DOE/MC/26042-3302

PFBC HGCU Test Facility
Technical Progress Report

Fourth Quarter, CY 1992

DOE/MC/26042--3302

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DISCLAIMER

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Prepared for:

The United States Department of Energy
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DISCLAIMER

I. INTRODUCTION

This is the thirteenth Technical Progress Report submitted to the Department of Energy (DOE) in connection with the cooperative agreement between the DOE and Ohio Power Company for the Tidd PFBC Hot Gas Clean Up Test Facility. This report covers the period of work completed during the Fourth Quarter of CY 1992.

The following are highlights of the activities that occurred during this report period:

- Initial operation of the Advanced Particle Filter (APF) occurred during this quarter. The following table summarizes the operating dates and times.

Run #	Coal Fire Date	Coal Fire Time	Trip Date	Trip Time	Cause of Trip	Coal Fire Operating Time Hours:Mins	Coal Fire Cumulative Time Hours:Mins
1	10/28	18:10	11/01	23:32	a	101:22	101:22
2	11/17	9:33	11/17	10:50	b	1:17	102:39
3	11/21	18:41	11/24	22:50	c	76:09	178:48
4	11/25	12:11	12/07	9:56	d	285:45	464:33

a HGCU ash lockhopper valve plugged with ash.

b Primary cyclone ash pluggage.

c Problems with the coal water paste. Unit restarted warm 13 hours later.

d HGCU expansion joint #7 leak in internal ply of bellows.

- Problems encountered during these initial tests included hot spots on the APF, backup cyclone and instrumentation spools, two breakdowns of the backpulse air compressor, pluggage of the APF hopper and ash removal system, failure (breakage) of 21 filter candles, leakage of the inner ply of one (1) expansion joint bellows, and numerous other smaller problems. These operating problems are discussed in detail in a subsequent section of this report.

- Following shutdown and equipment inspection in December, design modifications were initiated to correct the problems noted above. The system is scheduled to resume operation in March, 1993.

II. WORK ACCOMPLISHED DURING THE REPORTING PERIOD

2.1 Detailed Design-Engineering

Engineering effort during this quarter was concentrated on following initial operation of the HGCU system at Tidd Plant. During most of the test periods, engineers from AEPSC and Westinghouse provided round-the-clock surveillance at Tidd Plant. Following shutdown of the system, we conducted equipment inspections, analyzed operating data, and devised plans for eliminating problems encountered during operation. The following is a summary of significant problems that arose during tests and the actual, or proposed, solutions to those problems.

Test of 10/28 to 11/02/92:

1. During the run, large areas of the surface of the backup cyclone exhibited temperatures higher than expected. The temperatures exceeded 750°F at some points, but were typically in the range of 300-500°F in the affected areas. Fans were used to reduce temperatures which exceeded 750°F.

   Upon inspection following shutdown, numerous cracks were observed in the internal refractory. It was also thought that the refractory may not have been dried completely following installation, and that steam might have formed in certain areas. Consequently, the refractory was dried again using a combination of internal heat (gas burner) and external heat (electric heating blankets). Following this dry out, all cracks and penetrations were sealed using an abrasion resistant refractory. Finally, a thin coating of this refractory was applied to the entire surface of the internal refractory.

   During the following test run, the cyclone surface temperatures were significantly lower in the affected areas. However, one area near the inlet nozzle exceeded 600°F during part of the run.

The original design temperature of the backup and bypass cyclones was 200°F. Code calculations by the manufacturer show that the vessels are capable of 750 and 725°F for the backup and bypass cyclones, respectively. Therefore, we are in the process of recertifying the vessels to these temperatures.

2. The APF outlet nozzle and portions of the APF head exhibited elevated temperatures (above 700°F) during this run. Fans were used to cool the hottest spots, and the system temperature was reduced to lower these temperatures. Upon inspection following shutdown, it became apparent that gaps between insulation and the head liner or pipe nozzles allowed hot gas to flow toward the affected areas.

   As a result of this inspection, several modifications were made to the head and nozzle insulation and liner to eliminate, or reduce, unwanted gas flow paths. These modifications eliminated some, but not all, of the hot spots.

3. While most of the piping system did not indicate excessive temperatures, certain nozzles in the two instrumentation spools exhibited elevated temperatures (up to 830°F). During the outage following this run, the instrumentation ports were opened up and resealed with refractory to eliminate any gas flow toward the nozzles. This proved to be quite successful and eliminated all but one of the hot spots, which reached 450°F in the next run.

4. During this run, pipe and nozzle movements were monitored and recorded. It was noted that the APF outlet nozzle moved up more than predicted. As a result, one support of the backup cyclone was lifted up about 1/4" off the support steel.

   In order to provide additional flexibility and reduce nozzle loads, it was decided to support the cyclone on spring supports. During the outage following this run, the necessary hardware was designed, purchased and installed. Additional guides were also installed to hold the cyclone and piping in the proper alignment.

5. Pluggage of the ash removal system is what ultimately forced the unit to shut down. Ash buildup in the lockhopper inlet isolation valve prevented full stroking of the valve. In addition, pressure instrumentation lines on the ash lockhopper system became plugged and caused the system logic to "hang up" on numerous occasions. In order to eliminate these problems, a drier source of purge air was installed to the lockhopper valves, and continuous purge air was installed on the pressure sensing lines. Many logic revisions were also made. The operation of the system proved to be much more reliable during the following test, but not trouble free.

6. Some of the air preheater elements became inoperable shortly after initial operation. It is believed that moisture may have caused grounding of the elements. The heater was used, but its output was limited. A replacement heater element assembly was ordered and will be installed prior to the next start-up. The start-up procedure of the heater will be changed to use reduced voltage initially to allow any residual moisture to dry out before full voltage is applied.

7. Visual inspection of the APF internals following shutdown revealed that the filter candles were in excellent condition with no ash deposits on them. Some ash accumulation was seen on the lower portion of the hopper liner. The internal portion of the APF above the tube sheet and piping downstream of the APF was extremely clean with no trace of ash.

Tests of 11/21 - 11/24 and 11/25 - 12/7/92:

Since these test runs occurred back-to-back, they will be discussed as one test run.

1. The major problem that occurred during this run was the failure of the backpulse air compressor on two occasions, 11/23 and again on 11/27. During the periods when the compressor was being repaired, high pressure nitrogen trucks were rented to allow backpulsing of the APF to continue. However, during the 17 hour time period the compressor was down and before the nitrogen supply could be set up, no filter cleaning was possible and, as a result, the APF

baseline ▲P increased significantly. The compressor failed as a result of inadequate lubrication in the fourth stage cylinder, which was caused by the incorrect location of the oil port in the cylinder liner. The second failure also resulted in a broken crosshead to the second/third stage pistons.

The cylinder liner was replaced following the second failure and a new crosshead was installed. Larger moisture separator drain valves were also installed since it was suspected that moisture carryover from the first to second stage may have also contributed to the crosshead failure. Following these repairs, the compressor was test run 125 hours without incident.

In order to ensure uninterrupted backpulsing should the compressor fail in the future, backup air compressors will be rented and maintained on site in standby mode to take over supplying backpulse air.

2. Ash buildup in the APF hopper became a chronic problem when backpulsing resumed following the first compressor outage. The high level alarm activated at that time evidently due to the large quantity of ash removed from the filter elements. The air purge at the ash outlet was used with partial success, and rapping on the outside of the APF hopper was less effective. Sudden opening of the lockhopper inlet valve, with full system ▲P across the valve, also helped clear the high level alarm on some occasions.

It is an open question whether the APF hopper would have become full if the compressor failure and resulting sudden ash loading had not occurred. Westinghouse is currently investigating the feasibility of installing a false hopper with a steeper slope, an air purge system or vibrator in the hopper. Whatever design is selected will be installed prior to the next test run.

3. On 12/28, the APF internals were removed from the vessel and placed into the maintenance tower. The following was observed:

   There were no broken candles in any of the middle or upper clusters.

   Cluster A Bottom: There were 15 broken candles; 14 of them were broken about 2" below the top, all adjacent to each other. The three outermost candles had fresh breaks, as there was no ash deposition on the fractured surface. One of the candles was broken about 15" from the bottom. There was ash bridging between the candles about halfway up the cluster, and on the outside half of the cluster.

   Cluster B Bottom: There were four broken candles; three of them broke about 2" below the top, and one of those was a fresh break. One candle broke about 15" from the bottom. The ash was built up about two-thirds of the length of the candles; and there were several candles which were cocked out of plumb.

Cluster C Bottom: There were two candles which broke about 15" from the bottom. Both of them were fresh breaks. There was an ash buildup about halfway up the candles, mostly on the outer half of the cluster. There were several candles which were cocked out of plumb.

On 12/30, the candles were cleaned of ash by knocking off the ash between the candles with wooden yard sticks, and then vacuuming up the dust from the floor below. Two surveillance candles will be removed from Cluster A Top, and two surveillance candles will be removed from Cluster A Middle.

We believe that the candle failures resulted from ash buildup in the hopper to such a level that it covered the lower portion of the bottom candles. This could induce bending stresses in the candles during backpulsing and other unpredictable thermal stresses. The primary reason for this theory is the lack of any failed candles in the upper and middle plenums.

All broken candles will be replaced, along with new gaskets, prior to the next test. Assuming that the APF ash hopper does not become plugged again, this type of failure should not reoccur.

4. The expansion joints are a 2-ply design, with a pressure gauge installed to monitor the pressure between the plies. During the last test run, the gauge on XJ7 indicated significant pressure, but below the system pressure. A hot spot on the top of the bellows also appeared at this time. It was later discovered that a leak at the pressure gauge thread resulted in a faulty reading. When the thread leak was eliminated, the inner ply pressure increased to system pressure and the unit was shut down.

XJ6/7 was removed from location on 12/15 and sent to Badger for disassembly and repair.

In the Badger shop, a pressure test was conducted on both expansion joints. XJ6 exhibited no loss in pressure from 25 psi overnight. XJ7 dropped from 25 psi to 0 in several minutes. On 12/17/92, XJ7 was disassembled. There was a large amount of condensation deposition on the internal bellows near the top center convolutions. Corrosion or mechanical pitting had occurred, mostly on the first two convolutions from the pipe weld, near the top of the bellows. The location of the leak could not be identified during the disassembly, as the seal weld between the two bellows was cut out in order to remove the bellows.

There were greenish-blue condensation deposits in the vicinity where the hot spot was observed during operation. The lowest three insulating bricks of the expansion joint near the pipe end were damaged to where they were mushy from moisture condensation. The bad portion of the bricks will be cut out and replaced with new bricks. At this time, it is suspected that the corrosion may be due to iron oxide causing accelerated uniform corrosion in local areas. A new section of bellows will be fabricated from C-22.

XJ6 was disassembled for inspection on 12/22. Badger reported that there was no observable pitting; however, some condensation deposits were discovered. This bellows will be sent out to a chemical lab for corrosion inspection.

The brickwork on the flanged end of XJ6 was found to be broken, probably due to shipping or handling. Allen Refractories will provide new bricks for XJ6 and repair the deteriorated bricks on XJ7.

On 12/29, Dolan Lab ran a pressure test on XJ7 bellows. A single leak was detected from one of the pits in the inner bellows. This bellows will be sent out to Cortest Labs for an EDS spectra analysis of the pits to more accurately define the mode of failure.

In order to preclude corrosion in the future, some expansion joint bellows may be externally insulated to keep the metal above the acid dew point.

5. The APF head exhibited hot spots near the knuckle weld throughout the test. The entire circumference of the head became hot enough (>300°F) to change the paint color. The hottest spot reached 703°F, and fans were used to limit the temperature to 650°F. Upon disassembly of the APF, a

circular plate, used to help support insulation between the APF head and tube sheet expansion cone, was found to be severely warped due to thermal stresses. The deformation of this plate would have opened up gaps between it and the insulation, thereby allowing a gas flow path to the shell.

Westinghouse plans to remove the plate since it is no longer deemed necessary. Additional design enhancements will be made to the head liner to mitigate any gas paths to the shell.

6. All air-actuated ball valves on the backpulse skid will be replaced with valves having an improved mounting bracket, stem, and coupling design. One valve became inoperable during this test due to a worn coupling.

7. The backpulse solenoid valves exhibited random failures to actuate during these tests. In all cases, the backup valve functioned properly. Upon inspection, galling was seen on the valves plugs and cylinder walls. Westinghouse is working with Atkomatic to improve the valve design.

2.3 Westinghouse Engineering & Design

See Appendix 1.

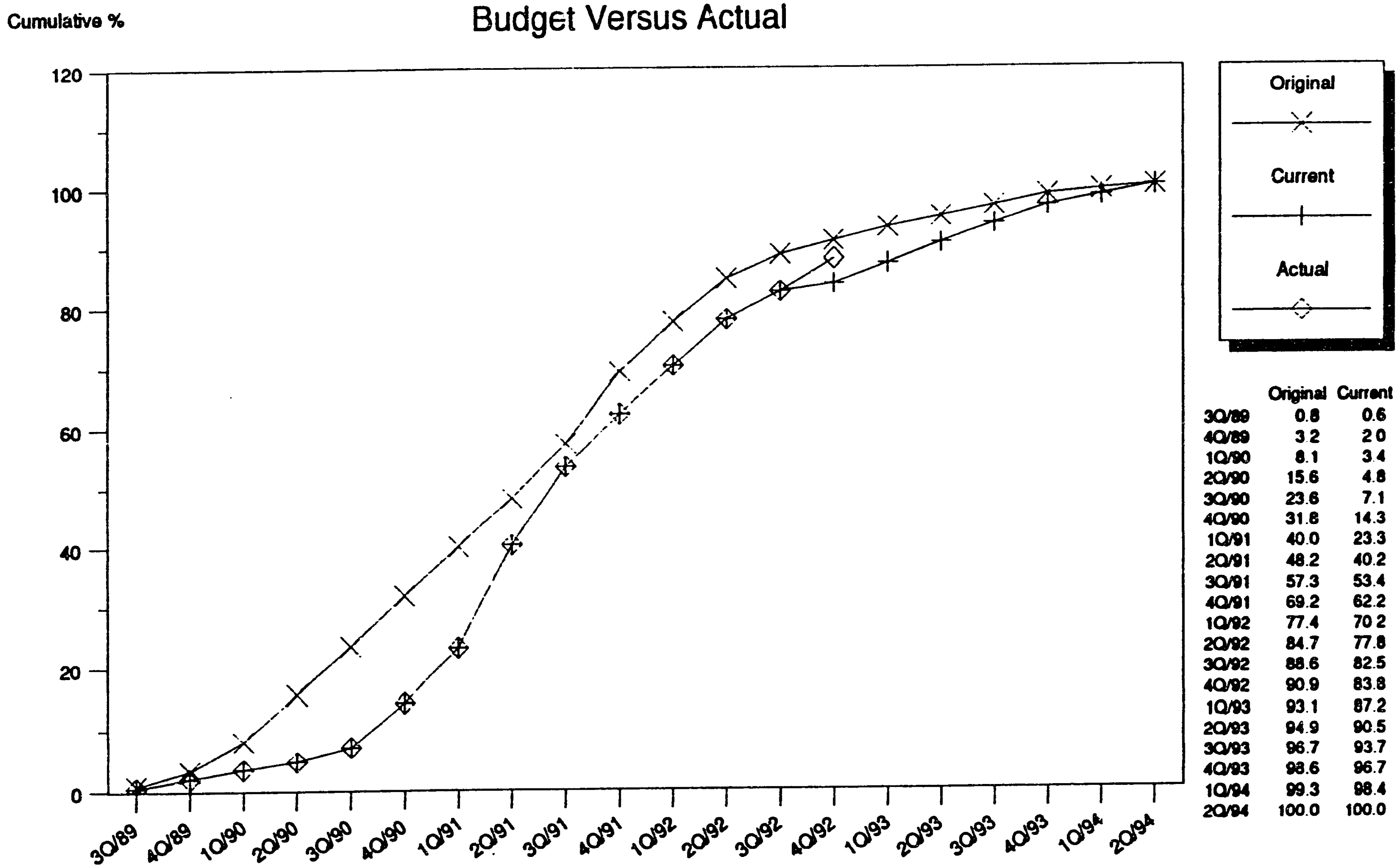
III. MANPOWER REPORT AND COST DATA

As of December 31, 1992, the AEPSC Engineering, Design and Project Support cumulative work-hours were 60,734 or 87.9% of the total 69,097 revised work-hours projected for the project. Figure 1 compares the actual work-hours expended versus the current estimate. For the reporting period, a total of 3,758 hours were charged to the project by AEPSC personnel.

The actual DOE's cost expenditures during the Fourth Quarter - 1992 were $1,132,038. As of December 31, 1992, the cumulative DOE's cost expenditures were $14,266,879. Figure 2 depicts the cumulative expenditure forecast for the project which includes Westinghouse cost share. During the Fourth Quarter - 1992, Westinghouse was paid a total of $158,520. Total payments to Westinghouse through December 31, 1992 were $5,209,596. No major contractual commitments during this reporting period were recorded.

Figure 1

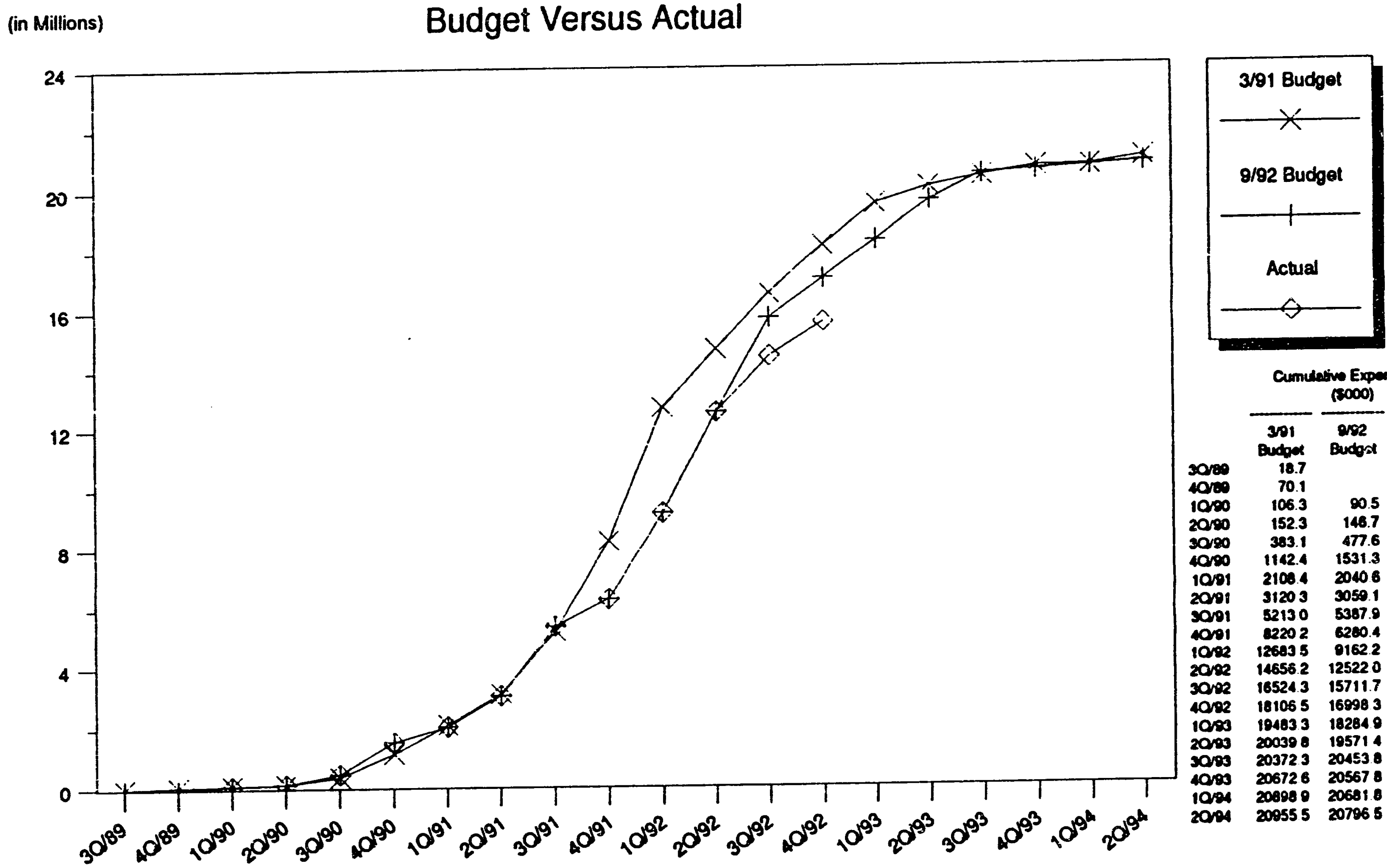
PFBC HOT GAS CLEAN-UP TEST PROGRAM
AEPSC Eng.,Design & Project Support Work-Hours
Budget Versus Actual



	Original	Current	Actual
3Q/89	0.8	0.6	0.6
4Q/89	3.2	2.0	2.0
1Q/90	8.1	3.4	3.4
2Q/90	15.6	4.8	4.8
3Q/90	23.6	7.1	7.1
4Q/90	31.8	14.3	14.3
1Q/91	40.0	23.3	23.3
2Q/91	48.2	40.2	40.2
3Q/91	57.3	53.4	53.4
4Q/91	69.2	62.2	62.2
1Q/92	77.4	70.2	70.2
2Q/92	84.7	77.8	77.8
3Q/92	88.6	82.5	82.5
4Q/92	90.9	83.8	87.9
1Q/93	93.1	87.2	
2Q/93	94.9	90.5	
3Q/93	96.7	93.7	
4Q/93	98.6	96.7	
1Q/94	99.3	98.4	
2Q/94	100.0	100.0	

Figure 2

PFBC HOT GAS CLEAN-UP TEST PROGRAM
Cumulative Expenditures
Budget Versus Actual



Cumulative Expenditures ($000)

	3/91 Budget	9/92 Budget	Actual
3Q/89	18.7		
4Q/89	70.1		
1Q/90	106.3	90.5	90.5
2Q/90	152.3	146.7	146.7
3Q/90	383.1	477.6	477.6
4Q/90	1142.4	1531.3	1531.3
1Q/91	2108.4	2040.6	2040.6
2Q/91	3120.3	3059.1	3059.1
3Q/91	5213.0	5387.9	5387.9
4Q/91	8220.2	6280.4	6280.4
1Q/92	12683.5	9162.2	9162.2
2Q/92	14656.2	12522.0	12522.0
3Q/92	16524.3	15711.7	14397.6
4Q/92	18106.5	16998.3	15569.3
1Q/93	19483.3	18284.9	
2Q/93	20039.8	19571.4	
3Q/93	20372.3	20453.8	
4Q/93	20672.6	20567.8	
1Q/94	20898.9	20681.8	
2Q/94	20955.5	20796.5	

ADVANCED PARTICLE FILTER

Technical Progress Report No. 10
October through December 1992

Prepared by

Westinghouse Science and Technology Center
Pittsburgh, Pennsylvania

For

American Electric Power Service Corporation
Columbus, Ohio

AEPSC Contract No. C8014

TIDD ADVANCED PARTICLE FILTER

STATUS

During this report period, Westinghouse has supported the startup and commissioning of the APF unit. Approximately 500 hours of operation were achieved in three separate test runs, Table 1. This report summarizes the major results of this testing and ongoing program activities.

Although promising test results were achieved regarding the filter performance and operation, twenty-one (21) candle elements were broken. This occurred when ash filled the vessel hopper causing dust to bridge between candle elements.

Table 1

Summary of APF/PFBC Operation - 1992

Test	Date	Hours of Operation (Coal)	Coal/Sorbent	Comments
1	10/28-11/2 (1992)	102	Pgh #8/Plum Run	APF Inspection
	11/15-11/17 (1992)	False Start - No Coal Feed		
2	11/21-11/25 (1992)	78	Pgh #8/Plum Run	Trip/Restart No Inspection
3	11/25-12/07 (1992)	286	Pgh #8/Plum Run Ohio #6/Plum Run	APF Inspection
		466		

DISCUSSION

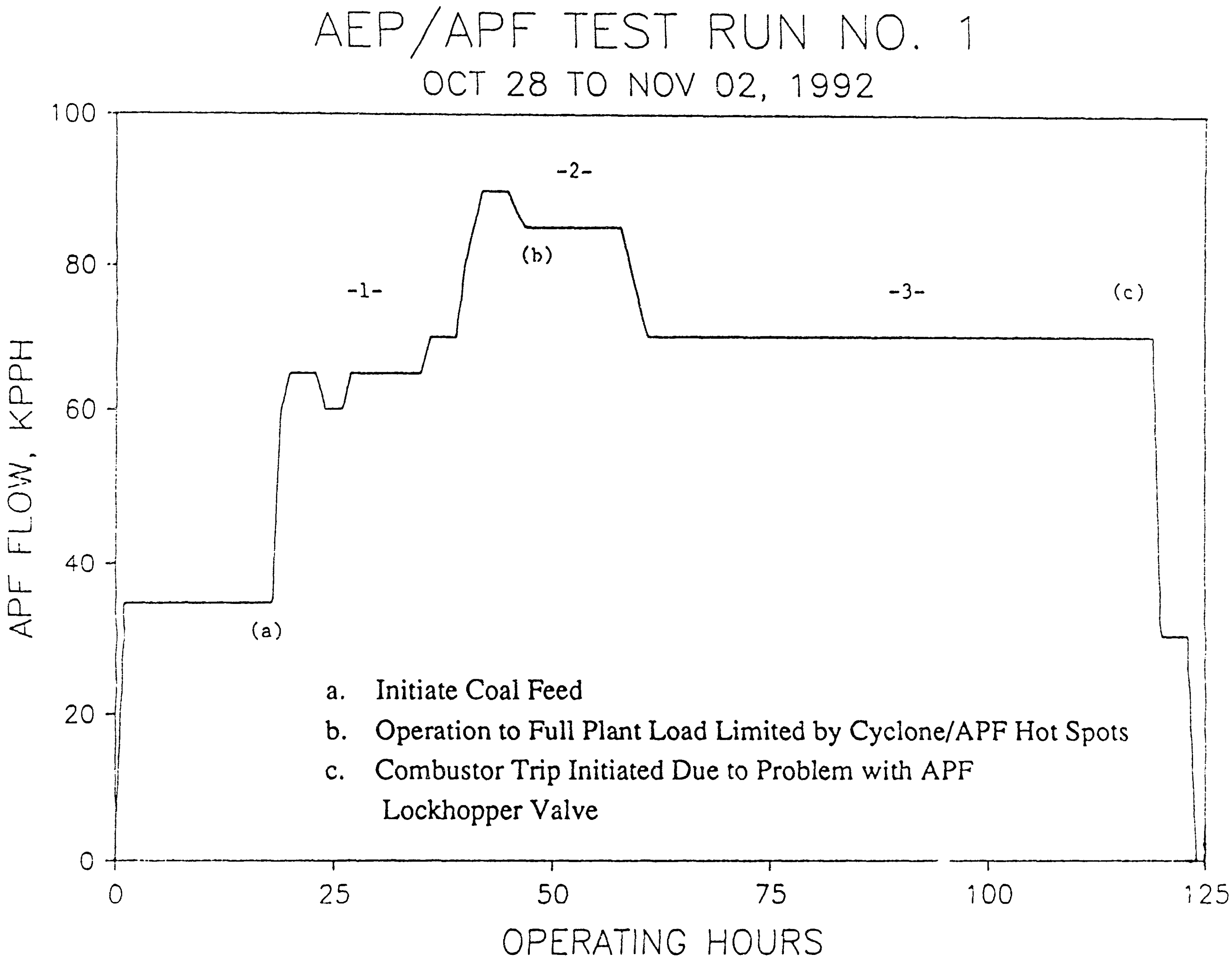
APF Commissioning and Test Run No. 1 (October 28 to November 2)

Figure 1 and Tables 2 and 3 provide a summary of the APF operation during Test Run 1. Figure 1 shows a plot of the APF gas flow as a function of operating time and identifies major operating events. Table 1 provides a summary of the operating characteristics of the filter for the different test segments identified in Figure 1. Table 3 provides an hourly summary of the filter operating data with additional comments reflecting on the status of the APF taken from the Westinghouse log book.

For the 100 hour test period (on coal), the APF showed stable operating pressure drop, exemplified by the data shown in Figures 2 and 3, over the range of plant conditions experienced. Filter pressure drop values were within expected and predicted ranges. Although the APF was operated to approximately 90% of its design flow with the PFBC plant operating at 80 to 85% of full load, full plant load (70 MW_e) was not achieved due to hot spots on the backup cyclone vessel and APF outlet nozzle. The PFBC (and APF) was shut down due to pluggage of instrument lines associated with the control of the APF ash removal system.

Following shutdown and cooldown the filter was visually inspected through the large access nozzles provided on the APF dome and vessel ash hopper. This inspection, although limited to the clean gas side and to bottom candle plenums on the dirty gas side, showed the APF unit to be in excellent condition with no evidence of any failed filter or dust breach between the dirty and clean gas side. Figure 4 shows a photograph taken of the candle filters through the ash hopper access. From this inspection, the candles appeared to be uniformly cleaned, with no indication of ash buildup or bridging. The ash hopper was clear of solids except for a coating (approximately one inch thick) on the

Figure 1


AEP/APF TEST RUN NO. 1
OCT 28 TO NOV 02, 1992
APF FLOW, KPPH
100
80
60
40
20
0
OPERATING HOURS
0
25
50
75
100
125
-1-
-2-
-3-
(a)
(b)
(c)
a. Initiate Coal Feed
b. Operation to Full Plant Load Limited by Cyclone/APF Hot Spots
c. Combustor Trip Initiated Due to Problem with APF Lockhopper Valve

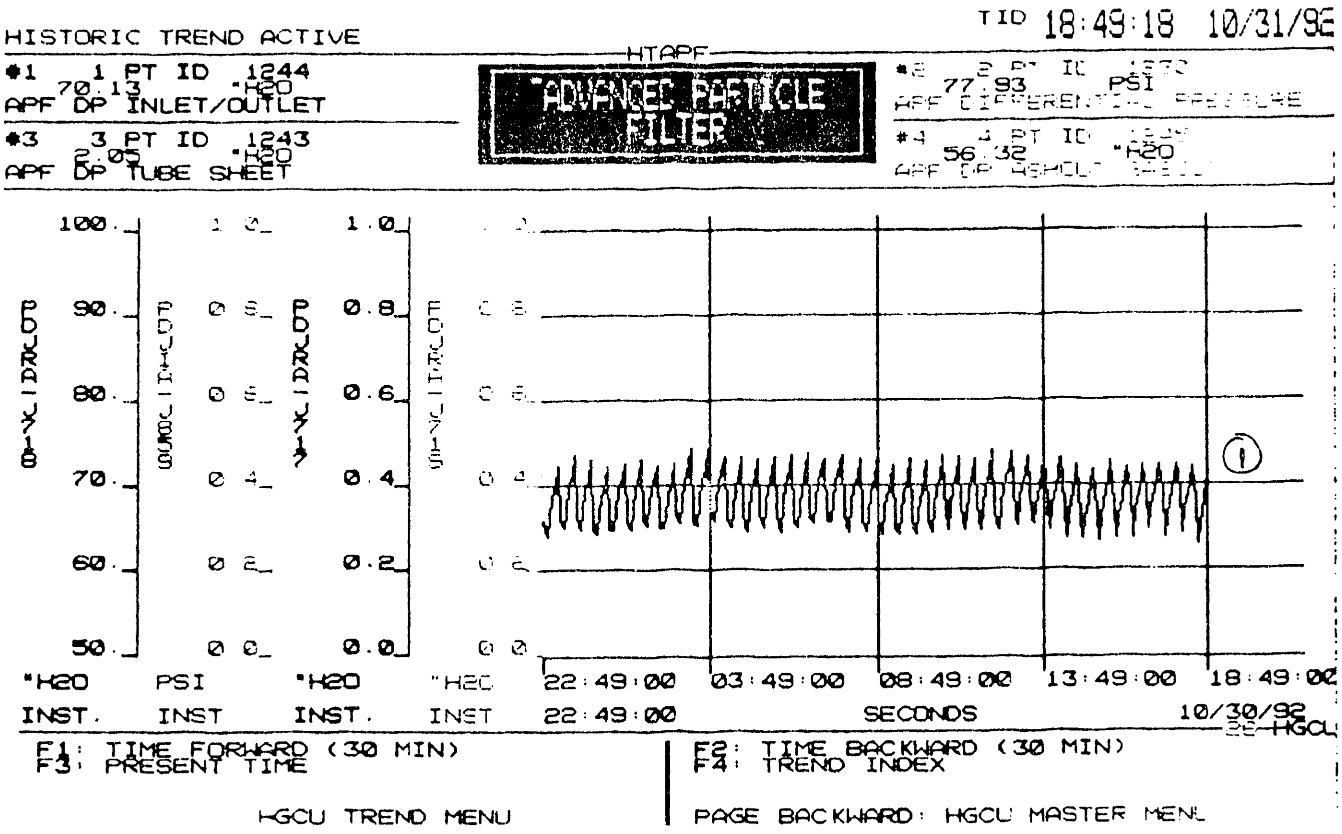


Figure 2 - APF Pressure Drop Traces (20 hr period) Showing Stable Operation

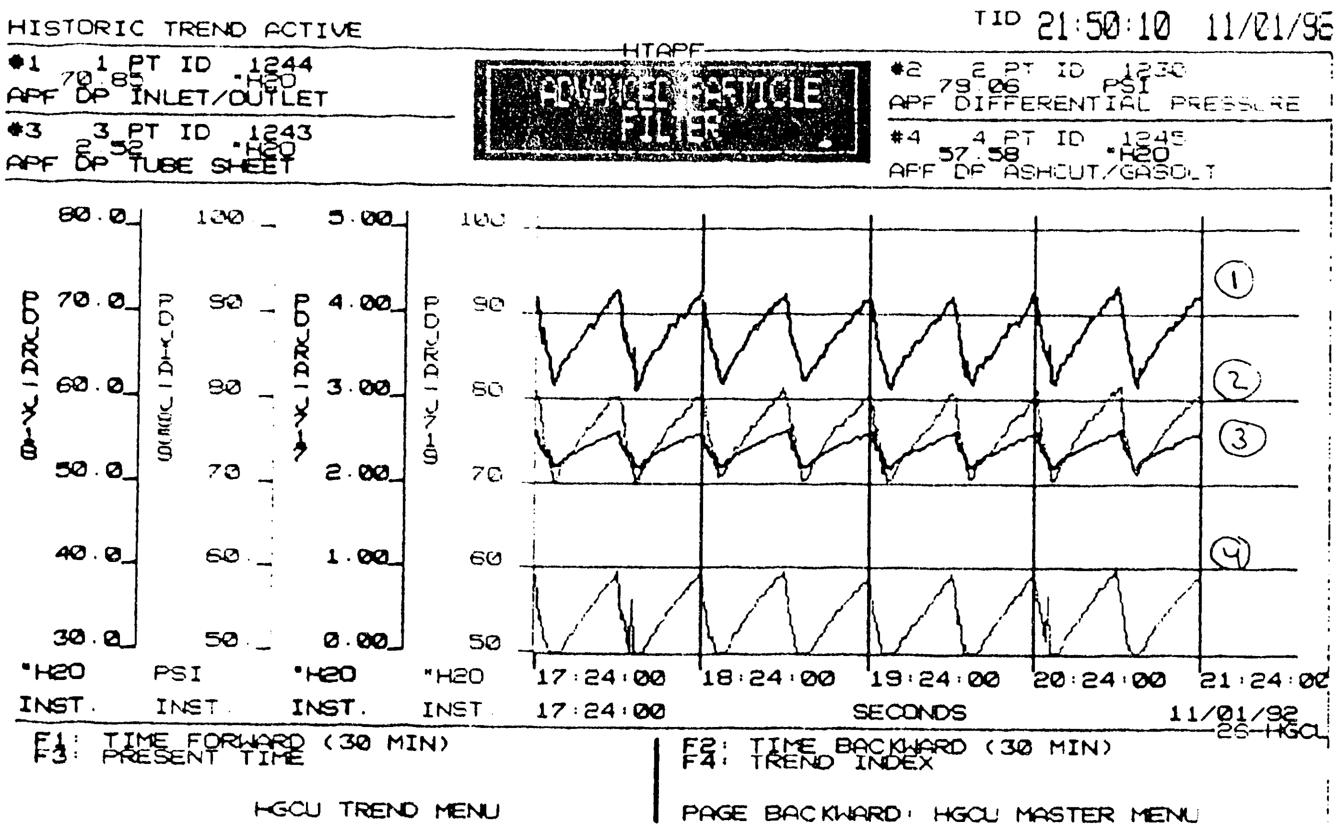


Figure 3 - APF Pressure Drop Showing Characteristic of Cake Buildup and Cleaning

Table 2

Summary of Test Run No. 1 (October 28 to November 2, 1992)

		Test Period		
Nominal Conditions		1	2	3
Plant Load, MW_e		10 - 25	50 - 60	35
APF Flow, KPPH		65 - 70	85 - 90	70
Temperature, °F		1150 - 1200	1350 - 1400	1200 - 1225
Pressure, psig		85 - 90	130 - 135	100
ΔP_{TS}, in wg		25 - 40	65 - 75	50 - 60
Face Velocity		6.1 - 6.4	6.1 - 6.5	5.9
Time at Conditions, Hrs		20	16*	62
Total Hours on Coal	102			
Total Quantity of Ash Filtered (Estimated), lbs	4400			

* Limited By Cyclone/APF Hot Spots

TABLE 3 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 1 (OCT 28 THRU NOV 2, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
10/28/92	0:00	0	0									* System preheated to 175 F.
	1:00	1	35									* Gas turbine rolled.
	2:00	2	35									* APF cleaning set on 30 minute cycle in cluster mode.
	3:00	3	35									
	4:00	4	35									* Oil firing initiated, APF heated to about 600 F
	5:00	5	35									
	6:00	6	35									
	7:00	7	0	35	600	30	8		4.8			
	8:00	8	0	35	600	30	8	9	4.8			
	9:00	9	0	35	600	30	8	9	4.8			
	10:00	10	0	35	600	30	8	9	4.8			
	11:00	11	0	35	600	30	8	9	4.8			
	12:00	12	0	35	650	30	8	9	5			
	13:00	13	0	35	650	30	8	9	5			* Steam turbine rolled.
	14:00	14	0	35	650	30	8	9	5			
	15:00	15	0	35	650	30	8	9	5			* Blocked backup cyclone.
	16:00	16	0	35	650	30	8	9	5			* Backup cyclone unblocked and has normal ash level.
	17:00	17	0	35	650	30	8	9	5			
	18:00	18	0	35	700	40	12	20	4.3	21		* Coal feed initiated.
	19:00	19	8	60	800	50	15	23	6.8	36	57	* First pulse at 800 psig.
	20:00	20	9	65	950	70	20	30	6.3	39	98	
	21:00	21	9	65	950	70	20	30	6.3	39	135	* Small tank pressure drop during pulse of bottom plenum no. 3
	22:00	22	10	65	950	70	20	30	6.3	39	174	caused by a bent bracket on valve HCV-J798.
	23:00	23	10	65	950	70	20	30	6.3	39	213	* Blocked backup cyclone.
10/29/92	0:00	24	10	60	950	70	20	25	5.8	36	249	
	1:00	25	10	60	950	70	20	25	5.8	36	285	* 260 F hot spot near exit pipe on vessel head.
	2:00	26	10	60	950	70	20	25	5.8	36	321	* 330 F hot spot near exit pipe on vessel head.
	3:00	27	11	65	1000	75	20	25	6.1	39	360	* 260 F hot spot near exit pipe on vessel head.
	4:00	28	13	65	1000	75	20	30	6.1	39	399	
	5:00	29	20	65	1000	80	20	30	5.8	39	438	
	6:00	30	25	65	1150	85	20	35	6.1	39	477	
	7:00	31	25	65	1150	85	25	37	6.1	39	516	
	8:00	32	25	65	1150	85	25	37	6.1	39	555	* 250 F hot spot on dirty gas inlet pipe.
	9:00	33	25	65	1150	85	25	35	6.1	39	594	* 407 F hot spot near exit pipe on vessel head.
	10:00	34	25	65	1150	85	25	35	6.1	39	633	
	11:00	35	25	65	1150	85	25	35	6.1	39	672	
	12:00	36	25	70	1150	90	25	35	6.2	42	714	* No screw rotation/ash removal since 8:00, 10/29/92
	13:00	37	30	70	1200	90	25	40	6.4	42	756	
	14:00	38	30	70	1200	90	25	40	6.4	42	798	
	15:00	39	37	70	1200	90	25	40	6.4	42	840	
	16:00	40	45	80	1250	110	30	50	6.3	48	888	
	17:00	41	48	85	1350	115	33	53	6.9	51	939	
	18:00	42	60	90	1400	120	40	55	7.2	54	993	* Full load operation limited by hot spot on backup cyclone
	19:00	43	60	90	1400	135	45	70	6.5	54	1047	* APF outlet nozzle also shows hot spots, but below 650 F.
	20:00	44	60	90	1400	135	50	70	6.5	54	1101	* 18:15 Ash removal system not working
	21:00	45	55	90	1400	135	60	70	6.5	54	1155	
	22:00	46	55	87	1350	135	60	70	6.1	52	1207	
	23:00	47	53	85	1350	133	62	72	6	51	1258	
10/30/92	0:00	48	53	85	1350	130	62	72	6.1	51	1309	
	1:00	49	53	85	1350	130	62	72	6.1	51	1360	* Vessel head 700 - 750 F on east side.
	2:00	50	53	85	1350	130	62	72	6.1	51	1411	* Multiple hot spots on backup cyclone and piping from APF to
	3:00	51	51	85	1350	130	65	72	6.1	51	1462	backup cyclone.
	4:00	52	51	85	1350	130	65	72	6.1	51	1513	

TABLE 3 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 1 (OCT 28 THRU NOV 2, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	5:00	53	51	85	1350	130	65	72	6.1	51	1564	* Most of the APF vessel's outer surface is above 140 F
	6:00	54	51	85	1350	130	65	72	6.1	51	1615	* Pulse cycle 18 - 20 minutes.
	7:00	55	51	85	1350	130	65	72	6.1	51	1666	
	8:00	56	51	85	1350	130	65	72	6.1	51	1717	* Screw conveyor rotation 5 rpm.
	9:00	57	50	85	1350	130	65	75	6.1	51	1768	
	10:00	58	47	85	1325	125	65	75	6.3	51	1819	
	11:00	59	45	80	1300	120	60	72	6	48	1867	* Started dropping bed. Pulse cycle 30 minutes.
	12:00	60	40	75	1300	110	60	70	6.1	45	1912	
	13:00	61	35	70	1250	110	60	68	5.5	42	1954	
	14:00	62	35	70	1250	100	53	63	6	42	1996	
	15:00	63	35	70	1225	100	53	63	5.9	42	2038	
	16:00	64	35	70	1225	100	53	63	5.9	42	2080	
	17:00	65	35	70	1225	100	53	63	5.9	42	2122	* Screw conveyor rotation 6 rpm.
	18:00	66	35	70	1225	100	53	63	5.9	42	2164	
	19:00	67	35	70	1225	100	52	62	5.9	42	2206	
	20:00	68	35	70	1200	100	52	62	5.9	42	2248	
	21:00	69	35	70	1200	100	50	60	5.9	42	2290	
	22:00	70	33	70	1200	100	50	60	5.9	42	2332	
	23:00	71	33	70	1200	100	50	60	5.9	42	2374	
10/31/92	0:00	72	32	70	1200	100	50	60	5.9	42	2416	
	1:00	73	33	70	1200	100	50	60	5.9	42	2458	
	2:00	74	33	70	1200	100	50	60	5.9	42	2500	
	3:00	75	33	70	1200	100	50	60	5.9	42	2542	
	4:00	76	35	70	1225	100	51	61	5.9	42	2584	
	5:00	77	35	70	1225	100	51	61	5.9	42	2626	
	6:00	78	35	70	1225	100	51	61	5.9	42	2668	
	7:00	79	35	70	1225	100	50	61	5.9	42	2710	
	8:00	80	35	70	1225	100	50	61	5.9	42	2752	
	9:00	81	35	70	1225	100	50	60	5.9	42	2794	
	10:00	82	35	70	1225	100	50	60	5.9	42	2836	
	11:00	83	35	70	1225	100	50	60	5.9	42	2878	
	12:00	84	35	70	1225	100	50	60	5.9	42	2920	
	13:00	85	35	70	1225	100	50	60	5.9	42	2962	* Ash is jamming at elbow in ash outlet pipe.
	14:00	86	35	70	1225	100	50	60	5.9	42	3004	
	15:00	87	35	70	1225	100	50	60	5.9	42	3046	
	16:00	88	35	70	1225	100	50	60	5.9	42	3088	
	17:00	89	35	70	1225	100	50	60	5.9	42	3130	
	18:00	90	35	70	1225	100	50	60	5.9	42	3172	
	19:00	91	35	70	1225	100	50	60	5.9	42	3214	
	20:00	92	35	70	1225	100	50	60	5.9	42	3256	* Ash removal system has stopped working.
	21:00	93	35	70	1225	100	50	60	5.9	42	3298	
	22:00	94	35	70	1225	100	50	60	5.9	42	3340	
	23:00	95	35	70	1225	100	50	60	5.9	42	3382	* Ash removal system has started working.
11/01/92	0:00	96	35	70	1225	100	50	60	5.9	42	3424	
	1:00	97	35	70	1225	100	50	60	5.9	42	3466	
	2:00	98	35	70	1225	100	50	60	5.9	42	3508	
	3:00	99	35	70	1225	100	50	60	5.9	42	3550	
	4:00	100	35	70	1225	100	50	60	5.9	42	3592	
	5:00	101	35	70	1225	100	50	60	5.9	42	3634	
	6:00	102	35	70	1225	100	50	60	5.9	42	3676	
	7:00	103	35	70	1225	100	50	60	5.9	42	3718	
	8:00	104	35	70	1225	100	50	60	5.9	42	3760	* APF head hot spot is at 480 F.
	9:00	105	35	70	1225	100	50	60	5.9	42	3802	* Hot spots at lugs under main flange are 295 F (South)

TABLE 3 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 1 (OCT 28 THRU NOV 2, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	10:00	106	35	70	1225	100	50	60	5.9	42	3844	and 275 F (West).
	11:00	107	35	70	1225	100	50	60	5.9	42	3886	
	12:00	108	35	70	1225	100	50	60	5.9	42	3928	
	13:00	109	35	70	1225	100	50	60	5.9	42	3970	
	14:00	110	35	70	1225	100	50	60	5.9	42	4012	* Ash removal system is not working at 100% capacity.
	15:00	111	35	70	1225	100	50	60	5.9	42	4054	
	16:00	112	35	70	1225	100	50	60	5.9	42	4096	
	17:00	113	35	70	1225	100	50	60	5.9	42	4138	* Nozzles 5A & 8A thermowells at 10 psig. 450 F head hot spot.
	18:00	114	35	70	1225	100	50	60	5.9	42	4180	* Valve between surge hopper & lock hopper under APF won't open for ash removal.
	19:00	115	35	70	1225	100	50	60	5.9	42	4222	
	20:00	116	35	70	1225	100	50	60	5.9	42	4264	
	21:00	117	35	70	1225	100	50	60	5.9	42	4306	
	22:00	118	35	70	1225	100	50	60	5.9	42	4348	
	23:00	119	35	70	1225	100	50	60	5.9	42	4390	
11/02/92	0:00	120	0	30	900	32	23	25	5.1	18	4408	* Combustor trip initiated due to inability to operate Everlasting APF ash valve.
	1:00	121	0	30	600	30	20	22	4.1	18	4426	
	2:00	122	0	30	500	30	18	20	3.7	18	4444	
	3:00	123	0	30	430	30	17	19	3.5	18	4462	
	4:00	124	0	0	380	0	0	0	0	0	4462	* Gas turbine tripped, depressurization has started.

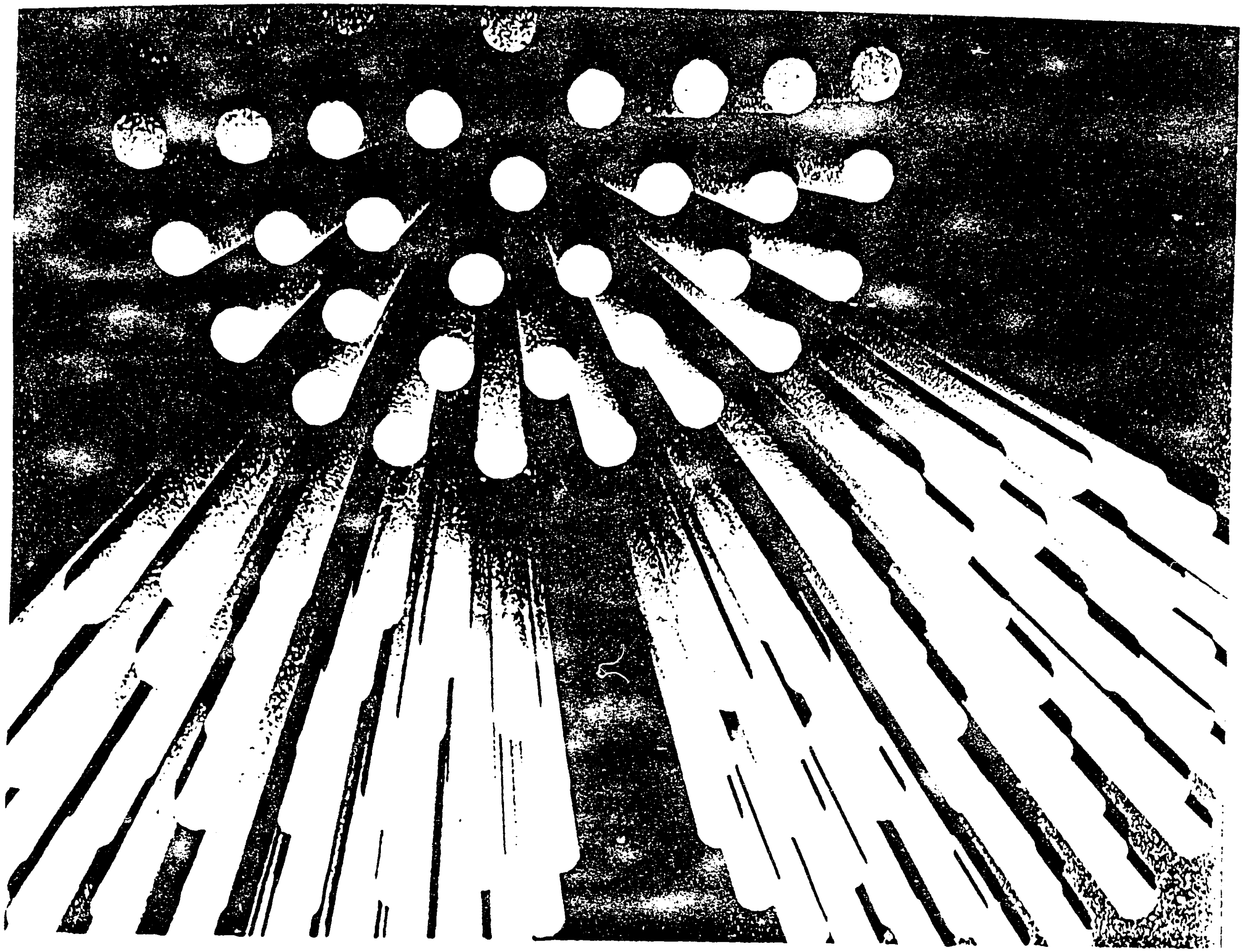


Figure 4 - Photograph of APF Bottom Plenum Following Test Run 1

hopper walls at the level of the access nozzle. It could not be determined if this ash coating was over the full length of the hopper. Entrance into the clean gas side and inspection revealed no evidence of dust on any of the clean side surfaces.

Results from Test Run 1 show:

- Stable and reproducible operation of the APF.
- The ability to clean a large array of candle elements utilizing a single pulse nozzle source.
- That high collection efficiencies are achievable in large barrier filter units.

APF Test Run 2 (November 21 to November 25, 1992)

Following repair and maintenance of the APF outlet nozzle and backup cyclone to eliminate hot spot issues and implementation of continuous instrument purges, the operation of the PFBC plant was resumed.

Figure 5 and Tables 4 and 5 provide a summary of the APF operation during Test Run 2. This data is analogous to the type of information provided and described in Test Run 1.

In Test Run 2, the APF was operated for approximately 78 hours on coal, achieving a maximum operating temperature of 1450°F and 90% of design flow. Again, stable filter operating pressure drops were demonstrated over the range of plant operating conditions experienced. Figure 6 shows the APF pressure drop during the early operation of this test run.

Figure 5

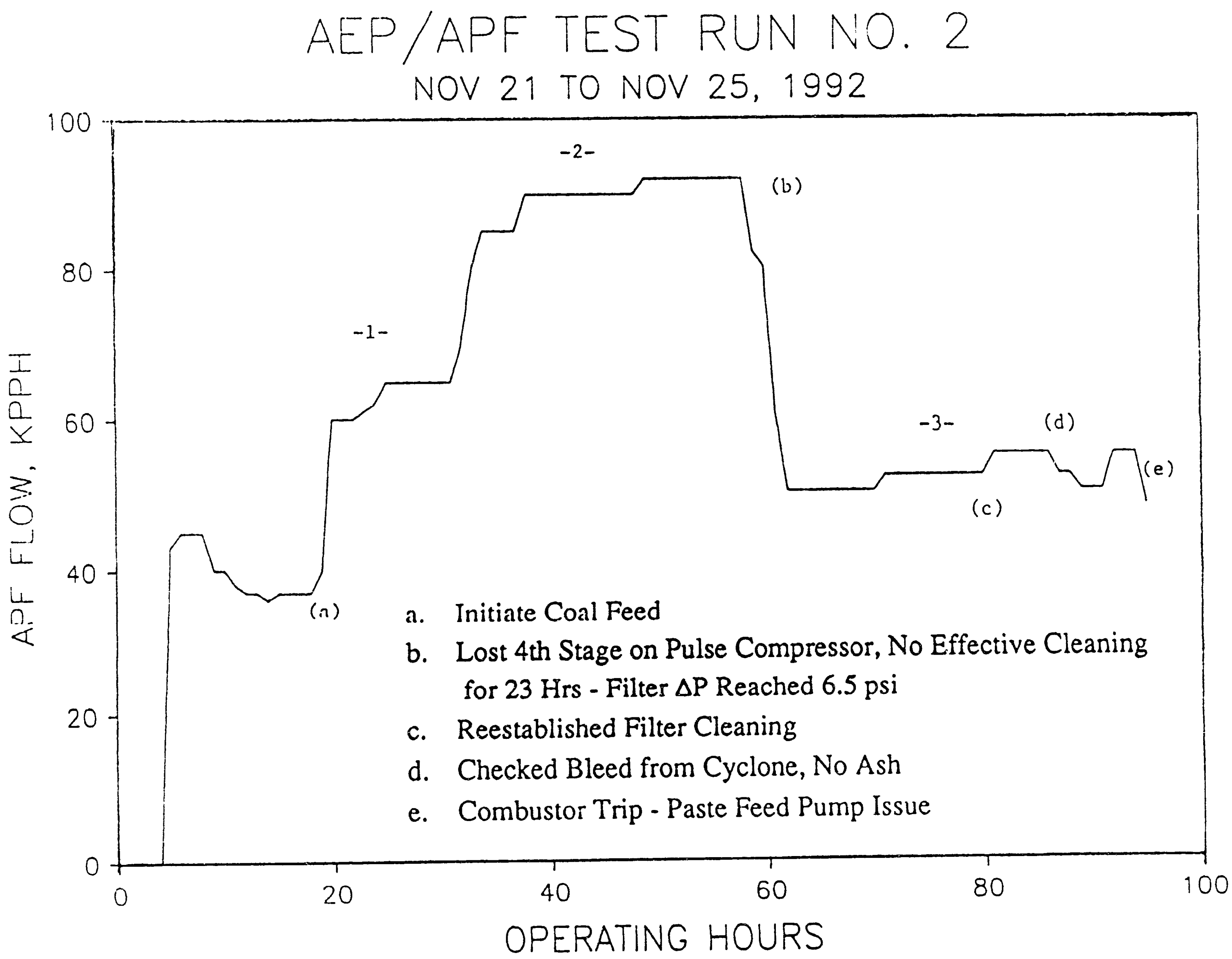

AEP/APF TEST RUN NO. 2
NOV 21 TO NOV 25, 1992
APF FLOW, KPPH
OPERATING HOURS
0
20
40
60
80
100
-1-
-2-
-3-
(a)
(b)
(c)
(d)
(e)
a. Initiate Coal Feed
b. Lost 4th Stage on Pulse Compressor, No Effective Cleaning for 23 Hrs - Filter ΔP Reached 6.5 psi
c. Reestablished Filter Cleaning
d. Checked Bleed from Cyclone, No Ash
e. Combustor Trip - Paste Feed Pump Issue

Table 4

Summary of Test Run No. 2 (November 21 to November 25, 1992)

Nominal Conditions		Test Period 1	2	3
Plant Load, MW_e		10 - 25	50 - 60	35
APF Flow, KPPH		60 - 65	85 - 92	50 - 55
Temperature, °F		1000 - 1150	1400 - 1450	1200
Pressure, psig		70 - 87	125 - 135	100
ΔP_{TS}, in wg		40 - 50	65 - 80	140* - 180
Face Velocity		5.5 - 5.9	6.1 - 6.6	4.3 - 4.6
Time at Conditions, Hrs		12	24	30**
Total Hours on Coal	78			
Total Quantity of Ash Filtered (Estimated), lbs	3450			

* Baseline Not Recovered After Loss of Pulse Compressor

** Includes 24 Hr Period With No or Very Limited Pulse Cleaning

TABLE 5 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 2 (NOV 21 THRU NOV 25, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
11/21/92	0:00	0		0								
	1:00	1										
	2:00	2										
	3:00	3										
	4:00	4	0	0	200	0	13		0	0		* Rolled gas turbine
	5:00	5	0	43	210	10	13		6.6	25.8	25.8	
	6:00	6	0	45	225	30	14		3.9	27	52.8	
	7:00	7	0	45	250	32	14		3.9	27	79.8	
	8:00	8	0	45	250	32	14		3.9	27	106.8	
	9:00	9	0	40	250	32	14		3.5	24	130.8	
	10:00	10	0	40	250	32	14		3.5	24	154.8	* Started pulsing
	11:00	11	0	38	400	32	18	20	4	22.8	177.6	
	12:00	12	0	37	600	32	20	23	4.8	22.2	199.8	
	13:00	13	0	37	625	32	21	23	4.9	22.2	222	
	14:00	14	0	36	625	32	22	24	4.8	21.6	243.6	
	15:00	15	0	37	625	32	22	24	4.9	22.2	265.8	
	16:00	16	0	37	625	32	22	24	4.9	22.2	288	
	17:00	17	0	37	625	32	22	24	4.9	22.2	310.2	
	18:00	18	5	37	700	32	22	24	5.2	22.2	332.4	* Initiate coal feed
	19:00	19	9	40	800	40	30	40	5.3	24	356.4	
	20:00	20	10	60	900	70	35	45	5.5	36	392.4	
	21:00	21	10	60	960	71	35	45	5.7	36	428.4	
	22:00	22	10	60	970	71	35	45	5.7	36	464.4	
	23:00	23	10	61	970	72	35	45	5.8	36.6	501	
11/22/92	0:00	24	11	62	970	75	40	50	5.7	37.2	538.2	
	1:00	25	12	65	100	78	40	50	2.2	39	577.2	
	2:00	26	15	65	1020	80	40	50	5.8	39	616.2	
	3:00	27	15	65	1025	80	40	52	5.8	39	655.2	
	4:00	28	20	65	1000	82	41	59	5.6	39	694.2	
	5:00	29	25	65	1150	87	45	65	5.9	39	733.2	
	6:00	30	25	65	1150	87	45	65	5.9	39	772.2	
	7:00	31	25	65	1150	87	50	60	5.9	39	811.2	* DP triggered pulse cleaning initiated.
	8:00	32	31	70	1200	100	50	60	5.8	42	853.2	* Ash removal system not working
	9:00	33	40	80	1250	115	55	60	6	48	901.2	* Pulsing cycle 10 - 12 minutes.
	10:00	34	50	85	1400	125	58	60	6.5	51	952.2	* APF outlet nozzle running warm. Pulsing cycle 7 min.
	11:00	35	55	85	1400	125	58	60	6.5	51	1003.2	
	12:00	36	54	85	1350	125	55	80	6.3	51	1054.2	
	13:00	37	55	85	1350	130	58	80	6.1	51	1105.2	
	14:00	38	60	90	1450	135	65	80	6.6	54	1159.2	* Liner temp. in bottom is dropping, maybe ash build up.
	15:00	39	60	90	1425	135	70	80	6.5	54	1213.2	* Forced suction at lock hoppers improved liner temp.
	16:00	40	57	90	1425	135	70	80	6.5	54	1267.2	Significant amount of ash came out.
	17:00	41	57	90	1425	135	70	80	6.5	54	1321.2	
	18:00	42	57	90	1425	135	70	80	6.5	54	1375.2	* Full load operation limited by hot spot on backup cyclone.
	19:00	43	56	90	1425	135	70	80	6.5	54	1429.2	* APF outlet nozzle also shows hot spots, but below 650 F
	20:00	44	55	90	1425	135	70	80	6.5	54	1483.2	
	21:00	45	55	90	1425	135	70	80	6.5	54	1537.2	
	22:00	46	53	90	1425	135	70	80	6.5	54	1591.2	
	23:00	47	52	90	1425	135	68	80	6.5	54	1645.2	* Pulse cleaning baseline dropped to 76" from 82" H2O.
11/23/92	0:00	48	52	90	1425	135	63	80	6.5	54	1699.2	Pulsing cycle 15 minutes.
	1:00	49	52	92	1425	135	68	80	6.6	55.2	1754.4	
	2:00	50	52	92	1425	135	68	80	6.6	55.2	1809.6	
	3:00	51	52	92	1425	135	68	80	6.6	55.2	1864.8	* Pulse valve HCV-J781 inlet to sec. accumulator tank is leaking
	4:00	52	52	92	1425	135	68	80	6.6	55.2	1920	* Ash temp. in vessel bottom is dropping

TABLE 5 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 2 (NOV 21 THRU NOV 25, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	5:00	53	52	92	1425	135	68	80	6.6	55.2	1975.2	* Vessel bottom temp. coming back up after purging.
	6:00	54	52	92	1425	135	68	80	6.6	55.2	2030.4	* Leak repaired in valve HCV-J781.
	7:00	55	52	92	1425	135	68	80	6.6	55.2	2085.6	* Temporary loss of pulse pressure.
	8:00	56	52	92	1425	135	68	80	6.6	55.2	2140.8	Tank pressure increased to 1100 psig.
	9:00	57	55	92	1450	138	75	80	6.6	55.2	2196	* 9:30 the pulse compressor was lost.
	10:00	58	60	92	1490	138		100	6.7	55.2	2251.2	Pressure drop continues to build.
	11:00	59	60	82	1450	135		138	6	49.2	2300.4	* Flow slowly decreases.
	12:00	60	60	80	1450	135		180	5.8	48	2348.4	
	13:00	61	60	60	1300	135		195	4	36	2384.4	
	14:00	62	50	50	1200	100		170	4.1	30	2414.4	
	15:00	63	35	50	1200	100		170	4.1	30	2444.4	
	16:00	64	35	50	1200	100		173	4.1	30	2474.4	
	17:00	65	35	50	1200	100		178	4.1	30	2504.4	
	18:00	66	35	50	1200	100	180	183	4.1	30	2534.4	* Pulsing with low pressure (500 psig).
	19:00	67	35	50	1200	100	180	183	4.1	30	2564.4	
	20:00	68	35	50	1200	100	180	183	4.1	30	2594.4	
	21:00	69	35	50	1175	100	180	183	4.1	30	2624.4	* Valve HCV-J798 leaking. Tidd personnel going to repair valve.
	22:00	70	35	50	1175	100	180	183	4.1	30	2654.4	
	23:00	71	35	52	1175	98	180	183	4.3	31.2	2685.6	
11/24/92	0:00	72	35	52	1175	98	180	183	4.3	31.2	2716.8	
	1:00	73	35	52	1175	98	180	183	4.3	31.2	2748	
	2:00	74	35	52	1150	98	180	183	4.3	31.2	2779.2	
	3:00	75	35	52	1150	98	180	183	4.3	31.2	2810.4	* Valve HCV-J798 replaced with new body & coupling.
	4:00	76	35	52	1150	98	180	183	4.3	31.2	2841.6	
	5:00	77	35	52	1150	98	180	183	4.3	31.2	2872.8	* Compressor off for N2 hookup. No pulsing.
	6:00	78	35	52	1150	98	180	183	4.3	31.2	2904	
	7:00	79	35	52	1150	98	180	183	4.3	31.2	2935.2	* Pulsed 4 cycles manually from 550 psig to 200 psig.
	8:00	80	35	52	1150	98	180	183	4.3	31.2	2966.4	* Primary accumulator tank ready with 1500 psig N2.
	9:00	81	35	55	1200	100	155	165	4.6	33	2999.4	* Continued pulsing using nitrogen tanks, 1000 psig.
	10:00	82	35	55	1200	100	150	162	4.6	33	3032.4	* Began 10 minute manual mode pulsing cycle with N2.
	11:00	83	35	55	1200	100	140	148	4.6	33	3065.4	
	12:00	84	35	55	1200	100	140	148	4.6	33	3098.4	* Ash hopper thermocouples appear to be responding.
	13:00	85	35	55	1200	100	140	155	4.6	33	3131.4	* Return to 30 min pulsing cycle.
	14:00	86	35	55	1200	100		163	4.6	33	3164.4	Trying to build thick cake, overcome patchy cleaning.
	15:00	87	35	52	1200	100		170	4.3	31.2	3195.6	
	16:00	88	35	52	1200	100		175	4.3	31.2	3226.8	
	17:00	89	35	50	1200	100		177	4.1	30	3256.8	
	18:00	90	35	50	1200	100		182	4.1	30	3286.8	
	19:00	91	35	50	1200	100		185	4.1	30	3316.8	* Pulsed at 1200 psig.
	20:00	92	35	55	1200	100	140	160	4.6	33	3349.8	* High ash level alarm in APF.
	21:00	93	35	55	1200	100		160	4.6	33	3382.8	* Ash hopper temperature not responding.
	22:00	94	85	55	1200	100		175	4.6	33	3415.8	* Reduce flow/load.
	23:00	95	0	48	1200	60		90	6.1	28.8	3444.6	* Combustor trip due to paste pump failures.

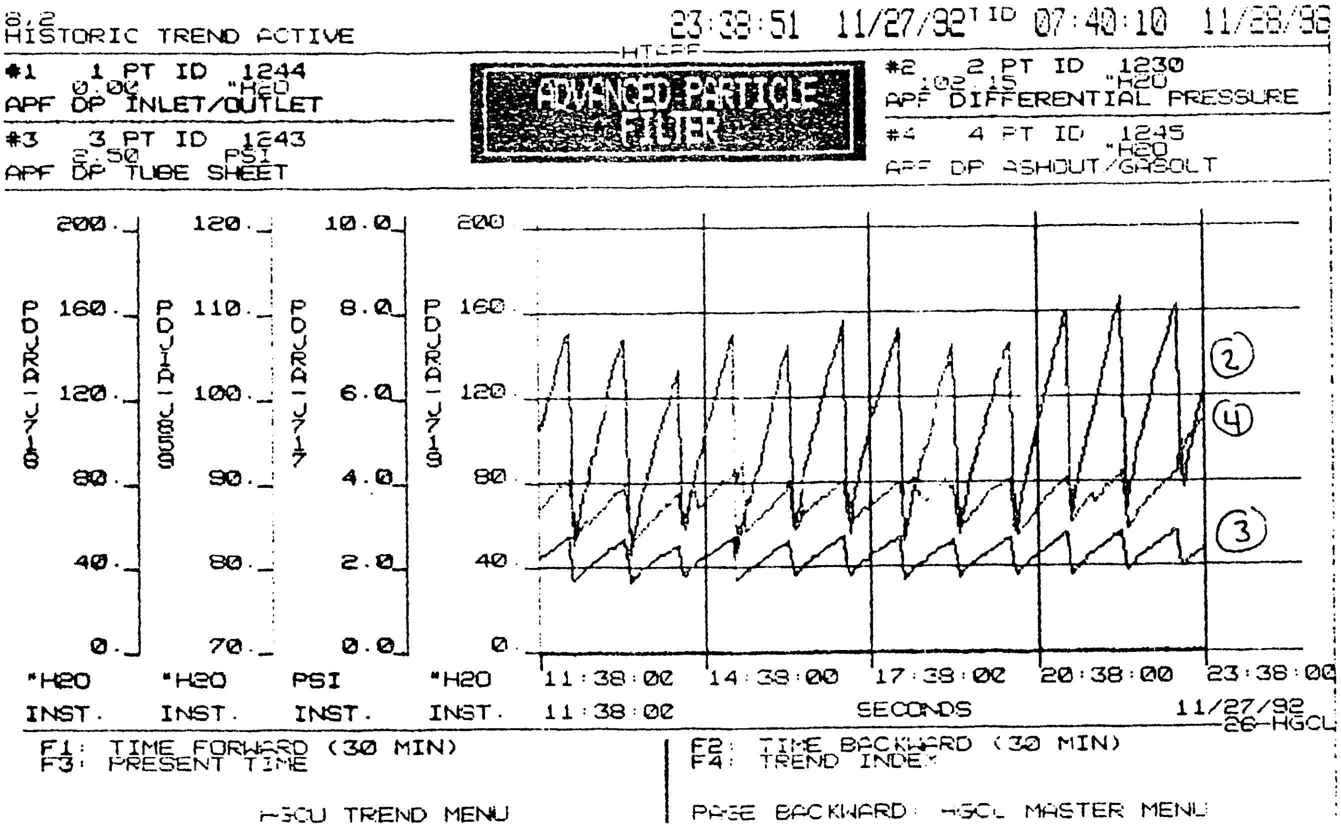


Figure 6 - APF Pressure Drop Over a 12 Hour Period During Run 2

Approximately 36 hours into this test run, a failure in the fourth stage of the APF back pulse compressor occurred that limited the ability to effectively clean the filter for a 24 hour period (until a backup N_2 system was installed). During this period, the filter pressure drop continued to build, reaching 6.5 psi (180 in wg), Figure 7. With subsequent pulse cleaning using the backup N_2 system, stable filter operation was again achieved but the original APF baseline pressure drop could not be reestablished, Figure 8.

Following the compressor outage event and the reestablishment of stable filter operation, the performance of the APF was (indirectly) checked by briefly opening a vent valve on the backup cyclone ash discharge line. Visual inspection of the short bursts of gas emitted from the vent valve showed no evidence of dust. It was concluded that no serious damage was done to the filter unit as a result of the compressor outage event. In this test, the PFBC plant was shut down due to a paste feed pump issue unrelated to the APF. No inspection of the filter unit was made.

Results of Test Run 2 show:

- Stable and reproducible operation of the APF
- Ability of the APF to operate under high pressure drop conditions and maintain high collection efficiency.

<u>APF Test Run 3 (November 25 to December 7, 1992)</u>

Figure 9 and Tables 6 and 7 provide a summary of the APF operation during Test Run 3. This data is again analogous to the type of information provided and described above in Test Runs 1 and 2.

Test Run 3 was a hot restart of the plant following Test Run 2, accumulating an additional 286 hours of coal operation. At the restart of this test, a nominally low APF

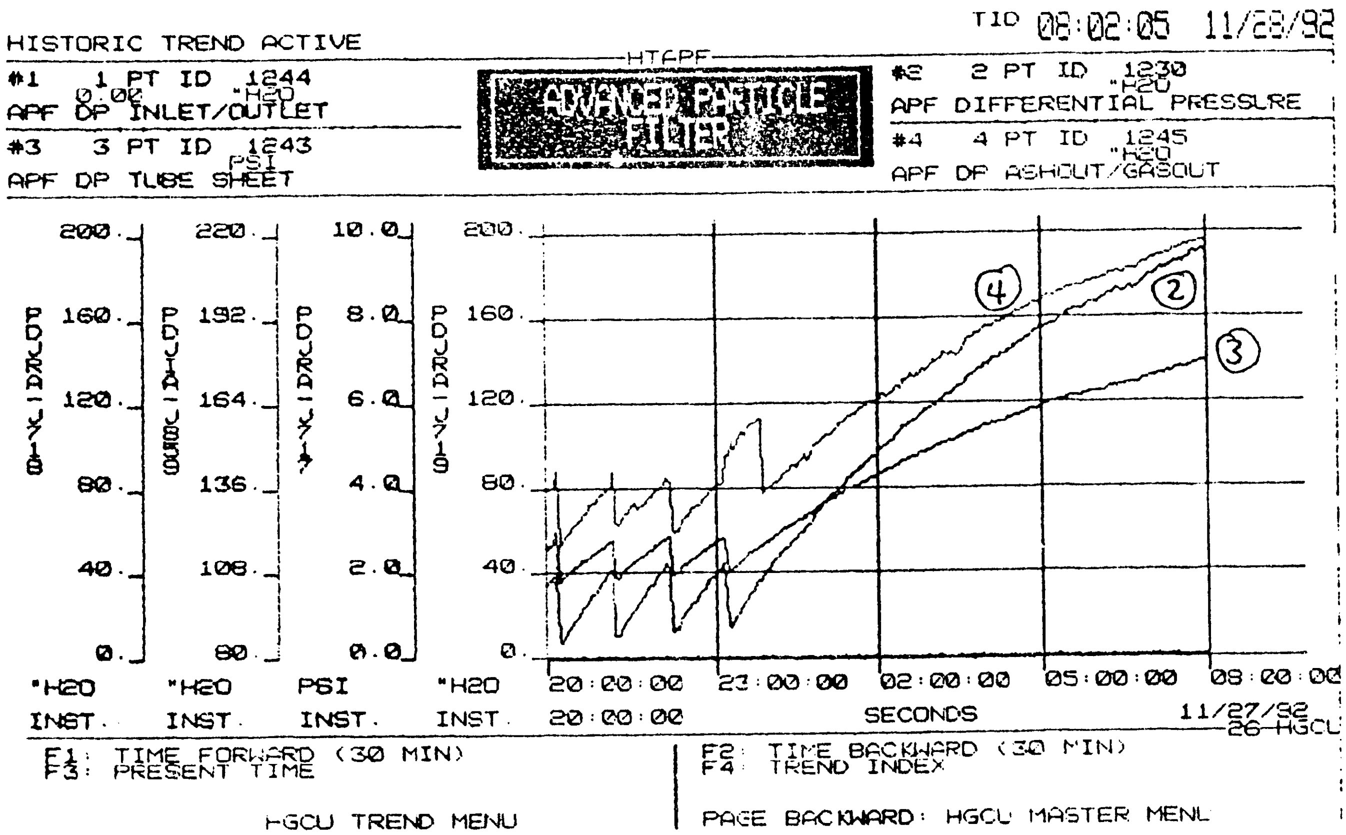


Figure 7 - APF Pressure Buildup During Compressor Outage

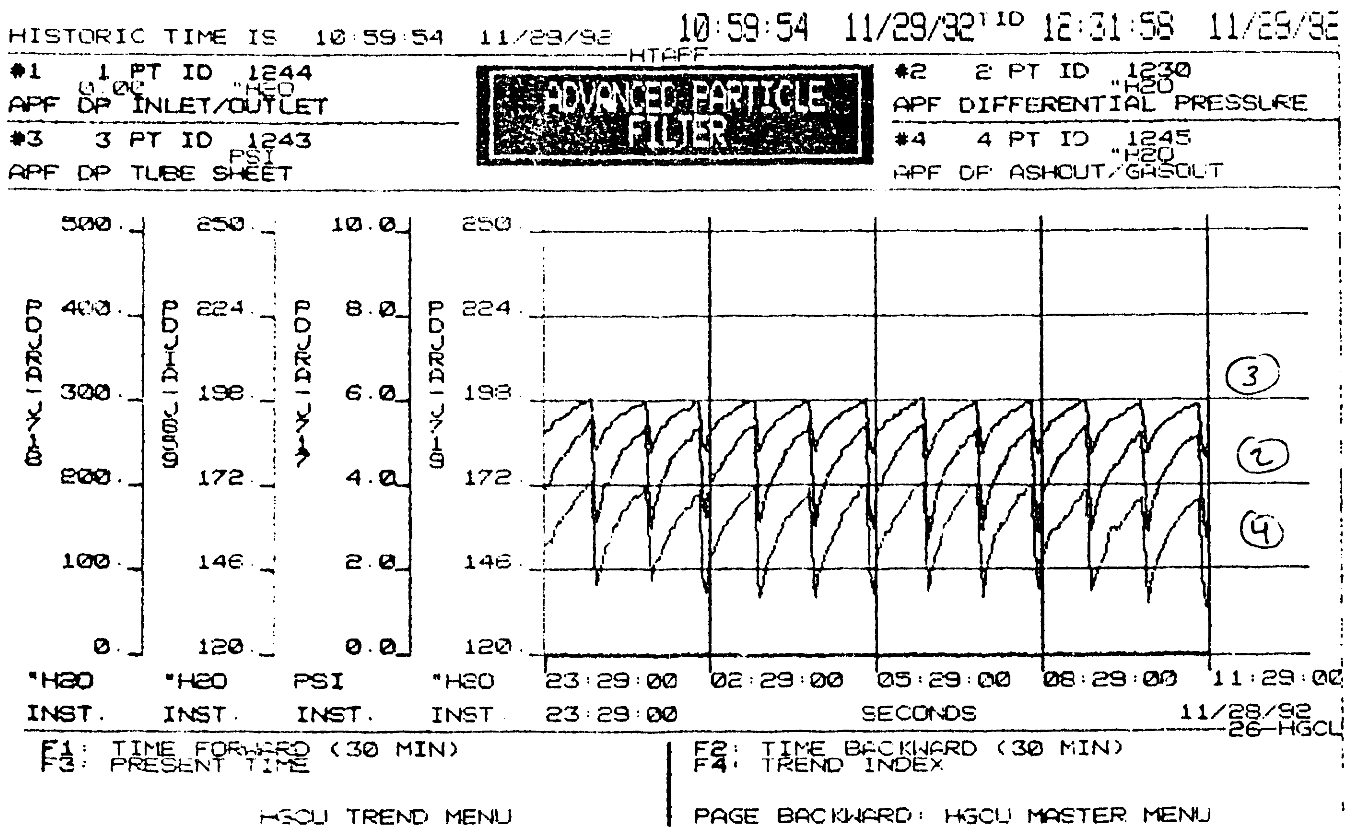
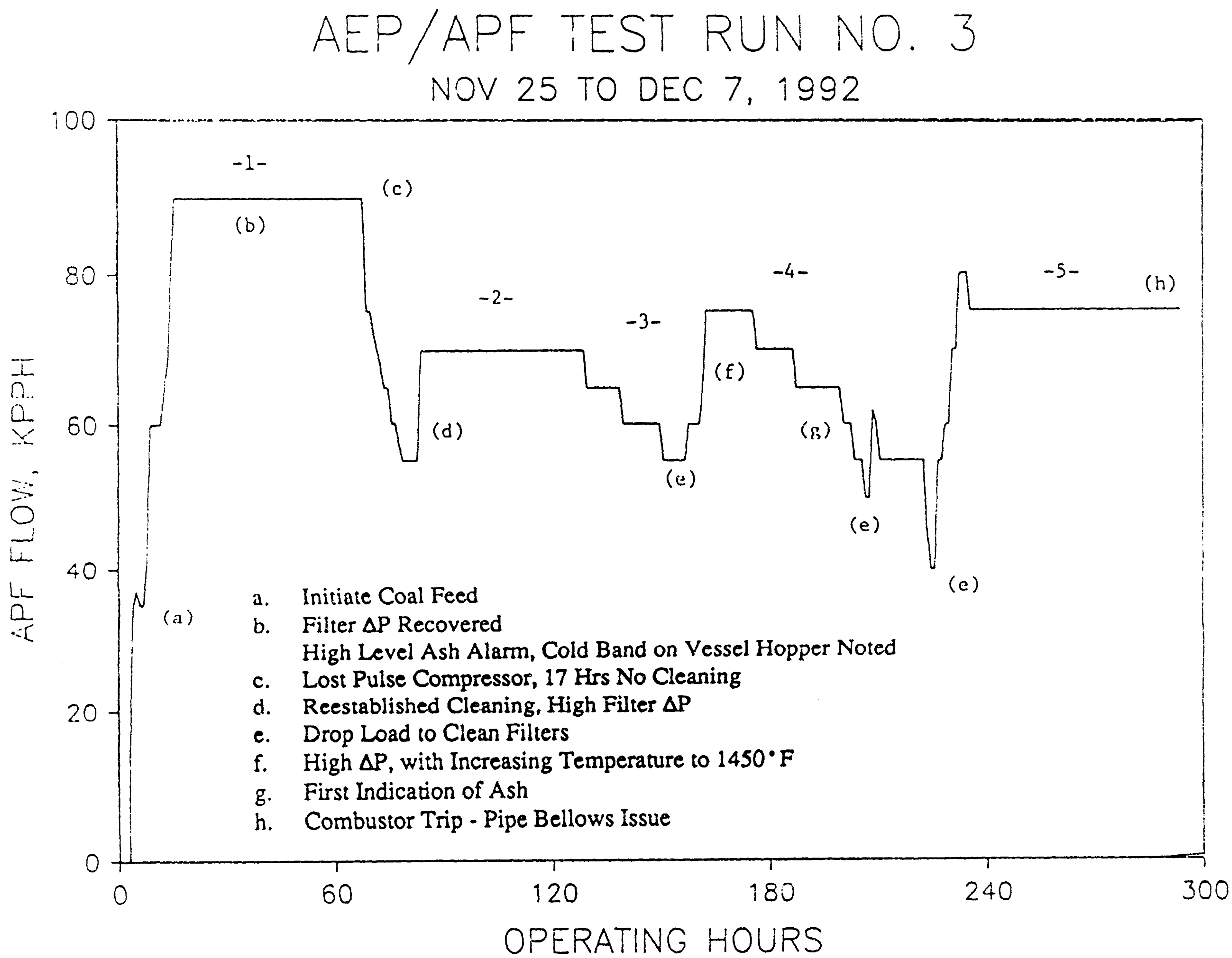


Figure 8 - APF Pressure Drop Following Compressor Outage

Figure 9



AEP/APF TEST RUN NO. 3
NOV 25 TO DEC 7, 1992
APF FLOW, KPPH
OPERATING HOURS
0
20
40
60
80
100
0
60
120
180
240
300
-1-
-2-
-3-
-4-
-5-
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
a. Initiate Coal Feed
b. Filter ΔP Recovered
High Level Ash Alarm, Cold Band on Vessel Hopper Noted
c. Lost Pulse Compressor, 17 Hrs No Cleaning
d. Reestablished Cleaning, High Filter ΔP
e. Drop Load to Clean Filters
f. High ΔP, with Increasing Temperature to 1450°F
g. First Indication of Ash
h. Combustor Trip - Pipe Bellows Issue

Table 6

Summary of Test Run No. 3 (November 25 to December 7, 1992)

Nominal Conditions		Test Period				
		1	2	3	4	5
Plant Load, MW_e		43-48	43-47			
APF Flow, KPPH		90	70	65-55	75-50	75
Temperature, °F		1300-1350	1325-1370	1400-1450	1450-1490	1335-1350
Pressure, psig		130	135	130	130	125
ΔP_{TS}, in wg		45-80	140*-170	**	**	80-120
Face Velocity		6.2-6.4	4.8-5.1	4.4-4.7	4.8-5.7	5.5-5.6
Time at Conditions, Hrs		32	46	27	45	60
Total Hours on Coal	286					
Total Quantity of Ash Filtered (Estimated), lbs	12,500					

* Pulse Compressor Lost, Baseline Not Recovered

** Pressure Drop Increasing with Temperature

TABLE 7 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 3 (NOV 25 THRU DEC 7, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
11/25/92	0:00		0	17	800	30		80	2.7	10.2	10.2	* Manual pulsing every 30 minutes.
	1:00		0	35	500	30	5	14	4.3	21	31.2	
	2:00		0	36	450	30	4	8	4.2	21.6	52.8	* Automatic pulsing at a 30 minute cycle. Norwalk compressor
	3:00		0	36	400	30	4	8	3.9	21.6	74.4	now working. Primary accumulator tank at 1453 psig at 70 F.
	4:00	0	0	0	400	0		0	0	0	74.4	* Turbine trip. Pulsing stopped.
	5:00	1	0	0	380	0		0	0	0	74.4	
	6:00	2	0	0	360	0		0	0	0	74.4	
	7:00	3	0	0	340	0		0	0	0	74.4	* Roll gas turbine at 7:30. Many pulse valve failure indications
	8:00	4	0	35	340	25		10	4	21	95.4	
	9:00	5	0	37	500	35		22	4.1	22.2	117.6	
	10:00	6	0	35	550	35		28	4.1	21	138.6	
	11:00	7	0	35	650	35	12	40	4.5	21	159.6	* Pulsed once at 400 psig.
	12:00	8	5	40	700	40	17	42	4.8	24	183.6	* Initiated coal feed
	13:00	9	10	60	900	70	20	42	5.5	36	219.6	* Pulsed manually at 800 psig.
	14:00	10	10	60	950	75	20	42	5.4	36	255.6	
	15:00	11	15	60	1000	75	20	55	5.6	36	291.6	
	16:00	12	25	60	1100	80	25	60	5.7	36	327.6	
	17:00	13	25	65	1200	87	30	70	6.1	39	366.6	
	18:00	14	35	68	1300	87	30	80	6.7	40.8	407.4	
	19:00	15	40	80	1325	112	40	85	6.5	48	455.4	
	20:00	16	45	90	1350	130	40	85	6.4	54	509.4	
	21:00	17	45	90	1350	130	42	82	6.4	54	563.4	
	22:00	18	48	90	1350	130	42	82	6.4	54	617.4	
	23:00	19	48	90	1350	130	43	82	6.4	54	671.4	
11/26/92	0:00	20	48	90	1350	130	43	80	6.4	54	725.4	
	1:00	21	48	90	1350	130	43	80	6.4	54	779.4	
	2:00	22	48	90	1350	130	43	80	6.4	54	833.4	
	3:00	23	47	90	1350	130	43	80	6.4	54	887.4	
	4:00	24	46	90	1350	130	43	80	6.4	54	941.4	
	5:00	25	46	90	1350	130	43	80	6.4	54	995.4	* Vessel head hot spot at 630 F.
	6:00	26	45	90	1350	130	43	80	6.4	54	1049.4	
	7:00	27	45	90	1350	130	43	80	6.4	54	1103.4	* Vessel head hot spot at 628 F.
	8:00	28	45	90	1350	130	43	80	6.4	54	1157.4	* Vessel head hot spot at 664 F.
	9:00	29	43	90	1350	130	43	80	6.4	54	1211.4	* Valves HCV-J777 & J778 physically hung up. Control room
	10:00	30	43	90	1350	130	43	80	6.4	54	1265.4	manually pulsing middle plenums B and C.
	11:00	31	43	90	1350	130	43	80	6.4	54	1319.4	* Vessel head temp. 570 F.
	12:00	32	43	90	1350	130	43	80	6.4	54	1373.4	
	13:00	33	43	90	1350	130	43	80	6.4	54	1427.4	* Pulse solenoid for valve HCV-J765 failed closed. Backup
	14:00	34	43	90	1350	130	43	80	6.4	54	1481.4	valve HCV-J770 functioned properly.
	15:00	35	43	90	1300	130	43	80	6.3	54	1535.4	* Valves HCV-J777 & J778 physically hung up again.
	16:00	36	43	90	1300	130	43	80	6.3	54	1589.4	* Solenoid for valve HCV-J765 repaired and ready for pulsing.
	17:00	37	43	90	1300	130	43	80	6.3	54	1643.4	
	18:00	38	43	90	1300	130	43	80	6.3	54	1697.4	
	19:00	39	43	90	1300	130	43	80	6.3	54	1751.4	
	20:00	40	43	90	1300	130	43	80	6.3	54	1805.4	
	21:00	41	43	90	1300	130	43	80	6.3	54	1859.4	
	22:00	42	43	90	1300	130	43	80	6.3	54	1913.4	
	23:00	43	43	90	1300	130	43	80	6.3	54	1967.4	
11/27/92	0:00	44	43	90	1300	130	43	80	6.3	54	2021.4	
	1:00	45	43	90	1300	130	43	80	6.3	54	2075.4	
	2:00	46	43	90	1300	130	43	80	6.3	54	2129.4	
	3:00	47	43	90	1300	130	43	80	6.3	54	2183.4	
	4:00	48	43	90	1300	130	43	80	6.3	54	2237.4	

TABLE 7 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 3 (NOV 25 THRU DEC 7, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	5:00	49	43	90	1300	130	43	80	6.3	54	2291.4	
	6:00	50	43	90	1300	130	43	80	6.3	54	2345.4	
	7:00	51	40	90	1300	130	43	80	6.3	54	2399.4	* Vessel head temp. 547 F.
	8:00	52	40	90	1300	130	43	80	6.3	54	2453.4	* Vessel hopper wall temp. is slowly decreasing, probably due
	9:00	53	40	90	1300	130	43	80	6.3	54	2507.4	to ash build up. Pulse valve HCV-J765 failed.
	10:00	54	43	90	1325	133	43	85	6.2	54	2561.4	
	11:00	55	45	90	1350	133	43	85	6.3	54	2615.4	* Bed level is 112.2 inches.
	12:00	56	45	90	1350	133	48	80	6.3	54	2669.4	* Bed level is 116.4 inches. Valves HCV-J765 & J785 failed
	13:00	57	45	90	1350	135	48	80	6.2	54	2723.4	because of a logic issue.
	14:00	58	48	90	1350	135	50	80	6.2	54	2777.4	* Pulse compressor having trouble maintaining the tank pressure.
	15:00	59	48	90	1350	135	50	80	6.2	54	2831.4	* Vessel hopper temperature dropped dramatically. Head at 532 F
	16:00	60	48	90	1350	135	55	80	6.2	54	2885.4	* High level alarm in vessel hopper. Purging air through lock
	17:00	61	48	90	1350	135	55	80	6.2	54	2939.4	hopper & screwfeeder into APF vessel to remove ash.
	18:00	62	48	90	1350	135	55	80	6.2	54	2993.4	* Vessel head temp. 654 F. Purged through bottom nozzle &
	19:00	63	48	90	1350	135	55	80	6.2	54	3047.4	screwfeeder several times. Primary accu. tank at 1200 psig.
	20:00	64	48	90	1350	135	55	80	6.2	54	3101.4	* 3 foot wide band in vessel hopper is cold, hitting area with
	21:00	65	48	90	1350	135	55	80	6.2	54	3155.4	rubber sledge hammer to loosen ash, purging is continuing.
	22:00	66	48	90	1350	135	55	80	6.2	54	3209.4	
	23:00	67	48	90	1350	135	55	80	6.2	54	3263.4	
11/28/92	0:00	68	48	90	1350	135	55	80	6.2	54	3317.4	* Lost pulse compressor at 0:00, stopped pulsing. Screw cooler
	1:00	69	48	75	1350	135		110	5.2	45	3362.4	problems.
	2:00	70	48	75	1350	135		120	5.2	45	3407.4	
	3:00	71	48	72	1350	135		140	5	43.2	3450.6	* At 3:30 N2 at 300 psig is flowing into primary accu. tank.
	4:00	72	48	70	1350	135		155	4.8	42	3492.6	* High ash level alarm is still on.
	5:00	73	48	68	1350	135		165	4.7	40.8	3538.4	
	6:00	74	48	65	1350	135		175	4.5	39	3572.4	* Vessel head temp. 250 - 300 F. Purge didn't increase temp.
	7:00	75	48	65	1350	135		187	4.5	39	3611.4	in bottom of vessel much.
	8:00	76	48	60	1350	135		195	4.2	36	3647.4	
	9:00	77	48	60	1370	135		205	4.2	36	3683.4	
	10:00	78	48	57	1365	135		215	4	34.2	3717.6	
	11:00	79	48	55	1365	135		220	3.8	33	3750.6	
	12:00	80	48	55	1365	135		224	3.8	33	3783.6	
	13:00	81	48	55	1365	135		226	3.8	33	3816.6	
	14:00	82	48	55	1365	135		227	3.8	33	3849.6	
	15:00	83	45	55	1365	135		227	3.8	33	3882.6	* Nitrogen tank installed. Pulsing at 1300 psig.
	16:00	84	45	70	1325	135	142	168	4.8	42	3924.6	
	17:00	85	43	70	1325	135	142	168	4.8	42	3966.6	
	18:00	86	43	70	1325	135	142	168	4.8	42	4008.6	* Bed level raised to 112 inches.
	19:00	87	43	70	1350	135	142	168	4.8	42	4050.6	
	20:00	88	43	70	1350	135	142	168	4.8	42	4092.6	
	21:00	89	48	70	1350	135	142	168	4.8	42	4134.6	* Compressor's 4th stage has a broken piston ring & rod.
	22:00	90	48	70	1350	135	142	168	4.8	42	4176.6	
	23:00	91	48	70	1350	135	142	168	4.8	42	4218.6	* High level ash alarm in hopper has stopped.
11/29/92	0:00	92	48	70	1350	135	142	168	4.8	42	4260.6	* Vessel head temp. 540 F.
	1:00	93	47	70	1350	135	142	168	4.8	42	4302.6	
	2:00	94	47	70	1350	135	142	168	4.8	42	4344.6	
	3:00	95	47	70	1350	135	142	168	4.8	42	4386.6	
	4:00	96	47	70	1350	135	142	168	4.8	42	4428.6	* Vessel head temp. 609 F.
	5:00	97	47	70	1350	135	142	168	4.8	42	4470.6	
	6:00	98	47	70	1350	135	142	168	4.8	42	4512.6	
	7:00	99	47	70	1350	135	142	168	4.8	42	4554.6	
	8:00	100	47	70	1350	135	142	168	4.8	42	4596.6	
	9:00	101	47	70	1350	135	142	168	4.8	42	4638.6	

TABLE 7 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 3 (NOV 25 THRU DEC 7, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	10:00	102	47	70	1350	135	142	168	4.8	42	4680.6	
	11:00	103	47	70	1350	135	142	168	4.8	42	4722.6	
	12:00	104	47	70	1350	135	142	168	4.8	42	4764.6	
	13:00	105	47	70	1350	135	142	168	4.3	42	4806.6	
	14:00	106	47	70	1350	135	142	168	4.8	42	4848.6	
	15:00	107	47	70	1350	135	142	168	4.8	42	4890.6	
	16:00	108	47	70	1350	135	142	168	4.8	42	4932.6	* Started manual pulsing.
	17:00	109	47	70	1350	135	142	168	4.8	42	4974.6	* Switched back to automatic pulsing.
	18:00	110	47	70	1350	135	142	168	4.8	42	5016.6	* Bed level is 116.5 inches.
	19:00	111	47	70	1350	135	142	168	4.8	42	5058.6	
	20:00	112	47	70	1350	135	142	168	4.8	42	5100.6	
	21:00	113	47	70	1350	135	142	168	4.8	42	5142.6	* High level ash alarm in vessel.
	22:00	114	47	70	1350	135	142	168	4.8	42	5184.6	
	23:00	115	47	70	1350	135	142	168	4.8	42	5226.6	
11/30/92	0:00	116		70	1370	130	142	168	5.1	42	5268.6	* Bed level is down to 108 inches.
	1:00	117		70	1370	130	142	168	5.1	42	5310.6	
	2:00	118		70	1370	130	142	168	5.1	42	5352.6	
	3:00	119		70	1370	130	142	168	5.1	42	5394.6	* Vessel head temp. 450 F.
	4:00	120		70	1370	180	142	168	5.1	42	5436.6	
	5:00	121		70	1370	130	142	168	5.1	42	5478.6	
	6:00	122		70	1370	130	142	168	5.1	42	5520.6	
	7:00	123		70	1370	130	142	168	5.1	42	5562.6	
	8:00	124		70	1370	130	142	168	5.1	42	5604.6	
	9:00	125		70	1370	130	142	168	5.1	42	5646.6	
	10:00	126		70	1370	130	142	168	5.1	42	5688.6	
	11:00	127		70	1370	130	142	168	5.1	42	5730.6	
	12:00	128		70	1370	130	142	168	5.1	42	5772.6	
	13:00	129		70	1370	130	142	168	5.1	42	5814.6	* Build cake.
	14:00	130		65	1400	130	142	168	4.8	39	5853.6	
	15:00	131		65	1400	130	142	170	4.8	39	5892.6	
	16:00	132		65	1400	130	142	190	4.8	39	5931.6	
	17:00	133		65	1400	130	142	200	4.8	39	5970.6	
	18:00	134		65	1400	130	142	170	4.8	39	6009.6	
	19:00	135		65	1400	130	142	170	4.8	39	6048.6	
	20:00	136		65	1400	180	142	180	4.8	39	6087.6	* Pulsing stopped switching N2 trucks.
	21:00	137		65	1400	130	142	180	4.8	39	6126.6	
	22:00	138		65	1400	130	164	185	4.8	39	6165.6	* Pulsing stopped switching N2 trucks. Valve HCV-J777 failed closed. Valve failing due to trouble with logic.
	23:00	139		65	1400	130	164	185	4.8	39	6204.6	
12/01/92	0:00	140		60	1400	130	164	190	4.4	36	6240.6	* Purging vessel hopper due to high ash level.
	1:00	141		60	1400	130	166	190	4.4	36	6276.6	
	2:00	142		60	1400	130	166	190	4.4	36	6312.6	
	3:00	143		60	1400	130	166	190	4.4	36	6348.6	
	4:00	144		60	1400	130	166	195	4.4	36	6384.6	
	5:00	145		60	1400	130	170	195	4.4	36	6420.6	
	6:00	146		60	1400	130	170	195	4.4	36	6456.6	
	7:00	147		60	1400	130	170	195	4.4	36	6492.6	
	8:00	148		60	1400	130	175	195	4.4	36	6528.6	* Vessel head temp. is 460 F.
	9:00	149		60	1400	130	175	200	4.4	36	6564.6	
	10:00	150		60	1400	130	180	200	4.4	36	6600.6	
	11:00	151		55	1400	100		170	5.1	33	6633.6	* Drop load/flow to clean filters. Bed level is 128 inches.
	12:00	152		55	1350	100	150	160	5	33	6666.6	* Pulsing cycle is 60 minutes at 1300 psig. Bed level is 85".
	13:00	153		55	1300	90	150	160	5.3	33	6699.6	
	14:00	154		55	1200	90	145	155	5	33	6732.6	

TABLE 7 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 3 (NOV 25 THRU DEC 7, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	15:00	155		55	1200	90	145	150	5	33	6765.6	
	16:00	156		55	1100	90		80	4.7	33	6798.6	
	17:00	157		55	1100	90		50	4.7	33	6831.6	* Bed level is 49.9 inches. Pulsing cycle 30 min. at 1300 psig.
	18:00	158		60	1000	90	50	70	4.8	36	6867.6	* Pulsing manually.
	19:00	159		60	1000	90	50	70	4.8	36	6903.6	* Pulsing cycle 60 minutes at 1300 psig.
	20:00	160		60	1100	90	60	100	5.1	36	6939.6	
	21:00	161		60	1200	100	70	110	5	36	6975.6	
	22:00	162		65	1400	130	80	120	4.8	39	7014.6	* Ash level high. Hitting hopper with rubber sledge hammer.
	23:00	163		75	1450	130	100	130	5.7	45	7059.6	
12/02/92	0:00	164		75	1450	130	105	135	5.7	45	7104.6	
	1:00	165		75	1450	130	105	135	5.7	45	7149.6	
	2:00	166		75	1450	130	105	135	5.7	45	7194.6	
	3:00	167		75	1450	130	105	135	5.7	45	7239.6	
	4:00	168		75	1450	130	105	135	5.7	45	7284.6	
	5:00	169		75	1450	130	105	135	5.7	45	7329.6	
	6:00	170		75	1450	130	105	135	5.7	45	7374.6	
	7:00	171		75	1450	130	110	140	5.7	45	7419.6	
	8:00	172		75	1450	130	110	140	5.7	45	7464.6	* Bed level is 120 inches.
	9:00	173		75	1450	130	110	140	5.7	45	7509.6	* Bed level is 124 inches.
	10:00	174		75	1450	130	110	140	5.7	45	7554.6	
	11:00	175		75	1450	130	110	140	5.7	45	7599.6	
	12:00	176		75	1450	130	110	140	5.7	45	7644.6	
	13:00	177		70	1425	130	113	152	5.2	42	7686.6	
	14:00	178		70	1425	130	120	155	5.2	42	7728.6	
	15:00	179		70	1425	130	125	155	5.2	42	7770.6	* Backup cyclone vent is showing first evidence of dust.
	16:00	180		70	1425	130	130	158	5.2	42	7812.6	
	17:00	181		70	1425	130	136	160	5.2	42	7854.6	
	18:00	182		70	1425	130	138	166	5.2	42	7896.6	
	19:00	183		70	1425	130	139	166	5.2	42	7938.6	
	20:00	184		70	1425	130	140	169	5.2	42	7980.6	
	21:00	185		70	1425	130	144	169	5.2	42	8022.6	
	22:00	186		70	1425	130	148	170	5.2	42	8064.6	
	23:00	187		70	1425	130	148	170	5.2	42	8106.6	
12/03/92	0:00	188		65	1450	130	150	172	4.9	39	8145.6	* Valves are double pulsing
	1:00	189		65	1450	130	152	174	4.9	39	8184.6	
	2:00	190		65	1450	130	158	180	4.9	39	8223.6	
	3:00	191		65	1450	130	158	180	4.9	39	8262.6	
	4:00	192		65	1450	130	158	185	4.9	39	8301.6	
	5:00	193		65	1450	130	165	185	4.9	39	8340.6	
	6:00	194		65	1450	130	165	188	4.9	39	8379.6	* Bed level is 123 inches.
	7:00	195		65	1450	130	165	175	4.9	39	8418.6	* Pulsing at a 30 minute cycle.
	8:00	196		65	1450	130	165	175	4.9	39	8457.6	
	9:00	197		65	1450	130	167	177	4.9	39	8496.6	* Sample dust from backup cyclone shows initial puff then clean.
	10:00	198		65	1460	130	170	182	4.9	39	8535.6	
	11:00	199		65	1470	130	175	185	5	39	8574.6	
	12:00	200		65	1470	130	180	190	5	39	8613.6	
	13:00	201		60	1490	130			4.6	36	8649.6	
	14:00	202		60	1490	130			4.6	36	8685.6	* Pulsing at a 60 minute cycle. All valves working. Vessel hopper is hot.
	15:00	203		60	1490	130			4.6	36	8721.6	
	16:00	204		55	1490	130			4.2	33	8754.6	
	17:00	205		55	1490	130			4.2	33	8787.6	
	18:00	206		55	1490	130	205	210	4.2	33	8820.6	* Drop load/flow to clean filter. Compressor on line, N2 off.
	19:00	207		50	1490	130	205		3.9	30	8850.6	

TABLE 7 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 3 (NOV 25 THRU DEC 7, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	20:00	208		50	1490	130			3.9	30	8880.6	
	21:00	209		62	1350	125			4.6	37.2	8917.8	* Pulsing at a 60 minutes cycle at 1200 psig.
	22:00	210		60	1275	115	180	194	4.6	36	8953.8	
	23:00	211		55	1275	115	180	194	4.2	33	8986.8	* Compressor off line, N2 on.
12/04/92	0:00	212		55	1275	115	180	194	4.2	33	9019.8	
	1:00	213		55	1275	115	180	194	4.2	33	9052.8	* Compressor back on line, N2 off.
	2:00	214		55	1275	115	180	194	4.2	33	9085.8	
	3:00	215		55	1275	115	180	194	4.2	33	9118.8	
	4:00	216		55	1300	115	180	194	4.3	33	9151.8	
	5:00	217		55	1300	115	178	192	4.3	33	9184.8	
	6:00	218		55	1275	115	176	190	4.2	33	9217.8	
	7:00	219		55	1275	115	176	188	4.2	33	9250.8	
	8:00	220		55	1250	115	174	188	4.2	33	9283.8	
	9:00	221		55	1250	115	174	187	4.2	33	9316.8	
	10:00	222		55	1250	115	174	187	4.2	33	9349.8	
	11:00	223		55	1250	115		165	4.2	33	9382.8	* Drop load/flow to clean filters
	12:00	224		45	1150	90		152	4	27	9409.8	
	13:00	225		40	1000	80		148	3.5	24	9433.8	
	14:00	226		40	1000	80		145	3.5	24	9457.8	
	15:00	227		55	1000	80		30	4.8	33	9490.8	* Cleaned filters, 1400 psig.
	16:00	228		55	1000	80	30	65	4.8	33	9523.8	* Pulsing at a 60 minute cycle at 1200 psig.
	17:00	229		60	1050	90	30	70	5	36	9559.8	
	18:00	230		60	1100	100	30	90	4.7	36	9595.8	
	19:00	231		70	1150	100	35	95	5.6	42	9637.8	
	20:00	232		70	1250	115	40	100	5.3	42	9679.8	
	21:00	233		80	1300	130	50	120	5.6	48	9727.8	
	22:00	234		80	1350	130	60	120	5.7	48	9775.8	
	23:00	235		80	1400	130	60	120	5.9	48	9823.8	
12/05/92	0:00	236		75	1385	130	70	120	5.5	45	9868.8	
	1:00	237		75	1385	130	70	120	5.5	45	9913.8	
	2:00	238		75	1385	130	75	120	5.5	45	9958.8	
	3:00	239		75	1385	130	75	120	5.5	45	10003.8	
	4:00	240		75	1385	130	75	120	5.5	45	10048.8	
	5:00	241		75	1385	130	80	120	5.5	45	10093.8	
	6:00	242		75	1385	130	80	120	5.5	45	10138.8	
	7:00	243		75	1385	130	80	120	5.5	45	10183.8	
	8:00	244		75	1385	130	80	120	5.5	45	10228.8	
	9:00	245		75	1385	130	60	120	5.5	45	10273.8	
	10:00	246		75	1385	130	80	120	5.5	45	10318.8	
	11:00	247		75	1385	130	80	120	5.5	45	10363.8	
	12:00	248		75	1385	130	80	120	5.5	45	10408.8	* Manual pulsing at 1200 psig. Air purged through screwfeeder into APF.
	13:00	249		75	1350	125	80	120	5.6	45	10453.8	
	14:00	250		75	1350	125	80	120	5.6	45	10498.8	
	15:00	251		75	1350	125	80	120	5.6	45	10543.8	
	16:00	252		75	1350	125	80	120	5.6	45	10588.8	* Compressor's 4th stage is making a light tapping sound.
	17:00	253		75	1350	125	80	120	5.6	45	10633.8	
	18:00	254		75	1350	125	80	120	5.6	45	10678.8	
	19:00	255		75	1350	125	80	120	5.6	45	10723.8	
	20:00	256		75	1350	125	80	120	5.6	45	10768.8	
	21:00	257		75	1350	125	80	120	5.6	45	10813.8	
	22:00	258		75	1350	125	80	120	5.6	45	10858.8	
	23:00	259		75	1350	125	80	120	5.6	45	10903.8	
12/06/92	0:00	260		75	1325	125	80	120	5.5	45	10948.8	

TABLE 7 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 3 (NOV 25 THRU DEC 7, 1992)

DATE	TIME	HRS	MWe	FLOW KPPH	T DEG F	P PSIG	DP(ts) IN WG	TRIGGER IN WG	VELOCITY FT/MIN	ASH FILTERED	TOTAL ASH	REMARKS
	1:00	261		75	1325	125	80	120	5.5	45	10993.8	
	2:00	262		75	1325	125	80	120	5.5	45	11038.8	
	3:00	263		75	1325	125	80	120	5.5	45	11083.8	
	4:00	264		75	1325	125	80	120	5.5	45	11128.8	
	5:00	265		75	1325	125	80	120	5.5	45	11173.8	
	6:00	266		75	1325	125	80	120	5.5	45	11218.8	
	7:00	267		75	1325	125	80	120	5.5	45	11263.8	
	8:00	268		75	1325	125	80	120	5.5	45	11308.8	* At 10:28 change over to Pittsburgh no. 6 coal.
	9:00	269		75	1325	125	80	120	5.5	45	11353.8	* Vessel head temp. 300 F. Vessel discoloration on SE side from
	10:00	270		75	1325	125	80	120	5.5	45	11398.8	just below the flange down to the nozzle 8 level and under the
	11:00	271		75	1325	125	80	120	5.5	45	11443.8	inlet. Hammering on the hopper & around the nozzle 4 level
	12:00	272		75	1325	125	80	120	5.5	45	11488.8	with a rubber sledge hammer. Vessel head temp. 425 F.
	13:00	273		75	1325	125	72	95	5.5	45	11533.8	
	14:00	274		75	1325	125	72	95	5.5	45	11578.8	
	15:00	275		75	1325	125	72	95	5.5	45	11623.8	
	16:00	276		75	1325	125	72	95	5.5	45	11668.8	
	17:00	277		75	1325	125	72	95	5.5	45	11713.8	
	18:00	278		75	1325	125	72	95	5.5	45	11758.8	
	19:00	279		75	1325	125	72	95	5.5	45	11803.8	
	20:00	280		75	1325	125	72	95	5.5	45	11848.8	
	21:00	281		75	1325	125	72	95	5.5	45	11893.8	
	22:00	282		75	1325	125	72	95	5.5	45	11938.8	
	23:00	283		75	1325	125	72	95	5.5	45	11983.8	
12/07/92	0:00	284		75	1325	125	72	92	5.5	45	12028.8	
	1:00	285		75	1325	125	72	92	5.5	45	12073.8	
	2:00	286		75	1325	125	72	90	5.5	45	12118.8	
	3:00	287		75	1325	125	72	90	5.5	45	12163.8	
	4:00	288		75	1325	125	72	90	5.5	45	12208.8	
	5:00	289		75	1325	125	72	90	5.5	45	12253.8	
	6:00	290		75	1325	125	72	90	5.5	45	12298.8	
	7:00	291		75	1325	125	72	90	5.5	45	12343.8	
	8:00	292		75	1325	125	72	90	5.5	45	12388.8	
	9:00	293		75	1325	125	72	90	5.5	45	12433.8	
	10:00	294		75	1325	125	72	90	5.5	45	12478.8	* Combustor trip due to an over heated expansion joint.

baseline pressure drop was reestablished, Figure 10, apparently the result of pulse cleaning the filter during the Run 2 shutdown and subsequent to restart. Major operating events occurring during Run 3 include:

- First occurrence of a high level ash alarm and indication of ash accumulating in the APF vessel hopper.
- Second loss of the APF pulse compressor again resulting in an extended time period before cleaning could be reestablished and subsequent high (but stable) baseline pressure drop.
- Three separate incidences of dropping plant load to recover APF baseline pressure drop.
- First indication of unstable APF pressure drop operation when the plant load was increased and filter operating temperatures exceeded 1450°F, Figure 11.
- First indication of a dust breach between the dirty and clean gas side, occurring approximately 176 hours into the test run.
- First identifiable change in the APF pressure drop suggesting the possibility of loss of candle elements, Figure 12.

In this test run, the PFBC (and APF) was shut down due to a pipe bellows issue independent of the APF unit. After shutdown and cooldown, the filter unit was first inspected in place and then the APF tubesheet and cluster assembly were removed for detailed inspection, analysis and maintenance. These results (to date) are provide.

<u>APF Inspection Following Test Run 3</u>

Prior to removal of the tubesheet and cluster assembly from the APF vessel, an in situ inspection was conducted that included borescope penetration into the dirty gas

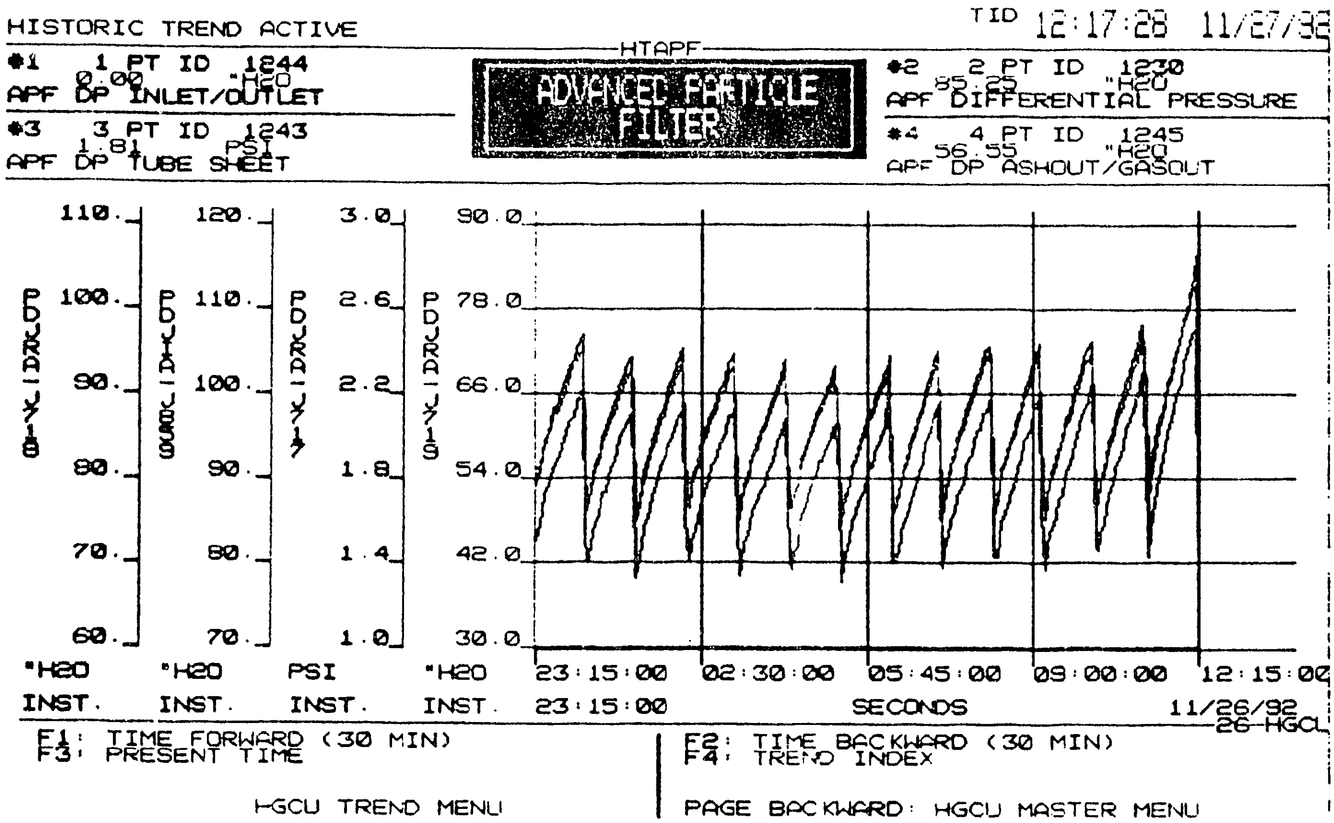


Figure 10 - APF Pressure Drop Following Shutdown and Hot Restart

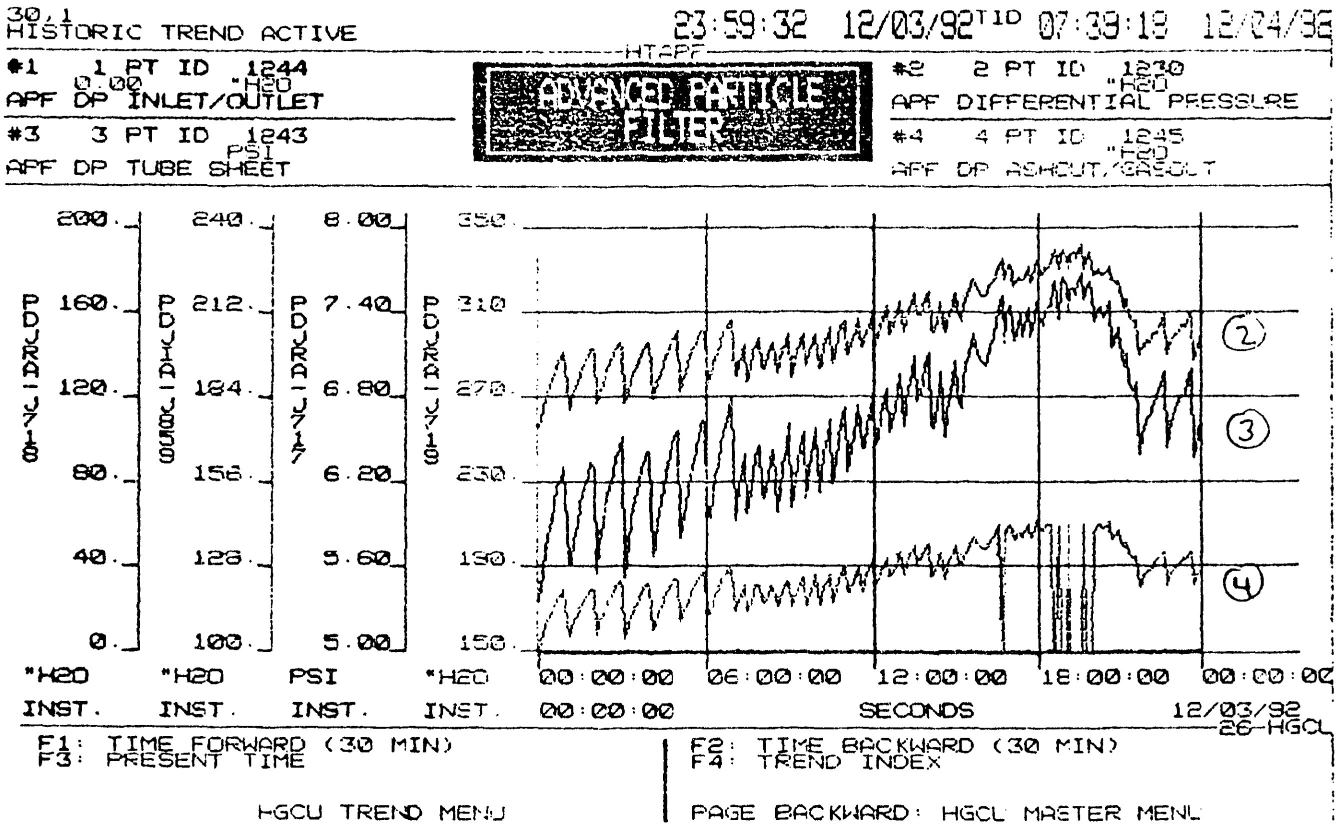


Figure 11 - APF Pressure Drop Showing Increasing Baseline During Period When Operating Temperature Exceeded 1450°F

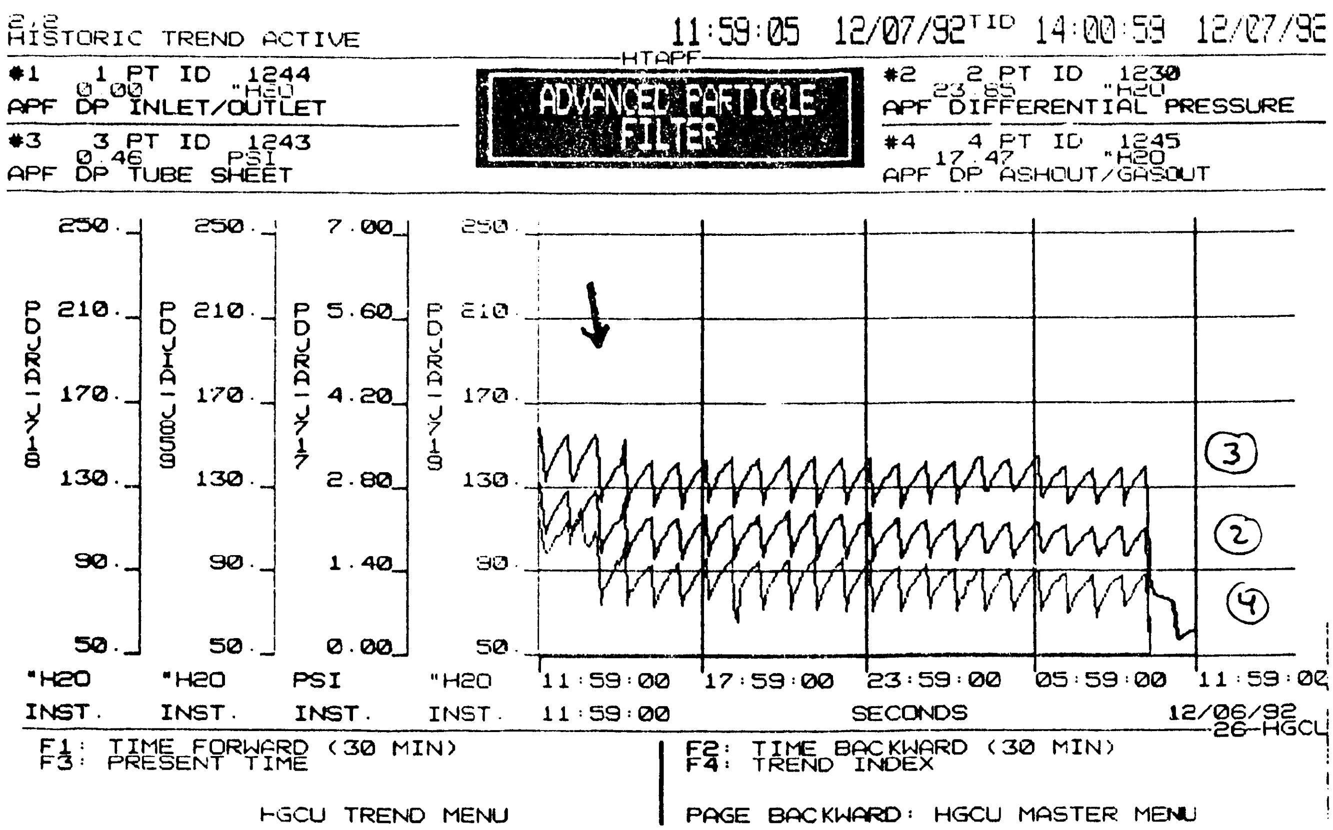


Figure 12 - APF Pressure Drop Showing Sudden Decrease Suggesting Candle Failure

side, and visual inspection through the large nozzle accesses. Results of these inspections showed:

- A fine or light dust coating on the clean gas side surfaces.

- The inside surfaces of the candle plenums were inspected by passing a borescope through the pulse nozzle, down through the clean gas side of the piping. This inspection showed all top plenums to be clean, a possible light dust coating on the middle plenum of Cluster B and a light dust coating on the bottom plenum of Clusters A and B. Interestingly, all the plenums in Cluster C appeared dust free.

- The ash level in the APF hopper was approximately 6 inches below the bottom of the candles on the lower plenums, at least in the region accessible with the borescope. The borescope could not be pushed through one access nozzle (4C) due to the buildup of ash. This would imply that at least in this area, the ash had accumulated above the candle level, Figure 13.

- Prior to visual inspection through the APF ash hopper access nozzle, ash accumulated in the vessel was removed. During this process, broken candle sections were recovered. It appeared that these sections had collected in the ash, above the large access nozzle. A total of 49 pieces of broken candles were found, corresponding to a total length approximately 832 inches. Table 8 provides details of these sections.

- Access through the ash hopper nozzle and inspection confirmed that significant damage to the candles on the bottom plenum had occurred. Dust bridging between candles and the physical displacement of candles was evident with missing candles (see photographs given in Appendix A).

At this point in the in situ inspection, it was unclear if any damage had occurred to the candles on the middle and top plenums. The borescope inspection of these plenums had suggested the possibility of ash in the middle plenum of cluster B. It was therefore decided to open the APF vessel and remove the tubesheet and candle cluster for further inspection and maintenance.

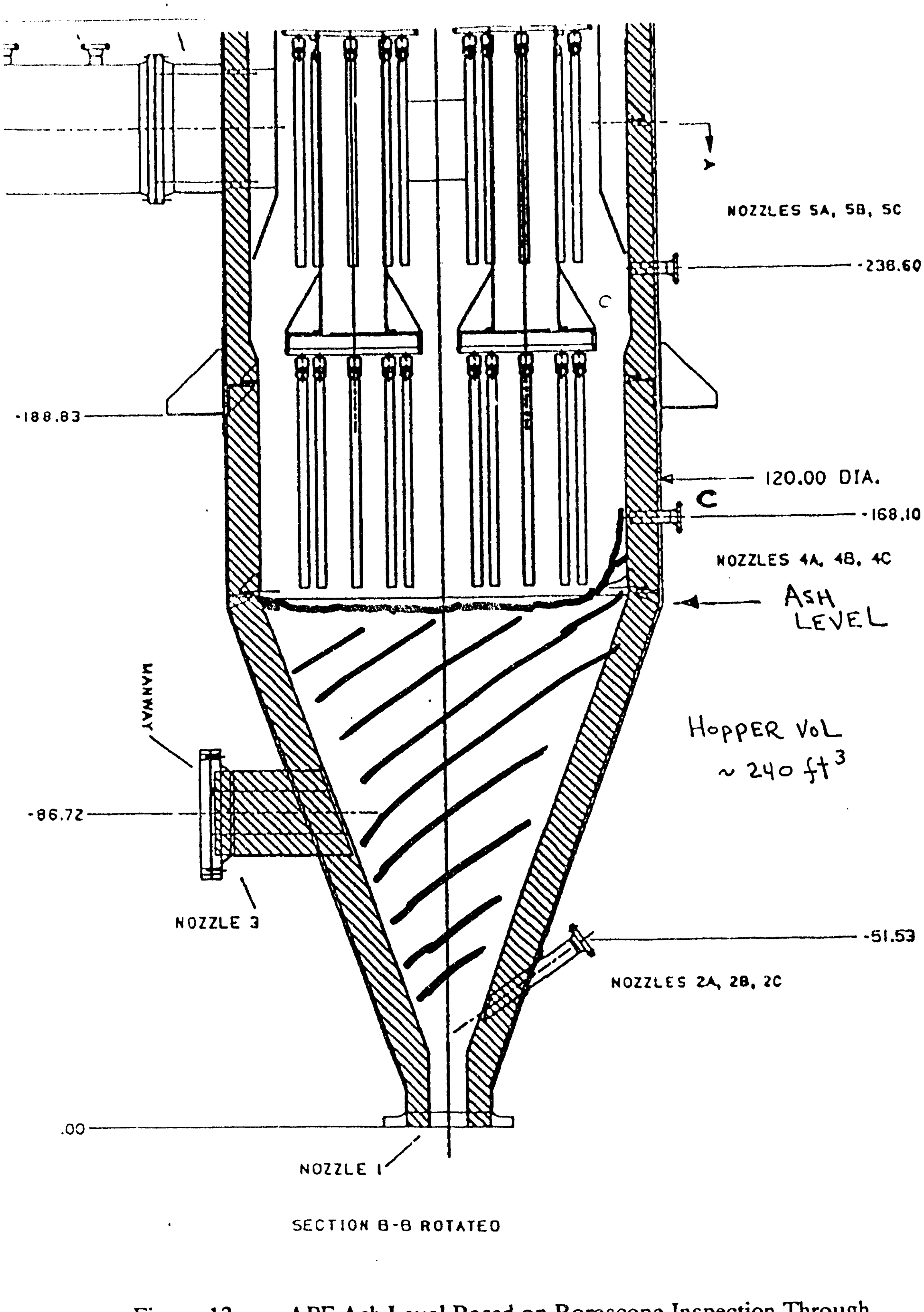


Figure 13 - APF Ash Level Based on Borescope Inspection Through Nozzles 4a, 4b and 4c

TABLE 8

CANDLE FILTER PIECES RETRIEVED FROM THE DECEMBER 16, 1992 INSPECTION

- Section Lengths, inches -

Number	Fracture/Fracture Caked/ Caked	Fracture/Fracture Caked/ Clean	Fracture/Fracture Clean/ Clean	Fracture/Closed Bottom Caked/ Caked	Fracture/Closed Bottom Caked/ Clean	Fracture/Closed Bottom Clean/ Clean	Comment
1*	12						Surface Scrape Lines
2**	~12						
3**	~12						
4				13			End Cap Chipped; Surface Scraped
5					13.5		End Cap Chipped Covered With Ash
6			17.25				Nicks; Scratches Filled With Ash
7			12.25				Surface Scratches
8			7.25				Surface Nicks; Wavy Fracture
9		10.25					Large Gouge On OD Fracture Surface
10		12					Chips, Gouges On Wall
11					12.5		End Cap Edge Chip
12		10					Somewhat Wavy Fracture On one End; Gouge On Wall
13					10.5		End Cap Edge And Wall Chips
14			10				Very Ragged Fracture; Chips On Walls
15			12				Somewhat Ragged Fracture On One End; Large Gouge On One End; Surface Scratches

* SEM/EDAX Characterization
** C-Ring Compression

TABLE 8 (continued)

CANDLE FILTER PIECES RETRIEVED FROM THE DECEMBER 16, 1992 INSPECTION

- Section Lengths, inches -

Number	Fracture/Fracture Caked/ Caked	Fracture/Fracture Caked/ Clean	Fracture/Fracture Clean/ Clean	Fracture/Closed Caked/ Caked	Fracture/Closed Caked/ Clean	Bottom Clean/ Clean	Comment
16			8.5				Ragged Fracture On Both Ends
17				18			End Cap Chip
18				15.5			End Cap Chips
19			12.25				Pronounced Nick On One End; Nick On Wall
20					14.25		Gouge On End Cap With Heavy Ash Deposit; Nicks On Wall
21				10.25			Heavy Dust Coating
22			7.5				Slight Angle On Both Fractured Surfaces
23						8.75	Went Through Super Sucker
24						5.75	Went Through Super Sucker
25	13.75						Chips, Scratches On Wall; One Angled Fractured Surface
26		32					Surface Chips, Edge Chips
27			25				Surface Gouges; Numerous Chips
28		20.5					
29		37					Surface Scratches; Gouges
30	24.5						Surface Scratches

TABLE 8 (continued)

CANDLE FILTER PIECES RETRIEVED FROM THE DECEMBER 16, 1992 INSPECTION

- Section Lengths, inches -

Number	Fracture/Fracture			Fracture/Closed		Bottom	Comment
	Caked/ Caked	Caked/ Clean	Clean/ Clean	Caked/ Caked	Caked/ Clean	Clean/ Clean	
31		23.25					Large Gouge Along Wall Near One Fracture Surface; Irregular Fracture; Fresh Chips And Scratches NO PENETRATION OF FINES ON ID WALL
32	35						Irregular Fracture; Edge Chips; ID WALL HAS FINES PENETRATION
33					21		Fresh Chips On Wall And End Cap
34	34.5						Large Gouge On Both Fractured Ends
35		38.75					Fresh Gouge On Wall
36					33.25		Scratches; Fresh Nicks
37		27.5					Side Wall Indented And Covered Heavily With Ash
38				31			Fresh Nicks

TABLE 8 (continued)

CANDLE FILTER PIECES RETRIEVED FROM THE DECEMBER 16, 1992 INSPECTION

- Section Lengths, inches -

Number	Fracture/Fracture			Fracture/Closed Bottom			Comment
	Caked/ Caked	Caked/ Clean	Clean/ Clean	Caked/ Caked	Caked/ Clean	Clean/ Clean	
39					23.25		Large Gouge Off End Cap
40				25.5			Scratches; Fresh Chips
41					30.75		Large Gouge On End Cap; Covered Heavily With Ash; Cap Chipped
42	10						White Inside; Nonuniform Edges
43				21			Filled ID
44					18		Shear Lip
45		10					Diagonal Edges
46		6.5					White ID Deposit
47		5					Very Irregular Ends
48		9					Filled ID
49		3					White ID

Removal of the internal assembly proceeded without major issue. Further detailed inspection of the APF showed:

- No broken candles were found on any of the top or middle plenums. Some ash bridging between the inner row of candles and the cluster support pipe was evident over the lower 5 or 6 inches of the candle on both the top and middle plenum sections. Figure 14 shows the general features of these arrays. Several of the candles from the top and middle plenums have been removed for subsequent characterization and destructive testing. Results of this effort will be reported next quarter.

- A total of 21 broken candles from the bottom three plenums were identified: 15 from Cluster A, 4 from Cluster B and 2 from Cluster C, Table 9. Six of the candles showed "fresh breaks", i.e., the candle section remaining in place did not show any dust over the fracture surface. It is speculated that these elements did not break loose until after the unit was shut down; but were probably damaged or cracked during operation. Seventeen of the 21 broken candles had apparently broken at or near the top of the candle in the area of the transition between the dense and more porous region that is characteristic of the manufacture of the Schumacher, Dia Schumalith SiC candles. Four of the candles had failed at the bottom end. These breaks ranged from 10 to 17 inches up, see Table 9.

- Visual inspection showed many of the unbroken candles on the bottom plenums to be bowed, Figure 15. Four failed candles have been rebuilt from the recovered pieces. These elements also show significant bow.

- Detailed analysis of both failed and unbroken candles is in progress. Initial data and evaluations made of the recovered broken candle sections is provided in Appendix A attached. This report describes results from initial material characterization, cold and hot strength tests, analysis of the candle fracture surfaces and the flow permeability of used candle elements.

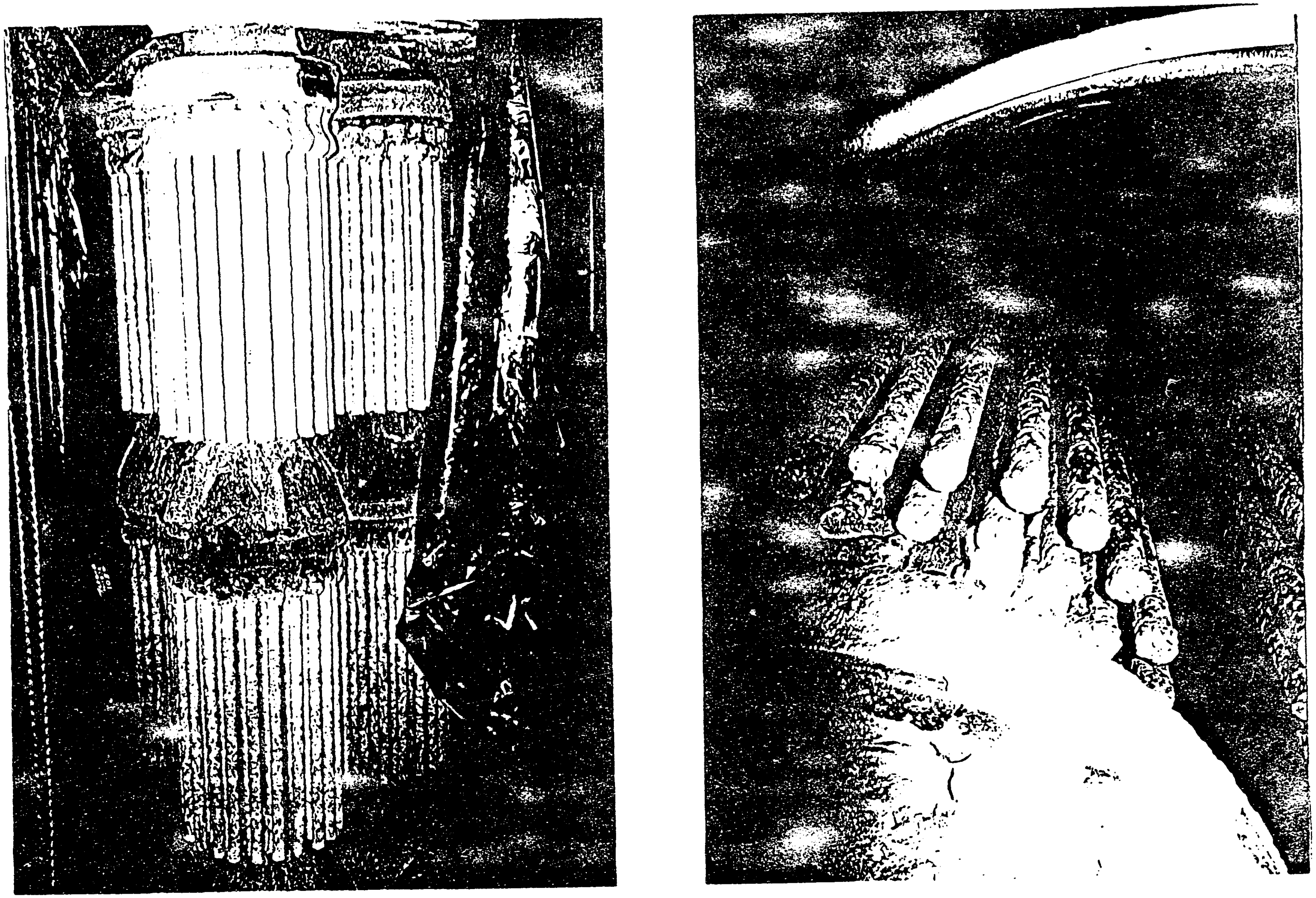


Figure 14 - Photographs of APF Cluster Showing General Feature of the Top and MIddle Plenums Following Test Run 3

Table 9

Identification of Broken Candle Elements and Cluster Position

Cluster	Position	Candle Number	Remaining Length (inches)	Remark
A	A/B-1	367	4.75	Fresh break *
A	A/B-2	104	45.0	
A	A/B-21	98	4.75	Fresh break *
A	A/B-22	92	4.5	Fresh break *
A	A/B-23	475	4.25	
A	A/B-24	29	4.75	
A	A/B-25	78	5.5	
A	A/B-26	174	4.25	
A	A/B-38	451	4.75	
A	A/B-39	16	4.75	
A	A/B-40	12	4.5	
A	A/B-41	186	5.0	
A	A/B-48	59	6.5	
A	A/B-49	53	4.5	
A	A/B-50	178	4.5	
B	B/B-21	309	50.0	
B	B/B-42	130	5.5	
B	B/B-43	125	4.0	Fresh break *
B	B/B-52	95	5.25	
C	C/B-1	308	47.0	Fresh break *
C	C/B-22	310	43.5	Fresh break *

* Clean surface at separation. Break did not occur during operation, but probably during handling after final shut down.

Figure 15 - Photograph Showing Bowed Candle in APF Bottom Cluster Array

Candle Filter Failure Scenario

Based on the preliminary evaluation of the test data and inspection, it is concluded that the observed candle failures were likely the results of the following scenario:

1. Loss of the pulse compressor during the Test Run 2 resulted in an overload (when cleaning was resumed) on the vessel ash discharge. Normally, approximately 45 lb of ash per cleaning sequence would be discharged to the vessel hopper. It is estimated that up to 600 lb of ash was discharged during the first cleaning event following the compressor outage.

2. Shortly following the above overload event (early in Run 3), a high ash level alarm signal was experienced suggesting the ash had reached the bottom of the large access nozzle on the vessel hopper.

3. Ash continued to accumulate to candle level (maybe higher) with continued operation of the APF unit.

4. Subsequent cleaning of the filter trapped ash between candles and around the bottom plenums (from above); building ash bridges in the lower plenum sections.

5. The high cohesive strength of this ash forced the candles to move laterally producing high shear loads near the top of the candles.

6. Candles failed as a result of the mechanical loads.

System Modifications

During APF operation, several equipment and logic related issues were identified for rework and maintenance. These efforts are summarized.

Compressor

1. Moisture separator drain lines became plugged.

   Resolution: Eliminated filters added manual drains in parallel with solenoid actuated drain lines, and ultimately replaced small port solenoids with solenoid actuated large port ball valves.

2. Fourth stage piston ring failed, apparently due to lack of lubrication.

   Resolution: Replaced rings, increased lubrication rate, replaced cylinder liner with a wear resistant cast iron liner and with properly oriented lubrication ports. With these modifications, the compressor has now been operated for 125 hours without further incident.

Vessel

1. Joint between outlet nozzle and vessel head showed overheating.

   Resolution: Outlet nozzle outlet liner was eliminated, joint between head insulation and outlet nozzle insulation was redesigned, and outlet nozzle was reinsulated. Potential holes around head penetrations were repacked.

2. Vessel head knuckle showed overheating (due to distortion of dome liner).

   Resolution: Brim of dome liner is being removed. Head has been totally dismantled, sandblasted, re-Plasited, and reinsulated. connection between dome liner and tubesheet liner is being redesigned.

3. Ash built up in vessel.

   Resolution: Modifications of the outlet region are being planned including liner, purges and diagnostics.

4. Pressure taps plugged (lines not purged).

   Resolution: Larger diameter tubes are being installed.

Back Pulse Skid

1. Actuators for ball valves were bent out of level and secondary accumulator tanks showed some vibration during pulsing.

   Resolution: Structural steel supports have been added to these components.

2. Some actuated ball valves show wear at couplers and some valves leak slightly.
   Resolution: Currently replacing all actuated ball valve bodies, couplers and actuator brackets (with improved design components) and valve gaskets as required.

3. Secondary accumulator tank regulators show evidence of drift and are difficult to recalibrate in service.
   Resolution: Upon receipt, Tescom will inspect and test the regulator showing the greatest drift. Tescom is designing a quick disconnect to facilitate in service calibration.

4. Pulse valves show axial scratches between cylinder and bore.
   Resolution: Atkomatic has supplied replacement cylinders and is redesigning the cylinder gripping flats to eliminate galling during actuation.

5. Logic limitations.
   Resolution: Instrument ranges are being extended. Options for pulse strategy are being expanded.

Extended Cluster Performance

AEP has expressed interest in running the APF at higher pressure differentials (10 psi vs 3 psi). A stress analysis has been conducted to determine the effectiveness of adding bars to stiffen the life limiting element - the bottom plate of the bottom plenum. At present it is planned to weld bars 1-1.5 inches wide by 2 inches high to these plates to help preserve predicted stress rupture life. Prior to this work a test will be conducted to check general weldability between Tidd exposed 310 and new 310 stainless steel.

AEP/KARHULA CANDLE FILTER TESTING

STATUS

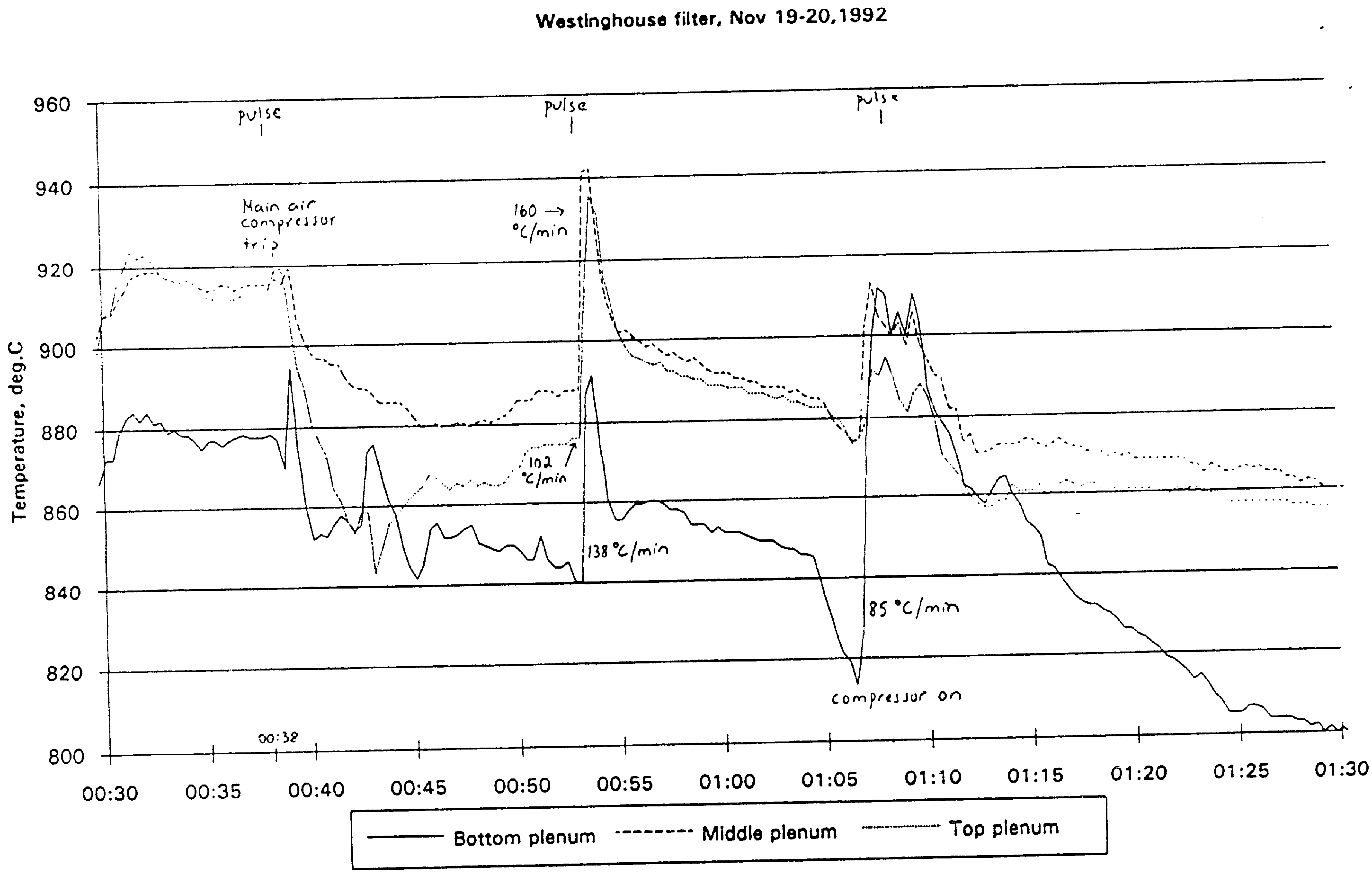
Commissioning of the 128 candle element unit comprising one Westinghouse APF cluster was initiated. To date four test runs have been made as summarized in Table 10. Detailed test reports on these runs have been received from Ahlstrom and copies will be forwarded under separate cover. Test runs to date include approximately 300 hours of operation with 150 hours on coal. Over the first 3 tests (weeks 44, 45 and 47) filter performance has been excellent with no indication of dust leakage or filter failure.

Prior to shutdown in Test Week 47, a failure occurred in the main air compressor supplying the CPFB unit while coal feed was maintained. Reducing gas conditions were generated in the filter unit. Continued pulse cleaning fo the filter (with air) and an attempted restart of the main compressor (two separate events, Figure 16, caused severe thermal transients to occur in the filter unit. Subsequent inspection showed two filters were initially fractured. Restart of the unit in Week 50 provided 12 additional broken filters (presumably initially broken by the earlier thermal transient events). All breakage was limited to the top plenum of the cluster assembly.

The filter unit has now been removed from the vessel for candle replacement and further inspection.

TABLE 10 - SUMMARY OF WESTINGHOUSE CANDLE CLUSTER TESTING AT AHLSTROM CPFBC FACILITY

FILTER OPERATING PARAMETERS	WEEK 43/44 OCT 19 THRU 28	WEEK 44 OCT 26-30	WEEK 45 NOV 2-6	WEEK 46 NOV 9-13	WEEK 47 NOV 16-20	WEEKS 48,49 THRU DEC 4	WEEK 50 DEC 7-11
TEST SCOPE	PREOPERATIONAL CHECKOUT	INITIAL COAL EXPOSURE	COMMISION	SCHEDULED SHUTDOWN		REPLACE TWO BROKEN CANDLES	RESTART
COAL TYPE		ILLINOS #6	ILLINOS #6		IOWA RAWHIDE		IOWA RAWHIDE
SORBENT		IOWA IND #1	IOWA/TSUKUMI		NONE		NONE
GAS FLOW, KG/S		3.3	4.6		4.5		4.6
SYSTEM PRESSURE, BAR		11.1	11.5		11		10.5
FILTER TEMPERATURE, DEG C		900	900		876		893
FACE VELOCITY, CM/S		2.9	3.8		3.9		4.3
INLET DUST LOADING, PPM		13000	16000		4400		4500
CLUSTER DP, MBAR							
BASELINE		45	90		110		115
MAXIMUM		55	100		115		125
CLEANING CYCLE, MIN		15 TO 30	20		15		30
CLEANING PRESSURE, BAR		23	23		22		34
OUTLET DUST LOADING,PPM		NONE	NONE		NONE		
TEST HOURS (GAS, OIL, COAL)		65.6	73		75.2		76
CUMULATIVE HOURS		65.6	138.6		213.8		289.8
TEST HOURS COAL		25.3	43.5		29.6		44.8
CUMULATIVE HOURS COAL		25.3	68.8		98.4		143.4
REMARKS		UNIT SHUTDOWN 10/29 DUE TO PLUGGING OF THE PRESSURE CONTROL VALVE.			COMPRESSOR TRIP & HIGH TEMPERATURE TRANSIENT. BROKEN FILTERS ON SHUTDOWN.		ADDITIONAL CANDLES FELL PROBABLY BROKEN IN COMPRESSOR TRANSIENT.



CONFIDENTIAL

W2470.XLS Chart 1

Figure 16 - Temperature Data Showing Occurrence of Severe Temperature Transients in Karhula Candle Cluster Unit.

APPENDIX A

MATERIAL CHARACTERIZATION OF THE
SCHUMACHER DIA SCHUMALITH CANDLE FILTERS AFTER
500 HOURS OF EXPOSURE TO PFBC CONDITIONS AT
AMERICAN ELECTRIC POWER

MATERIAL CHARACTERIZATION OF THE SCHUMACHER DIA SCHUMALITH CANDLE FILTERS AFTER 500 HOURS OF EXPOSURE TO PFBC CONDITIONS AT AMERICAN ELECTRIC POWER

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R. W. Palmquist, T. J. Mullen, A. L. Wolfe

January 18, 1993

Failed Candle Section Inspection and Primary Fracture Analysis

Initial inspection of the three bottom plenum clusters via the manway entrance in the Westinghouse Advanced Particle Filtration (W-APF) system on December 16, 1992 indicated that candles had been broken in each cluster array. Fifteen candles had broken in Cluster A, four in Cluster B, and two in Cluster C (Figure 1).[1] Segments from these twenty-one candle were initially considered to have dropped into the ash in the bottom of the W-APF vessel, and were retrieved during ash removal from the manway port. In Cluster B one candle was identified to be hanging below the bottom of the attached candles, indicating that it was also cracked, but supported in the array via the packed ash which bridged between the adjacent candles.

When viewed from the underside, severe bridging of ash was evident in Cluster B (Figure 2), while only marginal ash bridging was identified along the bottom to the mid-section of candles located in Cluster C (Figure 3). Cluster A (Figure 4) was virtually free of ash build-up, but contained the greatest number of candles that had failed during the second test sequence at Tidd.

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(1) Bottom segment of candle AEP/APF-150 located a position A/B-1 failed between the manway inspection and filter lift, producing a fresh fracture near the transition section of the candle filter. Similarly during transfer of the APF system from the vessel to the stationary support structure, candle filter AEP/APF-125 located at position B/B-43 dropped onto the support structure floor boards, again producing a fresh fracture near the transition section of the candle.

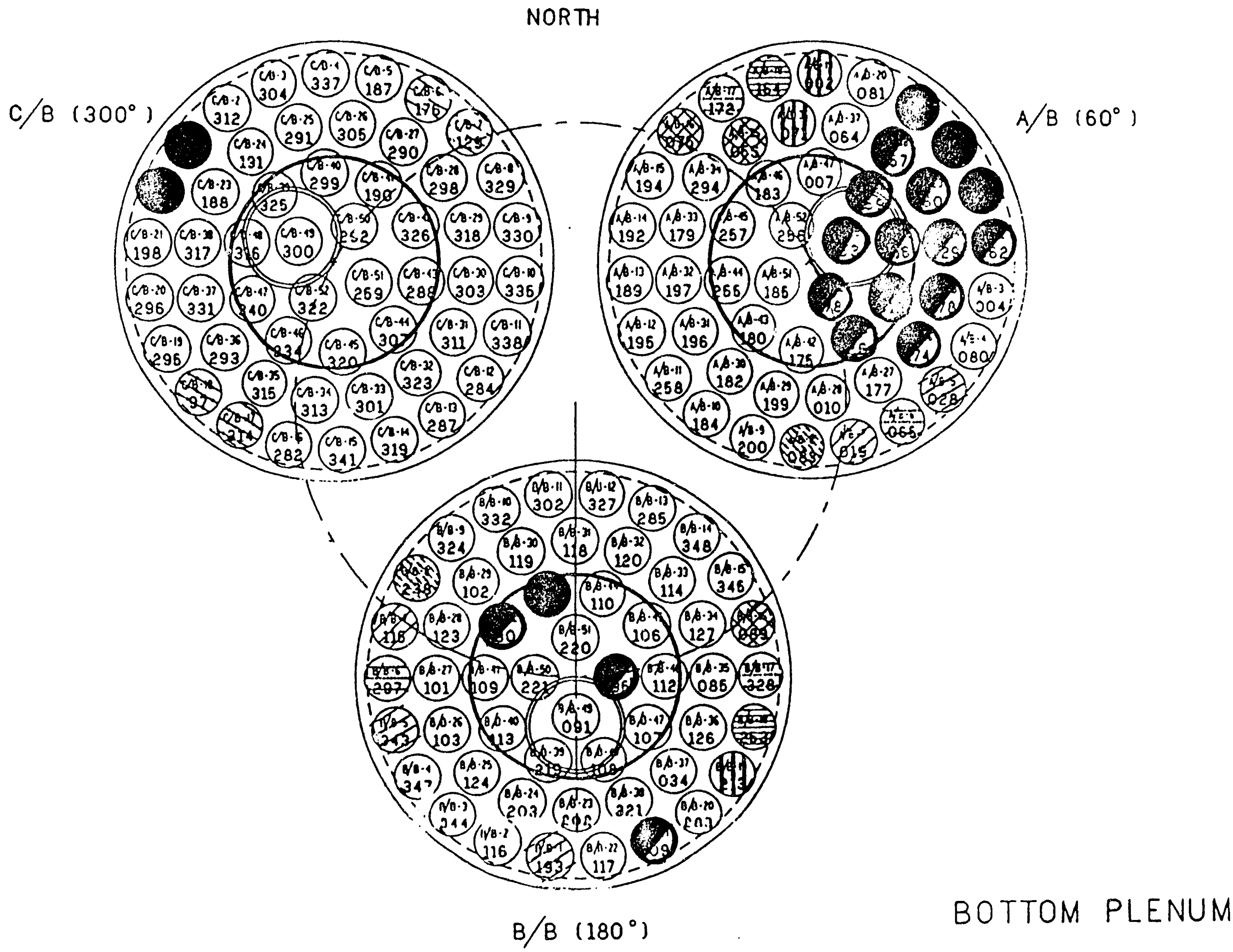


Figure 1 - Locat on of the Fractured Candles in the Bottom Clusters of the W-APF System

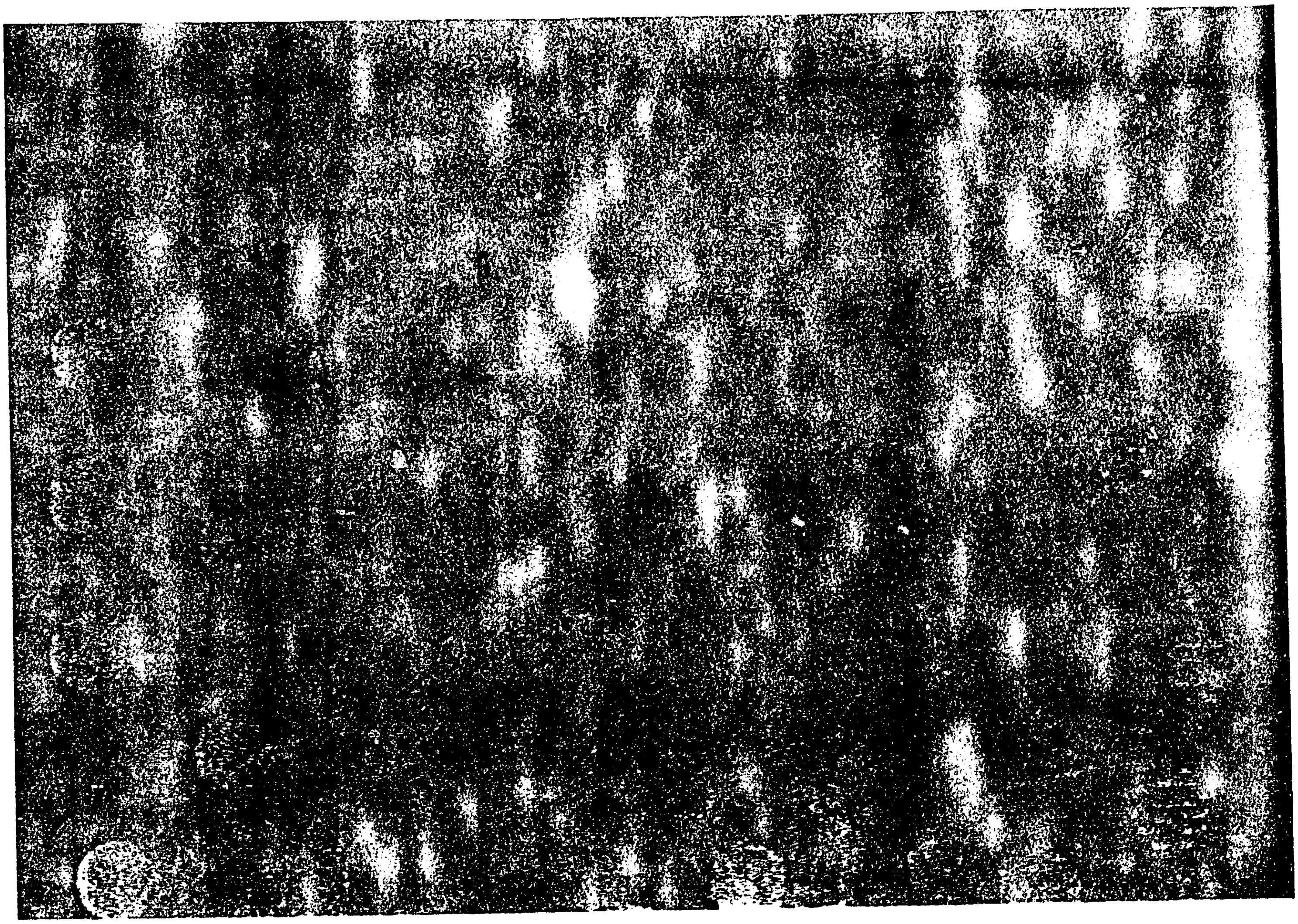


Figure 2 - Photo of Bottom Cluster B in the W-APF During the December 16, 1992 Manway Inspection

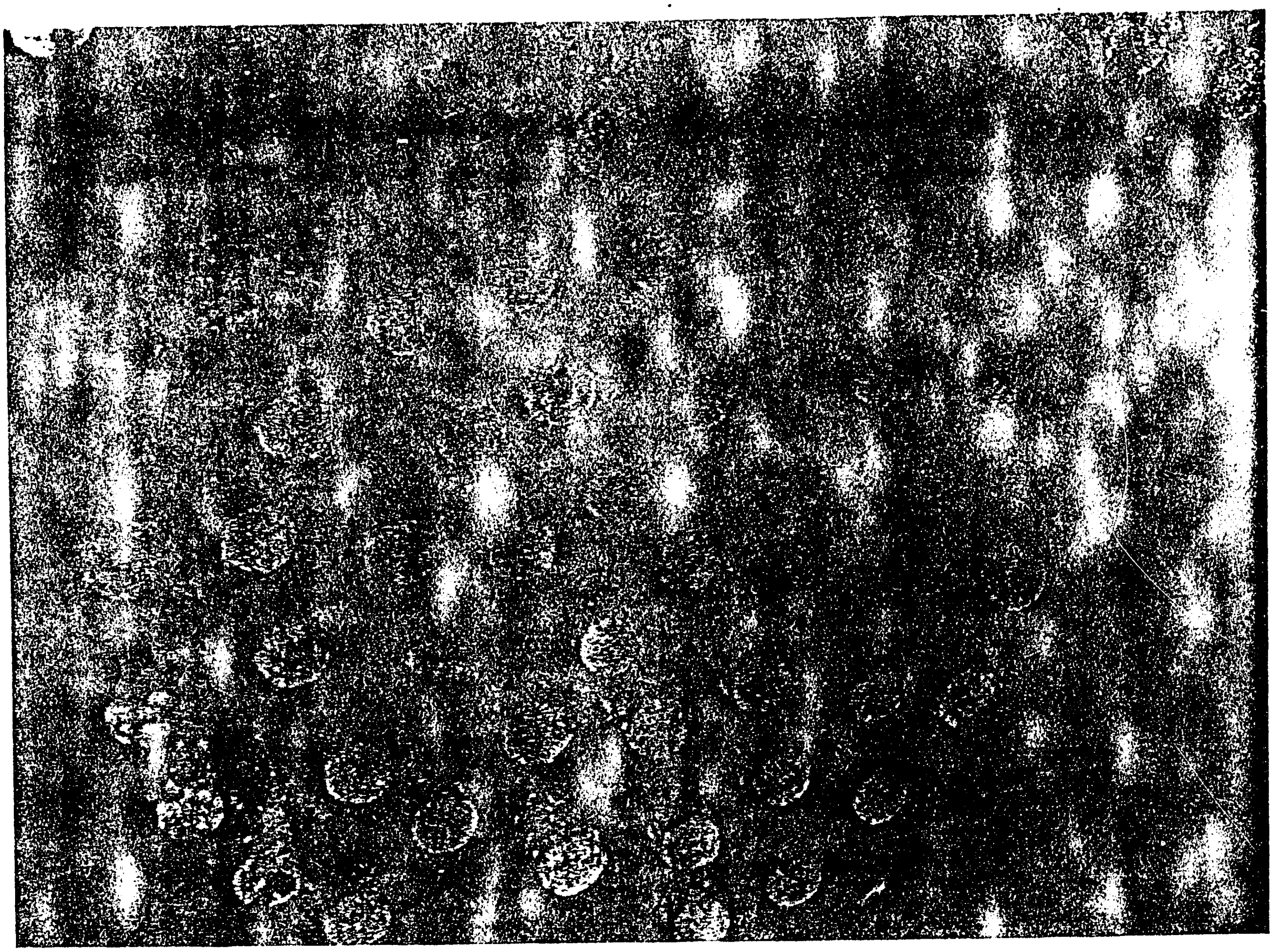


Figure 3 - Photo of Bottom Cluster C in the W-APF During the December 16, 1992 Manway Inspection

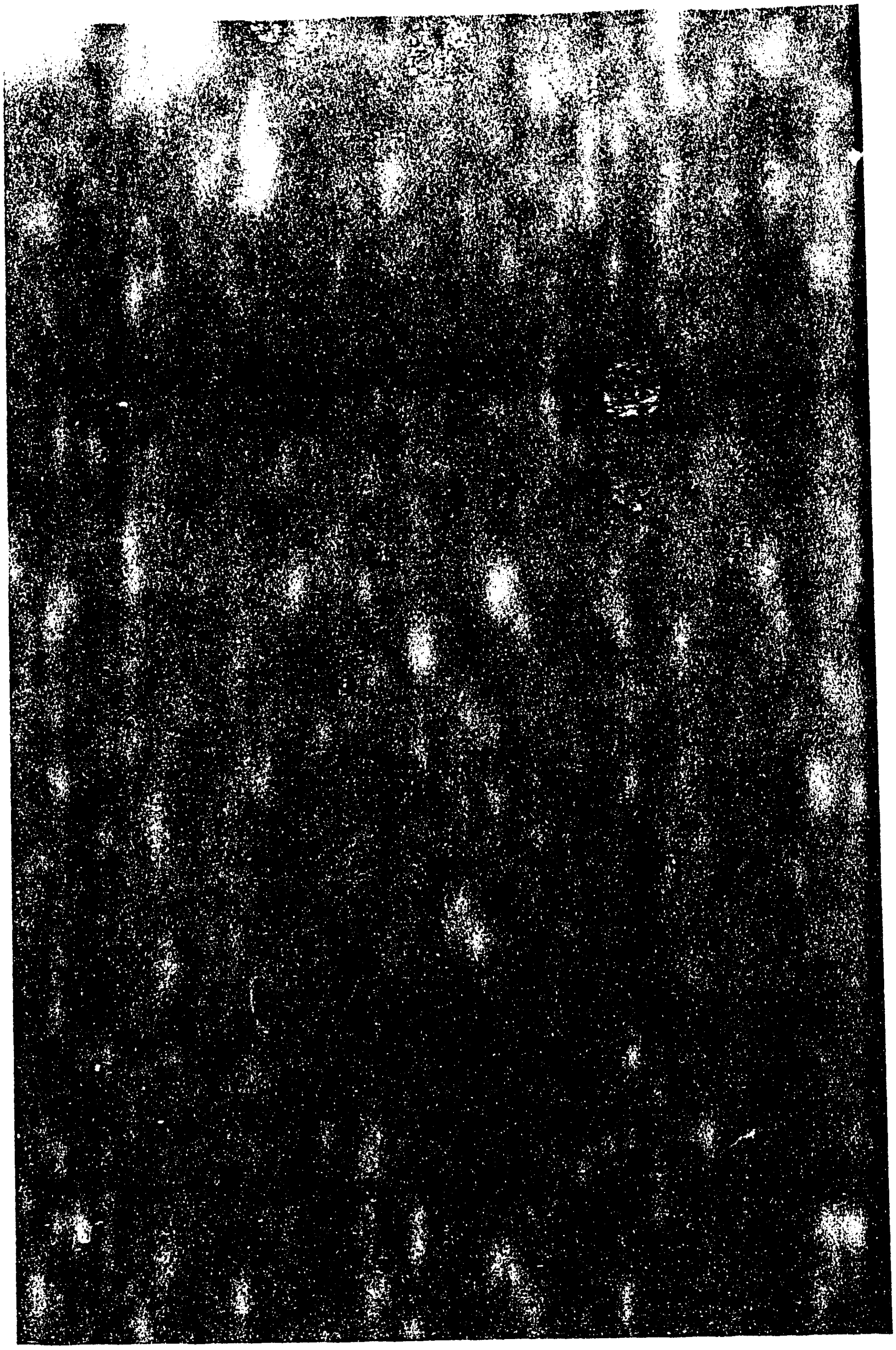


Figure 4 - Photo of Bottom Cluster A in the W-APF During the December 16, 1992 Manway Inspection

Forty-nine candle filter segments were retrieved during removal of the ash from the W-APF filter vessel, as well as during lift of the filter cluster array from the pressure shell. The length of the retrieved candle filter segments ranged from 3 to 38 inches. The average length was 17.28 inches (1σ = 9.64 inches). Twelve of the collected candle filter segments were between 10 and 12 inches in length.

Chips and surface scratches were evident along many candle segments. During retrieval of the broken candle segments, the various pieces were stacked into a large pile. Based on the virtually clean surface of the chips (i.e., dark silicon carbide grains evident; absence of dust), we believe that these chips occurred during stacking and were not the result of candle segments being broken during filter operation which then collided into an adjacent candle causing a cascade of falling candle sections to occur. If the in-situ failure had occurred the surface would be chipped, but a dust layer would be expected to blanket the chip similar to fractured candle wall.

What was interesting to note was that 13 candle sections were entirely caked with ash on both ends (7 closed end tips and an exposed fractured surface; 6 with both fractured surfaces exposed). Alternately, 25 candle segments had only one end surface caked with dust, with the opposite fractured during being virtually free of ash (9 closed end tips and an exposed fractured surface; 14 with both fracture surfaces exposed). In addition 11 candle filter segments were retrieved which appeared to have both relatively clean fractured surfaces (2 closed end tips and an exposed fractured surface; 9 with both fractured surfaces exposed).

When examining the ID bore of several candle segments that were retrieved from the ash hopper, we noted that the ID surface was either coated with the "pinkish" PFBC dust cake, or was entirely filled with ash. One 6.5 inch segment contained a "white" plug (i.e, dolomite-rich material) which entirely filled the candle bore. Similarly two candle filter segments (i.e., 3 and 10 inches in length) were heavily coated with the white dolomitic layer.

Based on this information it would appear that at least two events occurred to produce the variation in caking. One at the time of shutdown when a candle fractured and the bottom end plummeted into the ash, leaving the top freshly fracture surface exposed, and at a minimum, a second event which occurred earlier during filter operation that caused candles to break and fall into the ash bed which then continued to accumulate and bury the various candle segments.

This second scenario can further be divided into a period where candle segments fell into the ash hopper during startup of the unit when dolomite carryover from the primary cyclone to the candles occurred, forcing dolomite fines to be carried up through the broken candle(s) ID bore. Subsequent failure of these candles followed in a later event.

As a final candle failure event, candle filter AEP/APF-367 at location A/B-1 occurred during transfer of the cluster array from the W-APF vessel to its support structure.

When visually examining a segment of the candle we noted along the ID wall that approximately 3-4 mm of the cross-section wall was filled with ash (i.e., heavy "pinkish" ash band in contrast to the black clay bonded silicon carbide grains). Scanning electron micrographs indicate that the fines do not merely coat the pore cavity walls, but almost completely fill the pores within 3-4 mm along the candle ID. This is approximately 20-27% of the entire 15 mm Schumacher Dia Schumalith candle wall thickness. For this to occur, the bottom section of a candle had to be removed with dust passing through the ID bore into the clean plenum region. During pulse cleaning, dust was then returned through the ID and pushed through the silicon carbide wall. This scenario is descriptive of either a candle that had originally fractured and was partially plugged with ash, or an intact candle which had not suffered failure. For either an intact or broken candle we suspect that each candle in a plenum which experienced a candle failure (i.e., all bottom clusters) would be susceptible to fines penetrating into its ID wall. If only the obviously failed filters were removed and replaced, filters that contained the ID penetrated dust could release particulates into the clean gas stream, and simulate a failure which actually did not occur during restart. Similarly blinding along the ID surface is expected to increase gas flow resistance, lowering permeability through each ID blinded candle filter. As a result, the following are recommended:

- Remove and replace all candles along each plenum that contains failed candles.

- Install fail-safe mechanisms that prevent backflow of fines into the ID matrix of intact candle filters.

- Develop and manufacture candle filter elements with both ID and OD membranes to limit fines penetration into the wall during hot gas filtration or pulse gas cleaning.

Visual inspection of the original failed candle pieces indicated that the clean fractures occurred circumferentially through the clay bonded silicon carbide matrix. Longitudinal fractures, as well as "ragged or discontinuous" fractured surfaces were typically not evident. The crisp clean breaks were nearly almost all parallel to the flange top and bottom closed end planes. Two candle sections (i.e., 8.75 inches and 5.75 inches) were severely gouged along the OD, as well as through the candle wall) as a result of being vacuumed into the "Super Sucker" during ash removal.

Fracture analysis of the failed candle filter segment was performed to establish the primary fracture surface and failure mode. Initially attempts were made to identify primary fracture surfaces since the failed candle sections fell into the ash hopper with many secondary fractures occurring during these events. Approximately two-thirds of the 21 failed candles were retrieved from the ash hopper (832 inches of failed candle filter segments in total were found out of the 21 candle filters which had a total length of 1260 inches). Approximately 268 inches of the filter material remained in the holders where candles had failed. In total this accounts for an 87% candle filter recovery efficiency in the W-APF vessel.

Segments of the failed candles were reassembled into near full length candle filter elements (i.e., 60 inches). These reassembled candles clearly failed at the top of each filter element. The lengths of the reassembled candle filters were between 53.5 and 55.5 inches, indicating that the candles failed near the transition section of the Schumacher Dia Schumalith filter elements (i.e., fine to coarse grain transition section).

Three of the candle sections had well developed "shear lips" typical of a beam broken in a bending mode. The fourth candle did not have a well defined lip, but appeared to have somewhat of an abraded fracture surface. This may have occurred during handling and shipping, or alternately, the adjoining candle section may have fractured, thus leaving the reassemble candle somewhat shy of the initial 60 inch length. There was no evidence of longitudinal cracking along the primary fracture surfaces. Similarly the secondary fractures were virtually all transverse breaks.

The reassembled candles were noted to have an obvious bow along their length. One was bowed 0.2 inches over its 33 inch segment. This bowing suggests some period of sustained bending load that caused the candle to creep <u>or</u> a steady state thermal gradient across the candle diameter which caused a bending stress that was relaxed by creeping.

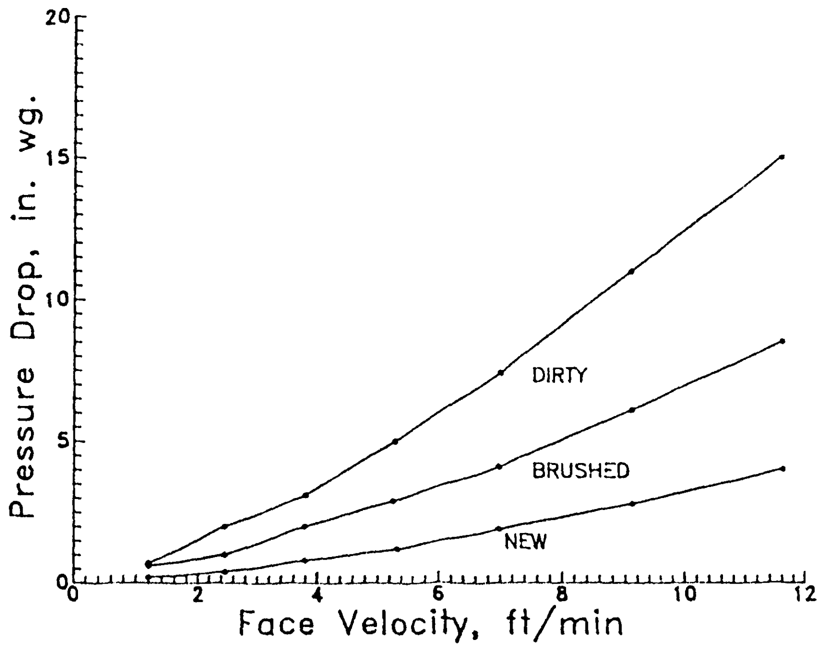
Since the top and middle clusters of the candles appeared to be completely intact, failure along the bottom clusters was most probably related to ash bridging. The presence of the bow along the failed candle filter sections, as well as the "shear lip" on the primary fracture surface suggests that either there was a catastrophic event (i.e., in addition to a sustained load) such as a cascade of ash causing a shock wave, or a sustained bending load causing delayed failure in bending. The bow appeared in general to be in the right direction relative to the "shear lip", suggesting that the latter scenario is likely.

Further inspection of the failed candle filter sections indicated that "white" areas below the dust cake layer were evident along the originally light grey outer membrane of the Schumacher Dia Schumalith candle. Visually this area did not appear to have an ash deposit along its surface, but merely a layer that accentuated dimpling in the membrane features.

In an attempt to ascertain whether there was a compositional variation between the "white" areas that coated the candle filter membrane and the "pink" PFBC dust cake ash, several of the ash deposits were removed from both failed and intact candle filter surfaces. Both "white" and "pink" areas remained along the ash surface that was adjacent to the candle filter surface. Scanning electron microscopy/energy dispersive x-ray analysis (SEM/EDAX), as well as elemental microprobe analysis (EMA) indicated that the "white" area contains a higher concentration of dolomite (34.50% magnesium (Mg), 32.72% calcium (Ca), 23.19% sulfur (S), 7.03% silicon (Si), and 2.56% iron (Fe); atomic percent basis) in comparison to the "pinkish" PFBC ash (36.06% S, 21.90% Si, 11.30% Al, 10.39% Mg, 15.50% Ca, 2.61% Fe, 2.25% K; atomic percent basis). The particle size of the dolomite deposit appeared to be somewhat smaller than the ash fines.

Notably the "white" dolomitic layer appeared to be thinly deposited along the length of the candle filters, while the relatively thick deposit of ash resulted along the ID of the 3 and 10 inch sections of candle that had fallen into the ash hopper. Figure 5 illustrates the relatively low permeability of an intact Schumacher Dia Schumalith candle filter after removal from the W-APF system. Brushing the surface of the candle to remove the heavy ash deposit while retaining the underlying "white" dolomitic surface regains approximately half of the original permeability of the as-fabricate matrix.

Roor Temperature



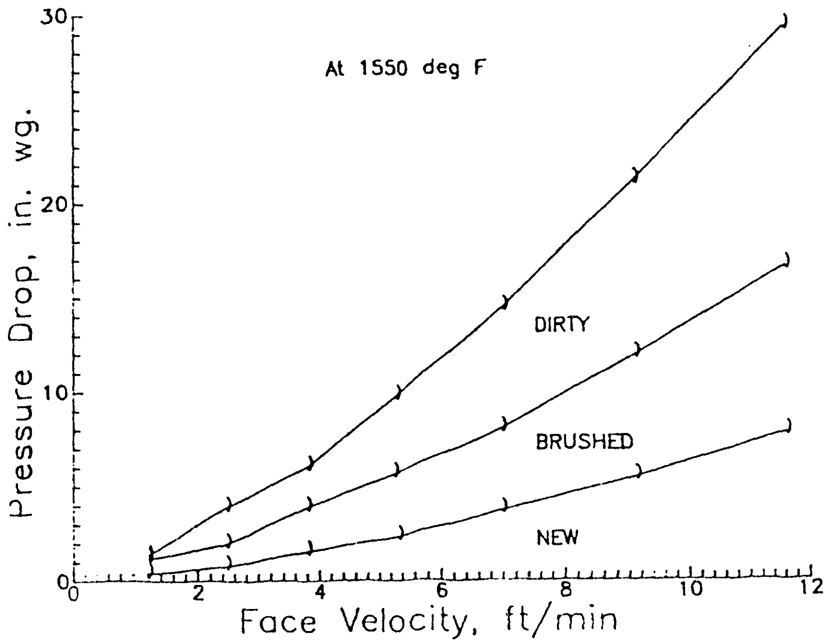


Figure 5 - Permeability of the Schumacher Dia Schumalith Candle Filters

In an attempt to discern whether there was any variation within the heavy ash deposit that formed along the intact candle filter surfaces, SEM/EDAX analyses were performed at 0.5 mm intervals through a 5 mm thick ash "dumpling" deposit. Table 1 indicates that along the ID of the deposit (i.e., surface directly adjacent to the candle filter membrane), a nearly equivalent calcium-to-magnesium atomic ratio is detected in the sulfur-enriched sorbent/ash deposit. As we progress through the thickness of the deposit (i.e., material laid down along the filter wall at a later time), the calcium-to-magnesium atomic ratio is no longer equivalent (i.e., lower magnesium contribution) implying ash carryover with a lower sorbent contribution. Along the OD surface of the deposit (i.e., surface directly in contact with the PFBC gas phase environment, farthest from the candle filter wall), we once again see that the calcium-to-magnesium atomic ratio is nearly equivalent, implying carryover of a dolomitic-enriched dust.

The composition of the overall ash deposit which was removed from the candle filter segments that had fallen into the ash hopper was determined qualitatively by emissions spectroscopy. The results generated at Westinghouse are provided in Table 2. The high calcium and magnesium concentrations in the ash are confirmed by these analyses. Similarly a high sulfur concentration was determined, and an ash pH of 4-5 was estimated. Note that the ash has an alkali concentration of 0.03 wt% sodium (Na) and 2% potassium (K). The concentration of soluble alkali will be determined by quantitative atomic absorption (AA) analyses to reflect the concentration of sodium and/or potassium that was released during coal combustion, and which condensed along the ash particle surfaces.

For comparison, Table 2 also provides the ash analyses that were generated by AEP. Minor variation in the elemental concentrations reflect both the analytical procedures that were used in the two independent analyses, as well as inhomogeneity in the sampled ash materials.

TABLE 1

ANALYSIS OF THE PFBC DUST COLLECTED IN THE W-APF VESSEL
(12/92)

Element	Westinghouse Emission* Spectroscopy Data, Wt%	AEP X-Ray Mass** Concentration Data, %
Al	> 5	5.55
Ag	< 0.001	
B	0.02	
Ba	0.03	
Be	0.001	
Bi	< 0.005	
Ca	> 5	9.67
Cd	< 0.02	
Co	0.003	
Cr	0.04	157.572 ppm
Cu	0.01	21.823 ppm
Fe	> 1	3.56
Ga	---	13.133 ppm
Ge	0.008	
K	2	1.25
Li	0.03	
Mg	> 5	5.64
Mn	0.02	140.078 ppm
Mo	0.004	
Na	0.03	NR
Nb	< 0.02	
Ni	0.02	45.707 ppm
Pb	0.04	140.894 ppm
Sb	< 0.02	
Si	> 5	8.11
Sn	< 0.01	
Sr	0.04	158.934 ppm
Ti	1	0.36
V	0.02	45.316 ppm
Zn	0.02	104.254 ppm
Zr	0.06	72.233 ppm
As	< 0.01	119.897 ppm
Rb	0.03	
P	< 0.1	
O		52.17
S		13.59

NR: Not Reported.
* Ash Removed From The Surface Of A Candle That Was Retrieved From The Ash Hopper.
** Characterization of the W-APF Hopper Ash.

TABLE 2

EDAX CHARACTERIZATION OF THE 5 mm ASH DEPOSIT FORMATION THAT WAS REMOVED FROM THE CANDLE FILTER WALL (B/B-1)

Element	Location OD	0.25 mm	0.75 mm	1.25 mm	1.75 mm	2.25 mm
Mg	12.12, 9.98	8.66	7.79	6.74	6.34	8.05
Al	11.95, 12.76	12.96	13.17	14.65	14.27	12.89
Si	21.14, 22.02	21.53	23.77	25.65	25.29	22.70
S	34.51, 34.91	3.51	32.57	29.88	30.50	33.19
K	2.41, 2.45	2.60	3.09	2.92	2.82	2.81
Ca	15.73, 15.52	16.25	15.04	14.43	15.24	16.06
Ti	--- ---	0.42	0.51	0.59	0.55	0.42
Fe	2.14, 2.35	4.07	3.89	5.13	4.97	3.89
NF*	0.63, 0.64	0.64	0.64	0.63	0.64	0.64

Element	Location 2.75 mm	3.25 mm	3.75 mm	4.25 mm	4.75 mm	ID
Mg	8.16	8.96	6.87	6.28	9.77	14.02, 19.54
Al	12.72	12.76	12.41	10.95	11.43	10.71, 9.36
Si	22.73	21.68	22.10	19.33	20.24	18.09, 15.70
S	33.10	33.99	33.12	33.67	34.02	33.78, 31.00
K	2.81	2.68	2.95	2.67	2.72	2.25, 1.83
Ca	15.86	15.86	17.36	20.57	17.81	18.57, 20.35
Ti	0.50	0.44	0.54	0.62	0.39	--- ---
Fe	4.10	3.62	4.64	5.83	3.60	2.58, 2.22
NF	0.64	0.64	0.65	0.67	0.65	0.64, 0.64

* NF: Normalization Factor.

Along the dust cake layer of the fractured candle sections, several darker red areas were evident which appeared to be "wet" or stained in comparison to the pinkish color of the dust cake. Although the cake appeared to be patchy along the surface of the "unbroken" candles, the fractured and submerged candle segments had a thicker more uniform ash cake appearance. The ash cake layer could be easily removed from the wall of the broken candle segments indicating that bonding and/or reaction had not occurred. Fines were suspected to be retained along the "dimpled" OD wall.

Material Characterization

One twelve inch section of the failed Schumacher candle filter was selected for further material characterization. This segment of candle had the "white" dolomitic layer beneath the dust cake layer along its OD surface. Both ends of the candle were fractured and heavily caked with dust. Fines were visually evident along the ID surface of this candle segment, and which extended 3-4 mm into the silicon carbide wall. One area of the candle appeared to contain a "gouge" along the membrane surface. The gouged area was heavily covered with packed dust. This implies that perhaps this section of candle had been chipped from impact of an adjacent falling candle section during filter operation. The heavy caking of dust along both fractured ends, as well as the "gouge" implies that the fracture occurred early in the filtration test, since the candle segment had been "buried" in the ash hopper dust.

A section of the broken candle was initially removed, and the exposed fresh fractured surface was carbon coated in preparation for scanning electron microscopy/energy dispersive x-ray analysis (SEM/EDAX). These analyses indicate that the aluminosilicate fibrous OD membrane retained the ash/dolomite fines, providing an effective barrier to prevent fines penetration during hot gas filtration. At low magnification using the scanning electron microscope, the morphology of the clay bonded silicon carbide (SiC) matrix appears to be virtually intact. At higher magnification, changes along the binder coating surface is evident, not only along the SiC grains, but also along the binder "posts" or channels that bonds adjacent grains together.

Initially within the first several SiC grain layers beneath the fibrous aluminosilicate OD membrane, sulfur- and calcium-enriched micron and submicron "fines" are evident (21.02% S, 10.19% Ca, 49.68% Si, 12.70% Al, 4.64% K, 1.00% Ti, 0.78% Fe; atomic percent basis; Binder phase is slightly enriched with sulfur and consists of 68.42% Si, 18.60% Al, 6.12% K, 5.47% S, 0.78% Ti, 0.62% Fe). The uniformity and multitude of the adhering micron and submicron "fines" implies deposition, adherence, and reaction (i.e., bonding, as well as phase change) of an aerosol particle formation. Note the absence of magnesium which suggests that these "aerosol formation" are not the result of direct particle carryover of the dolomitic sorbent matrix. Each adhering micron and submicron "fine" has a relatively flat surface that is in contact with the underlying binder coated SiC grain.

In several areas below the sulfur- and calcium-enriched "aerosol fines" formation we detect "deterioration or depletion" of the binder coating, as well as what appears to be "mullitization" of the binder matrix. Deterioration and/or mullitization is not detected along the binder surface that bonds adjacent SiC grains together. Along the fractured binder "posts" or channels, a more uniform texture of the matrix is observed. Therefore we suspect that the change in the binder matrix is a surface effect that has occurred after ~100-500 hours of filter operation.

Moving through the cross-sectioned candle filter wall we observe "crystallization" of the binder surface which results in the formation of sulfur-enriched "aggregates" (13.47% S, 71.04% Si, 9.43% Al, 3.73% K, 2.33% Na; atomic percent basis). The sulfur-enriched "aggregates" range between 5 and 10 microns in length. Note the relatively high silicon concentration within the aggregate phase, as well as the absence of calcium. Sodium is detected in isolated areas of the crystallized aggregated binder phase. Sodium which is present in relatively low concentrations in comparison to the sulfur content implies that if sodium sulfate (Na_2SO_4) were present, it occurred in an extremely low concentration that was carried through the Schumacher Dia Schumalith candle filter matrix. The principal cause of the change in the morphology of the binder surface is the result of sulfur, temperature, and possibly steam. Sulfur with its anions (i.e., sodium, potassium, calcium, etc.) is expected to enhance "fluxing" of the binder. Further effort will be expended to define the resulting phase composition of the binder, as well as to discern whether similar changes have occurred in the candle filters housed in the top and middle plenums of the W-APF system. What we have observed may be restricted to the candle that failed, and which collected in the ash hopper. Similar characterization as described above for the top and middle surveillance cluster candles will resolve this issue.

Two additional 10 and 12 inch candle filter segments were subjected to room temperature and 1350°F C-ring compression strength testing. Based on our initial data which were generated for the as-fabricate Schumacher Dia Schumalith candles, an apparent 25% loss of room temperature strength was determined to have resulted in the failed candle filter sections after 100-500 hours of exposure in the PFBC gas phase environment at the AEP Tidd plant facility (Table 3; Figure 6). Note that we do not have a method to discern the exact time of failure for the section of candle that was characterized, and therefore we cannot conclude that the strength of all other candle filter is equivalent to the values presented in Table 3.

Note that in our original analyses we determined that the as-fabricated Schumacher Dia Schumalith candle filter retains its brittle characteristics to temperatures between 870 and 1010°C. At 1010°C and higher, the clay bonded silicon carbide matrix is plastic in nature. Note also that the strength of the Schumacher Dia Schumalith filter matrix appears to be somewhat lower at 870°C in comparison to its room temperature strength. The AEP failed candle filter section also

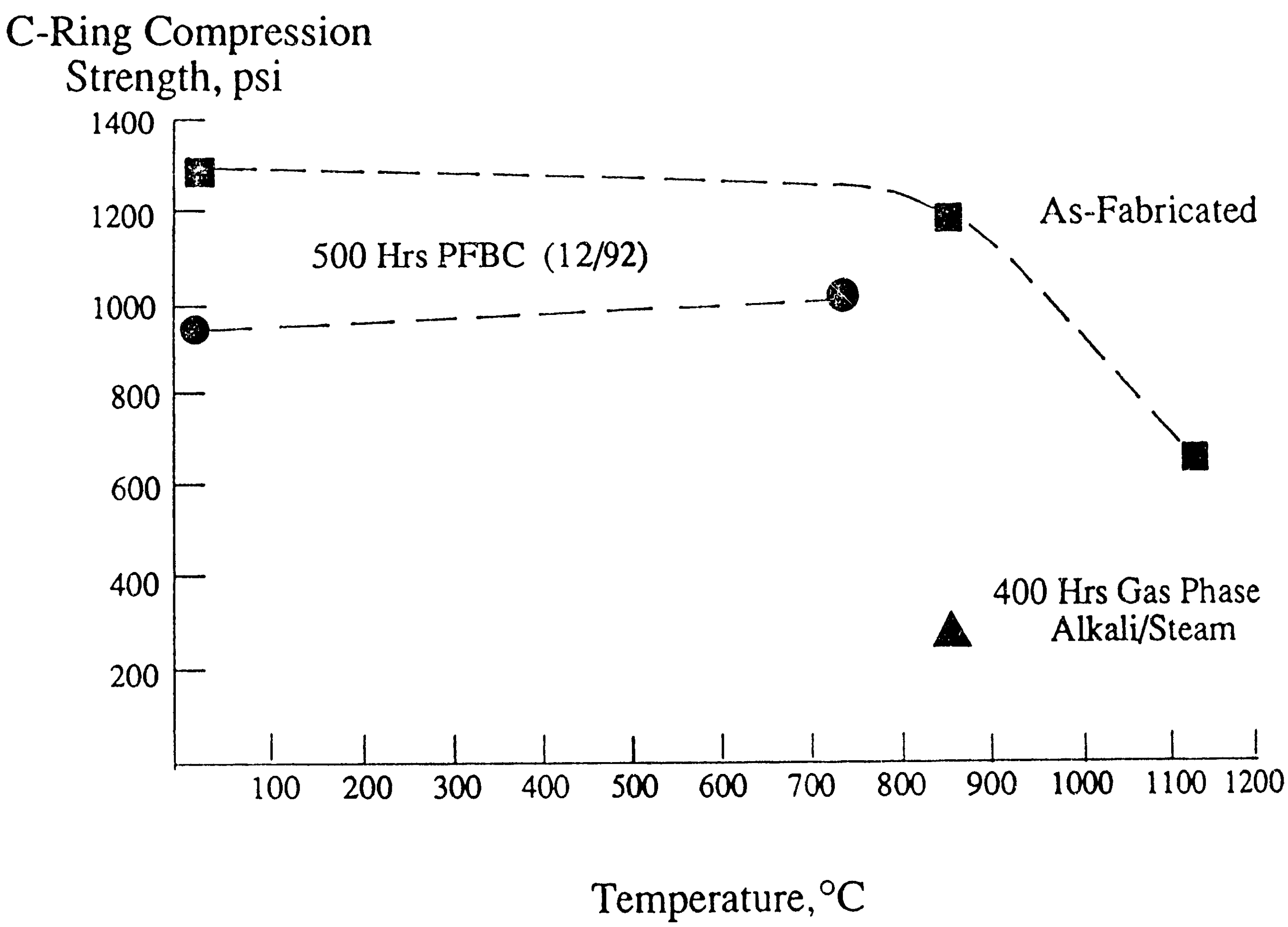


Figure 6 - C-Ring Compression Strength of the Schumacher Dia Schumalith Filter Matrix

TABLE 3

SCHUMACHER DIA SCHUMALITH C-RING COMPRESSION STRENGTH

As-Fabricated Matrix

Temperature	Strength, psi	Fracture Characteristic
Room Temperature	1285.6 ± 197.2	Brittle
870°C (1600°F)	1119.7 ± 104.6	Brittle
1010°C (1850°F)	618.6 ± 130.2	Plastic
1150°C (2102°F)		Plastic

Alkali Exposed Matrix

(400 Hrs, 20 ppm NaCl (g)/Steam/Air, 870°C, 1 atm)

Temperature	Strength, psi	Fracture Characteristic
870°C (1600°F)	251.2 ± 22.5	Plastic

W-APF PFBC Exposure

Temperature	Strength, psi	Fracture Characteristic
Room Temperature	965.7 ± 120	Brittle
730°C (1350°F)	1018.1 ± 113.7	Brittle

retained its brittle characteristics at both room temperature, as well as at 1350°F (732°C) (i.e., temperature where the majority of the 500 hour hot gas filtration test was performed).

The strength of the 500 hour exposed Schumacher Dia Schumalith filter matrix is slightly greater than its room temperature strength. During further characterization of the surveillance candles, we plan to generate the temperature-strength profile for the candle matrix over the 70 to 1550°F temperature range, with emphasis at 1350°F.

The fact that the exposed candle strength appears to be 25% lower than its as-fabricated strength is expected to have resulted from the minor surface morphology changes that were detected along the binder surface. Note that a 20-25% room temperature strength reduction has frequently been detected for the Schumacher Dia Schumalith candle filter matrix after >100-500 hours of exposure to PFBC gases. Perhaps the 20-25% loss of material strength is characteristic of the material, and therefore we may have achieved a "plateau or equilibrium" strength in the clay bonded SiC matrix. Further analyses of the candle matrix after extended PFBC exposure periods will resolve whether continued loss of material strength occurs.

Currently we are planning to initiate nondestructive and destructive characterization of the surveillance candle filters that were removed from the bottom three clusters in the W-APF system, as well as on four surveillance candle filters that were removed from the top and middle clusters. The as-received candle filters will be room temperature permeability tested, and then brushed to remove the ash cake layer. The brushed candles will then be resubjected to permeability testing prior to time-of-flight (TOF) characterization. Destructive C-ring strength testing will then be performed as a function of temperature. SEM/EDAX, EMA and phase characterization (i.e., x-ray diffraction analysis (XRD) or Auger analysis, etc.) will also be performed.

Additional characterization of the ash fines along the filter surface will include ash fusion testing, thermogravimetric analysis (TGA), differential thermogravimetric analysis (DTA), quantitative atomic absorption (AA) analysis to determine elemental partitioning within the water, acid soluble and acid insoluble constituents of the dust cake. Additional effort will be conducted to determine the influence of ash on the aluminosilicate membrane, as well as its interaction with the clay bonded SiC matrix.

We will also attempt to reconstruct the candle arrays to discern the extent and direction of the bowing of the candle filter elements in the bottom three clusters, and to assess whether there is a compositional or temperature variation being established within the three plenum areas (i.e., top, middle, bottom) of the W-APF.

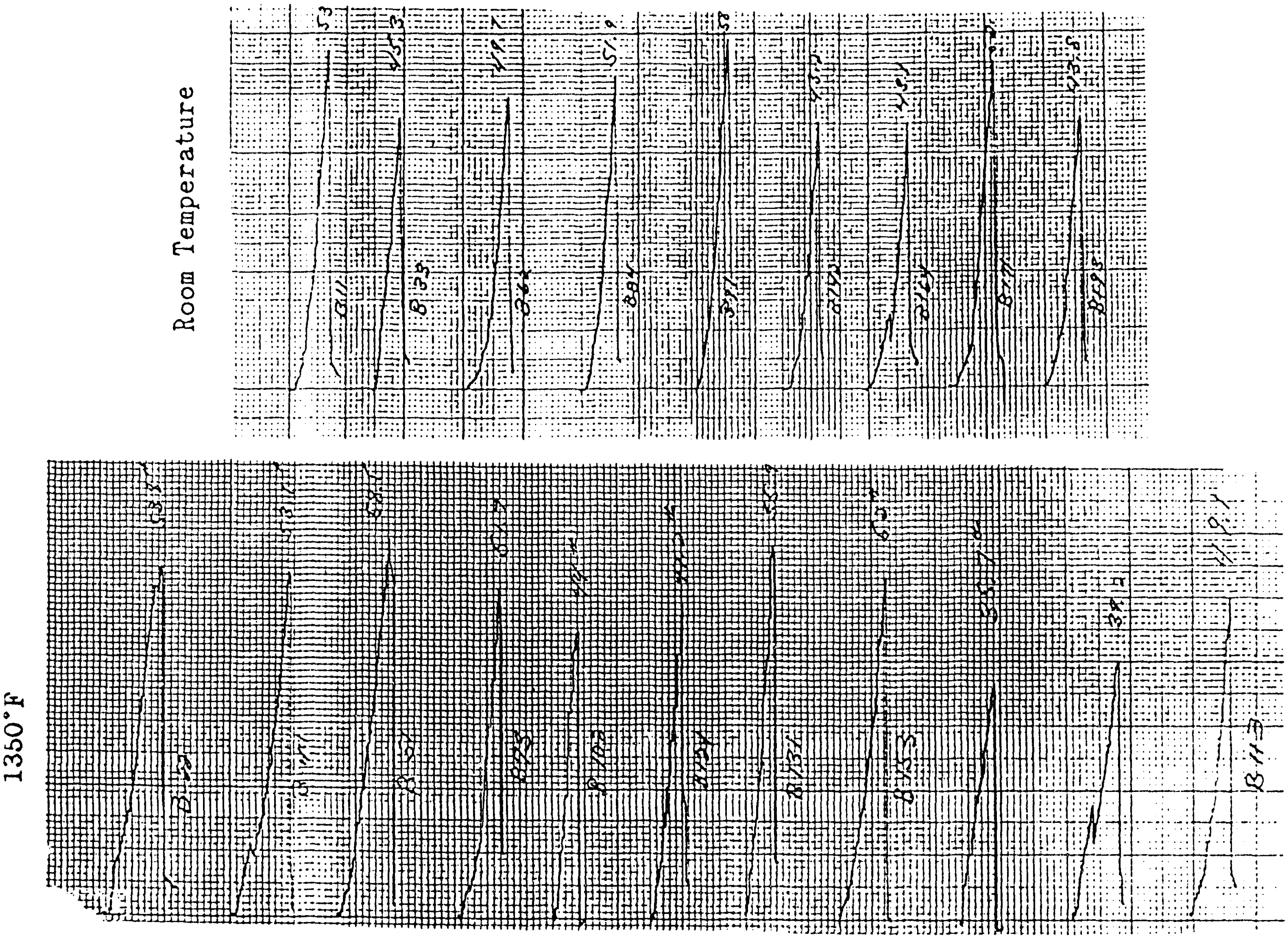


Figure 7 - Room Temperature and 1350°F C-Ring Deflection Curves Generated for the Schumacher Dia Schumalith Filter Matrix After Exposure in the PFBC Gas Environment (12/92)

END

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4 / 16 / 93