MASTER

LOW-BTU GASIFICATION OF COAL
FOR ELECTRIC POWER GENERATION

DOE/ET/10204--T1

Phases I, II and III

Monthly Progress Report

Period of April 1 - April 30, 1981

Combustion Engineering, Inc.
Windsor, Connecticut 06095

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Abstract

Oxygen-enriched operation of the PDU was initiated on April 1, 1981. Eleven oxygen enriched gasmaking tests were made during the month. These tests were interrupted upon eight occasions by slag tap pluggage or imminent pluggage. Direction was received from both contract sponsoring agencies (DOE and EPRI) changing the priority of April's testing from shakedown and parametric oxygen-enriched testing to running a 15-20 day sustained operations test. This test was begun during the month, but not successfully completed owing to the tap hole pluggage problems.

Iron reduction of the slag is the most obvious explanation for the tap hole pluggages.

I. Open Items

Remaining activities under this contract are:

- Sustained operation test,
- Oxygen enrichment tests, and
- Tests with other coals

II. Detailed Description of Monthly Progress

I. Summary of Month's Activities

Oxygen-enriched operation of the PDU was initiated for the first time on April 1, 1981. The test run on April 1 was both the first "trial" of the new oxygen system and a performance test of the entire PDU under oxygen enriched operation.

Direction had been received from both of the other contract sponsoring agencies (DOE and EPRI) which changed the priority of Run 12. Instead of shaking down the new subsystem and then running the previously planned oxygen enriched performance tests, C-E was to concentrate all efforts upon initiating a continuous 15-20 day sustained test. This test was to be run in the oxygen enriched mode, was to be run uninterrupted for 15-20 days with only minor changes or adjustments of input parameters, had to be run with 4 TPH or higher coal firing rate, and was to be run with balanced char bin conditions.

Although the new oxygen system appeared to work well and interplay smoothly with the balance of the plant, early troubles were encountered with slag tap hole pluggages. A total of eight tap hole pluggages occurred during the month and prevented completion of the 15-20 day test. The details of each tap hole pluggage are given elsewhere in this report. Analysis of the slag, the pluggage material itself, and the char which accumulated on the combustor floor indicate that reduction of iron from the slag caused most, if not all, of the pluggage problems.

In spite of the slag tap pluggages, twelve oxygen enriched tests were made during the month. Data for these tests is given. Product gas heating values between 70-85 Btu/scf were achieved even at low oxygen flow rates (2000-3000 lb/hr).

II. Detailed Description of Monthly Progress

I. Details of Month's Activities

A. Initial Operation in April

Oxygen-enriched operation of the PDU was initiated for the first time on April 1, 1981. The test done on that day (Test 12-3) was a combustor-only, coal-only test with 4200 lb/hr coal, 2000 lb/hr oxygen, 30,000 lb/hr air to the combustor. The test was both the first "trial" of the new oxygen system and a performance test of the entire PDU under oxygen enriched operation.

Direction had been received from both of the other contract sponsoring agencies (DOE and EPRI), which changed the priority of Run 12. Instead of shaking down the new subsystem and then running the previously planned oxygen-enriched performance tests (12-3 to 12-9), C-E was to "concentrate efforts during the on-going Run 12 toward achieving a continuous 15-20 day gasmaking test with the PDU gasifier. This objective to take precedence over all other test conditions during Run 12."

Additional ground rules to be followed in the 15 day test were:

- a) use oxygen-enrichment throughout test,
- b) operate with balanced char bin conditions,
- c) only minor changes or adjustments could be made in input parameters,
- d) minimum average coal firing rate to be ≥ 4 tons/hour,
- e) operate uninterrupted for 15 days.

The new oxygen system functioned without incident from the time flow was first initiated at 1530 hours on 4/1/81. The PDU gasifier and other plant equipment were noted to operate very smoothly throughout the one day trial run. The material and energy balance for the trial test (12-3) are contained elsewhere in this report and compare favorably with the "base test" (12-2) cited in the March report.

On 4/2/81, "ramped" changes to gasifier inputs were made to set up test 12-5. Test 12-5 was adjudged to provide reasonable gasifier input conditions for the 15 day extended test, as follows:

- combustor coal 3,000 lb/hr *
- reductor coal 6,000 lb/hr
- total combustor air 40,300 lb/hr
- reductor air 1,000 lb/hr (dense phase)
- combustor oxygen 2,000 lb/hr

It was planned to begin the 15 day test on 4/2/81 as soon as the test point conditions described above were achieved.

At 1500 hours on April 2, several problems with the reductor feed system occurred. At midnight on April 2, partial pluggage of the slag tap hole was observed. Changes were made in the char feed rate and in gasifier stoichiometry to address the pluggage problem. The tap hole pluggage fell out early afternoon on April 3, but the first attempt at achieving smooth operation at a selected 15 day test condition had failed. Of chief concern was the tap hole pluggage problem. There were no instances of tap hole pluggage during Runs 8, 10 and 11. Slag tapping problems were experienced during Runs 7-12 wherein slagging conditions were poor at several test conditions, but there had been no instances of completely plugged tap hole.

* Originally, combustor coal flow of 4,000 lb/hr had been planned

It was felt that the most likely cause of the April 2-3 pluggage was refractory melting caused by local high temperatures associated with oxygen firing. Analysis of the early April slag samples, however, showed only a small amount of refractory in the slag. Unlike slag composition later in this month, early April indications were that either the refractory did not play a role in the pluggage or that the ladle sample was not representative of the pluggage material.

B. PDU Testing Throughout Balance-of-Month

The tabulation of tests run in April shows twelve tests, which were punctuated with eight complete or near complete slag tap pluggages (such that testing was interrupted) as follows:

<u>Date</u>	<u>Test</u>	<u>Slag Tap Pluggage</u>
4/1/81	12-3	-
4/2/81	12-GP-01	-
4/3/81	12-GP-02	-
4/3/81 (0100)		Pluggage #1
4/4/81	12-6A	-
4/5/81	12-GP-03	-
4/5/81 (2000)		Pluggage #2
4/6/81	12-6AA	-
4/6/81 (1950)		Pluggage #3
4/8/81 (0930)		Pluggage #4
4/9/81 (2300)		Pluggage #5
4/10/81	12-GP-04	-
4/10/81	12-GP-05	-
4/10/81	12-GP-06	-
4/10/81 (1550)		Pluggage #6
4/15/81	12-GP-07	-
4/16/81 (0645)		Pluggage #7
4/22/81	12-GP-08	-
4/22/81	12-GP-09	-
4/22/81 (2200) Hrs		Pluggage #8

Attachment I describes each of the eight tap hole pluggages which occurred in April, while Attachment II cites gasifier operating conditions at times when each of the pluggages occurred.

Every effort was made in April to alleviate the slag tap hole pluggage problem. Fuel, air, char, oxygen firing conditions were altered in several combinations in an attempt to prevent build-up of solids on the combustor floor, which often times appeared to be associated with the slag tap pluggages. During alternate attempts, oxygen firing was varied by the amount introduced (1,000 - 3,000 lb/hr) and it was introduced to the combustor (i.e. behind the char, behind the coal, or behind both). Frequent samples of both flowing slag, slag pluggage material, and accumulated material on the combustor floor were taken and analyzed to understand the mechanism causing the pluggages. Attachment IIIA shows typical analysis of slag and pluggage material made during the month. Attachment IIIB, typical analysis of PDU coal. Beginning on April 10, char flow rates to the combustor were reduced to $\sim 2,500$ lb/hr to minimize the likelihood of char feed "flushing" which occasionally occurred at higher feed rates and was a prime suspect for contributing to the pluggage problem.

The Pittsburgh Seam Coal (striped mined, Delton Mine, Clarksburg, W. Virginia) used at the PDU, typically contains 9-10% ash. A typical analysis of this coal is shown on Attachment IIIB. As noted, ash fusibility of this coal yields a H.T. and F.T. values of $2,300^{\circ}\text{F}$ and $2,350^{\circ}\text{F}$, well below the $\sim 2,900^{\circ}\text{F}$ combustor temperatures generally measured throughout the month. Of concern however, was that fusibility analysis of gasifier slag, pluggage material, and material accumulated on the floor of the combustor collected from mid month on, often showed H.T. and F.T. values in the range of $2,600^{\circ}\text{F}$ - $2,700^{\circ}\text{F}$. At the end of the first week in April when high alumina (Al_2O_3) concentrations were observed for the first time in the month, the high ash fusion temperatures were attributed to refractory wastage. It was assumed that the ram refractory in and around the combustor windboxes which had been installed in the outage preceeding Run 12, would quickly "burn-back" to a stable frozen slag depth, after which time and owing to less refractory (and alumina) wastage, normal $2,300^{\circ}\text{F}$ - $2,400^{\circ}\text{F}$ ash fusion temperatures would result. Attachment IIIA infers that this did not occur as high fusibility temperatures and alumina concentrations continued to be measured throughout the month. Inspections inside the combustor and diffuser made several times during the month, showed refractory loss had occurred in the diffuser and around the combustor wall primarily at windbox elevations and on the combustor floor. The refractory dam was replaced upon three occasions in the month to afford every opportunity for tapping-off molten slag from the combustor floor. It had been the experience at the PDU that a dam was useful in our gasifier configuration in enhancing slag tapping. Insufficient time had existed to incorporate the new water cooled dam designed to eliminate the need for periodic replacement.

The concentration of iron oxide in the slag, pluggage material, and in accumulated material on the combustor floor, was measured and monitored during April, after metallic iron was found in combustor floor accumulations. Mr. Wate T. Bakker, Technical Area Manager in EPRI's Refractories and Ceramics Section, worked with and gave advise to the C-E Gasification Program during the month. Mr. Bakker's view was that some, if not most, of the tap hole pluggages occurring during April arose from reduction of iron oxide contained in the coal ash to metallic iron. Removal of iron from the slag shifts the composition of the slag into the area where mullite crystals precipitate, causing a significant increase in slag viscosity and fusion temperature. Normal concentration of iron oxide (expressed as Fe_2O_3) in the PDU coal is ~ 21 weight percent. Concentration of iron (as Fe_2O_3) found in slag "ladle" samples during April averaged 30%; ranged from 6.5-19% in pluggage materials; and were found to be $\sim 30\%$ in accumulated floor deposits. A review of April analyses clearly shows that iron was being reduced from the slag and did contribute to the pluggage problems during April. The most obvious explanation for iron depletion from the slag during April, was that suggested by Mr. Bakker. He suggested that the flow of slag through or under the char like build-up on the combustor floor caused the slag to be subjected to a reducing zone in the combustor. In this zone of low oxygen partial pressure, iron would be extracted from the slag. It is further likely, that the material accumulated on the combustor floor resulting from char bin flushing or other reason, would cool or otherwise cause slag temperature to be reduced 200°F or more below the indicated combustor temperature measured at a higher elevation in the combustor. This, of course, would cause slag freezing and tap hole pluggage.

Metallic iron had only been observed at one other time during PDU testing, in the Design Verification Test (Run 11-PV-1) in December. An inspection of the combustor floor following December's air blown design verification test showed an accumulation of ~ 6 " of unburned carbon. Reduction of iron from the coal ash was considered at that time. It was postulated that iron was the result of firing the gasifier at higher-than-design feed rates. It is postulated now that the low combustor stoichiometry ($\sim 57\%$) accompanied by floor deposits during the December design verification test, might have caused similar reducing conditions at the combustor floor to those experienced in April. At this time, it cannot be ruled out that oxygen firing itself is not a contributing, or even the primary cause, for iron reduction from the coal or coal ash. What is apparent, is that in some, if not all cases, the increase in Al_2O_3 content in the slag and tap hole pluggage material, was a reflection of the depletion of iron from the slag and not due to wastate of refractory as initially thought.

As previously discussed, April testing involved (or was restricted to) oxygen enriched firing only. It is planned to conduct some tests in May under air blown conditions to determine what extent of the iron depletion pluggages problem might be inherent in oxygen enriched firing.

C. Reductor Coal Transport Throughout Month

Other than PDU testing on April 1 and 2, all gasmaking tests done during the month used dilute phase reductor coal transport, rather than dense phase. When the rash of tap hole pluggage problems occurred, it was thought unreasonable to attempt to continue operations with two newly installed systems (dense phase plus oxygen enrichment).

D. Material and Energy Balances-April

Attachment IV gives the Material and Energy Balance Data for each of the thirteen tests performed in April. As noted, closure of the material balances was quite good (all except test 12-GP-08 being $\leq 5\%$). Roughly one-half of the energy balance closures were $\geq 5\%$. The failure to achieve good energy balances in half of April's tests, were attributed to errors associated with char feed rate measurements.

3. Work Forecast for May, 1981

Run 12 will extend into May, in an effort to initiate and complete the 15-20 day sustained test as the first priority activity.

ATTACHMENT I

CHRONOLOGY OF PDU SLAG TAP PLUGGAGES IN APRIL 1981

Pluggage 1, April 2-3

About 1700 hours, April 2, several problems with the reductor feed system occurred. E feeder was acting erratically and was noisy so it was shut down. Shortly thereafter, the dense phase coal pump tripped. Char feed was lowered at 2230 hours and continued to be lowered throughout the third shift, down to 500 lb/hr at 0600, April 3. (Plugging was noticed around the end of the second shift.)

Stoichiometry was increased to 1.04 from 0100 to 0600 hours, April 3, then lowered gradually through the morning. Char feed was increased to 4000 lb/hr at 1330. Forty minutes later, the pluggage dropped out by itself. It should be noted that the slag tap was never plugged solid.

It was felt that the problem may have been caused by high temperatures and melting refractory. Analysis of a ladle sample showed only a small amount of refractory in the slag (see Attachment 2). This could indicate that either refractory did not play a role in the pluggage, or that the ladle sample was not representative of the pluggage material.

Pluggage 2, April 5-6

The A-boiler tripped at 0800, April 5, but the unit was gasmaking by 1300. From 1300 to 2000, the gasifier operated at fairly constant conditions. At 2000, plugging was noted. Char flow was lowered and combustor air raised to increase stoichiometry. Char flow was gradually lowered from 3700 to 1200 lb/hr between 2000 and 2400, and air flow was dropped back down after one hour.

The slag neck fan was turned on about 0100, April 6. Combustor Ircon temperature, although on the average remained fairly constant, dropped to 2300°F twice between 0000 and 0130. At 0130, the slag neck cleared. (The slag neck fan was shut down about 0400.)

Operations found brick and refractory in the slag and also anchor brick, probably from the reductor.

ATTACHMENT I

Pluggage 3, April 6-7

Test 12-6AA was run from 1500 to 1830, April 6. Plugging problems continued throughout test. The slag neck fan was turned on at 1915. Char flow was lowered at 2200 hours and continued down to 1500 lb/hr at 0230, April 7. Pluggage cleared out by itself at 0500. Slag neck fan was shut off at 1100 hours.

Operations again found anchor bricks in the slag.

Pluggage 4, April 8

ADARS data was not available from 0000 to 0930. Slag neck problems were already existing at this time. The char secondary air damper was 0% when char flow was 4000 lb/hr between 0930 and 1100. Combustor stoichiometry was 0.65 at 0930 and continued this way until 1100 when it was increased to 0.96 by shutting down char flow. The tap hole plugged solid, and the unit was taken off coal at 1300.

It took two shifts to clear out the tap; a lot of manual rodding was required. Analysis of a pluggage sample showed that alumina content was high, but that may have been caused by the reduced iron oxide content in the ash. Carbon/slag balls which apparently fell from the diffuser were found. Analysis of these slag balls showed them to be about 75% carbon and the rest ash.

Pluggage 5, April 9

This problem occurred shortly after combustor coal was started up. There was a coal feeder flush. The slag neck fan was turned on and the tap cleaned up in about one hour.

Pluggage 6, April 10

A water leak was found in the reverse slag neck fan exhaust at approximately 1000. Water flow was shut off. The slag neck fan was on from 0300 to 1200. At 1100, damper positions were changed. Char damper at 0%. At 1200, tests were begun varying the amount and bias of oxygen flow. Slagging was bad; "chunks" were dropping through tap hole. By 1500, with tests still running,

ATTACHMENT I

the tap hole was about 2/3 closed. At 1550, the tap plugged; all coal and oxygen were taken out.

An internal inspection showed that the slag neck fan exhaust leak was about 3 to 5 gal/min., pointed down towards the combustor floor. The failure was apparently overheating of the inner jacket pipe. A small leak (weeper) was also found on the A4 secondary air nozzle. About 2 feet of debris was found on the combustor floor. Ram refractory in the combustor windboxes had burned back considerably (this caused hot windbox backing plates). A little more reductor ram refractory was also gone. Analysis of the pluggage showed that there was quite a bit of refractory in the slag. (The Ircon temperatures during the tests were fairly high.)

During the outage, the leaks were repaired, and a brick dam was installed around the slag coil.

Pluggage 7, April 15-16

Some char flushes were occurring about 1300 to 1500, April 15. Combustor Ircon temperatures were also erratic about the same time. Dampers were set at 100% coal/60% char. Char flow was increased to 5000 lb/hr at 1800 hours. ADARS then went down. Coal was shut off at 0100, April 16. The gasifier went down completely at 0645.

An internal inspection revealed that the pluggage material was greenish in color and was less dense than previous pluggage material. There was 2-1/2 to 3 ft. of debris on the combustor floor. No water leaks were found during this outage. The debris was cleaned up and a new dam was installed.

Analyses were made on: (1) pluggage material, (2) top layer of debris, and (3) bottom layer of debris (see Attachment 2). The bottom layer had a relatively high amount of Cr_2O_3 , indicating refractory, while the other two had iron reduced out causing the alumina content to increase.

Pluggage 8, April 22

Started firing combustor coal at 0900, oxygen at 1230. At 1200, char flow was 3 000 lb/hr with dampers set at 100% coal/60% char. At 0100, this was changed to 4000 lb/hr and 80%/80%. At 1830, char flow was removed and all oxygen was placed behind char. By 2200, the unit was plugged and coal feed

ATTACHMENT I

shut down.

An internal inspection was made. The slag coil center coils had sagged, probably due to the weight of the one foot high debris on top of it. A layer of iron was found on the floor around the outside slag coil. The reductor F5 nozzle was leaking about 2 gpm pointed down towards the throat. Two other small leaks (weepers) were found on a slag coil elbow and nozzle A2.

The major leak was apparently caused by local overheating. The nozzle was cut open and quite a bit of particulate build-up was found near the failure. The other nozzle leak seemed to be a porous weld, while the slag coil leak was probably caused by the sagging inner coils.

The leaks were repaired. Ram and brick refractory were added to the combustor floor to make a constant slope all the way to the slag dam. Braces were added to the coil.

P.LUG N.O.	DATE/ TIME	COMB TEMP °F	COMB COAL LB/HR	COMB CHAR LB/HR	RED COAL LB/HR	TOT COMB AIR 1000 LB/HR	COMB SEC AIR 1000 LB/HR	COAL/CHAR DAW/ROS %/%	COAL/CHAR OXYGEN LB/HR LB/HR	INPUT COMB STOICH	TIME @ CONDITION HR	SLAG TAP OBSERVATIONS	COMMENTS
1	4-2/1500	2900	4000	4700	4000	40	26.3	90/100	1973/0	0.73	8		PROBLEMS WITH REDUCTOR COAL FEED BETWEEN 1500 AND 2400. FEEDS UP AND DOWN
	4-3/0000	2900	4000	3600	0	40	26.3	90/100	2051/0	0.81	2		
	4-3/0100	2900	3000	3000	4000	40	26.3	90/110	2051/0	1.04	1	PLUGGING NOTED	LOWERED CHAR GRADUALLY BETWEEN 0300 AND 0600
	4-3/0600	2900	4750	500	1000	40	26.3	100/0	1997/0	0.98	5		PROBLEMS WITH REDUCTOR COAL FEED CHAR FEED
	4-3/1000	2900	5250	500	4000	40	26.3	100/20	2089/0	0.89	1.5		
	4-3/1330	2900	4000	4000	0	40	26.3	80/40	2040/0	0.72	5		
	4-3/1410												PLUGGAGE FELL OUT BY ITSELF
2	4-5/1300	3000	4000	3700	4000	36	22	100/50	1915/0	0.69	7		GASMAKING STARTED AFTER A-BOILER TRIP
	4-5/2000	3000	4000	3000	0	38	24	100/50	1933/0	0.77	1	PLUGGING NOTED	INCREASED STOICHIOMETRY TO HELP CLEAR TAP
	4-5/2100	3000	4000	3000	0	42	28	100/50	1937/0	0.83	1		LOWERED CHAR GRADUALLY BETWEEN 2000 AND 2400
	4-6/0000	2908	4000	1200	0	42	25.8	100/50	1553/0	1.02	1.5		COMBUSTOR GAS TEMP DROPPED TO 2300 °F TWICE
	4-6/0130	2900	4000	1600	0	42	27.8	100/70	1542/0	0.96	7		BETWEEN 0000 AND 0130 (SLAG NECK FAN ON)
	4-6/0150												PLUGGAGE CLEARED OUT BY ITSELF
3	4-6/1200	2600	4000	3500	4000	36	21.8	100/60	1503/0	0.78	3		COMB GAS TEMP UP AND DOWN 2100 TO 2900 °F
	4-6/1500	2900	4000	3200	4000	36	21.8	100/100	1550/0	0.81	7		RAN TEST FROM 1500 TO 1830
	4-6/1915											PLUGGING NOTED	
	4-6/2200	2950	4000	3000	4000	36	20.8	100/100	1568/0	0.75	2	(LOOKED BAD	SLAG NECK FAN ON
	4-7/0100	2900	4000	1800	3500	36	19.8	90/50	1172/0	0.80	1.5	ALL DAY)	
	4-7/0230	2750	4000	1500	0	35	28.8	90/50	1189/0	0.81	3		COMB. TEMP DROPPED TO 2400 ONCE, BACK UP TO 2900 °F
	4-7/0500												PLUGGAGE CLEARED OUT BY ITSELF FOUND ANCHOR BRICKS IN SLAG.

ATTACHMENT II: PDU OPERATING CONDITIONS DURING APRIL TAP HOLE PLUGGAGES

SLUG NO.	DATE/TIME	COMB TEMP °F	COMB COAL LB/HR	COMB CHAR LB/HR	RED COAL LB/HR	TOT COMB AIR 1000 LB/HR	COMB SEC AIR 1000 LB/HR	COAL/CHAR DAMPER POS %/%	COAL/CHAR OXYGEN LB/HR LB/HR	INPUT COMB STOICH	TIME @ CONDITION HR	SLAG TAP OBSERVATIONS	COMMENTS
4	4-8/0930	3050	4000	4000	4000	39	24.7	90/40 100/0	943/0	0.65	?	NECK BEGINNING TO PLUG	ADARS DOWN PRIOR TO THIS
	4-8/1030	2975	4000	4000	5300	39.5	23.0	100/0	943/0	0.66	.5		STARTED SLAG NECK FAN
	4-8/1100	3000	4000	0	4000	34	17.8	100/0	925/0	0.96	1		
	4-8/1200	2975	5000	0	4000	46	31.8	100/0	915/0	1.01	1		SLAG NECK FAN OFF
	4-8/1300												ALL COAL OUT; LARGE AMOUNT OF MANUAL RODDING REQUIRED. FOUND SLAG(?) BALLS WHICH FELL FROM DIFFUSER.
5	4-9/1900	2800	4000	0	0	39	27.4	100/10	0/0	0.97	4		
	4-9/2300	2850	4000	0	0	41	27.6	100/0	0/0	1.02	1		SLAG NECK FAN ON; COAL FEEDER FLUSH
	4-9/2355												SLAG TAP OPENED BY ITSELF
6	4-10/0700	2875	4000	2600	4200	41	25.2	80/40	0/944	0.79	4		FOUND WATER LEAK INTO GASIFIER AT 1000
	4-10/1100	2750	4000	2600	4200	41	25.0	80/0	0/943	0.77	1		COMB TEMP ERRATIC FROM 1000-1200
	4-10/1200	2900	4000	2600	4200	41	27.5	80/0	0/946	0.77	2	CHUNKS DROPPING	
	4-10/1400	3025	4000	2600	4200	36.3	22.9	80/0	933/938	0.76	1		
	4-10/1500	3050	4000	2600	4200	31.9	18.4	80/0	1519/1526	0.82	1	2/3 CLOSED	OFF COAL & O ₂
	4-10/1550												OUTAGE INSPECTION & REPAIRS:
													① LEAKS: ① SLAG NECK FAN EXHAUST, 3-5 GPM
													① 4A SEC AIR NOZZLE, WEEPER
													② 2 FT OF DEBRIS ON COMBUSTOR FLOOR
													③ REPAIRED LEAKS
													④ ADDED SLAG DAM

ATTACHMENT II

(SHEET 2 OF 3)

PLUG NO.	DATE/ TIME	COMB TEMP °F	COMB COAL LB/HR	COMB CHAR LB/HR	RED COAL LB/HR	TOT COMB AIR 1000 LB/HR	COMB SEC AIR 1000 LB/HR	COAL/CHAR DAMPEN PPS %/%	COAL/CHAR OXYGEN LB/HR/LB/HR	INPUT COMB STOICH	TIME @ CONDITION HR	SLAG TAP OBSERVATIONS	COMMENTS
7	4-15/1500	2800	2500	4000	4000	35	21.5	100/60	0/1905	0.88	3		SOME CHAR FLUSHES
	4-15/1800	2800	2500	5000	4000	35	21.5	100/60	0/1911	0.78	5		COMB TEMP ERRATIC; DOWN TO 2000°F TWICE
	4-16/0000	ADARS											SLAG NECK FAN ON (CHAR UP/DOWN BETWEEN 4.5°F)
	4-16/0100				NOT								COAL OFF/OIL ON
	4-16/0645							A VAIL					GASIFIER SHUT DOWN
													OUTAGE INSPECTION & REPAIRS:
													① PLUG WAS GREENISH IN COLOR; NOT AS DENSE AS PAST PLUGGAGES
													② 2 1/2 TO 3 FT OF DEBRIS ON FLOOR
													③ REPLACED BRICK SLAG DAM
													④ NO LEAKS FOUND
8	4-22/1000	2800	3700	0	0	42	28.7	100/60	0/0	1.13	3		
	4-22/1200	2625	4000	3000	4000	42	26.7	100/60	0/0	0.69	3		SLAG NECK FAN ON
	4-22/1500	2600	4000	4500	3700	30	14.7	80/80	1491/1563	0.66	2.5		
	4-22/1830	2800	4000	0	3000	30	14.7	80/80	0/2414	1.04	.5		SLAG NECK FAN OFF
	4-22/1930	2925	4000	0	0	39	27	80/80	0/2479	1.27	3		
	4-22/2200												OFF COAL/ON OIL
													OUTAGE INSPECTION & REPAIRS:
													① SLAG COIL DROOPED IN CENTER
													② 1 FT DEBRIS ON COMBUSTOR FLOOR (IRON POOLS)
													③ FOUND REFRACTORY IN SLAG
													④ THREE WATER LEAKS: ① FS NOZZLE, 2GPM SLAG COIL, WEEPER AL. WEEPER
													⑤ REPAIRED LEAKS, COIL; ADDED FLOOR BRICK/RAM

ATTACHMENT II

Analysis of Slag and Pluggage Material - April 1981

Date of Sample	4/3/81	4/8/81	4/11/81	Unkown [*]	4/12/81	4/12/81
Time of Sample	1500			Balls from	Reductor	14:30
Origin of Sample	Ladle	Pluggage	Pluggage	Cool. Pond	Slag	Combustor Wall
IT, °F		2070	1960	2020		
ST, °F		2290	2280	2140		
HT, °F		2600	2470	2230		
FT, °F		2700+	2510	2500		
SiO ₂	42.4	53.0	43.2	48.5	49.5	48.4
Al ₂ O ₃	22.1	26.9	29.4	22.3	21.6	20.8
Fe ₂ O ₃	30.0	11.8	19.9	22.4	22.7	24.7
CaO	1.7	2.6	2.2	2.2	2.3	2.1
MgO	0.6	0.9	0.7	0.8	0.7	0.7
Na ₂ O	0.5	0.8	0.6	0.9	0.7	0.7
K ₂ O	0.7	1.1	1.0	1.1	1.1	1.0
TiO ₂	0.7	1.0	0.9	0.8	0.8	0.8
SO ₃	0.9	0.1	0.4	0.1	< 0.1	0.5
CR ₂ O ₃	0.2	< 0.1	1.2	< 0.1	< 0.1	< 0.1
TOTAL	99.8	98.2	99.5	99.1	99.4	99.7
Base/Acid Ratio	0.514	0.213	0.332	0.383	0.382	0.417
Equiv. Silica %	56.76	77.60	65.45	65.63	65.82	63.77
Refractory in Slag %	2.3	6.9	10.6	2.3	1.6	0.8

* Sample is 23.6% Ash

Analysis of Slag and Pluggage Material - April 1981

Date of Sample	4/15/81	4/16/81	4/16/81	4/16/81	4/20/81	4/21/81
Time of Sample	0800				0600	0600
Origin of Sample	Ladle	Comb Flr Buildup- Top Layer	Comb Flr Buildup- Bottom Layer	Pluggage	Ladle	Ladle
IT, °F	1940	2200	2140	2150	1960	1970
ST, °F	2060	2420	2310	2310	2100	2090
HT, °F	2320	2590	2540	2500	2330	2350
FT, °F	2400	2660	2650	2700+	2570	2610
SiO ₂		48.91	40.13	54.53		
Al ₂ O ₃		34.07	31.68	30.80		
Fe ₂ O ₃		17.48	29.39	6.51		
CaO		4.17	2.08	3.00		
MgO		1.01	0.67	0.89		
Na ₂ O		0.16	0.39	0.77		
K ₂ O		0.53	0.69	1.43		
TiO ₂		1.33	1.22	1.45		
SO ₃		0.01	0.02	0.07		
Cr ₂ O ₃		0.21	1.21	0.18		
TOTAL		107.2	107.3	99.61		
Base/Acid Ratio		0.277	0.455	0.145		
Equiv. Silica %		68.34	55.53	83.98		
Refractory in Slag %		14.28	12.89	10.98		

COMBUSTION ENGINEERING, INC.
KREISINGER DEVELOPMENT LABORATORY
CHEMICAL SYSTEMS ENGINEERING
WINDSOR, CONN.

ATTACHMENT IIIB-1: COAL AND/OR ASH ANALYSES REPORT

COMPANY: C-E/PDU
LOCATION: WINDSOR
SAMPLE ID: RAW COAL
CONTRACT: 9080

DATE: 4/28/81

KDL NUMBER: 6791

PROJECT: 904009

	AS RECEIVED	MOISTURE FREE	MOISTURE AND ASH FREE
AIR DRY LOSS, WT. PERCENT	.3		
PROXIMATE, WT. PERCENT			
MOISTURE (TOTAL)	1.1		
VOLATILE MATTER	37.5	37.9	41.8
FIXED CARBON (DIFF)	52.1	52.7	58.2
ASH	9.3	9.4	
TOTAL	100.0	100.0	100.0
HHV, BTU/LB	13500.	13645.	15060.
LB ASH/MM BTU	6.9		
ULTIMATE, WT. PERCENT			
MOISTURE (TOTAL)	1.1		
HYDROGEN	4.7	4.8	5.3
CARBON	75.0	75.8	83.6
SULFUR	2.4	2.4	2.6
NITROGEN	1.5	1.5	1.7
OXYGEN (DIFF)	6.0	6.1	6.8
ASH	9.3	9.4	
TOTAL	100.0	100.0	100.0

ASH FUSIBILITY	RED ATM
I.T. DEG F	1960.
S.T. "	2270.
H.T. "	2360.
F.T. "	2420.
TEMP. DIFF. (F.T.-I.T.)	460.

ASH COMPOSITION, WT. PERCENT

SI02	47.4
AL2O3	22.9
FE2O3	22.2
CAO	2.3
MGO	.8
NA2O	.6
K2O	1.2
TiO2	1.1
P2O5	N/A*
SO3	1.3

BASE/ACID RATIO	.33
FE2O3/CAO RATIO	9.50
SI02/AL2O3 RATIO	2.07

TOTAL 99.8

* N/A = NOT ANALYZED

COMBUSTION ENGINEERING, INC.
KREISINGER DEVELOPMENT LABORATORY
CHEMICAL SYSTEMS ENGINEERING
WINDSOR, CONN.

ATTACHMENT IIIB-2: COAL AND/OR ASH ANALYSES REPORT

COMPANY:	C-E/FDU	DATE:	4/28/81
LOCATION:	WINDSOR	KDL NUMBER:	6789
SAMPLE ID:	PC FROM A-1 FEEDER		
CONTRACT:	9080	PROJECT:	904009

	AS RECEIVED -----	MOISTURE FREE -----	MOISTURE AND ASH FREE -----
PROXIMATE, WT. PERCENT			
MOISTURE (TOTAL)	.6		
VOLATILE MATTER	36.8	37.0	40.8
FIXED CARBON (DIFF)	53.4	53.7	59.2
ASH	9.2	9.3	
TOTAL	100.0	100.0	100.0
HHV, BTU/LB	3435.	3455.	3810.
LB ASH/MM BTU	26.8		
ULTIMATE, WT. PERCENT			
MOISTURE (TOTAL)	.6		
HYDROGEN	4.8	4.8	5.3
CARBON	74.8	75.2	82.9
SULFUR	2.3	2.4	2.6
NITROGEN	1.5	1.5	1.6
OXYGEN (DIFF)	6.8	6.8	7.6
ASH	9.2	9.3	
TOTAL	100.0	100.0	100.0

ASH FUSIBILITY	RED ATM	
I.T. DEG F	1960.	
S.T. "	2190.	
H.T. "	2300.	
F.T. "	2350.	
TEMP. DIFF. (F.T.-I.T.)	390.	

SCREEN ANALYSES	
MESH	%RET
+16	--
+30	trace
+50	0.2
+100	2.5
+200	19.8
+325	19.7
-325	57.8

ASH COMPOSITION, WT. PERCENT	
SiO2	49.5
Al2O3	21.8
Fe2O3	21.3
CaO	2.3
MgO	.8
Na2O	.6
K2O	1.2
TiO2	1.2
P2O5	N/A*
SO3	1.1

BASE/ACID RATIO	.36
FE2O3/CAO RATIO	9.10
SiO2/AL2O3 RATIO	2.27

TOTAL	99.8
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* N/A = NOT ANALYZED

COMBUSTION ENGINEERING, INC.
KREISINGER DEVELOPMENT LABORATORY
CHEMICAL SYSTEMS ENGINEERING
WINDSOR, CONN.

ATTACHMENT IIIB-3: COAL AND/OR ASH ANALYSES REPORT

COMPANY: C-E/PDU
LOCATION: WINDSOR
SAMPLE ID: CHAR FROM B-1
CONTRACT: 9080

PROJECT: 904009

DATE: 4/28/81
KDL NUMBER: 6792

	AS RECEIVED -----	MOISTURE FREE -----	MOISTURE AND ASH FREE -----
PROXIMATE, WT. PERCENT			
MOISTURE (TOTAL)	.0		
VOLATILE MATTER	1.7	1.7	2.8
FIXED CARBON (DIFF)	59.4	59.4	97.2
ASH	38.9	38.9	
TOTAL	100.0	100.0	100.0
HHV, BTU/LB	8740.	8740.	14300.
LB ASH/MM BTU	44.5		
ULTIMATE, WT. PERCENT			
MOISTURE (TOTAL)	.0		
HYDROGEN	.3	.3	.5
CARBON	57.9	57.9	94.7
SULFUR	2.0	2.0	3.2
NITROGEN	.7	.7	1.1
OXYGEN (DIFF)	.2	.2	.5
ASH	38.9	38.9	
TOTAL	100.0	100.0	100.0
ASH FUSIBILITY		SCREEN ANALYSES	
I.T. DEG F	RED ATM 1920.	MESH	%RET
S.T. "	2170.	+16	0.1
H.T. "	2340.	+30	0.2
F.T. "	2410.	+50	0.9
TEMP. DIFF. (F.T.-I.T.)	490.	+100	8.7
		+200	30.1
ASH COMPOSITION, WT. PERCENT		+325	16.8
SI02	51.5	-325	43.2
AL2O3	21.8		
FE2O3	19.9		
CAO	2.5		
MGO	.8		
NA2O	.6		
K2O	1.4		
TIO2	1.2		
P2O5	N/A*		
SO3	.4		
		BASE/ACID RATIO	.34
		FE2O3/CAO RATIO	8.04
		SI02/AL2O3 RATIO	2.36
TOTAL	100.1		

* N/A = NOT ANALYZED

TEST DESCRIPTION:

First test with oxygen enrichment. Combustor-only firing. Combustor coal set at 4200; char at 0; total air to combustor set at 29300; and oxygen set at 2000.

	<u>Objective</u>	<u>Actual</u>
<u>Coal Analysis (As Fired)</u>		
<u>Ultimate Analysis, wt %</u>		
carbon		75.85
hydrogen		5.05
oxygen		6.10
nitrogen		1.50
sulfur		2.20
moisture		0.40
ash		8.90
<u>Proximate Analysis, wt %</u>		
fixed carbon		52.90
volatile matter		37.80
moisture		0.40
ash		8.90
HHV of dried coal, Btu/lb		13200
<u>Char Analysis, wt %</u>		
carbon		45.10
ash		51.88
sulfur		2.70
moisture		0
HHV of char, Btu/lb		6246
<u>Solid Feed to Gasifier, lbs/hr</u>		
combustor coal	4200	4184
combustor char		0
reductor coal		0
<u>Air Flow to Gasifier, lbs/hr</u>		
primary air to combustor		10816
primary air to reductor		0
secondary air to combustor		17750
scanner/igniter air to combustor		1532
slag neck tempering air		0
total air to gasifier	29300	30098
<u>O₂ Flow to Combustor Coal/Char</u>	1500/0	1536/0
<u>Moisture in Air, lbs H₂O/lbs air</u>		.0066
<u>Gas Pressure, in. W.C. at Reductor Outlet</u>		-1.70
<u>Temperature, °F</u>		
primary air		336
secondary air		660
combustor gas		2916
reductor outlet gas		1905
ambient air		55

Objective Actual

Gross Energy Inputs to Gasifier, x 10⁶ Btu/hr

combustor coal	55.19
combustor char	0
reductor coal	0
sensible energy of air to combustor	3.38
sensible energy of air to reductor	0
total energy to gasifier	58.57

Gas Analysis at Stretford Outlet, % Vol

CO	6.67
CO ₂	1.62
H ₂	0.10
H ₂ O	0.47
N ₂	71.49
H ₂ S	0
CH ₄	0
O ₂	0
COS	0

Gas Flows at Stretford Outlet, lbs/hr

CO	2150
CO ₂	8204
H ₂	22
H ₂ O	971
N ₂	23040
H ₂ S	0
CH ₄	0
O ₂	0
COS	0

Materials Leaving Gasifier, lbs/hr

CO	2150
CO ₂	8204
H ₂	22
H ₂ O	1857
N ₂	23040
H ₂ S	0
CH ₄	0
O ₂	0
COS	0
Char in gas from gasifier	428

Ash Flow Rates, lbs/hr

combustor coal ash	330.5
combustor char ash	0
reductor coal ash	0
ash in char from gasifier	248.7
slag leaving tap hole	82.0
combustor slagging efficiency	24.8

	<u>Objective</u>	<u>Actual</u>
<u>Char Balance, lbs/hr</u>		
char from gasifier		428
char to combustor		0
net char accumulation - bin		267
- thickener		149
<u>Carbon Balance</u>		
carbon to gasifier		3174
carbon from gasifier		3327
percent closure		-4.84
<u>Nitrogen Balance, lbs/hr</u>		
total nitrogen input to gasifier		22890
total nitrogen in product gas		23040
percent closure		-0.65
<u>Sulfur Balance, lbs/hr</u>		
sulfur in feed coal		92
sulfur in product gas (at Stretford outlet)		N/A
sulfur in slag		N/A
efficiency of sulfur removing		N/A
<u>Oxygen Balance, lbs/hr</u>		
total oxygen input to gasifier		8900
total oxygen in product gas		8843
percent closure		0.65
<u>Energy from Gasifier, x 10⁶ Btu/hr</u>		
chemical energy of raw gas		10.69
sensible energy of raw gas		20.33
chemical energy of char in gas		2.33
sensible energy of char in gas		0.25
heat radiated to slag tank		0.85
sensible energy of slag		0.06
heat of fusion of slag		0.01
waterwall heat absorption		22.60
HHV of Product Gas, Btu/scf (dry)		25.68
<u>Gasifier Stoichiometries, %</u>		
combustor stoichiometry	80	84.74
overall stoichiometry	80	84.74
<u>Percent Closure of Material and Energy Balance</u>		
total material to gasifier, lbs/hr		35815
total material from gasifier, lbs/hr		35784
percent closure of material balance	±5.00	0.09
total energy to gasifier, 10 ⁶ Btu/hr		58.57
total energy from gasifier, 10 ⁶ Btu/hr		57.13
percent closure of energy balance	±5.00	2.46
<u>Set Point Duration (hr)</u>		1.60

TEST DESCRIPTION:

Gasifier performance testing with oxygen firing and dense phase reductor coal feed. Firing conditions were 4000 lb/hr of coal to the combustor, 4000 lb/hr of coal to the reductor, and 41000 lb/hr of total air. The char flow rate was set based on a combustor stoichiometry of 70%. The oxygen flow rate was 2000 lb/hr behind the coal fuel nozzles.

Objective Actual

Coal Analysis (As Fired)

Ultimate Analysis, wt %

carbon	75.85
hydrogen	5.05
oxygen	6.10
nitrogen	1.50
sulfur	2.20
moisture	0.40
ash	8.90

Proximate Analysis, wt %

fixed carbon	N/A
volatile matter	N/A
moisture	0.4
ash	8.9
HHV of dried coal, Btu/lb	13200

Char Analysis, wt %

	<u>In</u>	<u>Out</u>
carbon	50	58.7
ash	50	41.3
sulfur	0	0
moisture	0	0
HHV of char, Btu/lb	7058	8475

Solid Feed to Gasifier, lbs/hr

combustor coal	4000	3970
combustor char		4681
reductor coal	4000	4066

Air Flow to Gasifier, lbs/hr

primary air to combustor	12565
primary air to reductor	353
secondary air to combustor	26190
scanner/igniter air to combustor	1714
slag neck tempering air	0
total air to gasifier	40822

O₂ Flow to Combustor Coal/Char

2000/0 1997/0

Moisture in Air, lbs H₂O/lbs air

0.006

Gas Pressure, in. W.C. at Reductor Outlet

N/A

Temperature, °F

primary air	321
secondary air	738
combustor gas	2930
reductor outlet gas	1845
ambient air	51

Objective

Actual

Gross Energy Inputs to Gasifier, $\times 10^6$ Btu/hr

combustor coal	52.37
combustor char	33.00
reductor coal	53.65
sensible energy of air to combustor	5.24
sensible energy of air to reductor	0
total energy to gasifier	144.25

Gas Analysis at Stretford Outlet, % Vol

CO	14.95
CO ₂	9.79
H ₂	4.74
H ₂ O	9.38
N ₂	60.42
H ₂ S	0
CH ₄	0.27
O ₂	0.45
COS	0

Gas Flows at Stretford Outlet, lbs/hr

CO	7435
CO ₂	7647
H ₂	170
H ₂ O	2999
N ₂	30050
H ₂ S	0
CH ₄	77
O ₂	257
COS	0

Materials Leaving Gasifier, lbs/hr

CO	7435
CO ₂	7647
H ₂	170
H ₂ O	2107
N ₂	30050
H ₂ S	0
CH ₄	77
O ₂	257
COS	0
Char in gas from gasifier	5020

Ash Flow Rates, lbs/hr

combustor coal ash	353
combustor char ash	2341
reductor coal ash	362
ash in char from gasifier	2072
slag leaving tap hole	984
combustor slagging efficiency	36.59

	<u>Objective</u>	<u>Actual</u>
<u>Char Balance, lbs/hr</u>		
char from gasifier		5020
char to combustor		4681
net char accumulation - bin		0
- thickener		321
<u>Carbon Balance</u>		
carbon to gasifier		8436
carbon from gasifier		8282
percent closure		1.8
<u>Nitrogen Balance, lbs/hr</u>		
total nitrogen input to gasifier		31090
total nitrogen in product gas		30050
percent closure		3.3
<u>Sulfur Balance, lbs/hr</u>		
sulfur in feed coal		177
sulfur in product gas (at Stretford outlet)		N/A
sulfur in slag		N/A
efficiency of sulfur removing		N/A
<u>Oxygen Balance, lbs/hr</u>		
total oxygen input to gasifier		12050
total oxygen in product gas		11940
percent closure		0.9
<u>Energy from Gasifier, x 10⁶ Btu/hr</u>		
chemical energy of raw gas		42.67
sensible energy of raw gas		26.88
chemical energy of char in gas		42.54
sensible energy of char in gas		2.81
heat radiated to slag tank		0.87
sensible energy of slag		0.75
heat of fusion of slag		0.17
waterwall heat absorption		21.25
<u>HHV of Product Gas, Btu/scf (dry)</u>		
		72.9
<u>Gasifier Stoichiometries, %</u>		
combustor stoichiometry	70	71.6
overall stoichiometry		44.6
<u>Material and Energy Balance</u>		
total material to gasifier, lbs/hr		55538
total material from gasifier, lbs/hr		53748
percent closure of material balance	±5.0	3.2
total energy to gasifier, 10 ⁶ Btu/hr		144.24
total energy from gasifier, 10 ⁶ Btu/hr		137.97
percent closure of energy balance	±5.0	4.4
<u>Set Point Duration (hr)</u>		
		3.0

Note: Gasifier performance testing (12-GP series) was performed in order to determine an optimum, practical set of operating conditions for a sustained operation.

TEST DESCRIPTION:

Gasifier performance testing with oxygen firing combustor-only test. Firing conditions were 4000 lb/hr of coal to the combustor and 40000 lb/hr of total air. The char flow rate was set based on a combustor stoichiometry of 70%. The oxygen flow rate was 2000 lb/hr behind the coal fuel nozzles.

	<u>Objective</u>	<u>Actual</u>
<u>Coal Analysis (As Fired)</u>		
<u>Ultimate Analysis, wt %</u>		
carbon		75.85
hydrogen		5.05
oxygen		6.10
nitrogen		1.50
sulfur		2.20
moisture		0.40
ash		8.90
<u>Proximate Analysis, wt %</u>		
fixed carbon		N/A
volatile matter		N/A
moisture		0.40
ash		8.90
HHV of dried coal, Btu/lb		13570
<u>Char Analysis, wt %</u>		
	<u>In</u>	<u>Out</u>
carbon	60.9	60.9
ash	39.1	39.1
sulfur	0	0
moisture	0	0
HHV of char, Btu/lb	8589	8589*
<u>Solid Feed to Gasifier, lbs/hr</u>		
combustor coal	4000	3927
combustor char		3918
reductor coal	0	0
<u>Air Flow to Gasifier, lbs/hr</u>		
primary air to combustor		11809
primary air to reductor		0
secondary air to combustor		25650
scanner/igniter air to combustor		1497
slag neck tempering air		0
total air to gasifier	40000	38956
<u>O₂ Flow to Combustor Coal/Char</u>	2000/0	2011/0
<u>Moisture in Air, lbs H₂O/lbs air</u>		0.014
<u>Gas Pressure, in. W.C. at Reductor Outlet</u>		N/A
<u>Temperature, °F</u>		
primary air		317
secondary air		712
combustor gas		2946
reductor outlet gas		1987
ambient air		77

*No analysis available; value assumed.

Objective

Actual

Gross Energy Inputs to Gasifier, x 10⁶ Btu/hr

combustor coal	53.29
combustor char	33.65
reductor coal	0
sensible energy of air to combustor	5.31
sensible energy of air to reductor	92.25
total energy to gasifier	

Gas Analysis at Stretford Outlet, % Vol

CO	8.87
CO ₂	14.99
H ₂	.39
H ₂ O	10.26
N ₂	65.05
H ₂ S	0
CH ₄	0
O ₂	0.45
COS	0

Gas Flows at Stretford Outlet, lbs/hr

CO	3810
CO ₂	10120
H ₂	12
H ₂ O	2837
N ₂	27960
H ₂ S	0
CH ₄	0
O ₂	220
COS	0

Materials Leaving Gasifier, lbs/hr

CO	3810
CO ₂	10120
H ₂	12
H ₂ O	2182
N ₂	27960
H ₂ S	0
CH ₄	0
O ₂	220
COS	0
Char in gas from gasifier	2896

Ash Flow Rates, lbs/hr

combustor coal ash	350
combustor char ash	1532
reductor coal ash	0
ash in char from gasifier	1132
slag leaving tap hole	751
combustor slagging efficiency	39.89

	<u>Objective</u>	<u>Actual</u>
<u>Char Balance, lbs/hr</u>		
char from gasifier		2896
char to combustor		3918
net char accumulation - bin		-1818
- thickener		781
<u>Carbon Balance</u>		
carbon to gasifier		5365
carbon from gasifier		6160
percent closure		-14.8**
<u>Nitrogen Balance, lbs/hr</u>		
total nitrogen input to gasifier		29610
total nitrogen in product gas		27960
percent closure		5.6
<u>Sulfur Balance, lbs/hr</u>		
sulfur in feed coal		86
sulfur in product gas (at Stretford outlet)		N/A
sulfur in slag		N/A
efficiency of sulfur removing		N/A
<u>Oxygen Balance, lbs/hr</u>		
total oxygen input to gasifier		11650
total oxygen in product gas		11690
percent closure		-0.4
<u>Energy from Gasifier, x 10⁶ Btu/hr</u>		
chemical energy of raw gas		17.29
sensible energy of raw gas		26.33
chemical energy of char in gas		24.88
sensible energy of char in gas		1.75
heat radiated to slag tank		0.88
sensible energy of slag		0.57
heat of fusion of slag		0.13
waterwall heat absorption		24.13
<u>HHV of Product Gas, Btu/scf (dry)</u>		33.1
<u>Gasifier Stoichiometries, %</u>		
combustor stoichiometry	70	69.4
overall stoichiometry		69.4
<u>Material and Energy Balance</u>		
total material to gasifier, lbs/hr		48814
total material from gasifier, lbs/hr		47953
percent closure of material balance	±5.0	1.8
total energy to gasifier, 10 ⁶ Btu/hr		92.24
total energy from gasifier, 10 ⁶ Btu/hr		95.98
percent closure of energy balance	±5.0	-4.1
<u>Set Point Duration (hr)</u>		3.0

**Balance off due to char HHV leaving gasifier assumption.

TEST DESCRIPTION:

Test at conditions set for extended run. Firing conditions were set at 8000 lbs/hr total coal, 35,300 lbs/hr air to the combustor, 6000 lbs/hr air to the reductor, and 2000 lbs/hr O₂ to the combustor. Combustor coal feed rate was set at 4000 lbs/hr; char feed rate was set based on a combustor stoichiometry of 70%.

	<u>Objective</u>	<u>Actual</u>
<u>Coal Analysis (As Fired)</u>		
<u>Ultimate Analysis, wt %</u>		
carbon		74.9
hydrogen		5.2
oxygen		7.1
nitrogen		1.4
sulfur		2.4
moisture		0.4
ash		8.6
<u>Proximate Analysis, wt %</u>		
fixed carbon		52.8
volatile matter		37.0
moisture		0.7
ash		9.5
HHV of dried coal, Btu/lb		13570
<u>Char Analysis, wt %</u>		
	<u>In</u>	<u>Out</u>
carbon	56.1	62.2
ash	41.0	35.1
sulfur	2.0	1.8
moisture	0	0
HHV of char, Btu/lb	8308	9155
<u>Solid Feed to Gasifier, lbs/hr</u>		
combustor coal	4000	3992
combustor char	As req'd.	3656
reductor coal	4000	4122
<u>Air Flow to Gasifier, lbs/hr</u>		
primary air to combustor		12023
primary air to reductor		5920
secondary air to combustor		22810
scanner/igniter air to combustor		1718
slag neck tempering air		65
total air to gasifier	41300	42530
O ₂ Flow to Combustor Coal/Char	2000/0	1902/0
Moisture in Air, lbs H ₂ O/lbs air		0.0095
Gas Pressure, in. W.C. at Reductor Outlet		-0.40
<u>Temperature, °F</u>		
primary air		331
secondary air		754
combustor gas		2942
reductor outlet gas		2010
ambient air		66

Objective

Actual

Gross Energy Inputs to Gasifier, x 10⁶ Btu/hr

combustor coal	54.16
combustor char	30.36
reductor coal	55.92
sensible energy of air to combustor	4.88
sensible energy of air to reductor	0.42
total energy to gasifier	145.7

Gas Analysis at Stretford Outlet, % Vol

CO	12.11
CO ₂	11.21
H ₂	4.43
H ₂ O	9.63
N ₂	62.44
H ₂ S	0
CH ₄	0
O ₂	0
COS	

Gas Flows at Stretford Outlet, lbs/hr

CO	6126
CO ₂	8907
H ₂	161.2
H ₂ O	3134
N ₂	31600
H ₂ S	0
CH ₄	26.18
O ₂	52.23
COS	0

Materials Leaving Gasifier, lbs/hr

CO	6126
CO ₂	8907
H ₂	161.2
H ₂ O	2895
N ₂	31600
H ₂ S	0
CH ₄	26.18
O ₂	52.23
COS	0
Char in gas from gasifier	4266

Ash Flow Rates, lbs/hr

combustor coal ash	343.3
combustor char ash	1499
reductor coal ash	354.5
ash in char from gasifier	1497
slag leaving tap hole	699.5
combustor slagging efficiency	38.0 %

	<u>Objective</u>	<u>Actual</u>
<u>Char Balance, lbs/hr</u>		
char from gasifier		4266
char to combustor		3656
net char accumulation - bin		350
- thickener		240
<u>Carbon Balance</u>		
carbon to gasifier		8128
carbon from gasifier		7731
percent closure		4.9
<u>Nitrogen Balance, lbs/hr</u>		
total nitrogen input to gasifier		32400
total nitrogen in product gas		31620
percent closure		2.4
<u>Sulfur Balance, lbs/hr</u>		
sulfur in feed coal		193
sulfur in product gas (at Stretford outlet)		N/A
sulfur in slag		N/A
efficiency of sulfur removing		N/A
<u>Oxygen Balance, lbs/hr</u>		
total oxygen input to gasifier		12.59
total oxygen in product gas		12.43
percent closure		1.2
<u>Energy from Gasifier, x 10⁶ Btu/hr</u>		
chemical energy of raw gas		36.47
sensible energy of raw gas		31.20
chemical energy of char in gas		39.05
sensible energy of char in gas		2.61
heat radiated to slag tank		0.57
sensible energy of slag		0.47
heat of fusion of slag		0.12
waterwall heat absorption		18.24
HHV of Product Gas, Btu/scf (dry)		59.85
<u>Gasifier Stoichiometries, %</u>		
combustor stoichiometry	70	68.23
overall stoichiometry		46.84
<u>Percent Closure of Material and Energy Balance</u>		
total material to gasifier, lbs/hr		56207
total material from gasifier, lbs/hr		54539
percent closure of material balance	±5.00	3.0
total energy to gasifier, 10 ⁶ Btu/hr		145.7
total energy from gasifier, 10 ⁶ Btu/hr	±5.00	128.7
percent closure of energy balance		11.7
<u>Set Point Duration (hr)</u>		2

TEST DESCRIPTION:

Gasifier performance testing with oxygen firing. Firing conditions were 4000 lb/hr of combustor coal, 4000 lb/hr of reductor coal and 43000 lb/hr total air. The char flow rate was set based on a combustor stoichiometry of 70%. The oxygen flow rate was 1500 lb/hr behind the coal fuel nozzles.

	<u>Objective</u>	<u>Actual</u>
<u>Coal Analysis (As Fired)</u>		
<u>Ultimate Analysis, wt %</u>		
carbon		74.95
hydrogen		5.20
oxygen		7.10
nitrogen		1.40
sulfur		2.40
moisture		0.40
ash		8.60
<u>Proximate Analysis, wt %</u>		
fixed carbon		N/A
volatile matter		N/A
moisture		0.40
ash		8.60
HHV of dried coal, Btu/lb		13890
<u>Char Analysis, wt %</u>		
	<u>In</u>	<u>Out</u>
carbon	60.9	60.9
ash	39.1	39.1
sulfur	0	0
moisture	0	0
HHV of char, Btu/lb	8589*	8589*
<u>Solid Feed to Gasifier, lbs/hr</u>		
combustor coal	4000	3926
combustor char		3620
reductor coal	4000	4158
<u>Air Flow to Gasifier, lbs/hr</u>		
primary air to combustor		12326
primary air to reductor		5870
secondary air to combustor		22650
scanner/igniter air to combustor		1860
slag neck tempering air		0
total air to gasifier		42708
<u>O₂ Flow to Combustor Coal/Char</u>	1500/0	1471/0
<u>Moisture in Air, lbs H₂O/lbs air</u>		0.010
<u>Gas Pressure, in. W.C. at Reductor Outlet</u>		N/A
<u>Temperature, °F</u>		
primary air		316
secondary air		732
combustor gas		2968
reductor outlet gas		1830
ambient air		67

*No analysis available; value assumed.

Objective Actual

Gross Energy Inputs to Gasifier, x 10⁶ Btu/hr

combustor coal	54.52
combustor char	31.08
reductor coal	57.74
sensible energy of air to combustor	4.76
sensible energy of air to reductor	0.43
total energy to gasifier	148.53

Gas Analysis at Stretford Outlet, % Vol

CO	13.43
CO ₂	9.06
H ₂	4.70
H ₂ O	6.62
N ₂	66.01
H ₂ S	0
CH ₄	0.19
O ₂	0
COS	0

Gas Flows at Stretford Outlet, lbs/hr

CO	6648
CO ₂	7045
H ₂	167
H ₂ O	2108
N ₂	32690
H ₂ S	0
CH ₄	53
O ₂	0
COS	0

Materials Leaving Gasifier, lbs/hr

CO	6648
CO ₂	7045
H ₂	167
H ₂ O	2497
N ₂	32690
H ₂ S	0
CH ₄	53
O ₂	0
COS	0
Char in gas from gasifier	3554

Ash Flow Rates, lbs/hr

combustor coal ash	338
combustor char ash	1415
reductor coal ash	358
ash in char from gasifier	1389
slag leaving tap hole	723
combustor slagging efficiency	41.22

Objective Actual

Char Balance, lbs/hr

char from gasifier	3554
char to combustor	3620
net char accumulation - bin	-300
- thickener	216

Carbon Balance

carbon to gasifier	8264
carbon from gasifier	6978
percent closure	15.6**

Nitrogen Balance, lbs/hr

total nitrogen input to gasifier	32510
total nitrogen in product gas	32690
percent closure	-0.5

Sulfur Balance, lbs/hr

sulfur in feed coal	194
sulfur in product gas (at Stretford outlet)	N/A
sulfur in slag	N/A
efficiency of sulfur removing	N/A

Oxygen Balance, lbs/hr

total oxygen input to gasifier	12210
total oxygen in product gas	11140
percent closure	8.8

Energy from Gasifier, x 10⁶ Btu/hr

chemical energy of raw gas	39.11
sensible energy of raw gas	27.83
chemical energy of char in gas	30.52
sensible energy of char in gas	1.98
heat radiated to slag tank	0.91
sensible energy of slag	0.55
heat of fusion of slag	0.12
waterwall heat absorption	21.19

HHV of Product Gas, Btu/scf (dry)

64.4

Gasifier Stoichiometries, %

combustor stoichiometry	70	65.3
overall stoichiometry		45.0

Material and Energy Balance

total material to gasifier, lbs/hr		55883
total material from gasifier, lbs/hr		53372
percent closure of material balance	±5.0	4.5
total energy to gasifier, 10 ⁶ Btu/hr		148.52
total energy from gasifier, 10 ⁶ Btu/hr		122.23
percent closure of energy balance	±5.0	17.7**

Set Point Duration (hr)

3.0

**Balances off due to char HHV assumption.

TEST DESCRIPTION:

This test is a repeat of Test 12-6A with a lower O₂ flow. Flow rates to the gasifier were set at 8000 lbs/hr total coal and 45000 lbs/hr total air. Char feed rate was set based on a combustor stoichiometry of 70%. Oxygen to the combustor was set at 1200 lbs/hr.

	<u>Objective</u>	<u>Actual</u>
<u>Coal Analysis (As Fired)</u>		
<u>Ultimate Analysis, wt %</u>		
carbon		74.35
hydrogen		4.85
oxygen		7.10
nitrogen		1.40
sulfur		2.40
moisture		.40
ash		9.50
<u>Proximate Analysis, wt %</u>		
fixed carbon		52.80
volatile matter		37.70
moisture		0.40
ash		9.50
HHV of dried coal, Btu/lb		13180
<u>Char Analysis, wt %</u>		
	<u>In</u>	<u>Out</u>
carbon	56.20	59.60
ash	41.20	37.80
sulfur	1.90	1.90
moisture	0	0
HHV of char, Btu/lb	8305	8825
<u>Solid Feed to Gasifier, lbs/hr</u>		
combustor coal	4000	3922
combustor char	As req'd.	3177
reductor coal	4000	4109
<u>Air Flow to Gasifier, lbs/hr</u>		
primary air to combustor		12197
primary air to reductor		5946
secondary air to combustor		25600
scanner/igniter air to combustor		2425
slag neck tempering air		0
total air to gasifier	45650	46166
<u>O₂ Flow to Combustor Coal/Char</u>	1000/0	1214/0
<u>Moisture in Air, lbs H₂O/lbs air</u>		.004
<u>Gas Pressure, in. W.C. at Reductor Outlet</u>		-2.80
<u>Temperature, °F</u>		
primary air		332
secondary air		722
combustor gas		2898
reductor outlet gas		1966
ambient air		45

ObjectiveActualGross Energy Inputs to Gasifier, x 10⁶ Btu/hr

combustor coal	52.55
combustor char	26.35
reductor coal	54.09
sensible energy of air to combustor	4.88
sensible energy of air to reductor	.39
total energy to gasifier	138.30

Gas Analysis at Stretford Outlet, % Vol

CO	13.02
CO ₂	10.62
H ₂	3.52
H ₂ O	7.00
N ₂	65.82
H ₂ S	0
CH ₄	0
O ₂	.04
COS	0

Gas Flows at Stretford Outlet, lbs/hr

CO	6641
CO ₂	8511
H ₂	128.70
H ₂ O	2297
N ₂	33580
H ₂ S	0
CH ₄	0
O ₂	21.68
COS	0

Materials Leaving Gasifier, lbs/hr

CO	6641
CO ₂	8511
H ₂	128.70
H ₂ O	2483
N ₂	33580
H ₂ S	0
CH ₄	0
O ₂	21.68
COS	0
Char in gas from gasifier	3845

Ash Flow Rates, lbs/hr

combustor coal ash	379.20
combustor char ash	1309
reductor coal ash	390.40
ash in char from gasifier	1519
slag leaving tap hole	559.20
combustor slagging efficiency	33.19

Objective Actual

Char Balance, lbs/hr

char from gasifier		3177
char to combustor		3177
net char accumulation - bin		0
- thickener		632

Carbon Balance

carbon to gasifier		7809
carbon from gasifier		7393
percent closure		5.32

Nitrogen Balance, lbs/hr

total nitrogen input to gasifier		35150
total nitrogen in product gas		33600
percent closure		4.42

Sulfur Balance, lbs/hr

sulfur in feed coal		193
sulfur in product gas (at Stretford outlet)		N/A
sulfur in slag		N/A
efficiency of sulfur removing		N/A

Oxygen Balance, lbs/hr

total oxygen input to gasifier		12510
total oxygen in product gas		12210
percent closure		2.41

Energy from Gasifier, x 10⁶ Btu/hr

chemical energy of raw gas		36.72
sensible energy of raw gas		30.83
chemical energy of char in gas		33.41
sensible energy of char in gas		2.30
heat radiated to slag tank		.83
sensible energy of slag		.44
heat of fusion of slag		.10
waterwall heat absorption		21.42

HHV of Product Gas, Btu/scf (dry)

57.11

Gasifier Stoichiometries, %

combustor stoichiometry	70	68.83
overall stoichiometry		46.82

Percent Closure of Material and Energy Balance

total material to gasifier, lbs/hr		57959
total material from gasifier, lbs/hr		55804
percent closure of material balance	±5.00	4.93
total energy to gasifier, 10 ⁶ Btu/hr		138.25
total energy from gasifier, 10 ⁶ Btu/hr		126.07
percent closure of energy balance	±5.00	8.83

Set Point Duration (hr)

1.7

TEST DESCRIPTION:

Gasifier performance testing with oxygen firing. Firing conditions were 4000 lb/hr of coal to the combustor and 4000 lb/hr of coal to the reductor. Char firing rate based on a combustor stoichiometry of 70%. Total air to the gasifier is 46000 lb/hr. Approximately 1000 lb/hr of O₂ is fired behind the char fuel nozzles.

	<u>Objective</u>	<u>Actual</u>
<u>Coal Analysis (As Fired)</u>		
<u>Ultimate Analysis, wt %</u>		
carbon		74.9
hydrogen		5.2
oxygen		7.1
nitrogen		1.4
sulfur		2.4
moisture		0.4
ash		8.6
<u>Proximate Analysis, wt %</u>		
fixed carbon		N/A
volatile matter		N/A
moisture		0.4
ash		8.6
HHV of dried coal, Btu/lb		13570
<u>Char Analysis, wt %</u>		
	<u>In</u>	<u>Out</u>
carbon	62.9	62.9
ash	37.1	37.1
sulfur	0	0
moisture	0	0
HHV of char, Btu/lb	8827	8827*
<u>Solid Feed to Gasifier, lbs/hr</u>		
combustor coal	4000	3987
combustor char		2581
reductor coal	4000	4128
<u>Air Flow to Gasifier, lbs/hr</u>		
primary air to combustor		12457
primary air to reductor		5813
secondary air to combustor		28030
scanner/igniter air to combustor		1506
slag neck tempering air		23
total air to gasifier		47829
O ₂ Flow to Combustor Coal/Char	0/1000	0/738
Moisture in Air, lbs H ₂ O/lbs air		0.008
Gas Pressure, in. W.C. at Reductor Outlet		-1.6
<u>Temperature, °F</u>		
primary air		314
secondary air		711
combustor gas		2879
reductor outlet gas		1899
ambient air		61

*No data available; value assumed.

Objective Actual

Gross Energy Inputs to Gasifier, x 10⁶ Btu/hr

combustor coal	54.08
combustor char	22.77
reductor coal	56.00
sensible energy of air to combustor	5.45
sensible energy of air to reductor	0.41
total energy to gasifier	138.71

Gas Analysis at Stretford Outlet, % Vol

CO	12.08
CO ₂	8.91
H ₂	4.29
H ₂ O	10.42
N ₂	64.29
H ₂ S	0
CH ₄	0
O ₂	0
COS	0

Gas Flows at Stretford Outlet, lbs/hr

CO	6740
CO ₂	7811
H ₂	172
H ₂ O	3739
N ₂	35870
H ₂ S	0
CH ₄	0
O ₂	0
COS	0

Materials Leaving Gasifier, lbs/hr

CO	6740
CO ₂	7811
H ₂	172
H ₂ O	2547
N ₂	35870
H ₂ S	0
CH ₄	0
O ₂	0
COS	0
Char in gas from gasifier	3277

Ash Flow Rates, lbs/hr

combustor coal ash	343
combustor char ash	958
reductor coal ash	355
ash in char from gasifier	1216
slag leaving tap hole	442
combustor slagging efficiency	33.98

Objective Actual

Char Balance, lbs/hr

char from gasifier	3277
char to combustor	2581
net char accumulation - bin	600
- thickener	77

Carbon Balance

carbon to gasifier	7702
carbon from gasifier	7085
percent closure	8.0

Nitrogen Balance, lbs/hr

total nitrogen input to gasifier	36400
total nitrogen in product gas	35870
percent closure	1.5

Sulfur Balance, lbs/hr

sulfur in feed coal	195
sulfur in product gas (at Stretford outlet)	N/A
sulfur in slag	N/A
efficiency of sulfur removing	N/A

Oxygen Balance, lbs/hr

total oxygen input to gasifier	12610
total oxygen in product gas	11790
percent closure	6.5

Energy from Gasifier, x 10⁶ Btu/hr

chemical energy of raw gas	39.81
sensible energy of raw gas	30.95
chemical energy of char in gas	28.93
sensible energy of char in gas	1.89
heat radiated to slag tank	0.82
sensible energy of slag	0.33
heat of fusion of slag	0.07
waterwall heat absorption	21.43

HHV of Product Gas, Btu/scf (dry)

58.8

Gasifier Stoichiometries, %

combustor stoichiometry	70	75.2
overall stoichiometry		49.7

Material and Energy Balance

total material to gasifier, lbs/hr		59263
total material from gasifier, lbs/hr		56858
percent closure of material balance	±5.0	4.1
total energy to gasifier, 10 ⁶ Btu/hr		138.71
total energy from gasifier, 10 ⁶ Btu/hr		124.26
percent closure of energy balance	±5.0	10.4

Set Point Duration (hr)

0.42

TEST DESCRIPTION:

Gasifier performance testing with oxygen firing. Firing conditions were set at 4000 lb/hr of coal to the combustor and 4000 lb/hr of coal to the reductor. Char firing rate was based on a combustor stoichiometry of 70%. Total air to the gasifier is 41000 lb/hr. Approximately 1000 lb/hr of O₂ is fired behind the coal fuel nozzles and 1000 lb/hr of O₂ behind the char fuel nozzles.

Objective Actual

Coal Analysis (As Fired)

Ultimate Analysis, wt %

carbon	74.9
hydrogen	5.2
oxygen	7.1
nitrogen	1.4
sulfur	2.4
moisture	0.4
ash	8.6

Proximate Analysis, wt %

fixed carbon	N/A
volatile matter	N/A
moisture	0.4
ash	8.6
HHV of dried coal, Btu/lb	13570

Char Analysis, wt %

	<u>In</u>	<u>Out</u>
carbon	64.2	64.2
ash	35.8	35.8
sulfur	0	0
moisture	0	0
HHV of char, Btu/lb	9007	9007*

Solid Feed to Gasifier, lbs/hr

combustor coal	4000	3954
combustor char		2585
reductor coal	4000	4129

Air Flow to Gasifier, lbs/hr

primary air to combustor	12279
primary air to reductor	5773
secondary air to combustor	23160
scanner/igniter air to combustor	1507
slag neck tempering air	0
total air to gasifier	42719

<u>O₂ Flow to Combustor Coal/Char</u>	1000/1000	738/738
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<u>Moisture in Air, lbs H₂O/lbs air</u>	0.009
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<u>Gas Pressure, in. W.C. at Reductor Outlet</u>	-1.9
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Temperature, °F

primary air	314
secondary air	729
combustor gas	2984
reductor outlet gas	1874
ambient air	61

*No data available; value assumed

Objective Actual

Gross Energy Inputs to Gasifier, x 10⁶ Btu/hr

combustor coal	53.64
combustor char	23.27
reductor coal	56.01
sensible energy of air to combustor	4.77
sensible energy of air to reductor	0.41
total energy to gasifier	138.10

Gas Analysis at Stretford Outlet, % Vol

CO	13.53
CO ₂	9.07
H ₂	5.85
H ₂ O	10.77
N ₂	61.79
H ₂ S	0
CH ₄	0
O ₂	0
COS	0

Gas Flows at Stretford Outlet, lbs/hr

CO	7160
CO ₂	7540
H ₂	185
H ₂ O	3667
N ₂	32720
H ₂ S	0
CH ₄	0
O ₂	0
COS	0

Materials Leaving Gasifier, lbs/hr

CO	7160
CO ₂	7540
H ₂	185
H ₂ O	2416
N ₂	32720
H ₂ S	0
CH ₄	0
O ₂	0
COS	0
Char in gas from gasifier	3279

Ash Flow Rates, lbs/hr

combustor coal ash	340
combustor char ash	925
reductor coal ash	355
ash in char from gasifier	1174
slag leaving tap hole	449
combustor slagging efficiency	35.49

COAL GASIFICATION DISTRIBUTION

C-E POWER SYSTEMS

H. E. Andrus - 9015-2227
H. J. Blaskowski - 9015-2227
S. S. Blackburn - 8001-EG05
C. R. Bozzuto - 9002-2228
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R. E. Lorentz - Chatt-914
E. H. Luther - 6107-1936
J. A. Makuch - 8001-2222
S. F. Mumford - 9011-2227
C. L. Richards - 8002-428
C. R. Russell - 9011-2227
A. P. Selker - 9002-2324
J. R. Stewart - 7032-1932
M. C. Tanca - 9015-2228
J. E. Thalhauser - 9539-6BB
P. R. Thibeault - 9015-2226

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