{T_m^{\circ}K}$, but for the orifice, the corrections took the form of $\sqrt{\frac{273}{T_o^{\circ}K}}$. These same corrections were used on all test run data to normalize the gas flows to 20°C.

Correction for downstream orifice pressure deviations (where the system ran at a pressure different from the original calibration pressure) takes the form of $\sqrt{\frac{P_o, \text{ psia}}{14.7}}$. The test data were also corrected for these variations on all test runs.

APPENDIX B

PROCESS INPUT/OUTPUT DATA SUMMARIES

III. #6 Feed Coal

Test No.	Date	Feed %	S _T	S _O	S _P	S _S	Ash	C	H	N	O	Btu
	1980											
Slurry	7-20	—										
P * 1	8-11	18.2	3.28	2.12	1.13	0.03	11.37	69.84	4.97	1.12	9.43	12616
2	8-28	15.5	3.35	2.11	1.23	0.01	11.21	69.65	5.08	1.31	9.39	12594
3A	8-29	15.4	3.36	2.14	1.20	0.02	11.24	69.57	5.19	1.29	9.35	12656
6	9-2	15.4	3.30	2.22	1.07	0.01	11.11	69.63	5.40	1.21	9.35	12673
Slurry	9-4	—	3.32±0.04	2.15±0.05	1.16±0.07		11.23±0.11	69.67±0.12	5.16±0.18	1.23±0.09	9.38±0.04	12635±36
4	9-5	18.5	3.20	2.08	1.25	0.01	11.44	69.55	5.18	1.32	9.16	12662
5A	9-10	18.1	3.41	2.19	1.21	0.01	11.29	69.83	5.17	1.26	9.03	12629
6A	9-11	17.9	3.35	2.06	1.29	0.01	11.17	69.21	5.19	1.32	9.75	12337
Slurry	9-15	—	3.32±0.11	2.11±0.07	1.25±0.04		11.30±0.14	69.53±0.31	5.18±0.01	1.30±0.03	9.31±0.38	12543±179
3C	9-16	18.4	3.42	2.09	1.37	0.01	11.39	69.74	5.09	1.30	9.02	12656
Add CO ₃	9-16	—	3.42	2.09	1.37		11.39	69.74	5.09	1.30	9.02	12656
A 7A	9-17	19.0	3.39	2.08	1.30	0.01	12.09	68.83	5.03	1.28	9.37	12405
8A	9-29	17.0	3.28	(2.51)	(0.74)	0.02	11.56	69.32	5.01	1.28	9.55	12557
9F	10-1	17.2	3.32	2.28	1.03	0.01	11.77	68.60	4.96	1.18	10.17	12469
NH ₃ Slurry	10-7	—	3.33±0.06	2.18±0.14	1.16±0.19		11.81±0.27	68.92±0.37	5.00±0.04	1.25±0.06	9.70±0.42	12477±76
K 15	10-7	36.0	3.48	2.21	1.26	0.02	11.31	69.01	4.93	1.38	9.90	12510
14	10-8	35.6	3.46	2.15	1.30	0.01	11.34	69.36	4.94	1.48	9.42	12576
13	10-9	(27.5)	3.47	2.15	1.31	0.01	11.29	69.09	4.92	1.43	9.79	12534
Dilute												
14C	10-15	28.2	3.41	2.05	1.35	0.01	11.48	69.59	5.03	1.47	9.02	12534
Dilute	10-16	—	3.46±0.03	2.14±0.07	1.30±0.04		11.36±0.09	69.26±0.26	4.96±0.05	1.44±0.05	9.53±0.40	12538±27
17	10-16	18.9	3.49	2.35	1.12	0.02	11.65	69.48	4.91	1.38	9.10	12552
16	10-17	(20.4)	3.41	(2.52)	(0.87)	0.01	11.61	69.54	4.92	1.37	9.16	(12031)
18	10-20	18.6	3.28	2.09	1.16	0.02	11.55	69.67	5.02	1.46	9.03	12663
			3.35±0.11		1.14±0.03		11.60±0.05	69.56±0.10	4.95±0.06	1.40±0.05	9.10±0.07	12608±78
Mean			3.37	2.15	1.22	0.01	11.44	69.42	5.05	1.32	9.39	12566
±σ			±0.08	±0.12	±0.10	±0.01	±0.24	±0.35	±0.13	±0.10	±0.34	±96
Dry Top of Bin (blend of 5)			3.45	2.14	1.28	0.03	11.92	68.10	4.91	1.29	10.33	12342

*P = PETC PROCESS

A = AMES PROCESS

K = KENNECOTT PROCESS (LEDGEMONT)

Ky #9 Feed Coal

TEST NO.	Date	Feed %	S _T	S _O	S _P	S _S	Ash	C	H	N	O	Btu
	1980											
Slurry	10-22	—										
P 20	10-23	19.1	3.30	1.58	1.66	0.06	22.13	61.74	4.28	1.16	7.40	11206
24	10-24	18.7	3.21	1.40	1.75	0.06	22.00	(60.85)	4.40	1.35	(8.19)	11204
22	10-27	18.8	3.02	1.17	1.84	0.02	21.98	62.26	4.43	1.37	6.93	11267
23	10-28	18.6	3.18	1.28	1.86	0.03	21.91	62.33	4.38	1.34	6.86	11265
21	10-29 ^A	18.5	3.22	1.43	1.78	0.02	21.99	62.23	4.37	1.32	6.86	11321
19	10-29 ^P	18.3	3.06	1.25	1.77	0.04	21.72	62.44	4.38	1.28	7.13	11270
21A	10-30	18.4	3.15	1.28	1.85	0.01	21.77	62.39	4.50	1.31	6.88	11162
CO ₃ Slurry	10-30	—	3.16±0.10	1.34±0.14	1.79±0.07		21.93±0.14	62.23±0.25	4.39±0.07	1.30±0.07	7.01±0.22	11242±54
A 25	10-30	18.2	3.13	1.28	1.83	0.02	22.66	61.83	4.34	1.37	6.67	11150
27	11-4	18.1	3.00	1.23	1.79	0.02	22.36	61.71	4.23	1.37	7.33	11146
26A	11-6	17.7	2.82	1.22	1.59	0.01	22.72	61.96	4.33	1.37	6.79	11144
30	11-10			NO DATA								
NH ₃ Slurry	11-11	—	2.98±0.16	1.24±0.03	1.74±0.13		22.58±0.19	61.83±0.13	4.30±0.06	1.37±0	6.03±0.35	11147±3
K 35	11-13	24.6	3.17	1.24	1.91	0.01	22.47	61.70	4.39	1.45	6.83	11170
34	11-14	23.6	3.17	1.06	2.09	0.01	22.30	62.17	4.42	1.50	6.45	11172
36	11-17	23.8	3.24	1.01	2.19	0.04	22.81	61.10	4.38	1.48	6.99	10994
NH ₃ Slurry	11-18	—	3.19±0.04	1.10±0.12	2.06±0.14		22.53±0.26	61.66±0.54	4.40±0.02	1.48±0.03	6.76±0.28	11145±44
32	11-18	29.3	3.35	1.32	1.98	0.06	22.90	61.65	4.44	1.21	6.44	11081
31B	11-20	29.2	3.32	(1.81)	(1.47)	0.04	22.97	61.36	4.40	1.32	6.63	11094
33	11-24	30.2	3.28	1.33	1.93	0.02	22.87	60.98	4.45	1.23	7.20	10972
33	11-24	—	3.33	1.33	1.99	0.01	22.80	60.73	4.50	1.45	7.18	10958
			3.32±0.03	1.33±0.01	1.97±0.03		22.88±0.07	61.18±0.41	4.45±0.04	1.30±0.11	6.86±0.39	11126±71
Mean			3.17	1.28	1.86	0.03	22.37	61.78	4.39	1.35	6.91	11152
+σ			+0.14	+0.14	+0.15	+0.02	+0.43	+0.53	+0.07	+0.09	+0.29	+106
Dry Top of Bin (Blend of 5)			3.93	1.66	1.94	0.32	22.85	59.73	4.11	1.31	8.07	13992

Lucas #5 Feed Coal

TEST NO.	Date	Feed %	S _T	S _O	S _p	S _S	Ash	C	H	N	O	Btu
	1980											
Slurry	11-24	—										
P 37	11-25	13.4	1.94	0.73	1.20	0.01	8.70	72.93	5.34	1.25	9.84	13142
I 38	11-26	13.3	2.01	1.21	0.79	0.01	9.03	72.34	5.62	1.45	9.58	12758
Add CO ₃	11-26	—	1.98±0.05	0.97±0.34	1.00±0.29		8.86±0.23	72.64±0.42	5.48±0.20	1.35±0.14	9.71±0.18	12950±272
A 43	12-1	13.0	1.83	1.12	0.70	0.01	10.46	71.77	5.17	1.40	9.37	12929
I 44	12-2	12.9	1.88	1.33	0.55	0.01	10.04	(70.96)	5.01	1.51	(10.59)	12991
NH ₃ Slurry	12-3	—	1.86±0.04	1.22±0.15	0.62±0.11		10.25±0.30	71.77	5.09±0.11	1.46±0.08	9.37	12960±44
K 50	12-5	27.2	2.05	0.73	1.31	0.01	8.31	73.48	5.26	1.87	9.04	13264
I 51	12-8	26.1	2.05	(0.16)	(1.88)	0.01	8.27	72.98	5.39	1.82	9.49	13315
			2.05±0	0.73	1.31		8.29±0.03	73.23±0.35	5.32±0.09	1.84±0.04	9.26±0.32	13290±36
Mean			.96	1.02	0.91	0.01	9.14	72.70	5.30	1.55	9.46	13066
±σ			±0.09	±0.28	±0.33	±0.00	±0.92	±0.66	±0.21	±0.24	±0.29	±213
Dry Top of Bin (Blend of 5)			2.17	0.90	1.26	0.01	8.29	72.66	4.93	1.56	10.39	13116

III. #6 Output

TEST NO.	Feed %	Out %	S _T	S _O	S _P	S _S	Ash	C	H	N	O	Btu	O _{MIN}	Press	Temp
	Slurry													psig	°C
Slurry															
IP 1	18.2	—				NO DATA							25	985	200-230
2	15.5	12.0	2.66	2.08	0.56	0.02	10.26	66.85	4.41	1.22	14.60	11476	58	988	185
3A	15.4	17.2	2.53	1.97	0.58	0.01	10.99	64.87	4.25	1.17	15.90	11153	58	985	203
6	15.4	13.1	2.06	1.70	0.35	0.01	11.18	62.99	3.84	1.18	18.76**	10192	Target 120	985	181
Slurry															
4	18.5	14.0	2.24	1.68	0.31	0.26*	10.76	62.20	3.21	1.30	20.29*	10083	Target 120	1000	224
5A	18.1	10.8	3.06	2.02	1.04	0.01	10.41	67.64	4.62	1.22	13.05	11052	84	981	183
6A	17.9	18.1	2.81	1.89	0.91	0.01	10.16	66.79	4.34	1.29	14.60	11568	116	998	180
Slurry															
3C	18.4	17.9	3.03	2.11	0.92	0.01	9.98	67.43	4.39	1.31	13.85	11670	53	987	202
Add CO ₃			2.63±0.38	1.92±0.17	0.67±0.29	0.05±0.09 (0.01±0)	10.53±0.45	65.54±2.21	4.15±0.48	1.24±0.06	15.86±2.68 *(15.13±2.01) **(14.40±1.06)	11142±719			
A 7A	19.0	17.9	2.74	2.06	0.68	0.01	16.26	64.43	4.68	1.27	10.61	11402	60	250	150
8A	17.0	12.0	2.62	2.29	0.31	0.02	13.78	65.44	4.50	1.20	12.56	11361	57	250	153
9F	17.2	9.6	2.50	2.05	0.39	0.06	14.65	63.95	4.30	1.23	13.38	11212	104	275	153
NH ₃ Slurry			2.62±0.12	2.13±0.14	0.46±0.19	0.03±0.03	14.90±1.26	64.61±0.76	4.49±0.19	1.23±0.04	12.15±1.41	11325±100			
K 15	36.0	21.8	2.47	1.83	0.63	0.01	10.39	64.68	3.95	4.36	14.15	10917	55	295	1 2,3 160/200
14	35.6	29.1	2.57	2.08	0.45	0.04	10.39	63.22	3.93	4.50	15.39	10825	58	320	1 2,3 155/195
13	(27.5)	30.1	2.29	1.89	0.39	0.01	9.50	64.66	4.38	3.83	15.34	11067	112	296	130
14C	28.2	24.0	2.21	1.72	0.46	0.03	11.16	62.71	4.03	4.92	14.97	10778	59	300	1,3 2 160/190
Dilute															
17	18.9	20.3	2.23	1.95	0.24	0.04	10.52	63.40	4.11	6.16	13.58	10793	65	290	160
16	(20.4)	18.6	2.28	1.92	0.33	0.03	11.75	64.62	4.29	4.67	12.40	11248	102	310	130
18	18.6	12.6	2.16	1.81	0.31	0.04	12.65	62.19	3.67	6.45	12.88	10405	28	297	195
			2.32±0.15	1.89±0.12	0.40±0.13	0.03±0.01	10.91±1.04	63.64±1.02	4.05±0.24	4.98±0.97	14.10±1.20	10862±263			

Ky #9 Output

TEST NO.	Feed %	Out %	S _T	S _O	S _P	S _S	As ₁	C	H	N	O	Btu	θ _{MIN}	Press	Temp	
	Slurry													psig	°C	
Slurry																
P	20	19.1	20.6	2.35	1.45	0.29	0.51	21.19	57.57	3.42	1.13	14.35	9742	66	998	181
	24	18.7	20.2	2.45	1.69	0.45	9.32	21.11	58.82	3.80	1.26	12.56	10099	103	978	165
	22	18.8	21.0	2.26	1.62	0.63	0.02*	20.84	58.51	3.43	1.29	13.67	9946	82	987	180
	23	18.6	19.7	2.24	1.43	0.38	0.42	20.75	59.32	3.74	1.32	12.63	10108	81	992	170
	21	18.5	17.9	2.20	1.44	0.29	0.47	20.51	59.16	3.98	1.24	12.92	10205	62	1009	170
	19	18.3	18.9	2.21	1.21	0.63	0.36	20.25	58.98	3.78	1.27	13.52	10143	31	980	185
	21A	18.4	19.3	2.31	1.59	0.35	0.37	20.61	59.24	3.74	1.25	12.85	10112	60	990	170
CO ₃ Slurry			2.25±0.09	1.49±0.06	0.43±0.15	0.36±0.18 (1.42±.11)	20.75±0.33	58.80±0.61	3.70±0.20	1.25±0.06	13.21±0.66	10051±157				
A	25	18.2	13.0	1.77	1.20	0.55	0.02	22.35	59.47	3.83	1.41	11.18	10320	54	260	150
	27	18.1	14.4	1.75	1.15	0.58	0.02	21.29	60.46	3.79	1.39	10.33	10427	119	250	150
	26A	17.7	16.8	1.76	1.09	0.66	0.02	23.80	59.06	3.79	1.38	10.21	10265	69	250	155
	30	—	13.4	1.64	1.37	0.26	0.01	27.24*	55.94	3.64	1.30	10.24	9634	62	260	152
NH ₃ Slurry			173±0.06	1.20±0.12	0.51±0.17	0.92±0.01 (22.4 ±1.26)	23.67±2.59	58.73±1.95	3.76±0.08	1.37±0.05	10.49±0.46	10161±358				
K	35	24.6	26.9	1.80	0.98	0.80	0.92	15.55	60.40	3.61	3.82	10.81	10242	60	301	160
	34	23.6	24.0	1.89	0.90	0.94	0.04	22.25	57.99	3.95	4.10	9.83	10060	108	293	128
	36	23.8	23.3	1.93	0.66	1.23	0.94	22.46	56.30	3.50	4.97	10.84	9586	30	300	190
NH ₃ Slurry																
	32	29.3	29.4	1.53	1.29	0.26	0.02	19.94	56.74	3.62	4.04	14.08*	9578	Target 60	300	1,2 3 160/170
	31B	29.2	31.1	1.83	1.16	0.64	0.03	21.11	58.49	3.91	3.54	11.13	10183	118	295	135
	33	30.2	20.6	1.93	1.16	0.74	0.03	22.88	55.51	3.62	4.45	11.61	9185	61	295	1,2 3 190/200
			1.83±0.13	1.02±0.23	0.77±0.32	0.03±0.01	21.36±1.39	57.57±1.77	3.70±0.18	4.15±0.53	11.38±1.44 *(10.84±0.65)	9806±420				
Alternate 34			1.79	1.04	0.74	0.01	21.94	58.16	4.06	4.03	10.01	10174				
Alternate 35			1.60	1.19	0.38	0.04	21.59	57.76	3.94	4.23	10.87	9843				
Alternate 36			1.53	0.80	1.06	0.03	22.70	56.61	3.60	5.01	10.15	9517				
			1.77±0.17	1.02±0.18	0.73±0.34	0.03±0.02	22.08±0.57	57.51±0.80	3.87±0.24	4.42±0.52	10.34±0.46	9844±329				

Lucas #5 Output

TEST NO	Feed %	Out %	S _T	S _O	S _P	S _S	Ash	C	H	N	O	Btu	θ _{MIN}	Press	Temp
	Slurry													psig	°C
Slurry															
P 37	13.4	12.8	1.43	1.06	0.35	0.01	6.72	71.05	4.96	1.59	14.25	12281	34	994	185
I 38	13.3	13.4	1.51	1.12	0.38	0.91	7.19	70.09	4.46	1.54	15.20	12178	65	1016	180
Add CO ₃			1.47±0.06	1.09±0.04	0.36±0.02	0.01±0.00	6.96±0.33	70.57±0.68	4.71±0.35	1.56±0.04	14.72±0.67	12230±73			
A 43	13.0	13.1	1.33	1.08	0.24	0.01	13.75	67.96	4.68	1.49	10.80	11886	61	250	150
I 44	12.9	11.2	1.22	0.94	0.27	0.01	13.05	68.54	4.58	1.47	11.15	11948	60	250	150
NH ₃ Slurry			1.28±0.08	1.01±0.10	0.26±0.02	0.01±0.00	13.40±0.41	4.63±0.07	1.48±0.01	10.98±0.25	11917±44				
K 50	27.2	28.8	1.08	0.82	0.25	0.91	7.74	67.61	4.02	5.25	14.30	11358	59	300	1,3 2 160/170
I 51	26.1	19.6	0.81	0.57	0.23	0.01	8.93	61.68	3.30	5.96	19.32	9934	116	316	190
			0.94±0.20	0.70±0.18	0.24±0.01	0.01±0.00	8.34±0.84	64.64±4.19	3.66±0.51	5.60±0.50	16.81±3.55	10646±1007			

III #6

TEST NO.		Flow, Kg/Hr		Coal Flow, Kg/Hr			Solids Recovery	Btu Out Btu In	% Coal Recovery
		In	Out	Nominal In	In	Out	%	%	%
P	1	21.1	20.0	3.5	3.84	-	-	-	-
P	2	8.8	9.8	1.8	1.36	1.18	87	91	79
P	3A	8.8	6.5	1.8	1.36	1.12	82	88	73
P	6	[Target 4.4]	-	0.9	-	-	-	80	-
P	4	[Target 6.6]	-	1.1	-	-	-	80	-
P	5A	6.0	6.1	1.1	1.09	1.15	106	94	99
P	6A	4.4	4.8	0.9	0.79	0.87	110	94	103
A	3C	9.7	9.6	1.8	1.78	1.72	96	92	89
A	7A	8.7	9.2	1.8	1.65	1.65	100	92	92
A	8A	9.2	7.5	1.8	1.56	0.90	58	90	52
A	9F	5.0	5.5	0.9	0.86	0.53	62	90	55
K	15	9.6	16.6	1.8	3.46	3.62	105	87	91
K	14	9.1	11.0	1.8	3.24	3.20	99	86	85
K	13	4.6	3.1	1.9	(1.61) (1.26)	0.93	58 (75)	88	51 (65)
K dil>	14C	8.1	9.1	2.7	2.28	2.18	96	86	82
K dil>	17	7.7	6.8	1.8	1.46	1.38	95	86	81
	16	4.9	4.6	0.9	(0.92) (1.00)	0.86	94 (86)	(93)	(80)
	15	17.6	18.5	3.5	3.27	2.34	72	82	59

REACTION Δ 's FOR I #6; K #9

	S_T	S_O	S_P	S_S	Ash	C	H	N	O	Btu
<u>I #6</u> All	3.37	2.15	1.22	0.01	11.44	69.42	5.05	1.32	9.39	12566
(Input) P	3.33	2.13	1.22	0.01	11.28	69.63	5.16	1.27	9.31	12603
A	3.33	2.18	1.16	0.01	11.81	68.92	5.00	1.25	9.70	12477
K	3.43	2.17	1.25	0.01	11.46	69.39	4.95	1.42	9.35	12562
Δ vs All P	-0.74	-0.23	-0.55	+0.04	- 0.91	- 3.88	-0.90	-0.08	+6.47	-1424
A	-0.75	-0.02	-0.76	+0.02	+ 3.46	- 4.81	-0.56	-0.09	+2.76	-1241
K	-1.05	-0.26	-0.82	+0.02	- 0.53	- 5.78	-1.00	+3.66	+4.71	-1704
ΔP	-0.70	-0.21	-0.55	+0.04	- 0.75	- 4.09	-1.01	-0.03	+6.55	-1461
ΔA	-0.71	-0.05	-0.70	+0.02	+ 3.09	- 4.31	-0.51	-0.02	+2.45	-1152
ΔK	-1.12	-0.28	-0.85	+0.02	- 0.55	- 5.28	-0.90	+3.56	+4.75	-1700
<u>K #9</u> All	3.17	1.28	1.86	0.03	22.37	61.78	4.39	1.35	6.91	11152
(Input) P	3.16	1.34	1.79	0.03	21.93	62.23	4.39	1.30	7.01	11242
A	2.98	1.24	1.74	0.02	22.58	61.83	4.30	1.37	6.93	11147
K	3.27	1.22	2.02	0.03	22.73	61.38	4.43	1.38	6.82	11063
Δ vs All P	-0.88	+0.21	-1.43	+0.33	- 1.62	- 2.98	-0.69	-0.10	+6.30	-1101
A	-1.44	-0.08	-1.35	-0.01	+ 1.30	- 3.05	-0.63	+0.02	+3.58	-991
K	-1.34	-0.26	-1.09	0.00	- 1.01	- 4.21	-0.69	+2.80	+4.47	-1346
ΔP	-0.87	+0.15	-1.36	+0.33	- 1.18	- 3.43	-0.69	-0.05	+6.20	-1191
ΔA	-1.25	-0.04	-1.23	0.00	+ 1.09	- 3.10	-0.54	0.00	+3.56	-986
ΔK	-1.44	-0.20	-1.25	0.00	- 1.37	- 3.81	-0.74	+2.77	+4.56	-1257

REACTION Δ 's (cont) L #5

	S_t	S_o	S_p	S_s	Ash	C	H	N	O	Btu
L #5 All	1.96	1.02	0.91	0.01	9.14	72.70	5.30	1.55	9.46	13066
(Input) P	1.98	0.97	1.00	0.01	8.86	72.64	5.48	1.35	9.71	12950
A	1.86	1.22	0.62	0.01	10.25	71.77	5.09	1.46	9.37	12960
K	2.05	0.73	1.31	0.01	8.29	73.23	5.32	1.84	9.26	13290
Δ vs All P	-0.49	+0.07	-0.55	0.00	- 2.18	- 2.13	-0.59	+0.01	+5.26	-836
A	-0.68	-0.01	-0.65	0.00	+ 4.26	- 4.45	-0.67	-0.07	+1.52	-1149
K	-1.02	-0.32	-0.67	0.00	-0.80	- 8.06	-1.54	+4.05	+7.35	-2420
ΔP	-0.51	+0.12	-0.64	0.00	-1.90	- 2.07	-0.77	+0.21	+5.01	-720
ΔA	-0.58	-0.21	-0.36	0.00	-3.15	- 3.52	-0.46	+0.02	+1.61	-1043
ΔK	-1.11	-0.03	-1.07	0.00	+0.05	- 8.59	-1.66	+3.76	+7.55	-2644

SUMMARY

	I #6	K #9	L #5	I #6	K #9	L #5	I #6	K #9	L #5	I #6	K #9	L #5
S_T				S_o			S_p			S_s		
P	-0.7	-0.9	-0.5	-0.2	0.2	0.1	-0.6	-1.4	-0.6	0	0.3	0
A	-0.8	-1.4	-0.7	0	-0.1	0	-0.8	-1.4	-0.6	0	0	0
K	-1.0	-1.3	-1.0	-0.3	-0.3	-0.3	-0.8	-1.1	-0.7	0	0	0
C				H			N			0		
P	-3.9	-3.0	-2.1	-0.9	-0.7	-0.6	-0.1	-0.1	0	6.5	6.3	5.3
A	-4.8	-3.0	-4.4	-0.6	-0.6	-0.7	-0.1	0	-0.1	2.8	3.6	1.5
K	-5.8	-4.2	-8.1	-1.0	-0.7	-1.6	3.7	2.8	4.0	4.7	4.5	7.4
Ash				Btu								
P	-0.9	-1.6	-2.2	-1400	-1100	- 800						
A	3.5	1.3	4.3	-1200	-1000	-1100						
K	-0.5	-1.0	-0.8	-1700	-1300	-2400						