DOE/MC/31384 -- 5355
Distribution Category UC-132

Analysis and Control of the METC Fluid Bed Gasifier

Quarterly Report
July 1 - September 30, 1995

Work Performed Under Contract No.: DE-FG21-94MC31384

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
University of South Carolina
Swearingen Engineering Center
Columbia, South Carolina 29208

Disclaimer

I. Overview of Present Work

This document summarizes work performed for the period 7/01/95 to 9/30/95 on contract no. DE-FG21-94MC31384. Note that the previous progress report (made for the period 4/1/95 to 6/30/95) actually reported results through 9/30/95. As a result, this progress report will simply be an abbreviated version of that report. In this work, three components will form the basis for design of a control scheme for the Fluidized Bed Gasifier (FBG) at METC: 1) a control systems analysis based on simple linear models derived from process data, 2) review of the literature on fluid bed gasifier operation and control, and 3) understanding of present FBG operation and real world considerations.

Tasks accomplished during the present reporting period include: 1) Observation of the FBG during the week of July 17 to July 21, 2) Suggested improvements to the control of FBG backpressure and MGCR pressure, and 3) Data collection from FBG run #11 and transfer of data to USC.

II. Gasifier Run 11

Table 1 below summarizes the steady-state operating conditions for FBG run 11.

Coal Type	Montana #7
Coal Feed rate	70 lb/hr
Reactor Air flow	1025 scfh
Convey Air	1600 scfh
Steam flow rate	52 lb/hr
Cone Nitrogen flow	0 scfh
Cone Steam	9 lb/hr
Nitrogen Underflow	300 scfh
Operating Pressure	425 psi

Table 1: FBG Run #10 Baseline Operating Condition

Note that during the initial part of the run, 50 scfh of cone Nitrogen was fed instead of cone steam. The switch to cone steam was made part way through the run.

Table 2 summarizes the run 11 planned tests, and Tables 3 and 4 give the tests that were made during the run. Note that the run covered two time periods, from July 16 to 22, and July 24 to August 8. The data from run 11 includes changes in reactor air, coal feed rate, underflow N_2, reactor steam, switch from cone steam to cone Nitrogen, and switch from Montana #7 coal to coke breeze.

Test Period (TP#)	Hrs.	Cum. Time	Start Time	End Time	Coal Type	Coal Feed Rate	Reactor Air	Convey Air	Reactor Steam	Cone Steam	Cone N2	UnderFlow N2	Reactor Pressure	Test Parameters
						lb/h	scfh	scfh	lb/h	lb/h	scfh	scfh	psig	
	12	12				0	5000	0	0	0	50	350	425	Startup
	8	20			Montant #7	70	525-825	1600	52	0	50	350	425	Fill bed
1+++	12	32			#7	70	1025	1600	52	0	50	300	425	Stabilization
2*	12	44			#7	70	1085	1600	52	0	50	300	425	Reactor
3*	12	56			#7	70	1025	1600	52	0	50	300	425	Air
4	12	68			#7	70	1025	1600	52	[illegible]	0	300	425	Cone N2 to
5++	12	80			#7	70	1025	1600	45	7	0	300	425	Cone Steam
6	12	92			#7	70	1085	1600	45	7	0	300	425	
7***	6	98			#7	70	965	1600	45	7	0	300	425	Reactor Air
8	12	110			#7	70	1025	1600	45	7	0	300	425	
9	12	122			#7	88	1025	1600	45	7	0	300	425	Coal
10	12	134			#7	64	1025	1600	45	7	0	300	425	Feed
11	12	146			#7	70	1025	1600	45	7	0	300	425	Rate
12	12	158			#7	70	1025	1600	45	7	0	250	425	Underflow
13	12	170			#7	70	1025	1600	45	7	0	300	425	Nitrogen
14	12	182			#7	70	1025	1600	45	7	0	300	415	Rx Press.**
	10	192			Change Feed	0	1025 - 0 N2	1600 - 100 N2	0	0	100	300	425-0	Hot- Hold
15	10	202			Coke Breeze	70	825-1025	1600	45	7	0	500	425	Coke Breeze
16	8	210			Illinois #6	70	1200	1600	45	7	0	500	425	Bituminous
17	22	232			Blacksville #2	70	1200	1600	45	7	0	500	425	Coals
	8	240				0	4200-7000 N2	800 N2	0	0	100	2000	425-0	Cool Down

+++ Old Baseline (94FBG10). ++ New Baseline (95FBG11) *** Will not perform if time is off schedule. + May be replaced by Fort-Martin (Martiki) coal if available.

** Put PCV-713 on "Manual" mode. * Sample UF & OF each per hour during the 2nd half of TP#2 and the entire TP#3; total of 36 samples between TP#2 and 3.

Table 2: Test Matrix Planned for 95FBG11 (July 16 to 26, 1995)

Test Period (TP#)	Hrs.	Cum. Time***	Start Time	End Time	Coal Type	Coal Feed Rate	Reactor Air	Convey Air	Reactor Steam	Cone Steam	Cone N2	UnderFlow N2	Reactor Pressure	Test Parameters
						lb/h	scfh	scfh	lb/h	lb/h	scfh	scfh	psig	
	16	16	7/16/95 20:00	7/17/95 11:56		0	5000	0	0	0	50	350	425	Startup
	1.25	17.25	7/17/95 11:56	7/17/95 13:13	Montant #7	30.6	2300+	800-1600	0	0	55	350	425	Combustion/Fill Bed
	5.25	22.5	7/17/95 13:13	7/17/95 18:30	#7	70	525-825	1600	56	0	55	350	425	Stabilization
1a	4	26.5	7/17/95 18:30	7/17/95 22:21	#7	70	1025	1600	56	0	50	300	425	Baseline**
	6	32.5	7/17/95 22:21	7/18/95 4:30	Lost of coal feed due to feeder plug by foreign material in feed									Hot-Hold
1b	9	41.5	7/18/95 4:30	7/18/95 13:30	#7	70	1025	1600	52	0	50	300	425	Baseline*
2#	12	53.5	7/18/95 13:30	7/19/95 1:30	#7	70	1045	1600	52	0	50	300	425	Reactor Air
3#	12	65.5	7/19/95 1:30	7/19/95 13:30	#7	70	1025	1600	52	0	50	300	425	
4	13.25	78.75	7/19/95 13:30	7/20/95 2:45	#7	70	1025	1600	[illegible]	[illegible]	0	300	425	Cone N2 to Steam
5	6.75	85.5	7/20/95 2:45	7/20/95 9:32	#7	70	1025	1600	52	6	[illegible]	250	425	Baseline**
6	16	101.5	7/20/95 9:32	7/21/95 1:30	#7	70	1025	1600	52->60	[illegible]	0	250	425	Rx & Cone Steam
7	12.3	113.8	7/21/95 1:30	7/21/95 13:49	#7	80	1025	1600	66	9	0	250	425	Coal Feed Rate
8	12	125.8	7/21/95 13:49	7/22/95 1:40	#7	70	1025	1600	66	9	0	250	425	
9	12.2	138	7/22/95 1:40	7/22/95 13:52	#7	60	1025	1600	66	9	0	250	425	
	6	144	7/22/95 13:52	7/22/95 20:00		0	4200/7000 N2	800 N2	0	0	100	2000	425-0	Cool Down

* Old Baseline (94FBG10). ** New Baseline (95FBG11) *** Total Gasification Time = 115 hours

Sample UF & OF each per hour during the 2nd half of TP#2 and the entire TP#3; total of 19 samples between TP#2 and 3.

Table 3: Test Matrix Completed for 95FBG11 (July 16 to 22, 1995)

Test Period	Hrs.	Cum. Time***	Start Time	End Time	Coal Type	Coal Feed Rate lb/h	Reactor Air scfh	Convey Air scfh	Reactor Steam lb/h	Cone Steam lb/h	Cone N2 scfh	Underflow N2 scfh	Reactor Pressure psig	Test Parameters
	22	22	7/24/95 20:00	7/25/95 17:53		0	5000	0	0	0	50	350	425	Startup
	1	23	7/25/95 17:53	7/25/95 18:53	Montana #7	30.6	2300+	800-1600	0	0	55	350	425	Combustion
	1	24	7/25/95 18:53	7/25/95 20:00	#7	70	525-825	1600	66	0	55	350	425	Fill bed
	5.75	29.75	7/25/95 20:00	7/26/95 1:45	#7	70	1025	1600	66->52	0	50	300	425	Stabilization
1	5.5	35.25	7/26/95 1:45	7/26/95 7:15	#7	70	1025	1600	52	0	50	250	425	Baseline**
	12	47.25	7/26/95 7:15	7/26/95 19:13	Shut down due to valve malfunction									Shut Down
	1	48.25	7/26/95 19:13	7/26/95 20:15	#7	30.6	1025	1600	0	0	55	250	425	Combustion
		48.25	7/26/95 20:15		#7	30.6->70	500->1025	1600	60	0	55	250	425	Fill Bed
	5.25	53.5		7/27/95 1:30	#7	70	1025	1600	60->52	0	50	250	425	Stabilization
2	12	65.5	7/27/95 1:30	7/27/95 13:30	#7	70	1025	1600	52	0	50	250	425	Baseline**
3	12	77.5	7/27/95 13:30	7/28/95 1:30	#7	70	1025	1600	52	0	50	[illegible]	425	Underflow Nitrogen
4	12.75	90.25	7/28/95 1:30	7/28/95 14:17	#7	70	1025	1600	52	0	50	280	425	
5	11.3	101.55	7/28/95 14:17	7/29/95 1:30	#7	70	1025	1600	52	0	50	250	425	
6	12.43	113.98	7/29/95 1:30	7/29/95 13:50	#7	70	1025	1600	72	0	50	250	425	Reactor Steam
7	2.5	116.48	7/29/95 13:50	7/29/95 16:20	#7	70	1025	1600	52	0	50	250	425	
	3.75	120.23	7/29/95 16:20	7/29/95 20:00	Fixed rupture disc on secondary cyclone									Hot-Hold
	5.5	125.73	7/29/95 20:00	7/30/95 1:30	#7	70	825->1025	1600	52	0	50	250	425	Fill Bed
	13.25	138.98	7/30/95 1:30	7/30/95 14:42	#7	70	1025	1600	52	0	50	250	425	Stabilization
8	10.75	149.73	7/30/95 14:42	7/31/95 1:30	#7	70	1025	1600	57	0	50	250	425	Cone Steam
9	12	161.73	7/31/95 1:30	7/31/95 13:30	#7	70	1025->1400	1600	57	0	50	250	425	
10	12	173.73	7/31/95 13:30	8/1/95 1:30	#7	80	1400	1600	57	0	50	250	425	Coal Feed Rate
11	9	182.73	8/1/95 1:30	8/1/95 10:30	#7	70	1025	1600	52	0	50	250	425	Baseline**
12	75.42	258.15	8/1/95 10:30	8/4/95 13:49	#7	70	1085	1600	52	0	50	250	425	Reactor Air
	11	269.15	8/4/95 13:49	8/5/95 0:47	Allowing MGCR to load the sorbent									Hot-Hold
13	4.3	273.45	8/5/95 0:47	8/5/95 5:10	#7	70	1085	1600	52	0	50	250	425	Baseline**
	14.3	287.75	8/5/95 5:10	8/5/95 20:00	Loss of coal feed due to clinker									Shut Down
	3.85	291.6	8/5/95 20:00	8/5/95 23:50		0	4000	0	0	0	0	250	425	Heat Up
	1.75	293.35	8/5/95 23:50	8/6/95 1:35	#7	12	4000	800	0	0	0	250	425	Combustion/ Fill Bed
	4	297.35	8/6/95 1:35	8/6/95 5:30	#7	12->70	500->1085	1600	52	0	0	250	425	Stabilization
14	16.5	313.85	8/6/95 5:30	8/6/95 22:00	#7	70	1085	1600	52	0	0	250	425	Sorbent Test
15	12	325.35	8/6/95 22:00	8/7/95 10:00	Coke Breeze	70	1085	1600	55	0	0	400	425	Coke Breeze
	8.83	334.58	8/7/95 10:00	8/7/95 18:50	Loss of Rx Air and Steam due to Clinker									Shut Down
	1.44	336.12	8/7/95 18:50	8/7/95 20:15	Coke Breeze	70	500->1085	1600	0	0	0	400	425	Combustion/ Fill Bed
16	5.4	341.52	8/7/95 20:15	8/8/95 1:35	Coke Breeze	70	1085	1600	55	0	0	400	425	Stabilization
17	0.1	341.62	8/8/95 1:35	8/8/95 1:40	Blackville Coal	70	1085	1600	55	0	0	400	425	Bituminous Coal
	18.38	360	8/8/95 1:40	8/8/95 20:00	Cool Down									Cool Down/ Shut Down

* Old Baseline (94FBG10). ** New Baseline (95FBG12) *** Total Gasification Time = 261 hours % availability = 82% (319 hrs = 100%)

Table 4: Test Matrix Completed for 95FBG11 (July 24 to Aug 8, 1995)

Gasifier Operation and Control:

In operating and controlling the FBG a number of objectives must be met. They are summarized below:

1. No clinkering
2. High carbon conversion
3. Meet targeted gas make
4. Meet targeted bed density
5. High gas heating value
6. Meet targeted Fuel/noncombustible mole ratio
7. Meet targeted mean bed temperature
8. Maintain HOC balances and inventories.

Presently all of these objectives and more are considered by operators during gasifier operation. All inlet gas flow rates are flow controlled with simple PID-type controllers, gasifier backpressure is controlled via a split range controller, and MGCR pressure is controlled via a PID controller. The backpressure control is critical to steady operation of the gasifier, as fluctuations in backpressure impact inlet gas flowrates and bed density. More detail on backpressure and MGCR control is given in the next section. Typically the maximum bed temperature is maintained by adjusting the air flow setpoint, gas moisture content is maintained at 10% by adjusting the steam flow setpoint.

III. Backpressure and MGCR Control

Good pressure control is critical to successful operation of the FBG. Fluctuations in gasifier pressure affect inlet gas flowrates, gasifier temperatures, and downstream MGCR pressure. Over the last several gasifier runs, the FBG backpressure has been controlled using a split-range automatic controller. Most of the time this controller maintains the pressure within plus or minus 5 psi of setpoint. However, frequently the controller overreacts and the pressure swings dramatically. If the operator does not take the proper intervention steps immediately, the pressure swings will ultimately shut down the gasifier.

This section identifies several sources of problems with the present pressure control system and then suggests modifications to the present scheme.

i. Problems with the present control scheme

Below are summarized some of the major problems with the present backpressure controller.

1. *Split-range control scheme*: A large valve and a small valve operating in parallel are manipulated in order maintain desired FBG pressure. The small valve opens first to control pressure at low to moderate make-gas flowrates, while the large valve remains closed. At high make-gas flows, the small valve is open completely, and the large valve is manipulated to maintain pressure. At the operating condition used in the first four days of 95FBG11, the make-gas flow was such that the split-range controller operated at the crossover point from the large valve to the small valve (that is, the large valve closed, the small valve open). One can not expect good control in this region.

2. *Interactions with the MGCR pressure controller:* The MGCR pressure fluctuates due to a large dead time between the upstream valve and the vessel pressure (V-100). Fluctuations in the valve controlling the MGCR pressure (PV-254) affect the backpressure controller.

3. *Upstream disturbances:* The inlet gas flow controllers interact with the backpressure. Changes in inlet gas flowrates will affect gasifier pressure. Similarly gasifier pressure will affect inlet flow of gases. Most of the time when the gasifier backpressure cycles, so do the inlet gas flows.

4. *Controller tuning:* Optimal controller tuning parameters will change as the operating condition changes. For example, one would expect markedly different tuning parameters in the backpressure controller under conditions where the large valve is adjusted than under conditions where the small valve is being adjusted. In one observed instance, the backpressure loop was swinging rather dramatically. The operator on duty intervened by simply putting the controller in manual and maintaining a constant valve position. Almost immediately, the backpressure stabilized. This points to poor controller tuning.

5. *Buildup of solids at the control valve:* There is evidence to suggest that fine solids particles are accumulating just upstream of the control valve. In one case, backpressure was oscillating continuously with increasing amplitude. Finally, the pressure swings were large enough to force solids out of the gasifier and into the incinerator (and damaging the incinerator). After this 'burp' gasifier control was very good for a long period of time.

ii. Suggested modifications to backpressure and MGCR pressure controllers.

The following modifications are suggested in order to eliminate backpressure control problems:

A. Backpressure controller

1. Replace the split-range configuration with the following: Two valves placed in parallel (similar to the present configuration). One valve should be tied to a PID controller and will directly control FBG backpressure. This valve should be sized to cover the range of desired operating conditions. A second, larger valve will be used to let down system pressure quickly. This valve can only be manipulated manually or through a safety override. With this configuration, under normal, steady operation of the gasifier, the large valve will remain static and the controller will manipulate the other valve to maintain backpressure.

2. Install a purge system to remove solids accumulation in the exit line.

3. Establish good controller tuning guidelines - how controllers should be tuned and who should tune them. An autotuning facility available in most DCS's should be most useful.

B. MGCR pressure control

1. Implement a cascade control arrangement to reduce the large time lag between valve V-254 and vessel V-100. In a cascade arrangement, an inner controller would control the pressure just downstream of the valve V-254 or in the particulate removal vessel,

F-100. The outer or master controller maintains the pressure in V-100 by adjusting the setpoint of the inner controller. The result is a control system that responds much faster and rejects disturbances in upstream pressure.

C. Diagram of suggested backpressure and MGCR pressure control scheme.

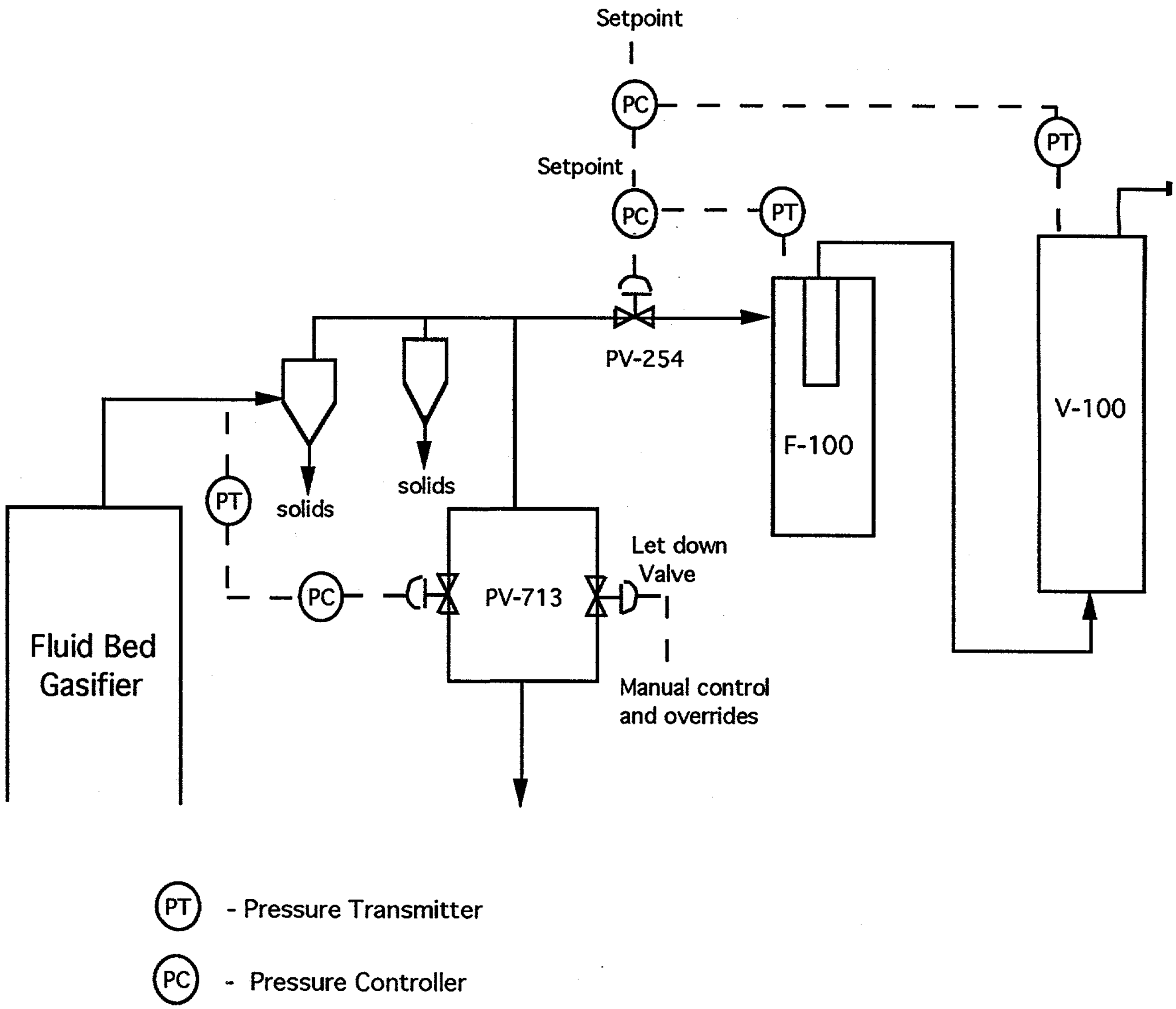

Figure 1 - Suggested FBG backpressure and MGCR pressure control scheme

IV. Data Collection and Transfer to USC

Data from the FBG run #11 has been collected by METC and transferred to USC via a removable hard disk. The disk contains approximately 80 mb of data which will be loaded onto the server at USC. In the next progress report, we will discuss FBG run #11 data in more detail and present a linear model of the gasifier derived from the data.