DOE/MC/26042--4047
UC-103

PFBC HGCU Test Facility
Technical Progress Report

Fourth Quarter, CY 1994

DISCLAIMER

Prepared by:

American Electric Power Service Corporation
Columbus, Ohio 43215

Prepared for:

The United States Department of Energy
Under DOE Instrument No. DE-FC21 89MC26042

January, 1995

I. INTRODUCTION

This is the twenty-first 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 work completed during the Fourth Quarter of CY 1994.

During this quarter, the Tidd Hot Gas Clean Up System completed a 691-hour test run which began during the third quarter. Table I summarizes all test runs since initial operation. Following this test run the system was shut down and the filter opened for inspection and recandling. The system remained out of service during the remainder of the quarter. It is planned to resume operation of the system early in the next quarter.

II. WORK ACCOMPLISHED DURING THE REPORTING PERIOD

2.1 Detailed Design and Engineering

In addition to monitoring and evaluating the performance of the HGCU system during testing, engineering effort was devoted to posttest inspection of the APF and evaluation of the effects of totally spoiling the primary cyclone. In addition, we worked with Westinghouse in the selection of replacement candles that were installed during the fourth quarter.

During the unit outage this quarter, the primary cyclone upstream of the APF was modified to force all of the ash to pass through the cyclone and enter the APF without using spoiling air.

On October 12 we made a presentation at DOE summarizing HGCU test results between July and October, 1994.

On December 12, 1994, Amendment No. 12 to the DOE Cooperative Agreement was issued by the DOE which increased funding for the current budget period by $1.8 million.

Modification No. 10 to the Westinghouse contract was submitted to Westinghouse on December 13, 1994, authorizing additional funds for the continuation of surveillance testing through March, 1995.

2.3 Westinghouse Engineering and Design

See Appendix 1

5.0 Testing

Test Run 24 - 9/22/94 to 10/21/94

Due to a problem with erosion of the BUC ash line observed following the previous run, it was decided to operate the unit with the primary cyclone only partially spoiled for the first three weeks of this scheduled four-week run, and operate with it completely spoiled during the final week of operation. It should be noted that approximately 14 candles were known to be broken at the beginning of this run. Figure 1 shows a plot of the filter differential pressure (DP) and temperature for this run. The DP increased significantly during the first 300 hours of operation, increased gradually over the next 300 hours, and increased dramatically when the cyclone was spoiled due to the increased ash loading.

Posttest Inspection and Modifications

On 10/27/94 the APF internals were removed from the vessel for inspection and candle replacement. A total of 30 candles were observed to be broken, as listed below:

Location of Broken Candles

October 1994

	PLENUM A	PLENUM B	PLENUM C
TOP	6	1	7
MIDDLE	4	2	6
BOTTOM	2	1	1

Ten of the 30 breaks had clean fracture surfaces indicating that the breaks occurred after shutdown or during removal from the vessel. Heavy ash bridging was apparent near the bottoms of the candles in clusters B Top and B Middle, while light to moderate ash bridging was seen in clusters C Top, A Bottom, and B Bottom. It was evident that the ash accumulation that occurred during the first 600 hours of this run was not removed during the last 90 hours of operation with the cyclone spoiled. Additional details of the inspection are presented in Appendix 1.

Two of the nine back pulse tubes were found to have longitudinal cracks through the wall about 12 to 16 inches long. The cracks occurred only on two of the bottom plenum tubes which were backpulsed at a higher pressure (1300 psig) than the upper and middle plenums (1000 psig). The cracks were believed to be due to thermal fatigue. All nine tubes were replaced in kind following Run 24.

The ash removal line from the Backup cyclone was replaced during the quarter with a larger diameter, heavier wall pipe. This was done to produce lower velocity in the ash line and provide more margin for erosion and wear in case a filter candle should break during the next run.

7.0 Hazardous Air Pollutants

Radian submitted a final report of HAP test results in November and it was forwarded to DOE.

III. MANPOWER REPORT AND COST DATA

As of December 31, 1994, the AEPSC Engineering, Design and Project Support cumulative work-hours were 72,097 or 104.3% of the total 69,097 revised work-hours projected for the project. Figure 2 compares the actual work-hours expended versus the current estimate. For the reporting period, a total of 916 hours were charged to the project by AEPSC personnel.

The actual DOE's cost expenditure during the Fourth quarter 1994 was $1,678,921. As of December 31, 1994, the cumulative DOE's cost expenditures were $21,230,733. Figure 3 depicts the cumulative expenditure forecast for the project which includes Westinghouse cost share. During the Fourth Quarter 1994, Westinghouse was paid a total of $356,375. Total payments to Westinghouse through December 31, 1994, were $7,232,743. Major contractual commitments during this reporting period totalled $57,940 and are summarized as follows:

Contract Purchase Order	Description (Contractor)	Contracted Costs
07004-071-4X	Replace Internal Liner Bellows and Install Insulation (Badger Industries)	$ 6,940
84116	Advanced Particle Filter Fail-Safe Regenerator Devices	$51,000

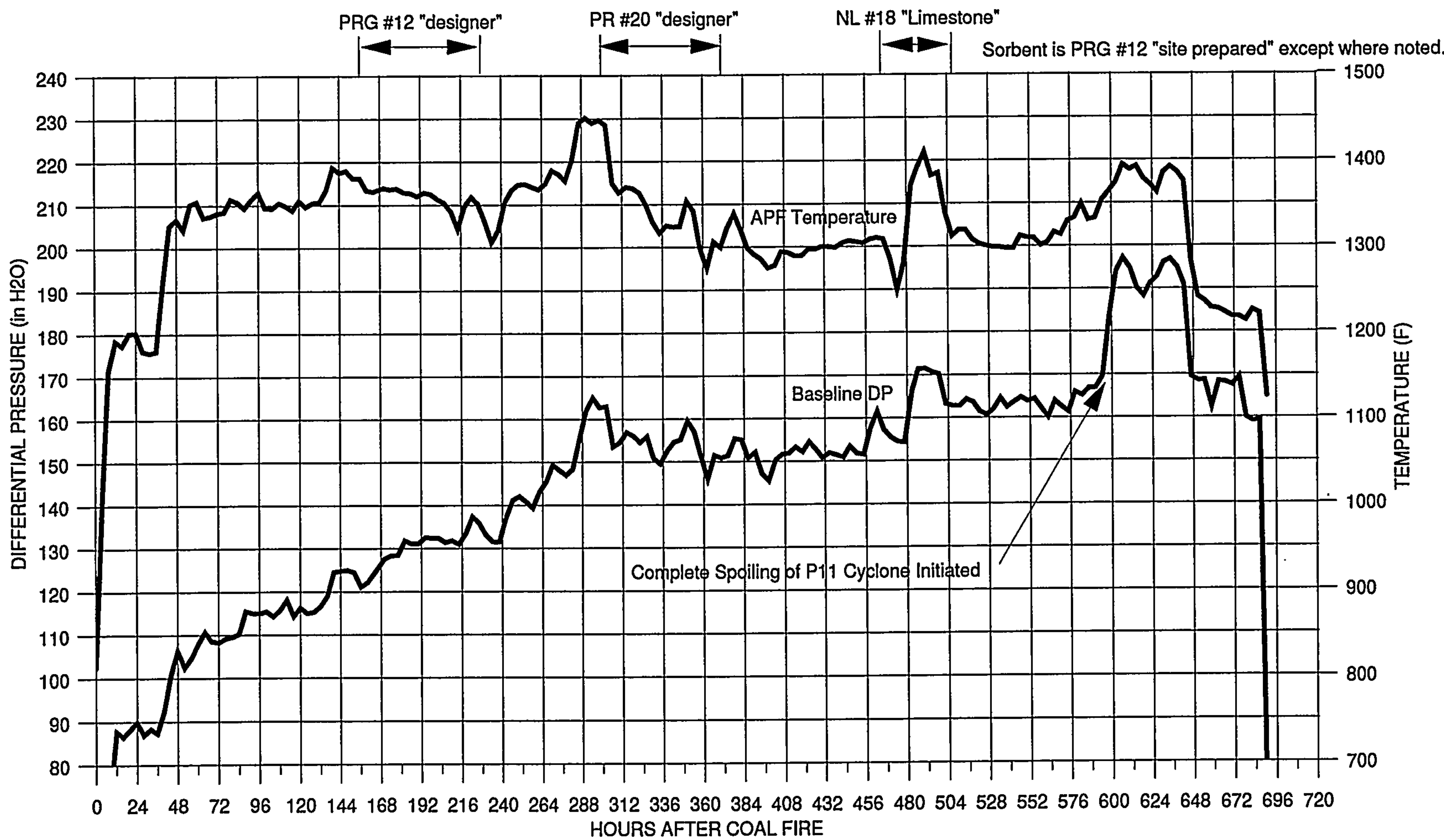
TABLE 1.
TIDD HGCU RUNS SUMMARY

RUN NO.	COAL FIRE DATE	COAL FIRE TIME	UNIT TRIP DATE	UNIT TRIP TIME	COAL FIRE HOURS	NOTES
0	05/21/92	20:26	05/23/92	07:41	35.2	Bypass mode. Coal fire hours not included in totals. Unit trip due to XJ-4 failure.
1	10/28/92	18:10	11/01/92	23:32	101.4	Unit trip due to HGCU ash lockhopper pluggage.
2	11/17/92	09:33	11/17/92	10:50	1.3	Unit trip due to plugged primary cyclones.
3	11/21/92	18:41	11/24/92	22:50	76.2	Unit trip due to coal paste problems.
4	11/25/92	12:11	12/07/92	09:56	285.7	Warm startup. Unit trip due to XJ-7 failure. 21 candles found broken during outage.
TOTAL FOR RUNS 1 - 4					**464.5**	
5	06/30/93	17:28	07/03/93	05:04	59.6	Shutdown to change GT telemetry instrumentation.
6	07/05/93	00:35	07/05/93	17:17	16.7	Completed GT testing.
7	07/18/93	18:20	08/05/93	12:22	426.0	Shutdown due to ash buildup on APF liner.
8	08/09/93	10:18	08/09/93	11:37	1.3	GT trip due to bearing vibration.
9	08/10/93	22:29	08/14/93	05:27	79.0	Warm startup. Shutdown due to low O2 resulting from high coal paste excursion.
10	08/19/93	17:48	08/24/93	13:28	115.7	Manual combustor trip due to unstable bed conditions after switching to limestone.
11	08/29/93	23:31	09/23/93	20:12	596.7	Combustor trip due to leak in sorbent transport pipe. 62 candles found broken during outage.
TOTAL FOR RUNS 5 - 11					**1295.0**	
12	01/10/94	06:41	01/11/94	01:36	18.9	Manual combustor trip due to plugged primary cyclone.
13	01/15/94	23:42	01/29/94	20:31	332.8	Manual combustor trip due to boiler tube leak.
14	02/17/94	14:58	02/18/94	14:14	23.3	Manual combustor trip due to leak in HGCU gas sample connection.
15	02/19/94	06:12	02/25/94	13:09	150.9	Manual combustor trip due to loss of sorbent air compr.
16	03/03/94	10:22	03/09/94	11:30	145.1	Manual combustor trip due to loss of two paste pumps.
17	03/16/94	14:48	03/23/94	10:50	164.0	GT trip due to low lube oil pressure.
18	03/31/94	09:04	04/18/94	20:43	443.7	Manual combustor trip due to internal sorbent injection pipe leak. 28 candles found broken during outage.
TOTAL FOR RUNS 12 - 18					**1278.8**	
19	07/16/94	01:56	07/16/94	04:27	2.5	Manual combustor trip due to loss of three paste pumps.
20	07/16/94	12:59	07/16/94	13:55	0.9	Manual combustor trip due to plugged primary cyclones.
21	07/20/94	19:18	07/27/94	12:08	160.8	Shutdown due to GT vibration.
22	07/28/94	09:59	08/25/94	17:47	679.8	Manual combustor trip due to bad signal relay from the ST generator. 12 candles found broken during outage.
23	09/03/94	01:01	09/10/94	04:07	171.1	Manual combustor trip due to sorbent pipe leak. Operated part-time with P11 cyclone totally spoiled.
24	09/22/94	17:02	10/21/94	11:39	690.6	Planned outage. 30 total candles found broken during outage.
TOTAL FOR RUNS 19 - 24					**1705.8**	
TOTAL FOR RUNS 1 - 24					**4744.1**	

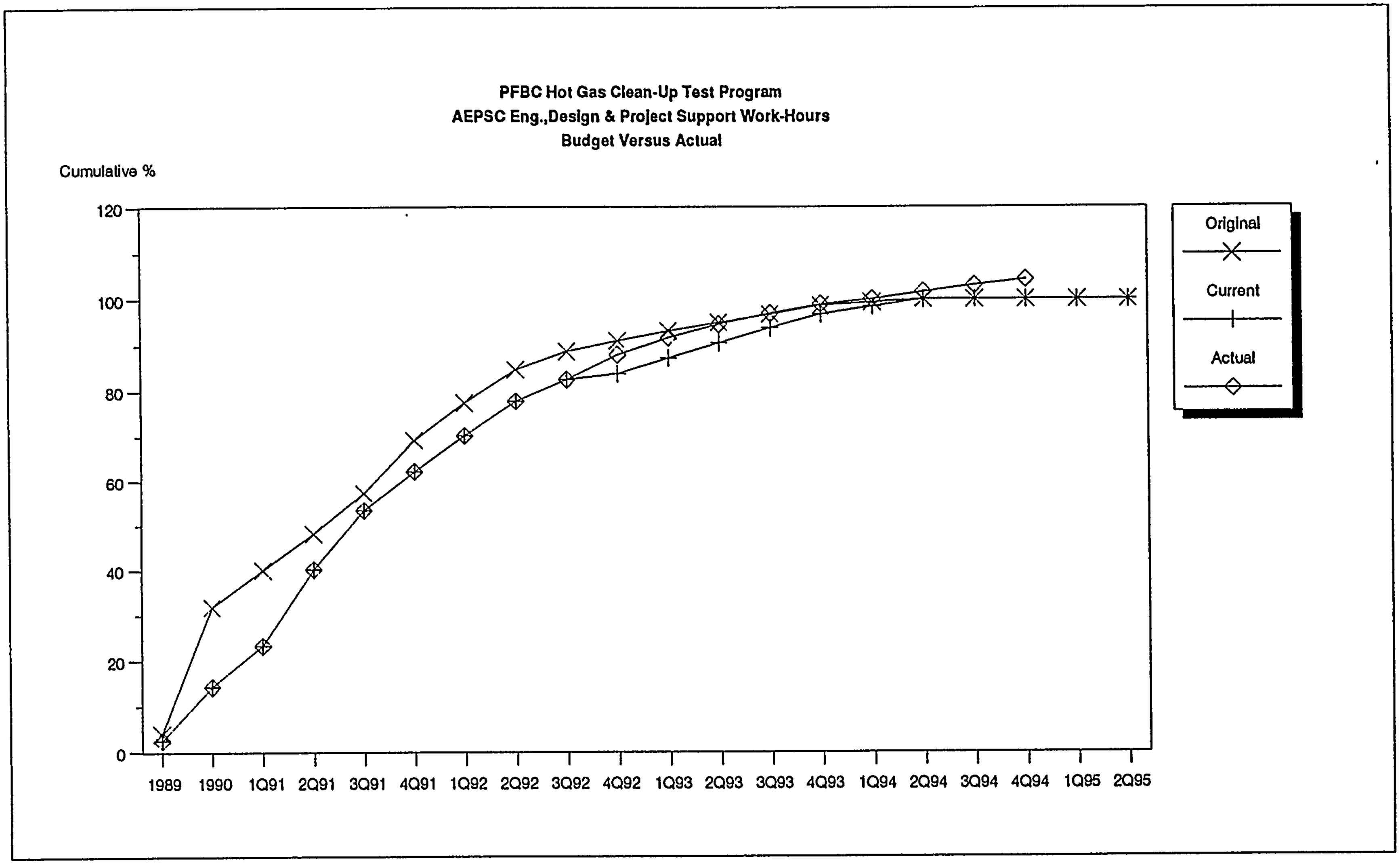
FIGURE 1.

FILTER DP AND TEMPERATURE DURING TEST RUN 24

SEPTEMBER 22 - OCTOBER 21, 1994

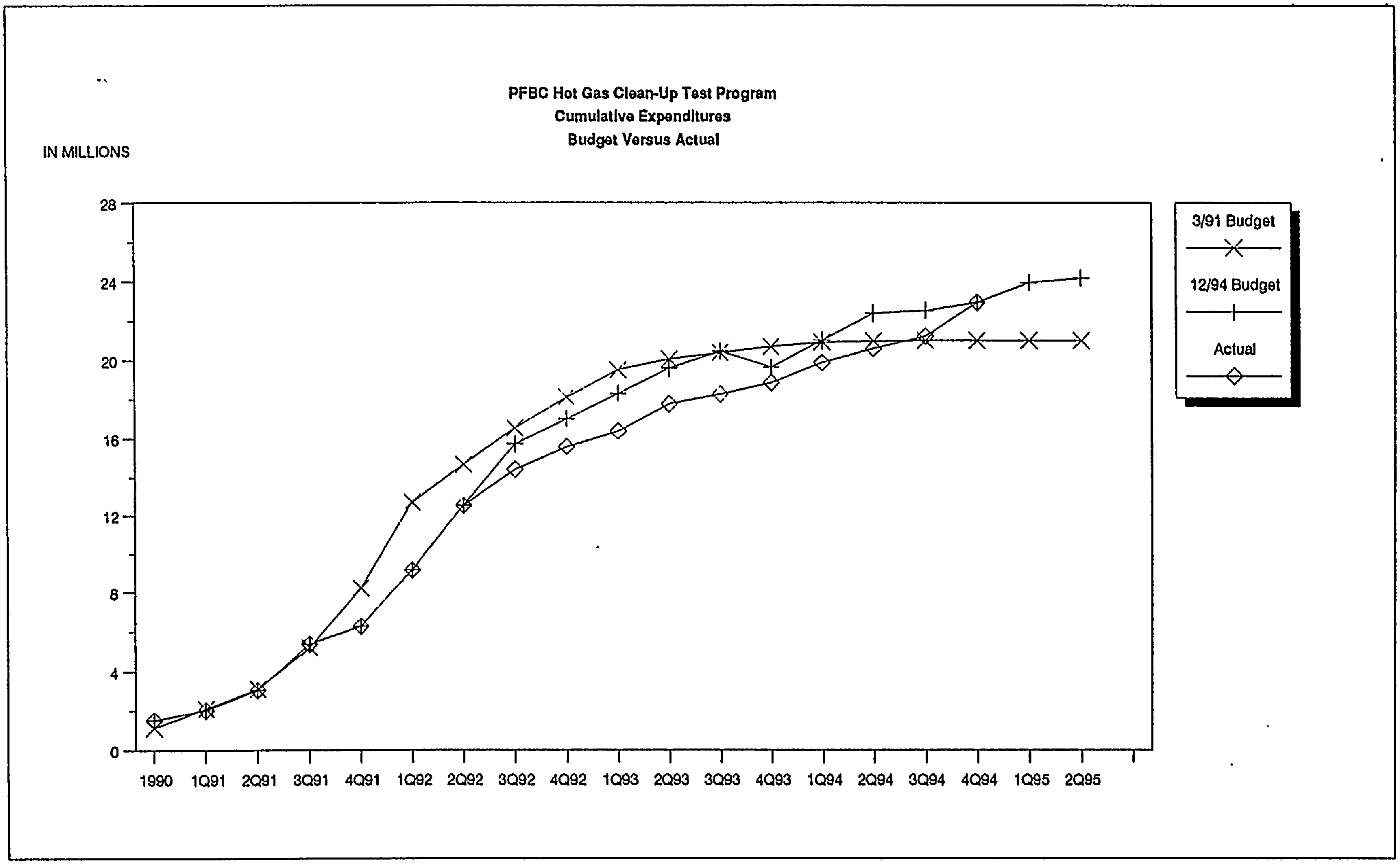


Note: Temperature based on 4 hour averages, DP based on minimum value over 4 hour periods.



	1989	1990	1Q91	2Q91	3Q91	4Q91	1Q92	2Q92	3Q92	4Q92	1Q93	2Q93	3Q93	4Q93	1Q94	2Q94	3Q94	4Q94	1Q95	2Q95
Original	4.0	31.8	40.0	48.2	57.3	69.2	77.4	84.7	88.6	90.9	93.1	94.9	96.7	98.6	99.3	100.0	100.0	100.0	100.0	100.0
Current	2.6	14.3	23.3	40.2	53.4	62.2	70.2	77.8	82.5	83.8	87.2	90.5	93.7	96.7	98.4	100.0	100.0	100.0	100.0	100.0
Actual	2.6	14.3	23.3	40.2	53.4	62.2	70.2	77.8	82.5	87.9	91.6	94.5	96.9	98.9	100.0	101.6	103.0	104.3		

FIGURE 2



	($000)																
	1990	1Q91	2Q91	3Q91	4Q91	1Q92	2Q92	3Q92	4Q92	1Q93	2Q93	3Q93	4Q93	1Q94	2Q94	3Q94	4Q94
3/91 Budget	1142.4	2108.4	3120.3	5213.0	8220.2	12683.5	14656.2	16524.3	18106.5	19483.3	20039.8	20372.3	20672.6	20898.9	20955.5	20995.5	20995.5
12/94 Budget	1531.3	2040.6	3059.1	5387.9	6280.4	9162.2	12522.0	15711.7	16998.3	18284.9	19571.4	20453.8	19628.2	21002.3	22376.4	22511.4	22928.6
Actual	1531.3	2040.6	3059.1	5387.9	6280.4	9162.2	12522.0	14397.6	15569.3	16362.4	17753.2	18254.2	18835.3	19853.4	20593.6	21200.6	22928.6

FIGURE 3

FORM EIA 459E
(10/80)

U.S. DEPARTMENT OF ENERGY

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

FORM APPROVED
OMB No. 1900 0127

95 FEB -2 PM 3:12

1. Program/Project Identification No. 89-MC-26042	2. Program/Project Title PFBC HGCU Test Program
3. Reporting Period 10/01/94 through 12/31/94	
4. Name and Address Morgantown Energy Technology Center, P. O. Box 880, 3610 Collins Ferry Road, Morgantown, WV 26505	5. Program/Project Start Date 08/02/89
	6. Completion Date 06/30/95

7. FY 1994

8. Months or Quarters: 1Q, 2Q, 3Q, 4Q

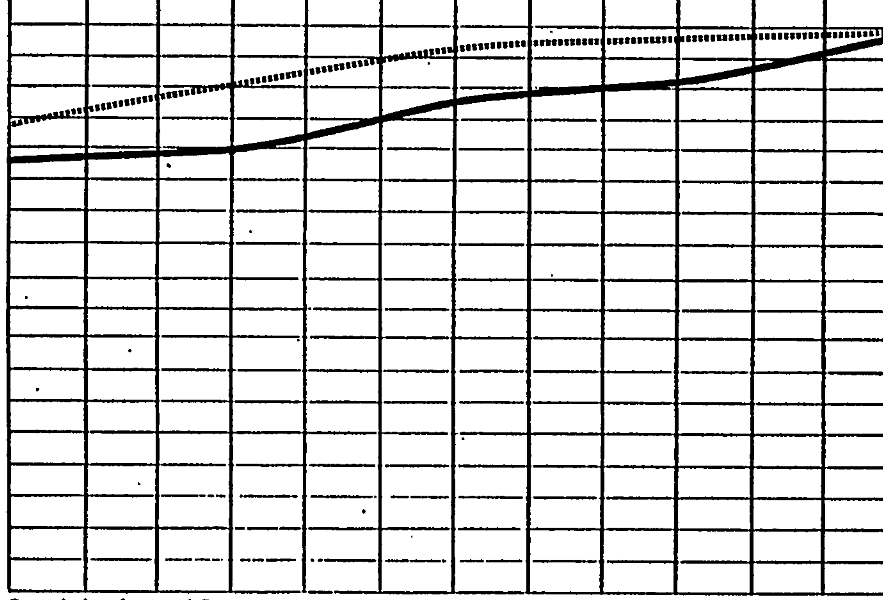
9. Cost Status — a. Dollars Expressed In: In Millions — b. Dollar Scale: 23, 20, 15, 10

10. Cost Chart — In Thousands

Fund Source		Quarter 1st	2nd	3rd	4th	Cum. to Date	Tot. Plan
DOE*	P	1251	1250	135	592	21231	22440
	A	936	711	627	1679	21231	
WSTG*	P	124	123	0	(174	1698	1738
	A	36	8	47	49	1698	
	P						
	A						
	P						
	A						
Total P		1375	1373	135	418	22929	24178
Total A		972	719	674	1728	22929	
Variance		(403)	(654)	539	1310	0	

P = Planned A = Actual

Total Planned Costs for Program/Project: $24,177,414



c. Cumulative Accrued Costs

	1Q	2Q	3Q	4Q
Planned	21003	22376	22511	22929
Actual	19853	20594	21201	22929
Variance	(1150)	(1783	(1310)	0

11. Major Milestone Status

	Units Planned / Units Complete	
TASK 1 DESIGN SPECIFICATION	P	
	C	COMPLETE
TASK 2 DETAIL DESIGN	P	
	C	COMPLETE
TASK 3 TEST PLAN	P	
	C	COMPLETE
PROCUREMENT, FABRICATION &	P	

Total A	972	719	674	1728	22929
Variance	(403)	(654)	539	1310	0

P = Planned A = Actual

Total Planned Costs for Program/Project

$24,177,414

√C Cumulative Accrued Costs

Planned			21003			22376			22511			22929
Actual			19853			20594			21201			22929
Variance			(1150)			(1783)			(1310)			0

11. Major Milestone Status	Units Planned / Units Complete	
TASK 1 DESIGN SPECIFICATION	P / C	COMPLETE
TASK 2 DETAIL DESIGN	P / C	COMPLETE
TASK 3 TEST PLAN	P / C	COMPLETE
TASK 4 PROCUREMENT, FABRICATION & ERECTION	P / C	COMPLETE
TASK 5 TESTING	P / C	
TASK 6 DATA ANALYSIS & REPORTING	P / C	
TASK 7 AIR POLLUTANTS	P / C	
TASK 8 SYSTEM ENHANCEMENTS & ADDITIONAL TESTING	P / C	
	P / C	
	P / C	
	P / C	
	P / C	
	P / C	
	P / C	
	P / C	
	P / C	
	P / C	

12 Remarks

* Forecast based on budget period 5 as revised by Amendment A012

WSTG budget adjusted to reflect non-shared costs

-----------Planned

_________ Actual

13 Signature of Recipient and Date 1/26/95

14 Signature of DOE Reviewing Representative and Date

If this form is used as a report:

No further monies or other benefits may be paid out under this program unless this report is completed and filed as required by existing law and regulations (DOE Organizational Act PL 95-91· 42 USC 7254 and Federal Grant and Cooperative Agreement Act of 1977 PL 95-224 41 USC 508)

If this form is used as a plan:

No grant or cooperative agreement may be awarded unless a completed application has been received (DOE Organizational Act. PL 95-91: 42 USC 7254 and Federal Grant and Cooperative Agreement Act of 1977: PL 95-224: 41 USC 508).

FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPO

PURPOSE

A graphic presentation of costs and milestone status that provides rapid visual analysis and trend forecasting. The funding levels should represent all available resources.

INSTRUCTIONS

Item 1 — Enter the Federal grant or agreement identification number for the current year as it appears in the official award.

Item 2 — Enter the program/project official title as it appears in the award and, if applicable, the project identification number.

Item 3 — For Baseline Planning — if the program/project duration is 12 months or less, omit this item. For durations greater than 12 months, one copy of this form must be completed for each 12 month period (funding year) within the program/project duration. Enter the beginning and ending dates for the year or part year for which the costs and activities are to be displayed.
For Status Reporting — enter the start and completion dates for the current reporting period.

Item 4 — Enter the name and address of the agency or office responsible for managing the project.

Item 5 — Enter the official start date of the original agreement.

Item 6 — Enter the official completion date as of the latest modification.

Item 7 — Enter the current Federal government fiscal year (FY 79).

Item 8 — Enter the first letter of each month of the period in the 12 blocks, if reporting by quarters, use three column spaces separated by heavy vertical lines and identify the quarter, such as first quarter and so on.

Item 9a — Show the unit of dollars used, such as "hundreds" or "thousands".
b — Enter the appropriate dollar scale for the large grid.
c — Enter the planned cumulative accrued costs for each month or quarter. Then,
- On the grid, use a solid line extending horizontally to show the dollar ceiling. Then,
- Enter the actual cumulative accrued costs for each month or quarter for the current reporting period. Then,
- Subtract the planned cost from the actual costs for each month or quarter and show the difference (variance). Show the minus amounts in parentheses. Then,
- On the grid, use a dashed line to plot the planned cumulative costs by the dollar scale and the month or quarter. Then,
- Use a solid line to plot the actual cumulative costs for each month or quarter up to and including the month or quarter being reported. If any cost projection will vary from the planned cost for the remainder of the period, indicate this by a dotted line extending from the solid line.

Item 10 — Show planned and actual costs by the source of funding, such as DOE, other Federal agencies (HUD, HEW), state, or other sources for each quarter, as well as the cumulative to date and the total funding source. Also show the total planned costs for the life of the program or project

Item 11 — Enter the current period milestone descriptions. Milestones are activities or tasks needed to be completed to accomplish the project's objectives. Milestones are measurable units of work and can be elements from the work breakdown structure. Then,
- In the column labeled Units Planned, Completed, show the appropriate figures for the current reporting period. Enter, when quantification is possible, the number of items to be produced, serviced, or acted upon.
- Show the milestones graphically, using the charting information below.

Item 12 — Enter any brief
planations in a P

Item 13 — Enter the signatu

Item 14 — Enter the signatu
project to verify
review should al

CERTAIN PROGRAMS MA
ATTACHED TO THIS FOR

SYMBOLS

△ Major Milestone

▽ Intermediate event (Deliverable, Suppor ing Milestone, or Decision Point)

▲ Intermediate Event completed early or late

◇ Proposed Schedulec Deviation (late or early) for a major Milestone

▭ Activity Bar

— Dollar Ceiling

┆ Time Now

∬ Continues beyond Time frame shown

m is used as a plan·

or cooperative agreement may be awarded unless a completed
n has been received (DOE Organizational Act. PL. 95-91: 42 USC
Federal Grant and Cooperative Agreement Act of 1977: PL.
1 USC 508).

See DOE/CR-0001-3 for provisions concerning confidentiality of information.

ASSISTANCE MANAGEMENT SUMMARY REPORT

analysis and trend

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DOE, other Federal
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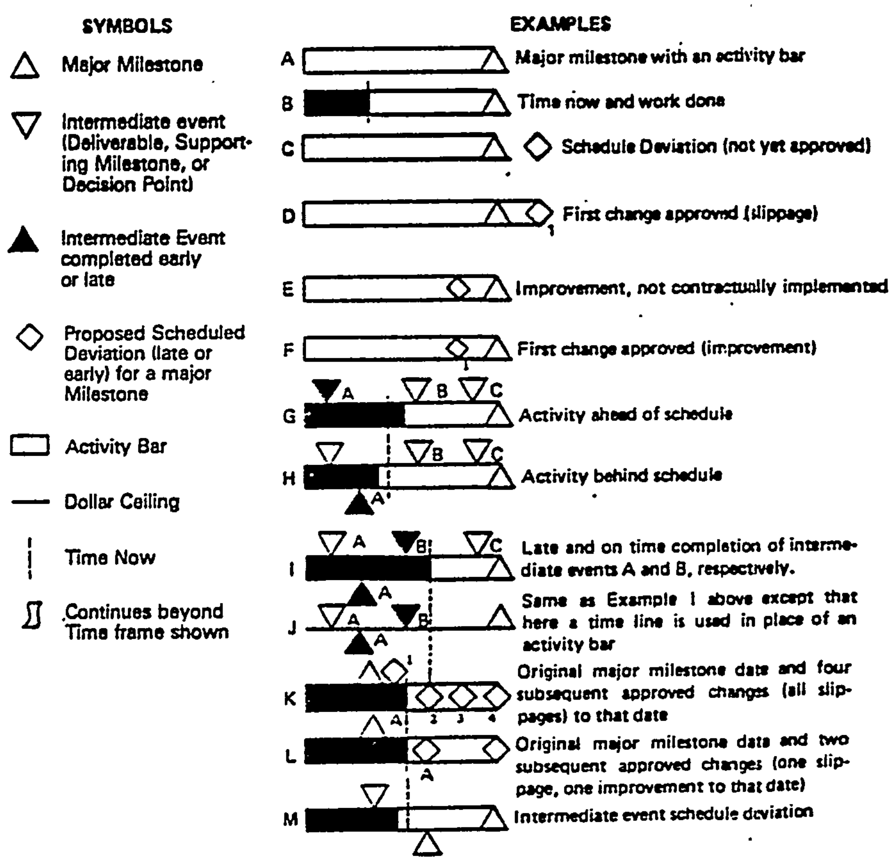
Item 12 — Enter any brief explanatory remarks regarding schedule deviations. (Include detailed explanations in a Project Status Report, if required).

Item 13 — Enter the signature and date of the recipient's activity manager for reference.

Item 14 — Enter the signature of the DOE program manager responsible for monitoring the program/project to verify the plan has been reviewed and appears reasonable. The date of the review should also be entered.

CERTAIN PROGRAMS MAY REQUIRE ADDITIONAL INSTRUCTIONS WHICH WILL BE ATTACHED TO THIS FORM.

CHARTING INFORMATION



FINANCIAL STATUS REPORT

(Follow instructions on the back)

1. FEDERAL AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH R[...]
The U.S. Department of Energy
Morgantown Energy Technology Center

3. RECIPIENT ORGANIZATION *(Name and complete address, including ZIP code)*
Ohio Power Co.
P.O. Box 24400
Canton, OH 44701

4. EMPLOYER IDENTIFICATION NUMBER
31-4271000

5. REC[...]

8. PROJECT/GRANT PERIOD *(See instructions)*
FROM *(Month, day, year)* 7/13/89
TO *(Month, day, year)* 6/30/94

10. STATUS OF FUNDS

PROGRAMS/FUNCTIONS/ACTIVITIES ▶	(a) HGCU	(b) APFBC Thru 12/31/91	(c)	(d)
a. Net outlays previously reported	$ 19,740,323	$ 0	$	$
b. Total outlays this report period	95,111	0		
c. *Less:* Program income credits	0	0		
d. Net outlays this report period *(Line b minus line c)*	95,111	0		
e. Net outlays to date *(Line a plus line d)*	19,835,434	0		
f. *Less:* Non-Federal share of outlays	189,770	0		
g. Total Federal share of outlays *(Line e minus line f)*	19,645,664	0		
h. Total unliquidated obligations	0	0		
i. *Less:* Non-Federal share of unliquidated obligations shown on line h	0	0		
j. Federal share of unliquidated obligations	0	0		
k. Total Federal share of outlays and unliquidated obligations	19,645,664	0		
l. Total cumulative amount of Federal funds authorized				
m. Unobligated balance of Federal funds				

11. INDIRECT EXPENSE

a. TYPE OF RATE *(Place "X" in appropriate box)* ☐ PROVISIONAL ☒ PREDETERMINED ☐ FINAL ☐ FIXED

b. RATE	c. BASE	d. TOTAL AMOUNT	e. FEDERAL SHARE
Actual 21.5%	2,205	2,678	2,678

12. REMARKS: *Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation.*

13. CERTIFICATION
I certify to the best of my [...] lief that this report is correc[...] that all outlays and unliqu[...] are for the purposes set f[...] documents.

269-102

ENCY AND ORGANIZATIONAL ELEMENT TO WHICH REPORT IS SUBMITTED	2. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER	OMB Approved No. 80-RO180	PAGE	OF
. Department of Energy own Energy Technology Center	DE-FC21-89MC26042.000		1	1 PAGES

DENTIFICATION NUMBER	5. RECIPIENT ACCOUNT NUMBER OR IDENTIFYING NUMBER	6. FINAL REPORT	7. BASIS
000	C-6700	☐ YES ☒ NO	☒ CASH ☐ ACCRUAL

PROJECT/GRANT PERIOD (See instructions)		9. PERIOD COVERED BY THIS REPORT	
day, year)	TO (Month, day, year) 6/30/94	FROM (Month, day, year) October 1, 1994	TO (Month, day, year) October 31, 1994

STATUS OF FUNDS

	(c)	(d)	(e)	(f)	TOTAL (g)
31/91					
0	$	$	$	$	$ 19,740,323
0					95,111
0					0
0					95,111
0					19,835,434
0					189,770
0					19,645,664
0					0
0					0
0					0
0					19,645,664
					20,639,556
					993,892

	13. CERTIFICATION	SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL	DATE REPORT SUBMITTED
☐ FINAL ☐ FIXED	I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.	T. P. Bowman dk	Nov. 15, 1994
EDERAL SHARE 2,678		TYPED OR PRINTED NAME AND TITLE T. P. Bowman Assistant Treasurer	TELEPHONE (Area code, number and extension) (216) 438-7125
ncy in compliance with			

STANDARD FORM 269 (7-76)
Prescribed by Office of Management and Budget

INSTRUCTIONS

Please type or print legibly. Items 1, 2, 3, 6, 7, 9, 10d, 10e, 10g, 10i, 10l, 11a, and 12 are self-explanatory, specific instructions for other items are as follows:

Item	*Entry*
4	Enter the employer identification number assigned by the U.S. Internal Revenue Service or FICE (institution) code, if required by the Federal sponsoring agency.
5	This space is reserved for an account number or other identifying numbers that may be assigned by the recipient.
8	Enter the month, day, and year of the beginning and ending of this project period. For formula grants that are not awarded on a project basis, show the grant period.
10	The purpose of vertical columns (a) through (f) is to provide financial data for each program, function, and activity in the budget as approved by the Federal sponsoring agency. If additional columns are needed, use as many additional forms as needed and indicate page number in space provided in upper right; however, the totals of all programs, functions or activities should be shown in column (g) of the first page. For agreements pertaining to several Catalog of Federal Domestic Assistance programs that do not require a further functional or activity classification breakdown, enter under columns (a) through (f) the title of the program. For grants or other assistance agreements containing multiple programs where one or more programs require a further breakdown by function or activity, use a separate form for each program showing the applicable functions or activities in the separate columns. For grants or other assistance agreements containing several functions or activities which are funded from several programs, prepare a separate form for each activity or function when requested by the Federal sponsoring agency.
10a	Enter the net outlay. This amount should be the same as the amount reported in Line 10e of the last report. If there has been an adjustment to the amount shown previously, please attach explanation. Show zero if this is the initial report.
10b	Enter the total gross program outlays (less rebates, refunds, and other discounts) for this report period, including disbursements of cash realized as program income. For reports that are prepared on a cash basis, outlays are the sum of actual cash disbursements for goods and services, the amount of indirect expense charged, the value of in-kind contributions applied, and the amount of cash advances and payments made to contractors and subgrantees. For reports prepared on an accrued expenditure basis, outlays are the sum of actual cash disbursements, the amount of indirect expense incurred, the value of in-kind contributions applied, and the net increase (or decrease) in the amounts owed by the recipient for goods and other property received and for services performed by employees, contractors, subgrantees, and other payees.
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11d	Enter total amount of indirect cost charged during the report period.
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☆U.S. Government Printing Office: 1985—461-275/20171

FINANCIAL STATUS REPORT

(Follow instructions on the back)

1. FEDERAL AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH R
The U.S. Department of Energy
Morgantown Energy Technology Center

3. RECIPIENT ORGANIZATION *(Name and complete address, including ZIP code)*

Ohio Power Co.
P.O. Box 24400
Canton, OH 44701

4. EMPLOYER IDENTIFICATION NUMBER
31-4271000

5. RECI

8. PROJECT/GRANT PERIOD *(See instructions)*
FROM *(Month, day, year)* 7/13/89
TO *(Month, day, year)* 6/30/94

10. STATUS OF FUNDS

PROGRAMS/FUNCTIONS/ACTIVITIES ►	(a) HGCU	(b) APFBC Thru 12/31/91	(c)	(d)
a. Net outlays previously reported	$ 19,835,434	$ 0	$	$
b. Total outlays this report period	167,931	0		
c. *Less:* Program income credits	0	0		
d. Net outlays this report period *(Line b minus line c)*	167,931	0		
e. Net outlays to date *(Line a plus line d)*	20,003,365	0		
f. *Less:* Non-Federal share of outlays	191,462	0		
g. Total Federal share of outlays *(Line e minus line f)*	19,811,903	0		
h. Total unliquidated obligations	0	0		
i. *Less:* Non-Federal share of unliquidated obligations shown on line h	0	0		
j. Federal share of unliquidated obligations	0	0		
k. Total Federal share of outlays and unliquidated obligations	19,811,903	0		
l. Total cumulative amount of Federal funds authorized				
m. Unobligated balance of Federal funds				

11. INDIRECT EXPENSE

a. TYPE OF RATE *(Place "X" in appropriate box)* ☐ PROVISIONAL ☒ PREDETERMINED ☐ FINAL ☐ FIXED

b. RATE	c. BASE	d. TOTAL AMOUNT	e. FEDERAL SHARE
Actual 21.5%	191	232	232

12. REMARKS: *Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation.*

13. CERTIFICATION
I certify to the best of my k
lief that this report is correct
that all outlays and unliqu
are for the purposes set fo
documents.

269-102

ENCY AND ORGANIZATIONAL ELEMENT TO WHICH REPORT IS SUBMITTED	2. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER	OMB Approved No. 80-RO180	PAGE 1 OF 1 PAGES
. Department of Energy own Energy Technology Center	DE-FC21-89MC26042.000		

DENTIFICATION NUMBER	5. RECIPIENT ACCOUNT NUMBER OR IDENTIFYING NUMBER	6. FINAL REPORT	7. BASIS
000	C-6700	☐ YES ☒ NO	☒ CASH ☐ ACCRUAL

PROJECT/GRANT PERIOD (*See instructions*)		9. PERIOD COVERED BY THIS REPORT	
ay, year)	TO (*Month, day, year*) 6/30/94	FROM (*Month, day, year*) November 1, 1994	TO (*Month, day, year*) November 30, 1994

STATUS OF FUNDS

31/91	(c)	(d)	(e)	(f)	TOTAL (g)
0	$	$	$	$	$ 19,835,434
0					167,931
0					0
0					167,931
0					20,003,365
0					191,462
0					19,811,903
0					0
0					0
0					0
0					19,811,903
					20,639,556
					827,653

	13. CERTIFICATION	SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL	DATE REPORT SUBMITTED
FINAL ☐ FIXED	I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.	T. P. Bowman (signature)	Dec. 16, 1994
DERAL SHARE 232		TYPED OR PRINTED NAME AND TITLE T. P. Bowman Assistant Treasurer	TELEPHONE (*Area code, number and extension*) (216) 438-7125
cy in compliance with			

STANDARD FORM 269 (7-76)
Prescribed by Office of Management and Budget

INSTRUCTIONS

Please type or print legibly. Items 1, 2, 3, 6, 7, 9, 10d, 10e, 10g, 10i, 10l, 11a, and 12 are self-explanatory, specific instructions for other items are as follows:

Item	*Entry*
4	Enter the employer identification number assigned by the U.S. Internal Revenue Service or FICE (institution) code, if required by the Federal sponsoring agency.
5	This space is reserved for an account number or other identifying numbers that may be assigned by the recipient.
8	Enter the month, day, and year of the beginning and ending of this project period. For formula grants that are not awarded on a project basis, show the grant period.
10	The purpose of vertical columns (a) through (f) is to provide financial data for each program, function, and activity in the budget as approved by the Federal sponsoring agency. If additional columns are needed, use as many additional forms as needed and indicate page number in space provided in upper right; however, the totals of all programs, functions or activities should be shown in column (g) of the first page. For agreements pertaining to several Catalog of Federal Domestic Assistance programs that do not require a further functional or activity classification breakdown, enter under columns (a) through (f) the title of the program. For grants or other assistance agreements containing multiple programs where one or more programs require a further breakdown by function or activity, use a separate form for each program showing the applicable functions or activities in the separate columns. For grants or other assistance agreements containing several functions or activities which are funded from several programs, prepare a separate form for each activity or function when requested by the Federal sponsoring agency.
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☆ U.S. Government Printing Office: 1985—461-275/20171

FINANCIAL STATUS REPORT

(Follow instructions on the back)

1. FEDERAL AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH I
The U.S. Department of Energy
Morgantown Energy Technology Center

3. RECIPIENT ORGANIZATION *(Name and complete address, including ZIP code)*
Ohio Power Co.
P.O. Box 24400
Canton, OH 44701

4. EMPLOYER IDENTIFICATION NUMBER
31-4271000

5. RE

8. PROJECT/GRANT PERIOD *(See instructions)*
FROM *(Month, day, year)* 7/13/89
TO *(Month, day, year)* 6/30/94

10. STATUS OF FUNDS

PROGRAMS/FUNCTIONS/ACTIVITIES ►	(a) HGCU	(b) APFBC Thru 12/31/91	(c)	(d)
a. Net outlays previously reported	$20,003,365	$ 0	$	$
b. Total outlays this report period	1,414,133	0		
c. *Less:* Program income credits	0	0		
d. Net outlays this report period *(Line b minus line c)*	1,414,133	0		
e. Net outlays to date *(Line a plus line d)*	21,417,498	0		
f. *Less:* Non-Federal share of outlays	186,765	0		
g. Total Federal share of outlays *(Line e minus line f)*	21,230,733	0		
h. Total unliquidated obligations	0	0		
i. *Less:* Non-Federal share of unliquidated obligations shown on line h	0	0		
j. Federal share of unliquidated obligations	0	0		
k. Total Federal share of outlays and unliquidated obligations	21,230,733	0		
l. Total cumulative amount of Federal funds authorized				
m. Unobligated balance of Federal funds				

11. INDIRECT EXPENSE

a. TYPE OF RATE *(Place "X" in appropriate box)* ☐ PROVISIONAL ☒ PREDETERMINED ☐ FINAL ☐ FIXED

b. RATE	c. BASE	d. TOTAL AMOUNT	e. FEDERAL SHARE
Actual 21.1%	14,419	17,463	17,463

12. REMARKS: *Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation.*

13. CERTIFICATION
I certify to the best of my
lief that this report is corre
that all outlays and unli
are for the purposes set
documents.

269-102

ENCY AND ORGANIZATIONAL ELEMENT TO WHICH REPORT IS SUBMITTED	2. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER	OMB Approved No. 80-RO180	PAGE	OF
. Department of Energy own Energy Technology Center	DE-FC21-89MC26042.000		1	1 PAGES

DENTIFICATION NUMBER	5. RECIPIENT ACCOUNT NUMBER OR IDENTIFYING NUMBER	6. FINAL REPORT	7. BASIS
000	C-6700	☐ YES ☒ NO	☒ CASH ☐ ACCRUAL

PROJECT/GRANT PERIOD (*See instructions*)		9. PERIOD COVERED BY THIS REPORT	
day, year)	TO (*Month, day, year*) 6/30/94	FROM (*Month, day, year*) December 1, 1994	TO (*Month, day, year*) December 31, 1994

STATUS OF FUNDS

31/91	(c)	(d)	(e)	(f)	TOTAL (g)
0	$	$	$	$	$ 20,003,365
0					1,414,133
0					0
0					1,414,133
0					21,417,498
0					186,765
0					21,230,733
0					0
0					0
0					0
0					21,230,733
					22,439,556
					1,208,823

FINAL ☐ FIXED EDERAL SHARE 17,463 *ncy in compliance with*	**13. CERTIFICATION** I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.	SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL T. P. Bowman TYPED OR PRINTED NAME AND TITLE T. P. Bowman Assistant Treasurer	DATE REPORT SUBMITTED Jan. 23, 1995 TELEPHONE (*Area code, number and extension*) (216) 438-7125

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☆U.S. Government Printing Office: 1985—461-275/20171

ADVANCED PARTICLE FILTER

Technical Progress Report No. 18
October through December 1994

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

SUMMARY

Tidd APF test run 24 started 09/22/94 5:02 PM (coal fire) and ended 10/21/94 11:39 AM (scheduled combustor trip). A series of reports follow that describe various Westinghouse activities supporting the APF operation, system reconfiguration and material surveillance.

REPORT HIGHLIGHT

Appendix A (E.V.Carelli) covers the design of the straps which act as a backup to the weld which attaches the original dust shroud to a new 26 inch long top section which was added during the November and December 1994 outage. The original top 26 inches of the dust shroud was out of round from previous operation.

Appendix B (E.V.Carelli) is an analysis to determine if support-transferred vibrations during pulse cleaning are a possible source of stresses sufficient enough to induce failure in ceramic candle filters. The report concludes that vibrations in the ceramic candle filters induced from the plenum plate have been ruled out as a possible cause behind candle failure.

Appendix C (J.P.Oberst) summarizes the APF operating conditions for test run 24. Test run 24 set a new record for the APF with 690:42 hours of continuous operation including approximately 96 hours with a 100% detuned cyclone. Test run 24 concluded APF test segment 4 which included test runs 19 through 24 and extended from 7/16/94 through 10/21/94 for approximately 1,705 hours of operation. The APF now has a total of 4,744 hours of coal fire operation.

Appendix D (G.J.Bruck) documents the results of a borescope inspection of the APF internals and candles through the inspection nozzles after the conclusion of test run 24 on 10/25/94. Some ash bridging and broken candles were found during this inspection.

Appendix E (M.A.Alvin) describes the results of inspection performed immediately after the APF internals lift on 10/27/94 following conclusion of test run 24. This memo covers the ash bridging and the location and type of candle filters which failed during the July through October 1994 APF test segment.

Appendix F (M.A.Alvin) tallies the total number of candle filters found broken after the 10/27/94 internals lift (30), as well as additional candles broken during cleaning and candle replacement (31).

Appendix G (M.A.Alvin) characterizes the ash bridging and residual dust cake layer found on the various types of candles installed during the July through October 1994 test segment. Included in this report is a discussion of ash cake formations and morphology and filter permeability, cleanability and surface roughness.

Appendix H (M.A.Alvin) characterizes the as-manufactured and PFBC-exposed 3M CVI-SiC composite filter matrix candles. The report explores the architecture of the 3M chemically vapor infiltrated silicon carbide composite filter matrix, its as-manufactured morphology, composition and strength, as well as changes which result in the composite matrix after 1705 hours of exposure to the pressurized fluidized-bed combustion (PFBC) gas environment.

Appendix I (M.A.Alvin) characterizes the strength of various first and second generation candle filters after 1705 hours of PFBC operation at Tidd. The candle filters tested included eight Coors P-100A-1 alumina/mullite filters, eight Pall Vitropore 442T filters, three DuPont PRD-66 filters, three 3M CVI-SiC composite filters and eight Schumacher Dia Schumalith FT20 filters.

Appendix J (M.A.Alvin) identifies the number, type and general location of candle filters installed in the APF during November and December 1994 for operation during the first quarter of 1995.

Three Westinghouse proprietary memos on 3M CVI-SiC composite candle filter testing at Tidd have been forwarded under separate cover and are not included here. Two of the three memos dated 10/21/94 and 12/27/94 cover 3M candle filters which have been installed in the APF for 1995 testing and the third memo dated 10/31/94 covers inspection of the three 3M filters used during the July through October 1994 APF test segment.

APPENDIX A

DUST SHROUD SUPPORT STRAP DESIGN

E.V.Carelli

From: Eric V. Carelli
WIN: (412) 256-2501
Date: September 30, 1994
Subject: Dust Shroud Support Straps

To: Ed Rutt

cc: G.J. Bruck
T.E. Lippert

During the next shutdown at the Tidd Pressurized Fluidized Bed Combustion (PFBC) Plant, the current dust shroud will be taken out and repaired. The top 26" will be removed and replaced by a new, reinforced section, which will be welded to the remaining lower part. A system of straps will bridge the weld on the inside the shroud, and will support the lower section should the weld ever fail. The following will describe the dimensions of the straps, their placement on the shroud, and the materials that must be ordered.

Dimensions

The straps will be made of 310 Stainless Steel. The plate thickness will 0.25", while its length will be 9.0" and its width will be 3.5". The top part of the strap will be welded onto the new section by FC, while the lower section will be held on by pins. The pins will also be made of 310 Stainless Steel, and will have a diameter of 1.0" and will be 2.25 long. The center of the hole will be 1.5" above the bottom of the plate and 1.75" from the edges. Each pin will have 1/8 " holes drilled 0.75" from each end, thus leaving 0.75" between the holes. Figures 1 shows a diagram of the plate and pin.

Placement

There will be 8 straps, all placed on the inside of the shroud. They should be placed 45° apart. The plate's top 4" are to be placed above the weld and be welded onto the shroud. There should be 5" of the plate below the weld so that there will be 3.5" between the center of the hole and the weld. The pins will be held in place by passing 310 Stainless Steel weld wire through the 1/8 " holes. Figure 2 shows the strap's placement in relation to the weld.

Materials

The materials that need to be ordered are:

- One rectangular sheet of 0.25" thick 310 Stainless Steel, 9.0" x 30.0" (which will be divided into eight 9.0" x 3.5" sections)
- 2 ft. of 1.0" diameter 310 Stainless Steel (to be divided into eight 2.25" long section)

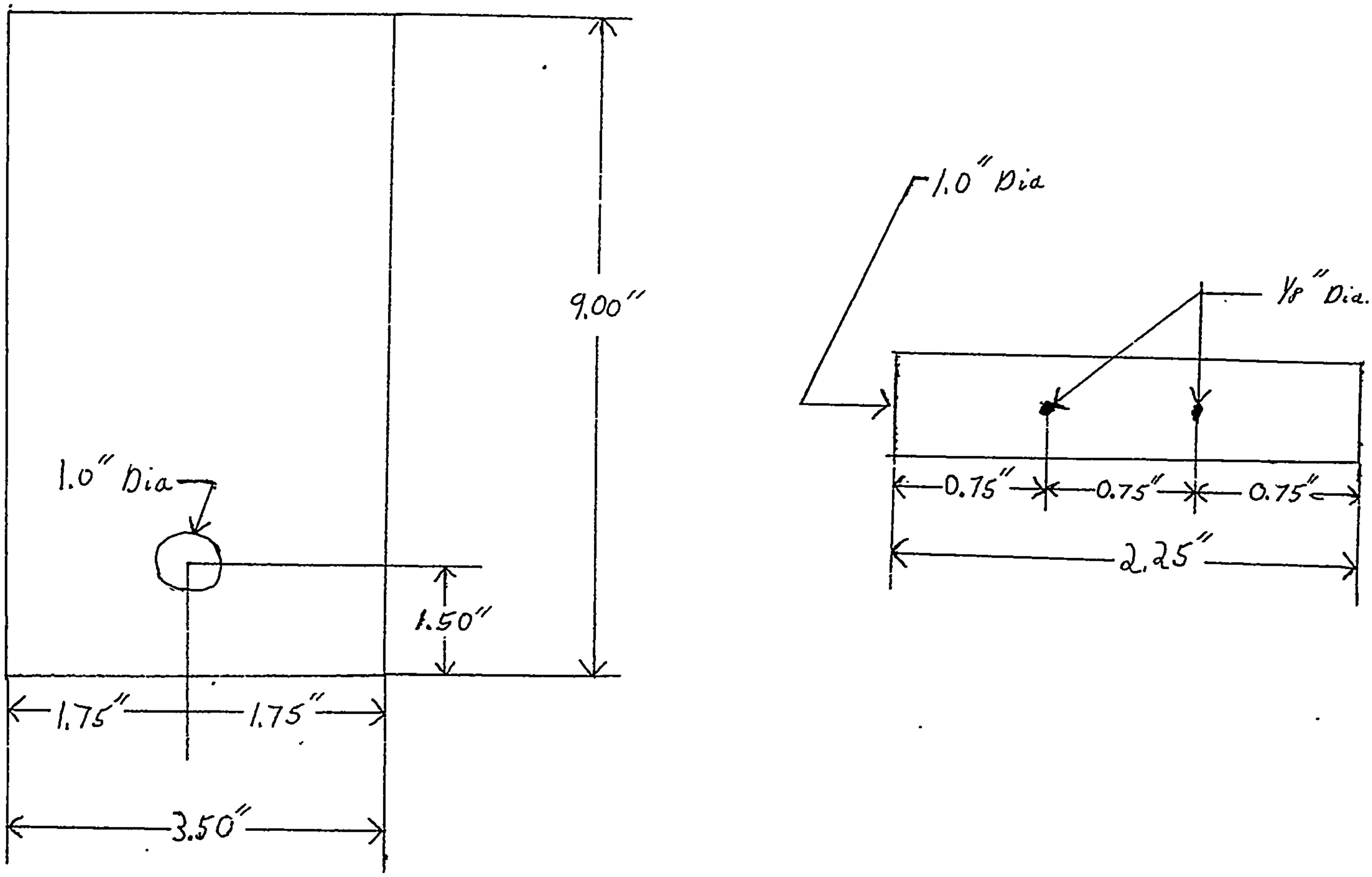
Calculations

In determining the area of the straps and the material to be used, failure by both tensile and shear forces must be kept in consideration. The ultimate tensile strength of 310 Stainless Steel at room temperature is 82,600 psi. However, a material that is subjected to very high temperatures for long stretches of time will fail from creep at stresses much lower than the ultimate tensile strength. For these calculations, the temperature was assumed to be at 1600° F for a time of 10,000 hours. This is about 100° F and 5,000 hours more than the facility has experienced so far. Thus, by "overkilling" these parameters, a factor of safety is automatically built in. At 1600° F, 310 SS experiences creep rupture after 10,000 hours at a sustained stress of at least 900 psi.

The total weight of the shroud after the new, reinforced section is added is 1140.16 lb. Since it was already decided that the weight would be best distributed among 8 straps set 45° apart, each strap would hold 142.52 lb. Using the standard equation $P=\sigma*A$ (P = load, A = cross-section area, σ = stress), the minimum cross-sectional area of the plate would have to be 0.158 sq. in.. The plate would have to have a minimum width of 0.63". To make it wide enough to accommodate the pin hole, it was decided to make the 0.25" thick plate 3.5" wide.

There was no data available to determine the minimum shear stress that would cause rupture at that temperature and time. In order to be conservative, it was arbitrarily decided to make the pin with a diameter of 1.0". Thus, the pin would experience a shear stress of 181.46 psi. This low shear stress, along with the conservative allowances for temperature and exposure time, make it very unlikely that the pin would fail during a run. The plate would have a cross-sectional area of 0.625 sq. in, and thus have a tensile stress of 228.03 psi, well below the allowed 900 psi.

The bearing stress was also considered. However, since the bearing strength is usually higher than the tensile strength and shearing strength for most steels, it was felt that failure due to bearing stress is not a concern.



Plate

Pin

Figure 1: Dimensions of Plate and Pin

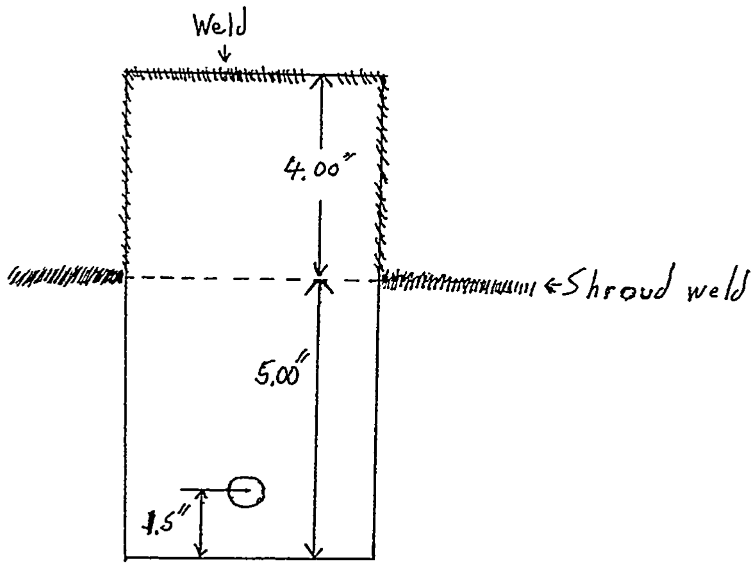


Figure 2: Placement of the Plate in Relation to the Shroud Weld

APPENDIX B

ANALYSIS OF THE EFFECT OF SUPPORT-TRANSFERRED VIBRATIONS ON THE FAILURE OF CERAMIC CANDLE FILTERS

E.V.Carelli

Analysis of the Effect of Support-Transferred Vibrations on the Failure of Ceramic Candle Filters

Objective

The objective of this study is to determine if support-transferred vibrations are a possible source of stresses sufficient enough to induce failure in porous ceramic candle filters.

Introduction

Hot gas particulate filtration systems for coal based, combined cycle power generators are currently being developed and demonstrated. Test runs of significant length are being conducted at the Tidd Pressurized Fluidized Bed Combustion (PFBC) 70 MW_e clean coal demonstration plant in Brilliant, Ohio, and at the 10 MW_t circulating PFBC plant in Karhula, Finland. Hollow, ceramic candles are hung in clusters and trap dust as gas passes through on its way to the turbines. The dust trapped on the outside of the candles is periodically knocked off by a very short backpulse of cold air. A major problem that has occurred repeatedly during these tests has been the failure of the ceramic candle filter elements. At the end of several test runs, a number of candles are discovered broken or cracked, most often right underneath the point where the candle is held in place by a flange.

Several possible causes are under investigation, including ash bridging, thermally induced stresses, material degradation, creep/crack growth, and dynamically-induced stress. In studying possible vibration related mechanisms, R.M. Roidt et. al. (1) have already eliminated flow-induced vibrations as a source of significant stresses and strains. In order to complete the evaluation of vibrational mechanisms, support induced vibrations and backpulse related plastic deformation must also be considered. The backpulse could initiate vibrations in the plenum support plate, which are then transferred to the candles. The following report describes the examination, and conclusions, regarding support-induced vibrations as a possible cause of failure in the ceramic candles.

Description of Experiments

A series of experiments were conducted previously at the Tidd-APF facility by J. Oberst and R.M. Roidt. Three accelerometers were epoxied to the B cluster of the bottom plenum plate. Their locations and the candles' layout are shown in Figure 1. The x and y accelerometers were mounted on the side of the plate, 90 degrees apart. The z accelerometer was mounted on the bottom surface of the plate, 4 inches in from the edge of the plate. The plenum acceleration was measured for 12 room temperature backpulses with a HP 3562A Dynamic Signal Analyzer. Six tests were done with a backpulse pressure of 350 psi, while the other 6 were done with a backpulse pressure of 700 psi.

Figures 2-7 give the low-frequency power spectra for the x, y, and z directions at the two pressures. Some of the higher spikes are marked with their frequency and power level (in dB rms G^2). These are possible natural frequencies of the plate. Since there are many spikes of the same magnitude, and the exact boundary conditions of the plate are not known, it was necessary to calculate the theoretical natural frequencies, to compare with the actual test results, and to find the most likely natural frequency. This procedure is described in the following section.

Natural Frequency of the Plenum Support Plate

Looking at Figures 2-7, one will notice that there is a great number of spikes that could all be possible natural frequencies. To narrow down the possibilities, it is necessary to calculate the natural frequencies theoretically, and then compare them with the experimental results. This also allows one to check up on the possibility of resonance taking place between the plates and the candles.

In calculating the natural frequencies of the plate, the possible boundary conditions are free, fixed, or simply supported. However, since the rigidity of the plate is not known, it is impossible to eliminate any one of the three. According to Timoshenko, the equation for the natural frequency f of a circular plate is:

$$f = \frac{\alpha}{2 * \pi * r} * \sqrt{\frac{D * g}{\rho * h}}$$

where:

α = modal constant

r = radius of plate (19")

g = gravitational constant (386 in/s^2)

ρ = density

h = thickness of the plate (1.563")

D = Flexural rigidity, which is given by the equation:

$$D = \frac{E * h^3}{12 * (1 - \nu^2)}$$

where:

E = elastic modulus

ν = Poisson's ratio (0.3)

Figure 8 shows a schematic of the bottom plenum. Normally the density and modulus of SS310 at room temperature, which are 0.29 lb./in^3 and 29.0*10^6 lb./in^2 respectively, could be used in these equations. However, the weight of the candles and the holes in the plate must be taken into account. There are 52 candles on the plate. The holes in the plate have a diameter of 1.47". The plate has a total volume 215.719 in^3, thus having a total weight of 62.56 lb. The candles weigh 9.81 lb. each, and each is held by a flange holder that weighs 4.41 lb. Assuming that the weight is evenly distributed, the effective density of the plate is 3.72 lb./in^3.

Yu (2) created a series of graphs that define the effective bending and in-plane elastic modulus in the pitch and diagonal directions for a square pattern of circular holes. Since the pitch and diagonal distance between the holes varies by as much as 1.54", it was decided to use a range of E' = 0.8E - E.

The mode of the circular plate depends on the number of nodal diameters (N) and nodal circles (S) that are present. The constants for each mode, for all three boundary conditions, are given on p. 501 in Vibration Problems in Engineering and on pp. 714-715 in Roark's Formulas for Stress and Strain. The following experimentally found frequencies fell within the calculated, theoretical ranges for both backpulse pressures of 350 psi and 700 psi. Listed in Table 1, along with frequency, are the boundary condition, the modes, and the calculated frequency range.

Table 1: Experimental and Calculated Frequencies

Direction	Frequency @350 psi	Frequency @700 psi	Boundary Condition	# of Nodal Diameters	# of Nodal Circles	Calculated Freq. Range
X	93.75	93.18	FREE	0	1	94.01-103.87
X	331.82	334.10	SS	0	1	313.47-341.01
Y	217.04	236.87	FREE	1	0	215.86-234.82
Y	336.25	-	SS	0	1	313.47-341.01
Z	160.00	159.37	SS	1	0	146.22-159.06
Z	324.37	322.73	SS	0	1	313.47-341.01
Z	378.75	378.75	FREE	2	1	370.70-403.27

Having found the most probable natural frequencies, the next step is to find the maximum possible stresses due to vertical and horizontal accelerations.

Stresses and Strains from Vertical Accelerations

Stresses can result in the candle from the up-down motion of the plate as it is vibrating. On p.702 in Roark's Formulas for Stress and Strain, Young (3) gives the equations for stress and strain in a slender, uniform rod that is given a motion of translation with an acceleration parallel to its axis by a force applied at one end. These equations are as follows:

$$\sigma = \frac{W * a}{g * A}$$

$$\varepsilon = \frac{W * a * L}{2 * g * A * E}$$

where:

σ = maximum stress, located at loaded end

ε = elongation

W = weight of the candle (9.81 lb.)

a = acceleration in the z-direction

g = gravitational constant (386 in/s^2)

A = cross-section Area (2.43 in^2)

L = length of candle (59.06 in)

E = elastic modulus of candle (4.66*10^6 psi)

In order to be consistent, the same elastic modulus that Roidt et. al. (1) used for his analysis of flow induced vibrations in the candles was also used for this analysis. To find the accelerations, the decibel level (dB) of each of the selected frequencies is read off the power spectra (Figures 2-7), and then inserted into the following equation:

$$a = 1.41 * g * \sqrt{10\wedge(\frac{dB}{10})}$$

Tables 2 and Tables 3 shows the decibel level, acceleration, stress, and strain of the three possible natural frequencies in the z-direction for the backpulse pressures of 350 psi and 700 psi, respectively.

Table 2: Axial Stress and Strain at 350 psi

Frequency (Hz)	Decibel Level (dB)	Acceleration (in/s^2)	Stress (psi)	Strain (in/in)
160.00	-44.156	3.383	0.0354	2.24*10^{-7}
324.37	-59.997	0.546	5.71*10^{-3}	3.62*10^{-8}
378.75	-48.486	2.055	0.0215	8.06*10^{-10}

Table 3: Axial Stress and Strain at 700 psi

Frequency (Hz)	Decibel Level (dB)	Acceleration (in/s^2)	Stress (psi)	Strain (in/in)
159.37	-49.888	1.749	0.0183	$1.16*10^{-7}$
322.73	-58.889	0.620	$6.49*10^{-3}$	$4.11*10^{-8}$
378.75	-45.826	2.791	0.02919	$1.12*10^{-9}$

As can be seen from the above tables, the stresses and strains are negligible. Assuming the worst case scenario, these three frequency are in phase with each other, and so their resultant stress and strains would be added together. Thus, the greatest axial stress one could expect is 0.063 psi at 350 psi and 0.054 at 700 psi. So, it can be concluded that at least the vertical component of the plate's vibrations does not make a meaningful contribution to the candles' stress and strain. It remains to be seen if the horizontal components are at all significant.

Moment Forces and Deflections from Horizontal Vibrations

The same procedure as described above was used to find the horizontal accelerations of the plate. On p. 703 in his book, Young (3) gives the equations for maximum moment and shear in a long rod, supported at one end, experiencing a horizontal acceleration at the supported end. The equations for maximum moment, which occurs at a third of the rod's length away from the supported end, and maximum shear, which is at the supported end, are as follows:

$$M = \frac{W * L * a}{27 * g}$$

$$V = \frac{W * a}{12 * g}$$

where:

M= moment force
V= shear force
a= acceleration
L= length of the candle (59.06 in)

The other variables all have the same values used in the calculations described previously. Tables 5 and 6 give the results for the selected frequencies in the x and y directions. In addition to the frequencies given in Table 1, several other frequencies that had relatively high spikes (please see Fig. 2-3, 5-6) were also included as possible harmonic frequencies. In this manner, everything is accounted for a worse-case scenario.

Table 5: Moment and Shear at 350 psi

Direction	Frequency (Hz)	Decibel Level (dB)	Acceleration (in/s^2)	Moment (lb.-in)	Shear (lb.)
X	93.75	-46.62	2.547	0.142	0.0161
X	331.82	-46.67	2.532	0.141	0.0161
X	446.87	-46.31	2.639	0.147	0.0168
Y	106.87	-41.04	4.840	0.269	0.0308
Y	217.04	-41.39	4.652	0.258	0.0296
Y	336.25	-39.94	5.497	0.306	0.0349

Table 6: Moment and Shear at 700 psi

Direction	Frequency (Hz)	Decibel Level (dB)	Acceleration (in/s^2)	Moment (lb.-in)	Shear (lb.)
X	56.82	-45.00	3.070	0.171	0.0195
X	93.18	-44.44	3.274	0.182	0.0208
X	276.25	-45.14	3.020	0.168	0.0192
X	334.10	-46.39	2.616	0.145	0.0166
Y	236.87	-48.60	2.027	0.113	0.0129
Y	393.12	-45.58	2.870	0.160	0.0182

Again, if one assumes the worst case scenario, all of the frequencies are in phase with each other. After summing all of the accelerations in the x and y directions, and then adding the sums vectorially, one finds that the maximum overall moment is 0.9372 lb.-in at 350 psi and 0.7194 lb.-in at 700 psi. As with the vertical accelerations, the resultant forces are very small.

To find the overall deflection in the candles due to the horizontal vibrations, refer to Table 11 on p.176 in Roark's Formula's for Stress and Strain. Young (3) gives a series of formulas and variables for beams under simultaneous axial tension and transverse loading. In this case, the weight of the candle is providing the axial tension. Using case 3 (concentrated moment) for the left end free and right end fixed boundary condition, the largest deflection is $1.58*10^{-4}$ in., and occurs at the free end. Appendix A shows the deflections as a function of length along the candle, with the origin located at the free end. From Tables 5 and 6 and Appendix A one can easily conclude that the horizontal accelerations resulting from the plate's vibrations do not create any significant forces or deflections that could lead to failure. While insignificant just by themselves, the effect of these vibrations could be multiplied by other mechanisms which must be taken into account. One of these mechanisms is resonance, which will be discussed in the next section.

Resonance

In their study of flow-induced vibrations in the candle filters, Roidt et. al. (1) determined that the candle's natural frequency was most probably 84.37 Hz. As pointed out in previous sections, one of the possible natural frequencies for the plate is 93.75 Hz. With the two natural frequencies so closely spaced, resonance between the plate and the candle becomes very possible. On p. 712 in his book, Young (3) gives a formula to find the relative amplification factor y/y_s, where y is the near resonance vibration and y_s is the regular deflection. The formula is as follows:

$$\frac{y}{y_s} = \frac{1}{1-(\frac{f}{f_n})^2}$$

where:

f = frequency of the forcing impulse

f_n = natural frequency of the candle

If one uses the numbers straight off the power spectra, 84.37 and 93.75, the amplification factor would be 4.26. All of the deflections along the candle would be 4 times those given in Appendix A . The error associated with the frequency values has yet to be determined, so it is difficult to say what kind of amplification factor could be expected. The error would have to be about 4.5 Hz before the amplification factor would surpass 100. The amplification factor grows rapidly as the error becomes greater than 4.5 . While the amplification factor would have to be at least several thousand to make any of the deflections significant, the frequencies observed from the experiments are close enough to keep it under consideration as something that could occasionally become significant.

Discussion

In doing a vibrational analysis of the plate, there were several possibilities that needed to be examined. Namely, it was necessary to determine if vibrations from the plate were creating stresses and deflections in the candle sufficient to break the candle. It was also needed to see if these vibrations were producing forces and/or stresses that were supporting other failure mechanisms, such as crack propagation or plastic deformation. Determining the natural frequencies of the plate helped to pinpoint the appropriate data from the accelerometer tests conducted by R.M Roidt and J.P. Oberst. A comparison of the data in Table 1 with the power spectra in Figures 2-7 shows a number of very good matches. This helps to demonstrate that the data from the tests are credible.

The as-manufactured tolerance specifications for the ceramic candles permit a 0.12 in. bow and 0.49 in. deflection from the end. During test runs, the candles have shown elongation of 0.0787-1.38 inches without failing, and tension strengths over 2000 psi. (4) Thus, it is obvious from the "worst case scenario" results given in Tables 2-6 that vibrations induced by the plenum plate could hardly ever become significant in causing the candles to fail. Also, M.A. Alvin et. al. (4) determined that the threshold stress intensity for crack growth varies from 1800 psi to 2700 psi. Again, it is apparent that plate induced vibrations cannot contribute significantly to crack propagation or plastic deformation.

The long-term effects of the plate-induced vibrations have not been examined. So, while the static values are so small that it seems unlikely, the possibility of a fatigue mechanism taking place has not been totally ruled out. Also, resonance between the plate and the candles could, in some cases, possibly amplify the candle deflections enough to cause a significant strain. Finally, this analysis should be repeated taking into account the high temperatures at which the candles operate.

Conclusions

Vibrations in the ceramic candle filters induced from the plenum plate have been ruled out as a possible cause behind candle failure. The most probable way vibrations could have any effect is through resonance between the plate and candle. The possibility that the vibrations might be part of a fatigue mechanism has to still be investigated.

References

(1) Roidt, R.M., Oberst, J.P., Meyer, J.H., Summary of Vibrational Testing and Analysis of Hot Gas Ceramic Filter Candles, STC Memo No. 93-1TBO-ISSUE-M1, July 21,1993.

(2) Yu, Ing-Wu, Effective Elastic Constant for Perforated Plates with a Square Penetration Pattern of Circular Holes, 76-1E7-MECAN-R1, Nov. 9, 1976.

(3) Young, Warren C., Roark's Formulas for Stress and Strain, 6th ed., McGraw-Hill, Inc., 1989.

(4) Alvin, M.A., Lippert, T.E., Diaz, E.S., Smeltzer, E.E, Tressler, R.E., Durability of Ceramic Filters, 94-9TBO-XFDEG-P1, Aug. 1, 1994.

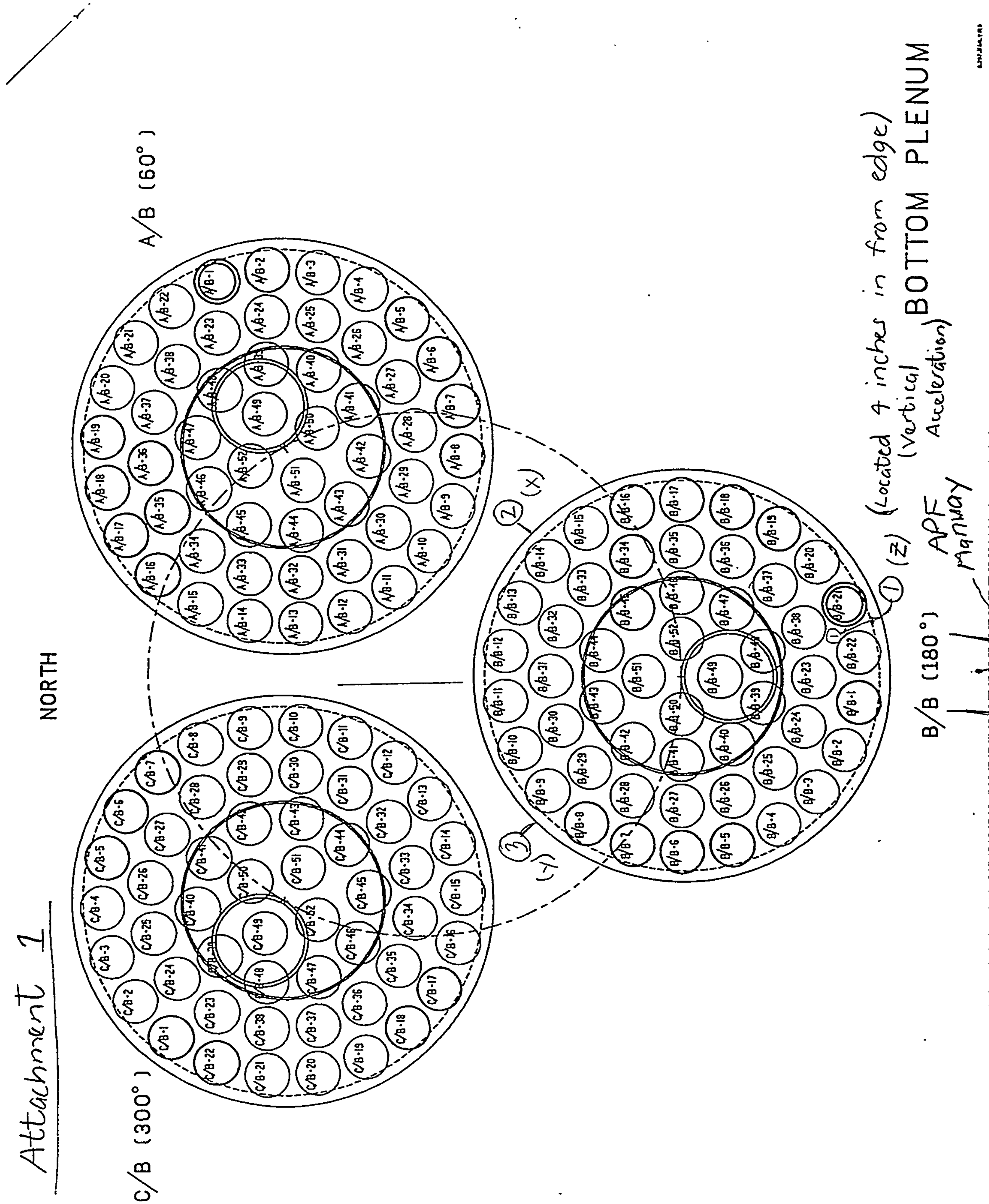


Figure 1: Location of the Test Accelerometers

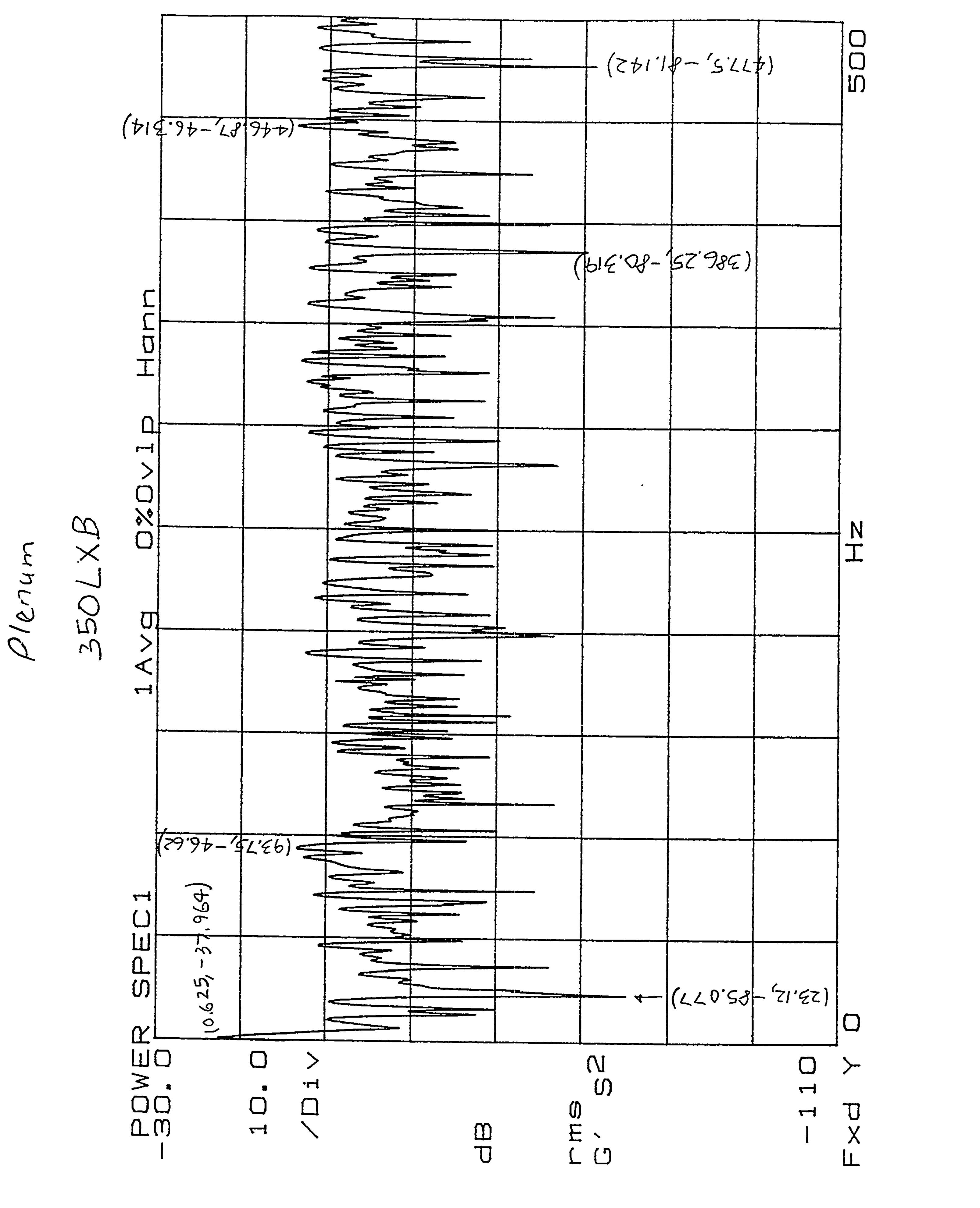


Figure 2: Power Spectrum, X-direction, 350 psi

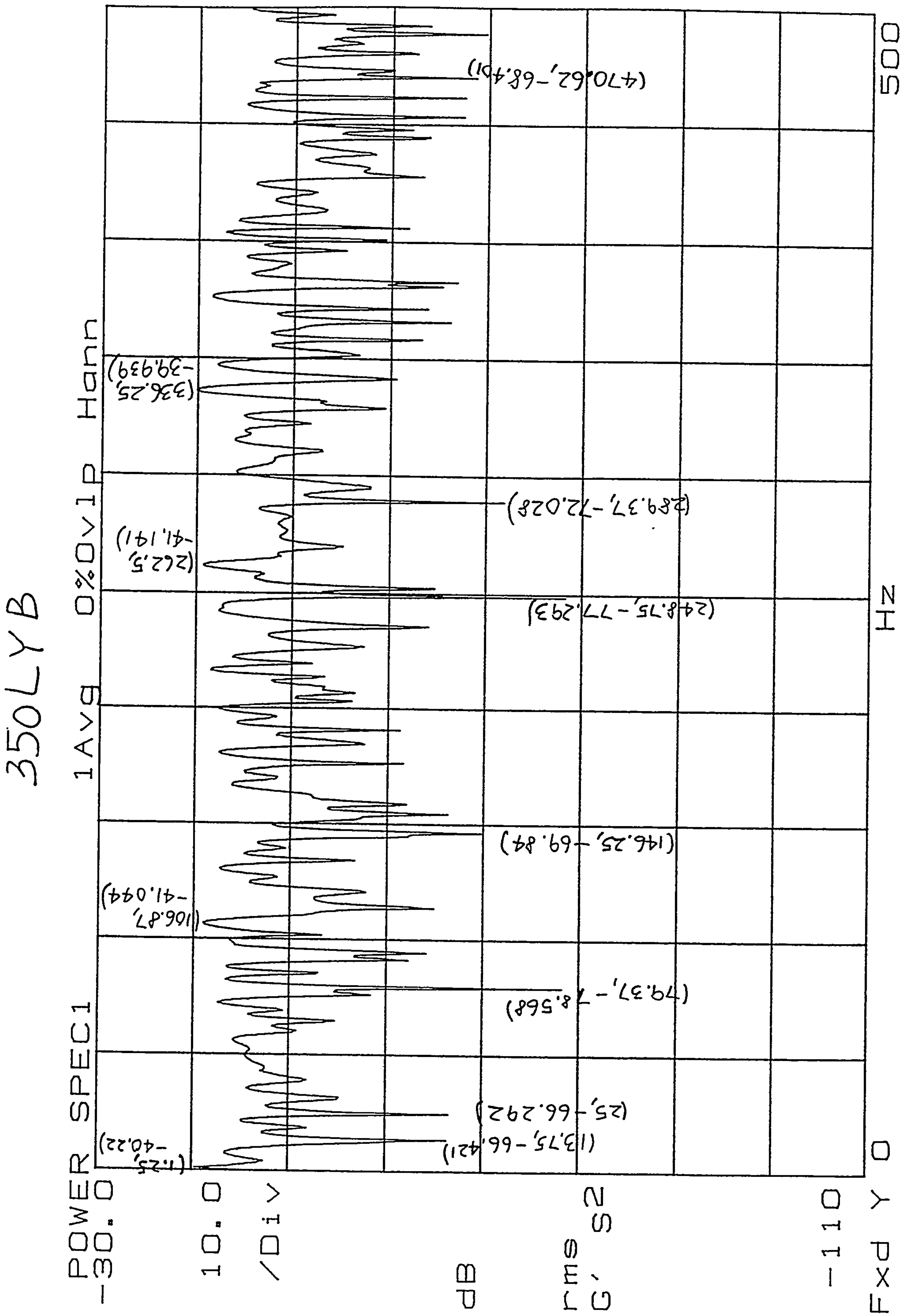


Figure 3: Power Spectrum, Y-direction, 350 psi

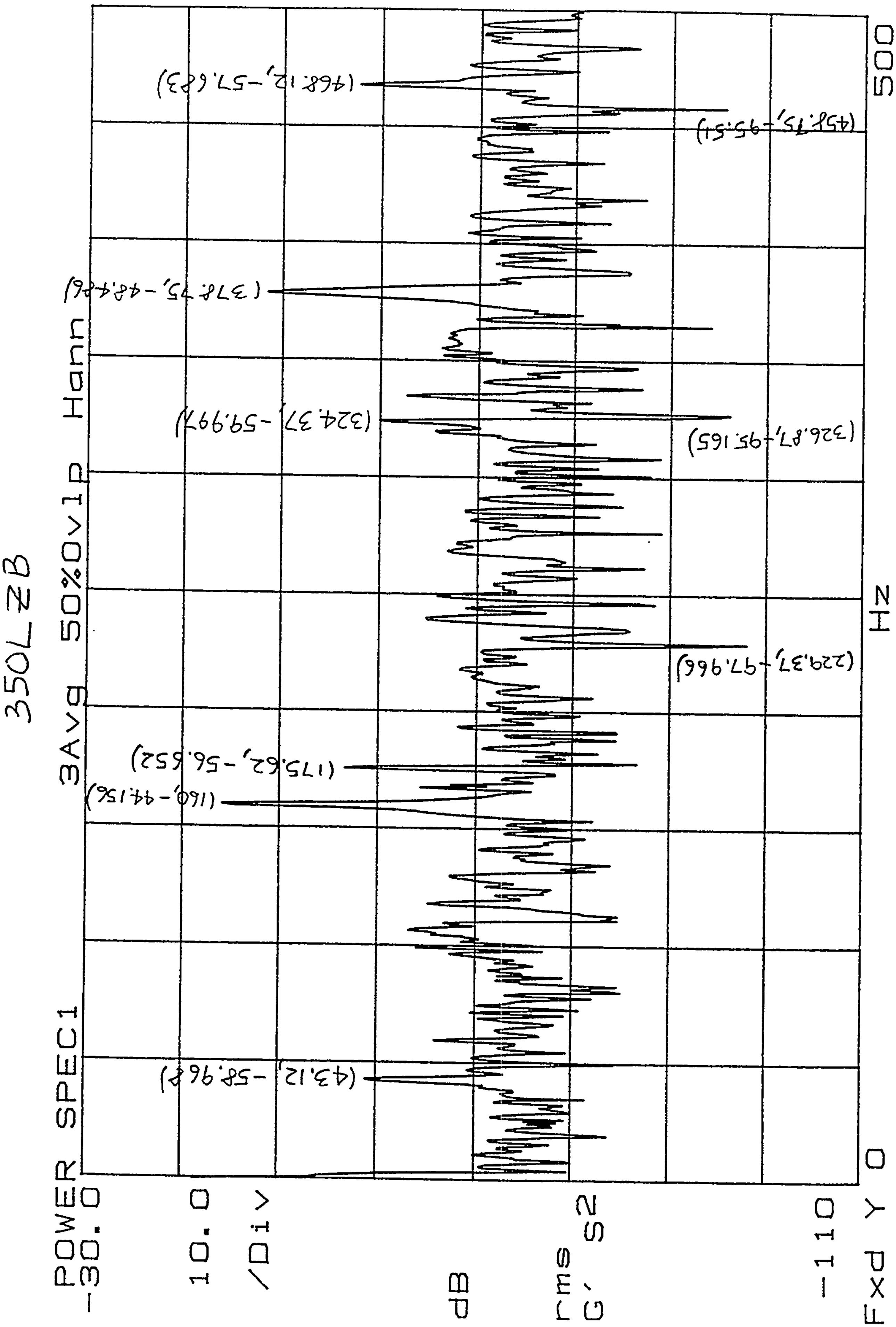


Figure 4: Power Spectrum, Z-direction, 350 psi

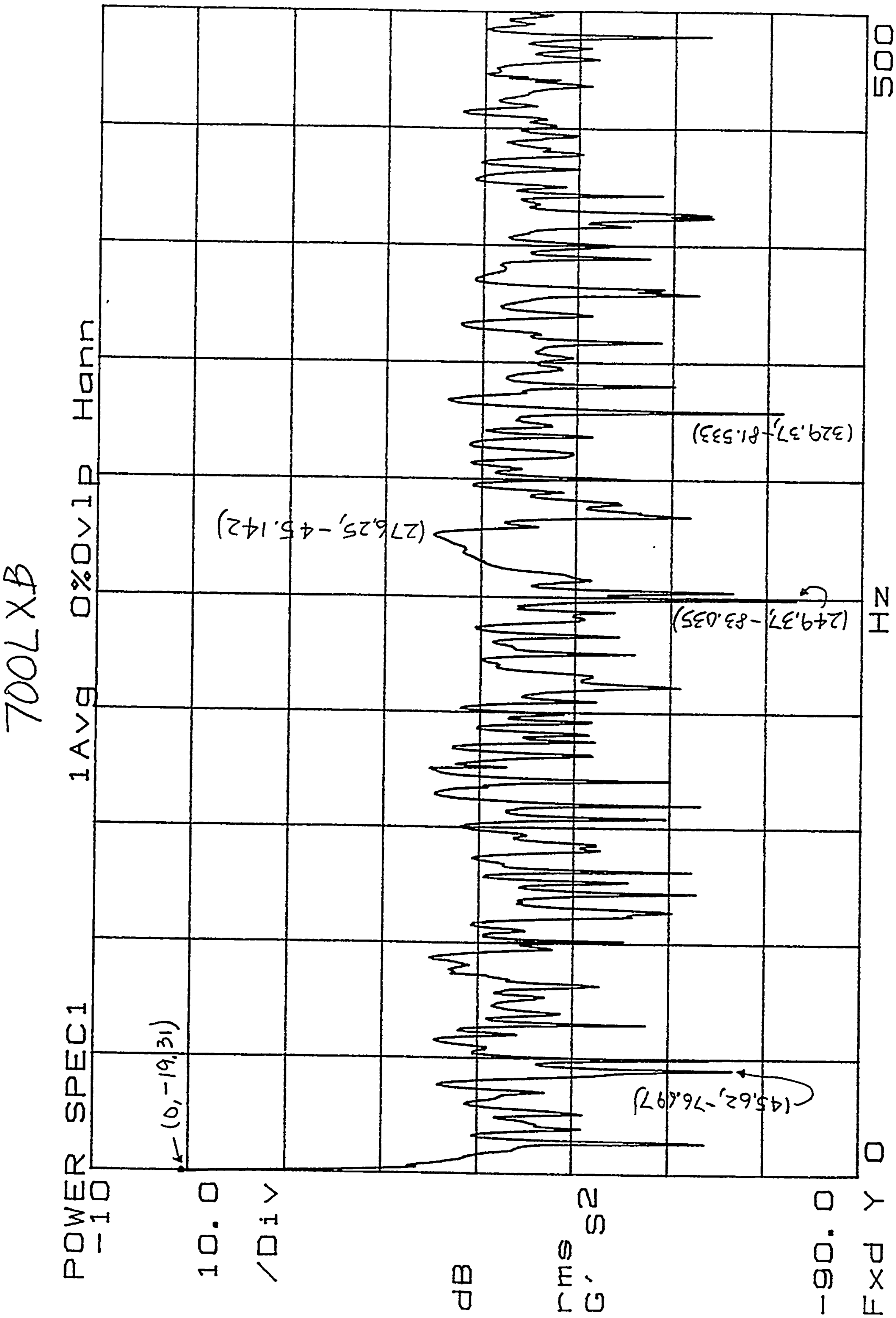


Figure 5: Power Spectrum, X-direction, 700 psi

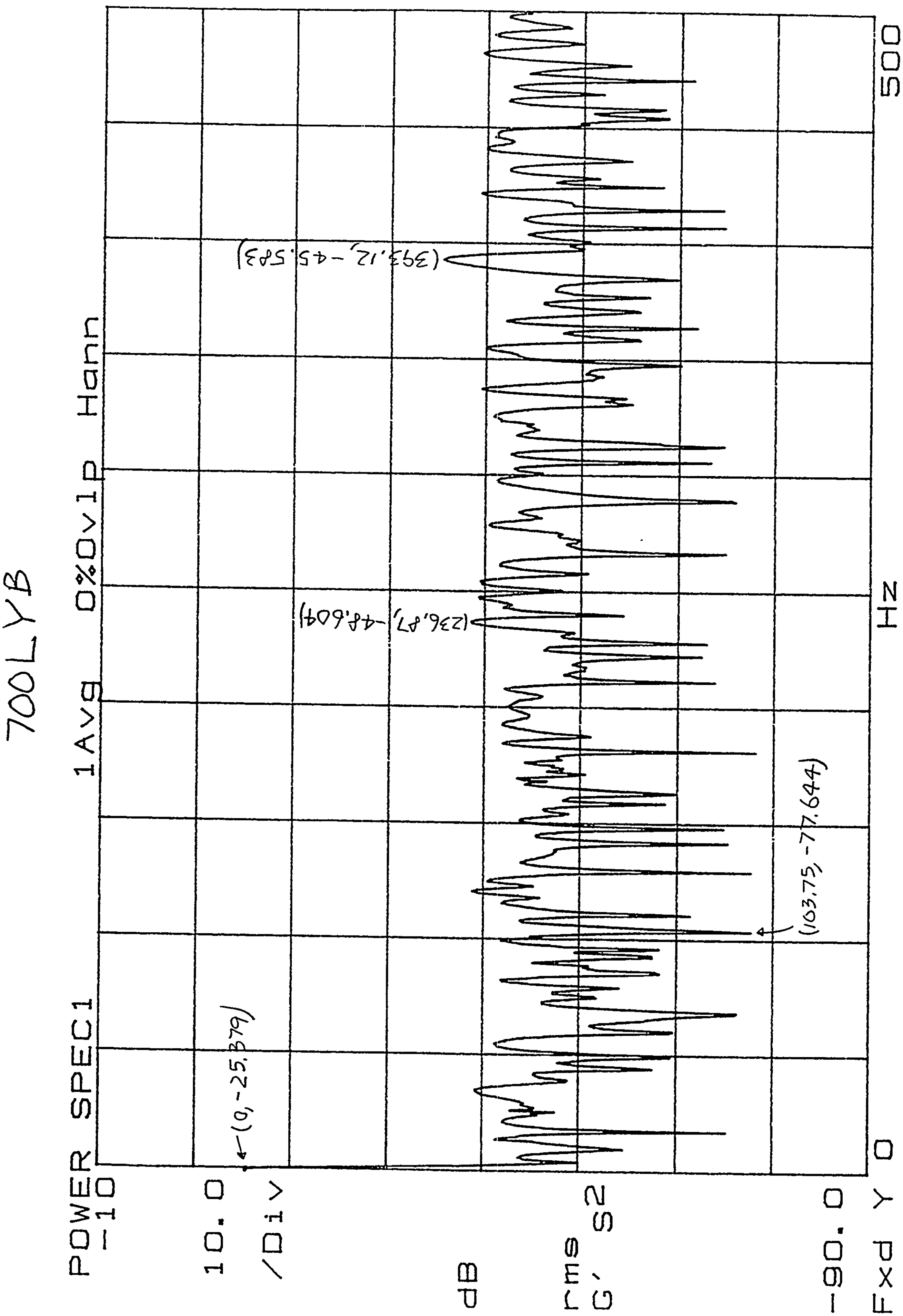


Figure 6: Power Spectrum, Y-direction, 700 psi

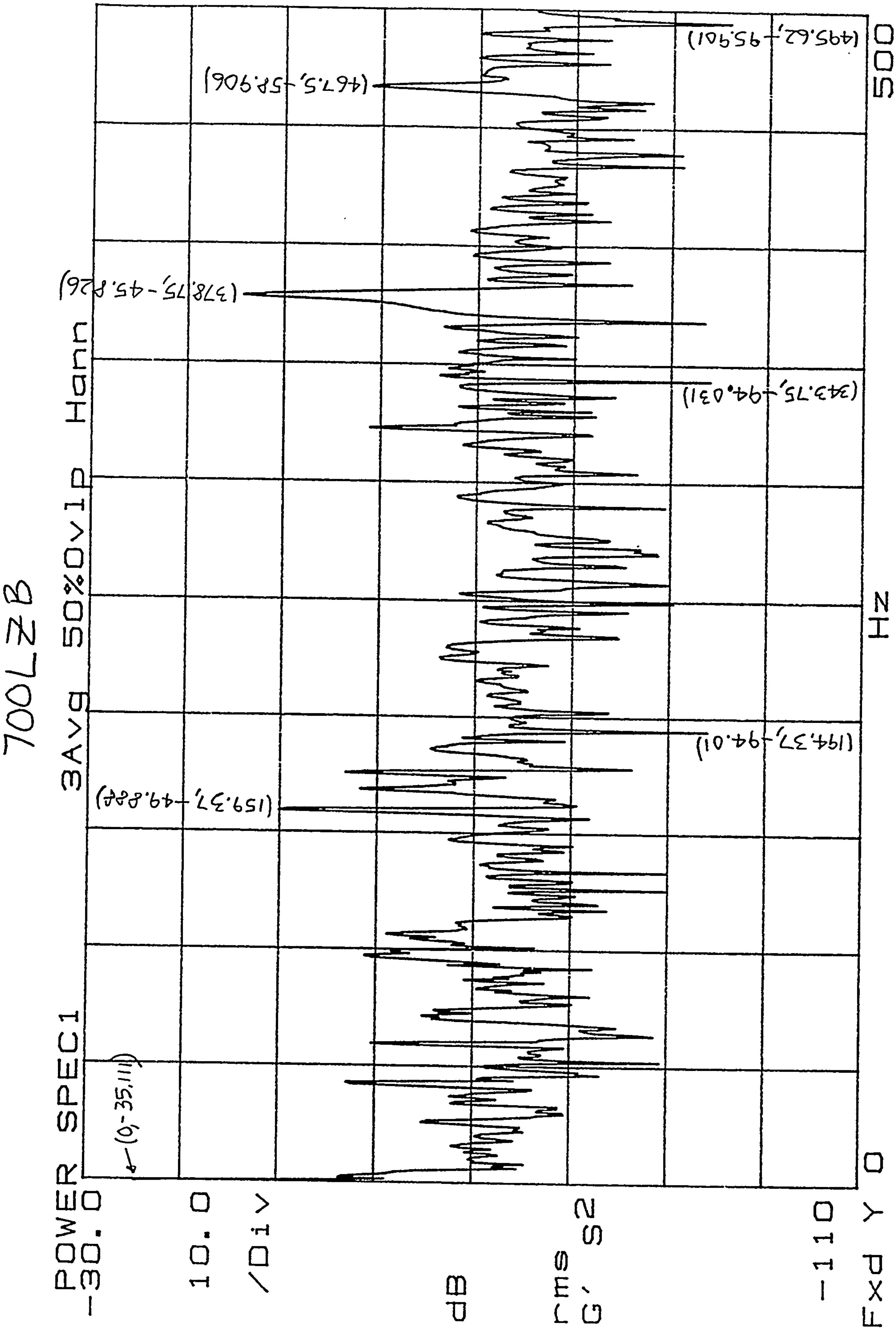


Figure 7: Power Spectrum, Z-direction, 700 psi

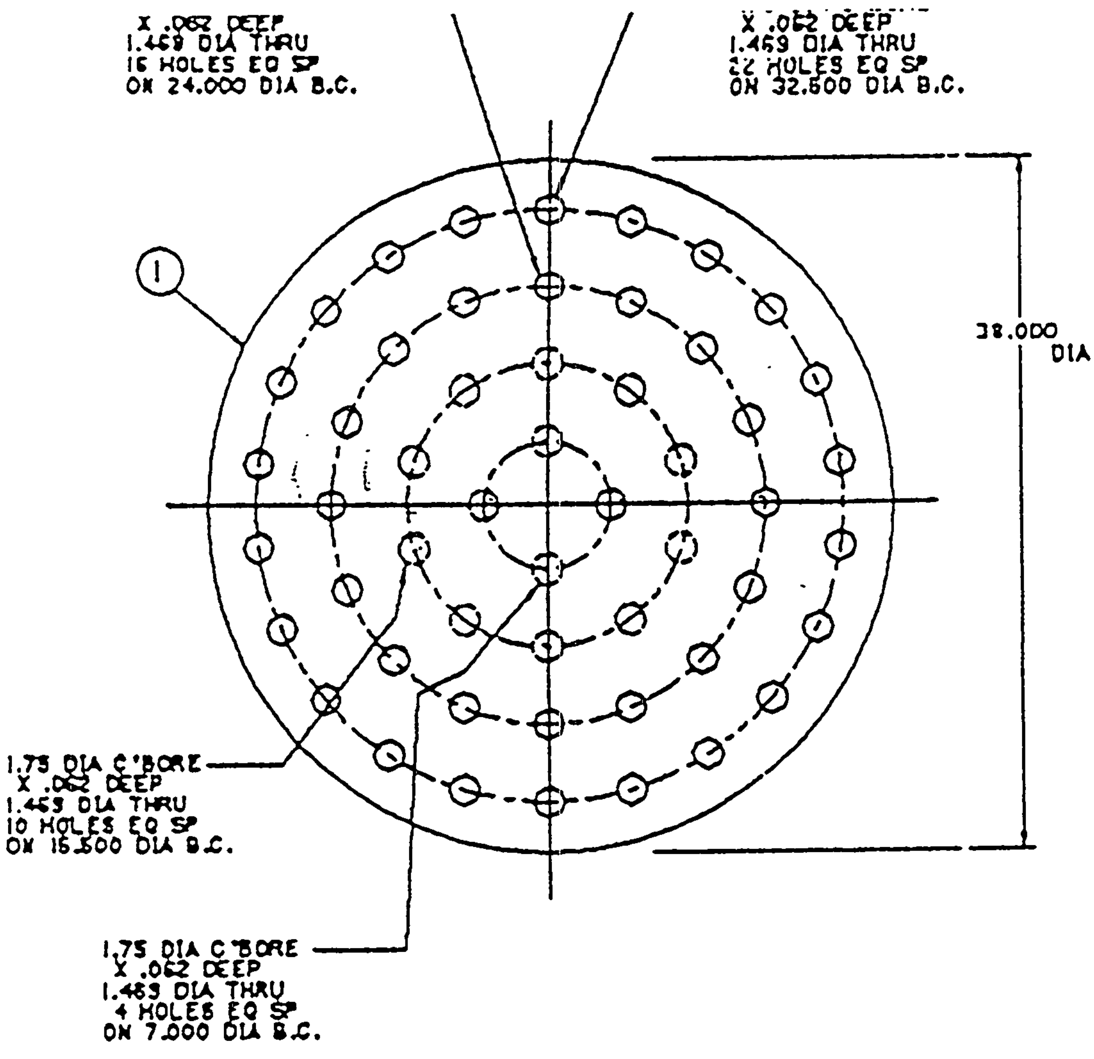


Figure 8: Schematic of the Bottom Plenum

Appendix A: Deflection of a Candle Subjected to Horizontal Acceleration at the Fixed End

	X (in.)	DEFLECTION		X (in.)	DEFLECTION	
		350psi	700psi		350psi	700psi
	0	0.000158	0.000122	48	9.54E-06	9.46E-06
	1	0.000155	0.00012	49	7.81E-06	8.48E-06
	2	0.000152	0.000117	50	6.24E-06	7.67E-06
	3	0.000148	0.000115	51	4.84E-06	7.02E-06
	4	0.000145	0.000112	52	3.61E-06	6.53E-06
	5	0.000142	0.00011	53	2.53E-06	6.21E-06
	6	0.000139	0.000107	54	1.62E-06	6.05E-06
	7	0.000135	0.000105	55	8.78E-07	6.05E-06
	8	0.000132	0.000102	56	2.95E-07	6.22E-06
	9	0.000129	9.98E-05	57	-1.2E-07	6.55E-06
	10	0.000126	9.73E-05	58	-3.8E-07	7.05E-06
	11	0.000123	9.48E-05	59	-4.7E-07	7.71E-06
	12	0.000119	9.24E-05	60	-4E-07	8.53E-06
	13	0.000116	8.99E-05			
	14	0.000113	8.74E-05			
	15	0.00011	8.49E-05			
	16	0.000107	8.25E-05			
	17	0.000103	8E-05			
	18	0.0001	7.75E-05			
	19	9.68E-05	7.51E-05			
	20	9.36E-05	7.26E-05			
	21	9.04E-05	7.01E-05			
	22	8.72E-05	6.77E-05			
	23	8.4E-05	6.52E-05			
	24	8.07E-05	6.27E-05			
	25	7.75E-05	6.02E-05			
	26	7.43E-05	5.78E-05			
	27	7.11E-05	5.53E-05			
	28	6.79E-05	5.28E-05			
	29	6.46E-05	5.04E-05			
	30	6.14E-05	4.79E-05			
	31	5.82E-05	4.54E-05			
	32	5.5E-05	4.29E-05			
	33	5.18E-05	4.05E-05			
	34	4.85E-05	3.8E-05			
	35	4.53E-05	3.55E-05			
	36	4.21E-05	3.3E-05			
	37	3.89E-05	3.06E-05			
	38	3.57E-05	2.81E-05			
	39	3.24E-05	2.56E-05			
	40	2.93E-05	2.32E-05			
	41	2.62E-05	2.09E-05			
	42	2.33E-05	1.88E-05			
	43	2.06E-05	1.68E-05			
	44	1.81E-05	1.5E-05			
	45	1.57E-05	1.34E-05			
	46	1.35E-05	1.19E-05			
	47	1.14E-05	1.06E-05			

APPENDIX C

TIDD APF OPERATION

J.P.Oberst

APF Operation

Table 1 summarizes the operating conditions of the APF for Test Run 24 (09/22/94 16:57 - 10/21/94 11:39) completed during the fourth quarter of 1994. No other APF tests were performed during the fourth quarter due to required APF maintenance. Test Run 24 set a new record for the APF with 690:42 hours of operation, this tops the previous record of 679:46 hours set during test run 22.

The flow in the summary table is the APF outlet gas flow estimated from similar conditions from earlier 1994 test run data. The flow measurement instrument failed at the beginning of test run 24 and no flow data was available for the remainder of the test. The temperature is the APF vessel internal temperature at the 0 degree nozzle 8A location. The pressure is the APF outlet pressure. The baseline and trigger delta-p are measured across the APF tubesheet. The initial permeability used to determine the relative permeability is calculated at a 0.4 psi delta-p at a face velocity of 10 ft/min at 1550°F. The ash filtered data in the table is estimated using an inlet dust loading of 3353 ppm (measured APF inlet loading by Battelle in January 1994).

During test run 24 from 10/17/94 12:00 through the end of the test, pulsing was performed on a plenum by plenum basis every 1.67 minutes (100 seconds), i.e. all nine plenums were pulsed every 15 minutes. During this period the baseline and trigger delta-p in Table 1 was the minimum and maximum tubesheet delta-p during the period 15 minutes before to 15 minutes after the time listed.

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/22/94	16:30		-3	35	709	35	33	37	6.4	0.17			
9/22/94	17:00	0	-2	35	726	35	34	46	6.5	0.17			* 16:57 coal fire. Pittsburgh No. 8 coal and #12 mesh
9/22/94	17:30		3	48	833	48	43	54	7.7	0.17	80		Plum Run Greenfield Dolomite sorbent.
9/22/94	18:00	1	4	52	858	58	47	57	7.3	0.15	87	167	* Flow data is inaccurate, ash passing through broken
9/22/94	18:30		5	57	888	68	51	64	7.3	0.14	96	263	candles is clogging APF outlet flow instrument. Flow
9/22/94	19:00	2	7	61	909	71	53	66	7.6	0.15	102	365	data is estimated from similar conditions in
9/22/94	19:30		8	61	935	73	53	66	7.6	0.15	102	467	previous test runs.
9/22/94	20:00	3	9	61	951	75	55	67	7.4	0.14	102	569	* Only partial cyclone detuning. 30 minute pulse
9/22/94	20:30		10	61	970	77	56	69	7.4	0.14	102	672	cycle.
9/22/94	21:00	4	14	61	986	78	58	71	7.4	0.13	102	774	
9/22/94	21:30		16	61	1006	78	59	76	7.5	0.13	102	876	
9/22/94	22:00	5	21	61	1031	80	61	77	7.5	0.13	102	978	
9/22/94	22:30		23	61	1046	80	61	78	7.6	0.13	102	1081	
9/22/94	23:00	6	24	72	1057	81	63	81	8.9	0.16	121	1201	
9/22/94	23:30		25	72	1069	81	62	80	9.0	0.16	121	1322	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/23/94	0:00	7	27	76	1089	92	69	89	8.6	0.14	127	1450	
9/23/94	0:30		31	76	1113	92	69	89	8.7	0.14	127	1577	
9/23/94	1:00	8	35	76	1142	94	71	96	8.7	0.14	127	1704	
9/23/94	1:30		39	76	1168	94	70	91	8.8	0.14	127	1832	
9/23/94	2:00	9	41	76	1189	101	73	95	8.4	0.13	127	1959	
9/23/94	2:30		41	80	1204	113	79	117	8.1	0.12	134	2093	
9/23/94	3:00	10	45	80	1215	114	79	107	8.1	0.12	134	2227	
9/23/94	3:30		44	80	1213	113	80	111	8.2	0.12	134	2362	
9/23/94	4:00	11	42	80	1209	113	79	103	8.1	0.12	134	2496	
9/23/94	4:30		41	80	1201	111	79	106	8.2	0.12	134	2630	
9/23/94	5:00	12	40	80	1202	113	80	104	8.1	0.11	134	2764	
9/23/94	5:30		41	80	1208	112	78	115	8.2	0.12	134	2898	
9/23/94	6:00	13	40	80	1202	111	78	104	8.2	0.12	134	3032	
9/23/94	6:30		39	80	1193	110	79	104	8.2	0.12	134	3166	
9/23/94	7:00	14	40	80	1198	113	81	103	8.1	0.11	134	3300	
9/23/94	7:30		40	80	1201	112	79	104	8.2	0.12	134	3435	
9/23/94	8:00	15	39	80	1192	113	79	101	8.1	0.11	134	3569	
9/23/94	8:30		39	80	1197	112	80	104	8.2	0.11	134	3703	
9/23/94	9:00	16	41	80	1206	113	81	104	8.1	0.11	134	3837	
9/23/94	9:30		40	80	1209	111	80	102	8.2	0.12	134	3971	
9/23/94	10:00	17	38	80	1186	112	79	104	8.1	0.11	134	4105	
9/23/94	10:30		39	80	1189	111	80	104	8.1	0.11	134	4239	
9/23/94	11:00	18	39	80	1189	113	80	103	8.1	0.11	134	4373	
9/23/94	11:30		39	80	1194	112	81	104	8.1	0.11	134	4507	
9/23/94	12:00	19	40	80	1205	113	80	106	8.1	0.11	134	4642	
9/23/94	12:30		40	80	1204	112	81	104	8.2	0.11	134	4776	
9/23/94	13:00	20	40	80	1209	113	82	105	8.1	0.11	134	4910	
9/23/94	13:30		40	80	1208	112	81	104	8.2	0.11	134	5044	
9/23/94	14:00	21	41	80	1213	113	82	105	8.2	0.11	134	5178	
9/23/94	14:30		40	80	1212	113	82	106	8.2	0.11	134	5312	
9/23/94	15:00	22	41	80	1214	114	83	107	8.1	0.11	134	5446	
9/23/94	15:30		40	80	1215	113	82	105	8.2	0.11	134	5580	
9/23/94	16:00	23	41	80	1224	114	82	107	8.1	0.11	134	5715	
9/23/94	16:30		39	80	1206	113	82	104	8.2	0.11	134	5849	
9/23/94	17:00	24	41	80	1205	113	83	107	8.1	0.11	134	5983	
9/23/94	17:30		41	80	1212	113	82	106	8.1	0.11	134	6117	
9/23/94	18:00	25	40	80	1214	114	83	108	8.1	0.11	134	6251	
9/23/94	18:30		40	80	1211	113	83	107	8.2	0.11	134	6385	
9/23/94	19:00	26	39	80	1198	113	83	106	8.1	0.11	134	6519	
9/23/94	19:30		41	80	1209	113	83	106	8.2	0.11	134	6653	
9/23/94	20:00	27	40	80	1215	114	82	107	8.1	0.11	134	6788	
9/23/94	20:30		39	80	1203	112	83	107	8.2	0.11	134	6922	
9/23/94	21:00	28	37	80	1185	112	82	104	8.1	0.11	134	7056	
9/23/94	21:30		37	80	1183	111	82	104	8.1	0.11	134	7190	
9/23/94	22:00	29	36	80	1184	112	82	104	8.1	0.11	134	7324	
9/23/94	22:30		37	80	1180	111	81	104	8.1	0.11	134	7458	
9/23/94	23:00	30	37	80	1181	112	82	103	8.1	0.11	134	7592	
9/23/94	23:30		37	80	1185	111	82	102	8.1	0.11	134	7726	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/24/94	0:00	31	37	80	1179	112	81	104	8.1	0.11	134	7860	
9/24/94	0:30		37	80	1181	111	81	104	8.1	0.11	134	7995	
9/24/94	1:00	32	37	80	1181	112	82	104	8.1	0.11	134	8129	
9/24/94	1:30		38	80	1186	111	83	102	8.1	0.11	134	8263	
9/24/94	2:00	33	38	80	1193	112	83	114	8.1	0.11	134	8397	
9/24/94	2:30		37	80	1187	111	82	103	8.2	0.11	134	8531	
9/24/94	3:00	34	38	80	1191	112	83	104	8.1	0.11	134	8665	
9/24/94	3:30		37	80	1193	111	82	103	8.2	0.11	134	8799	
9/24/94	4:00	35	36	80	1181	111	82	104	8.1	0.11	134	8933	
9/24/94	4:30		35	80	1175	110	82	103	8.1	0.11	134	9068	
9/24/94	5:00	36	37	80	1179	111	83	103	8.1	0.11	134	9202	
9/24/94	5:30		37	80	1181	111	83	103	8.1	0.11	134	9336	
9/24/94	6:00	37	38	80	1191	112	83	103	8.1	0.11	134	9470	
9/24/94	6:30		37	80	1189	111	82	105	8.2	0.11	134	9604	
9/24/94	7:00	38	39	80	1198	112	84	105	8.1	0.11	134	9738	
9/24/94	7:30		39	80	1205	112	84	105	8.2	0.11	134	9872	
9/24/94	8:00	39	42	80	1225	114	85	107	8.2	0.11	134	10006	
9/24/94	8:30		42	80	1234	114	84	110	8.2	0.11	134	10141	
9/24/94	9:00	40	45	80	1248	115	87	113	8.2	0.11	134	10275	
9/24/94	9:30		44	80	1255	114	86	110	8.3	0.11	134	10409	
9/24/94	10:00	41	47	80	1270	116	88	111	8.2	0.11	134	10543	
9/24/94	10:30		47	80	1286	116	88	114	8.3	0.11	134	10677	
9/24/94	11:00	42	50	80	1301	118	91	117	8.3	0.10	134	10811	
9/24/94	11:30		51	80	1316	120	92	117	8.2	0.10	134	10945	
9/24/94	12:00	43	51	90	1319	121	92	117	9.2	0.12	151	11096	
9/24/94	12:30		52	90	1329	120	93	118	9.3	0.12	151	11247	
9/24/94	13:00	44	54	90	1338	122	95	117	9.2	0.12	151	11398	
9/24/94	13:30		52	90	1329	120	94	122	9.3	0.12	151	11549	
9/24/94	14:00	45	52	90	1331	121	93	122	9.2	0.12	151	11700	
9/24/94	14:30		52	90	1322	121	92	122	9.2	0.12	151	11851	
9/24/94	15:00	46	55	90	1351	123	95	119	9.2	0.12	151	12001	
9/24/94	15:30		56	90	1369	124	97	122	9.2	0.11	151	12152	
9/24/94	16:00	47	54	90	1340	124	96	122	9.1	0.11	151	12303	
9/24/94	16:30		54	90	1342	124	97	128	9.1	0.11	151	12454	
9/24/94	17:00	48	54	90	1344	125	99	123	9.1	0.11	151	12605	
9/24/94	17:30		55	90	1353	124	99	126	9.1	0.11	151	12756	
9/24/94	18:00	49	56	90	1358	125	100	123	9.1	0.11	151	12907	
9/24/94	18:30		52	90	1317	123	97	125	9.1	0.11	151	13058	
9/24/94	19:00	50	53	90	1325	123	97	126	9.1	0.11	151	13209	
9/24/94	19:30		54	90	1340	122	97	125	9.2	0.11	151	13359	
9/24/94	20:00	51	53	90	1326	123	99	123	9.1	0.11	151	13510	
9/24/94	20:30		54	90	1327	123	97	124	9.1	0.11	151	13661	
9/24/94	21:00	52	53	90	1328	123	98	122	9.1	0.11	151	13812	
9/24/94	21:30		49	90	1292	121	96	118	9.0	0.11	151	13963	
9/24/94	22:00	53	51	90	1301	122	97	115	9.0	0.11	151	14114	
9/24/94	22:30		55	90	1345	124	98	115	9.1	0.11	151	14265	
9/24/94	23:00	54	55	90	1359	124	98	124	9.2	0.11	151	14416	
9/24/94	23:30		55	90	1353	124	97	118	9.2	0.11	151	14566	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME- ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/25/94	0:00	55	54	90	1348	124	97	121	9.2	0.11	151	14717	
9/25/94	0:30		54	90	1346	123	97	121	9.2	0.11	151	14868	
9/25/94	1:00	56	54	90	1351	124	96	114	9.2	0.11	151	15019	
9/25/94	1:30		55	90	1352	124	98	119	9.2	0.11	151	15170	
9/25/94	2:00	57	56	90	1368	124	99	118	9.2	0.11	151	15321	
9/25/94	2:30		56	90	1370	124	99	119	9.2	0.11	151	15472	
9/25/94	3:00	58	56	90	1360	125	99	120	9.2	0.11	151	15623	
9/25/94	3:30		56	90	1361	124	99	118	9.2	0.11	151	15774	
9/25/94	4:00	59	57	90	1376	125	99	117	9.2	0.11	151	15924	
9/25/94	4:30		57	90	1370	127	99	118	9.1	0.11	151	16075	
9/25/94	5:00	60	56	90	1366	127	99	119	9.0	0.11	151	16226	
9/25/94	5:30		56	90	1365	127	99	118	9.0	0.11	151	16377	
9/25/94	6:00	61	56	90	1361	126	99	118	9.0	0.11	151	16528	
9/25/94	6:30		55	90	1351	126	100	121	9.0	0.11	151	16679	
9/25/94	7:00	62	55	90	1352	126	100	122	9.0	0.11	151	16830	
9/25/94	7:30		55	90	1355	126	100	121	9.0	0.11	151	16981	
9/25/94	8:00	63	55	90	1352	126	101	122	9.0	0.11	151	17132	
9/25/94	8:30		54	90	1355	125	99	123	9.1	0.11	151	17282	
9/25/94	9:00	64	55	90	1350	126	101	121	9.0	0.11	151	17433	
9/25/94	9:30		53	90	1346	125	99	118	9.1	0.11	151	17584	
9/25/94	10:00	65	52	90	1331	125	101	118	9.0	0.10	151	17735	
9/25/94	10:30		50	90	1324	124	98	117	9.0	0.11	151	17886	
9/25/94	11:00	66	52	90	1326	126	101	118	8.9	0.10	151	18037	
9/25/94	11:30		54	90	1354	126	101	121	9.1	0.11	151	18188	
9/25/94	12:00	67	54	90	1358	127	102	120	9.0	0.10	151	18339	
9/25/94	12:30		54	90	1361	126	102	121	9.0	0.11	151	18489	
9/25/94	13:00	68	54	90	1353	127	102	122	9.0	0.10	151	18640	
9/25/94	13:30		51	90	1337	125	101	118	9.0	0.11	151	18791	
9/25/94	14:00	69	50	90	1315	125	101	120	8.9	0.10	151	18942	
9/25/94	14:30		52	90	1335	125	99	117	9.0	0.11	151	19093	
9/25/94	15:00	70	54	90	1343	125	100	120	9.0	0.11	151	19244	
9/25/94	15:30		54	90	1355	125	101	120	9.1	0.11	151	19395	
9/25/94	16:00	71	53	90	1345	125	101	119	9.1	0.11	151	19546	
9/25/94	16:30		54	90	1349	124	101	118	9.1	0.11	151	19697	
9/25/94	17:00	72	55	90	1362	126	101	118	9.1	0.11	151	19847	
9/25/94	17:30		53	90	1345	124	102	121	9.1	0.11	151	19998	
9/25/94	18:00	73	53	90	1354	124	101	119	9.2	0.11	151	20149	
9/25/94	18:30		53	90	1346	124	101	118	9.1	0.11	151	20300	
9/25/94	19:00	74	51	90	1330	124	100	114	9.0	0.11	151	20451	
9/25/94	19:30		51	90	1339	122	100	121	9.2	0.11	151	20602	
9/25/94	20:00	75	52	90	1330	124	102	121	9.0	0.10	151	20753	
9/25/94	20:30		53	90	1336	124	101	120	9.1	0.11	151	20904	
9/25/94	21:00	76	53	90	1351	124	101	120	9.1	0.11	151	21055	
9/25/94	21:30		52	90	1338	124	101	123	9.1	0.11	151	21205	
9/25/94	22:00	77	55	90	1335	125	103	124	9.0	0.10	151	21356	
9/25/94	22:30		55	90	1355	125	102	120	9.1	0.11	151	21507	
9/25/94	23:00	78	55	90	1360	125	101	118	9.1	0.11	151	21658	
9/25/94	23:30		55	90	1367	125	100	120	9.2	0.11	151	21809	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/26/94	0:00	79	54	90	1351	125	101	120	9.1	0.11	151	21960	
9/26/94	0:30		55	90	1351	124	101	120	9.1	0.11	151	22111	
9/26/94	1:00	80	54	90	1353	125	101	121	9.1	0.11	151	22262	
9/26/94	1:30		55	90	1358	125	102	124	9.1	0.11	151	22412	
9/26/94	2:00	81	55	90	1359	125	103	130	9.1	0.11	151	22563	
9/26/94	2:30		56	90	1372	125	104	121	9.2	0.10	151	22714	
9/26/94	3:00	82	56	90	1360	126	103	122	9.1	0.10	151	22865	
9/26/94	3:30		55	90	1362	125	103	123	9.1	0.10	151	23016	
9/26/94	4:00	83	56	90	1371	126	104	121	9.1	0.10	151	23167	
9/26/94	4:30		54	90	1375	123	102	119	9.3	0.11	151	23318	
9/26/94	5:00	84	52	90	1331	124	101	122	9.0	0.10	151	23469	
9/26/94	5:30		52	90	1338	124	103	123	9.1	0.10	151	23620	
9/26/94	6:00	85	54	90	1352	126	105	126	9.0	0.10	151	23770	
9/26/94	6:30		56	90	1365	125	107	127	9.1	0.10	151	23921	
9/26/94	7:00	86	56	90	1366	126	109	128	9.1	0.10	151	24072	
9/26/94	7:30		56	90	1365	126	108	128	9.1	0.10	151	24223	
9/26/94	8:00	87	55	90	1360	126	108	128	9.1	0.10	151	24374	
9/26/94	8:30		54	90	1352	124	106	123	9.1	0.10	151	24525	
9/26/94	9:00	88	54	90	1355	125	106	126	9.1	0.10	151	24676	
9/26/94	9:30		51	90	1331	123	105	127	9.1	0.10	151	24827	
9/26/94	10:00	89	56	90	1360	126	108	125	9.1	0.10	151	24978	
9/26/94	10:30		54	90	1355	124	106	125	9.1	0.10	151	25128	
9/26/94	11:00	90	53	90	1338	125	106	126	9.0	0.10	151	25279	
9/26/94	11:30		53	90	1344	124	106	126	9.1	0.10	151	25430	
9/26/94	12:00	91	53	90	1344	125	107	124	9.0	0.10	151	25581	
9/26/94	12:30		53	90	1346	124	107	124	9.1	0.10	151	25732	
9/26/94	13:00	92	55	90	1361	126	108	124	9.0	0.10	151	25883	
9/26/94	13:30		56	90	1377	126	106	126	9.1	0.10	151	26034	
9/26/94	14:00	93	54	90	1360	126	107	127	9.1	0.10	151	26185	
9/26/94	14:30		53	90	1356	125	106	124	9.1	0.10	151	26336	
9/26/94	15:00	94	54	90	1363	126	106	123	9.1	0.10	151	26486	
9/26/94	15:30		55	90	1365	126	106	126	9.1	0.10	151	26637	
9/26/94	16:00	95	53	90	1353	126	107	125	9.0	0.10	151	26788	
9/26/94	16:30		54	90	1363	126	106	124	9.1	0.10	151	26939	
9/26/94	17:00	96	56	90	1374	127	108	124	9.1	0.10	151	27090	
9/26/94	17:30		54	90	1364	126	106	125	9.1	0.10	151	27241	
9/26/94	18:00	97	53	90	1361	125	106	124	9.1	0.10	151	27392	
9/26/94	18:30		54	90	1369	125	106	123	9.2	0.10	151	27543	
9/26/94	19:00	98	55	90	1368	126	107	124	9.1	0.10	151	27693	
9/26/94	19:30		54	90	1375	125	105	123	9.2	0.10	151	27844	
9/26/94	20:00	99	52	90	1342	125	107	119	9.0	0.10	151	27995	
9/26/94	20:30		52	90	1343	124	106	124	9.1	0.10	151	28146	
9/26/94	21:00	100	53	90	1349	125	107	122	9.1	0.10	151	28297	
9/26/94	21:30		53	90	1355	124	105	121	9.2	0.10	151	28448	
9/26/94	22:00	101	53	90	1355	125	107	132	9.1	0.10	151	28599	
9/26/94	22:30		52	90	1347	123	106	121	9.2	0.10	151	28750	
9/26/94	23:00	102	52	90	1346	124	108	123	9.1	0.10	151	28901	
9/26/94	23:30		53	90	1353	124	106	122	9.1	0.10	151	29051	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/27/94	0:00	103	53	90	1348	124	107	122	9.1	0.10	151	29202	
9/27/94	0:30		52	90	1344	124	107	122	9.1	0.10	151	29353	
9/27/94	1:00	104	53	90	1347	124	106	121	9.1	0.10	151	29504	
9/27/94	1:30		53	90	1352	124	107	126	9.1	0.10	151	29655	
9/27/94	2:00	105	52	90	1346	125	106	123	9.1	0.10	151	29806	
9/27/94	2:30		52	90	1345	124	107	122	9.1	0.10	151	29957	
9/27/94	3:00	106	52	90	1346	124	108	122	9.1	0.10	151	30108	
9/27/94	3:30		51	90	1344	123	106	122	9.2	0.10	151	30259	
9/27/94	4:00	107	52	90	1345	124	107	121	9.1	0.10	151	30409	
9/27/94	4:30		53	90	1348	124	107	124	9.1	0.10	151	30560	
9/27/94	5:00	108	52	90	1350	125	108	123	9.1	0.10	151	30711	
9/27/94	5:30		53	90	1359	124	108	124	9.2	0.10	151	30862	
9/27/94	6:00	109	53	90	1349	125	108	126	9.1	0.10	151	31013	
9/27/94	6:30		53	90	1347	125	108	124	9.1	0.10	151	31164	
9/27/94	7:00	110	54	90	1360	125	108	123	9.1	0.10	151	31315	
9/27/94	7:30		55	90	1367	126	109	125	9.1	0.10	151	31466	
9/27/94	8:00	111	54	90	1360	125	108	127	9.1	0.10	151	31616	
9/27/94	8:30		53	90	1353	125	108	123	9.1	0.10	151	31767	
9/27/94	9:00	112	52	90	1352	125	107	124	9.1	0.10	151	31918	
9/27/94	9:30		51	90	1340	124	107	123	9.1	0.10	151	32069	
9/27/94	10:00	113	52	90	1338	125	113	124	9.0	0.09	151	32220	
9/27/94	10:30		52	90	1347	125	117	130	9.1	0.09	151	32371	
9/27/94	11:00	114	51	90	1342	124	121	135	9.1	0.09	151	32522	
9/27/94	11:30		53	90	1354	126	124	139	9.0	0.08	151	32673	
9/27/94	12:00	115	55	90	1376	127	127	139	9.1	0.08	151	32824	
9/27/94	12:30		52	90	1345	125	127	141	9.0	0.08	151	32974	
9/27/94	13:00	116	54	90	1351	126	129	145	9.0	0.08	151	33125	
9/27/94	13:30		54	90	1350	126	130	145	9.0	0.08	151	33276	
9/27/94	14:00	117	52	90	1342	125	108	142	9.0	0.10	151	33427	
9/27/94	14:30		51	90	1330	125	111	127	9.0	0.09	151	33578	
9/27/94	15:00	118	52	90	1334	125	105	129	9.0	0.10	151	33729	
9/27/94	15:30		53	90	1343	126	106	126	9.0	0.10	151	33880	
9/27/94	16:00	119	52	90	1342	126	106	126	9.0	0.10	151	34031	
9/27/94	16:30		55	90	1359	127	106	128	9.0	0.10	151	34182	
9/27/94	17:00	120	53	90	1342	126	107	125	9.0	0.10	151	34332	
9/27/94	17:30		54	90	1356	126	107	127	9.1	0.10	151	34483	
9/27/94	18:00	121	56	90	1371	127	108	124	9.0	0.10	151	34634	
9/27/94	18:30		54	90	1362	127	107	129	9.0	0.10	151	34785	
9/27/94	19:00	122	55	90	1362	127	108	127	9.0	0.10	151	34936	
9/27/94	19:30		53	90	1345	126	108	125	9.0	0.10	151	35087	
9/27/94	20:00	123	54	90	1352	126	108	127	9.0	0.10	151	35238	
9/27/94	20:30		53	90	1348	126	106	124	9.0	0.10	151	35389	
9/27/94	21:00	124	54	90	1346	126	107	125	9.0	0.10	151	35539	
9/27/94	21:30		52	90	1345	124	106	125	9.1	0.10	151	35690	
9/27/94	22:00	125	54	90	1353	125	107	122	9.1	0.10	151	35841	
9/27/94	22:30		53	90	1348	125	108	124	9.0	0.10	151	35992	
9/27/94	23:00	126	53	90	1345	126	108	125	9.0	0.10	151	36143	
9/27/94	23:30		52	90	1345	126	109	126	9.0	0.10	151	36294	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/28/94	0:00	127	53	90	1343	126	109	123	9.0	0.10	151	36445	
9/28/94	0:30		54	90	1348	127	109	123	9.0	0.10	151	36596	
9/28/94	1:00	128	53	90	1346	126	109	126	9.0	0.10	151	36747	
9/28/94	1:30		53	90	1345	126	110	127	9.0	0.10	151	36897	
9/28/94	2:00	129	53	90	1345	125	109	124	9.1	0.10	151	37048	
9/28/94	2:30		52	90	1347	125	109	124	9.1	0.10	151	37199	
9/28/94	3:00	130	53	90	1351	125	110	126	9.1	0.10	151	37350	
9/28/94	3:30		53	90	1358	125	111	126	9.1	0.10	151	37501	
9/28/94	4:00	131	53	90	1351	125	111	125	9.1	0.10	151	37652	
9/28/94	4:30		54	90	1345	125	110	125	9.0	0.10	151	37803	
9/28/94	5:00	132	53	90	1343	125	109	126	9.0	0.10	151	37954	
9/28/94	5:30		53	90	1350	125	111	126	9.1	0.10	151	38105	
9/28/94	6:00	133	53	90	1351	125	110	125	9.1	0.10	151	38255	
9/28/94	6:30		54	90	1355	125	110	127	9.1	0.10	151	38406	
9/28/94	7:00	134	53	90	1350	125	110	126	9.1	0.10	151	38557	
9/28/94	7:30		54	90	1348	125	110	123	9.1	0.10	151	38708	
9/28/94	8:00	135	54	90	1352	124	110	124	9.2	0.10	151	38859	
9/28/94	8:30		51	90	1336	124	110	125	9.1	0.10	151	39010	
9/28/94	9:00	136	52	90	1331	123	110	126	9.1	0.10	151	39161	
9/28/94	9:30		52	90	1344	125	111	127	9.1	0.10	151	39312	
9/28/94	10:00	137	53	90	1364	126	110	126	9.1	0.10	151	39462	
9/28/94	10:30		55	90	1381	128	113	129	9.0	0.09	151	39613	
9/28/94	11:00	138	55	90	1384	127	113	130	9.1	0.09	151	39764	
9/28/94	11:30		56	90	1393	128	114	130	9.1	0.09	151	39915	
9/28/94	12:00	139	55	90	1388	127	115	131	9.1	0.09	151	40066	
9/28/94	12:30		0	0	0	0			0.0	ERR	0	40066	* Data acquistion problem from 12:15 to 12:32.
9/28/94	13:00	140	55	90	1382	128	115	134	9.1	0.09	151	40217	
9/28/94	13:30		55	90	1377	127	115	131	9.1	0.09	151	40368	
9/28/94	14:00	141	55	90	1392	128	115	131	9.1	0.09	151	40519	
9/28/94	14:30		56	90	1397	128	115	130	9.1	0.09	151	40670	
9/28/94	15:00	142	56	90	1397	129	116	132	9.1	0.09	151	40820	
9/28/94	15:30		56	90	1394	128	116	132	9.1	0.09	151	40971	
9/28/94	16:00	143	55	90	1392	128	115	131	9.1	0.09	151	41122	
9/28/94	16:30		55	90	1396	127	115	129	9.2	0.09	151	41273	
9/28/94	17:00	144	54	90	1397	127	116	131	9.1	0.09	151	41424	
9/28/94	17:30		55	90	1386	127	115	130	9.1	0.09	151	41575	
9/28/94	18:00	145	55	90	1384	128	115	129	9.1	0.09	151	41726	
9/28/94	18:30		55	90	1382	127	115	129	9.1	0.09	151	41877	
9/28/94	19:00	146	55	90	1378	128	116	131	9.0	0.09	151	42028	
9/28/94	19:30		54	90	1377	127	116	132	9.1	0.09	151	42178	
9/28/94	20:00	147	55	90	1383	128	116	131	9.0	0.09	151	42329	
9/28/94	20:30		55	90	1394	128	117	132	9.1	0.09	151	42480	
9/28/94	21:00	148	55	90	1386	128	118	132	9.0	0.09	151	42631	
9/28/94	21:30		54	90	1386	127	117	132	9.1	0.09	151	42782	
9/28/94	22:00	149	54	90	1384	128	115	131	9.1	0.09	151	42933	
9/28/94	22:30		55	90	1391	127	116	130	9.2	0.09	151	43084	
9/28/94	23:00	150	55	90	1385	128	116	131	9.1	0.09	151	43235	
9/28/94	23:30		54	90	1382	127	115	130	9.1	0.09	151	43386	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/29/94	0:00	151	51	90	1355	127	113	137	9.0	0.09	151	43536	
9/29/94	0:30		53	90	1363	127	113	137	9.0	0.09	151	43687	
9/29/94	1:00	152	54	90	1367	128	114	130	9.0	0.09	151	43838	
9/29/94	1:30		55	90	1374	127	114	130	9.0	0.09	151	43989	
9/29/94	2:00	153	55	90	1382	128	116	131	9.0	0.09	151	44140	
9/29/94	2:30		55	90	1382	126	116	130	9.1	0.09	151	44291	
9/29/94	3:00	154	56	90	1387	128	114	131	9.1	0.09	151	44442	
9/29/94	3:30		55	90	1390	127	115	130	9.1	0.09	151	44593	
9/29/94	4:00	155	56	90	1385	128	114	129	9.1	0.09	151	44743	
9/29/94	4:30		55	90	1385	127	115	129	9.1	0.09	151	44894	
9/29/94	5:00	156	56	90	1386	128	114	130	9.1	0.09	151	45045	
9/29/94	5:30		56	90	1379	127	114	129	9.1	0.09	151	45196	
9/29/94	6:00	157	56	90	1370	128	115	128	9.0	0.09	151	45347	
9/29/94	6:30		56	90	1370	127	115	129	9.0	0.09	151	45498	
9/29/94	7:00	158	56	90	1376	128	116	132	9.0	0.09	151	45649	
9/29/94	7:30		56	90	1369	127	114	130	9.0	0.09	151	45800	
9/29/94	8:00	159	57	90	1374	128	115	130	9.0	0.09	151	45951	
9/29/94	8:30		56	90	1373	128	116	131	9.0	0.09	151	46101	
9/29/94	9:00	160	56	90	1374	127	116	131	9.0	0.09	151	46252	
9/29/94	9:30		55	90	1364	128	115	133	9.0	0.09	151	46403	
9/29/94	10:00	161	56	90	1366	128	114	131	9.0	0.09	151	46554	
9/29/94	10:30		56	90	1367	128	115	131	9.0	0.09	151	46705	
9/29/94	11:00	162	56	90	1366	127	115	129	9.0	0.09	151	46856	
9/29/94	11:30		56	90	1369	128	114	131	9.0	0.09	151	47007	
9/29/94	12:00	163	56	90	1363	127	114	130	9.0	0.09	151	47158	
9/29/94	12:30		57	90	1364	129	116	129	8.9	0.09	151	47309	
9/29/94	13:00	164	56	90	1360	127	116	132	9.0	0.09	151	47459	
9/29/94	13:30		56	90	1365	128	115	134	9.0	0.09	151	47610	
9/29/94	14:00	165	56	90	1364	128	115	132	9.0	0.09	151	47761	
9/29/94	14:30		57	90	1377	128	117	141	9.0	0.09	151	47912	
9/29/94	15:00	166	57	90	1369	128	116	133	9.0	0.09	151	48063	
9/29/94	15:30		58	90	1368	129	117	138	8.9	0.09	151	48214	
9/29/94	16:00	167	57	90	1368	128	117	135	9.0	0.09	151	48365	
9/29/94	16:30		57	90	1368	129	119	136	8.9	0.09	151	48516	
9/29/94	17:00	168	57	90	1368	128	118	135	9.0	0.09	151	48666	
9/29/94	17:30		57	90	1366	128	119	136	8.9	0.09	151	48817	
9/29/94	18:00	169	57	90	1367	128	117	134	8.9	0.09	151	48968	
9/29/94	18:30		59	90	1367	128	118	134	8.9	0.09	151	49119	
9/29/94	19:00	170	59	90	1368	129	118	135	8.9	0.09	151	49270	
9/29/94	19:30		59	90	1370	129	119	135	8.9	0.09	151	49421	
9/29/94	20:00	171	59	90	1372	129	119	138	8.9	0.09	151	49572	
9/29/94	20:30		58	90	1367	128	120	137	8.9	0.09	151	49723	
9/29/94	21:00	172	58	90	1368	128	119	136	9.0	0.09	151	49874	
9/29/94	21:30		58	90	1367	128	117	137	9.0	0.09	151	50024	
9/29/94	22:00	173	58	90	1363	128	119	136	8.9	0.09	151	50175	
9/29/94	22:30		58	90	1356	128	119	133	8.9	0.09	151	50326	
9/29/94	23:00	174	58	90	1368	128	118	134	9.0	0.09	151	50477	
9/29/94	23:30		59	90	1364	128	117	135	8.9	0.09	151	50628	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
9/30/94	0:00	175	57	90	1367	128	119	133	9.0	0.09	151	50779	
9/30/94	0:30		58	90	1366	128	119	133	9.0	0.09	151	50930	
9/30/94	1:00	176	59	90	1357	128	119	134	8.9	0.09	151	51081	
9/30/94	1:30		59	90	1355	128	119	134	8.9	0.09	151	51232	
9/30/94	2:00	177	58	90	1360	128	120	137	8.9	0.09	151	51382	
9/30/94	2:30		59	90	1363	128	119	136	8.9	0.09	151	51533	
9/30/94	3:00	178	59	90	1363	128	120	136	8.9	0.09	151	51684	
9/30/94	3:30		57	90	1361	128	120	136	8.9	0.09	151	51835	
9/30/94	4:00	179	59	90	1363	128	119	137	8.9	0.09	151	51986	
9/30/94	4:30		58	90	1363	130	122	145	8.8	0.08	151	52137	
9/30/94	5:00	180	59	95	1365	131	122	139	9.3	0.09	159	52296	
9/30/94	5:30		59	90	1373	130	121	141	8.9	0.09	151	52447	
9/30/94	6:00	181	59	90	1364	128	122	139	9.0	0.08	151	52598	
9/30/94	6:30		58	90	1359	128	123	139	9.0	0.08	151	52749	
9/30/94	7:00	182	59	90	1363	128	122	139	9.0	0.08	151	52900	
9/30/94	7:30		59	90	1374	130	125	139	8.9	0.08	151	53051	
9/30/94	8:00	183	58	90	1362	128	122	141	8.9	0.09	151	53201	
9/30/94	8:30		59	90	1359	130	121	139	8.8	0.08	151	53352	
9/30/94	9:00	184	60	95	1359	131	124	140	9.3	0.09	159	53512	
9/30/94	9:30		60	95	1366	131	125	141	9.3	0.09	159	53671	
9/30/94	10:00	185	58	95	1361	131	122	142	9.3	0.09	159	53830	
9/30/94	10:30		57	90	1354	130	124	144	8.8	0.08	151	53981	
9/30/94	11:00	186	60	95	1359	131	125	140	9.2	0.09	159	54140	
9/30/94	11:30		59	95	1361	130	123	140	9.3	0.09	159	54300	
9/30/94	12:00	187	59	95	1365	131	124	143	9.3	0.09	159	54459	
9/30/94	12:30		58	90	1363	129	124	146	8.9	0.08	151	54610	
9/30/94	13:00	188	57	90	1360	129	125	141	8.8	0.08	151	54761	
9/30/94	13:30		58	95	1356	131	125	141	9.2	0.09	159	54920	
9/30/94	14:00	189	59	95	1364	131	126	142	9.3	0.09	159	55079	
9/30/94	14:30		59	95	1361	131	125	142	9.2	0.09	159	55238	
9/30/94	15:00	190	59	90	1355	130	125	142	8.8	0.08	151	55389	
9/30/94	15:30		58	95	1358	131	125	143	9.3	0.09	159	55549	
9/30/94	16:00	191	58	90	1355	130	125	146	8.8	0.08	151	55699	
9/30/94	16:30		57	95	1353	130	126	141	9.3	0.09	159	55859	
9/30/94	17:00	192	57	90	1346	129	124	142	8.8	0.08	151	56010	
9/30/94	17:30		58	90	1356	130	126	142	8.8	0.08	151	56160	
9/30/94	18:00	193	59	90	1365	129	123	143	8.9	0.08	151	56311	
9/30/94	18:30		59	90	1358	130	125	142	8.8	0.08	151	56462	
9/30/94	19:00	194	58	90	1357	128	124	141	8.9	0.08	151	56613	
9/30/94	19:30		58	90	1350	130	125	146	8.8	0.08	151	56764	
9/30/94	20:00	195	59	90	1363	129	124	146	8.9	0.08	151	56915	
9/30/94	20:30		58	90	1361	130	125	143	8.8	0.08	151	57066	
9/30/94	21:00	196	59	90	1358	129	125	140	8.9	0.08	151	57217	
9/30/94	21:30		60	95	1362	131	127	142	9.3	0.09	159	57376	
9/30/94	22:00	197	61	90	1380	129	126	144	9.0	0.08	151	57527	
9/30/94	22:30		59	90	1356	130	125	145	8.8	0.08	151	57678	
9/30/94	23:00	198	58	90	1354	129	125	143	8.9	0.08	151	57829	
9/30/94	23:30		59	90	1353	130	125	142	8.8	0.08	151	57979	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/01/94	0:00	199	59	90	1357	129	126	144	8.9	0.08	151	58130	
10/01/94	0:30		60	90	1363	130	126	144	8.8	0.08	151	58281	
10/01/94	1:00	200	58	90	1357	129	127	143	8.9	0.08	151	58432	
10/01/94	1:30		59	95	1355	130	127	144	9.3	0.08	159	58591	
10/01/94	2:00	201	59	90	1350	129	127	148	8.8	0.08	151	58742	
10/01/94	2:30		59	95	1356	130	128	150	9.3	0.08	159	58902	
10/01/94	3:00	202	58	90	1356	129	127	144	8.9	0.08	151	59052	
10/01/94	3:30		59	90	1351	130	127	144	8.8	0.08	151	59203	
10/01/94	4:00	203	58	90	1355	129	126	143	8.9	0.08	151	59354	
10/01/94	4:30		59	90	1354	130	128	152	8.8	0.08	151	59505	
10/01/94	5:00	204	58	90	1347	128	126	144	8.9	0.08	151	59656	
10/01/94	5:30		58	90	1349	129	127	144	8.8	0.08	151	59807	
10/01/94	6:00	205	57	90	1341	128	126	143	8.8	0.08	151	59958	
10/01/94	6:30		57	90	1345	129	127	145	8.8	0.08	151	60109	
10/01/94	7:00	206	56	90	1342	128	127	147	8.9	0.08	151	60259	
10/01/94	7:30		59	90	1342	130	126	144	8.8	0.08	151	60410	
10/01/94	8:00	207	57	90	1346	128	126	142	8.9	0.08	151	60561	
10/01/94	8:30		58	90	1349	130	127	143	8.8	0.08	151	60712	
10/01/94	9:00	208	58	90	1347	129	127	143	8.8	0.08	151	60863	
10/01/94	9:30		58	90	1354	130	128	144	8.8	0.08	151	61014	
10/01/94	10:00	209	58	90	1350	129	127	144	8.8	0.08	151	61165	
10/01/94	10:30		58	90	1352	130	129	145	8.8	0.08	151	61316	
10/01/94	11:00	210	58	90	1350	129	129	145	8.8	0.08	151	61467	
10/01/94	11:30		56	90	1344	128	127	145	8.8	0.08	151	61617	
10/01/94	12:00	211	56	90	1340	128	126	145	8.9	0.08	151	61768	
10/01/94	12:30		56	90	1326	128	125	146	8.8	0.08	151	61919	
10/01/94	13:00	212	54	90	1322	126	126	142	8.9	0.08	151	62070	
10/01/94	13:30		55	90	1318	127	126	143	8.8	0.08	151	62221	
10/01/94	14:00	213	54	90	1318	126	124	142	8.9	0.08	151	62372	
10/01/94	14:30		54	90	1319	126	126	143	8.9	0.08	151	62523	
10/01/94	15:00	214	54	90	1313	125	127	144	8.9	0.08	151	62674	
10/01/94	15:30		53	90	1308	126	126	143	8.8	0.08	151	62825	
10/01/94	16:00	215	55	90	1307	126	126	146	8.8	0.08	151	62975	
10/01/94	16:30		56	90	1318	128	128	145	8.7	0.08	151	63126	
10/01/94	17:00	216	56	90	1319	128	128	145	8.7	0.08	151	63277	
10/01/94	17:30		56	90	1325	129	128	146	8.7	0.08	151	63428	
10/01/94	18:00	217	56	90	1325	128	127	145	8.8	0.08	151	63579	
10/01/94	18:30		56	90	1325	128	127	149	8.8	0.08	151	63730	
10/01/94	19:00	218	57	90	1326	128	128	149	8.8	0.08	151	63881	
10/01/94	19:30		59	90	1344	130	129	147	8.7	0.08	151	64032	
10/01/94	20:00	219	59	90	1353	129	129	147	8.8	0.08	151	64182	
10/01/94	20:30		58	90	1352	129	130	146	8.8	0.08	151	64333	
10/01/94	21:00	220	58	90	1344	128	129	145	8.8	0.08	151	64484	
10/01/94	21:30		60	95	1363	130	132	154	9.3	0.08	159	64644	
10/01/94	22:00	221	59	90	1367	130	131	153	8.9	0.08	151	64794	
10/01/94	22:30		59	90	1365	129	131	148	8.9	0.08	151	64945	
10/01/94	23:00	222	60	90	1360	129	129	148	8.8	0.08	151	65096	
10/01/94	23:30		59	90	1337	130	130	146	8.7	0.08	151	65247	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/02/94	0:00	223	60	95	1348	130	131	154	9.2	0.08	159	65406	
10/02/94	0:30		58	90	1355	130	131	154	8.8	0.08	151	65557	
10/02/94	1:00	224	58	90	1335	129	131	147	8.8	0.08	151	65708	
10/02/94	1:30		59	95	1347	131	133	148	9.2	0.08	159	65867	
10/02/94	2:00	225	59	90	1366	129	130	147	8.9	0.08	151	66018	
10/02/94	2:30		57	90	1333	129	131	145	8.7	0.08	151	66169	
10/02/94	3:00	226	57	90	1336	129	130	146	8.8	0.08	151	66320	
10/02/94	3:30		58	95	1338	130	131	148	9.2	0.08	159	66479	
10/02/94	4:00	227	58	90	1347	130	132	153	8.8	0.08	151	66630	
10/02/94	4:30		59	95	1349	131	132	154	9.2	0.08	159	66789	
10/02/94	5:00	228	58	90	1353	130	131	148	8.8	0.08	151	66940	
10/02/94	5:30		58	95	1346	130	130	147	9.2	0.08	159	67100	
10/02/94	6:00	229	59	90	1358	130	130	147	8.8	0.08	151	67250	
10/02/94	6:30		59	95	1359	131	132	147	9.2	0.08	159	67410	
10/02/94	7:00	230	56	90	1349	129	128	146	8.8	0.08	151	67561	
10/02/94	7:30		54	90	1328	128	128	145	8.7	0.08	151	67712	
10/02/94	8:00	231	52	90	1312	127	128	143	8.8	0.08	151	67862	
10/02/94	8:30		52	90	1304	128	126	143	8.7	0.08	151	68013	
10/02/94	9:00	232	51	90	1299	127	127	143	8.7	0.08	151	68164	
10/02/94	9:30		51	90	1298	128	127	142	8.7	0.08	151	68315	
10/02/94	10:00	233	50	90	1298	127	127	143	8.7	0.08	151	68466	
10/02/94	10:30		50	90	1300	128	127	142	8.6	0.08	151	68617	
10/02/94	11:00	234	51	90	1300	127	126	142	8.7	0.08	151	68768	
10/02/94	11:30		51	90	1298	128	128	143	8.7	0.08	151	68919	
10/02/94	12:00	235	51	90	1304	128	127	142	8.7	0.08	151	69069	
10/02/94	12:30		51	90	1302	128	127	148	8.6	0.08	151	69220	
10/02/94	13:00	236	50	90	1295	127	126	141	8.7	0.08	151	69371	
10/02/94	13:30		49	90	1296	127	126	142	8.6	0.08	151	69522	
10/02/94	14:00	237	50	90	1290	127	126	145	8.7	0.08	151	69673	
10/02/94	14:30		49	90	1292	128	126	142	8.6	0.08	151	69824	
10/02/94	15:00	238	51	90	1298	127	127	141	8.7	0.08	151	69975	
10/02/94	15:30		53	90	1312	129	129	143	8.6	0.08	151	70126	
10/02/94	16:00	239	54	90	1328	129	128	143	8.7	0.08	151	70277	
10/02/94	16:30		55	90	1323	130	129	142	8.6	0.08	151	70427	
10/02/94	17:00	240	54	90	1324	129	128	144	8.7	0.08	151	70578	
10/02/94	17:30		54	90	1316	130	129	144	8.6	0.08	151	70729	
10/02/94	18:00	241	53	90	1320	129	128	143	8.7	0.08	151	70880	
10/02/94	18:30		55	90	1322	130	128	149	8.6	0.08	151	71031	
10/02/94	19:00	242	56	90	1332	130	130	148	8.7	0.08	151	71182	
10/02/94	19:30		56	95	1338	130	132	150	9.2	0.08	159	71341	
10/02/94	20:00	243	57	90	1348	129	132	146	8.8	0.08	151	71492	
10/02/94	20:30		57	95	1355	131	134	148	9.2	0.08	159	71651	
10/02/94	21:00	244	57	95	1363	130	132	146	9.3	0.08	159	71811	
10/02/94	21:30		58	95	1363	131	133	146	9.3	0.08	159	71970	
10/02/94	22:00	245	57	90	1356	130	132	146	8.8	0.08	151	72121	
10/02/94	22:30		58	95	1355	130	133	146	9.3	0.08	159	72280	
10/02/94	23:00	246	57	90	1351	129	133	146	8.8	0.08	151	72431	
10/02/94	23:30		58	95	1351	130	134	149	9.2	0.08	159	72590	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/03/94	0:00	247	58	90	1353	130	134	148	8.8	0.07	151	72741	
10/03/94	0:30		57	95	1355	130	134	148	9.3	0.08	159	72900	
10/03/94	1:00	248	57	90	1352	129	133	147	8.8	0.08	151	73051	
10/03/94	1:30		58	95	1356	131	135	153	9.2	0.08	159	73210	
10/03/94	2:00	249	57	90	1354	129	133	148	8.8	0.08	151	73361	
10/03/94	2:30		58	95	1363	131	135	147	9.3	0.08	159	73521	
10/03/94	3:00	250	57	90	1359	129	134	147	8.9	0.08	151	73671	
10/03/94	3:30		57	95	1354	130	134	148	9.3	0.08	159	73831	
10/03/94	4:00	251	56	90	1355	129	134	152	8.8	0.08	151	73982	
10/03/94	4:30		57	95	1355	130	135	148	9.3	0.08	159	74141	
10/03/94	5:00	252	57	90	1365	130	135	154	8.8	0.07	151	74292	
10/03/94	5:30		58	95	1366	131	136	149	9.2	0.08	159	74451	
10/03/94	6:00	253	57	90	1365	130	135	147	8.9	0.08	151	74602	
10/03/94	6:30		56	95	1353	130	136	149	9.3	0.08	159	74761	
10/03/94	7:00	254	55	90	1352	128	133	146	8.9	0.08	151	74912	
10/03/94	7:30		57	95	1359	130	135	153	9.3	0.08	159	75071	
10/03/94	8:00	255	57	90	1364	129	136	148	8.9	0.07	151	75222	
10/03/94	8:30		57	95	1368	130	136	149	9.3	0.08	159	75382	
10/03/94	9:00	256	56	90	1363	129	135	149	8.9	0.08	151	75532	
10/03/94	9:30		56	90	1353	129	134	145	8.8	0.08	151	75683	
10/03/94	10:00	257	56	90	1358	129	135	149	8.9	0.08	151	75834	
10/03/94	10:30		57	95	1370	130	136	149	9.3	0.08	159	75993	
10/03/94	11:00	258	54	90	1366	127	132	145	9.0	0.08	151	76144	
10/03/94	11:30		56	90	1369	129	135	147	8.9	0.08	151	76295	
10/03/94	12:00	259	55	90	1368	128	133	146	9.0	0.08	151	76446	
10/03/94	12:30		56	90	1361	129	134	146	8.9	0.08	151	76597	
10/03/94	13:00	260	55	90	1353	128	134	146	8.9	0.08	151	76748	
10/03/94	13:30		55	90	1353	129	135	146	8.8	0.07	151	76899	
10/03/94	14:00	261	54	90	1344	128	135	148	8.9	0.07	151	77050	
10/03/94	14:30		55	90	1345	129	133	146	8.8	0.08	151	77201	
10/03/94	15:00	262	56	90	1351	129	135	147	8.8	0.07	151	77351	
10/03/94	15:30		57	95	1362	130	137	151	9.3	0.08	159	77511	
10/03/94	16:00	263	57	90	1374	130	135	148	8.9	0.08	151	77662	
10/03/94	16:30		56	95	1362	130	135	148	9.3	0.08	159	77821	
10/03/94	17:00	264	55	90	1353	129	136	148	8.8	0.07	151	77972	
10/03/94	17:30		56	90	1361	130	135	148	8.8	0.07	151	78123	
10/03/94	18:00	265	55	90	1357	129	135	148	8.9	0.07	151	78273	
10/03/94	18:30		56	95	1354	130	136	150	9.3	0.08	159	78433	
10/03/94	19:00	266	56	90	1359	129	136	149	8.8	0.07	151	78584	
10/03/94	19:30		57	95	1354	130	138	150	9.3	0.08	159	78743	
10/03/94	20:00	267	57	90	1366	129	137	152	8.9	0.07	151	78894	
10/03/94	20:30		57	95	1375	131	136	150	9.3	0.08	159	79053	
10/03/94	21:00	268	56	90	1372	129	137	151	8.9	0.07	151	79204	
10/03/94	21:30		57	90	1368	129	137	152	8.9	0.07	151	79355	
10/03/94	22:00	269	57	95	1372	130	138	152	9.4	0.08	159	79514	
10/03/94	22:30		56	90	1373	129	138	152	8.9	0.07	151	79665	
10/03/94	23:00	270	57	90	1372	129	137	152	8.9	0.07	151	79816	
10/03/94	23:30		57	95	1373	130	138	157	9.3	0.08	159	79975	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/04/94	0:00	271	57	90	1374	130	139	154	8.9	0.07	151	80126	
10/04/94	0:30		58	95	1380	131	139	154	9.3	0.08	159	80285	
10/04/94	1:00	272	58	90	1383	130	140	152	8.9	0.07	151	80436	
10/04/94	1:30		58	95	1383	131	139	153	9.4	0.08	159	80595	
10/04/94	2:00	273	57	90	1364	129	140	152	8.9	0.07	151	80746	
10/04/94	2:30		57	95	1371	131	140	152	9.3	0.08	159	80906	
10/04/94	3:00	274	57	90	1380	130	140	150	8.9	0.07	151	81056	
10/04/94	3:30		58	90	1388	130	138	152	8.9	0.07	151	81207	
10/04/94	4:00	275	58	95	1394	130	139	151	9.5	0.08	159	81367	
10/04/94	4:30		57	90	1379	129	140	156	9.0	0.07	151	81517	
10/04/94	5:00	276	56	90	1377	129	140	150	8.9	0.07	151	81668	
10/04/94	5:30		55	90	1347	129	138	150	8.8	0.07	151	81819	
10/04/94	6:00	277	56	90	1356	129	138	150	8.9	0.07	151	81970	
10/04/94	6:30		56	90	1363	130	138	151	8.8	0.07	151	82121	
10/04/94	7:00	278	56	90	1361	129	138	151	8.9	0.07	151	82272	
10/04/94	7:30		57	95	1364	130	138	150	9.3	0.08	159	82431	
10/04/94	8:00	279	57	95	1362	130	139	150	9.3	0.08	159	82590	
10/04/94	8:30		56	90	1363	130	139	150	8.9	0.07	151	82741	
10/04/94	9:00	280	56	90	1371	130	137	152	8.9	0.07	151	82892	
10/04/94	9:30		57	95	1374	131	136	156	9.3	0.08	159	83051	
10/04/94	10:00	281	58	95	1385	131	139	153	9.4	0.08	159	83211	
10/04/94	10:30		57	95	1379	130	141	151	9.4	0.08	159	83370	
10/04/94	11:00	282	57	95	1371	130	139	153	9.3	0.08	159	83529	
10/04/94	11:30		57	95	1377	131	141	153	9.4	0.08	159	83689	
10/04/94	12:00	283	55	90	1382	129	140	154	9.0	0.07	151	83839	
10/04/94	12:30		58	95	1402	132	142	154	9.4	0.08	159	83999	
10/04/94	13:00	284	58	95	1411	132	143	157	9.5	0.08	159	84158	
10/04/94	13:30		59	95	1415	137	146	160	9.2	0.07	159	84317	
10/04/94	14:00	285	59	95	1411	137	146	157	9.1	0.07	159	84477	
10/04/94	14:30		60	95	1420	138	146	157	9.1	0.07	159	84636	
10/04/94	15:00	286	60	95	1433	139	147	159	9.1	0.07	159	84795	
10/04/94	15:30		63	102	1445	140	149	156	9.8	0.08	171	84966	
10/04/94	16:00	287	62	95	1443	140	150	157	9.1	0.07	159	85125	
10/04/94	16:30		63	102	1448	140	150	157	9.8	0.08	171	85296	
10/04/94	17:00	288	61	95	1442	137	148	157	9.3	0.07	159	85456	
10/04/94	17:30		62	95	1438	140	149	161	9.1	0.07	159	85615	
10/04/94	18:00	289	62	95	1439	140	150	161	9.1	0.07	159	85774	
10/04/94	18:30		64	102	1469	141	151	162	9.8	0.08	171	85945	
10/04/94	19:00	290	61	95	1435	139	149	158	9.1	0.07	159	86104	
10/04/94	19:30		62	95	1433	139	151	168	9.1	0.07	159	86264	
10/04/94	20:00	291	61	95	1427	139	152	166	9.1	0.07	159	86423	
10/04/94	20:30		62	95	1432	140	152	168	9.1	0.07	159	86582	
10/04/94	21:00	292	62	95	1439	138	151	167	9.2	0.07	159	86741	
10/04/94	21:30		61	95	1431	138	151	167	9.1	0.07	159	86901	
10/04/94	22:00	293	61	95	1436	139	152	167	9.1	0.07	159	87060	
10/04/94	22:30		61	95	1428	138	151	166	9.1	0.07	159	87219	
10/04/94	23:00	294	61	95	1426	139	151	164	9.1	0.07	159	87379	
10/04/94	23:30		61	95	1426	139	151	167	9.0	0.07	159	87538	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/05/94	0:00	295	61	95	1430	138	152	166	9.1	0.07	159	87697	
10/05/94	0:30		61	95	1430	139	152	166	9.1	0.07	159	87856	
10/05/94	1:00	296	62	95	1429	138	154	166	9.1	0.07	159	88016	
10/05/94	1:30		63	95	1439	140	156	166	9.1	0.07	159	88175	
10/05/94	2:00	297	62	95	1442	140	155	171	9.1	0.07	159	88334	
10/05/94	2:30		61	95	1431	139	154	167	9.1	0.07	159	88493	
10/05/94	3:00	298	61	95	1429	139	154	168	9.1	0.07	159	88653	
10/05/94	3:30		63	95	1431	139	154	171	9.1	0.07	159	88812	
10/05/94	4:00	299	61	95	1428	138	154	167	9.1	0.07	159	88971	
10/05/94	4:30		62	102	1436	141	155	169	9.6	0.07	171	89142	
10/05/94	5:00	300	63	102	1433	142	157	168	9.6	0.07	171	89313	* Beginning of a mix of Plum Run Greenfield and Peebles dolomite sorbent (#20 mesh).
10/05/94	5:30		63	102	1441	143	158	172	9.6	0.07	171	89484	
10/05/94	6:00	301	63	102	1448	143	159	171	9.6	0.07	171	89655	
10/05/94	6:30		65	102	1454	143	156	171	9.6	0.07	171	89826	
10/05/94	7:00	302	64	102	1453	142	154	173	9.7	0.07	171	89997	
10/05/94	7:30		63	102	1447	141	155	170	9.7	0.07	171	90168	
10/05/94	8:00	303	63	102	1438	141	155	170	9.7	0.07	171	90339	
10/05/94	8:30		61	95	1418	137	151	166	9.1	0.07	159	90499	
10/05/94	9:00	304	61	95	1408	136	150	167	9.2	0.07	159	90658	
10/05/94	9:30		60	95	1409	134	147	166	9.3	0.07	159	90817	
10/05/94	10:00	305	58	95	1388	130	146	158	9.4	0.07	159	90976	
10/05/94	10:30		59	95	1384	131	146	159	9.3	0.07	159	91136	
10/05/94	11:00	306	58	95	1383	131	146	160	9.3	0.07	159	91295	
10/05/94	11:30		58	95	1377	131	146	159	9.3	0.07	159	91454	
10/05/94	12:00	307	58	95	1367	130	146	160	9.3	0.07	159	91613	
10/05/94	12:30		59	95	1371	131	146	160	9.3	0.07	159	91773	
10/05/94	13:00	308	58	95	1364	131	147	161	9.3	0.07	159	91932	
10/05/94	13:30		57	90	1362	130	146	159	8.8	0.07	151	92083	
10/05/94	14:00	309	57	90	1351	130	147	162	8.8	0.07	151	92234	
10/05/94	14:30		58	95	1360	130	147	161	9.3	0.07	159	92393	
10/05/94	15:00	310	57	90	1362	130	147	160	8.8	0.07	151	92544	
10/05/94	15:30		58	95	1357	130	145	161	9.3	0.07	159	92703	
10/05/94	16:00	311	59	95	1364	130	148	161	9.3	0.07	159	92862	
10/05/94	16:30		59	95	1356	131	147	167	9.2	0.07	159	93022	
10/05/94	17:00	312	59	95	1359	130	148	166	9.3	0.07	159	93181	
10/05/94	17:30		58	95	1357	130	148	166	9.3	0.07	159	93340	
10/05/94	18:00	313	59	95	1371	131	149	168	9.3	0.07	159	93499	
10/05/94	18:30		60	95	1366	130	149	164	9.3	0.07	159	93659	
10/05/94	19:00	314	60	95	1361	131	150	165	9.2	0.07	159	93818	
10/05/94	19:30		61	95	1369	132	150	165	9.2	0.07	159	93977	
10/05/94	20:00	315	60	95	1368	131	152	171	9.3	0.07	159	94137	
10/05/94	20:30		59	95	1362	131	149	168	9.2	0.07	159	94296	
10/05/94	21:00	316	60	95	1368	131	150	167	9.3	0.07	159	94455	
10/05/94	21:30		60	95	1362	131	150	167	9.2	0.07	159	94614	
10/05/94	22:00	317	60	95	1370	132	152	168	9.2	0.07	159	94774	
10/05/94	22:30		60	95	1364	132	151	168	9.2	0.07	159	94933	
10/05/94	23:00	318	61	95	1365	133	151	167	9.2	0.07	159	95092	
10/05/94	23:30		61	95	1373	133	150	166	9.2	0.07	159	95251	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/06/94	0:00	319	61	95	1370	133	150	169	9.2	0.07	159	95411	
10/06/94	0:30		61	95	1374	133	150	169	9.2	0.07	159	95570	
10/06/94	1:00	320	60	95	1360	132	150	165	9.2	0.07	159	95729	
10/06/94	1:30		59	95	1355	132	152	163	9.2	0.07	159	95888	
10/06/94	2:00	321	60	95	1358	132	152	166	9.2	0.07	159	96048	
10/06/94	2:30		60	95	1362	133	153	168	9.1	0.07	159	96207	
10/06/94	3:00	322	61	95	1367	132	152	167	9.2	0.07	159	96366	
10/06/94	3:30		60	95	1348	133	152	168	9.1	0.07	159	96526	
10/06/94	4:00	323	60	95	1352	133	152	167	9.1	0.07	159	96685	
10/06/94	4:30		61	95	1363	133	152	168	9.1	0.07	159	96844	
10/06/94	5:00	324	61	95	1365	134	153	167	9.1	0.07	159	97003	
10/06/94	5:30		62	95	1363	134	153	168	9.0	0.07	159	97163	
10/06/94	6:00	325	61	95	1375	135	153	170	9.1	0.07	159	97322	
10/06/94	6:30		62	95	1368	134	152	169	9.1	0.07	159	97481	
10/06/94	7:00	326	60	95	1342	133	151	167	9.0	0.07	159	97640	
10/06/94	7:30		59	90	1330	129	148	167	8.7	0.07	151	97791	
10/06/94	8:00	327	59	90	1333	129	149	164	8.7	0.07	151	97942	
10/06/94	8:30		60	90	1338	129	150	163	8.8	0.07	151	98093	
10/06/94	9:00	328	59	90	1344	130	152	166	8.8	0.07	151	98244	
10/06/94	9:30		60	90	1354	130	151	168	8.8	0.07	151	98395	
10/06/94	10:00	329	59	90	1356	130	150	166	8.8	0.07	151	98546	
10/06/94	10:30		60	90	1348	130	150	168	8.8	0.07	151	98697	
10/06/94	11:00	330	56	90	1327	128	150	166	8.8	0.07	151	98847	
10/06/94	11:30		57	90	1327	129	149	167	8.7	0.07	151	98998	
10/06/94	12:00	331	57	90	1321	129	150	167	8.7	0.06	151	99149	
10/06/94	12:30		56	90	1318	129	149	163	8.7	0.07	151	99300	
10/06/94	13:00	332	57	90	1317	128	149	166	8.7	0.07	151	99451	
10/06/94	13:30		56	90	1308	129	147	166	8.6	0.07	151	99602	
10/06/94	14:00	333	57	90	1308	128	150	167	8.7	0.06	151	99753	
10/06/94	14:30		56	90	1307	128	151	167	8.6	0.06	151	99904	
10/06/94	15:00	334	55	90	1307	127	149	163	8.7	0.07	151	100055	
10/06/94	15:30		56	90	1304	129	147	161	8.6	0.07	151	100205	
10/06/94	16:00	335	56	90	1309	128	149	168	8.7	0.06	151	100356	
10/06/94	16:30		58	90	1321	129	147	161	8.7	0.07	151	100507	
10/06/94	17:00	336	57	90	1316	128	148	167	8.7	0.07	151	100658	
10/06/94	17:30		58	90	1322	129	149	167	8.7	0.07	151	100809	
10/06/94	18:00	337	57	90	1317	129	148	166	8.7	0.07	151	100960	
10/06/94	18:30		59	90	1320	129	145	166	8.7	0.07	151	101111	
10/06/94	19:00	338	58	90	1319	128	148	167	8.7	0.07	151	101262	
10/06/94	19:30		58	90	1319	129	147	161	8.7	0.07	151	101413	
10/06/94	20:00	339	59	90	1326	129	149	167	8.7	0.07	151	101563	
10/06/94	20:30		59	90	1323	130	150	167	8.7	0.06	151	101714	
10/06/94	21:00	340	58	90	1324	130	149	167	8.6	0.06	151	101865	
10/06/94	21:30		59	90	1324	130	148	163	8.6	0.07	151	102016	
10/06/94	22:00	341	58	90	1317	130	150	163	8.6	0.06	151	102167	
10/06/94	22:30		59	95	1318	131	151	166	9.0	0.07	159	102326	
10/06/94	23:00	342	59	95	1321	131	151	166	9.1	0.07	159	102485	
10/06/94	23:30		59	95	1324	130	151	166	9.1	0.07	159	102645	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/07/94	0:00	343	59	95	1327	130	152	166	9.1	0.07	159	102804	
10/07/94	0:30		58	90	1327	130	152	166	8.7	0.06	151	102955	
10/07/94	1:00	344	59	95	1326	131	151	167	9.1	0.07	159	103114	
10/07/94	1:30		59	90	1325	130	151	167	8.6	0.06	151	103265	
10/07/94	2:00	345	59	95	1322	130	152	168	9.1	0.07	159	103424	
10/07/94	2:30		58	90	1318	130	151	169	8.6	0.06	151	103575	
10/07/94	3:00	346	60	95	1318	132	154	173	9.0	0.07	159	103734	
10/07/94	3:30		59	95	1323	131	153	173	9.0	0.07	159	103894	
10/07/94	4:00	347	60	95	1331	132	153	168	9.0	0.07	159	104053	
10/07/94	4:30		60	95	1321	132	154	168	9.0	0.07	159	104212	
10/07/94	5:00	348	59	95	1326	131	155	168	9.0	0.07	159	104372	
10/07/94	5:30		60	95	1326	132	154	168	9.0	0.07	159	104531	
10/07/94	6:00	349	59	95	1327	132	154	174	9.0	0.07	159	104690	
10/07/94	6:30		61	95	1331	133	156	175	9.0	0.06	159	104849	
10/07/94	7:00	350	62	95	1353	134	156	178	9.0	0.07	159	105009	
10/07/94	7:30		62	95	1353	135	157	177	8.9	0.06	159	105168	
10/07/94	8:00	351	62	95	1356	135	158	179	9.0	0.06	159	105327	
10/07/94	8:30		63	95	1361	135	156	177	9.0	0.07	159	105486	
10/07/94	9:00	352	62	95	1358	135	158	177	9.0	0.06	159	105646	
10/07/94	9:30		62	95	1361	135	156	177	9.0	0.07	159	105805	
10/07/94	10:00	353	63	95	1370	136	158	178	9.0	0.06	159	105964	
10/07/94	10:30		63	95	1371	136	159	179	9.0	0.06	159	106123	
10/07/94	11:00	354	58	95	1382	132	156	168	9.3	0.07	159	106283	
10/07/94	11:30		57	95	1318	131	154	169	9.0	0.07	159	106442	
10/07/94	12:00	355	58	95	1327	131	154	169	9.1	0.07	159	106601	
10/07/94	12:30		59	90	1322	130	151	169	8.6	0.06	151	106752	
10/07/94	13:00	356	57	90	1314	130	152	172	8.6	0.06	151	106903	
10/07/94	13:30		57	90	1309	129	154	171	8.6	0.06	151	107054	
10/07/94	14:00	357	56	90	1311	128	153	172	8.7	0.06	151	107205	
10/07/94	14:30		56	90	1312	128	154	168	8.7	0.06	151	107356	
10/07/94	15:00	358	57	90	1315	128	153	166	8.7	0.06	151	107507	
10/07/94	15:30		56	90	1302	129	152	168	8.6	0.06	151	107657	
10/07/94	16:00	359	55	90	1295	129	151	168	8.6	0.06	151	107808	
10/07/94	16:30		52	90	1276	128	149	166	8.5	0.06	151	107959	
10/07/94	17:00	360	51	90	1262	127	148	167	8.5	0.06	151	108110	
10/07/94	17:30		50	90	1251	123	146	161	8.7	0.07	151	108261	
10/07/94	18:00	361	50	90	1252	120	144	159	8.9	0.07	151	108412	
10/07/94	18:30		51	90	1250	121	144	159	8.8	0.07	151	108563	
10/07/94	19:00	362	50	90	1252	121	143	160	8.8	0.07	151	108714	
10/07/94	19:30		52	90	1261	122	146	161	8.8	0.07	151	108865	
10/07/94	20:00	363	51	90	1266	121	144	162	8.9	0.07	151	109015	
10/07/94	20:30		51	90	1256	121	145	164	8.9	0.07	151	109166	
10/07/94	21:00	364	52	90	1265	122	145	163	8.9	0.07	151	109317	
10/07/94	21:30		55	90	1281	123	148	167	8.9	0.07	151	109468	
10/07/94	22:00	365	55	90	1298	123	147	167	9.0	0.07	151	109619	
10/07/94	22:30		56	90	1305	123	149	167	9.0	0.07	151	109770	
10/07/94	23:00	366	53	90	1287	122	147	167	9.0	0.07	151	109921	
10/07/94	23:30		55	90	1290	122	148	167	8.9	0.07	151	110072	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/08/94	0:00	367	54	90	1289	122	148	161	8.9	0.07	151	110223	
10/08/94	0:30		56	90	1293	123	148	161	8.9	0.07	151	110373	
10/08/94	1:00	368	56	90	1293	123	147	161	8.9	0.07	151	110524	
10/08/94	1:30		55	90	1292	122	147	163	9.0	0.07	151	110675	
10/08/94	2:00	369	55	90	1290	123	148	167	8.9	0.07	151	110826	
10/08/94	2:30		55	90	1289	123	148	166	8.9	0.07	151	110977	
10/08/94	3:00	370	55	90	1289	123	148	166	8.9	0.07	151	111128	
10/08/94	3:30		54	90	1281	122	149	161	8.9	0.07	151	111279	
10/08/94	4:00	371	55	90	1292	123	148	167	8.9	0.07	151	111430	
10/08/94	4:30		55	90	1288	123	150	167	8.9	0.07	151	111580	
10/08/94	5:00	372	54	90	1283	123	148	167	8.9	0.07	151	111731	* Returned to #12 mesh Plum Run Greenfield Dolomite sorbent.
10/08/94	5:30		55	90	1285	123	150	167	8.9	0.07	151	111882	
10/08/94	6:00	373	55	90	1290	123	150	168	8.9	0.07	151	112033	
10/08/94	6:30		55	90	1290	124	151	166	8.9	0.06	151	112184	
10/08/94	7:00	374	55	90	1295	124	148	167	8.9	0.07	151	112335	
10/08/94	7:30		57	90	1298	125	151	166	8.8	0.06	151	112486	
10/08/94	8:00	375	57	90	1309	125	151	167	8.9	0.07	151	112637	
10/08/94	8:30		57	90	1318	125	152	167	8.9	0.07	151	112788	
10/08/94	9:00	376	58	90	1327	126	150	168	8.9	0.07	151	112938	
10/08/94	9:30		59	90	1332	126	152	166	8.9	0.07	151	113089	
10/08/94	10:00	377	57	90	1340	126	152	168	9.0	0.07	151	113240	
10/08/94	10:30		57	90	1319	126	151	166	8.9	0.07	151	113391	
10/08/94	11:00	378	58	90	1329	126	149	169	8.9	0.07	151	113542	
10/08/94	11:30		59	90	1338	127	154	167	8.9	0.06	151	113693	
10/08/94	12:00	379	58	90	1342	127	153	167	8.9	0.07	151	113844	
10/08/94	12:30		57	90	1332	126	154	168	8.9	0.06	151	113995	
10/08/94	13:00	380	57	90	1327	126	151	168	8.9	0.07	151	114146	
10/08/94	13:30		58	90	1330	127	154	168	8.8	0.06	151	114296	
10/08/94	14:00	381	58	90	1324	127	154	166	8.8	0.06	151	114447	
10/08/94	14:30		56	90	1319	127	154	168	8.8	0.06	151	114598	
10/08/94	15:00	382	55	90	1308	126	152	166	8.8	0.06	151	114749	
10/08/94	15:30		58	90	1321	127	154	168	8.8	0.06	151	114900	
10/08/94	16:00	383	55	90	1314	126	151	167	8.8	0.07	151	115051	
10/08/94	16:30		57	90	1319	127	156	168	8.8	0.06	151	115202	
10/08/94	17:00	384	55	90	1310	126	153	166	8.8	0.06	151	115353	
10/08/94	17:30		54	90	1294	126	153	166	8.7	0.06	151	115504	
10/08/94	18:00	385	54	90	1292	125	154	167	8.8	0.06	151	115654	
10/08/94	18:30		54	90	1290	125	152	167	8.8	0.06	151	115805	
10/08/94	19:00	386	55	90	1289	125	152	167	8.7	0.06	151	115956	
10/08/94	19:30		55	90	1290	126	148	168	8.7	0.07	151	116107	
10/08/94	20:00	387	54	90	1287	125	150	166	8.7	0.06	151	116258	
10/08/94	20:30		54	90	1287	125	152	166	8.7	0.06	151	116409	
10/08/94	21:00	388	54	90	1290	126	150	165	8.7	0.06	151	116560	
10/08/94	21:30		54	90	1291	125	151	162	8.8	0.06	151	116711	
10/08/94	22:00	389	54	90	1286	125	149	166	8.8	0.06	151	116861	
10/08/94	22:30		54	90	1288	124	151	160	8.8	0.06	151	117012	
10/08/94	23:00	390	54	90	1282	124	149	161	8.8	0.07	151	117163	
10/08/94	23:30		53	90	1278	124	149	163	8.7	0.06	151	117314	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/09/94	0:00	391	53	90	1278	124	151	168	8.8	0.06	151	117465	
10/09/94	0:30		53	90	1276	126	151	168	8.7	0.06	151	117616	
10/09/94	1:00	392	54	90	1282	130	148	166	8.5	0.06	151	117767	
10/09/94	1:30		53	90	1276	130	153	166	8.4	0.06	151	117918	
10/09/94	2:00	393	53	95	1282	130	154	172	8.9	0.06	159	118077	
10/09/94	2:30		53	90	1272	130	154	171	8.4	0.06	151	118228	
10/09/94	3:00	394	53	90	1271	129	154	166	8.5	0.06	151	118379	
10/09/94	3:30		52	90	1271	126	154	163	8.6	0.06	151	118530	
10/09/94	4:00	395	51	90	1265	124	150	163	8.7	0.06	151	118680	
10/09/94	4:30		52	90	1268	120	148	160	9.0	0.07	151	118831	
10/09/94	5:00	396	51	80	1278	120	148	159	8.0	0.06	134	118965	
10/09/94	5:30		53	80	1281	119	148	163	8.1	0.06	134	119100	
10/09/94	6:00	397	53	80	1277	119	146	158	8.1	0.06	134	119234	
10/09/94	6:30		52	80	1280	118	147	159	8.2	0.06	134	119368	
10/09/94	7:00	398	52	90	1279	125	147	162	8.7	0.07	151	119519	
10/09/94	7:30		51	90	1267	124	150	166	8.7	0.06	151	119670	
10/09/94	8:00	399	49	90	1254	124	146	161	8.7	0.07	151	119820	
10/09/94	8:30		49	90	1251	123	147	161	8.7	0.06	151	119971	
10/09/94	9:00	400	47	90	1243	123	147	161	8.7	0.06	151	120122	
10/09/94	9:30		49	90	1243	123	147	159	8.7	0.06	151	120273	
10/09/94	10:00	401	48	90	1231	123	146	160	8.6	0.06	151	120424	
10/09/94	10:30		49	90	1243	123	143	160	8.7	0.07	151	120575	
10/09/94	11:00	402	51	90	1258	124	148	160	8.7	0.06	151	120726	
10/09/94	11:30		52	90	1266	125	147	160	8.7	0.06	151	120877	
10/09/94	12:00	403	52	90	1269	125	147	165	8.7	0.06	151	121028	
10/09/94	12:30		53	90	1277	124	149	160	8.8	0.06	151	121178	
10/09/94	13:00	404	53	90	1278	125	148	161	8.7	0.06	151	121329	
10/09/94	13:30		53	90	1283	125	151	166	8.7	0.06	151	121480	
10/09/94	14:00	405	53	90	1287	125	151	161	8.7	0.06	151	121631	
10/09/94	14:30		53	90	1286	126	151	161	8.7	0.06	151	121782	
10/09/94	15:00	406	51	90	1276	125	148	160	8.7	0.06	151	121933	
10/09/94	15:30		52	90	1277	125	149	161	8.7	0.06	151	122084	
10/09/94	16:00	407	52	90	1276	125	148	160	8.7	0.06	151	122235	
10/09/94	16:30		52	90	1277	125	149	164	8.7	0.06	151	122386	
10/09/94	17:00	408	52	90	1281	125	150	160	8.7	0.06	151	122536	
10/09/94	17:30		52	90	1281	125	148	161	8.7	0.07	151	122687	
10/09/94	18:00	409	53	90	1284	125	149	160	8.7	0.06	151	122838	
10/09/94	18:30		52	90	1283	125	151	162	8.7	0.06	151	122989	
10/09/94	19:00	410	53	90	1284	125	150	164	8.7	0.06	151	123140	
10/09/94	19:30		52	90	1280	125	149	163	8.7	0.06	151	123291	
10/09/94	20:00	411	53	90	1279	125	151	161	8.7	0.06	151	123442	
10/09/94	20:30		52	90	1275	125	149	166	8.7	0.06	151	123593	
10/09/94	21:00	412	51	90	1275	124	149	161	8.7	0.06	151	123744	
10/09/94	21:30		51	90	1279	125	152	162	8.7	0.06	151	123894	
10/09/94	22:00	413	52	90	1278	125	150	161	8.7	0.06	151	124045	
10/09/94	22:30		52	90	1281	125	152	160	8.7	0.06	151	124196	
10/09/94	23:00	414	52	90	1279	124	151	166	8.7	0.06	151	124347	
10/09/94	23:30		51	90	1275	125	150	164	8.7	0.06	151	124498	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/10/94	0:00	415	52	90	1276	124	152	163	8.8	0.06	151	124649	
10/10/94	0:30		52	90	1274	124	152	163	8.7	0.06	151	124800	
10/10/94	1:00	416	52	90	1275	125	148	162	8.7	0.06	151	124951	
10/10/94	1:30		52	90	1275	125	151	166	8.7	0.06	151	125101	
10/10/94	2:00	417	52	90	1272	125	152	162	8.7	0.06	151	125252	
10/10/94	2:30		51	90	1273	124	151	166	8.7	0.06	151	125403	
10/10/94	3:00	418	51	90	1281	125	152	164	8.7	0.06	151	125554	
10/10/94	3:30		51	90	1280	125	150	167	8.7	0.06	151	125705	
10/10/94	4:00	419	52	90	1286	125	149	166	8.8	0.06	151	125856	
10/10/94	4:30		50	90	1281	124	151	164	8.8	0.06	151	126007	
10/10/94	5:00	420	53	90	1289	125	151	166	8.8	0.06	151	126158	
10/10/94	5:30		53	90	1287	125	152	162	8.8	0.06	151	126309	
10/10/94	6:00	421	52	90	1288	125	149	167	8.8	0.07	151	126459	
10/10/94	6:30		51	90	1278	125	151	161	8.7	0.06	151	126610	
10/10/94	7:00	422	52	90	1288	124	151	162	8.8	0.06	151	126761	
10/10/94	7:30		52	90	1292	125	153	167	8.8	0.06	151	126912	
10/10/94	8:00	423	51	90	1292	124	149	166	8.8	0.07	151	127063	
10/10/94	8:30		52	90	1284	125	153	163	8.8	0.06	151	127214	
10/10/94	9:00	424	51	90	1282	124	151	162	8.8	0.06	151	127365	
10/10/94	9:30		50	90	1279	125	152	162	8.7	0.06	151	127516	
10/10/94	10:00	425	50	90	1285	124	152	161	8.8	0.06	151	127667	
10/10/94	10:30		51	90	1282	125	152	161	8.7	0.06	151	127817	
10/10/94	11:00	426	51	90	1288	125	150	161	8.7	0.06	151	127968	
10/10/94	11:30		50	90	1284	125	151	161	8.8	0.06	151	128119	
10/10/94	12:00	427	50	90	1286	125	149	161	8.8	0.06	151	128270	
10/10/94	12:30		51	90	1282	125	150	162	8.7	0.06	151	128421	
10/10/94	13:00	428	50	90	1285	124	150	163	8.8	0.06	151	128572	
10/10/94	13:30		51	90	1281	125	151	161	8.7	0.06	151	128723	
10/10/94	14:00	429	49	90	1282	125	150	161	8.7	0.06	151	128874	
10/10/94	14:30		50	90	1286	125	152	161	8.8	0.06	151	129024	
10/10/94	15:00	430	51	90	1282	125	152	161	8.7	0.06	151	129175	
10/10/94	15:30		49	90	1285	125	152	163	8.7	0.06	151	129326	
10/10/94	16:00	431	50	90	1283	125	150	160	8.7	0.06	151	129477	
10/10/94	16:30		50	90	1292	124	149	162	8.8	0.07	151	129628	
10/10/94	17:00	432	49	90	1287	124	149	160	8.8	0.07	151	129779	
10/10/94	17:30		50	90	1281	125	151	164	8.8	0.06	151	129930	
10/10/94	18:00	433	49	90	1282	124	151	160	8.8	0.06	151	130081	
10/10/94	18:30		50	90	1280	125	151	161	8.7	0.06	151	130232	
10/10/94	19:00	434	49	90	1285	125	151	160	8.8	0.06	151	130382	
10/10/94	19:30		51	90	1291	125	152	161	8.8	0.06	151	130533	
10/10/94	20:00	435	48	90	1281	124	149	164	8.8	0.07	151	130684	
10/10/94	20:30		50	90	1285	125	148	161	8.8	0.07	151	130835	
10/10/94	21:00	436	50	90	1285	124	146	161	8.8	0.07	151	130986	
10/10/94	21:30		51	90	1288	124	150	160	8.8	0.06	151	131137	
10/10/94	22:00	437	50	90	1290	124	151	161	8.8	0.06	151	131288	
10/10/94	22:30		49	90	1290	123	148	160	8.9	0.07	151	131439	
10/10/94	23:00	438	50	90	1282	124	148	157	8.8	0.07	151	131590	
10/10/94	23:30		50	90	1281	125	147	159	8.8	0.07	151	131740	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/11/94	0:00	439	50	90	1285	125	150	160	8.8	0.06	151	131891	
10/11/94	0:30		50	90	1285	125	150	160	8.7	0.06	151	132042	
10/11/94	1:00	440	51	90	1283	125	150	159	8.8	0.06	151	132193	
10/11/94	1:30		51	90	1283	125	149	160	8.7	0.06	151	132344	
10/11/94	2:00	441	50	90	1284	124	152	164	8.8	0.06	151	132495	
10/11/94	2:30		50	90	1286	125	151	162	8.8	0.06	151	132646	
10/11/94	3:00	442	50	90	1294	124	152	159	8.8	0.06	151	132797	
10/11/94	3:30		50	90	1296	125	150	160	8.8	0.07	151	132947	
10/11/94	4:00	443	48	90	1290	124	148	158	8.8	0.07	151	133098	
10/11/94	4:30		50	90	1291	125	150	160	8.8	0.07	151	133249	
10/11/94	5:00	444	49	90	1293	124	152	160	8.8	0.06	151	133400	
10/11/94	5:30		51	90	1297	125	151	160	8.8	0.06	151	133551	
10/11/94	6:00	445	49	90	1293	124	151	161	8.8	0.06	151	133702	
10/11/94	6:30		49	90	1294	124	152	161	8.8	0.06	151	133853	
10/11/94	7:00	446	50	90	1300	125	152	161	8.9	0.06	151	134004	
10/11/94	7:30		50	90	1298	125	152	163	8.8	0.06	151	134155	
10/11/94	8:00	447	49	90	1302	125	151	160	8.9	0.07	151	134305	
10/11/94	8:30		50	90	1292	125	153	164	8.8	0.06	151	134456	
10/11/94	9:00	448	49	90	1285	124	153	162	8.8	0.06	151	134607	
10/11/94	9:30		51	90	1291	124	157	166	8.9	0.06	151	134758	
10/11/94	10:00	449	50	90	1292	126	160	167	8.7	0.06	151	134909	
10/11/94	10:30		49	90	1285	125	151	168	8.7	0.06	151	135060	
10/11/94	11:00	450	50	90	1289	126	150	168	8.7	0.06	151	135211	
10/11/94	11:30		50	90	1293	126	150	160	8.7	0.06	151	135362	
10/11/94	12:00	451	51	90	1291	125	151	161	8.8	0.06	151	135513	
10/11/94	12:30		51	90	1297	126	151	163	8.7	0.06	151	135663	
10/11/94	13:00	452	50	90	1297	126	152	163	8.8	0.06	151	135814	
10/11/94	13:30		50	90	1289	126	150	159	8.7	0.06	151	135965	
10/11/94	14:00	453	51	90	1287	125	150	159	8.7	0.06	151	136116	
10/11/94	14:30		50	90	1286	126	150	159	8.7	0.06	151	136267	
10/11/94	15:00	454	49	90	1290	125	151	160	8.8	0.06	151	136418	
10/11/94	15:30		50	90	1292	125	152	166	8.8	0.06	151	136569	
10/11/94	16:00	455	51	90	1291	126	152	167	8.7	0.06	151	136720	
10/11/94	16:30		50	90	1294	126	154	166	8.7	0.06	151	136870	
10/11/94	17:00	456	50	90	1298	125	155	168	8.8	0.06	151	137021	
10/11/94	17:30		50	90	1299	125	150	164	8.8	0.07	151	137172	
10/11/94	18:00	457	50	90	1298	126	152	167	8.8	0.06	151	137323	
10/11/94	18:30		51	90	1295	125	152	166	8.8	0.06	151	137474	
10/11/94	19:00	458	50	90	1290	125	154	166	8.8	0.06	151	137625	
10/11/94	19:30		49	90	1290	125	154	166	8.8	0.06	151	137776	
10/11/94	20:00	459	50	90	1295	125	154	167	8.8	0.06	151	137927	
10/11/94	20:30		49	90	1298	123	150	167	8.9	0.07	151	138078	
10/11/94	21:00	460	50	90	1299	125	155	166	8.8	0.06	151	138228	
10/11/94	21:30		50	90	1301	125	158	168	8.8	0.06	151	138379	
10/11/94	22:00	461	50	90	1292	125	157	167	8.8	0.06	151	138530	
10/11/94	22:30		51	90	1301	124	158	167	8.9	0.06	151	138681	
10/11/94	23:00	462	50	90	1300	125	156	167	8.8	0.06	151	138832	
10/11/94	23:30		52	90	1300	125	156	167	8.8	0.06	151	138983	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/12/94	0:00	463	51	90	1300	125	159	166	8.8	0.06	151	139134	
10/12/94	0:30		51	90	1302	125	159	166	8.8	0.06	151	139285	
10/12/94	1:00	464	49	90	1299	123	157	168	8.9	0.06	151	139436	
10/12/94	1:30		50	90	1294	125	158	172	8.8	0.06	151	139586	
10/12/94	2:00	465	50	90	1300	124	157	166	8.9	0.06	151	139737	
10/12/94	2:30		51	90	1298	124	156	167	8.9	0.06	151	139888	
10/12/94	3:00	466	51	90	1295	124	156	166	8.9	0.06	151	140039	* Beginning of #18 mesh National Lime Bucyrus Limestone sorbent.
10/12/94	3:30		50	90	1290	124	157	168	8.8	0.06	151	140190	
10/12/94	4:00	467	51	90	1292	125	156	167	8.8	0.06	151	140341	
10/12/94	4:30		50	90	1300	125	158	166	8.8	0.06	151	140492	
10/12/94	5:00	468	51	90	1296	125	157	166	8.8	0.06	151	140643	
10/12/94	5:30		51	90	1295	125	156	166	8.8	0.06	151	140794	
10/12/94	6:00	469	50	90	1292	124	156	166	8.8	0.06	151	140944	
10/12/94	6:30		52	90	1293	125	156	166	8.8	0.06	151	141095	
10/12/94	7:00	470	51	90	1292	124	155	167	8.8	0.06	151	141246	
10/12/94	7:30		51	90	1299	125	157	168	8.8	0.06	151	141397	
10/12/94	8:00	471	50	90	1292	124	157	167	8.8	0.06	151	141548	
10/12/94	8:30		45	90	1268	123	154	163	8.8	0.06	151	141699	
10/12/94	9:00	472	40	90	1230	121	152	168	8.7	0.06	151	141850	
10/12/94	9:30		42	90	1227	122	154	168	8.6	0.06	151	142001	
10/12/94	10:00	473	42	90	1231	122	153	166	8.7	0.06	151	142151	
10/12/94	10:30		40	90	1235	122	159	168	8.7	0.06	151	142302	
10/12/94	11:00	474	42	90	1236	122	154	164	8.7	0.06	151	142453	
10/12/94	11:30		40	90	1237	121	154	162	8.7	0.06	151	142604	
10/12/94	12:00	475	41	90	1241	122	155	168	8.7	0.06	151	142755	
10/12/94	12:30		42	90	1240	122	153	167	8.7	0.06	151	142906	
10/12/94	13:00	476	41	90	1238	122	152	168	8.7	0.06	151	143057	
10/12/94	13:30		41	90	1242	122	154	167	8.7	0.06	151	143208	
10/12/94	14:00	477	41	90	1245	122	153	167	8.8	0.06	151	143359	
10/12/94	14:30		42	90	1246	123	154	167	8.7	0.06	151	143509	
10/12/94	15:00	478	43	90	1244	122	152	167	8.7	0.06	151	143660	
10/12/94	15:30		43	90	1248	122	153	167	8.7	0.06	151	143811	
10/12/94	16:00	479	48	90	1266	124	154	166	8.7	0.06	151	143962	
10/12/94	16:30		47	90	1274	125	154	166	8.7	0.06	151	144113	
10/12/94	17:00	480	51	90	1292	126	155	171	8.7	0.06	151	144264	
10/12/94	17:30		53	90	1319	127	159	171	8.8	0.06	151	144415	
10/12/94	18:00	481	55	90	1352	128	160	171	8.9	0.06	151	144566	
10/12/94	18:30		54	90	1354	128	160	171	8.9	0.06	151	144717	
10/12/94	19:00	482	54	90	1356	128	160	171	8.9	0.06	151	144867	
10/12/94	19:30		54	90	1361	128	160	172	8.9	0.06	151	145018	
10/12/94	20:00	483	52	90	1345	126	158	171	9.0	0.06	151	145169	
10/12/94	20:30		54	90	1355	128	160	172	8.9	0.06	151	145320	
10/12/94	21:00	484	55	90	1375	128	163	171	9.0	0.06	151	145471	
10/12/94	21:30		55	90	1381	129	162	173	9.0	0.06	151	145622	
10/12/94	22:00	485	55	90	1381	128	163	172	9.1	0.06	151	145773	
10/12/94	22:30		54	90	1373	128	163	172	9.0	0.06	151	145924	
10/12/94	23:00	486	54	90	1373	127	163	170	9.0	0.06	151	146074	
10/12/94	23:30		51	90	1371	127	160	169	9.1	0.06	151	146225	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/13/94	0:00	487	53	90	1373	127	163	174	9.1	0.06	151	146376	
10/13/94	0:30		53	90	1381	128	163	174	9.0	0.06	151	146527	
10/13/94	1:00	488	53	90	1384	128	164	173	9.1	0.06	151	146678	
10/13/94	1:30		53	90	1391	129	164	174	9.0	0.06	151	146829	
10/13/94	2:00	489	53	90	1405	129	166	173	9.1	0.06	151	146980	
10/13/94	2:30		53	90	1408	129	165	173	9.1	0.06	151	147131	
10/13/94	3:00	490	53	90	1393	128	164	172	9.1	0.06	151	147282	
10/13/94	3:30		53	90	1411	129	164	175	9.1	0.06	151	147432	
10/13/94	4:00	491	53	90	1417	128	165	173	9.2	0.06	151	147583	
10/13/94	4:30		53	90	1395	129	164	172	9.1	0.06	151	147734	
10/13/94	5:00	492	53	90	1378	127	165	171	9.1	0.06	151	147885	
10/13/94	5:30		53	90	1380	128	164	171	9.0	0.06	151	148036	
10/13/94	6:00	493	53	90	1388	127	165	175	9.1	0.06	151	148187	
10/13/94	6:30		53	90	1378	127	163	169	9.1	0.06	151	148338	
10/13/94	7:00	494	53	90	1371	127	163	171	9.1	0.06	151	148489	
10/13/94	7:30		53	90	1379	128	164	170	9.0	0.06	151	148640	
10/13/94	8:00	495	53	90	1380	127	165	170	9.1	0.06	151	148790	
10/13/94	8:30		53	90	1356	127	163	170	9.0	0.06	151	148941	
10/13/94	9:00	496	53	90	1349	127	163	171	9.0	0.06	151	149092	
10/13/94	9:30		53	90	1351	128	163	172	8.9	0.06	151	149243	
10/13/94	10:00	497	53	90	1347	127	162	168	8.9	0.06	151	149394	
10/13/94	10:30		53	90	1357	128	163	170	8.9	0.06	151	149545	
10/13/94	11:00	498	53	90	1360	127	164	169	9.0	0.06	151	149696	
10/13/94	11:30		53	90	1368	129	165	174	8.9	0.06	151	149847	
10/13/94	12:00	499	53	90	1385	128	165	174	9.0	0.06	151	149997	
10/13/94	12:30		53	90	1380	129	166	175	9.0	0.06	151	150148	
10/13/94	13:00	500	53	90	1381	126	166	172	9.2	0.06	151	150299	
10/13/94	13:30		53	90	1368	128	166	170	9.0	0.06	151	150450	
10/13/94	14:00	501	53	90	1360	127	166	171	9.0	0.06	151	150601	
10/13/94	14:30		53	90	1377	129	166	174	8.9	0.06	151	150752	
10/13/94	15:00	502	53	90	1357	125	165	174	9.1	0.06	151	150903	
10/13/94	15:30		53	90	1320	126	163	173	8.8	0.06	151	151054	
10/13/94	16:00	503	53	90	1300	125	163	173	8.8	0.06	151	151205	
10/13/94	16:30		53	90	1286	125	162	171	8.8	0.06	151	151355	
10/13/94	17:00	504	53	90	1283	125	161	173	8.8	0.06	151	151506	
10/13/94	17:30		53	90	1282	124	157	168	8.8	0.06	151	151657	
10/13/94	18:00	505	53	90	1287	125	160	167	8.8	0.06	151	151808	
10/13/94	18:30		53	90	1288	126	160	170	8.7	0.06	151	151959	
10/13/94	19:00	506	53	90	1288	125	160	169	8.8	0.06	151	152110	
10/13/94	19:30		53	90	1291	125	160	171	8.8	0.06	151	152261	
10/13/94	20:00	507	53	90	1283	125	159	168	8.7	0.06	151	152412	
10/13/94	20:30		53	90	1293	126	160	170	8.7	0.06	151	152563	
10/13/94	21:00	508	53	90	1286	126	160	169	8.7	0.06	151	152713	
10/13/94	21:30		53	90	1291	126	160	171	8.7	0.06	151	152864	
10/13/94	22:00	509	53	90	1299	125	162	171	8.8	0.06	151	153015	
10/13/94	22:30		53	90	1293	125	158	170	8.8	0.06	151	153166	
10/13/94	23:00	510	53	90	1294	125	160	169	8.8	0.06	151	153317	* Returned to #12 mesh Plum Run Greenfield Dolomite sorbent.
10/13/94	23:30		53	90	1302	126	160	170	8.8	0.06	151	153468	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/14/94	0:00	511	47	90	1307	126	160	171	8.8	0.06	151	153619	
10/14/94	0:30		46	90	1300	126	160	171	8.8	0.06	151	153770	
10/14/94	1:00	512	45	90	1292	124	159	168	8.8	0.06	151	153921	
10/14/94	1:30		48	90	1303	127	160	172	8.7	0.06	151	154071	
10/14/94	2:00	513	48	90	1308	126	162	173	8.8	0.06	151	154222	
10/14/94	2:30		47	90	1307	126	162	173	8.8	0.06	151	154373	
10/14/94	3:00	514	47	90	1305	126	160	172	8.8	0.06	151	154524	
10/14/94	3:30		45	90	1290	126	158	168	8.7	0.06	151	154675	
10/14/94	4:00	515	46	90	1296	125	160	169	8.8	0.06	151	154826	
10/14/94	4:30		46	90	1295	126	160	170	8.8	0.06	151	154977	
10/14/94	5:00	516	46	90	1297	125	160	171	8.8	0.06	151	155128	
10/14/94	5:30		47	90	1296	125	160	169	8.8	0.06	151	155278	
10/14/94	6:00	517	48	90	1290	126	160	168	8.7	0.06	151	155429	
10/14/94	6:30		46	90	1290	126	160	170	8.7	0.06	151	155580	
10/14/94	7:00	518	44	90	1291	125	160	171	8.8	0.06	151	155731	
10/14/94	7:30		46	90	1289	125	160	169	8.7	0.06	151	155882	
10/14/94	8:00	519	46	90	1286	125	160	169	8.8	0.06	151	156033	
10/14/94	8:30		46	90	1285	125	160	168	8.7	0.06	151	156184	
10/14/94	9:00	520	47	90	1280	125	159	169	8.7	0.06	151	156335	
10/14/94	9:30		46	90	1278	125	159	168	8.7	0.06	151	156486	
10/14/94	10:00	521	47	90	1276	125	160	171	8.7	0.06	151	156636	
10/14/94	10:30		46	90	1277	126	159	169	8.7	0.06	151	156787	
10/14/94	11:00	522	45	90	1282	125	156	171	8.8	0.06	151	156938	
10/14/94	11:30		46	90	1286	125	159	172	8.7	0.06	151	157089	
10/14/94	12:00	523	45	90	1283	125	160	170	8.8	0.06	151	157240	
10/14/94	12:30		46	90	1280	126	160	170	8.7	0.06	151	157391	
10/14/94	13:00	524	46	90	1280	125	160	172	8.7	0.06	151	157542	
10/14/94	13:30		47	90	1280	125	160	170	8.7	0.06	151	157693	
10/14/94	14:00	525	45	90	1281	125	160	170	8.7	0.06	151	157844	
10/14/94	14:30		47	90	1278	126	160	173	8.7	0.06	151	157994	
10/14/94	15:00	526	46	90	1276	125	160	173	8.7	0.06	151	158145	
10/14/94	15:30		47	90	1278	126	160	170	8.6	0.06	151	158296	
10/14/94	16:00	527	45	90	1275	124	160	170	8.7	0.06	151	158447	
10/14/94	16:30		46	90	1281	125	160	172	8.7	0.06	151	158598	
10/14/94	17:00	528	46	90	1273	125	160	172	8.7	0.06	151	158749	
10/14/94	17:30		47	90	1274	126	159	171	8.7	0.06	151	158900	
10/14/94	18:00	529	46	90	1276	125	160	172	8.7	0.06	151	159051	
10/14/94	18:30		44	90	1272	125	160	172	8.7	0.06	151	159201	
10/14/94	19:00	530	46	90	1269	124	160	171	8.7	0.06	151	159352	
10/14/94	19:30		44	90	1268	125	160	171	8.7	0.06	151	159503	
10/14/94	20:00	531	47	90	1278	125	160	172	8.7	0.06	151	159654	
10/14/94	20:30		44	90	1276	125	160	171	8.7	0.06	151	159805	
10/14/94	21:00	532	45	90	1276	124	160	171	8.7	0.06	151	159956	
10/14/94	21:30		45	90	1277	126	160	172	8.7	0.06	151	160107	
10/14/94	22:00	533	45	90	1274	124	160	172	8.7	0.06	151	160258	
10/14/94	22:30		45	90	1273	125	160	171	8.7	0.06	151	160409	
10/14/94	23:00	534	45	90	1277	125	160	171	8.7	0.06	151	160559	
10/14/94	23:30		45	90	1276	125	160	171	8.7	0.06	151	160710	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/15/94	0:00	535	46	90	1274	124	160	167	8.7	0.06	151	160861	
10/15/94	0:30		46	90	1271	125	160	167	8.7	0.06	151	161012	
10/15/94	1:00	536	46	90	1273	123	160	170	8.8	0.06	151	161163	
10/15/94	1:30		46	90	1270	125	160	170	8.7	0.06	151	161314	
10/15/94	2:00	537	46	90	1269	124	160	171	8.7	0.06	151	161465	
10/15/94	2:30		45	90	1266	124	160	171	8.7	0.06	151	161616	
10/15/94	3:00	538	45	90	1271	125	160	173	8.7	0.06	151	161767	
10/15/94	3:30		45	90	1273	125	160	172	8.7	0.06	151	161917	
10/15/94	4:00	539	45	90	1274	124	160	172	8.8	0.06	151	162068	
10/15/94	4:30		46	90	1274	125	160	170	8.7	0.06	151	162219	
10/15/94	5:00	540	44	90	1272	123	158	168	8.8	0.06	151	162370	
10/15/94	5:30		45	90	1268	125	159	167	8.7	0.06	151	162521	
10/15/94	6:00	541	46	90	1269	124	158	168	8.7	0.06	151	162672	* Beginning of a mix of Peabody and Pittsburgh #8 coal. Sorbent remained #12 mesh Plum Run Greenfield Dolomite.
10/15/94	6:30		47	90	1268	125	160	170	8.6	0.06	151	162823	
10/15/94	7:00	542	45	90	1270	124	159	169	8.7	0.06	151	162974	
10/15/94	7:30		47	90	1270	125	160	170	8.7	0.06	151	163124	
10/15/94	8:00	543	45	90	1270	124	159	170	8.8	0.06	151	163275	
10/15/94	8:30		45	90	1267	125	159	169	8.7	0.06	151	163426	
10/15/94	9:00	544	45	90	1265	124	160	168	8.7	0.06	151	163577	
10/15/94	9:30		46	90	1270	125	160	170	8.7	0.06	151	163728	
10/15/94	10:00	545	46	90	1277	125	160	173	8.7	0.06	151	163879	
10/15/94	10:30		48	90	1283	127	162	171	8.6	0.06	151	164030	
10/15/94	11:00	546	47	90	1289	125	160	171	8.8	0.06	151	164181	
10/15/94	11:30		45	90	1290	126	160	173	8.7	0.06	151	164332	
10/15/94	12:00	547	45	90	1292	125	160	170	8.8	0.06	151	164482	
10/15/94	12:30		47	90	1290	127	160	171	8.7	0.06	151	164633	
10/15/94	13:00	548	45	90	1287	125	160	170	8.8	0.06	151	164784	
10/15/94	13:30		44	90	1285	125	159	170	8.8	0.06	151	164935	
10/15/94	14:00	549	46	90	1283	125	160	171	8.7	0.06	151	165086	
10/15/94	14:30		46	90	1288	126	162	173	8.7	0.06	151	165237	
10/15/94	15:00	550	46	90	1287	125	160	172	8.8	0.06	151	165388	
10/15/94	15:30		46	90	1292	126	163	172	8.7	0.06	151	165539	
10/15/94	16:00	551	45	90	1287	124	159	170	8.8	0.06	151	165690	
10/15/94	16:30		46	90	1286	126	160	170	8.7	0.06	151	165840	
10/15/94	17:00	552	45	90	1280	125	160	172	8.7	0.06	151	165991	
10/15/94	17:30		45	90	1281	125	160	171	8.7	0.06	151	166142	
10/15/94	18:00	553	45	90	1278	124	160	171	8.8	0.06	151	166293	
10/15/94	18:30		45	90	1279	125	160	172	8.7	0.06	151	166444	
10/15/94	19:00	554	44	90	1283	124	160	171	8.8	0.06	151	166595	
10/15/94	19:30		45	90	1290	125	160	172	8.8	0.06	151	166746	
10/15/94	20:00	555	45	90	1287	124	160	172	8.8	0.06	151	166897	
10/15/94	20:30		45	90	1284	125	160	170	8.7	0.06	151	167047	
10/15/94	21:00	556	44	90	1281	124	160	171	8.8	0.06	151	167198	
10/15/94	21:30		44	90	1276	124	160	170	8.7	0.06	151	167349	
10/15/94	22:00	557	44	90	1272	123	160	171	8.8	0.06	151	167500	
10/15/94	22:30		45	90	1271	125	160	171	8.7	0.06	151	167651	
10/15/94	23:00	558	43	90	1271	123	160	170	8.8	0.06	151	167802	
10/15/94	23:30		45	90	1269	125	160	172	8.7	0.06	151	167953	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/16/94	0:00	559	44	90	1270	124	156	170	8.7	0.06	151	168104	
10/16/94	0:30		45	90	1271	125	156	170	8.7	0.06	151	168255	
10/16/94	1:00	560	44	90	1268	123	159	172	8.8	0.06	151	168405	
10/16/94	1:30		45	90	1272	125	158	169	8.7	0.06	151	168556	
10/16/94	2:00	561	43	90	1277	123	159	167	8.8	0.06	151	168707	
10/16/94	2:30		44	90	1277	124	157	169	8.8	0.06	151	168858	
10/16/94	3:00	562	44	90	1273	123	157	167	8.8	0.06	151	169009	
10/16/94	3:30		46	90	1275	125	160	168	8.7	0.06	151	169160	
10/16/94	4:00	563	44	90	1277	124	159	169	8.8	0.06	151	169311	
10/16/94	4:30		45	90	1281	125	160	170	8.7	0.06	151	169462	
10/16/94	5:00	564	44	90	1275	124	159	169	8.8	0.06	151	169613	
10/16/94	5:30		45	90	1276	125	160	174	8.7	0.06	151	169763	
10/16/94	6:00	565	44	90	1278	124	159	170	8.8	0.06	151	169914	
10/16/94	6:30		46	90	1279	125	160	169	8.7	0.06	151	170065	
10/16/94	7:00	566	44	90	1283	124	158	169	8.8	0.06	151	170216	
10/16/94	7:30		45	90	1287	124	158	170	8.8	0.06	151	170367	
10/16/94	8:00	567	45	90	1289	123	159	169	8.9	0.06	151	170518	
10/16/94	8:30		46	90	1290	125	160	170	8.8	0.06	151	170669	
10/16/94	9:00	568	45	90	1289	124	160	170	8.8	0.06	151	170820	
10/16/94	9:30		46	90	1292	125	159	170	8.8	0.06	151	170971	
10/16/94	10:00	569	46	90	1290	124	159	170	8.8	0.06	151	171121	
10/16/94	10:30		45	90	1284	125	160	169	8.8	0.06	151	171272	
10/16/94	11:00	570	45	90	1279	124	158	170	8.8	0.06	151	171423	
10/16/94	11:30		45	90	1278	125	158	169	8.7	0.06	151	171574	
10/16/94	12:00	571	43	90	1276	124	159	168	8.8	0.06	151	171725	
10/16/94	12:30		44	90	1278	125	160	170	8.7	0.06	151	171876	
10/16/94	13:00	572	44	90	1279	125	158	168	8.7	0.06	151	172027	
10/16/94	13:30		45	90	1279	126	158	169	8.7	0.06	151	172178	
10/16/94	14:00	573	45	90	1286	125	153	169	8.8	0.06	151	172328	
10/16/94	14:30		46	90	1293	127	159	170	8.7	0.06	151	172479	
10/16/94	15:00	574	45	90	1293	125	160	170	8.8	0.06	151	172630	
10/16/94	15:30		47	90	1296	127	159	170	8.7	0.06	151	172781	
10/16/94	16:00	575	48	90	1295	126	160	170	8.7	0.06	151	172932	
10/16/94	16:30		48	90	1297	127	160	172	8.7	0.06	151	173083	
10/16/94	17:00	576	48	90	1293	124	159	170	8.8	0.06	151	173234	
10/16/94	17:30		49	90	1298	127	160	172	8.7	0.06	151	173385	
10/16/94	18:00	577	49	90	1295	125	159	171	8.8	0.06	151	173536	
10/16/94	18:30		48	90	1292	126	160	170	8.7	0.06	151	173686	
10/16/94	19:00	578	47	90	1293	125	160	170	8.8	0.06	151	173837	
10/16/94	19:30		48	90	1291	126	160	172	8.7	0.06	151	173988	
10/16/94	20:00	579	47	90	1289	125	160	170	8.8	0.06	151	174139	
10/16/94	20:30		50	90	1299	127	160	173	8.7	0.06	151	174290	
10/16/94	21:00	580	47	90	1300	125	160	172	8.8	0.06	151	174441	
10/16/94	21:30		48	90	1304	126	165	172	8.8	0.06	151	174592	
10/16/94	22:00	581	48	90	1311	124	160	171	8.9	0.06	151	174743	
10/16/94	22:30		49	90	1313	127	163	171	8.8	0.06	151	174894	
10/16/94	23:00	582	50	90	1313	125	163	172	8.9	0.06	151	175044	
10/16/94	23:30		50	90	1318	127	164	173	8.8	0.06	151	175195	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/17/94	0:00	583	49	90	1313	125	163	173	8.9	0.06	151	175346	
10/17/94	0:30		48	90	1312	126	163	173	8.8	0.06	151	175497	
10/17/94	1:00	584	50	90	1310	125	162	172	8.9	0.06	151	175648	
10/17/94	1:30		50	90	1314	127	163	174	8.8	0.06	151	175799	
10/17/94	2:00	585	49	90	1302	125	161	176	8.8	0.06	151	175950	
10/17/94	2:30		49	90	1295	126	164	178	8.7	0.06	151	176101	
10/17/94	3:00	586	48	90	1299	125	160	173	8.8	0.06	151	176251	
10/17/94	3:30		49	90	1295	126	165	175	8.8	0.06	151	176402	
10/17/94	4:00	587	47	90	1293	125	160	173	8.8	0.06	151	176553	
10/17/94	4:30		48	90	1290	126	163	172	8.7	0.06	151	176704	
10/17/94	5:00	588	48	90	1288	125	163	172	8.8	0.06	151	176855	
10/17/94	5:30		49	90	1289	125	160	171	8.7	0.06	151	177006	
10/17/94	6:00	589	49	90	1288	125	160	171	8.7	0.06	151	177157	
10/17/94	6:30		48	90	1288	125	160	172	8.7	0.06	151	177308	
10/17/94	7:00	590	47	90	1285	125	160	171	8.8	0.06	151	177459	
10/17/94	7:30		49	90	1297	126	160	171	8.8	0.06	151	177609	
10/17/94	8:00	591	47	90	1298	125	160	172	8.8	0.06	151	177760	
10/17/94	8:30		50	90	1308	126	160	172	8.8	0.06	151	177911	
10/17/94	9:00	592	49	90	1310	126	160	171	8.8	0.06	151	178062	
10/17/94	9:30		49	90	1317	126	163	173	8.8	0.06	151	178213	
10/17/94	10:00	593	49	90	1317	126	164	174	8.9	0.06	151	178364	
10/17/94	10:30		49	90	1325	127	164	173	8.8	0.06	151	178515	
10/17/94	11:00	594	48	90	1320	126	159	172	8.9	0.06	151	178666	
10/17/94	11:30		48	90	1316	127	163	172	8.8	0.06	151	178817	
10/17/94	12:00	595	48	90	1330	126	160	168	8.9	0.06	151	178967	* 12:00 Beginning of 15 minute pulse cycle.
10/17/94	12:30		47	90	1354	127	160	170	9.0	0.06	151	179118	
10/17/94	13:00	596	47	90	1357	126	167	173	9.0	0.06	151	179269	
10/17/94	13:30		48	90	1348	127	167	179	9.0	0.06	151	179420	
10/17/94	14:00	597	48	90	1340	126	167	181	9.0	0.06	151	179571	
10/17/94	14:30		47	90	1348	127	178	187	9.0	0.06	151	179722	
10/17/94	15:00	598	47	90	1346	126	181	188	9.0	0.06	151	179873	
10/17/94	15:30		47	90	1345	127	185	191	8.9	0.05	151	180024	
10/17/94	16:00	599	46	90	1343	126	182	191	9.0	0.05	151	180174	
10/17/94	16:30		48	90	1344	127	186	192	8.9	0.05	151	180325	
10/17/94	17:00	600	48	90	1348	126	185	194	9.0	0.05	151	180476	
10/17/94	17:30		49	90	1362	127	186	195	9.0	0.05	151	180627	
10/17/94	18:00	601	48	90	1368	126	186	193	9.1	0.05	151	180778	
10/17/94	18:30		50	90	1361	127	185	194	9.0	0.05	151	180929	
10/17/94	19:00	602	49	90	1372	126	186	194	9.1	0.05	151	181080	
10/17/94	19:30		50	90	1380	126	187	195	9.1	0.05	151	181231	
10/17/94	20:00	603	49	90	1378	125	188	202	9.2	0.05	151	181382	
10/17/94	20:30		48	90	1388	126	189	198	9.2	0.05	151	181532	
10/17/94	21:00	604	49	90	1386	125	190	204	9.2	0.05	151	181683	
10/17/94	21:30		50	90	1395	126	192	199	9.2	0.05	151	181834	
10/17/94	22:00	605	48	90	1400	125	190	205	9.3	0.06	151	181985	
10/17/94	22:30		50	90	1392	126	191	200	9.2	0.05	151	182136	
10/17/94	23:00	606	48	90	1392	125	193	207	9.3	0.05	151	182287	
10/17/94	23:30		50	90	1403	126	193	208	9.3	0.05	151	182438	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/18/94	0:00	607	50	90	1405	125	189	198	9.3	0.06	151	182589	
10/18/94	0:30		50	90	1400	126	189	198	9.3	0.06	151	182740	
10/18/94	1:00	608	50	90	1406	125	189	203	9.3	0.06	151	182890	
10/18/94	1:30		49	90	1407	126	188	197	9.3	0.06	151	183041	
10/18/94	2:00	609	49	90	1403	125	186	197	9.3	0.06	151	183192	
10/18/94	2:30		50	90	1400	126	182	194	9.2	0.06	151	183343	
10/18/94	3:00	610	50	90	1398	126	187	202	9.3	0.06	151	183494	
10/18/94	3:30		49	90	1398	127	187	198	9.2	0.06	151	183645	
10/18/94	4:00	611	49	90	1395	125	186	197	9.3	0.06	151	183796	
10/18/94	4:30		49	90	1384	126	187	203	9.2	0.06	151	183947	
10/18/94	5:00	612	48	90	1386	125	185	195	9.2	0.06	151	184098	
10/18/94	5:30		50	90	1396	126	183	200	9.2	0.06	151	184248	
10/18/94	6:00	613	49	90	1386	125	184	192	9.3	0.06	151	184399	
10/18/94	6:30		48	90	1382	126	186	201	9.1	0.06	151	184550	
10/18/94	7:00	614	49	90	1378	125	183	197	9.2	0.06	151	184701	
10/18/94	7:30		50	90	1397	127	185	192	9.2	0.06	151	184852	
10/18/94	8:00	615	50	90	1405	126	184	199	9.3	0.06	151	185003	
10/18/94	8:30		50	90	1417	126	182	193	9.3	0.06	151	185154	
10/18/94	9:00	616	49	90	1410	125	179	190	9.4	0.06	151	185305	
10/18/94	9:30		49	90	1412	127	180	190	9.3	0.06	151	185455	
10/18/94	10:00	617	49	90	1405	126	180	190	9.3	0.06	151	185606	
10/18/94	10:30		50	90	1401	127	176	190	9.2	0.06	151	185757	
10/18/94	11:00	618	46	90	1385	125	179	187	9.3	0.06	151	185908	
10/18/94	11:30		46	90	1380	126	179	188	9.1	0.06	151	186059	
10/18/94	12:00	619	44	90	1365	125	179	188	9.1	0.06	151	186210	
10/18/94	12:30		45	90	1379	126	181	191	9.2	0.06	151	186361	
10/18/94	13:00	620	46	90	1374	125	181	190	9.2	0.06	151	186512	
10/18/94	13:30		45	90	1381	126	176	192	9.2	0.06	151	186663	
10/18/94	14:00	621	44	90	1378	125	182	192	9.2	0.06	151	186813	
10/18/94	14:30		46	90	1385	126	184	192	9.2	0.06	151	186964	
10/18/94	15:00	622	45	90	1381	126	183	192	9.2	0.06	151	187115	
10/18/94	15:30		45	90	1376	126	182	193	9.1	0.06	151	187266	
10/18/94	16:00	623	45	90	1378	125	183	192	9.2	0.06	151	187417	
10/18/94	16:30		45	90	1379	125	183	193	9.2	0.06	151	187568	
10/18/94	17:00	624	45	90	1368	125	184	192	9.2	0.06	151	187719	
10/18/94	17:30		45	90	1366	125	184	193	9.1	0.06	151	187870	
10/18/94	18:00	625	45	90	1372	125	185	193	9.2	0.06	151	188021	
10/18/94	18:30		45	90	1373	125	185	194	9.2	0.06	151	188171	
10/18/94	19:00	626	45	90	1371	125	184	193	9.2	0.06	151	188322	
10/18/94	19:30		46	90	1374	126	184	196	9.1	0.06	151	188473	
10/18/94	20:00	627	44	90	1363	124	186	194	9.2	0.06	151	188624	
10/18/94	20:30		47	90	1373	125	182	196	9.2	0.06	151	188775	
10/18/94	21:00	628	45	90	1370	125	186	194	9.2	0.06	151	188926	
10/18/94	21:30		45	90	1362	125	185	196	9.1	0.06	151	189077	
10/18/94	22:00	629	47	90	1374	125	186	196	9.2	0.06	151	189228	
10/18/94	22:30		48	90	1392	126	187	198	9.2	0.06	151	189378	
10/18/94	23:00	630	50	90	1398	126	187	197	9.2	0.06	151	189529	
10/18/94	23:30		50	90	1405	127	178	197	9.2	0.06	151	189680	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/19/94	0:00	631	49	90	1390	126	187	196	9.2	0.06	151	189831	
10/19/94	0:30		50	90	1397	127	187	196	9.2	0.06	151	189982	
10/19/94	1:00	632	50	90	1394	126	185	195	9.2	0.06	151	190133	
10/19/94	1:30		50	90	1404	127	186	195	9.2	0.06	151	190284	
10/19/94	2:00	633	49	90	1388	126	184	193	9.2	0.06	151	190435	
10/19/94	2:30		49	90	1394	127	185	197	9.2	0.06	151	190586	
10/19/94	3:00	634	49	90	1387	126	180	194	9.2	0.06	151	190736	
10/19/94	3:30		50	90	1400	127	187	195	9.2	0.06	151	190887	
10/19/94	4:00	635	49	90	1403	127	185	195	9.2	0.06	151	191038	
10/19/94	4:30		50	90	1404	127	186	195	9.2	0.06	151	191189	
10/19/94	5:00	636	50	90	1414	127	185	196	9.2	0.06	151	191340	
10/19/94	5:30		49	90	1411	127	186	197	9.2	0.06	151	191491	
10/19/94	6:00	637	50	90	1409	127	183	197	9.2	0.06	151	191642	
10/19/94	6:30		50	90	1408	127	189	197	9.2	0.06	151	191793	
10/19/94	7:00	638	50	90	1413	126	185	196	9.3	0.06	151	191944	
10/19/94	7:30		48	90	1393	126	186	195	9.2	0.06	151	192094	
10/19/94	8:00	639	47	90	1386	125	187	196	9.2	0.06	151	192245	
10/19/94	8:30		46	90	1384	125	186	196	9.2	0.06	151	192396	
10/19/94	9:00	640	47	90	1386	125	184	197	9.2	0.06	151	192547	
10/19/94	9:30		46	90	1375	125	175	192	9.2	0.06	151	192698	
10/19/94	10:00	641	47	90	1377	126	185	194	9.2	0.06	151	192849	
10/19/94	10:30		48	90	1384	126	188	198	9.1	0.05	151	193000	
10/19/94	11:00	642	48	90	1396	126	187	199	9.2	0.06	151	193151	
10/19/94	11:30		49	90	1403	126	187	196	9.3	0.06	151	193301	
10/19/94	12:00	643	47	90	1390	126	186	194	9.2	0.06	151	193452	
10/19/94	12:30		48	90	1395	126	182	195	9.2	0.06	151	193603	
10/19/94	13:00	644	46	90	1379	125	182	197	9.2	0.06	151	193754	
10/19/94	13:30		43	90	1347	125	182	190	9.1	0.06	151	193905	
10/19/94	14:00	645	41	90	1331	120	175	188	9.3	0.06	151	194056	
10/19/94	14:30		41	80	1322	119	175	184	8.3	0.05	134	194190	
10/19/94	15:00	646	40	80	1309	116	172	183	8.5	0.05	134	194324	
10/19/94	15:30		38	80	1300	114	171	179	8.5	0.05	134	194458	
10/19/94	16:00	647	36	80	1273	111	159	177	8.6	0.06	134	194592	
10/19/94	16:30		35	76	1255	110	165	172	8.2	0.05	127	194720	
10/19/94	17:00	648	34	76	1254	110	164	172	8.1	0.05	127	194847	
10/19/94	17:30		35	80	1253	110	165	173	8.5	0.06	134	194981	
10/19/94	18:00	649	34	76	1253	109	163	175	8.2	0.05	127	195109	
10/19/94	18:30		33	76	1250	109	164	173	8.1	0.05	127	195236	
10/19/94	19:00	650	34	76	1248	109	158	173	8.2	0.06	127	195364	
10/19/94	19:30		34	76	1249	110	163	172	8.1	0.05	127	195491	
10/19/94	20:00	651	34	76	1248	109	164	173	8.2	0.05	127	195618	
10/19/94	20:30		33	76	1245	110	165	172	8.1	0.05	127	195746	
10/19/94	21:00	652	32	76	1239	109	164	172	8.1	0.05	127	195873	
10/19/94	21:30		34	76	1240	109	163	172	8.1	0.05	127	196001	
10/19/94	22:00	653	33	76	1238	109	160	172	8.1	0.05	127	196128	
10/19/94	22:30		34	76	1239	109	156	172	8.1	0.06	127	196255	
10/19/94	23:00	654	34	76	1242	109	163	171	8.2	0.05	127	196383	
10/19/94	23:30		34	76	1241	109	164	172	8.1	0.05	127	196510	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/KO	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/20/94	0:00	655	33	76	1244	109	163	171	8.2	0.05	127	196638	
10/20/94	0:30		34	76	1247	109	163	171	8.1	0.05	127	196765	
10/20/94	1:00	656	33	76	1242	109	163	172	8.2	0.05	127	196893	
10/20/94	1:30		33	76	1239	109	164	171	8.1	0.05	127	197020	
10/20/94	2:00	657	34	76	1239	109	159	172	8.1	0.05	127	197147	
10/20/94	2:30		34	76	1238	109	162	172	8.1	0.05	127	197275	
10/20/94	3:00	658	33	76	1236	109	163	172	8.1	0.05	127	197402	
10/20/94	3:30		34	76	1236	109	165	173	8.1	0.05	127	197530	
10/20/94	4:00	659	34	76	1235	109	164	172	8.1	0.05	127	197657	
10/20/94	4:30		33	76	1232	109	165	172	8.1	0.05	127	197784	
10/20/94	5:00	660	34	76	1233	109	160	171	8.1	0.05	127	197912	
10/20/94	5:30		32	76	1230	109	163	173	8.1	0.05	127	198039	
10/20/94	6:00	661	33	76	1233	109	164	173	8.1	0.05	127	198167	
10/20/94	6:30		35	76	1236	109	164	173	8.1	0.05	127	198294	
10/20/94	7:00	662	34	76	1242	109	165	173	8.1	0.05	127	198422	
10/20/94	7:30		33	76	1231	109	165	173	8.1	0.05	127	198549	
10/20/94	8:00	663	34	76	1232	109	165	172	8.1	0.05	127	198676	
10/20/94	8:30		35	76	1237	110	163	173	8.1	0.05	127	198804	
10/20/94	9:00	664	32	76	1221	108	163	171	8.1	0.05	127	198931	
10/20/94	9:30		33	76	1224	109	164	172	8.0	0.05	127	199059	
10/20/94	10:00	665	34	76	1228	109	164	172	8.1	0.05	127	199186	
10/20/94	10:30		33	76	1228	109	164	173	8.1	0.05	127	199313	
10/20/94	11:00	666	34	76	1228	109	164	173	8.1	0.05	127	199441	
10/20/94	11:30		34	76	1228	109	165	172	8.1	0.05	127	199568	
10/20/94	12:00	667	32	76	1230	109	164	171	8.1	0.05	127	199696	
10/20/94	12:30		33	76	1226	109	166	174	8.0	0.05	127	199823	
10/20/94	13:00	668	33	76	1224	109	165	173	8.0	0.05	127	199950	
10/20/94	13:30		34	76	1225	110	166	173	8.0	0.05	127	200078	
10/20/94	14:00	669	35	76	1236	110	166	174	8.1	0.05	127	200205	
10/20/94	14:30		33	76	1224	110	163	171	8.0	0.05	127	200333	
10/20/94	15:00	670	34	76	1231	109	165	173	8.1	0.05	127	200460	
10/20/94	15:30		33	76	1217	109	160	171	8.0	0.05	127	200588	
10/20/94	16:00	671	33	76	1226	109	165	172	8.1	0.05	127	200715	
10/20/94	16:30		33	76	1217	109	164	173	8.0	0.05	127	200842	
10/20/94	17:00	672	32	76	1216	109	162	172	8.0	0.05	127	200970	
10/20/94	17:30		32	76	1214	109	164	172	8.0	0.05	127	201097	
10/20/94	18:00	673	32	76	1218	109	164	172	8.0	0.05	127	201225	
10/20/94	18:30		33	76	1220	109	163	172	8.0	0.05	127	201352	
10/20/94	19:00	674	34	76	1224	108	158	173	8.1	0.05	127	201479	
10/20/94	19:30		33	76	1228	109	164	173	8.1	0.05	127	201607	
10/20/94	20:00	675	33	76	1227	109	164	172	8.1	0.05	127	201734	
10/20/94	20:30		34	76	1229	109	166	172	8.1	0.05	127	201862	
10/20/94	21:00	676	33	76	1225	109	165	172	8.1	0.05	127	201989	
10/20/94	21:30		35	76	1224	109	167	174	8.0	0.05	127	202117	
10/20/94	22:00	677	34	76	1223	108	164	172	8.1	0.05	127	202244	
10/20/94	22:30		33	76	1219	109	166	172	8.0	0.05	127	202371	
10/20/94	23:00	678	33	76	1220	108	163	172	8.1	0.05	127	202499	
10/20/94	23:30		32	76	1218	109	165	173	8.0	0.05	127	202626	

TABLE 1 - ADVANCED PARTICLE FILTER SUMMARY OF CONDITIONS, TEST RUN 24 (SEPT 22 THRU OCT 21, 1994)

+ Estimated from previous 1994 test data.

DATE	TIME	HRS	MWe	FLOW+ KPPH	T DEG F	P PSIG	BASELINE DP(ts) IN WG	TRIGGER IN WG	FACE VELOCITY FT/MIN	RELATIVE PERME-ABILITY K/K0	ASH FILTERED LB	TOTAL ASH LB	REMARKS
10/21/94	0:00	679	33	76	1217	98	156	166	8.8	0.06	127	202754	
10/21/94	0:30		32	76	1219	99	156	166	8.7	0.06	127	202881	
10/21/94	1:00	680	32	76	1222	99	159	164	8.8	0.06	127	203008	
10/21/94	1:30		34	76	1226	99	148	166	8.8	0.06	127	203136	
10/21/94	2:00	681	33	76	1224	99	158	166	8.8	0.06	127	203263	
10/21/94	2:30		34	76	1227	99	159	166	8.7	0.06	127	203391	
10/21/94	3:00	682	36	76	1235	99	157	165	8.8	0.06	127	203518	
10/21/94	3:30		35	76	1237	100	159	166	8.8	0.06	127	203645	
10/21/94	4:00	683	35	76	1233	100	153	171	8.7	0.06	127	203773	
10/21/94	4:30		34	76	1236	99	155	163	8.8	0.06	127	203900	
10/21/94	5:00	684	35	76	1241	100	155	164	8.8	0.06	127	204028	
10/21/94	5:30		34	76	1230	100	157	164	8.7	0.06	127	204155	
10/21/94	6:00	685	34	76	1231	99	156	166	8.8	0.06	127	204283	
10/21/94	6:30		34	76	1230	100	157	166	8.7	0.06	127	204410	
10/21/94	7:00	686	32	76	1228	98	154	169	8.8	0.06	127	204537	
10/21/94	7:30		32	76	1223	99	155	163	8.7	0.06	127	204665	
10/21/94	8:00	687	34	76	1212	98	149	162	8.7	0.06	127	204792	
10/21/94	8:30		33	76	1225	99	155	163	8.7	0.06	127	204920	
10/21/94	9:00	688	35	76	1235	100	156	164	8.8	0.06	127	205047	
10/21/94	9:30		35	76	1240	100	158	166	8.7	0.06	127	205174	
10/21/94	10:00	689	35	76	1242	100	155	164	8.8	0.06	127	205302	
10/21/94	10:30		36	76	1243	99	157	164	8.8	0.06	127	205429	
10/21/94	11:00	690	38	76	1260	98	152	165	9.0	0.06	127	205557	
10/21/94	11:30		35	76	1261	98	135	162	9.0	0.07	127	205684	* 11:39 Combustor trip, scheduled shutdown.

APPENDIX D

TIDD APF BORESCOPE INSPECTION

G.J.Bruck

MEMO TO FILE: AEP 19.0
DATE: October 26, 1994

The PFBC at Tidd was shut down on October 21, 1994 to resolve a number of maintenance issues. A borescope inspection was performed on October 25, 1994.

Inspection through nozzles 8A and 8C revealed the following observations relative to the top plenum candles:

(1) Cluster A appeared clean and without ash bridging.
(2) Clusters B and C appeared to have ash bridges near the bottoms of some candles between candles and/or extending back to the support tube/ash shed. The bridges extended as much as 1/3 up along some candles.
(3) Cluster A appeared to have 5 missing candles - all broken off near to their top flange.

Inspection through nozzles 5A and 5C revealed the following observations relative to the middle plenum candles:

(1) Cluster A appeared clean and without ash bridging.
(2) Cluster B appeared to have ash bridges near the bottoms of at least 5 candles and cluster C appeared to have ash behind 2 candles and on its ash shed.
(3) Cluster A appeared to have 4 missing candles and cluster C appeared to have 6 missing candles -all broken off near to their top flange.
(4) Of the experimental candles that could be viewed in cluster B, none appeared to be missing.

Inspection through nozzle 4A revealed one evidence of a bridge between bottom plenum candles. One outer row candle was missing in one plenum and one non-outer row candle appeared to be missing in another plenum.

The general buildup of ash on candles was assessed to be approximately 1/8 inch, however, some areas were clean of ash and some areas may have had up to 1/4 inch of ash.

Visual and borescopic inspection outside and inside respectively of the nine back pulse pipes revealed that the pipes for cluster A bottom plenum and cluster B bottom plenum were cracked longitudinally. The cracks extended from approximately 2 feet to 3 feet from the flanged end of the assembly. One of the cracks followed one edge of the pipe weld then crossed to the opposite edge of the weld. Penetrant inspection on the outside of the 7 pipes that showed no cracks revealed no relevant indications.

G. J. Bruck

APPENDIX E

GENERAL INSPECTION OF TIDD FILTER INTERNALS - OCTOBER 1994

M.A.Alvin

October 27, 1994

M. J. Mudd, AEP
J. D. Hoffman, AEP
T. E. Lippert, W-STC
G. J. Bruck, W-STC
R. A. Dennis, DOE/METC
T. J. McMahon, DOE/METC
AEP File

Subject: W-APF LIFT - OCTOBER 27, 1994

Top Filter Plenums

During the W-APF lift at AEP on October 27, 1994 at least two candles were seen to be broken from the C/T plenum as the filter internals were lifted from the vessel. These candles were Schumacher Dia Schumalith F40 filters which had previously been used for testing at Tidd, and which were installed in the C/T plenum during the June 1994 re-candling effort. As shown in Table 1 and Figure 1, a total of seven (7) Schumacher Dia Schumalith F40 candles had broken in this general area, exposing fresh fractured surfaces directly below the flange (i.e., C/T-1, C/T-2, C/T-22, C/T-21, C/T-20, C/T-19, and C/T-18). The lengths of the filter segments that remained in the holders will be measured and reported once all pieces are returned to Westinghouse. Note that all seven of the fresh fractured candle filters were closest to, or in the general vicinity of the shroud. Bridging in the C/T plenum existed between candles C/T-4, C/T-5, and C/T-6, and between C/T-7 and C/T-8.

Although virtually no ash bridges were observed in plenum A/T, six (6) Schumacher Dia Schumalith F40 candles had failed prior to shut-down, exposing ash-covered fractured surfaces. The fractured surfaces were again directly below the flange. The fractured candle locations included A/T-5, A/T-9, A/T-10, A/T-13, A/T-14, and A/T-19. As in plenum C/T, plenum A/T contained previously PFBC-exposed Schumacher Dia Schumalith F40 candle filters.

In plenum B/T only one (1) new Schumacher Dia Schumalith F40 candle filter was observed to have been broken. This candle was located in position B/T-22, which was close to the shroud. The fractured surface was, however, ash-covered, implying that failure did not occur during the lift.

The Schumacher Dia Schumalith F40 candle filter which was positioned in B/T-16 had previously been exposed to the PFBC gas environment for 2,572 hours, prior to installation in the W-APF vessel in June 1994. During the October 27, 1994 inspection, B/T-16 was seen to be intact. Heavy ash bridges were observed between B/T-3, B/T-4, and B/T-5; between B/T-7 and B/T-8; and around B/T-20.

Fail-safes were not installed above any of the candle filter elements that were positioned in the top three plenums. In the general area of the fractured candle filters, adjacent candles, and/or the cluster support pipe were seen to be relatively clean.

Middle Filter Plenums

In June 1994 a false bottom was installed on plenum A/M. Four (4) previously exposed Schumacher Dia Schumalith F40 candle filters were observed to have been broken in plenum A/M during the June - October 1994 test campaign. These included candles positioned in locations A/M-10, A/M-11, A/M-13, and A/M-14. Note that the Schumacher Dia Schumalith F40 candle filter which was positioned in A/M-12 remained intact. All fractured surfaces in this plenum were ash-covered. Ash bridging in this plenum was not apparent.

Candles which were installed in plenum B/M included eight Pall Vitropore 442T filters, three 3M CVI-SiC composite filters, eight Coors alumina/mullite filters, and three DuPont PRD-66 filters. Post-test inspection indicated that two (2) of the 3M composite filters had failed, with the metal filter insert, gasketing, and double layered flange wall remaining firmly positioned within the holder mounts. The third 3M candle remained intact, and was firmly positioned within the filter holder. The gasket sleeve which surrounded one of the failed 3M filters was frayed, implying that failure had occurred prior to shut-down, and had experienced direct pulse cycling. Candle filter failure during test operation was also supported by the ash-covered fractured surface of the 3M composite matrix. Although the gasket sleeve which surrounded the second failed 3M filter was not frayed, the sleeve was heavily covered with ash (i.e., inside and outside), and as the first failed 3M filter, the filter fractured surface also appeared to be ash covered. A closer inspection will be made of the remaining 3M CVI-SiC composite pieces in an attempt to ascertain the nature and/or mode of filter failure, and its relation to the metal insert, holder mount, and possibly gasket configuration. Note that the inner sealing gasket surface appeared to be clean (i.e., an adequate seal was maintained).

The residual ash cake pattern that remained along the surface of the 3M composite candle was ~1/8 inch thick. The cake appeared to be evenly distributed, without any area along the OD surface of the 3M filter containing an abnormal quantity of the residual ash cake layer. Pin-holes appeared along the residual ash cake, perhaps at the center of the diamond-pattern, outer net, containment layer. A closer inspection will be made to identify the impact of the fibrous outer layer on the resulting ash cake morphology.

Heavy ash bridging was evident along the bottom of the Vitropore 442T candle filter elements (i.e., B/M-10, B/M-11, B/M-12, B/M-13, B/M-14, and B/M-15 (3M); and B/M-18 and B/M-19), as well as behind and between the Coors alumina/mullite candle filters (i.e., B/M-21, B/M-22; and B/M-2, B/M-3, B/M-4, B/M-5, and B/M-6). All Vitropore 442T and Coors alumina/mullite candle filters remained intact during this segment of testing.

The residual ash cake that remained along the Vitropore 442T candle filters resembled conditioned cake layers that formed along the surface of the Schumacher Dia Schumalith F40 candle filters.

A heavy ash build-up resulted along the bottom and between the Coors alumina/mullite candle filters (i.e., B/M-2, B/M-3, B/M-4, B/M-5, and B/M-6). A very light residual ash layer was observed along the Coors alumina/mullite candle OD surface which was not contacted via the bridged ash. Surface texture/smoothness of both the Coors alumina/mullite and PRD-66 candles may have a significant role in the residual thickness and morphology of the conditioned ash cake layer that remains along the filter OD surfaces.

All of the DuPont PRD-66 candle filters remained intact during this segment of testing. Ash bridging was not evident at the bottom of the DuPont PRD-66 candle filters. The white OD surface of the PRD-66 candle filter body was evident in several areas (i.e., nearly complete ash removal). The residual ash cake layer that remained along the PRD-66 candle filters which were positioned in B/M-8 and B/M-9 showed evidence of the diamond weave fiber pattern. The PRD-66 candle filter located in B/M-7 had a significantly thicker and different ash cake morphology in comparison to the PRD-66 candles located in B/M-8 and B/M-9.

During removal of the initially intact DuPont PRD-66 filter which was positioned in B/M-7, the candle was broken directly below the flange, exposing a fresh fractured surface. The entire candle ID was filled with ash (i.e., up to 1-3 inches below the fractured surface). The ash-filled candle filter ID was considered to have resulted from the off-centered positioning of the top gasket seal, which provided a leak path for the dirty gas stream. Efforts will be directed to determining the effectiveness of the PRD-66 OD membrane for this particular candle filter.

In plenum C/M, six (6) previously exposed Schumacher Dia Schumalith F40 candle filters had been broken during this segment of testing. All fractured surfaces appeared to be ash-covered. The positions of the fractured candles (i.e., C/M-9, C/M-10, C/M-11, C/M-12, C/M-13, and C/M-14) were adjacent to or in close proximity of the candles which had fractured along plenum A/M. The residual ash cake layer that remained along the Schumacher Dia Schumalith F40 candle filters in plenum C/M was thinner and more "nodular" in comparison to the thicker ash cake layer which resulted along the Schumacher FT20 candles which were also positioned in plenum C/M. Note that all of the Schumacher FT20 candle filters remained intact during this segment of testing. Ash bridging was not evident in plenum C/M.

Bottom Filter Plenums

Candle filters located in plenum A/B remained intact with the exception of two (2) filter elements located in positions A/B-1 and A/B-22. Both filters which were closest to the shroud exhibited a fresh fractured surface implying that failure had occurred during either the filter/plant shut-down or during the lift. Ash bridging was observed between candles located in positions A/B-17 and A/B-18. The rather pronounced nodular or "dumpling-like" ash was distinctly different in comparison to ash which remained along the Schumacher Dia Schumalith F40 candle filters located in the top and middle plenums. The nodules existed along the candle filter body, particularly along the bottom end cap area. Note that with the exception of A/B-6, A/B-16 (surveillance candle), and A/B-17, the A/B plenum candles had initially been installed during the November 1993 re-candling effort, and had not been removed nor cleaned during the June 1994 re-candling effort.

In plenum B/B, one of the previously tested Schumacher Dia Schumalith F40 candles was observed to have failed (i.e., B/B-10), exposing an ash-covered fractured surface. Plenum B/B contained "light" ash bridging, particularly between candles positioned in B/B-18, B/B-19, and B/B-36.

Although ash bridging was not observed in plenum C/B, the previously tested Schumacher Dia Schumalith F40 candle filter which was positioned in C/B-35 had failed, exposing a fresh fractured surface. C/B-35 was the only inner ring candle which was observed to have been broken during testing. C/B-35 was positioned directly diagonal to the Schumacher Dia Schumalith F40 surveillance candle filter positioned in location C/B-16. Note that all three Schumacher Dia Schumalith F40 surveillance candle filters which were located in the three bottom plenums (i.e., A/B-16, B/B-16, and C/B-16) remained intact throughout this segment of PFBC testing.

General Comments

- All candle filter elements which were utilized in the W-APF vessel were 1.5 m in length.

- Only the outer ring of candles were installed and operated in the top and middle plenums (June - October 1994). Full candle arrays were operated in the bottom plenums.

- Only the experimental candles were equipped with the fail-safe units. Previously the nine Schumacher Dia Schumalith F40 surveillance candle filters were equipped with the fail-safe device. During the June - October 1994 test segment, the Schumacher Dia Schumalith F40 candles were operated without the use of the fail-safe device.

- Only plenum A/M was equipped with the false bottom.

- With the exception of six new Schumacher Dia Schumalith F40 candle filters and three Schumacher Dia Schumalith F40 surveillance candle filters, all of the bottom plenum candle filters were installed in November 1993, and continued to be operated in the PFBC environment.

- When ash bridging resulted within the various plenum arrays, it occurred predominantly along the bottom of the filter elements. In the top and middle plenums, ash bridging contacted the plenum support pipe/ash shed. Minimal bridging resulted in the bottom plenums.

- Previously tested Schumacher Dia Schumalith F40 surveillance candle filters were installed in the top and bottom plenums, but not in the middle plenums.

- All three of the Schumacher Dia Schumalith F40 candle filters which experienced PFBC operation since the initiation of testing in the W-APF vessel at AEP have remained intact, surviving 3,083 hours prior to the June 1994 re-candling effort, and an additional ~1700 hours of operating life. These surveillance candles were located in the bottom plenums. A fourth Schumacher Dia Schumalith F40 surveillance candle was positioned in a top plenum. Prior to the June 1994 re-candling effort, this candle experienced 2,572 hours of PFBC test operation. This filter also remained intact during the June - October 1994 test campaign.

- In the general area of the fractured candle filters, adjacent candles, and/or the cluster support pipe were seen to be relatively clean.

- Extensive bowing of the clay bonded silicon carbide candle filters was not evident during post-test inspection conducted on October 27, 1994.

- Various ash cake morphologies are evident along the candle filters. This occurred not only along the Schumacher Dia Schumalith F40 candle filters, but the ash cake morphology also significantly varied along the OD surfaces of the experimental candle filters. The surface texture of the Coors alumina/mullite and DuPont PRD-66 filters typically had the least residual conditioned ash cake layer in comparison to the nodular, thicker layers that formed along the clay bonded silicon carbide candles, and/or the pin-hole features that resulted along the 3M CVI-SiC composite candles.

Best Regards,

Mary Anne

Mary Anne Alvin
Advanced Fossil Energy Systems

TABLE 1

SUMMARY OF THE FRACTURED CANDLE FILTER LOCATIONS
-- October 27, 1994 --

Plenum	Number Broken	Locations	Filter Type	Fracture Surface	Plenum Bridging
A/T	6	A/T-5, A/T-9 A/T-10, A/T-13 A/T-14, A/T-19 Random Positions	F40 * Prior Testing	Dirty	No Ash Bridges
B/T	1	B/T-22 Adjacent To Shroud	F40 Prior Testing	Dirty	Heavy Ash Bridging B/T-3, B/T-4, B/T-5; B/T-7 - B/T-8; B/T-20
C/T	7	C/T-1, C/T-2 C/T-22, C/T-21 C/T-20, C/T-19 C/T-18 Close/Adjacent To Shroud	F40 Prior Testing	Clean	Bridging Between C/T-4, C/T-5, C/T-6; C/T-7 and C/T-8

* Schumacher Dia Schumalith F40

TABLE 1 (Continued)

SUMMARY OF THE FRACTURED CANDLE FILTER LOCATIONS
-- October 27, 1994 --

Plenum	Number Broken	Locations	Filter Type	Fracture Surface	Plenum Bridging
A/M	4	A/M-10, A/M-11 A/M-13, A/M-14 Failure Closest To Adjacent Plenums; False Bottom Utilized	F40 Prior Testing	Dirty	No Bridging
B/M	2	B/M-16, B/M-17 Fail-Safes Used	3M	Dirty	Heavy Bridging B/M-2 Through B/M-6; B/M-10 Through B/M-15 B/M-18 Through B/M-22
C/M	6	C/M-9, C/M-10 C/M-11, C/M-12 C/M-13, C/M-14 Failure Closest To Adjacent Plenums	F40 Prior Testing	Dirty	No Bridging

TABLE 1 (Continued)

SUMMARY OF THE FRACTURED CANDLE FILTER LOCATIONS
-- October 27, 1994 --

Plenum	Number Broken	Locations	Filter Type	Fracture Surface	Plenum Bridging
A/B	2	A/B-1, A/B-22 Adjacent To Shroud	F40 Prior Testing	Clean	Ash Bridging Between A/B-17 and A/B-18
B/B	1	B/B-10 Close To Adjacent Plenum	F40 Prior Testing	Dirty	Light Ash Bridging Between B/B-18, B/B-19, and B/B-36
C/B	1	C/B-35 Inner Ring Candle	F40 Prior Testing	Clean	No Bridges

Figure 1 - W-APF Testing: June - October 1994

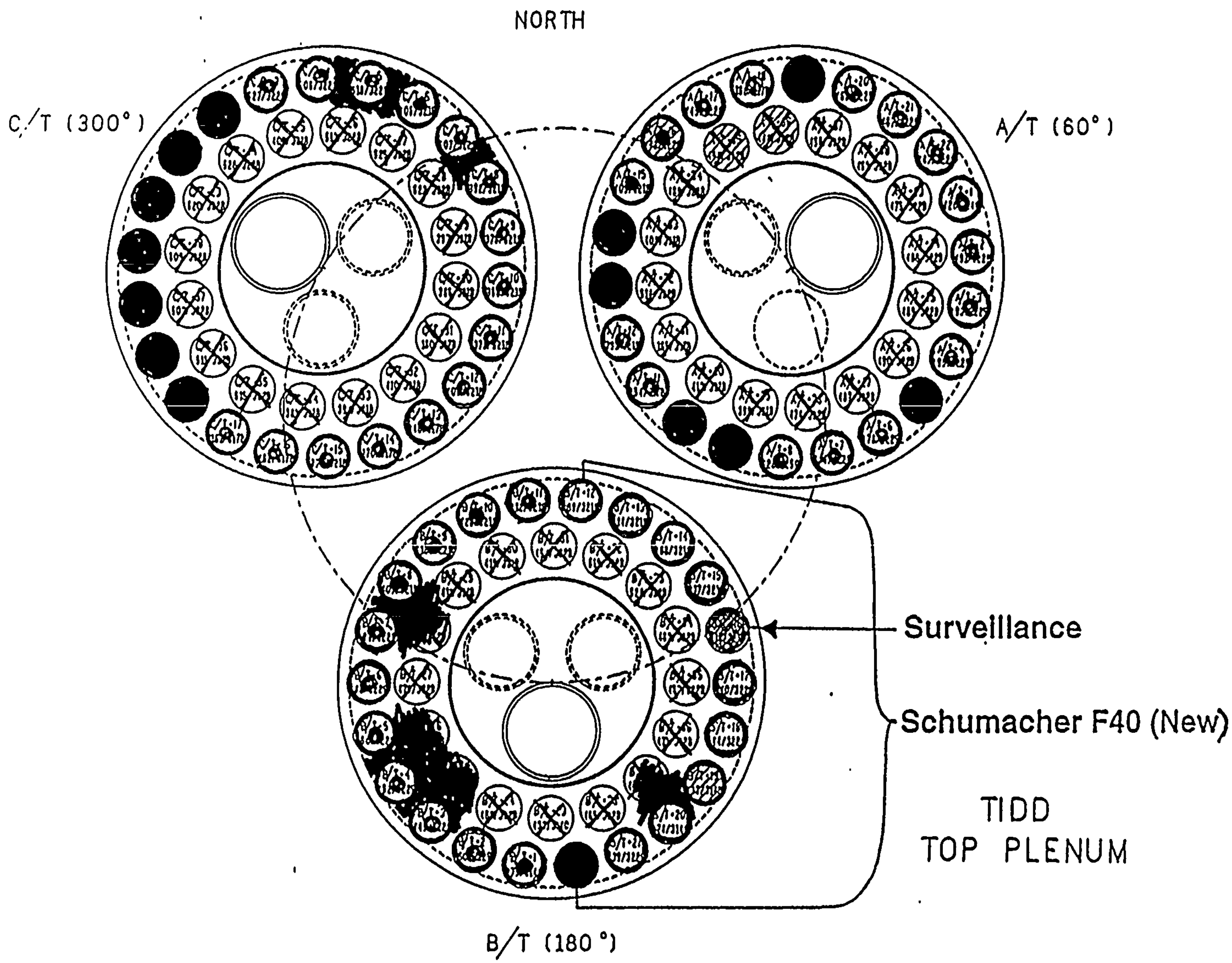


Figure 1 - W-APF Testing: June - October 1994

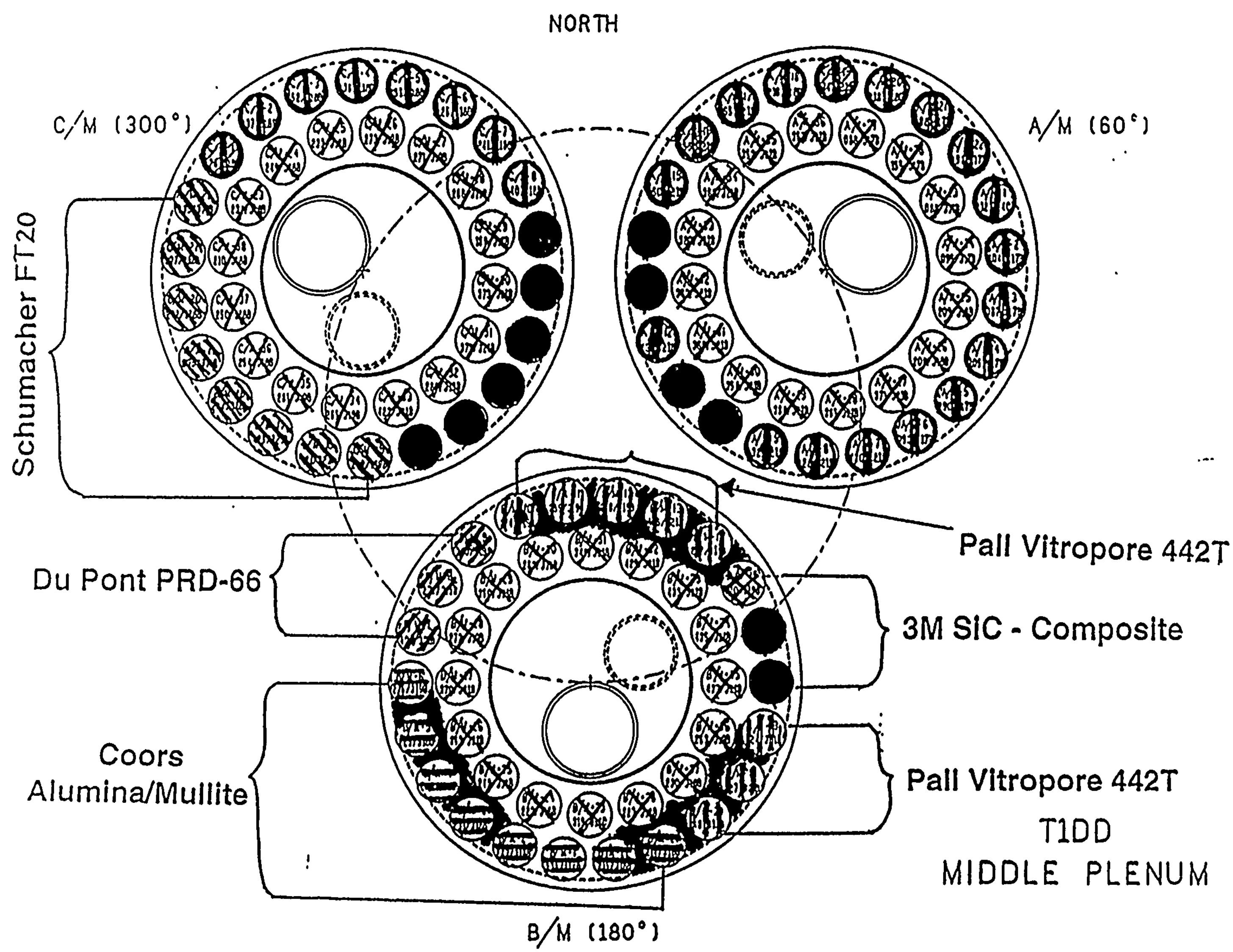
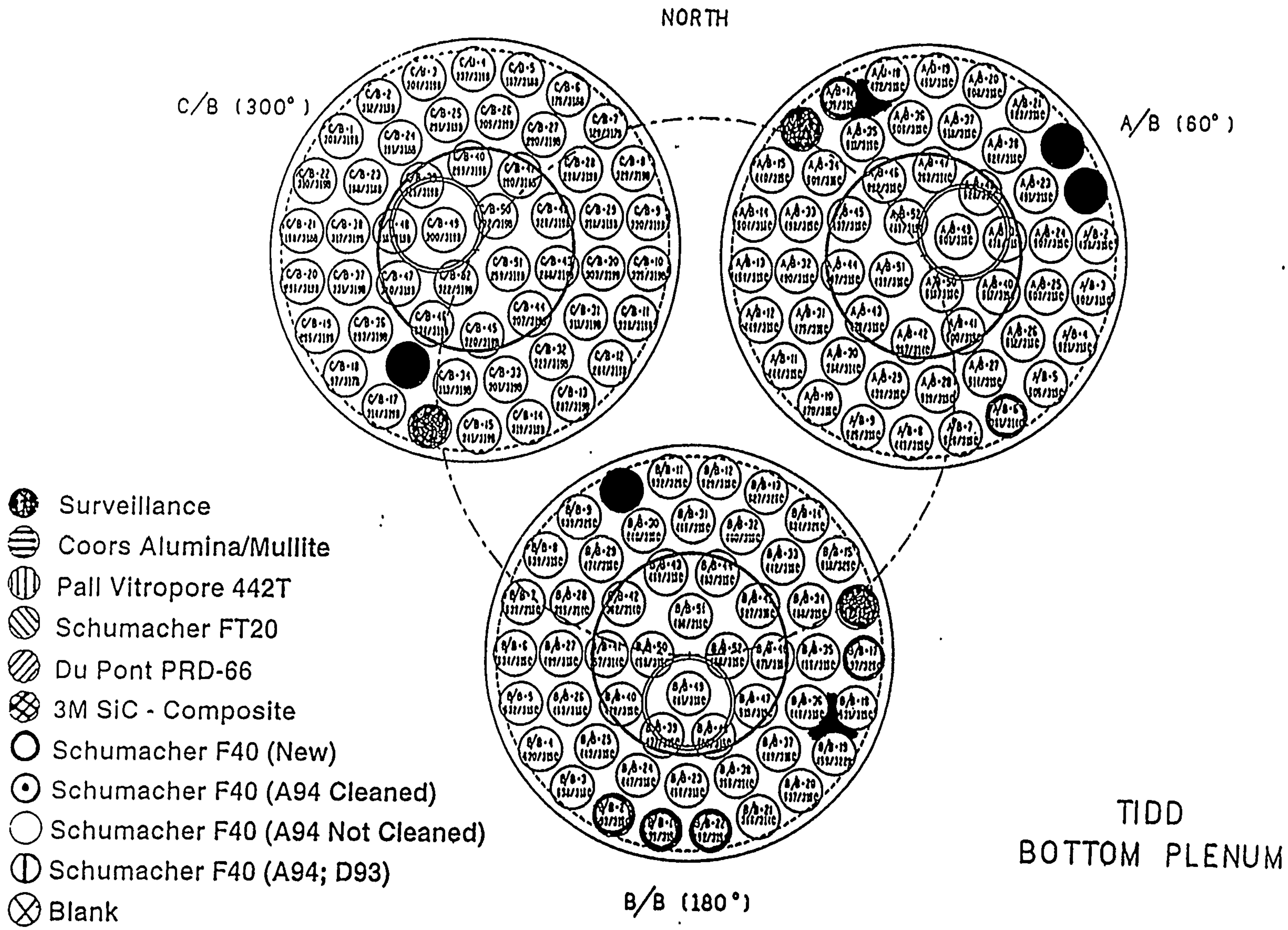


Figure 1 - W-APF Testing: June - October 1994



APPENDIX F

TALLY OF TIDD FILTERS

M.A.Alvin

November 9, 1994

T.E.Lippert
G.J.Bruck
AEP File

Subject: Candle Filter Tally

Candles Broken At Time Of Lift		Total Number Of Broken Candles	Comment
A/T	6	7	1ID not given
B/T	1	3	
C/T	7	7	
A/M	4	7	1 ID not given
B/M	2	2	
C/M	6	9	1 ID not given
A/B	2	8	
B/B	1	9	2 IDs not given; 2 duplicates
C/B	1	9	1 ID in question
Total	30	61	

Bottom plenum ID numbers will be confirmed with the original listing from November 1993. Top and middle plenum ID numbers will be confirmed with the June 1994 listing. Final templates will then be made.

Many of the candles that were broken during removal were indicated to have broken by themselves. Residual strength of the filters and/or handling during removal may be in question.

A summary sheet will be prepared illustrating whether the individual candles had a dusting of ash along their ID, or whether significant accumulation of ash had been collected inside the ID.

M.A.Alvin

APPENDIX G

ASH FORMATIONS IN THE W-APF
- OCTOBER 1994 POST-TEST INSPECTION

M.A.Alvin

ASH FORMATIONS IN THE W-APF
-- OCTOBER 1994 POST-TEST INSPECTION --

M. A. Alvin
December 22, 1994

ABSTRACT

Reinstallation of candle filters in the Westinghouse Advanced Particulate Filtration (W-APF) system at Tidd was completed in June 1994. During the initial 1015 hours of operation (i.e., July through September 1994; Test Runs 19-23; Test Segment 4), all of the advanced second generation candle filters remained functional and intact. Operation continued in the pressurized fluidized-bed combustion (PFBC) gas environment for an additional 690.5 hours in Test Run 24 during which time two of the 3M CVI-SiC composite filters failed. In this report we will describe the ash bridging which resulted within the various candle filter arrays.

ASH CAKE FORMATIONS

Second generation advanced candle filter elements were installed in the middle plenums of clusters B and C (i.e., B/M and C/M, respectively). These included eight Coors P-100A-1 alumina/mullite candles, eight Pall Vitropore 442T candles, three 3M CVI-SiC composite candles, and three DuPont PRD-66 candles in plenum B/M, and an additional eight Schumacher Dia Schumalith FT20 candles in plenum C/M. Four surveillance candles were included during this segment of testing. The surveillance filters were positioned in B/T-16 (S328/314C; 2572 hrs), A/B-16 (S228/318B; 3038 hrs), B/B-16 (S422/322B; 3038 hrs), C/B-16 (S492/322B; 3038 hrs). Two hundred thirty-eight (238) previously used and sixteen (16) new Schumacher Dia Schumalith F40 candle filters were located throughout the various arrays.

As shown in Figure 1, several candles fractured in one of the top plenums during removal of the W-APF internals from the pressure vessel (i.e., plenum C/T). Bridged ash formations were evident in several locations along the bottom ~1/3 of the candle filters (i.e., above and/or along the dust sheds), and in between the filter elements and the plenum pipes (Figure 2).

Ash bridging was also evident in the middle plenum array (Figure 3). The advanced, second generation candles which were initially positioned in the B/M plenum experienced ash bridging, particularly along the bottom of the P-100A-1 Coors alumina/mullite, Pall Vitropore 442T, and 3M CVI-SiC composite filter elements. Although two of the 3M CVI-SiC composite filter elements had failed during the last 690.5 hours of operation in Test Run 24, evidence of ash build-up remained along the dust shed and plenum pipe. In contrast, ash bridging was not evident along the bottom of the DuPont PRD-66 candle filters (Figures 4 through 8). Similarly, the clean as-manufactured surface of the PRD-66 candle filters was visible, particularly along the top ~1/3 portion of the DuPont filter elements (i.e., absence of the residual conditioned dust cake layer).

Typically ash accumulated around the filter holder mounts in each of the filter arrays (Figure 9). A false bottom was install on plenum A/M during this test campaign. Although ash accumulated in between the individual holders which were positioned above the false bottom of plenum A/M, limited ash accumulation resulted directly below the false bottom.

Limited ash bridging was also evident in the bottom filter arrays after 1705 hours of hot gas filtration in the PFBC gas environment (Figure 10). Figures 11, 12 and 13 illustrate the various ash formations that resulted along the outer surface of the Schumacher Dia Schumalith F40 candle filters in the bottom arrays.

With the exception of the filters which failed during the lift, failure of the candles during hot gas filtration testing and/or cool-down was attributed to ash bridging. Post-test inspection of the failed filter sections which remained in the holder mounts indicated random failure direction as the result of the force applied by the bridged ash (Figure 14). As shown in Table 1, the typical length of the remaining filter sections in the

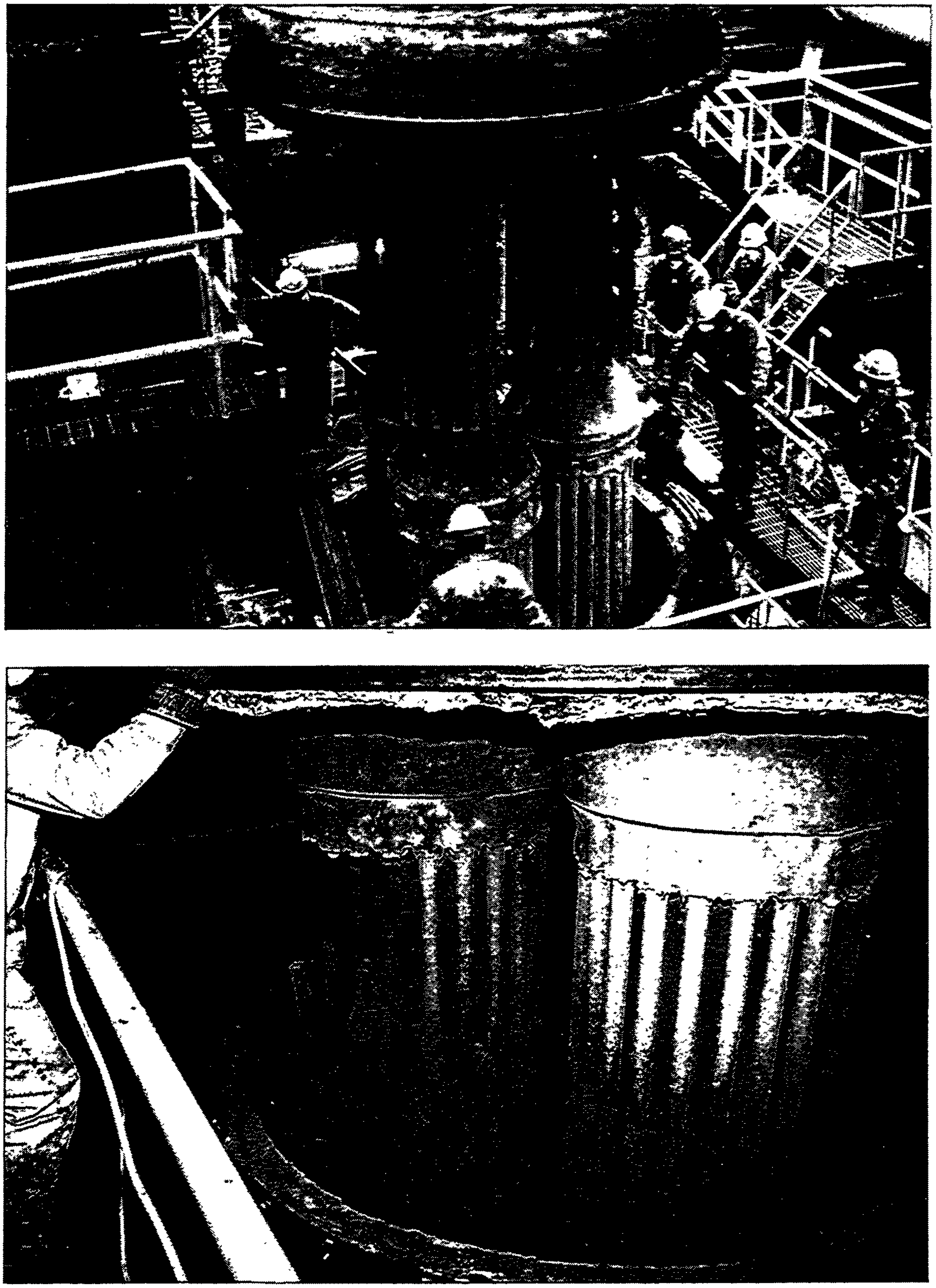


Figure 1 — Failure Of Several Filter Elements Occurred In The Top Plenum During The October 1994 Lift

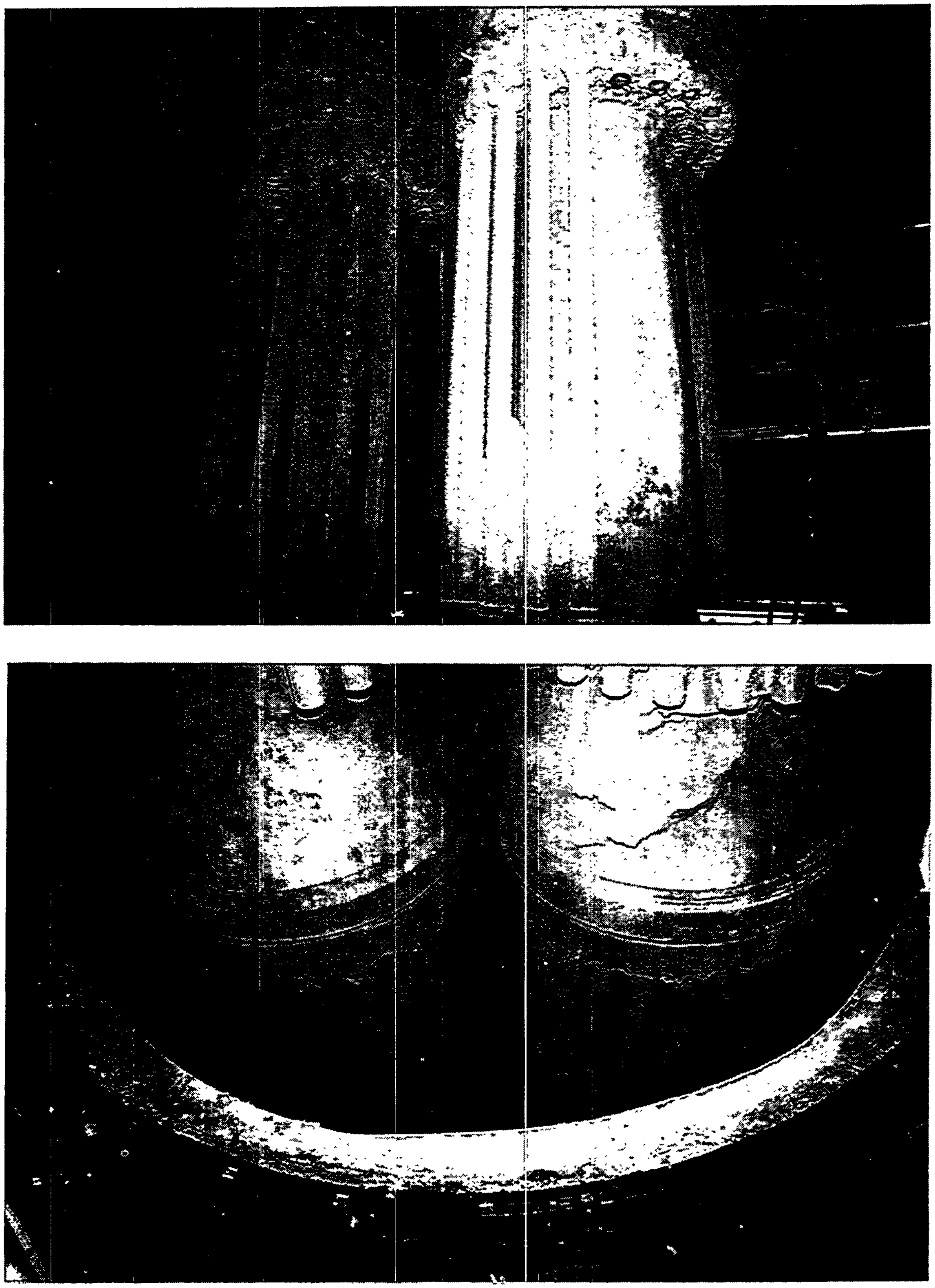


Figure 2 — Ash Bridging In The Top Filter Arrays In The W-APF. Ash Bridges Are Evident Along The Bottom ~1/3 Of The Candle Filters Near The Dust Sheds, And In Between The Candles And The Plenum Pipe.

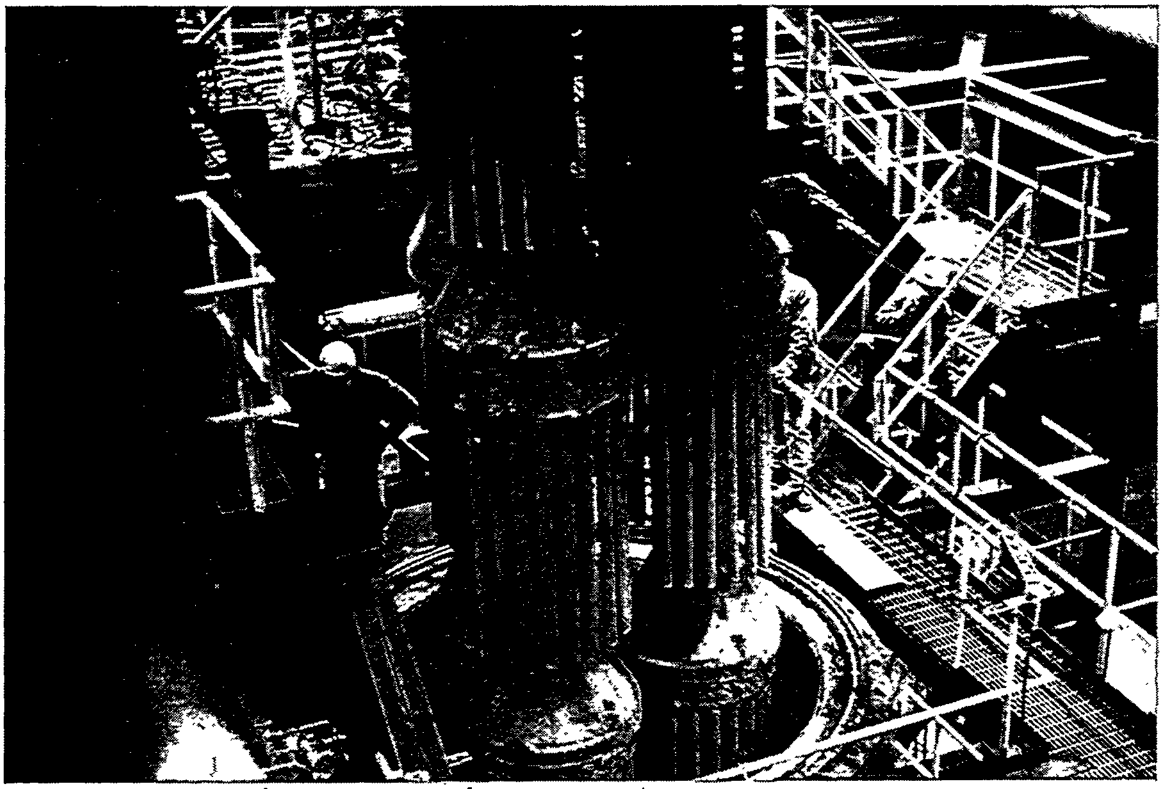


Figure 3 — Middle Plenum Filter Arrays In The W-APF During The October 1994 Lift

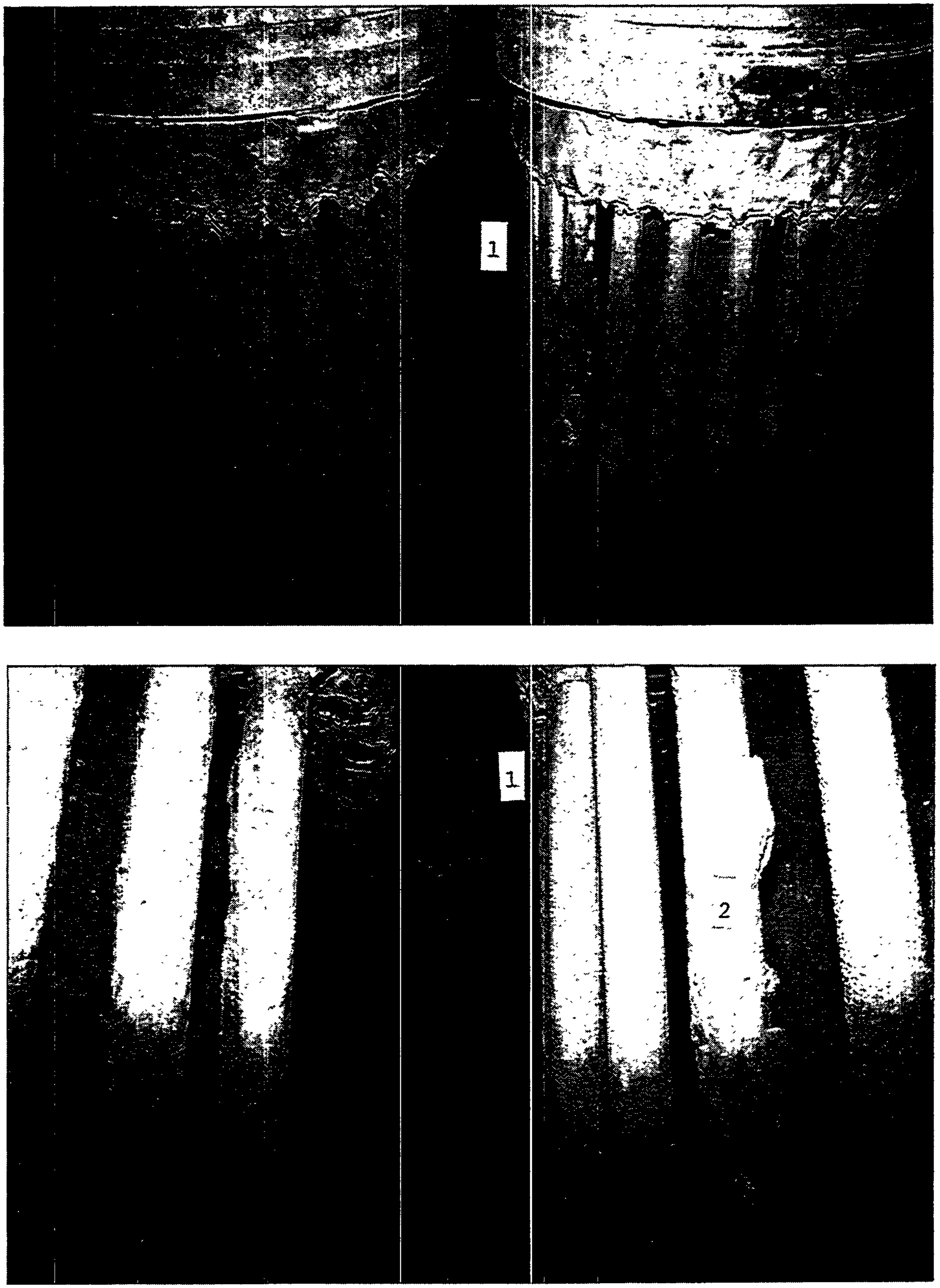


Figure 4 — Absence Of Dust Cake Layer Along The DuPont PRD-66 Candle Filter (Area 1). Extensive Ash Build-Up Along The DuPont PRD-66 Candle Filter Which Had Been Filled With Ash Fines Along Its ID Bore (Area 2).

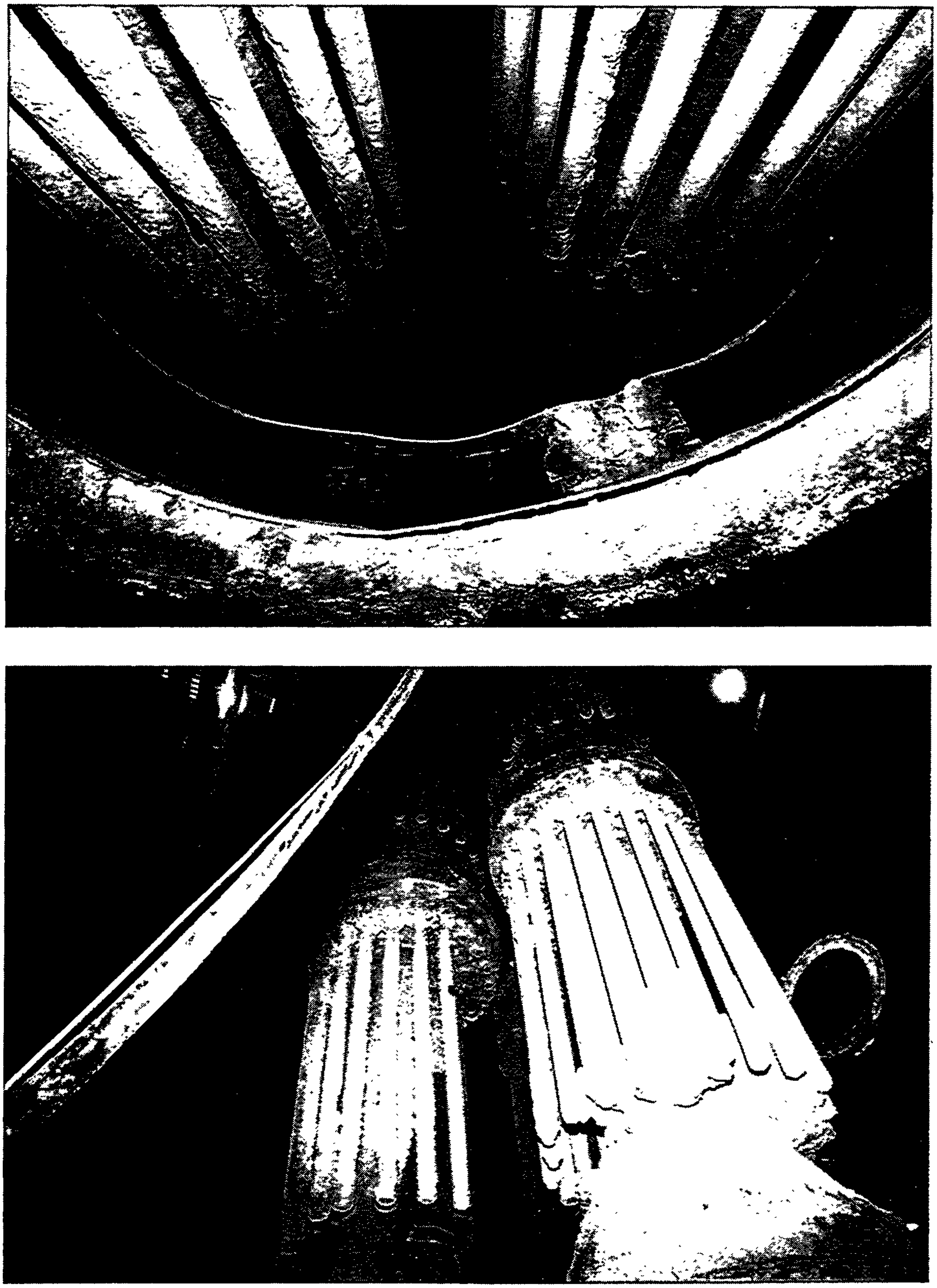


Figure 5 — Ash Bridging Along The Middle Plenum Filter Arrays

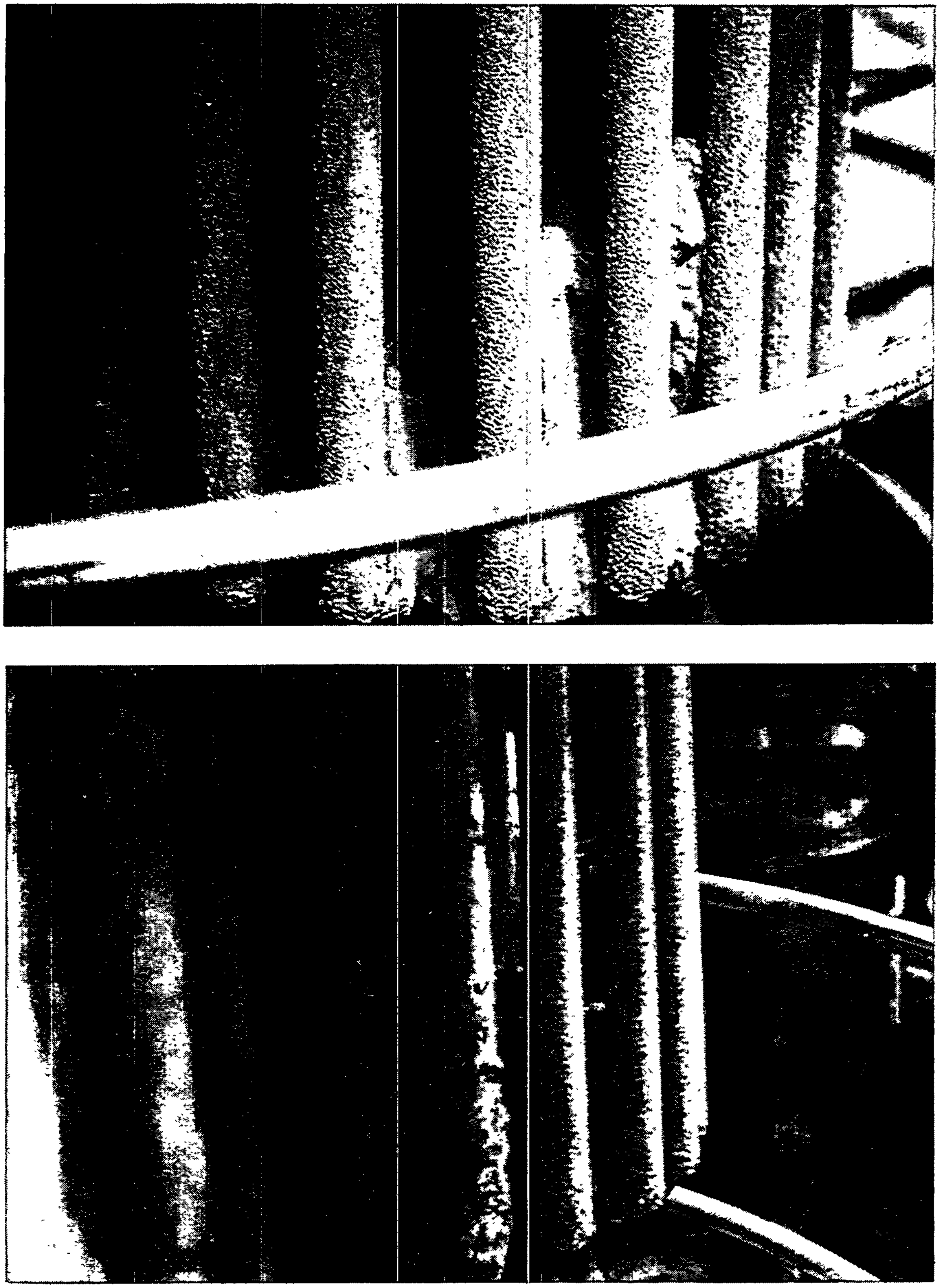


Figure 6 — Ash Bridging At The Bottom Of The Coors P-100A-1 Alumina/Mullite Candle Filters

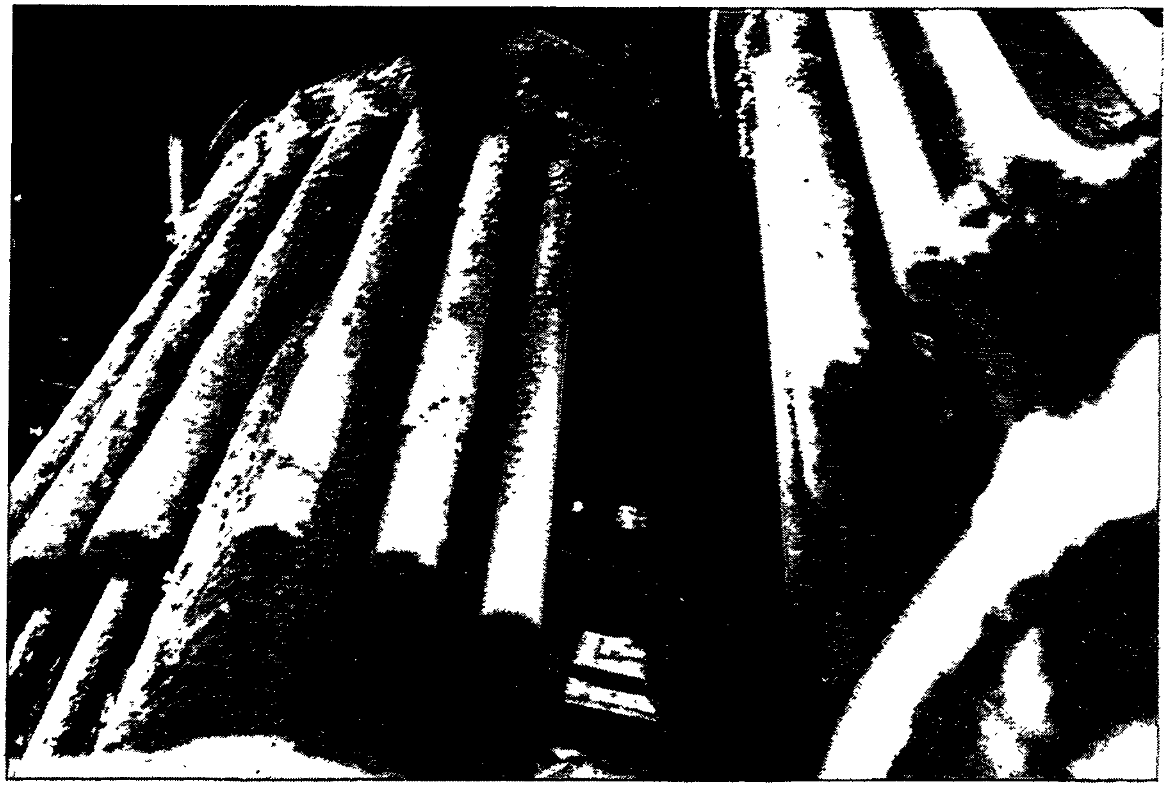


Figure 7 — Ash Bridging At The Bottom Of The Coors P-100A-1 Alumina/Mullite Candle Filters. Locations Of Failed Filter Elements Also Evident Along The Alternate Middle Plenum Arrays. The Surface Of The Plenum Pipe Below The Failed Candle Filters Is Virtually Free Of Ash.

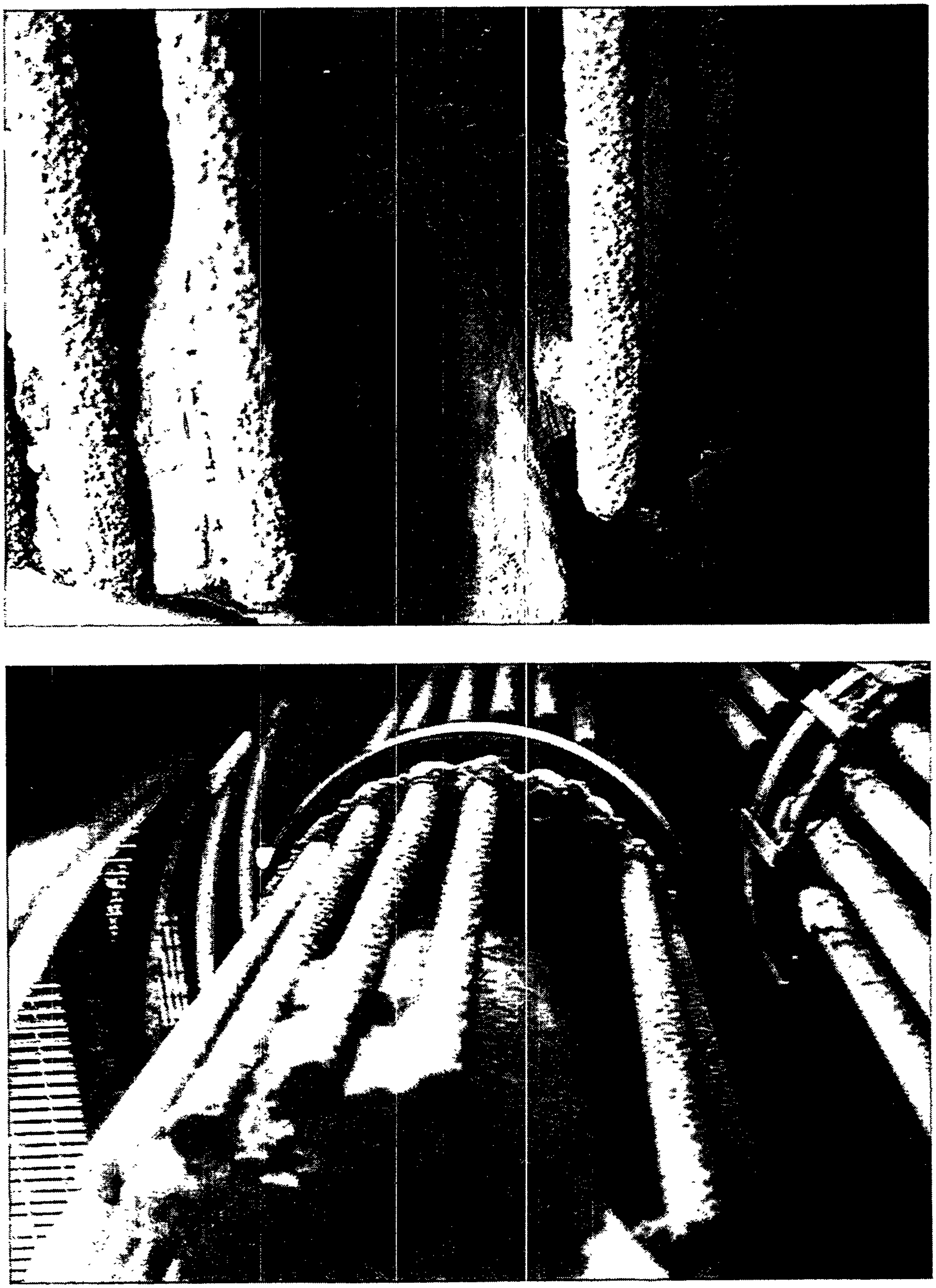


Figure 8 — Ash Bridging At The Base Of 3M CVI-SiC Composite And Pall Vitropore 442T Candle Filters

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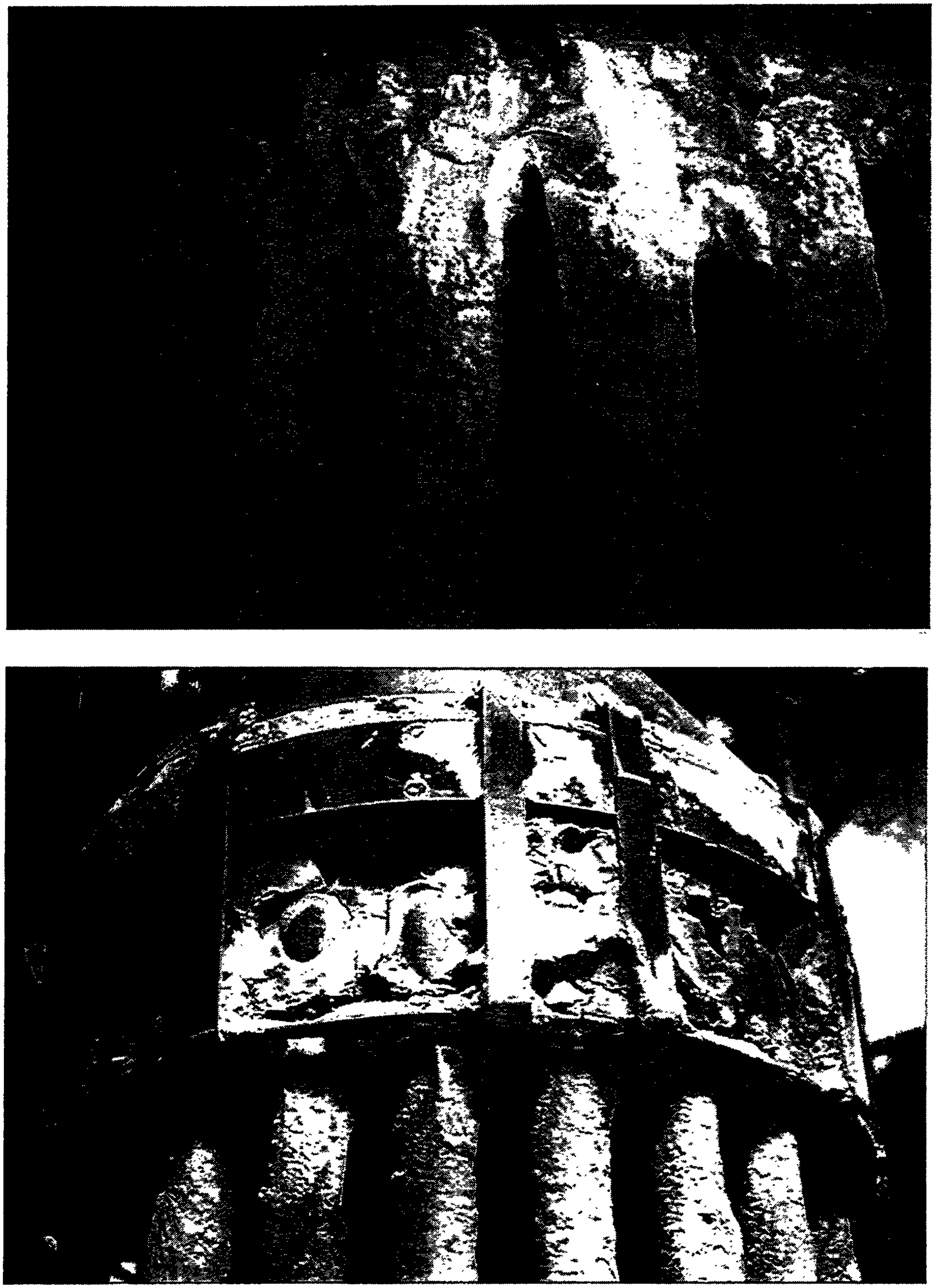

Figure 9 — Ash Formations Along The Filter Holder Mounts (Top Photo) And False Bottom (Bottom Photo)

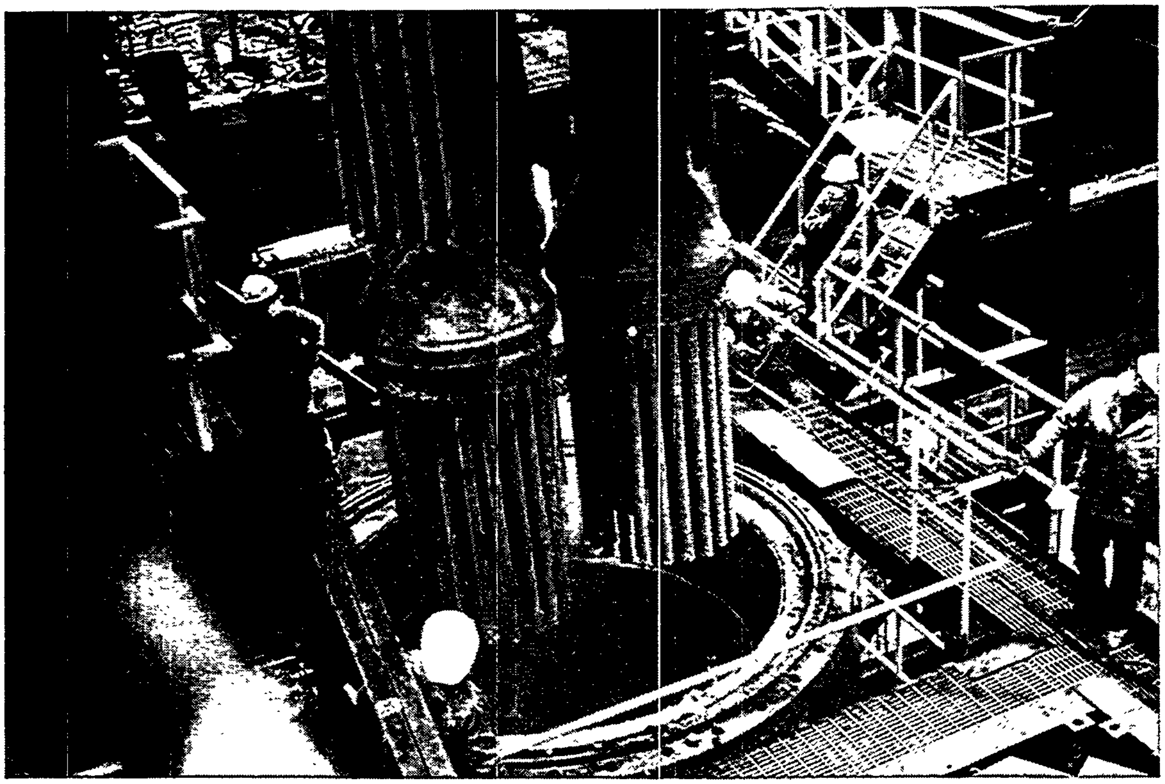

Figure 10 — Bottom Filter Arrays In The W-APF System (October 1994)

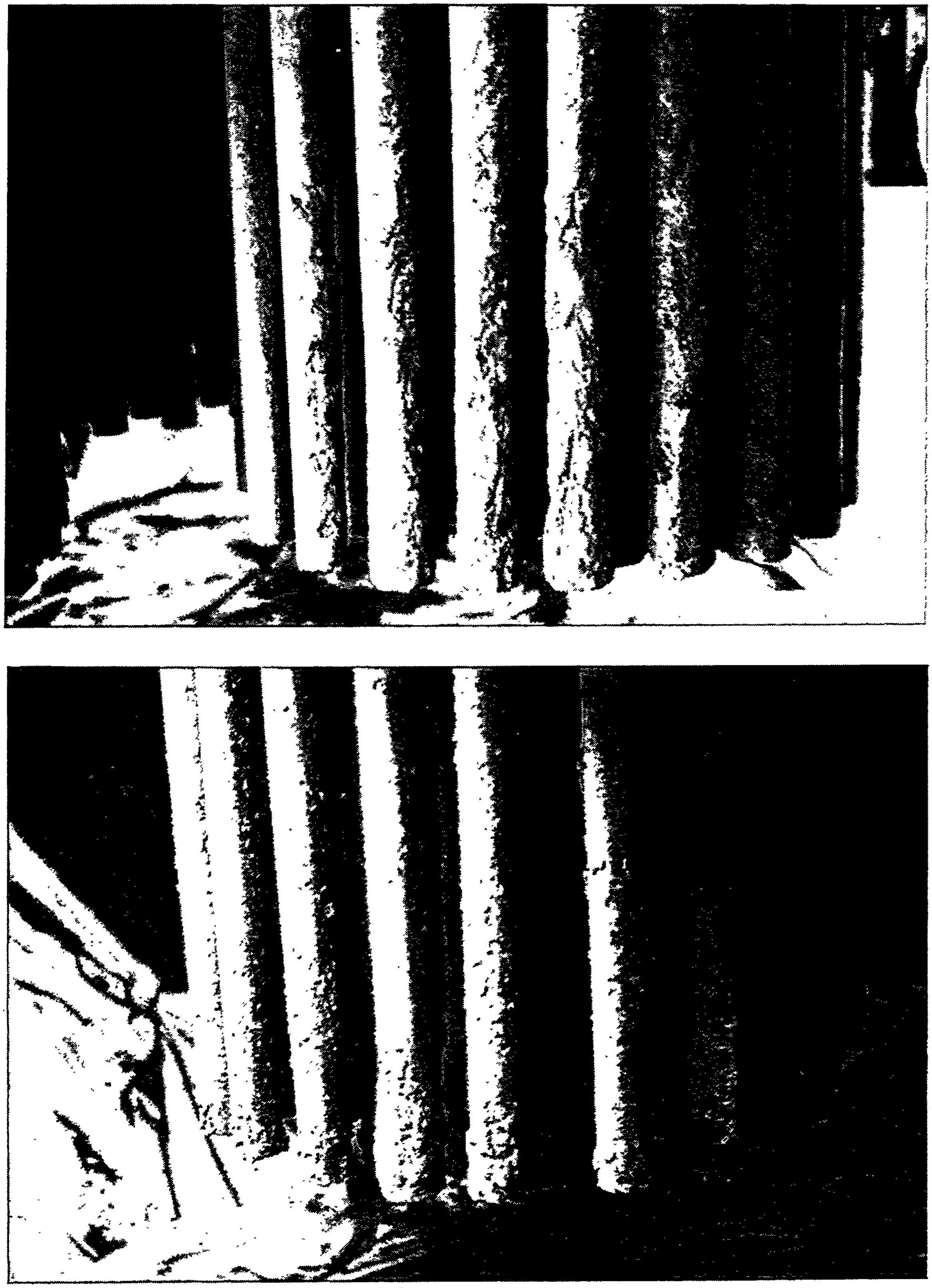

Figure 11 — Ash Cake Formations Along The Schumacher Dia Schumalith F40 Candle Filters In The Bottom Arrays In The W-APF System (October 1994)

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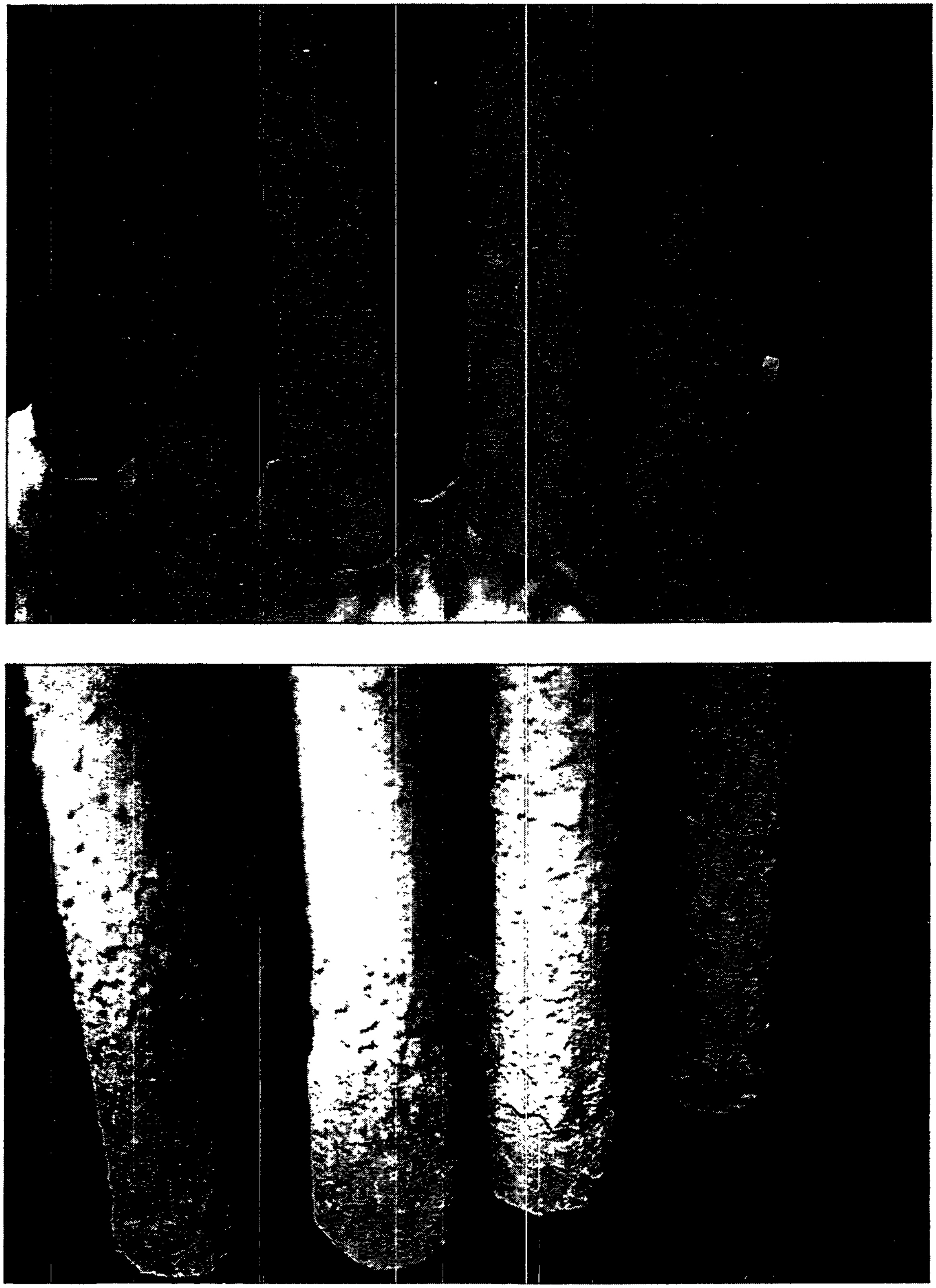

Figure 12 — Ash Cake Formations Along The Schumacher Dia Schumalith F40 Candle Filters In The Bottom Arrays In The W-APF System (October 1994)

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Figure 13 — Ash Cake Formations Along The Schumacher Dia Schumalith F40 Candle Filters In The Bottom Arrays In The W-APF System (October 1994)

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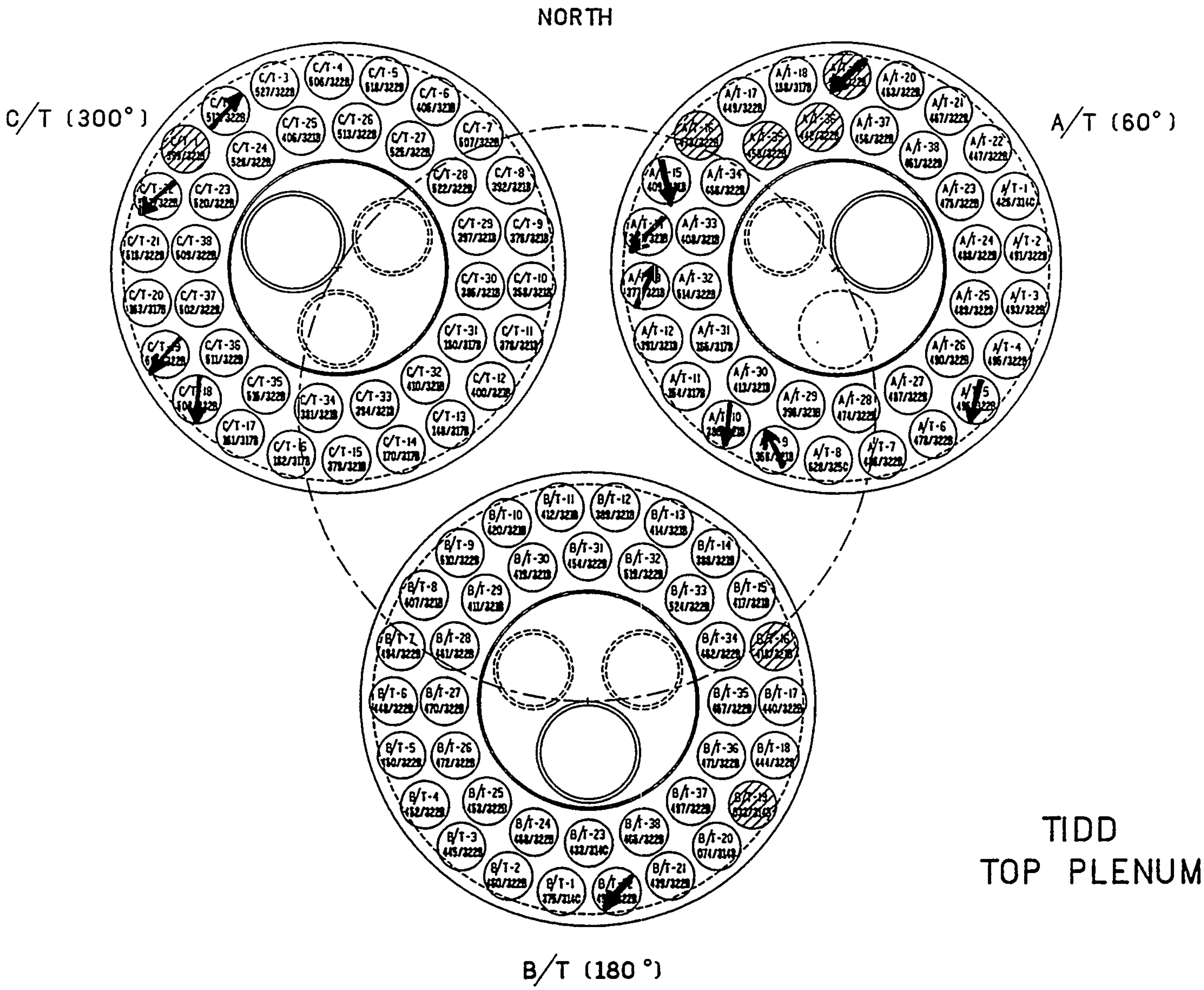


Figure 14 — Failure Direction Of The Candle Filters As A Result Of Ash Bridging (October 1994)

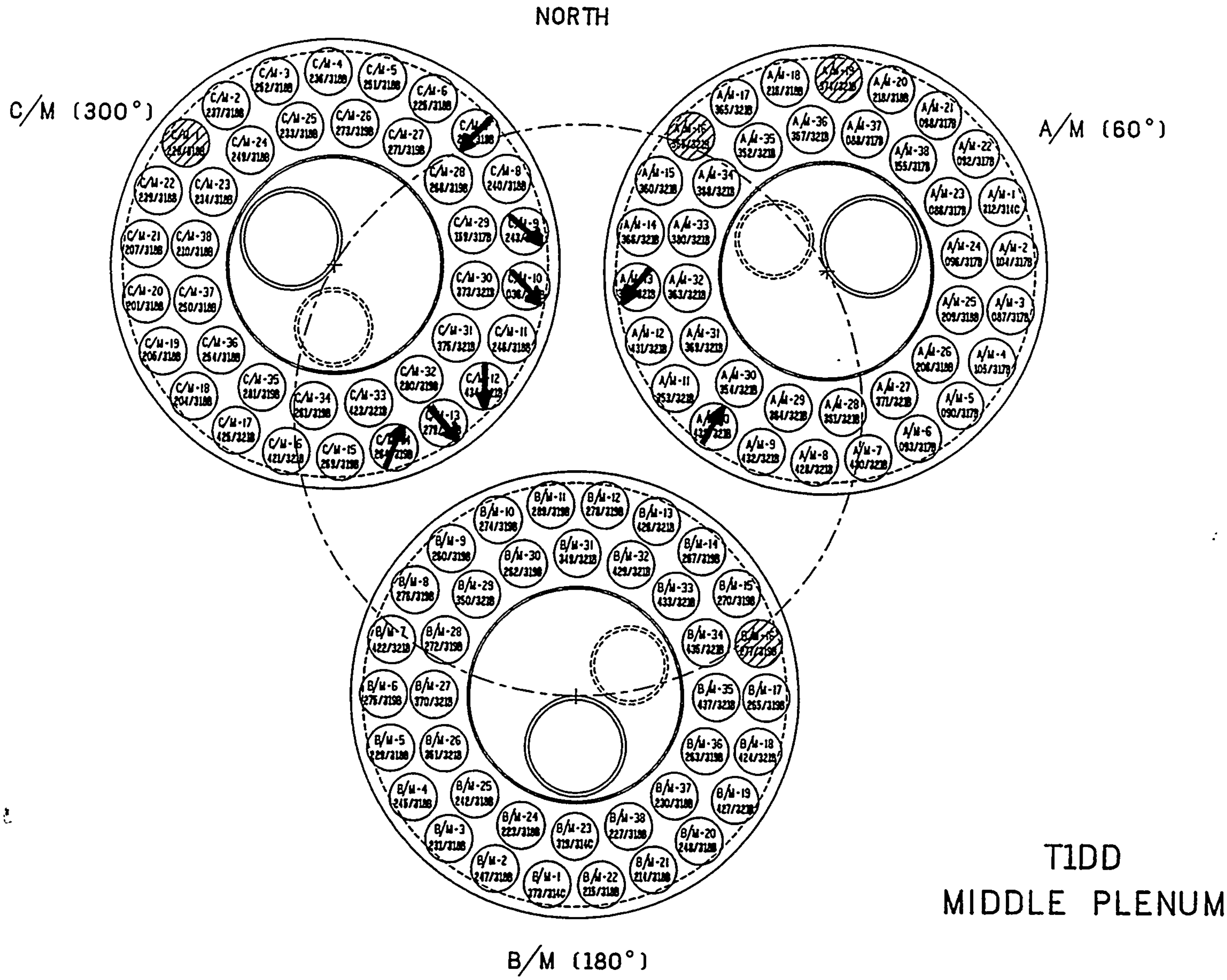


Figure 14 — Failure Direction Of The Candle Filters As A Result Of Ash Bridging (October 1994)

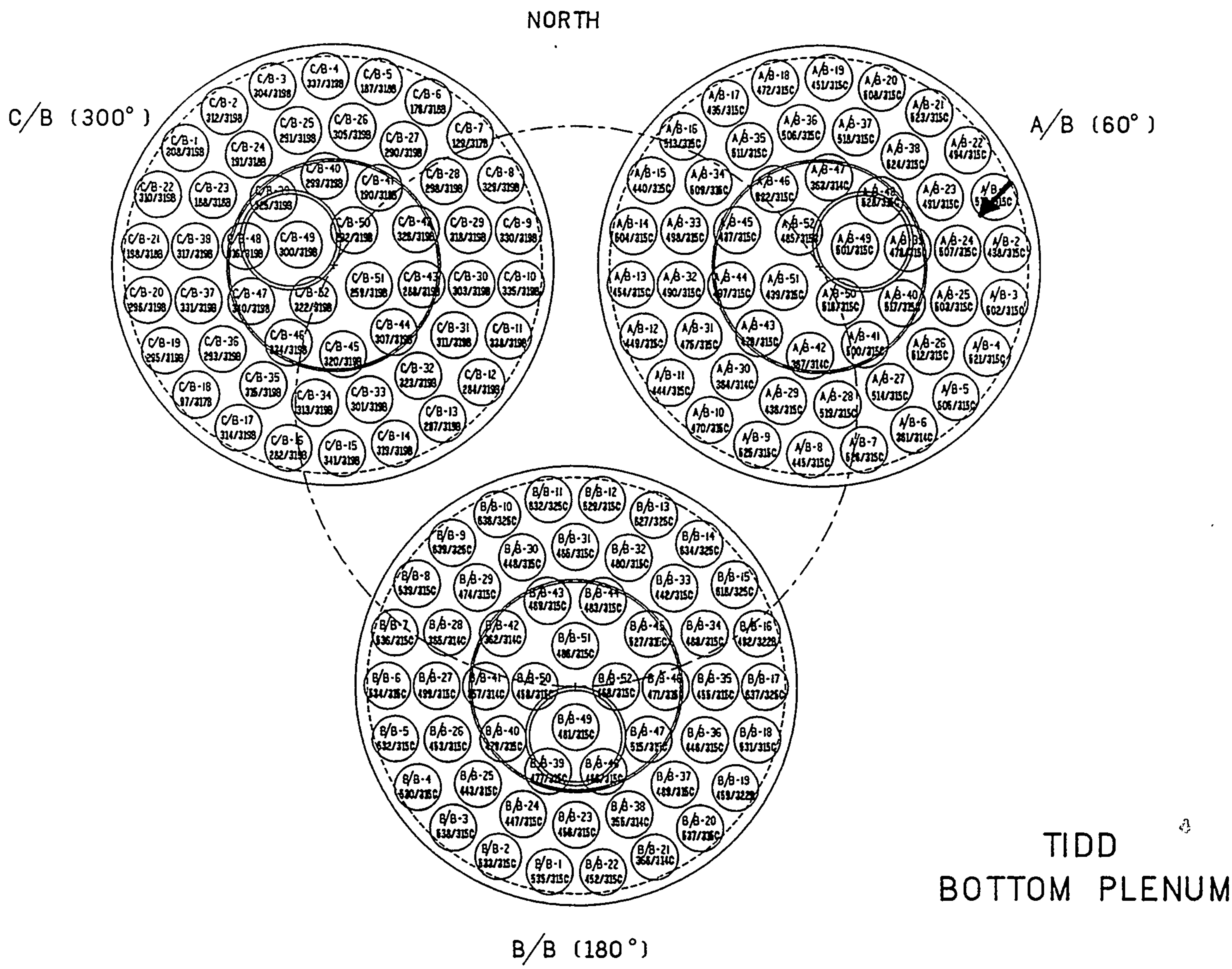


Figure 14 — Failure Direction Of The Candle Filters As A Result Of Ash Bridging (October 1994)

TABLE 1
FLANGE LENGTHS OF THE FAILED FILTER ELEMENTS
-- October 1994 --

Candle ID	Candle Location	Length Of Filter Section, inch	Comment
S2128/355C	B/B-44	3.75	Tangent Mark Not Evident *
S396/314C	A/M-7	3.375	
	A/T-10	3.75	
S304/314C	A/M-10	3.75	
S2111/355C	C/B-35	3.875	Tangent Mark Not Evident
S415/314C	A/M-6	3.5	Tangent Mark Not Evident
S2132/255C	C/B-19	3.625	Tangent Mark Not Evident
S359/314C	A/M-11	3.25	Tangent Mark Not Evident
S2109/355C	C/B-26	3.875	Tangent Mark Not Evident
S345/314C	A/M-8	4.00	Tangent Mark Not Evident
S2134/355C	B/B-47	4.00	Tangent Mark Not Evident
S2353/364C	A/B-1	3.75	
S2195/355C	B/B-24	3.375	Tangent Mark Not Evident
S2178/355C	A/B-22	4.00	Tangent Mark Not Evident
S2851/324C	A/T-9	3.875	
S289/314C	A/M-13	3.625	
S2316/364C	C/B-9	3.625	
S2160/355C	B/B-10	3.875	Tangent Mark Not Evident
S2387/364C	C/B-37	3.875	
S2106/355C	B/B-49	4.00	Tangent Mark Not Evident
S2333/364C	C/B-8	3.25	Tangent Mark Not Evident
S1733/348C	C/B-18	3.375	Tangent Mark Not Evident
S2177/355C		3.938	
S2189/355C		3.75	Tangent Mark Not Evident
S1740/348C	B/T-21	3.688	
S2374/364C	C/T-21	3.5	Tangent Mark Not Evident
S423/314C	C/T-22	3.75	
S2125/355C	C/T-20	3.75	Tangent Mark Not Evident
S1709/348C	C/T-18	3.375	
S418/314C	C/T-2	3.75	
S609/323C	C/M-2	3.75	
S548/376C	C/M-13	3.625	

TABLE 1 (continued)
FLANGE LENGTHS OF THE FAILED FILTER ELEMENTS
-- October 1994 --

Candle ID	Candle Location	Length Of Filter Section, inch	Comment
S2197/355C	A/B-42	3.313	Tangent Mark Not Evident
S1751/348C	C/T-19	3.625	
S883/368B	B/T-4	5.313	Tangent Mark Not Evident
	A/T-19	3.938	
S1761/348C	A/T-15	3.75	
S560/376C	A/T-5	3.625	
S2181/355C	B/T-22	3.75	Tangent Mark Not Evident
S427/314C	C/T-1	3.75	Tangent Mark Not Evident
S2149/355C	B/B-52	4.125	
S567/323C	A/T-14	4.188	
S2412/364C	A/B-34	3.5	
S1767/348C	C/M-9	3.313	
S570/323C	C/M-14	3.5	
S2163/355C	A/B-24	3.875	
S2117/355C	A/B-46	3.75	Tangent Mark Not Evident
S1790/348C	A/B-41	3.438	
S388/374C	C/M-11	3.5	Tangent Mark Not Evident
S592/323C	A/T-13	4.375	
S623/325C	C/M-12	3.563	
S344/314C	C/M-10	3.563	
S607/323C	C/M-7	20.25	

* Tangent Mark Indicated Position Of The Candle Relative To The Filter Vessel.

holder mounts was ~3-4 inches. The location of the fracture in the Schumacher Dia Schumalith F40 candles was principally in the coarse filter matrix below the dense flange transition section of the filter element.

ASH CAKE MORPHOLOGY

The morphology of the residual dust cake layer varied along the surface of each of the advanced second generation candle filter elements. As shown in Figure 15, slightly raised ash deposits remained along the surface of the Coors P-100A-1 alumina/mullite candle filter. Deposition and/or retention of fines along the alumina/mullite matrix was relatively uniform.

Thicker, raised, ash deposits uniformly coated the outer surface of the Pall Vitropore 442T candle filters (Figure 16). Pin holes were detected in the ash layer which deposited along the surface of the 3M CVI-SiC composite candle filters (Figure 17). The pin holes were generally slightly off-center in the open mesh weave of the outer confinement layer of the 3M composite filter matrix.

As shown in Figure 18, two of the three 3M CVI-SiC composite filters had failed below the flange during the last 690.5 hours of test operation in Test Run 24 at Tidd. Although bridged ash was evident between the filter holder mounts, evidence of ash was not apparent between the gasket sleeve and the sections of the 3M filter elements which remained in the filter holder mounts. Fail-safe/regenerators had been included above all filter elements in the B/M array. After failure of the 3M CVI-SiC composite candle filters had occurred, the fail-safe/regenerators above the failed filter elements effectively plugged (Figure 19).

Very little dust remained along the surface of the two DuPont PRD-66 candle filters which were exposed for 1705 hours in the PFBC gas environment (Figure 20). The as-manufactured woven diamond pattern of the DuPont PRD-66 matrix and outer membrane were evident along many areas of the filter elements which had been positioned in B/M-8 and B/M-9. A heavy ash cake deposit was, however, observed along the DuPont PRD-66 filter which was located in position B/M-7 (Figure 21). When removed from the array, the ID bore of the B/M-7 candle filter was seen to be filled with ash. This

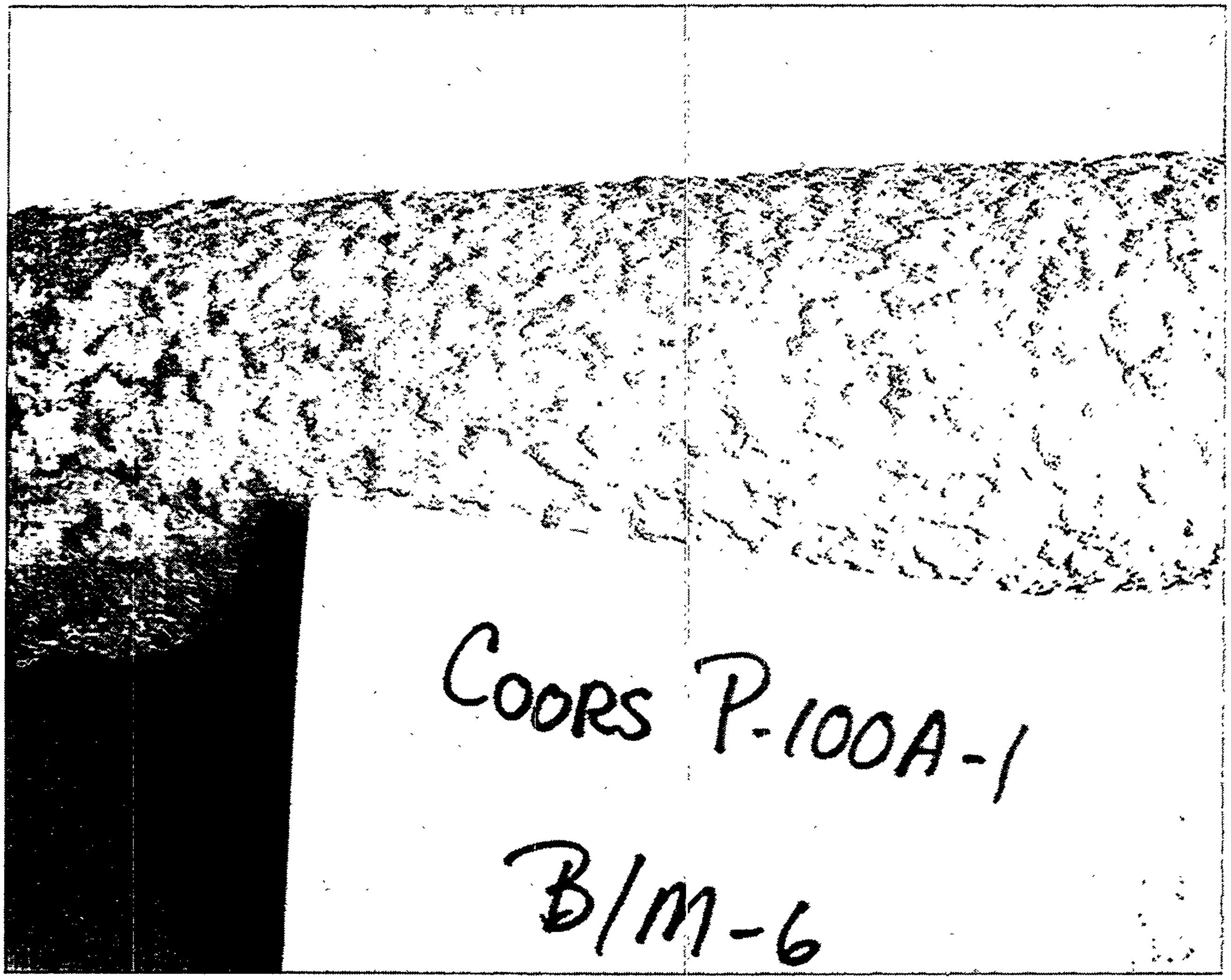


Figure 15a — Ash Cake Formations Along The Coors P-100A-1 Alumina/Mullite Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd

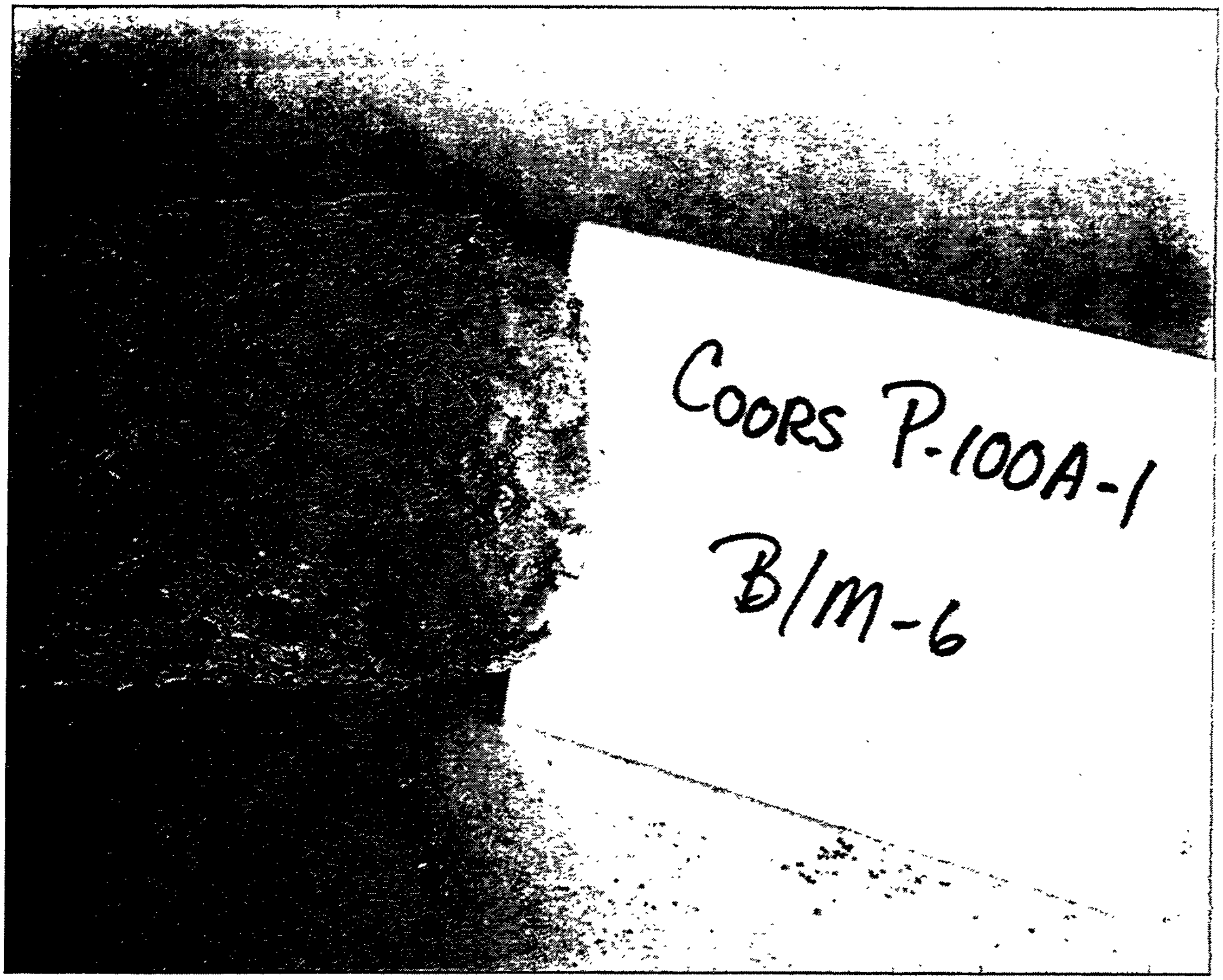


Figure 15b – Ash Cake Formations Along The Coors P-100A-1 Alumina/Mullite Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd

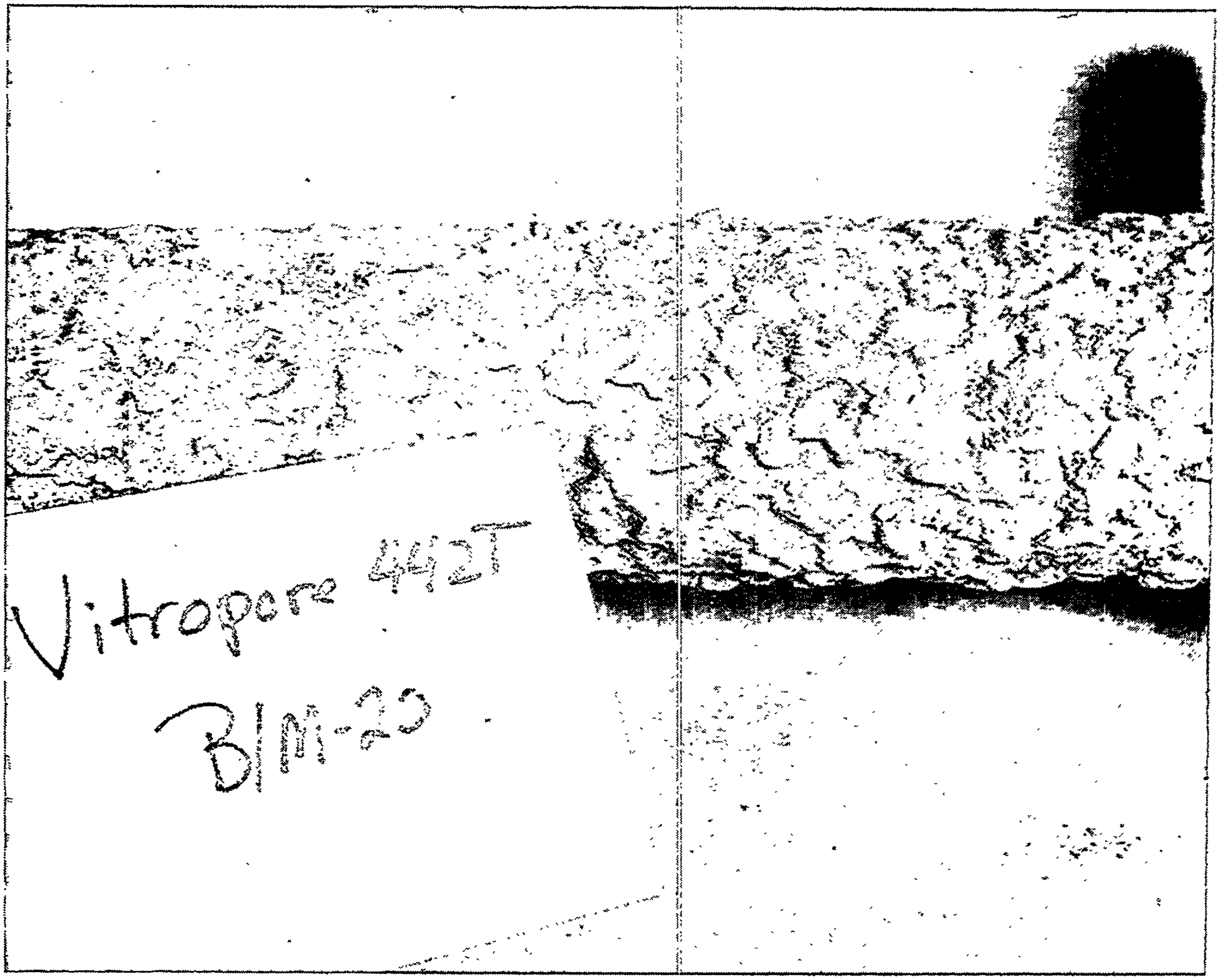


Figure 16a — Ash Cake Formations Along The Pall Vitropore 442T Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd

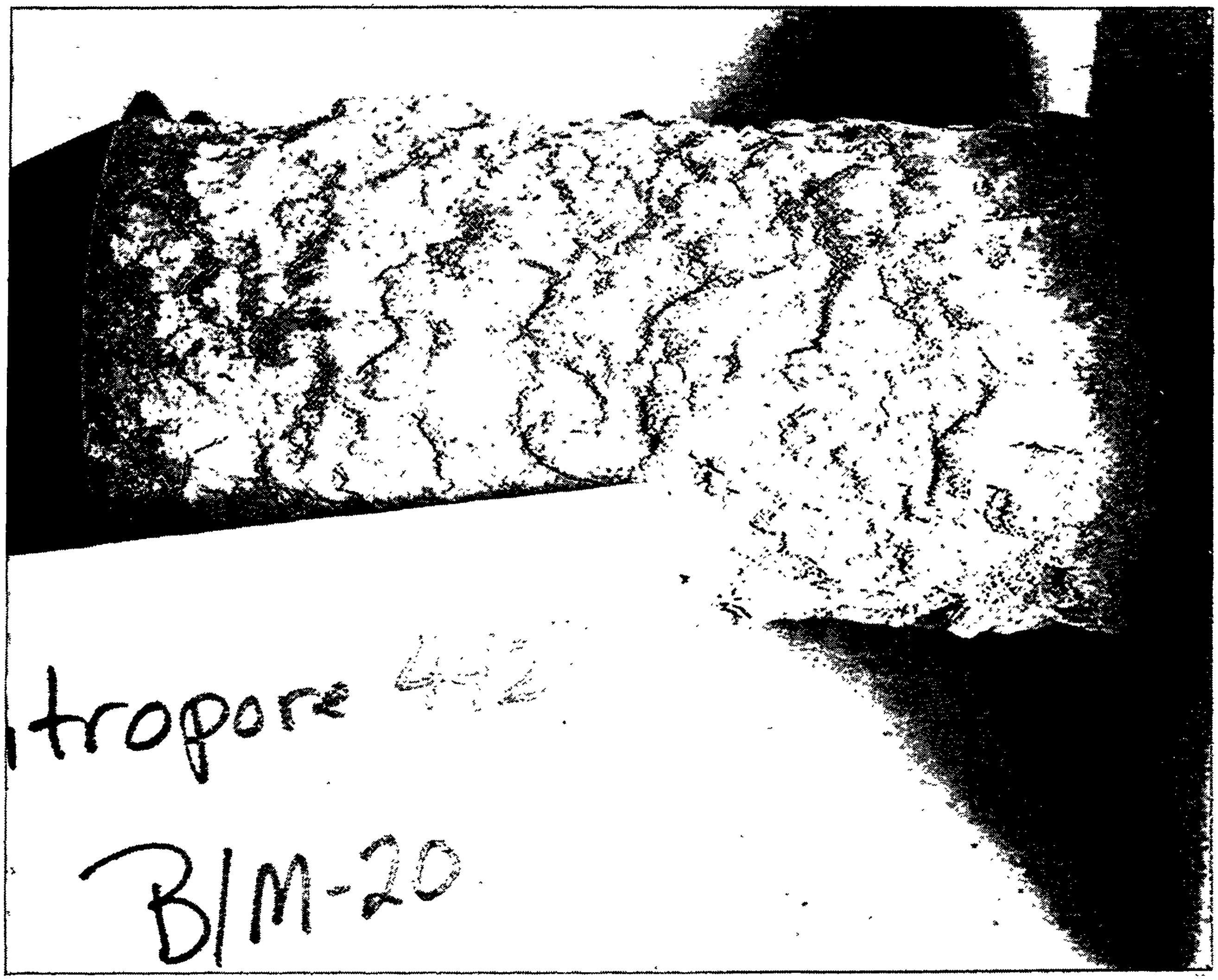


Figure 16b – Ash Cake Formations Along The Pall Vitropore 442T Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd

Figure 16b — Ash Cake Formations Along The Pall Vitropore 442T Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd

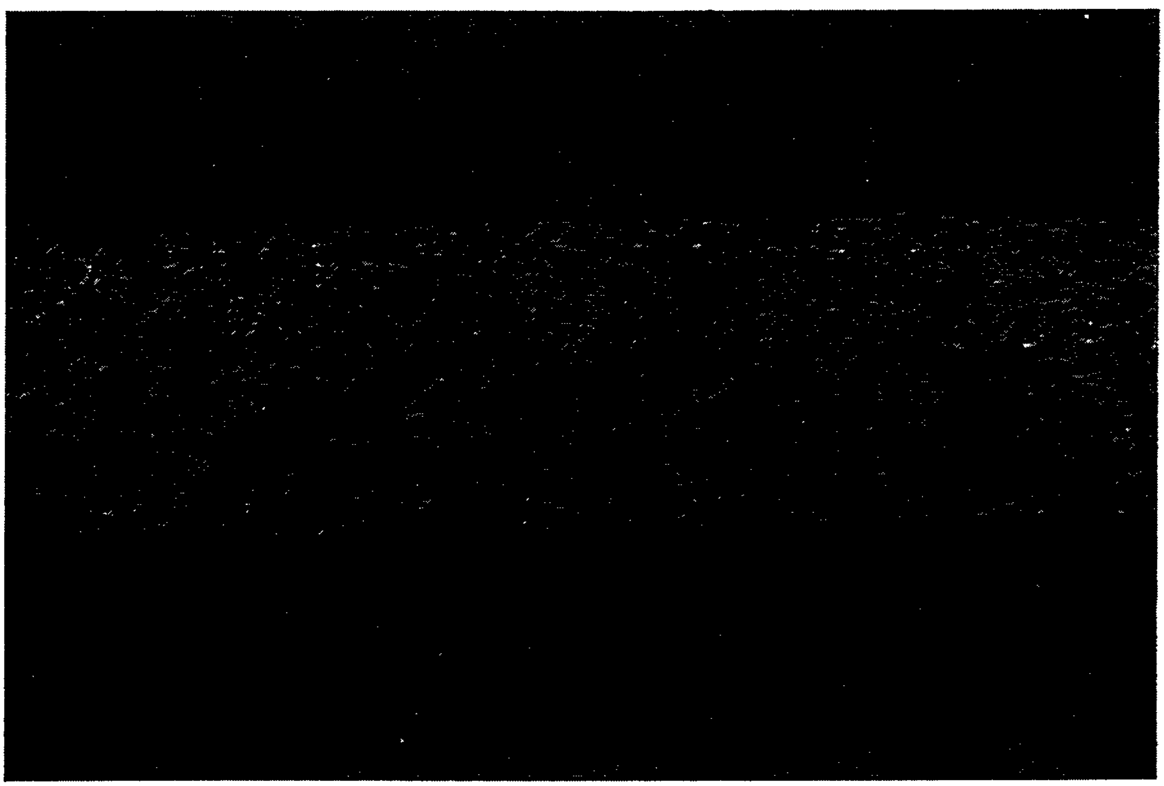


Figure 17 — Ash Cake Formations Along The 3M CVI-SiC Composite Filter Matrix After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd. Pin-Hole Are Evident In The Dust Cake Layer.

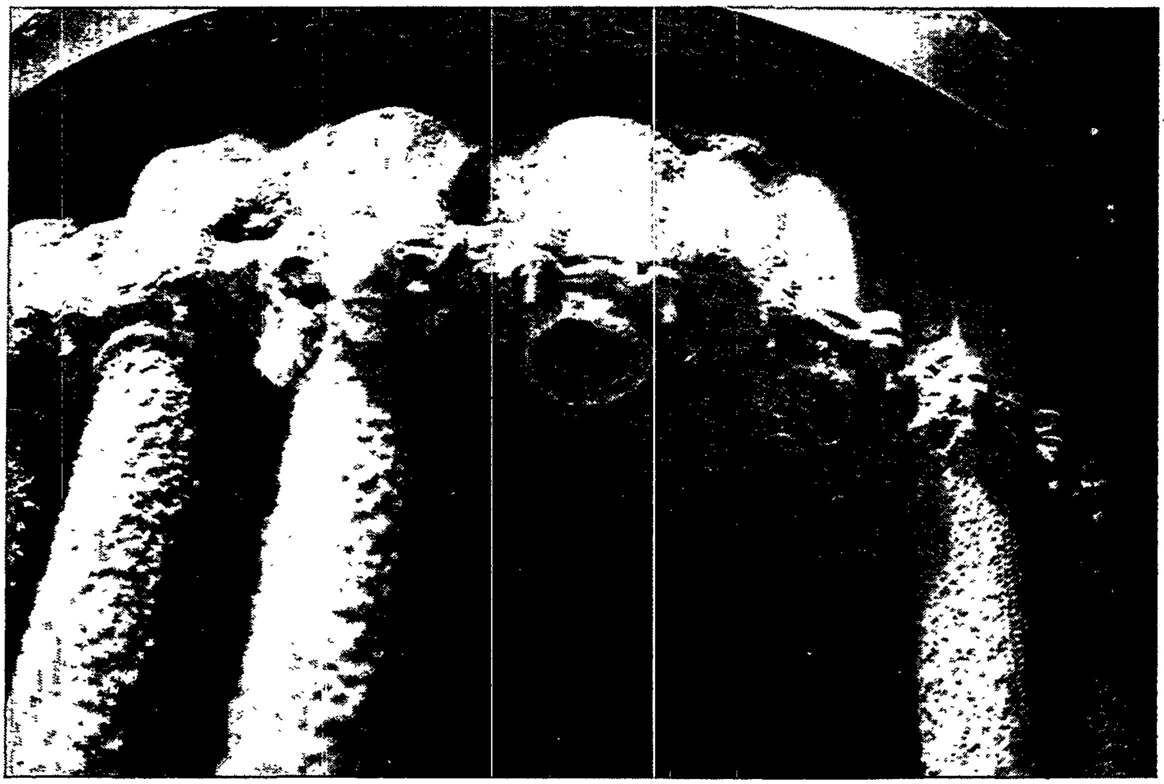
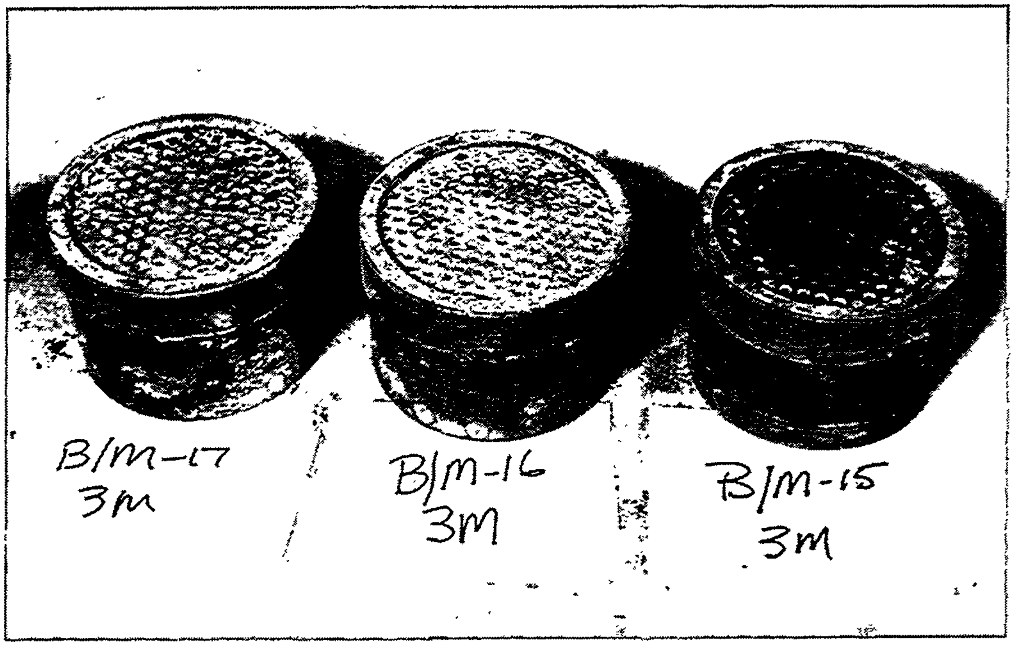


Figure 18 — Filter Holder Mounts Which Originally Housed The 3M CVI-SiC Composite Filters



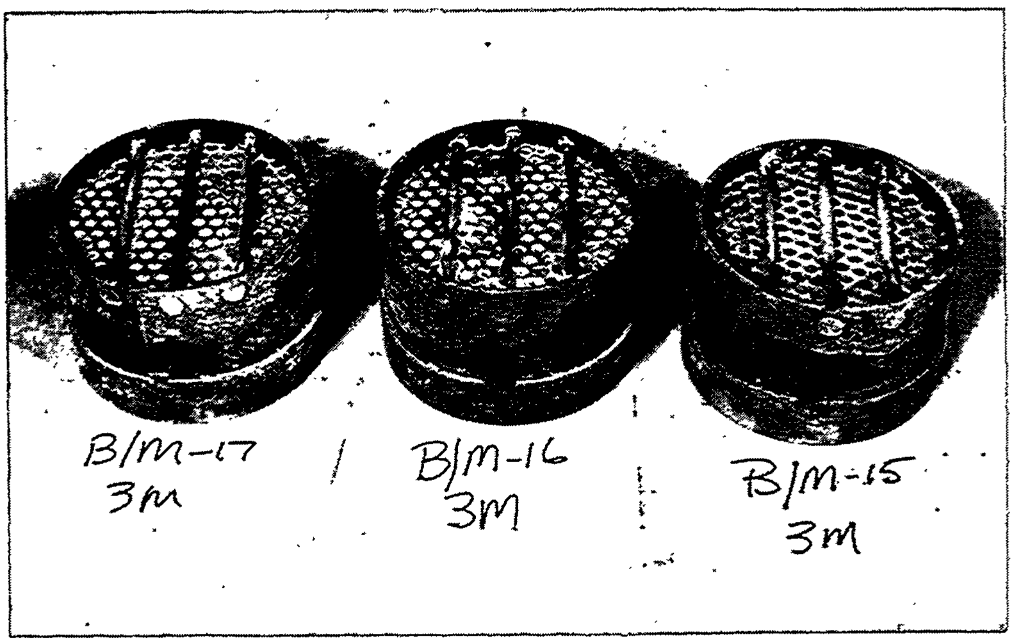


Figure 19 — Fail-Safe/Regenerators Located Above The 3M CVI-SiC Composite Filters

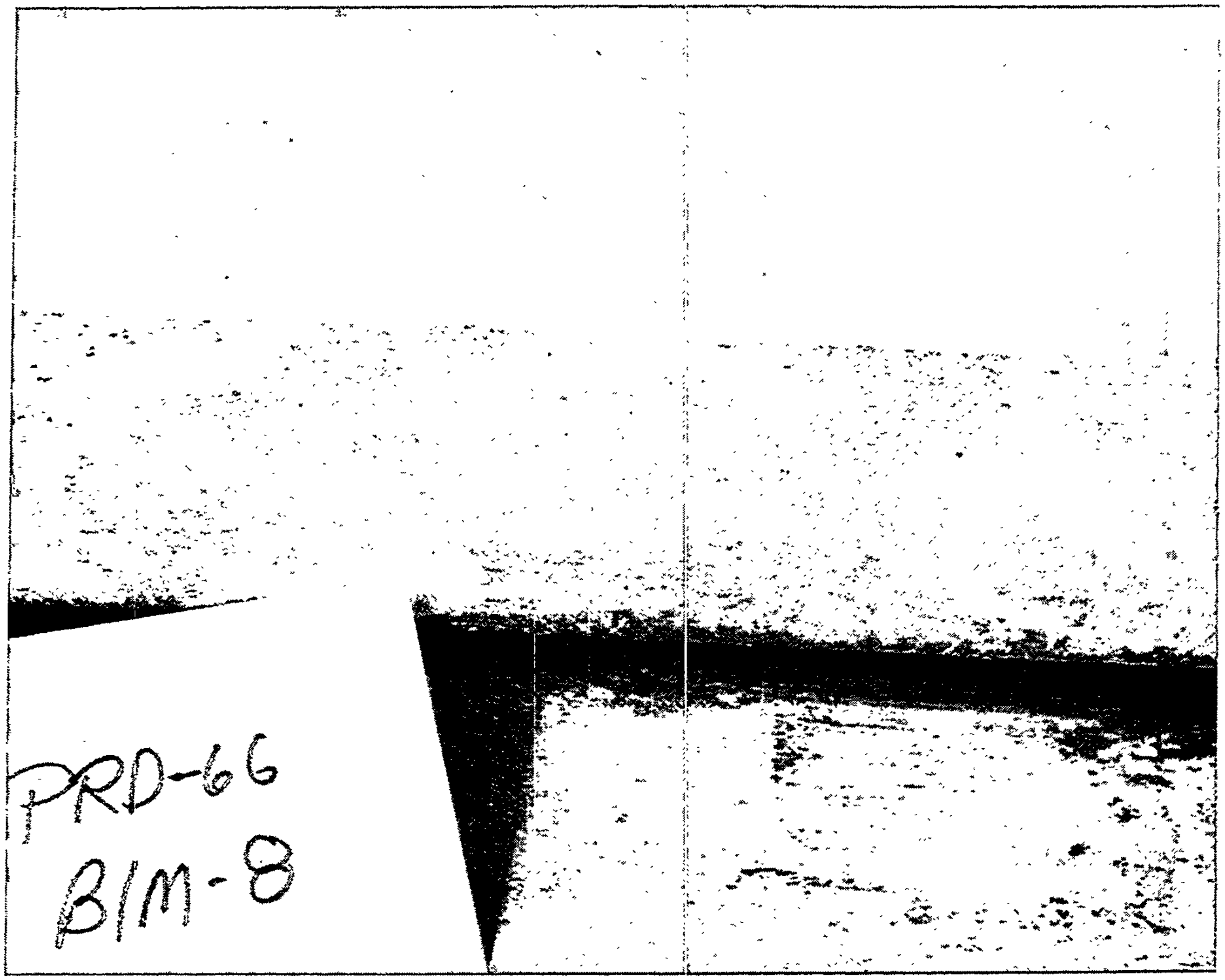


Figure 20a — Ash Cake Formations Along The DuPont PRD-66 Candle Filter After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd. Adherence And/Or Retention Of The Ash Cake Is Not Evident Along Several Areas Of The DuPont PRD-66 Filter Body.

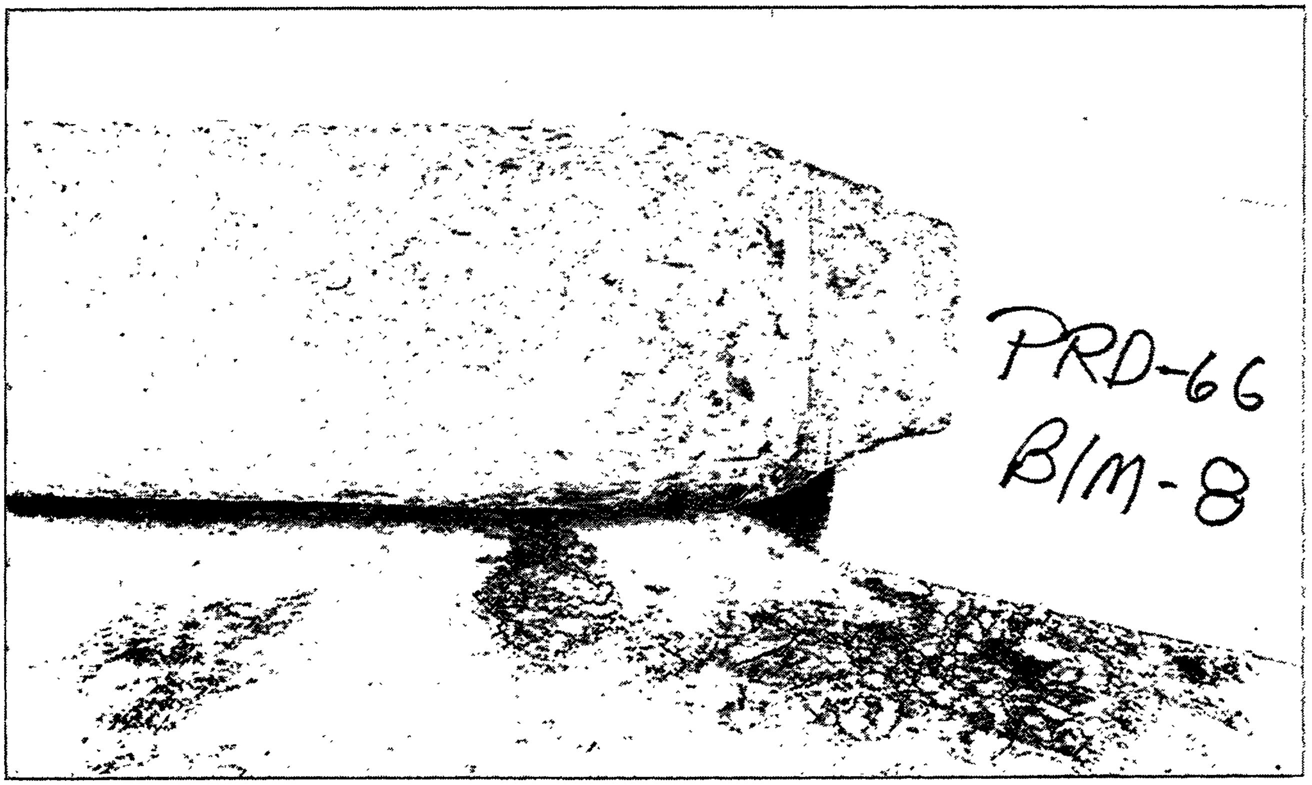


Figure 20b — Ash Cake Formations Along The DuPont PRD-66 Candle Filter After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment At Tidd. Adherence And/Or Retention Of The Ash Cake Is Not Evident Along The Closed End Cap Of The DuPont PRD-66 Candle Filter.

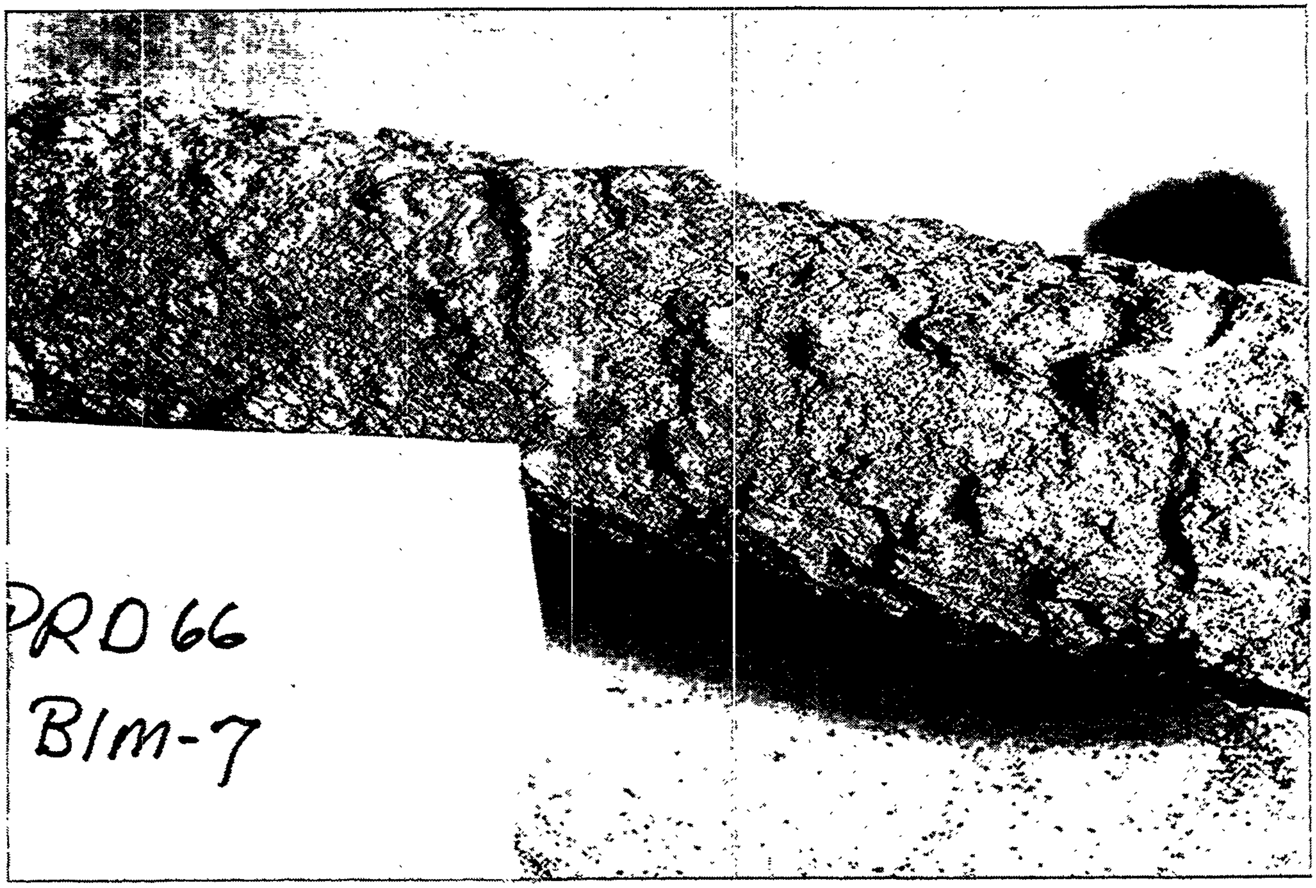


Figure 21a — Thick Ash Cake Formations Along The Surface Of The DuPont PRD-66 Candle Filter Which Filled With Ash Along Its ID Bore

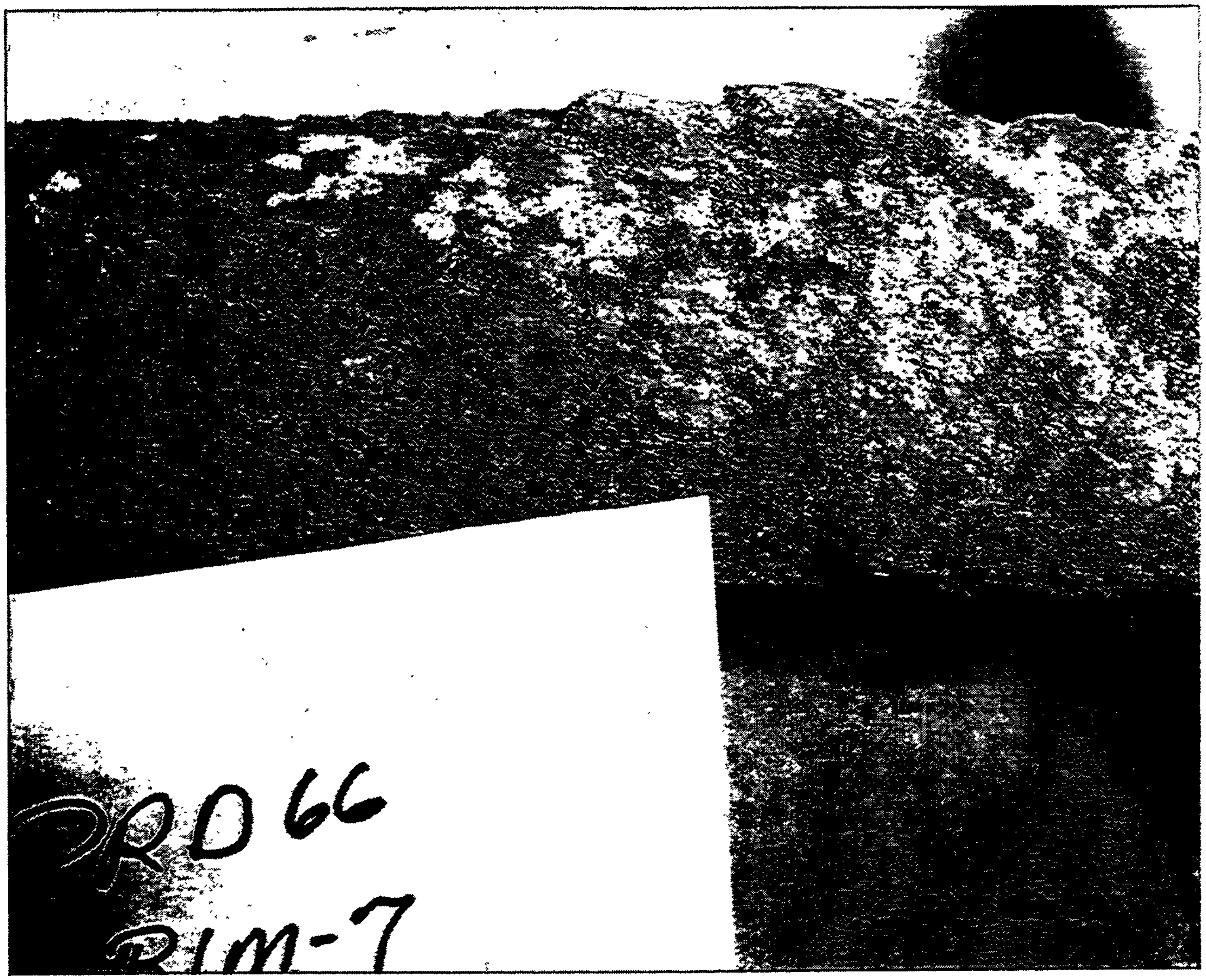


Figure 21b – Thick Ash Cake Formations Along The Surface Of The DuPont PRD-66 Candle Filter Which Filled With Ash Along Its ID Bore. In Several Areas The Clean Underlying Filter Surface Was Evident.

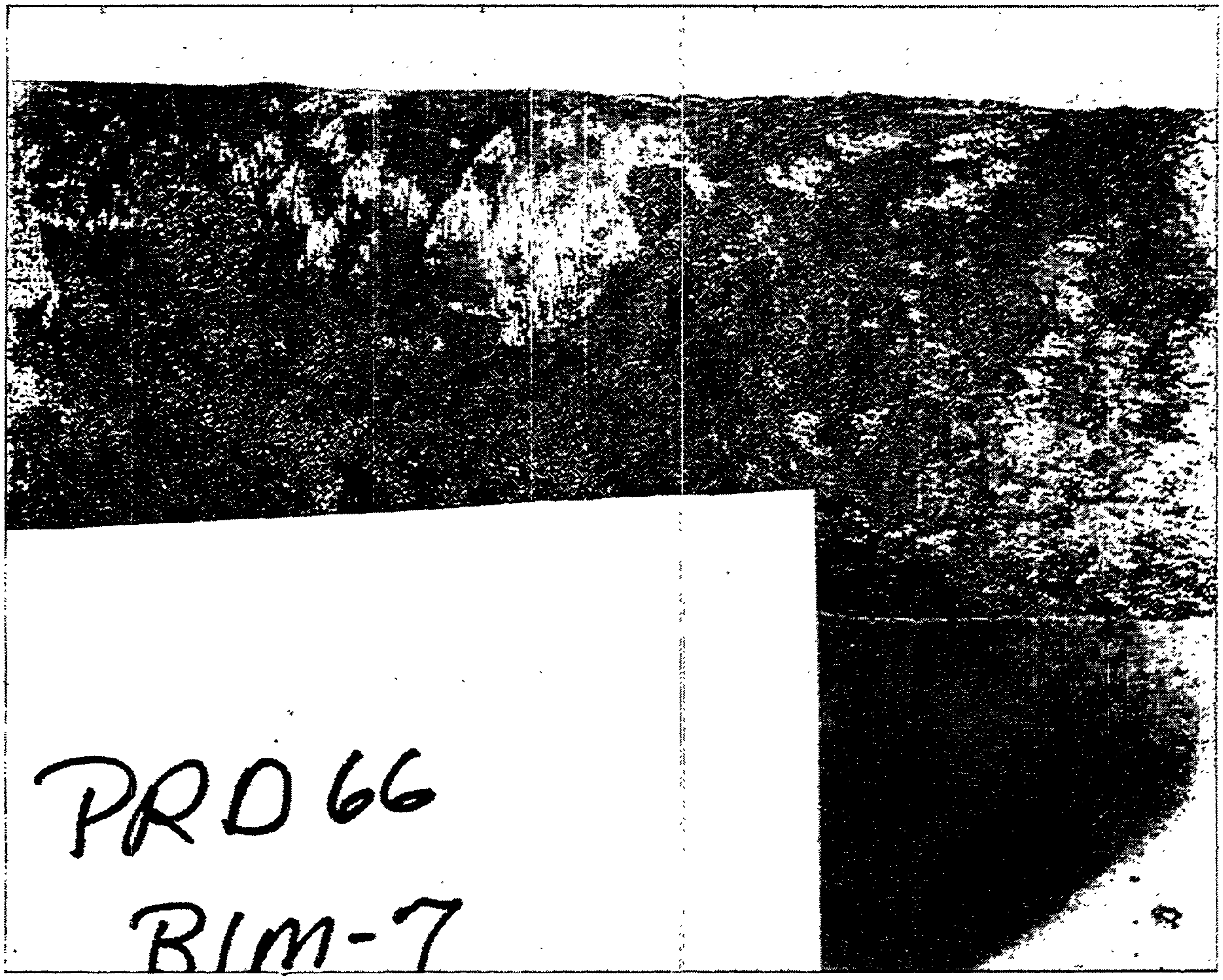


Figure 21c – Thick Ash Cake Formations Along The Surface Of The DuPont PRD-66 Candle Filter Which Filled With Ash Along Its ID Bore. In Several Areas The Clean Underlying Filter Surface Was Evident.

resulted from misalignment of the top gasket which permitted dust to enter and fill the inside of the filter element. During removal of the DuPont PRD-66 candle filter from its holder, the candle fractured at the base of its flange. The fail-safe/regenerator unit that was positioned above the B/M-7 PRD-66 candle filter was seen to be entirely plugged with ash fines after 1705 hours of hot gas filtration in the PFBC gas environment (Figure 22).

During preparation of the PRD-66 filter elements for strength testing, the candles were brushed and surface washed in order to remove any residual ash cake layer or attached fines. While air drying, a white crystalline residue formed along the outer surface of the PRD-66 candle filter. Energy dispersive x-ray analysis (EDAX) indicated that the crystalline formation contained magnesium sulfate (13.17% Mg, 10.49% S, and 76.34% O; atomic percent basis). As magnesium sulfate leached from the ash which filled the ID bore and wall of the PRD-66 candle filter, crystallization resulted along the outside surface of the filter element, forming the negative imprint of the PRD-66 woven matrix (Figure 23).

During the June 1994 recandling effort at Tidd, Schumacher Dia Schumalith F40 candle filters had been reinstalled in all of the top arrays, as well as in A/M and C/M plenums. Although the majority of these filters had previously been used at Tidd, all had been brushed prior to reinstallation into the various filter arrays. A thin residual ash cake layer remained along the surface of these filter elements prior to initiating testing in Test Segment 4. In contrast, the candles which were located in the bottom arrays in Test Segment 4 initially experienced 1268 hours of PFBC test operation during Test Runs 12 through 18 in Test Segment 3. These elements were not removed, nor cleaned prior to the July 1994 restart.

At test termination in October 1994, three Schumacher Dia Schumalith F40 candle filters were removed from the bottom array in Cluster B. These included candle filter S422/322B located in B/B-16 which had accumulated 4743 hours of test operation (Test Segments 1 through 4); S1742/348C located in B/B-17 which had accumulated 1705 hours of test operation (Test Segment 4); and S2129/355C located in B/B-18 which had accumulated 2973 hours of test operation (Test Segments 3 and 4). Although bridging was generally not evident between the candle filters in the bottom arrays, thick deposits

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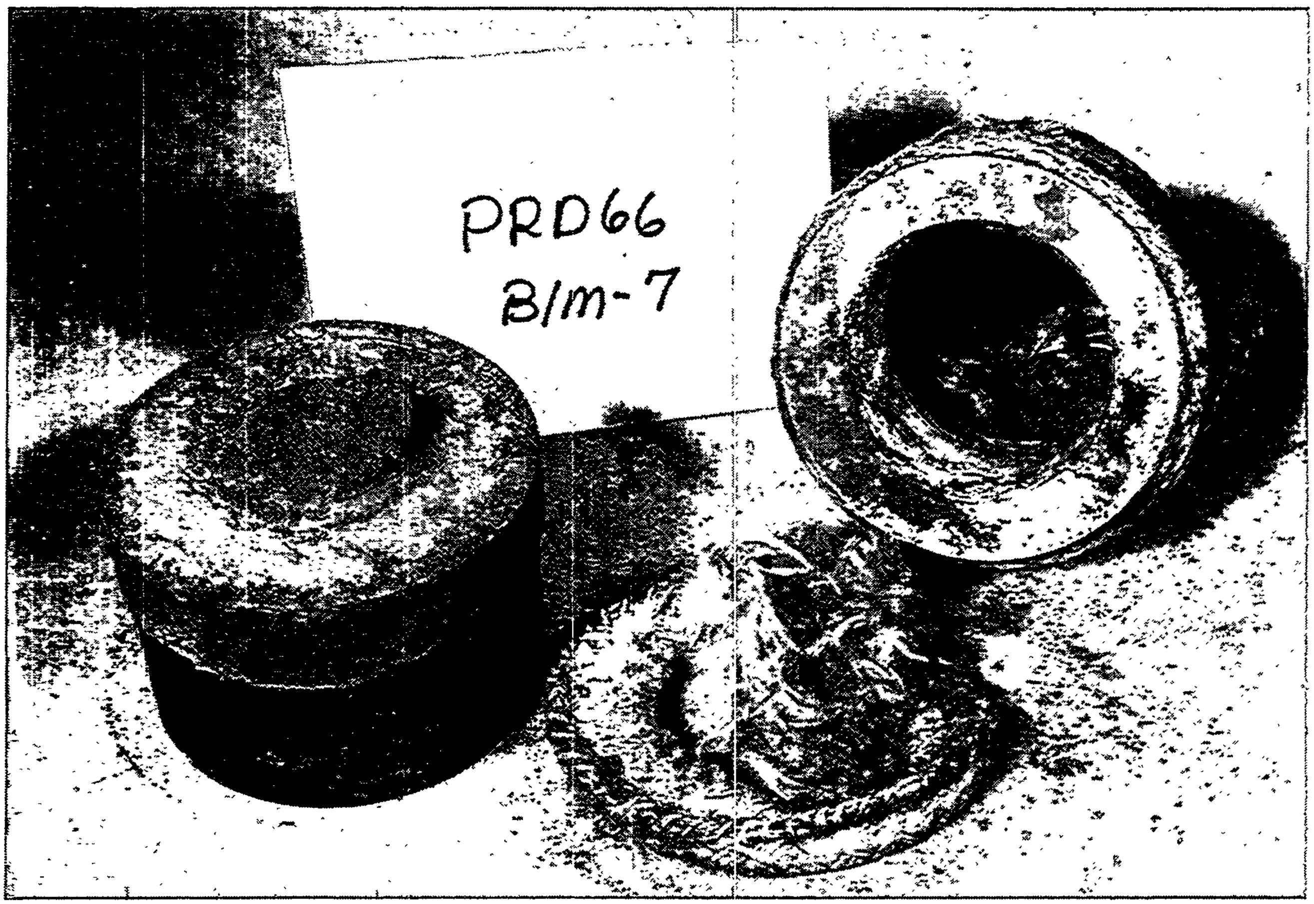

Figure 22a – Fail-Safe/Regenerator, Top Gasket And Flange Section Of The DuPont PRD-66 Candle Filter Which Filled With Ash Along Its ID Bore

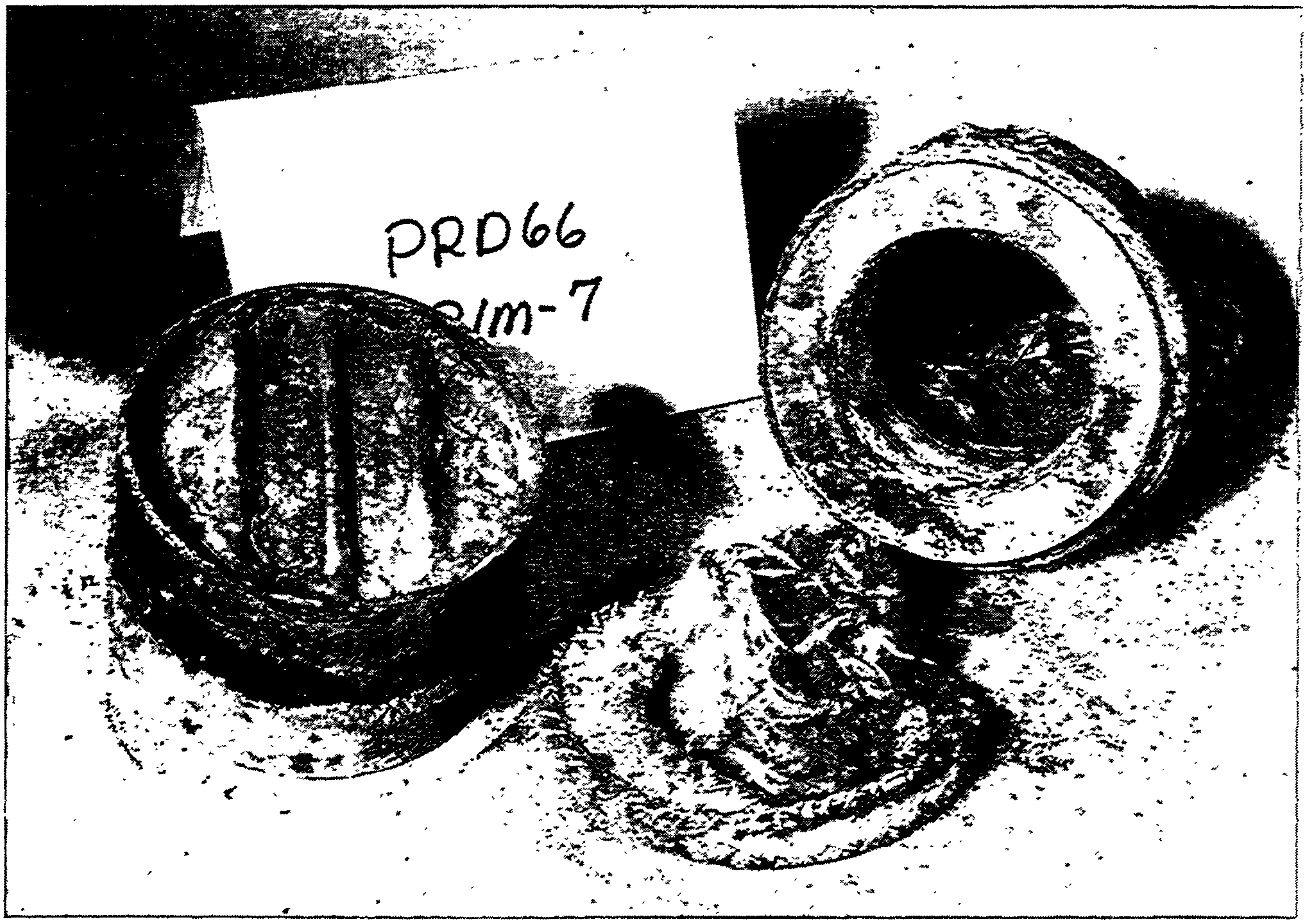

Figure 22b – Fail-Safe/Regenerator, Top Gasket And Flange Section Of The DuPont PRD-66 Candle Filter Which Filled With Ash Along Its ID Bore

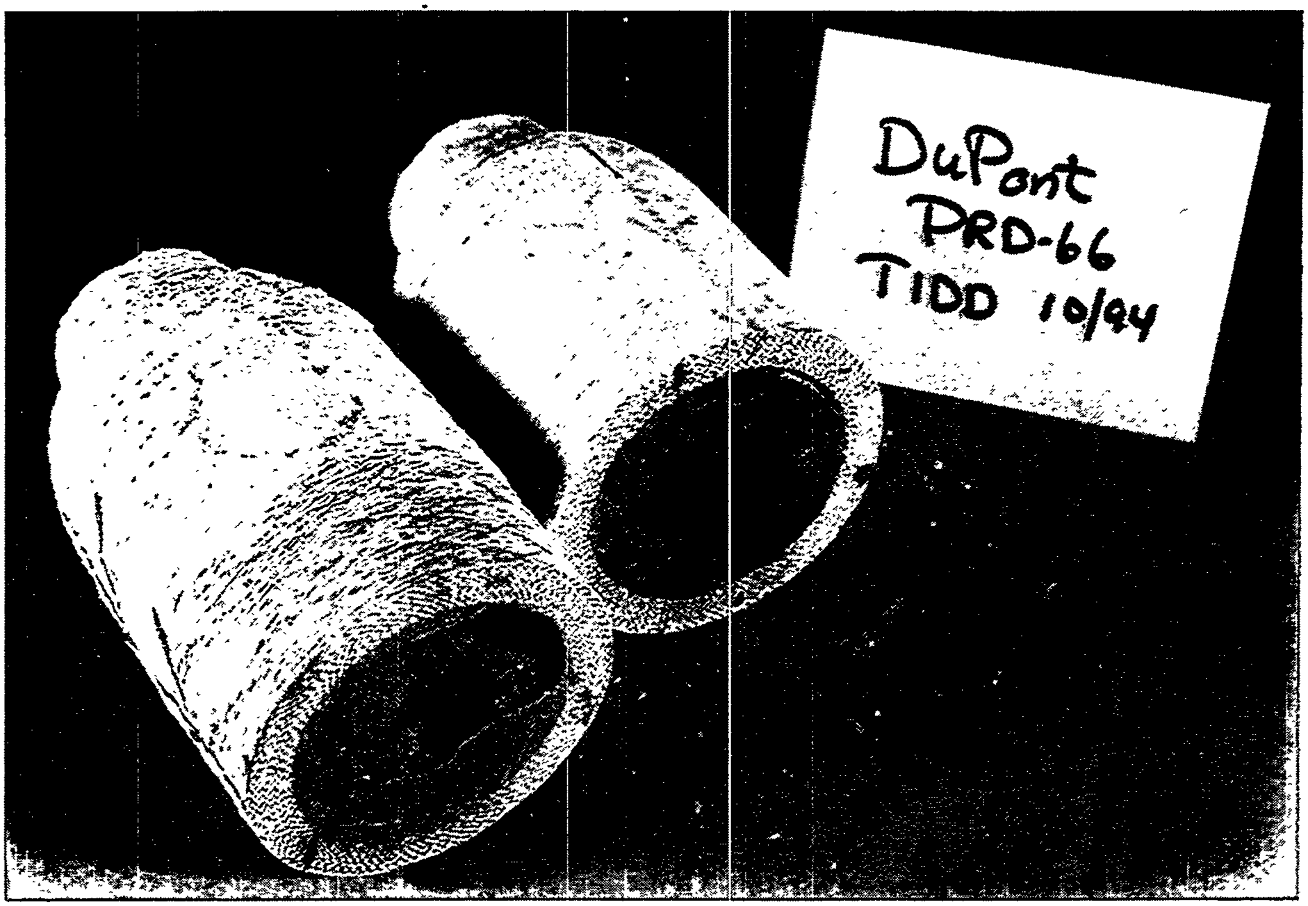

Figure 23a – Ash Filled The ID Bore Of The DuPont PRD-66 Candle Filters After 1705 Hours Of PFBC Operation At Tidd. During Washing Of The Filter Elements, Magnesium Sulfate Leached From The Ash And Formed Deposits Along The Outer Surface Of The Filter Elements.

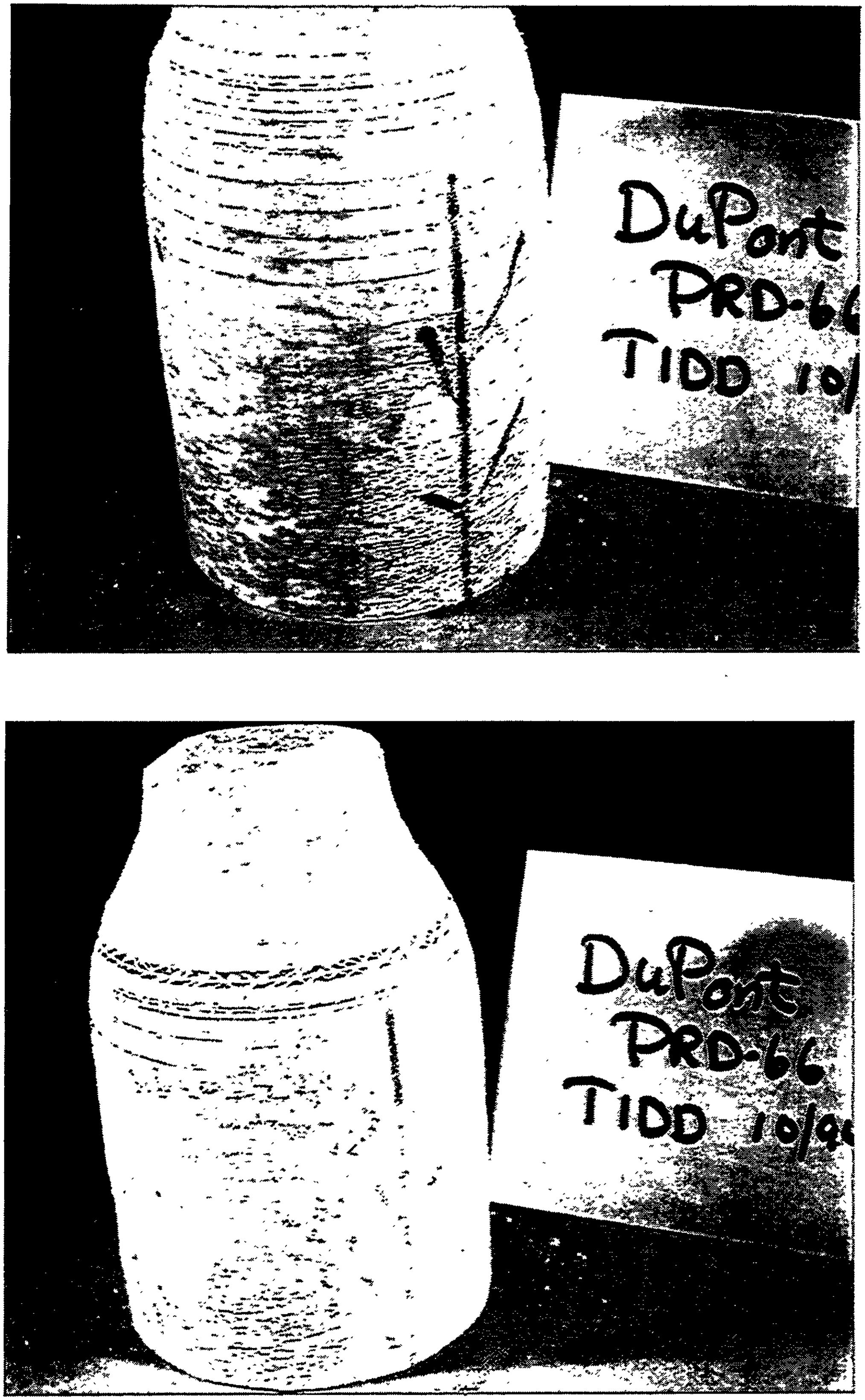

Figure 23b – Deposition Of Magnesium Sulfate Crystals Along The Outer Surface Of The DuPont PRD-66 Filter Elements After Water Washing

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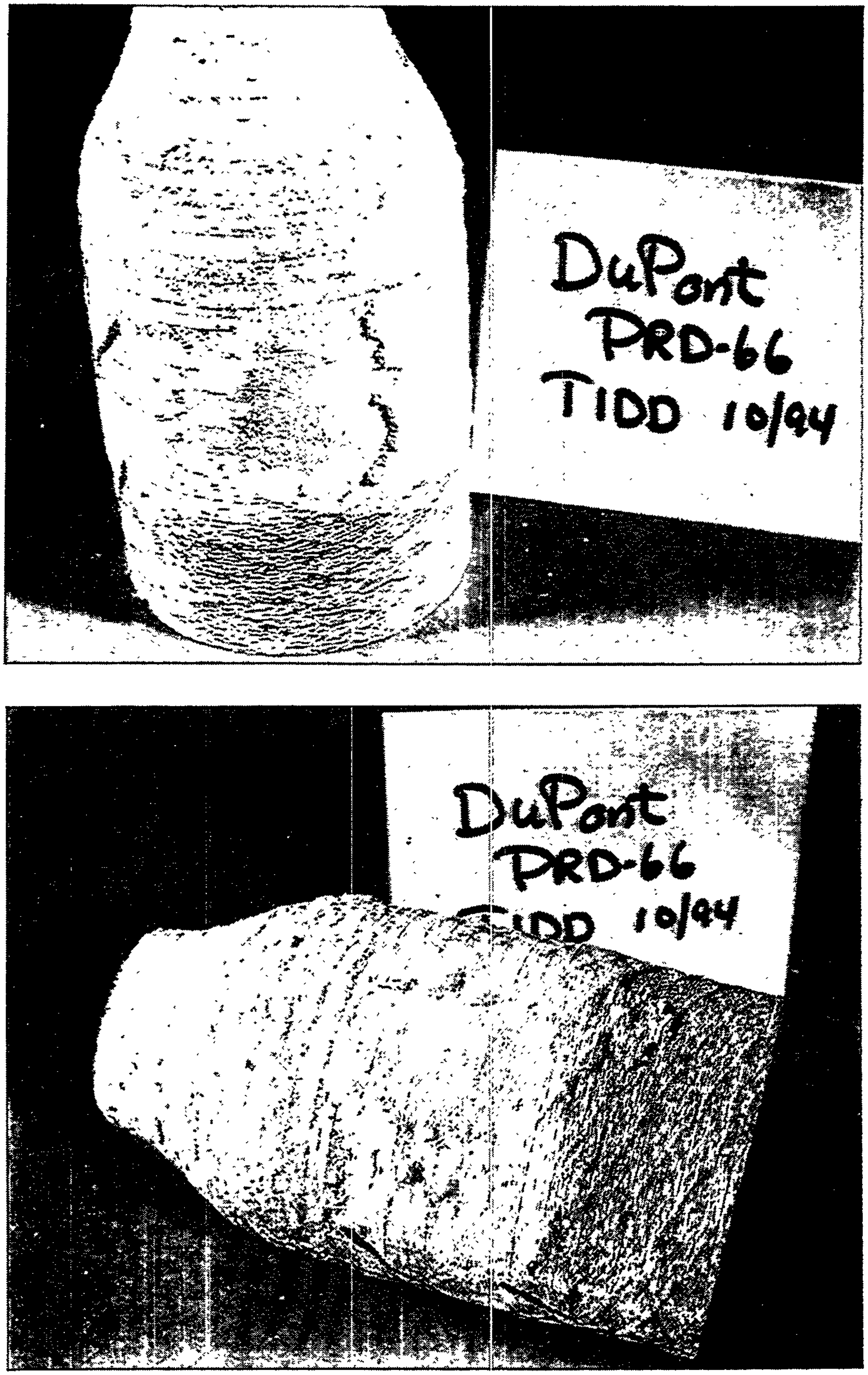

Figure 23c – Deposition Of Magnesium Sulfate Crystals Along The Outer Surface Of The DuPont PRD-66 Filter Elements After Water Washing were observed along the three Schumacher Dia Schumalith F40 candle filters which had been removed for material characterization. As shown in Figure 24, the morphology of the thick residual dust cake layer varied and was rather nondescript in many areas along the surface of the Schumacher Dia Schumalith F40 filter elements.

Ash deposition along the second generation Schumacher Dia Schumalith FT20 candle filters resulted in a very heavy dust cake coating along the length of each filter element (Figure 25). The characteristic nodular formations which typically resulted along the Schumacher Dia Schumalith F40 matrix prior to detuning of the cyclones were not evident. Removal of the Schumacher Dia Schumalith FT20 filters from the C/M array indicated that fines had filled the ID bore of each of the FT20 filter elements. Misalignment of the top gasket which would permit fines to enter and fill the ID bore (i.e., as with the DuPont PRD-66 filter element) was not apparent for the FT20 filter elements.

Typically the fail-safe/regenerator units which were removed from either the advanced second generation candle filter array (B/M) or from the Schumacher Dia Schumalith F40 surveillance candles were generally clean, showing little evidence of ash along their outer surfaces (Figure 26). Since thirty (30) candles had failed during the 1705 hours of PFBC test operation between July and October 1994, the opportunity existed for fines to enter the clean gas side of the filter system, and to be subsequently pulsed back into the ID walls of the filter elements during repetitive cleaning cycles. As previously recommended, the application of an inside membrane along the ID wall of the filter elements would be extremely useful to mitigate fines penetration into the coarse filter matrix.(1)

ROOM TEMPERATURE PERMEABILITY MEASUREMENTS

Room temperature permeability measurements were conducted on ~30 of the filter elements which had been removed from the filter array in October 1994. As shown in Table 2 and Figure 27, irrespective of whether the filters were tested in their as-received state or after brushing, gas flow permeability through many of the PFBC exposed filter elements was significantly lowered due to what was considered to be fines accumulation along the ID and OD surfaces, as well as through the filter walls.

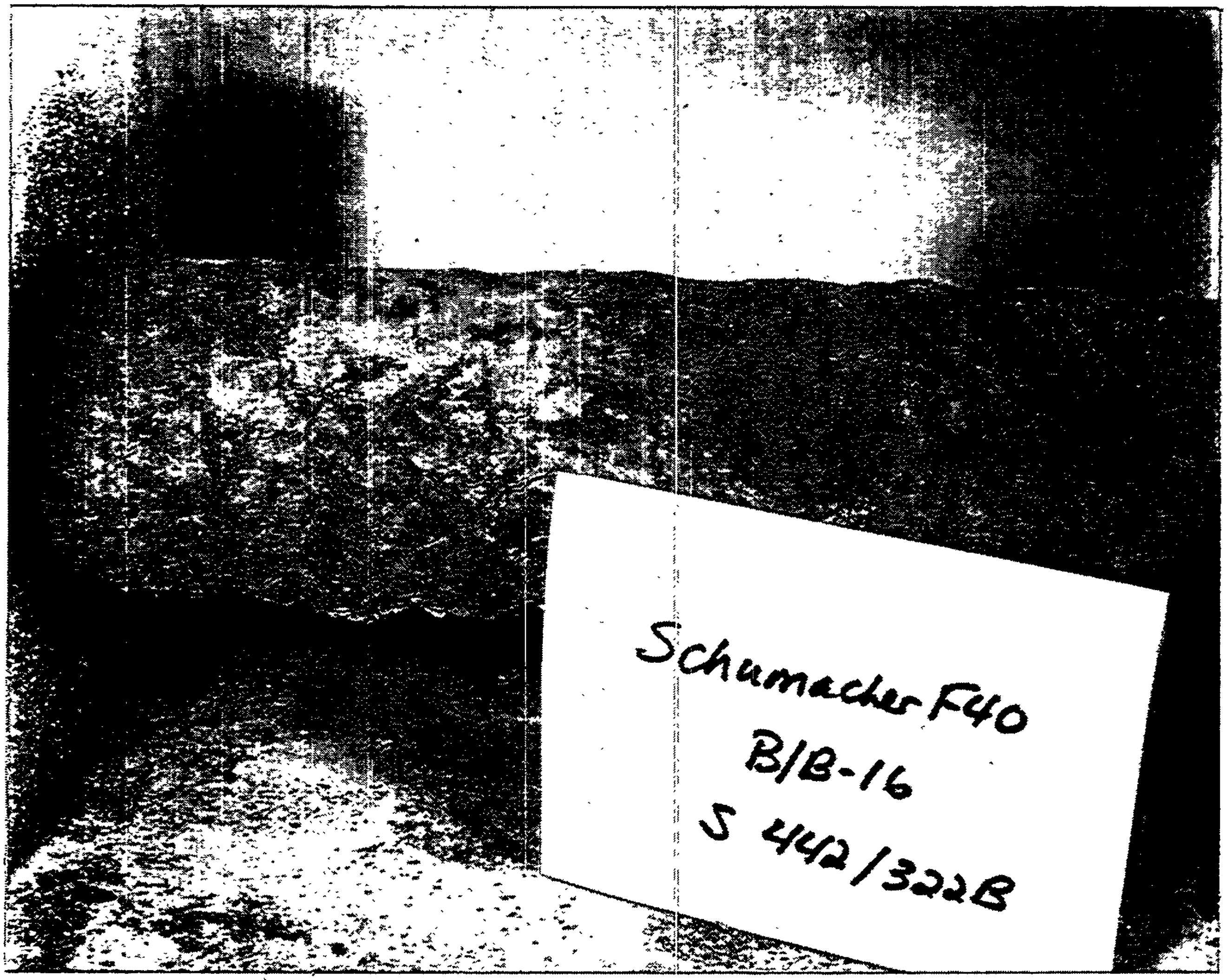

Figure 24a — Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith F40 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

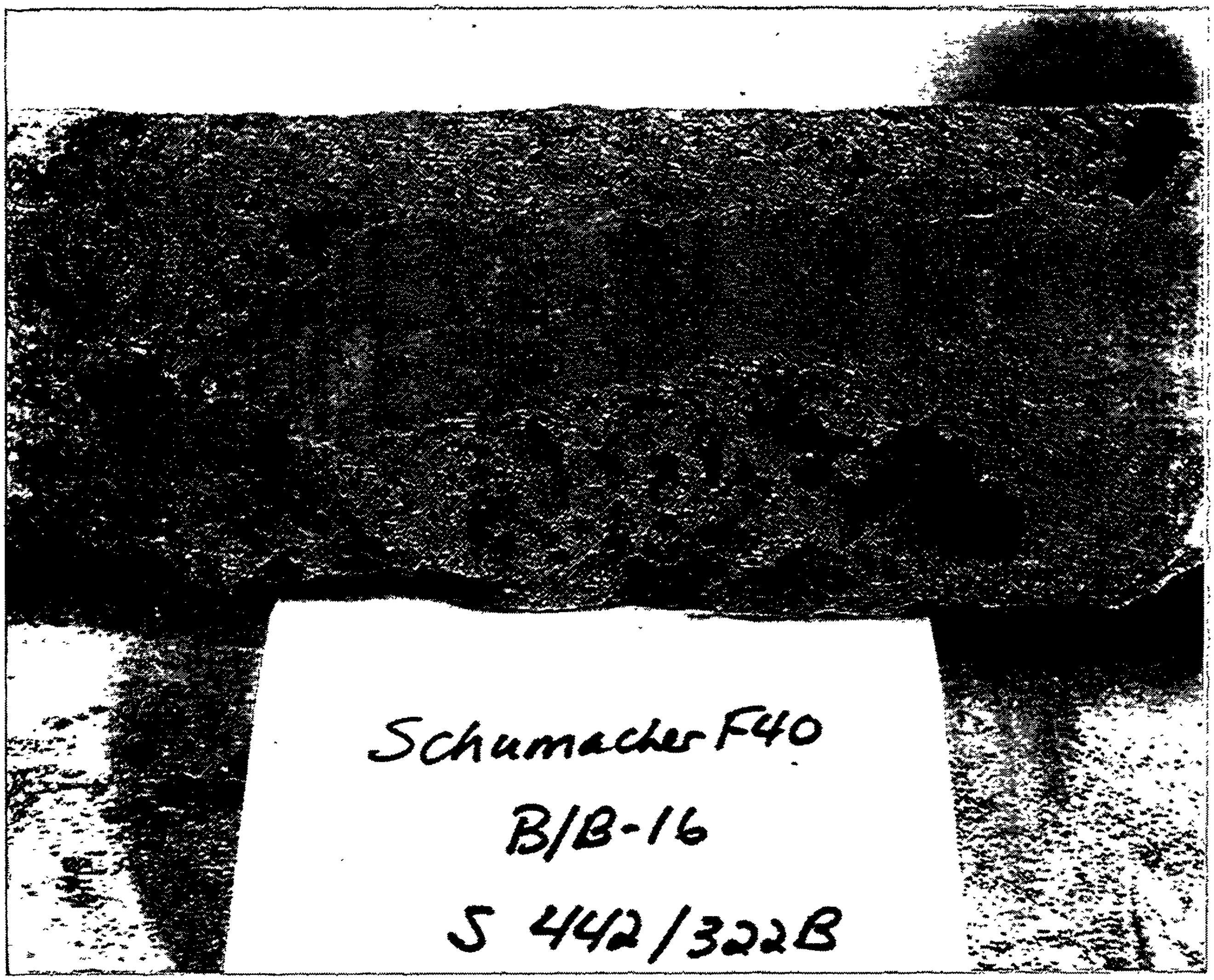

Figure 24b — Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith F40 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

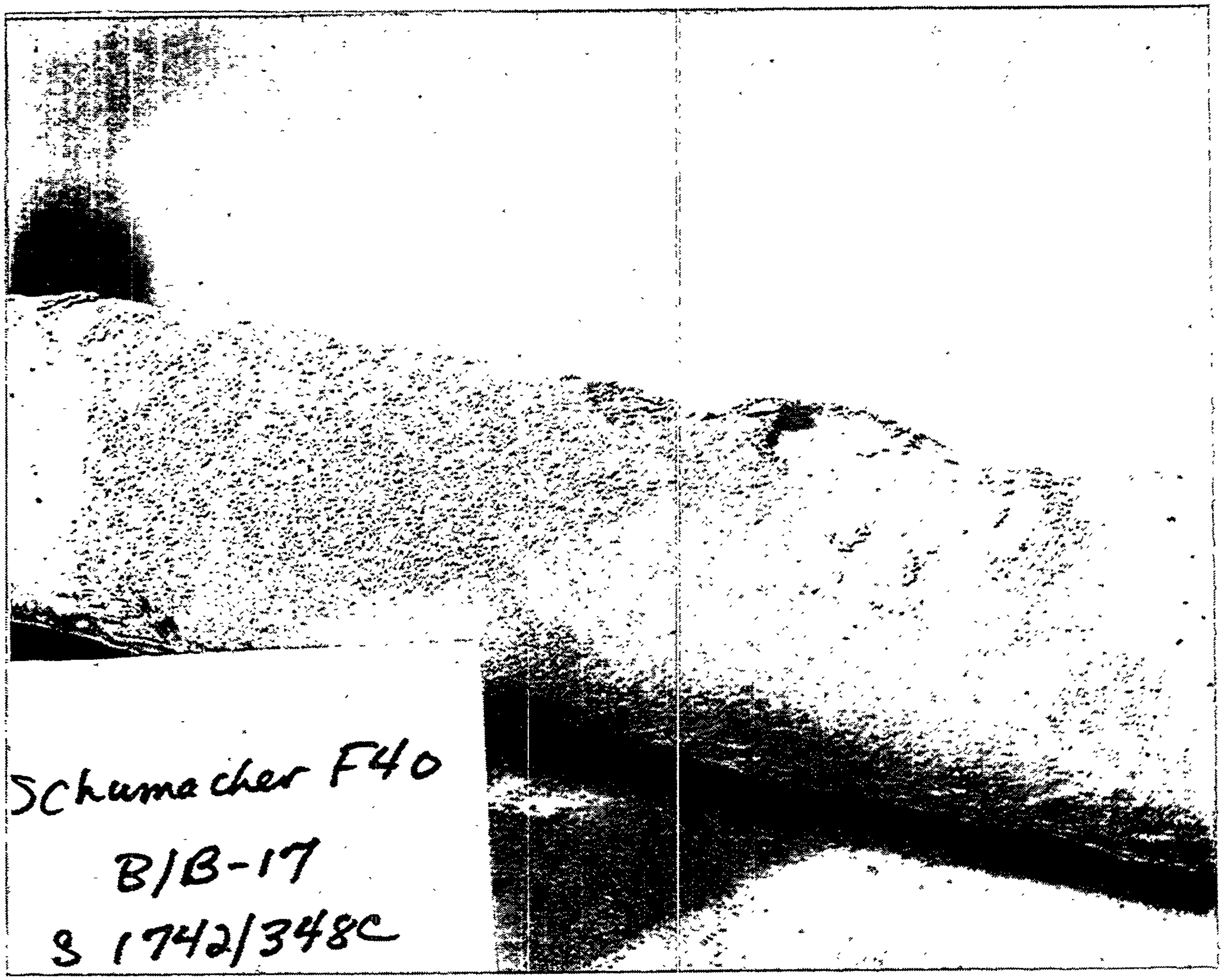

Figure 24c – Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith F40 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

Figure 24d – Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith F40 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

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Figure 24e — Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith F40 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

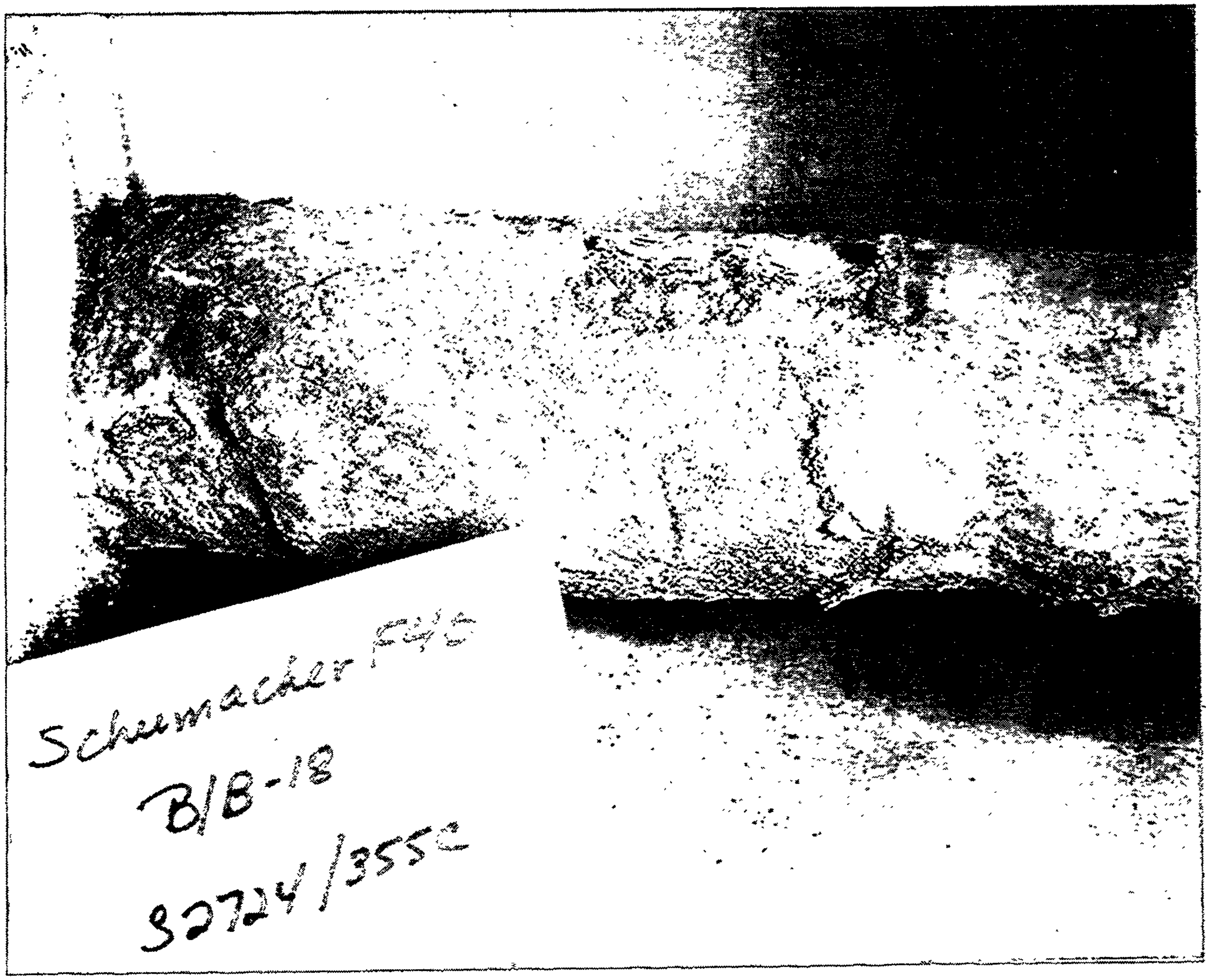

Figure 24f — Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith F40 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

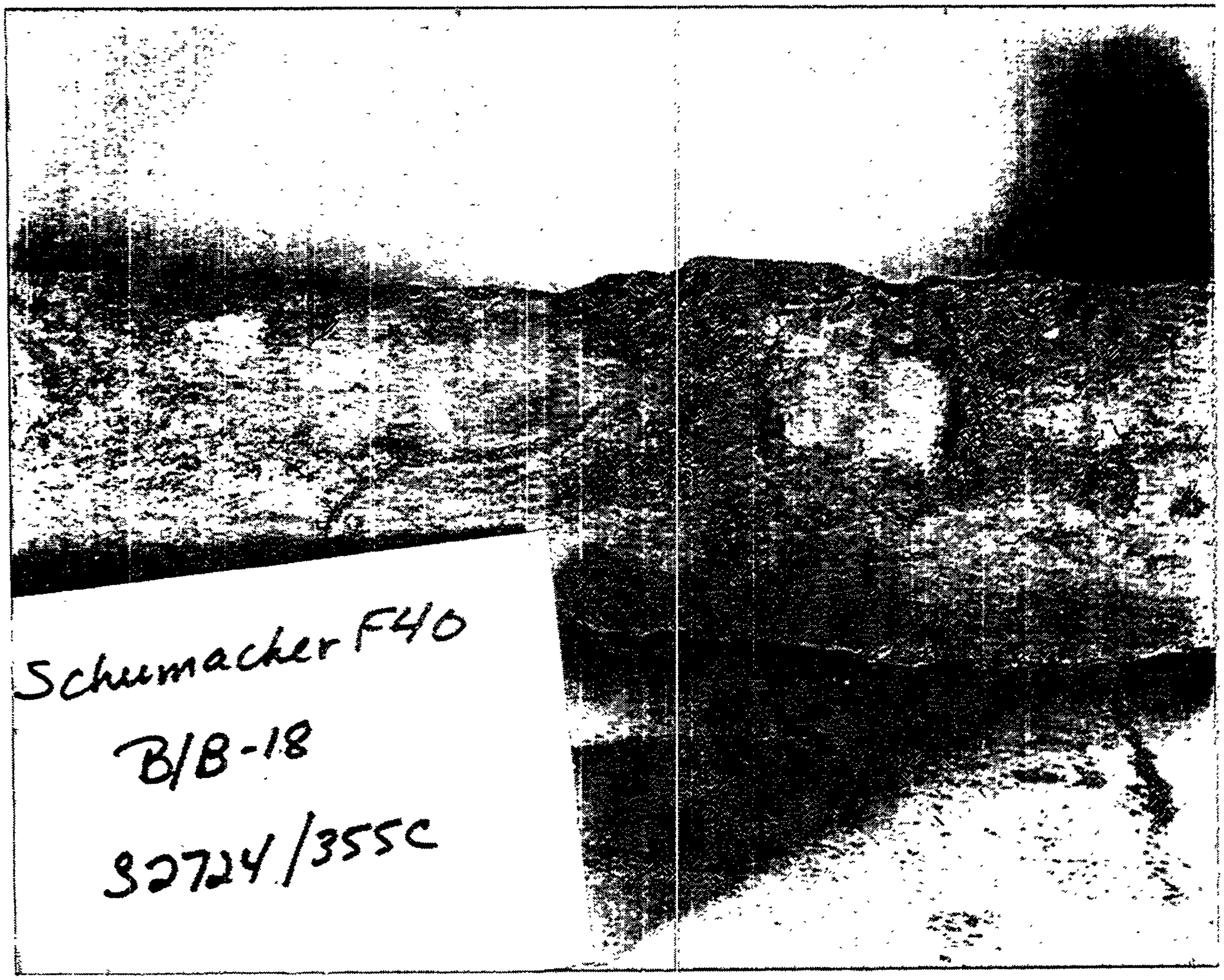

Figure 24g – Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith F40 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

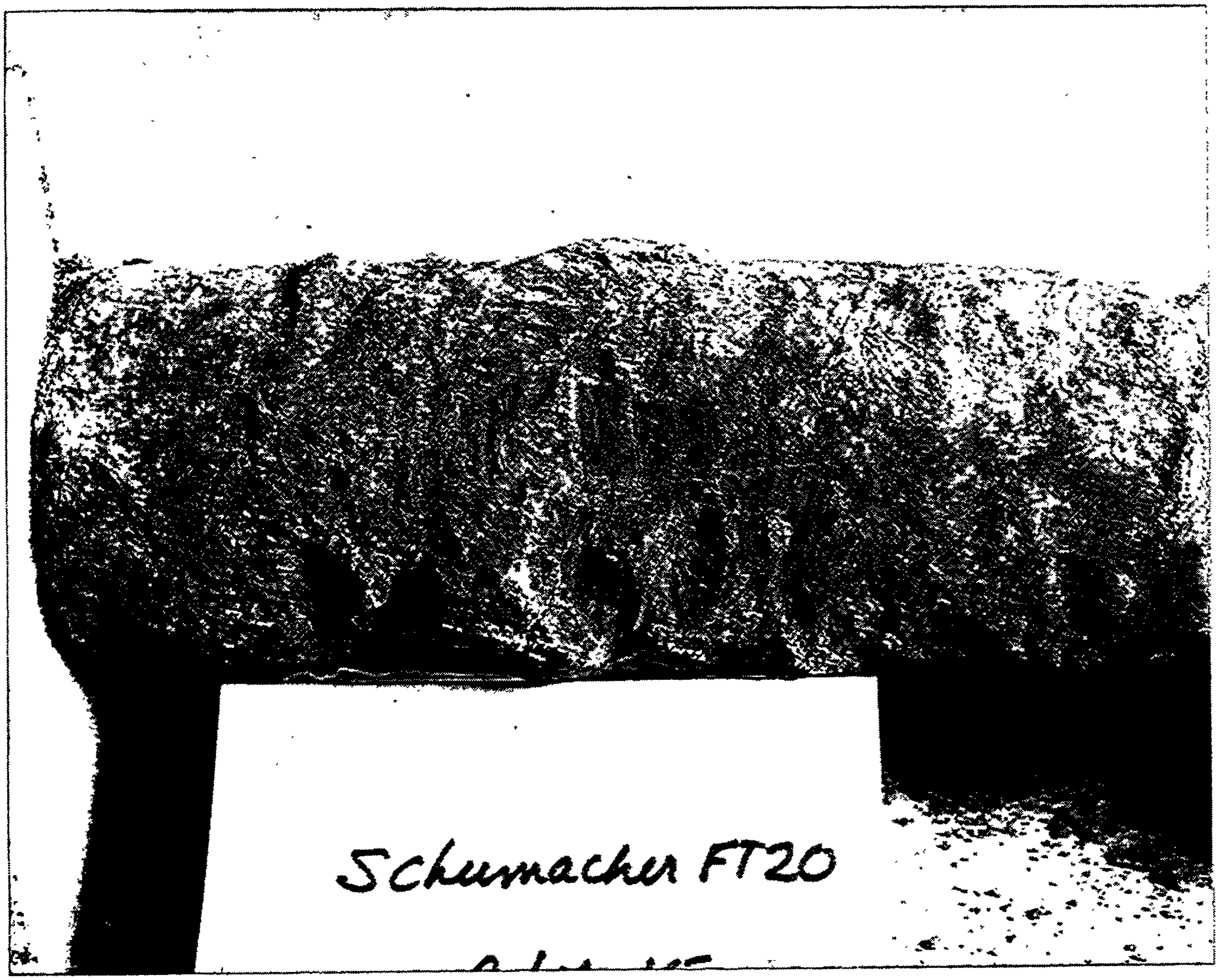

Figure 25a — Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith FT20 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment

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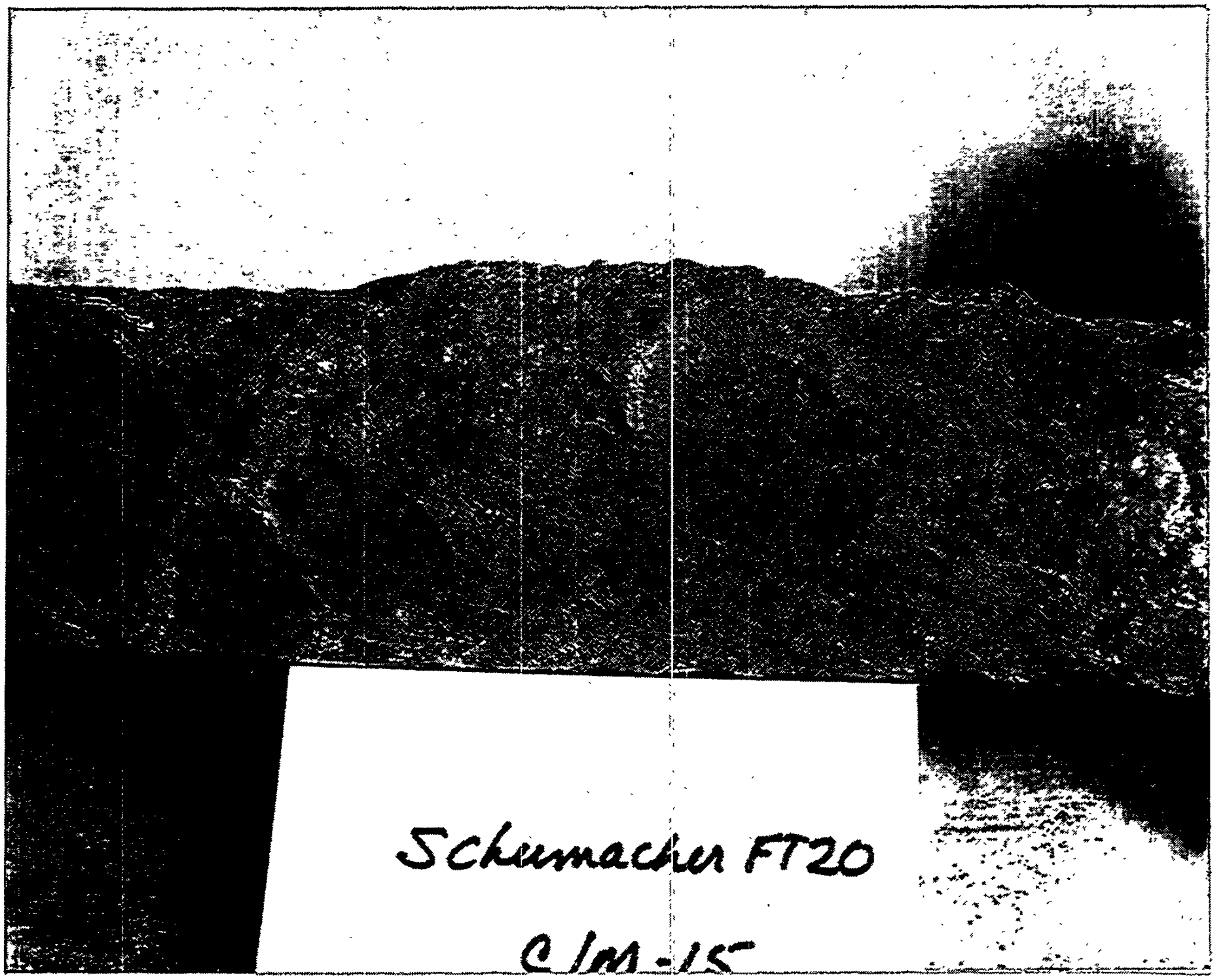
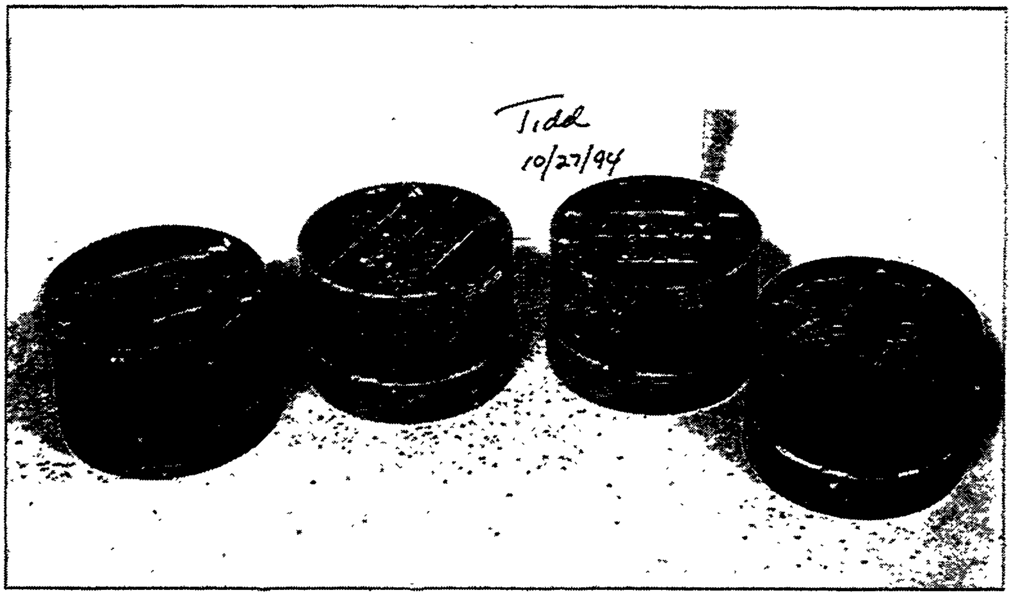


Figure 25b – Ash Cake Formations Along The Outer Surface Of The Schumacher Dia Schumalith FT20 Candle Filters After 1705 Hours Of Hot Gas Filtration In The PFBC Gas Environment



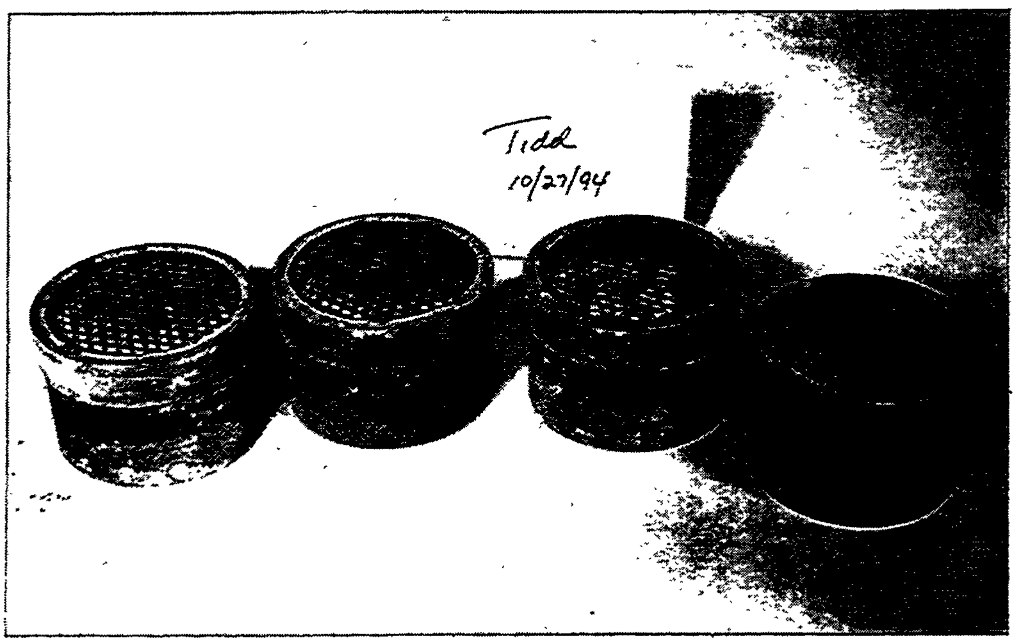


Figure 26 — Fail-Safe/Regenerators After 1705 Hours Of Hot Gas Filtration At Tidd

TABLE 2
PFBC EXPOSED CANDLE FILTER PERMEABILITY MEASUREMENTS

Filter ID No.	Room Temperature Permeability, iwg/10 fpm		
	As-Received	Brushed	Washed
Schumacher Dia Schumalith F40			
S328/314C (B/T-16) *			48
S228/318B (A/B-16) *			27
S492/322B (C/B-16) *		8.5	
S504/315C (A/B-16) *		7.0	
S1750/348C (A/B-17)	138		65
S1712/348C (A/B-19)	111	99	
S2343/364C (A/B-20)		111	
S2155/355C (A/B-3)	111		
S2152/355C (A/B-4)	125	111	
S1701/348C (A/B-5)	111		54
S2351/364C (A/B-21)	125	125	
S2308/364C (A/B-23)	138	133	
S2114/355C (A/B-26)	130	125	
S1804/348C (A/B-27)	111	111	
S1715/348C (A/B-29)	138	138	
Coors P-100A-1 Alumina/Mullite			
DC-009 (B/M-1)			28
DC-006 (B/M-2)			20
DC-004 (B/M-3)			28
DC-001 (B/M-4)			16
DC-010 (B/M-5)			15
DC-002 (B/M-21)			16
DC-011 (B/M-22)			15
DuPont PRD-66			
D126 (B/M-9)			5 psi @ 10% flow

TABLE 2 (continued)
PFBC EXPOSED CANDLE FILTER PERMEABILITY MEASUREMENTS

Filter ID No.	Room Temperature Permeability, iwg/10 fpm		
	As-Received	Brushed	Washed
Pall Vitropore 442T			
R3-300 (B/M-10)			19
R4-301 (B/M-11)			17
R2-302 (B/M-12)			26
R1-305 (B/M-13)			26
R4-300(B/M-14)			38
Schumacher Dia Schumalith FT20			
S039/312E (C/M-15)	Totally Plugged With Ash		
S126/315E (C/M-16)	Totally Plugged With Ash		
S106/312E (C/M-17)	Totally Plugged With Ash		
S125/315E (C/M-18)	Totally Plugged With Ash		
S202/315E (C/M-19)	Totally Plugged With Ash		
S197/315E (C/M-20)	Totally Plugged With Ash		
S105/312E (C/M-21)	Totally Plugged With Ash		
S045/312E (C/M-22)	Totally Plugged With Ash		

* Surveillance Candle Filters.

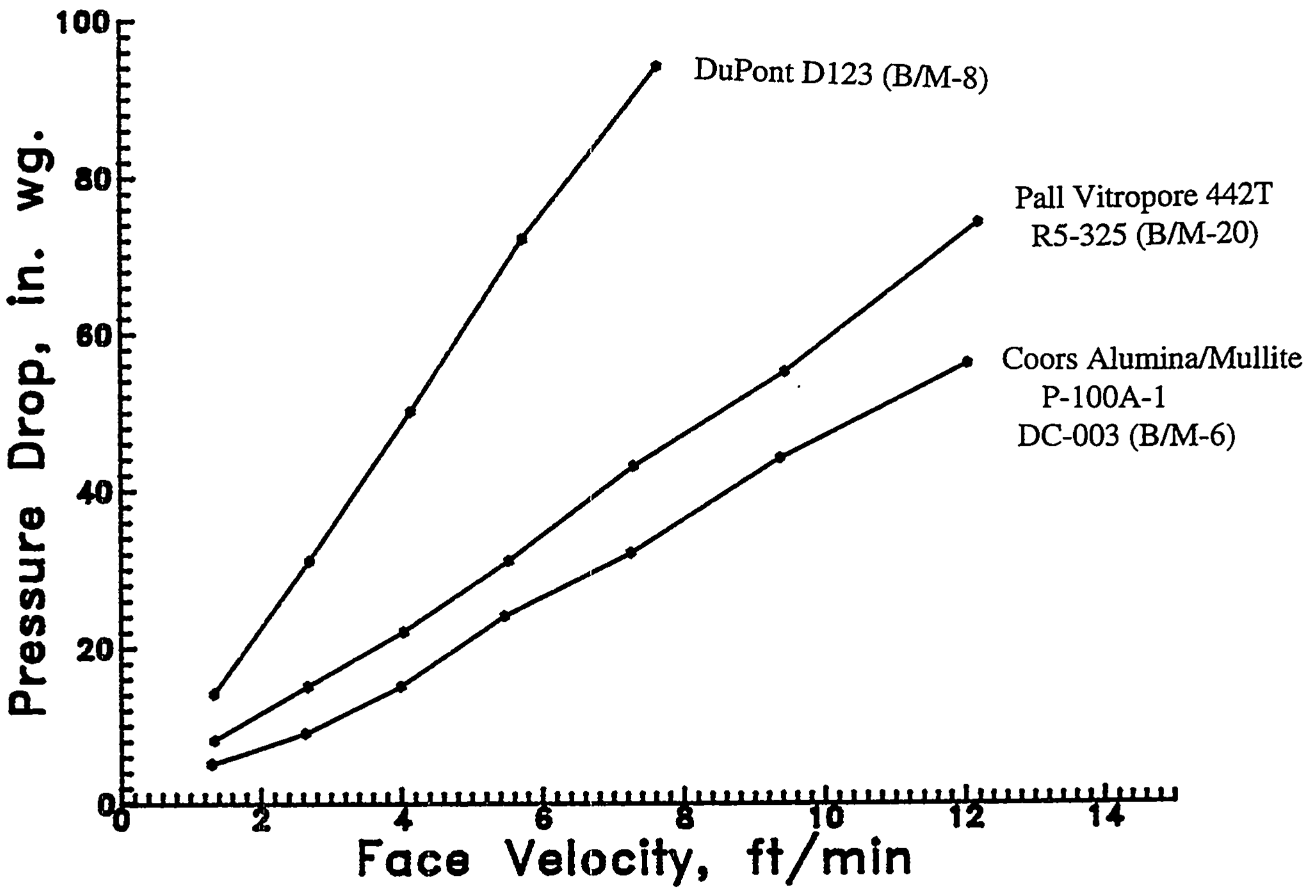


Figure 27 — Room Temperature Permeability Measurements Of Various PFBC Exposed Candle Filters

FILTER CLEANABILITY

Candles which had a minimal dust coating along their ID surfaces were selected for additional cleaning. Water was used to not only wash the outer surface of the filter elements, but was also flushed through the matrix. During drying, white "blotchy" patches of residue were evident along the outer surface of many of the darker filter elements (i.e., Schumacher Dia Schumalith F40 and Pall Vitropore 442T candles). Although thinner, the residue appeared to be similar to the crystalline deposit which formed along the outer surface of the DuPont PRD-66 filter section during wash and sample preparation for strength analysis. Crystalline growth of the leached magnesium sulfate in addition to the packing of the fines into the filter wall were considered to be responsible for the low gas flow permeability which resulted in the washed filter elements.

A mild acid leach was attempted to further clean two candles (S1750/348C and S1712/348C). Each candle was submerged in a bath of dilute acetic acid for approximately 24 hours. After removal and air drying, the permeability of these elements only slightly increased. Discussions with the various filter manufacturers agreed that the mild acetic acid treatment would solubilize the calcium-magnesium constituents of the entrapped sorbent fines, but cautioned as to possible attack of the porous ceramic filter matrices. Since strong acids (HCl, HF, H_2SO_4) were also considered to have deleterious effects on many of the phases which are present in the various filter element, extensive efforts were not undertaken to refurbish the plugged filters for immediate reinstallation at Tidd. Efforts should be directed to developing adequate procedures to rejuvenate plugged candle filters, as well as to identify the impact of the refurbishing procedures on the stability of the porous ceramic filter matrix.

CANDLE FILTER SURFACE ROUGHNESS

Table 3 provides a summary of the ash cake thickness that resulted along the various advanced second generation candle filters, and profilometer measurements of the initial surface finish (i.e., roughness) of these elements. Three surface finish

TABLE 3
ASH CAKE THICKNESS AND FILTER SURFACE ROUGHNESS MEASUREMENTS

Filter Element	Ash Cake Thickness	Surface Finish, μ-inch * Circum-ferential	Axial	Membrane Coating Versus Support Wall Characteristics
Coors Alumina/ Mullite	Thin Coating; Small Raised Deposits	170 220 170-220	170-210 200-250 200	Absence Of Membrane Coating; Uniform Wall Porosity
Pall Vitropore 442T	Thick Ash Deposit	300-380 300-380 250-300	240-330 240-370 290-380	Lower Porosity OD membrane
3M CVI-SiC Composite	Moderately Thick Deposits; Pin Holes Evident	Not Tested		Open Mesh Weave In Outer Confinement Layer; Underlying Filtration Mat And Triaxial Braid Support Structure
DuPont PRD-66	Negligible Deposition During Normal Operation	80-100 ** 60-90 40-75	380-720 540-650 520-680	Outer Surface Membrane Wrap
Schumacher Dia Schumalith F40	Thick Deposit	180-240 180-250 180-240	220-290 170-260 130-210	Lower Porosity OD Membrane
Schumacher Dia Schumalith FT20	Thick Deposit	250-320 200-290 210-230	260-340 220-290 210-270	Lower Porosity OD Membrane; Lower Permeability Matrix Relative To The F40 Matrix

* Arithmetic Average.
** Grooves Resulting From Fiber Membrane Wrap.

measurements were taken both axially, as well as circumferentially along O-ring sections which had been removed from each of the PFBC exposed filter matrices. The tighter range in the profilometer results (i.e., Coors alumina/mullite $\Delta R = 50$ μ-inch; circumferential $\Delta R = 35$ μ-inch for the DuPont PRD-66 matrix) appeared to provide a surface which limited ash cake formation and adherence of fines along the outer surface of fully functional candle filter elements (i.e., candle ID bore not filled and/or plugged with fines).

Thick ash cake layers resulted along the Schumacher Dia Schumalith F40 and FT20, and Pall Vitropore 442T candles which had rougher surface finishes (i.e., higher μ-inch readings; $\Delta R = 60\text{-}130$ μ-inch). Although these data are preliminary and qualitative in nature, dust cake adherence and/or removal may be influenced by the texture or roughness of the OD surface or membrane; the porosity of the surface or membrane; the tortuosity, homogeneity, or architecture of the underlying coarse or support matrix; as well as the composition and size of the fines that are carried to and which collect along the surface of the filter elements.

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1. Advanced Particle Filter, Quarterly Technical Progress #11; January 1 - March 31, 1993, Westinghouse STC GO No. CB-12406-CE, AEPSC Contact No. C8014.

APPENDIX H

CHARACTERIZATION OF THE AS-MANUFACTURED AND PFBC-EXPOSED 3M CVI-SiC COMPOSITE FILTER MATRIX

M.A.Alvin

CHARACTERIZATION OF THE AS-MANUFACTURED AND PFBC-EXPOSED 3M CVI-SiC COMPOSITE FILTER MATRIX

M. A. Alvin

December 22, 1994

ABSTRACT

Advanced second generation filter elements have focused on the development of fiber reinforced porous ceramic composite matrices. In this report we will explore the architecture of the 3M chemically vapor infiltrated silicon carbide (CVI-SiC) composite filter matrix, its as-manufactured morphology, composition and strength, as well as changes which result in the composite matrix after 1705 hours of exposure to the pressurized fluidized-bed combustion (PFBC) gas environment.

MORPHOLOGY OF THE 3M CVI-SiC COMPOSITE CANDLE FILTER MATRIX

AS-MANUFACTURED COMPOSITE FILTER MATRIX

The 3M CVI-SiC composite filter matrix consists of three layers -- an outer open mesh confinement layer; a middle filtration mat layer; and an inner triaxial braided fabric layer which forms the structural support matrix (Figure 1). Scanning electron micrographs (SEM) shown in Figures 2a and 2b indicate that the outer confinement layer contains elliptical Nextel^{TM} 312 fibers which are encapsulated by a ~1-2 μm silicon carbide (SiC) coating. During sample preparation, the SiC outer coating which encapsulated the confinement fiber bundles frequently cracked and/or was removed, revealing the underlying Nextel^{TM} 312 fibers (Figure 2c). The morphology of the outer surface of the CVI-SiC coating is shown at higher magnification in Figure 2d. Although the surface of the CVI-SiC deposited layer appears rather mottled, a uniform consistency exists along the surface of the coated Nextel^{TM} 312 fibers in the confinement layer.

Elemental microprobe analyses (EMA) were conducted on the fibers that were present in the as-manufactured outer confinement layers of the 3M CVI-SiC composite filter matrix (Figure 3). Fiber pull-out during sample preparation is evident in the micrographs shown in Figure 3. EMA indicates the presence of aluminum, silicon and oxygen within the Nextel^{TM} 312 fibers (i.e., an aluminosilicate), with silicon and carbon

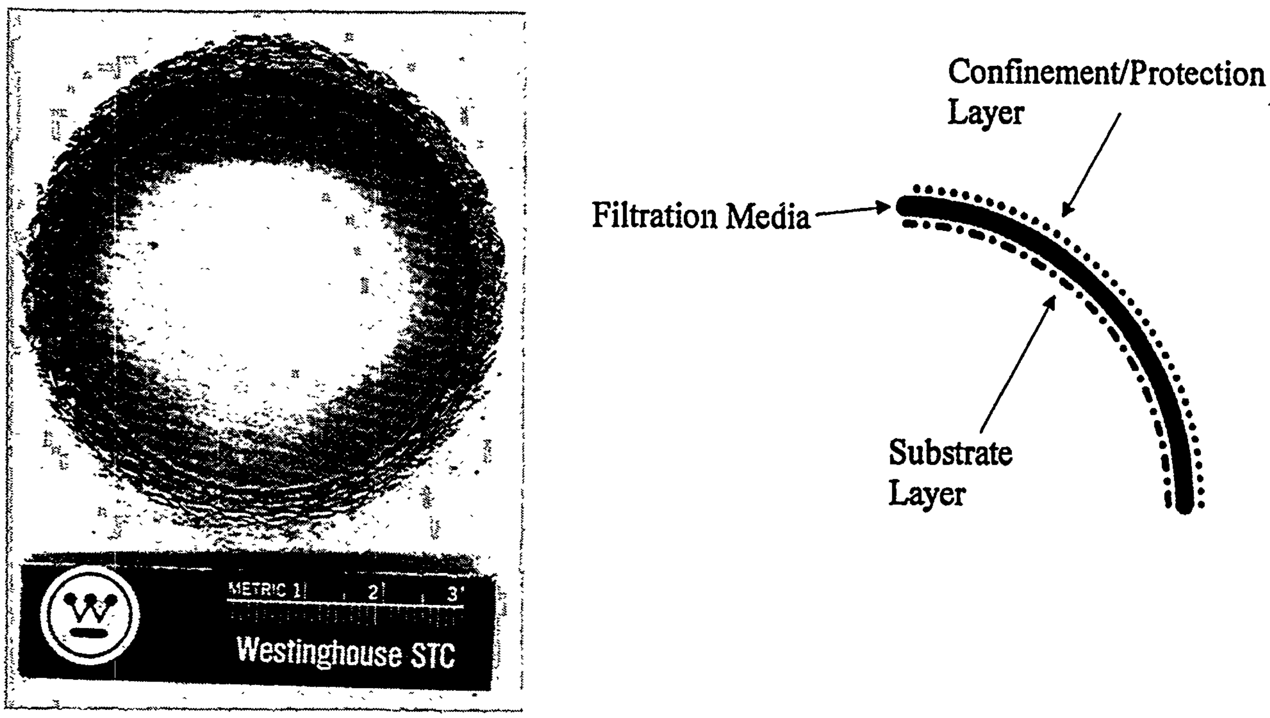
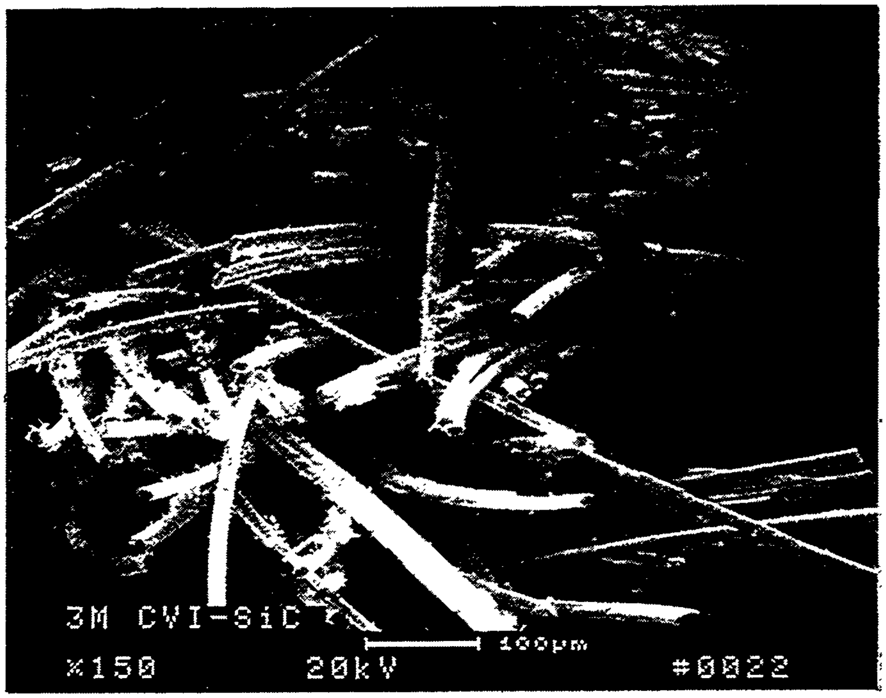


Figure 1 — Construction Of The 3M CVI-SiC Composite Filter Matrix



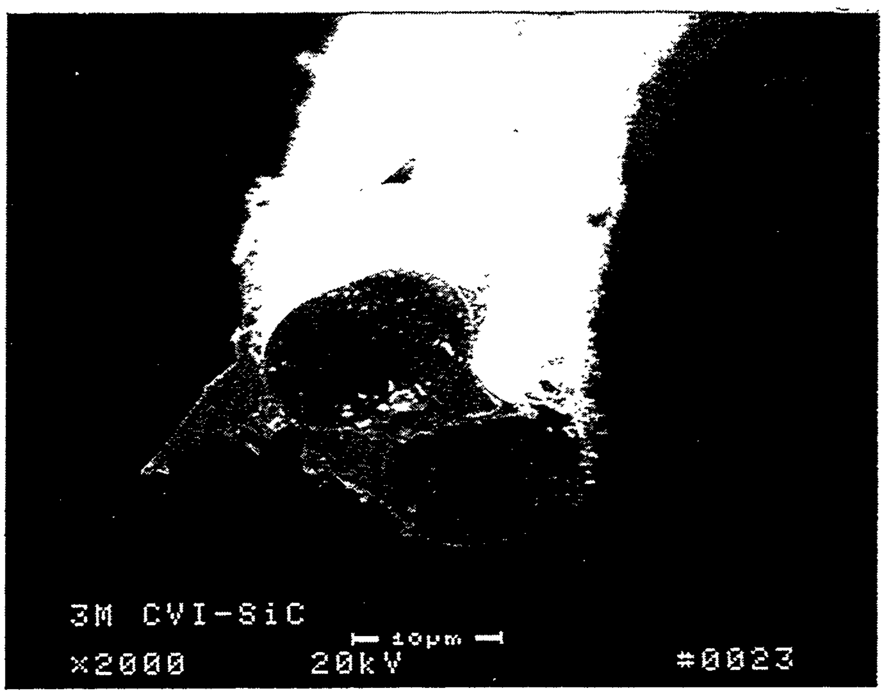


Figure 2a — Morphology Of The CVI-SiC Coated Nextel™ 312 Fibers In The Open Mesh Confinement Layer Of The As-Manufactured 3M Composite Filter

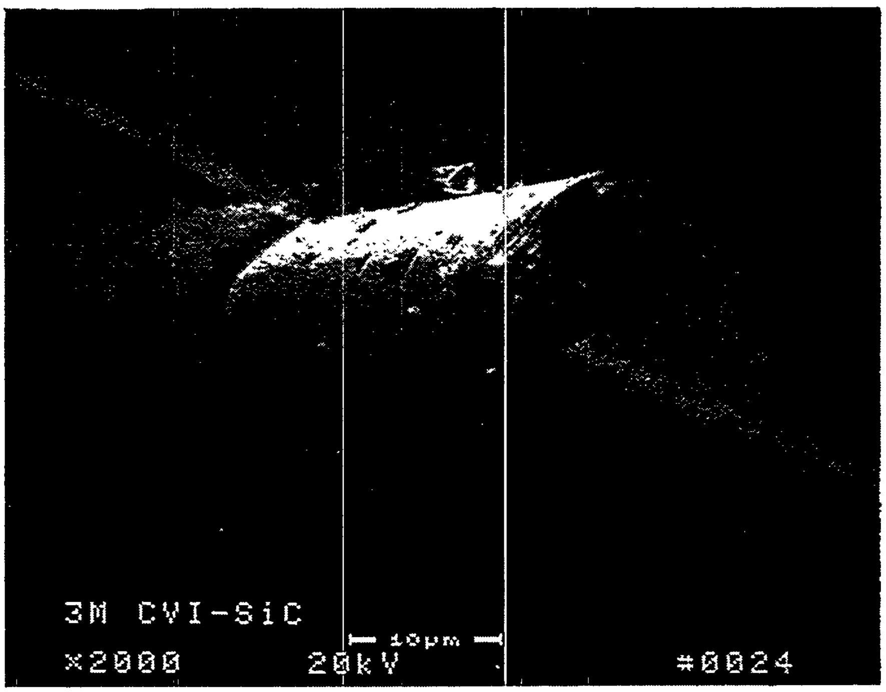


Figure 2b – SEM Illustrating The Morphology Of The CVI-SiC Coated Nextel™ 312 Fiber In The Open Mesh Confinement Layer Of The 3M Composite Filter Matrix

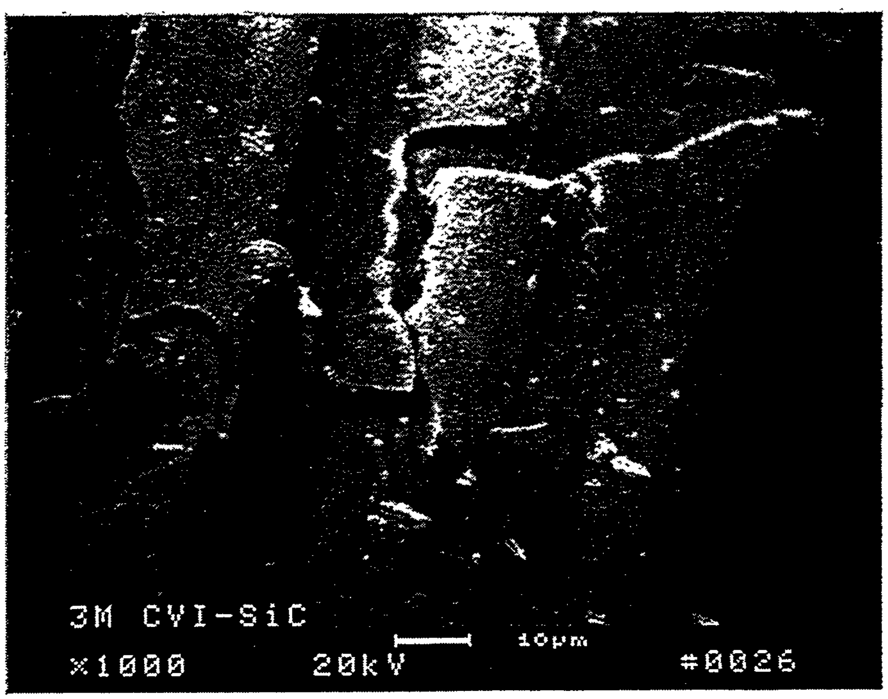


Figure 2c — Cracking Of The CVI-SiC Coating During Sample Preparation

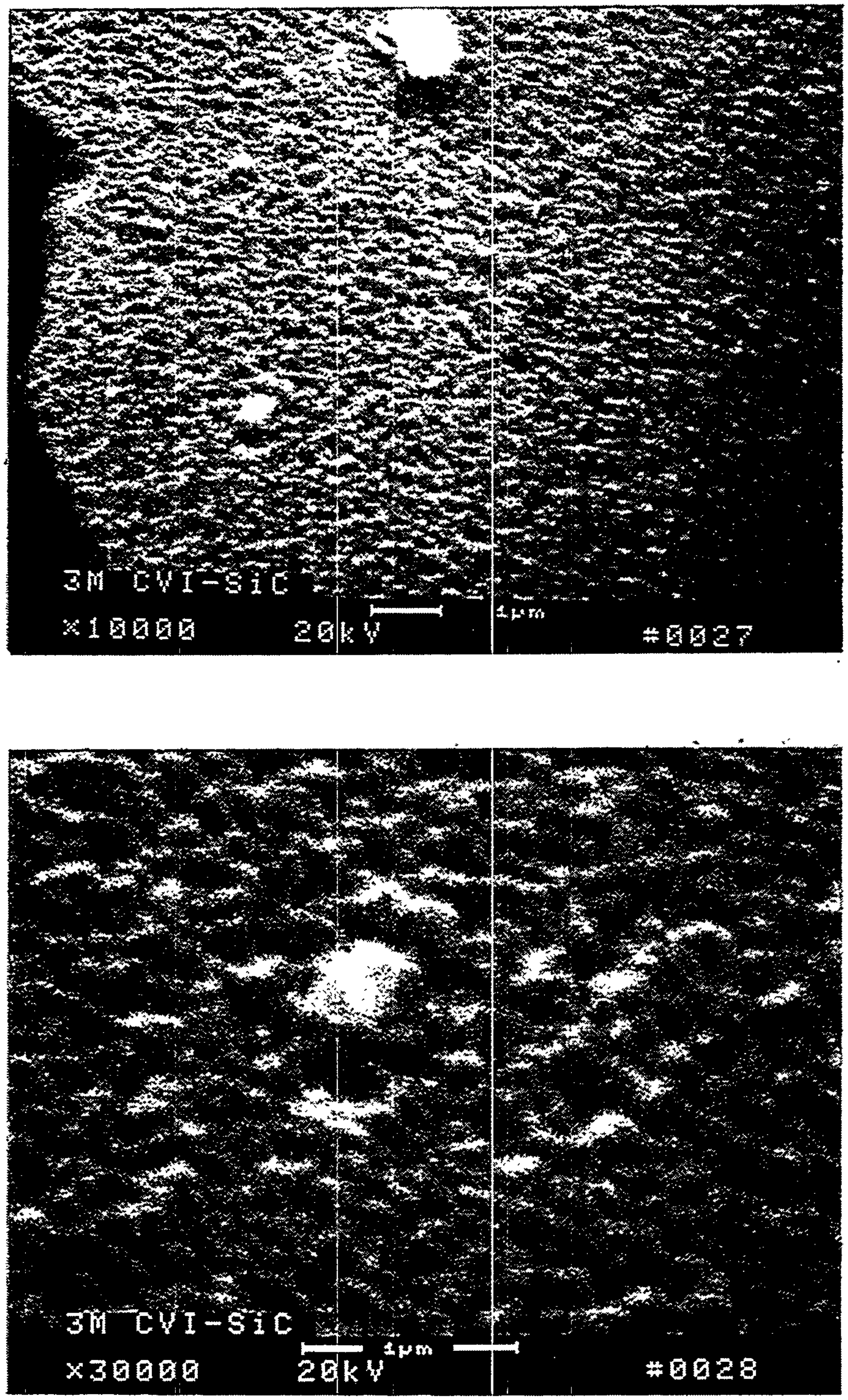
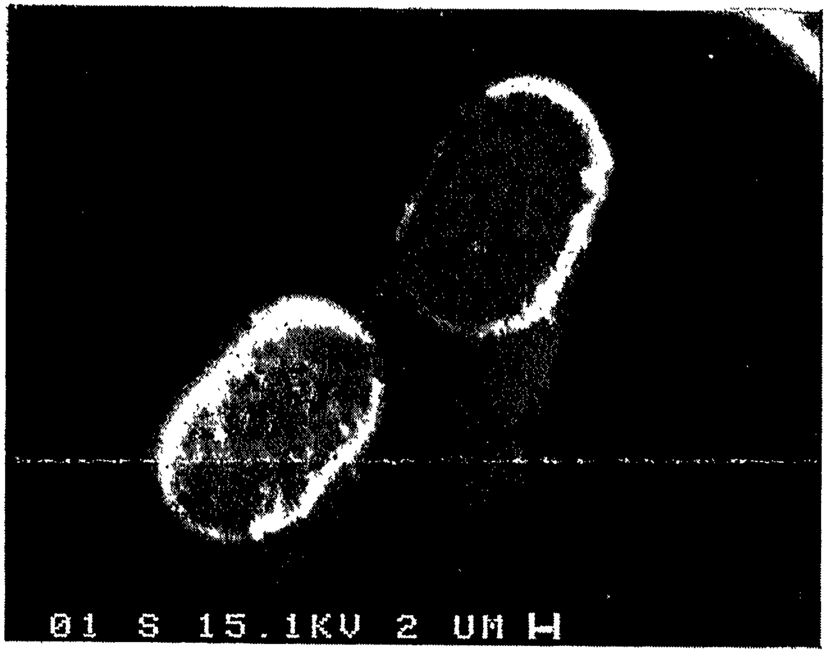


Figure 2d – High Magnification Micrographs Illustrating The Morphology Of The Surface Of The CVI-SiC Coating

SEM



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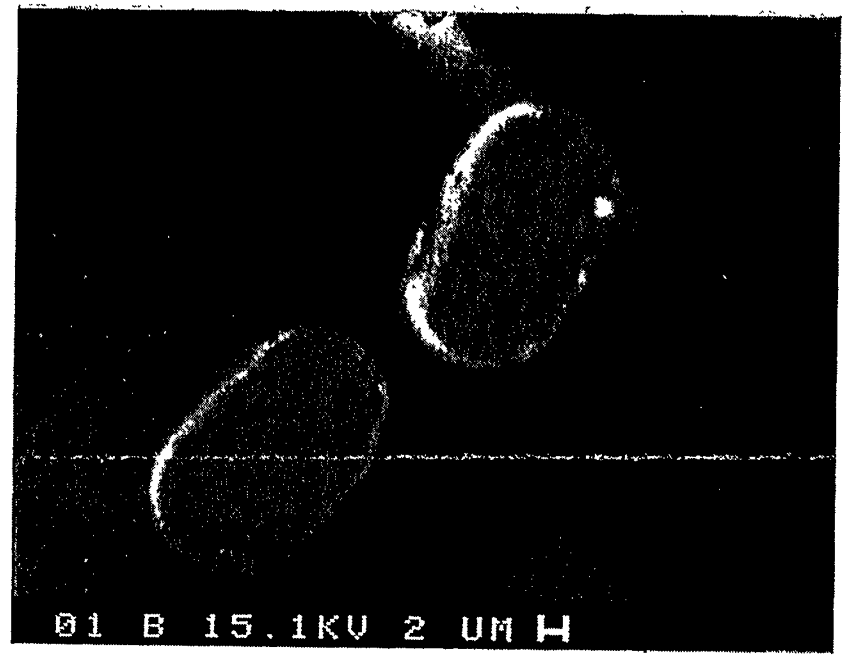

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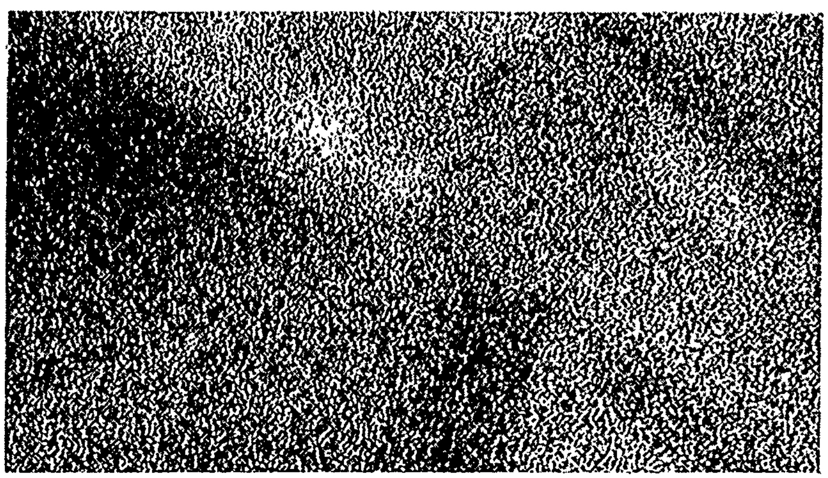

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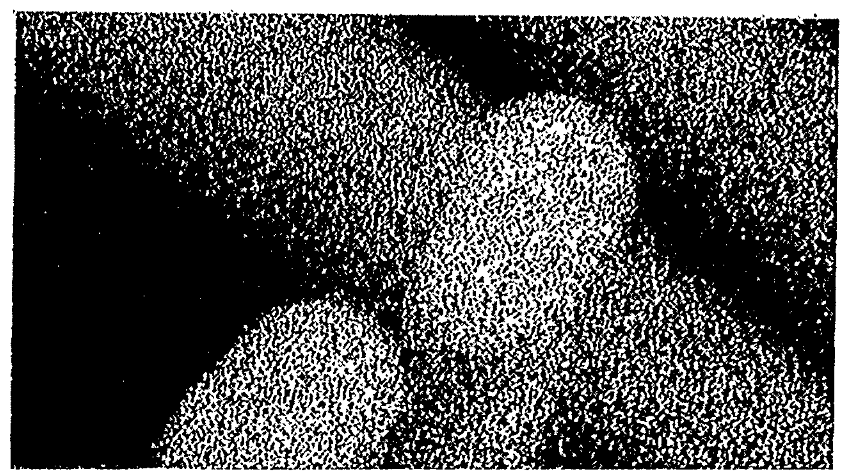


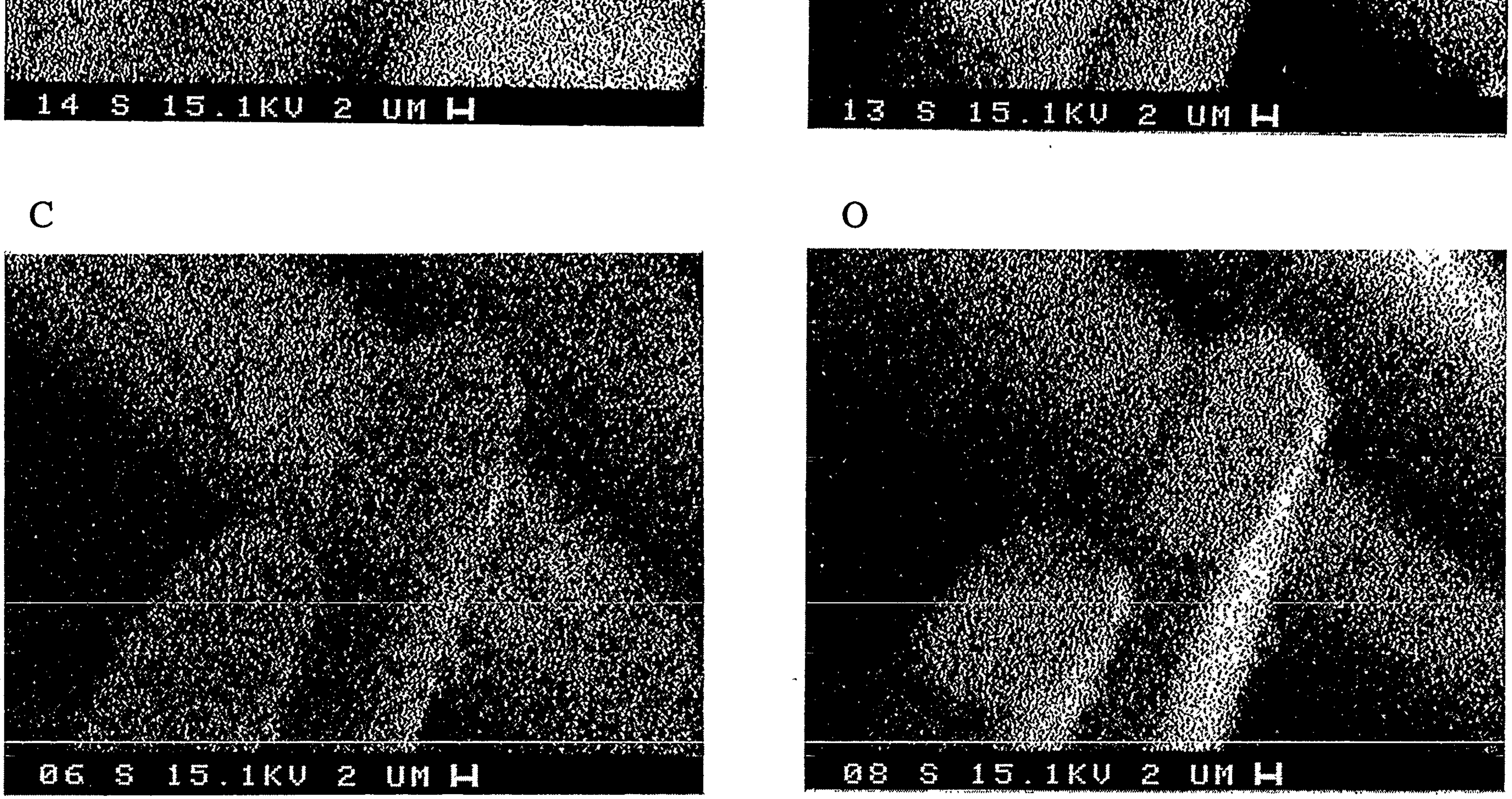
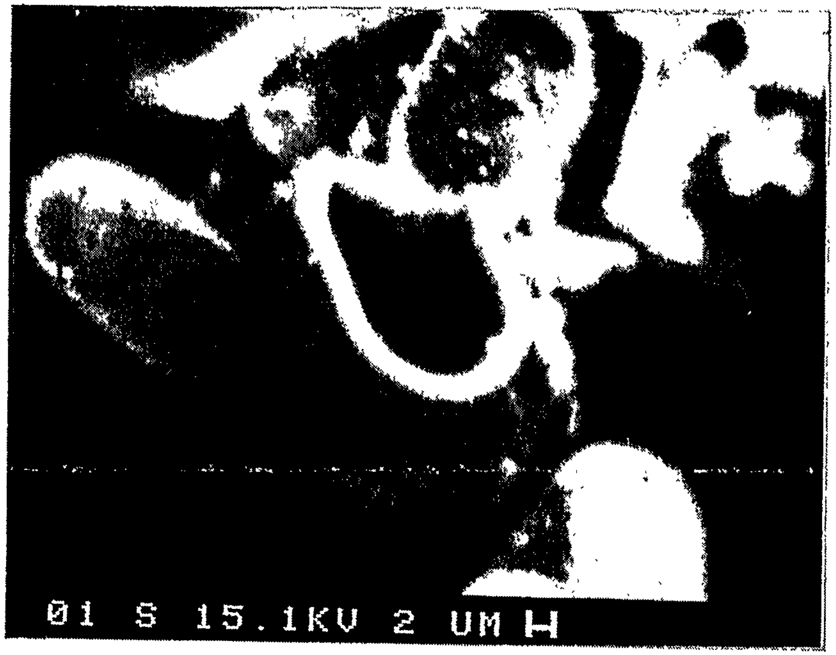


Figure 3a – Elemental Microprobe Analyses Of The Fibers Present In The As-Manufactured Confinement Layer Of The 3M CVI-SiC Composite Filter Matrix

SEM



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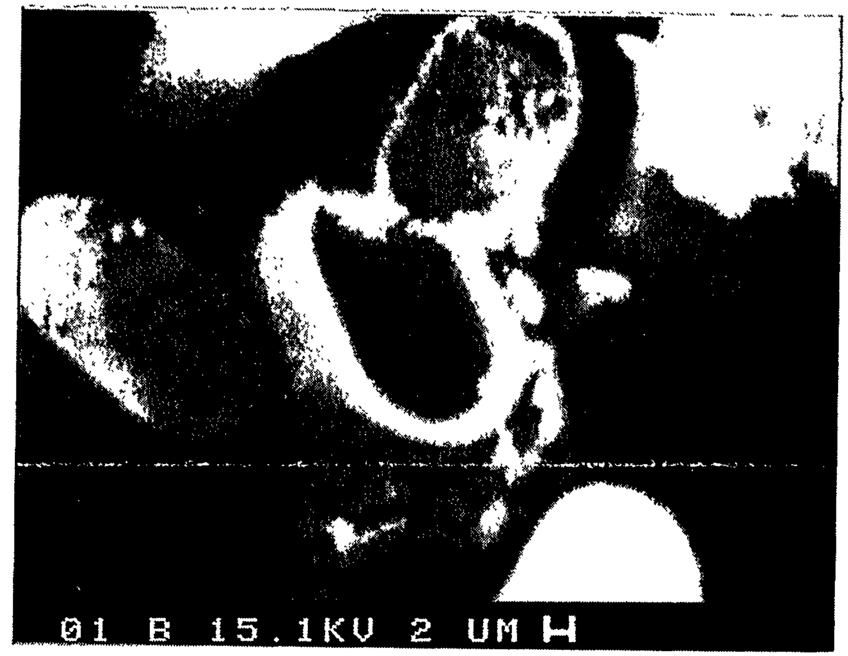

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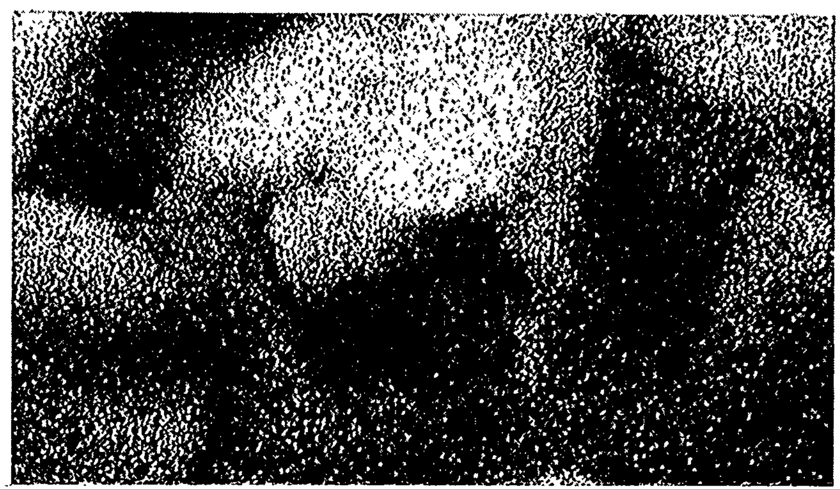


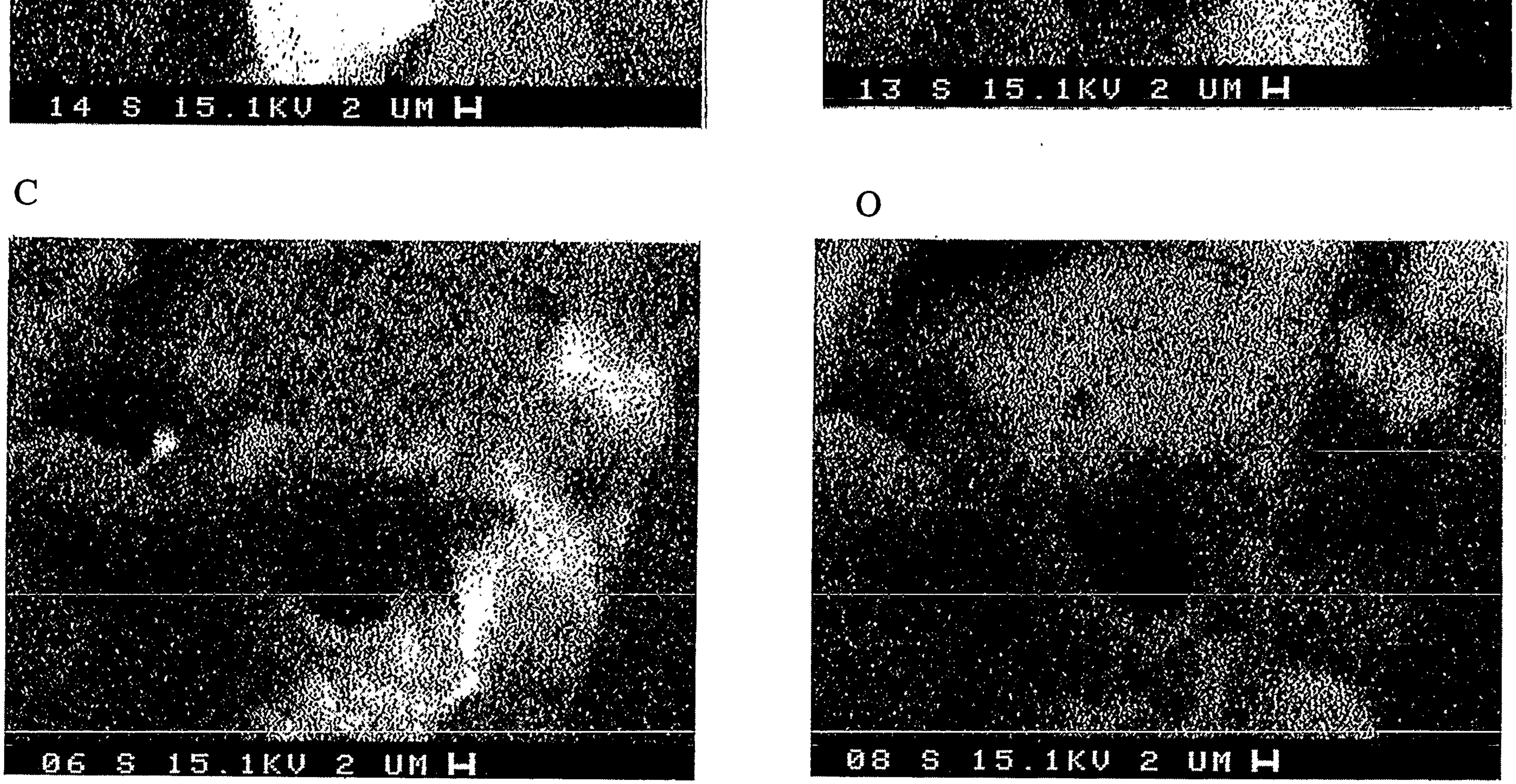
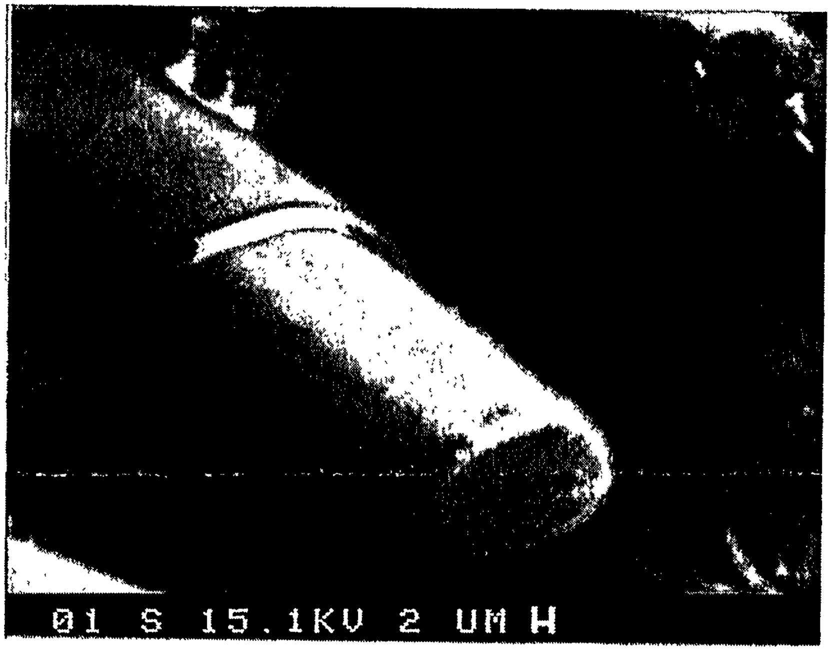


Figure 3b – Elemental Microprobe Analysis Illustrating Fiber Pull-Out During Sample Preparation

SEM



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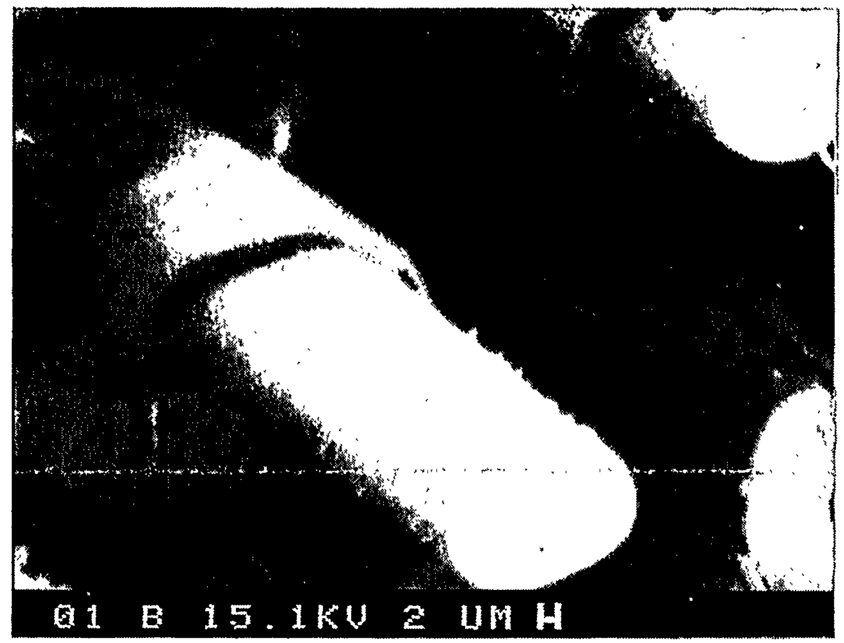

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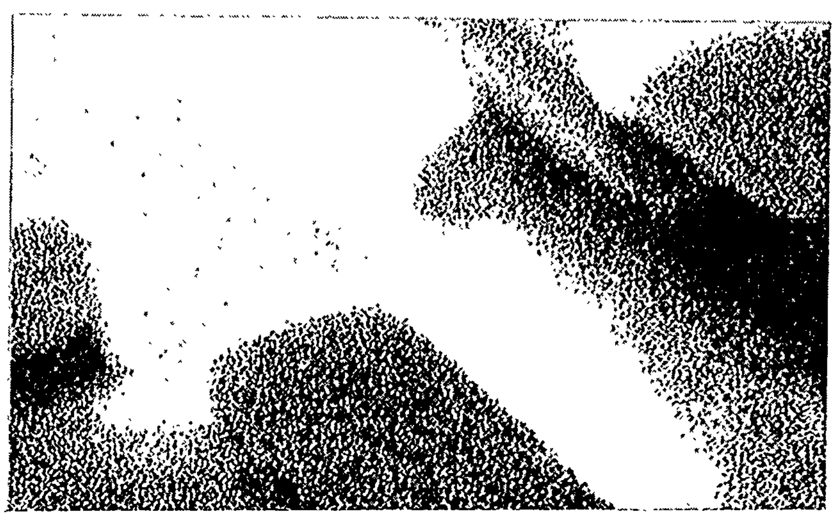

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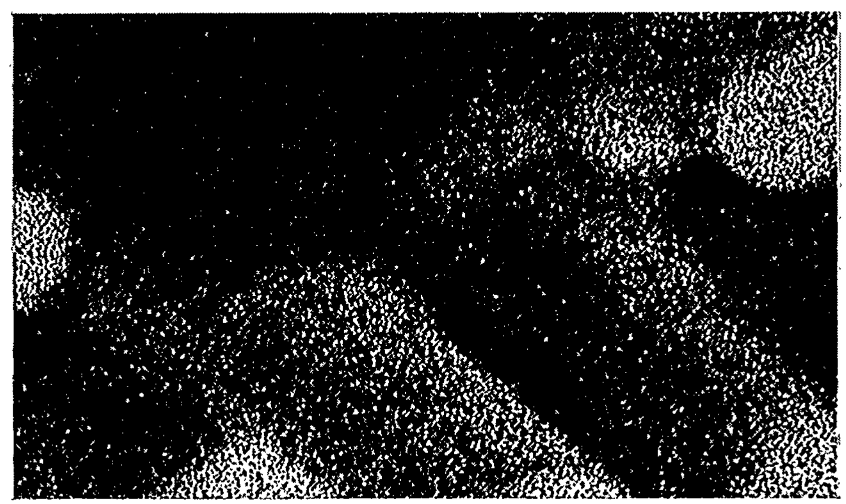

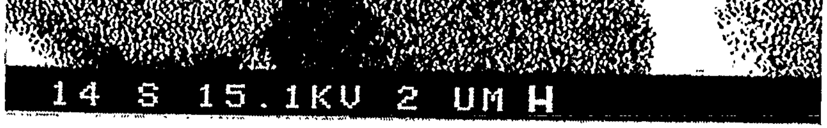

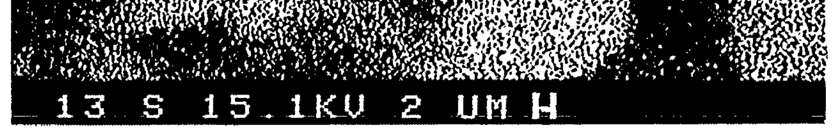

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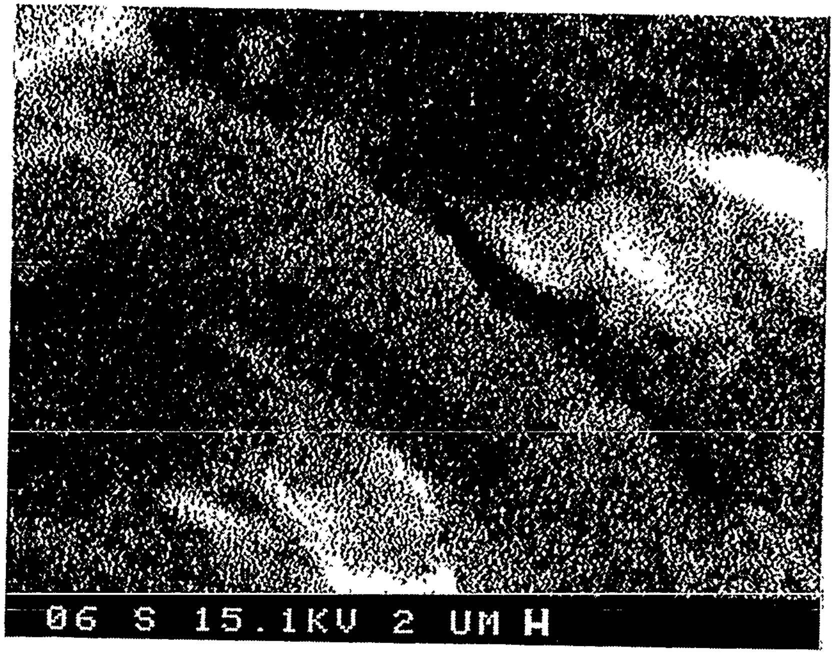

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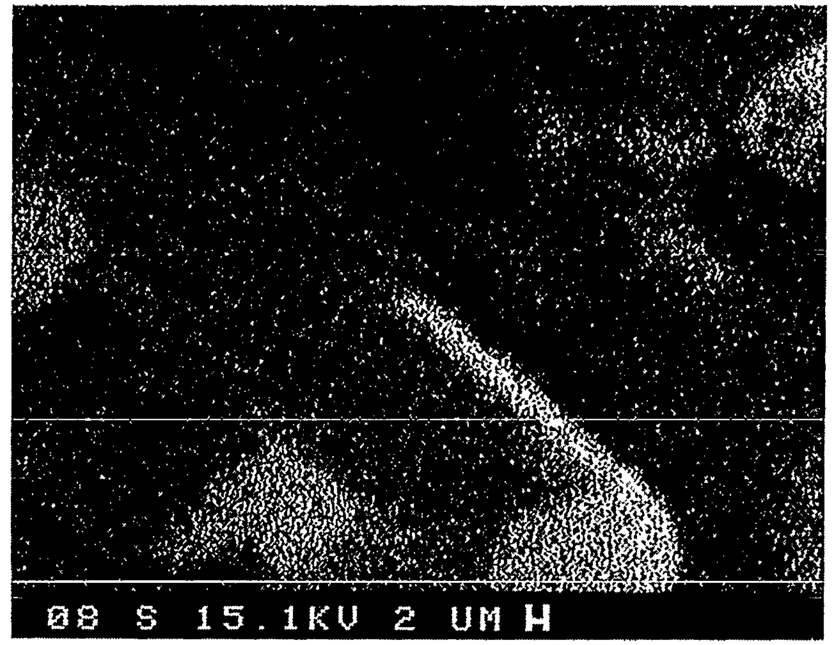

Figure 3c – Additional Elemental Microprobe Analyses Of The Nextel^{TM} 312 Fibers In The Confinement Layer Of The As-Manufactured 3M CVI-SiC Composite Filter Matrix

SEM

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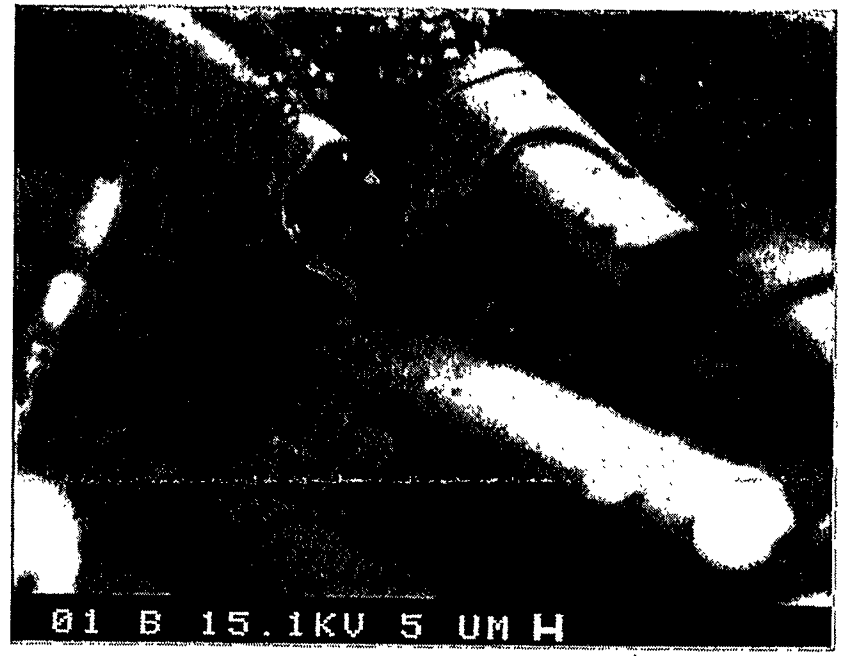

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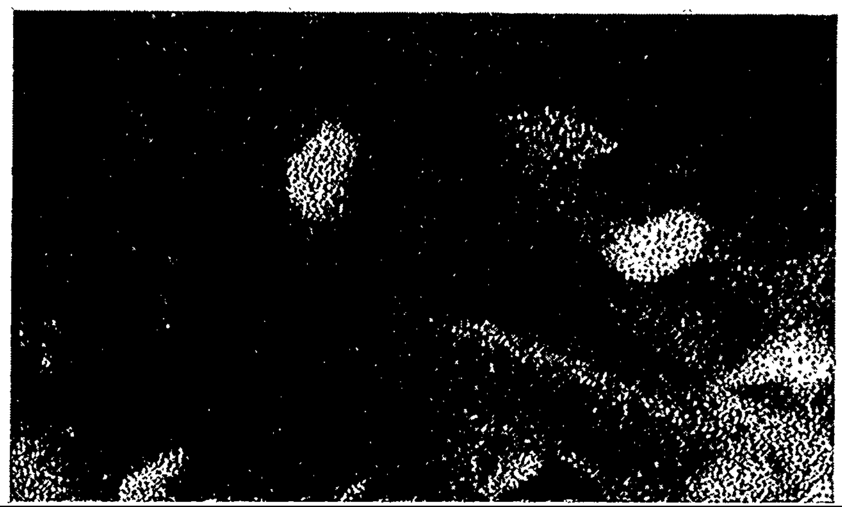

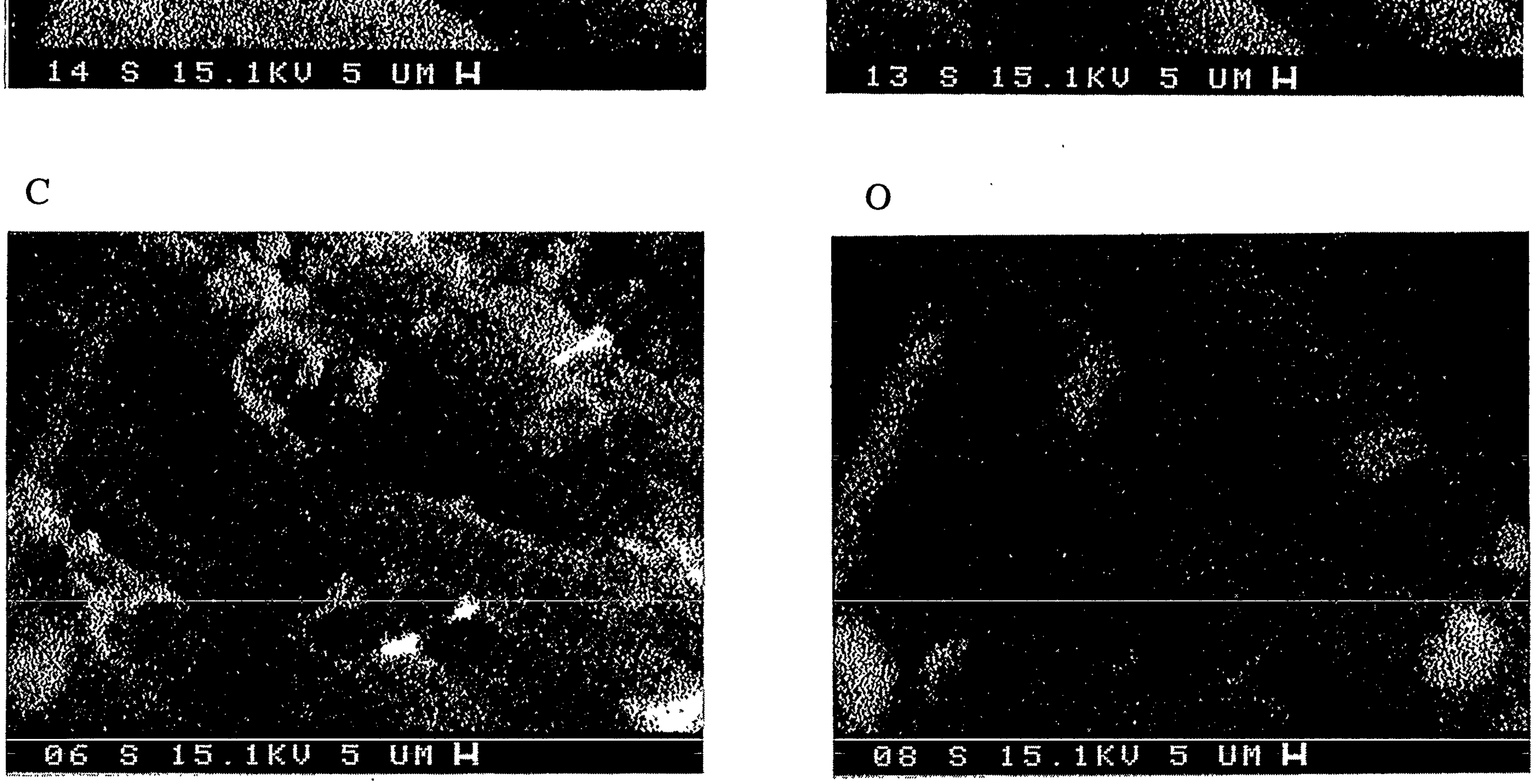

Figure 3d — Additional Elemental Microprobe Analyses Illustrating The Morphology Of The CVI-SiC Coating And Nextel^{TM} 312 Fibers (i.e., SiC) present in the surface coating. It is clearly evident that the outer CVI-SiC coating tightly encapsulates the Nextel™ 312 fibers in the as-manufactured confinement layer.

In an attempt to demonstrate whether the interface layer between the SiC coating and the Nextel™ 312 fibers could be identified, several of the as-manufactured confinement layer fibers were flashed with silver and nickel plated, mounted, and a polished cross-section was prepared for EMA. As shown in Figure 4, definitive separation between the outer SiC coating and the Nextel™ 312 fibers could not be identified. Elemental mapping at 10,000x (i.e., elemental line traces) may be capable of discerning the presence (i.e., composition) of the interface layer which is expected to exist between the SiC coating and the surface of the Nextel™ 312 fibers in the as-manufactured composite.

As shown in Figure 5, numerous fibers are present in the ~1 mm thick filtration mat layer which is present between the outer confinement layer and the triaxial support braid in the 3M CVI-SiC composite filter matrix. In contrast to the elliptical Nextel™ 312 fibers, the fibers which are present in the filtration mat are generally ~2-5 μm in diameter. An ~1 μm SiC layer coats the filtration mat fibers. Frequently several of the filtration mat fibers are adjacent to each other, and during the CVI-SiC deposition process are "twinned" together into what appears to be a "bundle-like" structure. An irregular or mottled surface texture is apparent along the outer surface of the CVI-SiC coating. Similarly a granular appearance is evident along the fractured fiber surface.

The structural support matrix of the 3M CVI-SiC composite filter consists of a triaxial braided layer of fabric which contains Nextel™ 312 fiber bundles. After being subjected to the CVI process, the triaxial braided layer is encapsulated by an ~100 μm thick coating of SiC (Figure 6). In the triaxial braid, individual fibers are coated with an ~1-2 μm thick layer of SiC (Figures 6a, 6b and 6c). The outer surface of the thin CVI-SiC coating which deposits along the Nextel™ 312 fibers frequently contains raised nodular formations which reflect growth of the SiC matrix (Figure 6d). The outer SiC layer is seen to be tightly held to the surface of the Nextel™ 312 fibers as shown in Figure 6e. The raised nodular formations which are present along the outer surface of the thin SiC coating are again shown in Figure 6f. Elemental microprobe analyses of the triaxial braid CVI-SiC coating and fiber bundles were also conducted, and the results of these analyses are provided in Figure 7. Once again the fibers are aluminum, silicon and oxygen rich (i.e., an aluminosilicate); the encapsulating layer consists of silicon and carbon (i.e., silicon carbide); and the interface layer between the SiC coating and Nextel™ 312 fibers is difficult to detect.

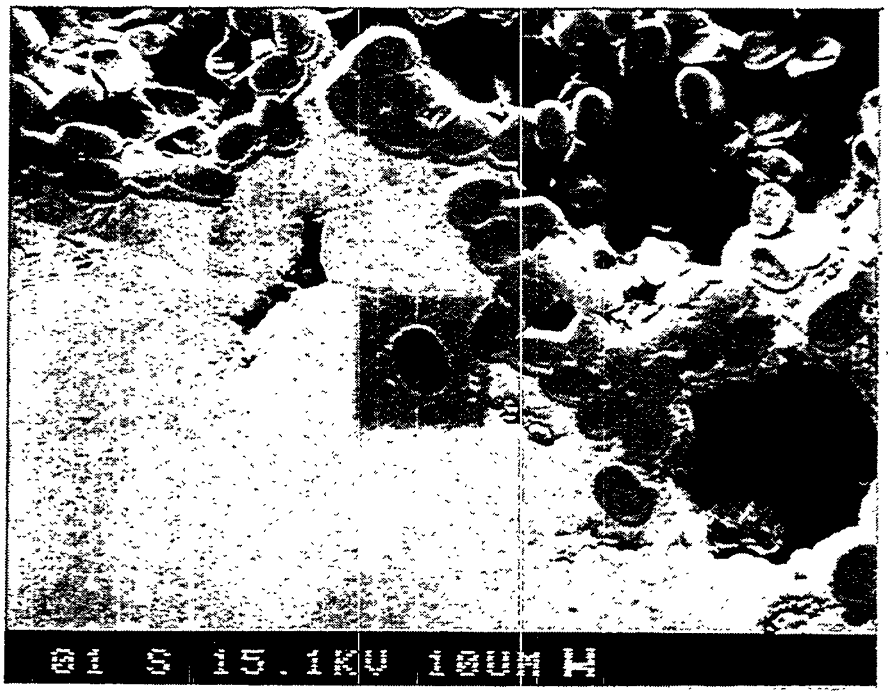

Figure 4a – Polished Cross-Section Of The Confinement Fibers In The As-Manufactured 3M Composite Filter Matrix

SEM

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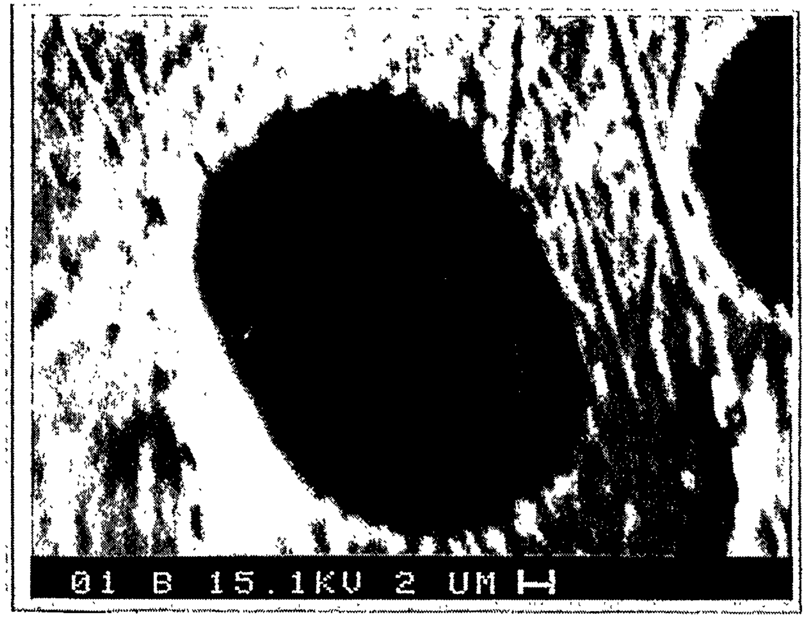

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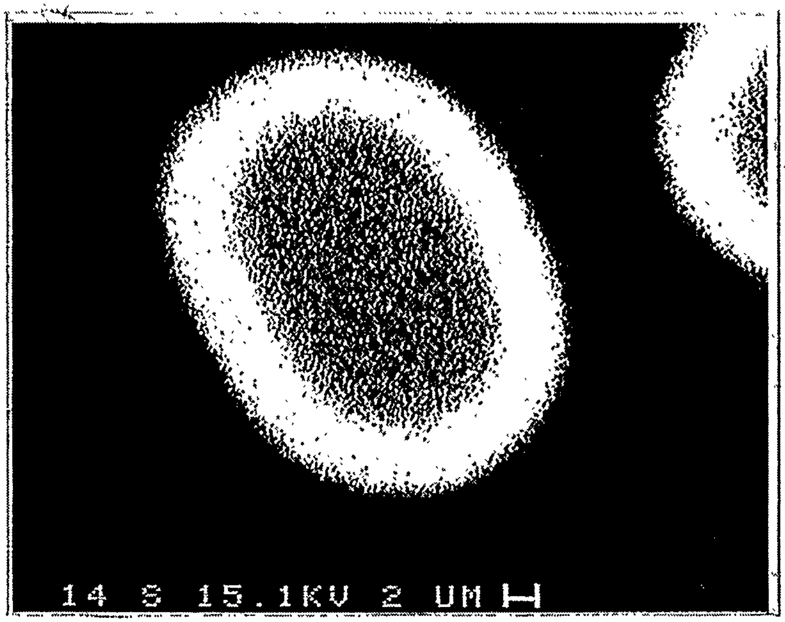

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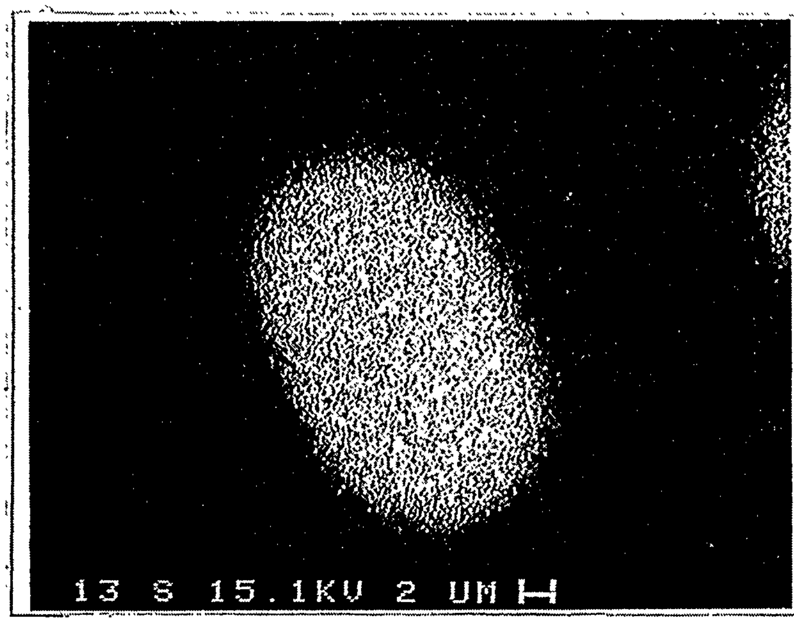

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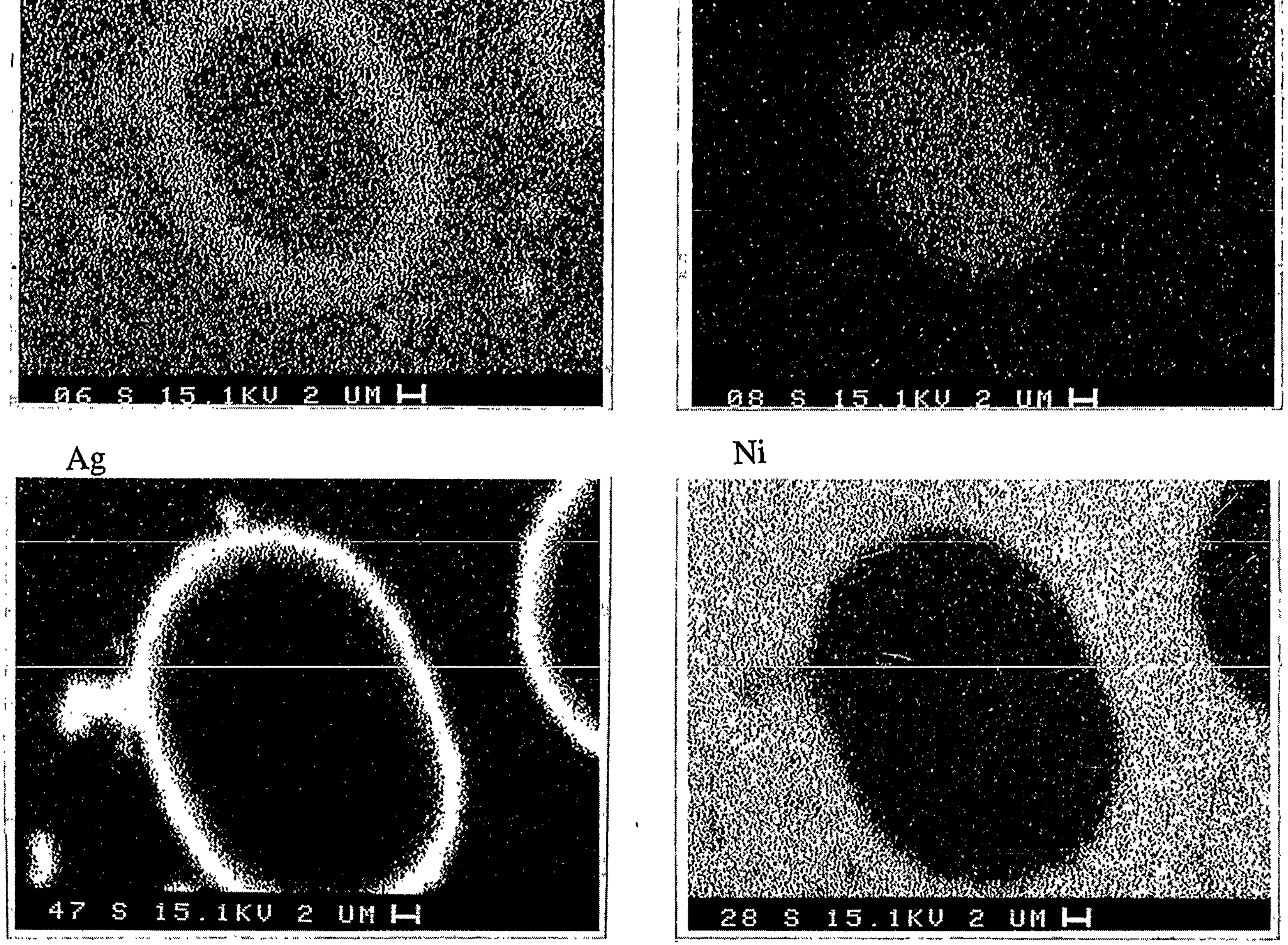
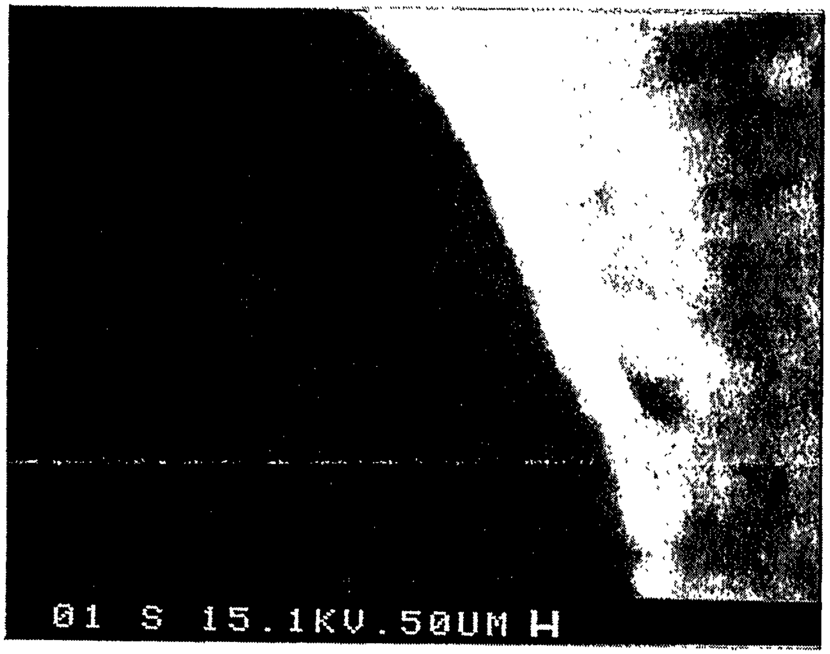


Figure 4b — Isolated Confinement Layer Fiber

SEM



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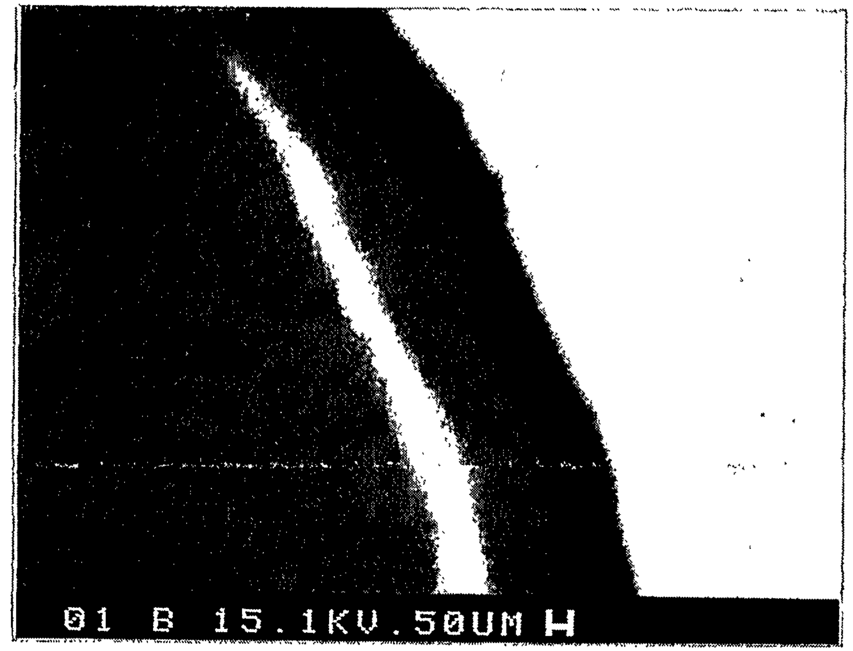

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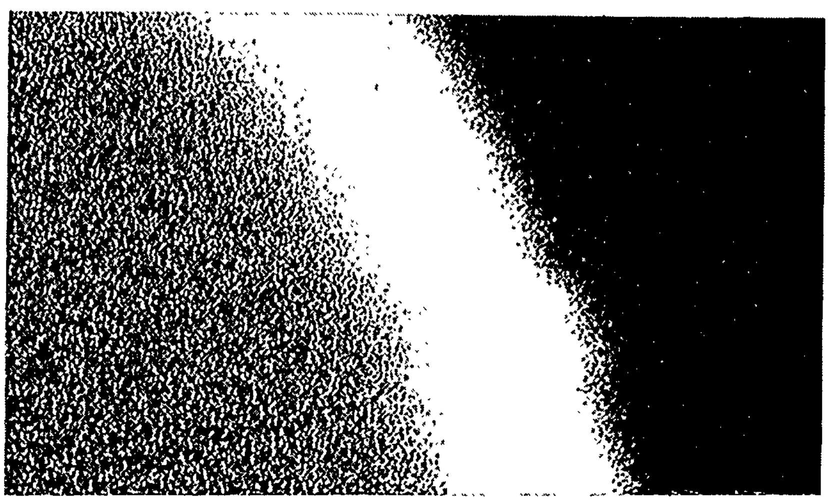

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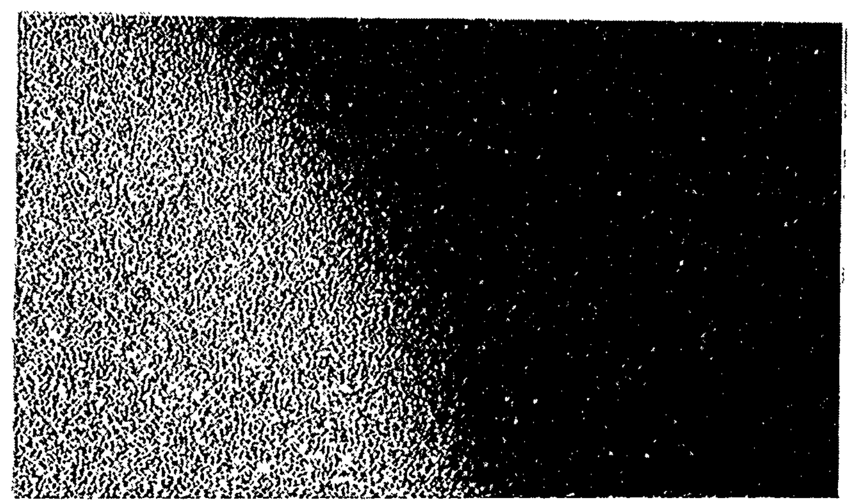


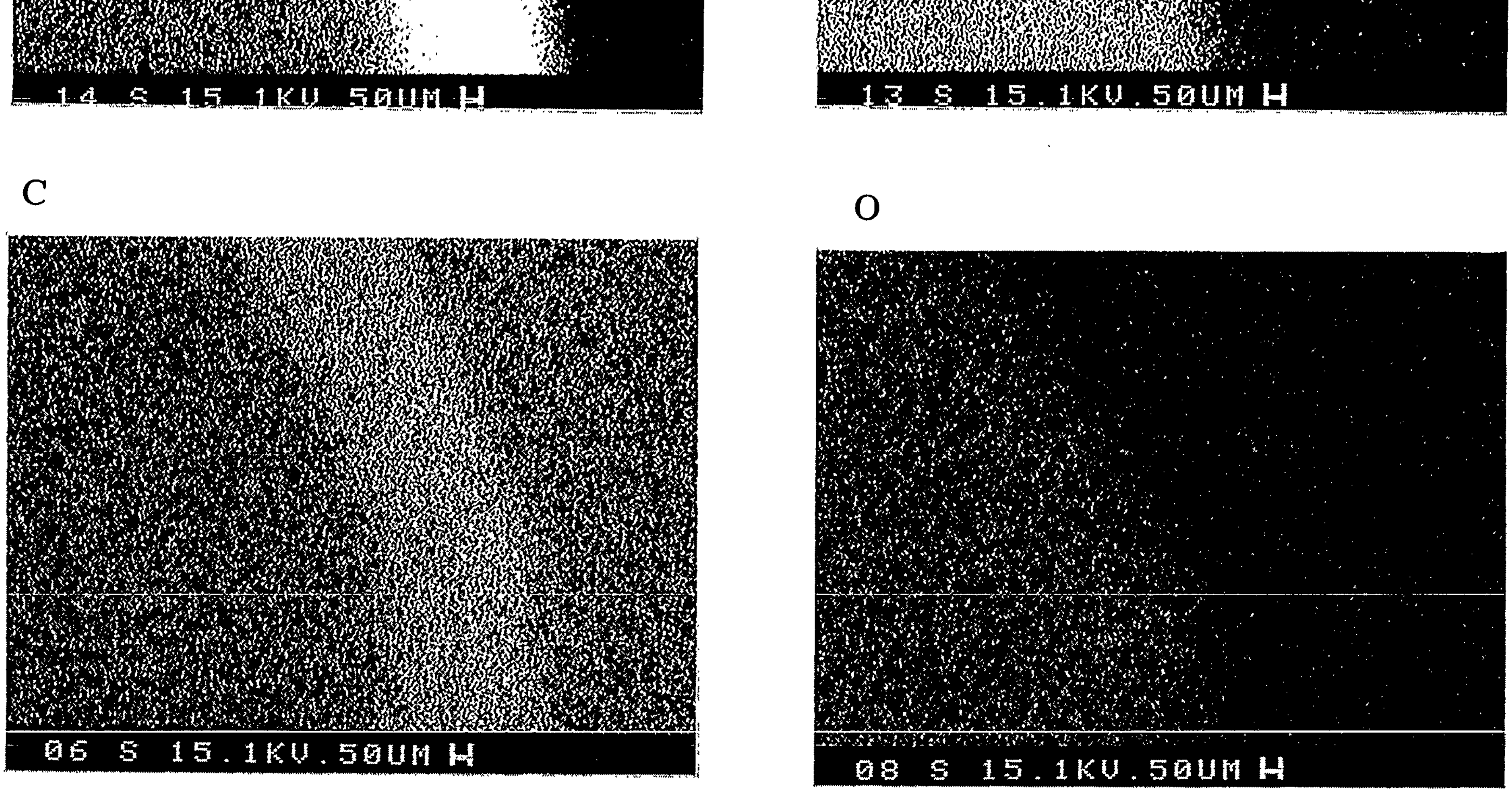


Figure 4c – Elemental Microprobe Analyses At High Magnification OF The CVI-SiC Coated Nextel™ 312 Fiber In The Confinement Layer Of The 3M Composite Filter Matrix

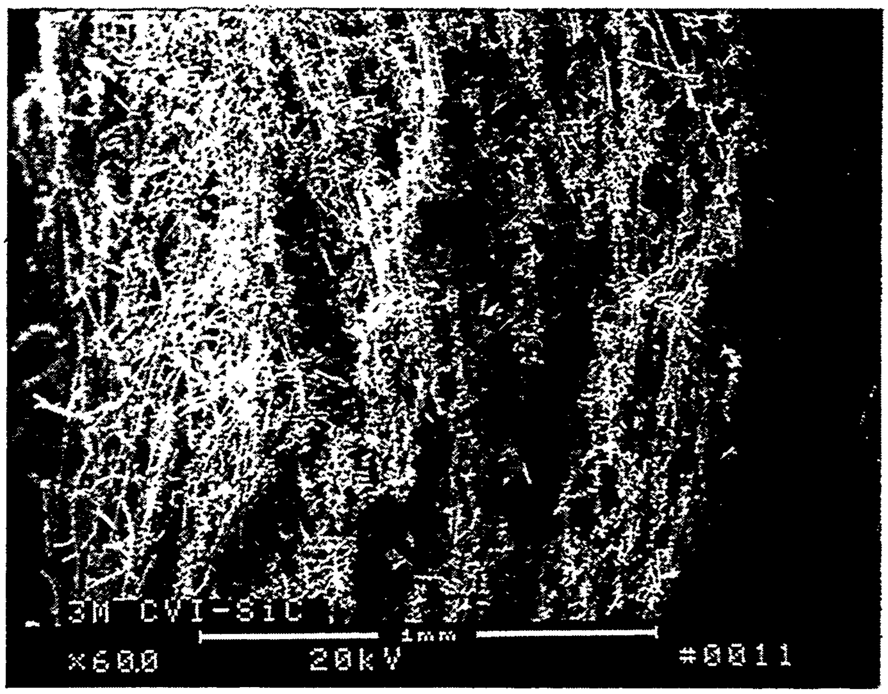
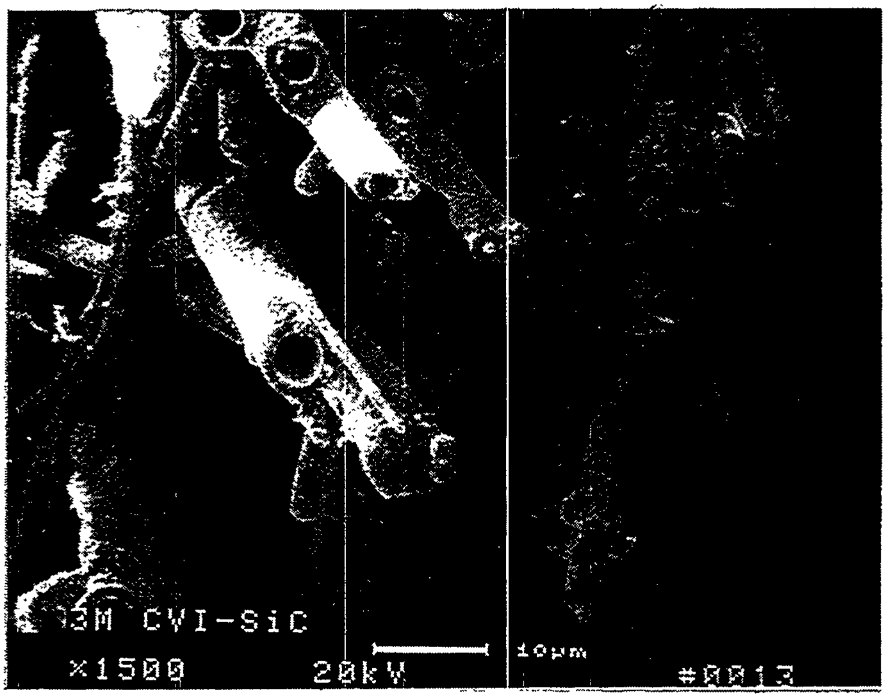


Figure 5a — Morphology Of The Cross-Sectioned Filtration Mat Layer In The As-Manufactured 3M CVI-SiC Composite Filter Matrix



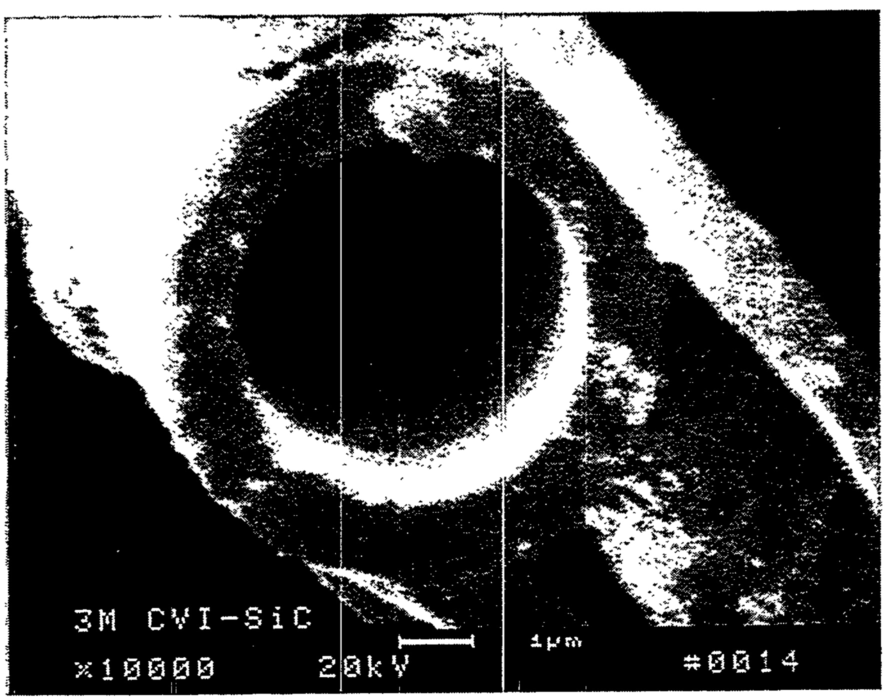
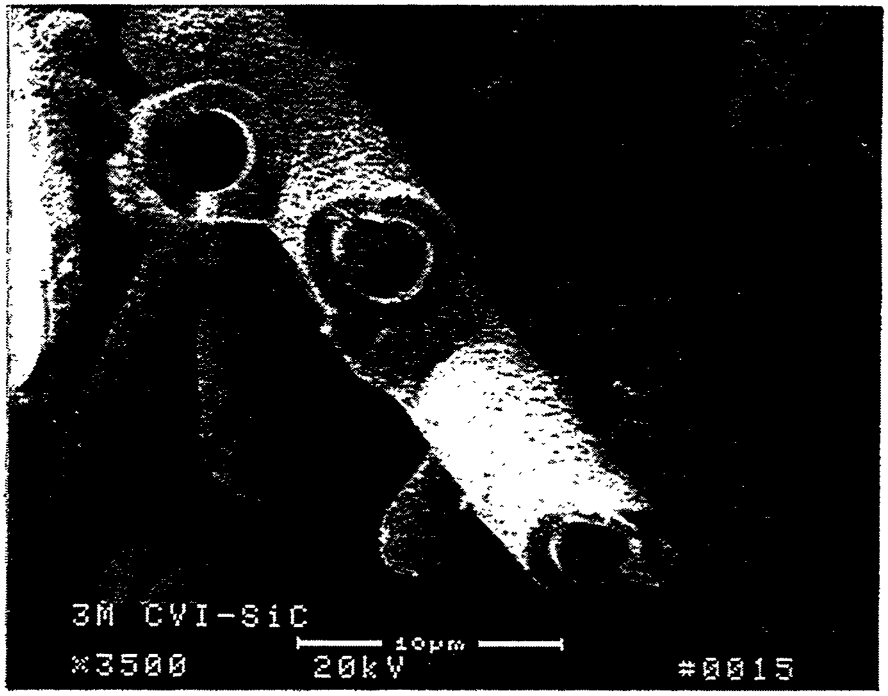


Figure 5b – Morphology Of The CVI-SiC Coated Fibers In The Filtration Mat Layer



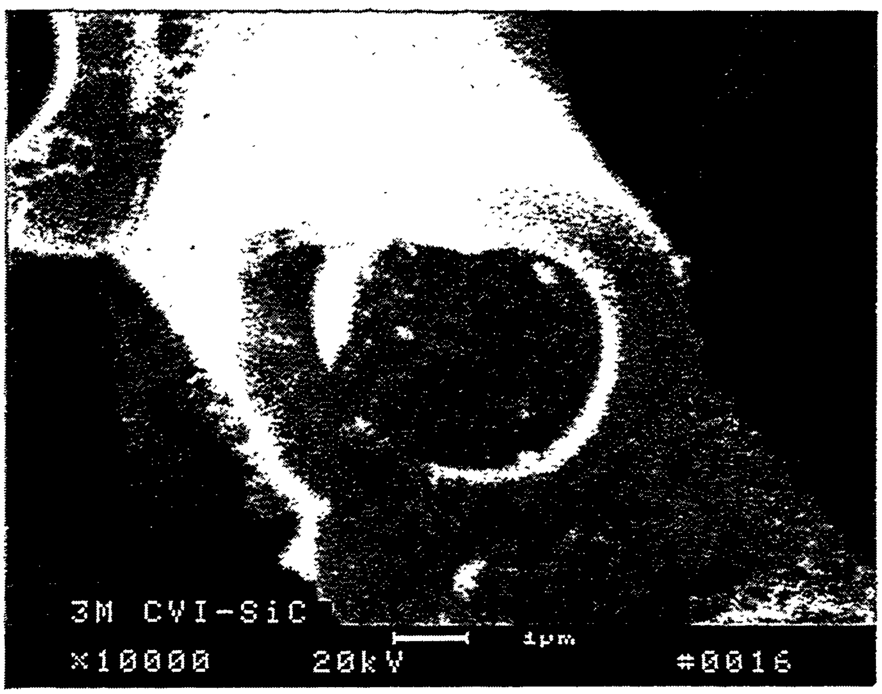


Figure 5c — Additional Micrographs Illustrating The Morphology Of The Filtration Mat Fibers

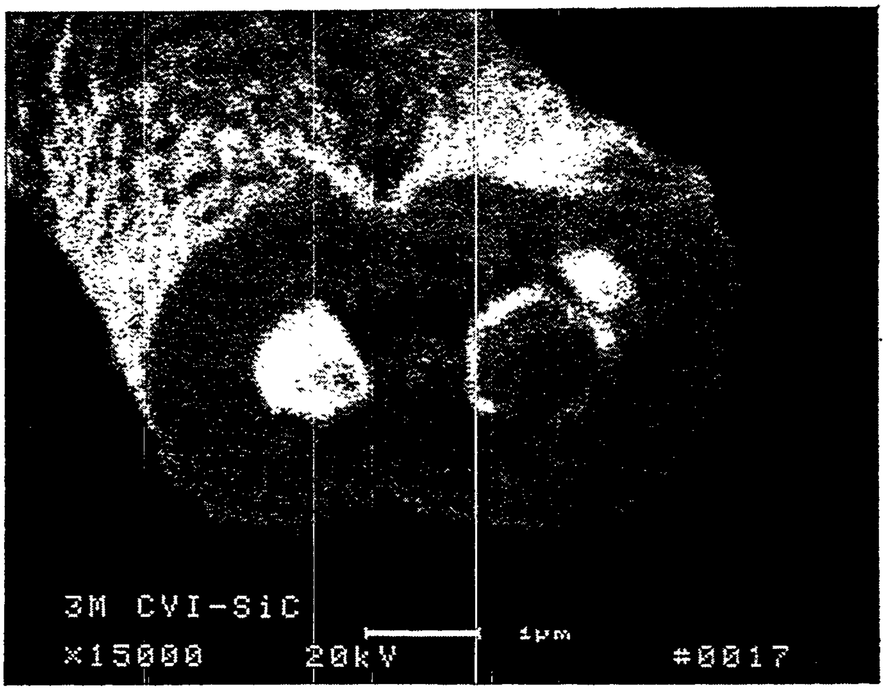
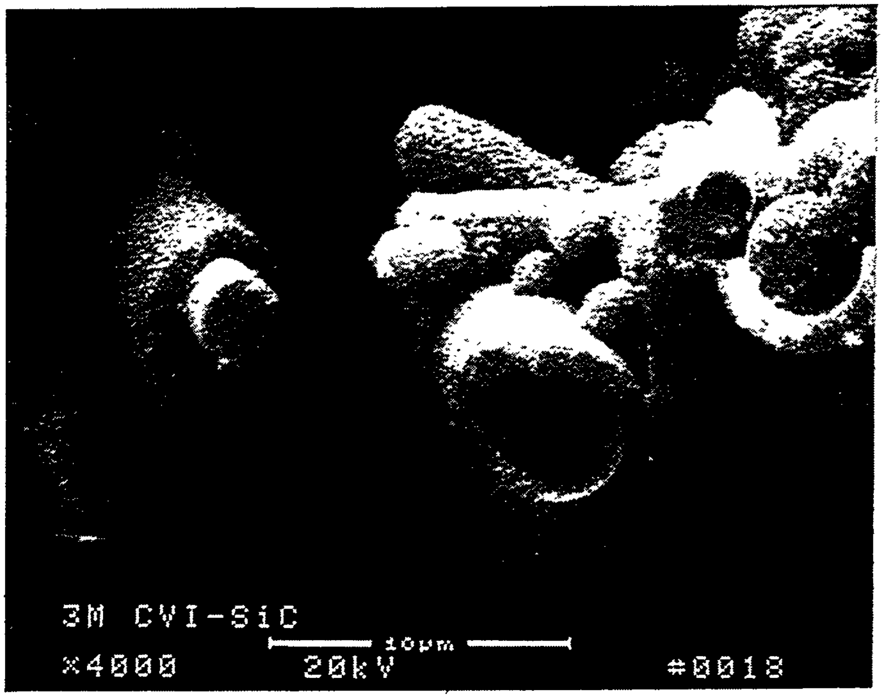


Figure 5d — Micrograph Illustrating The Twinned Effect Of Adjacent Fibers During SiC Deposition



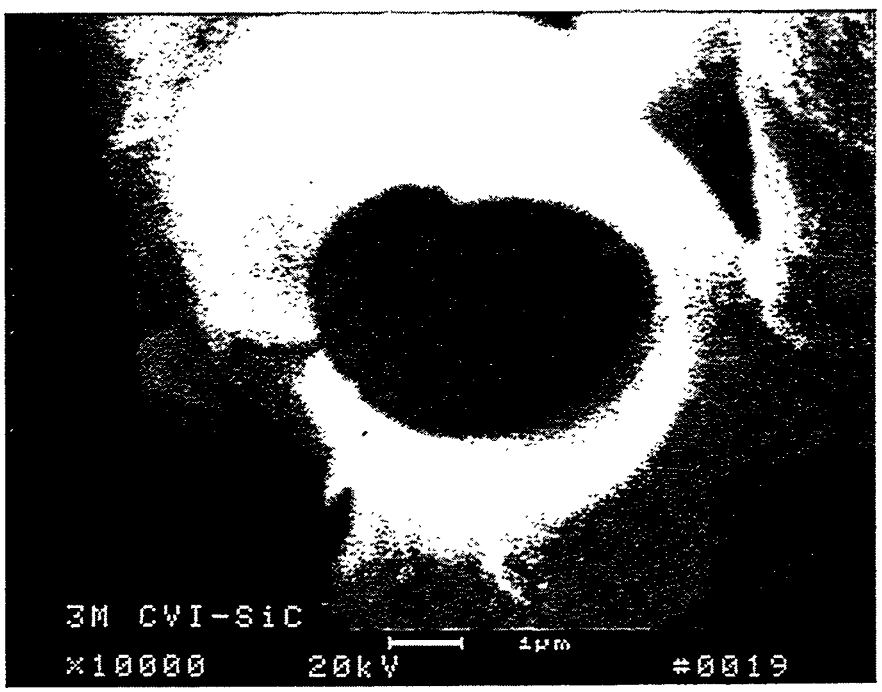
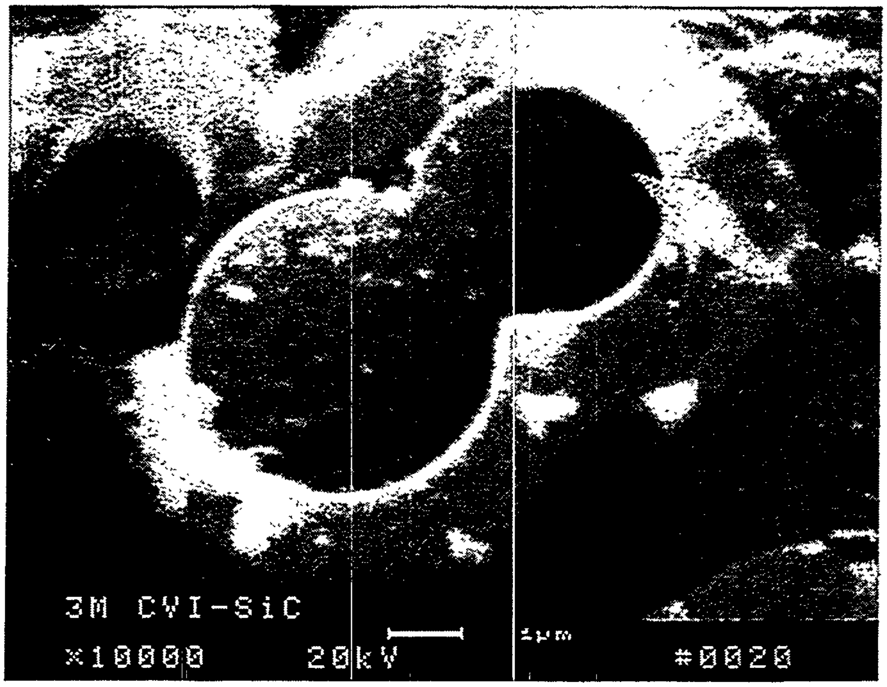


Figure 5e — Additional Micrographs Illustrating The Morphology Of The Filtration Mat Fibers In The As-Manufactured 3M CVI-SiC Composite Filter Matrix



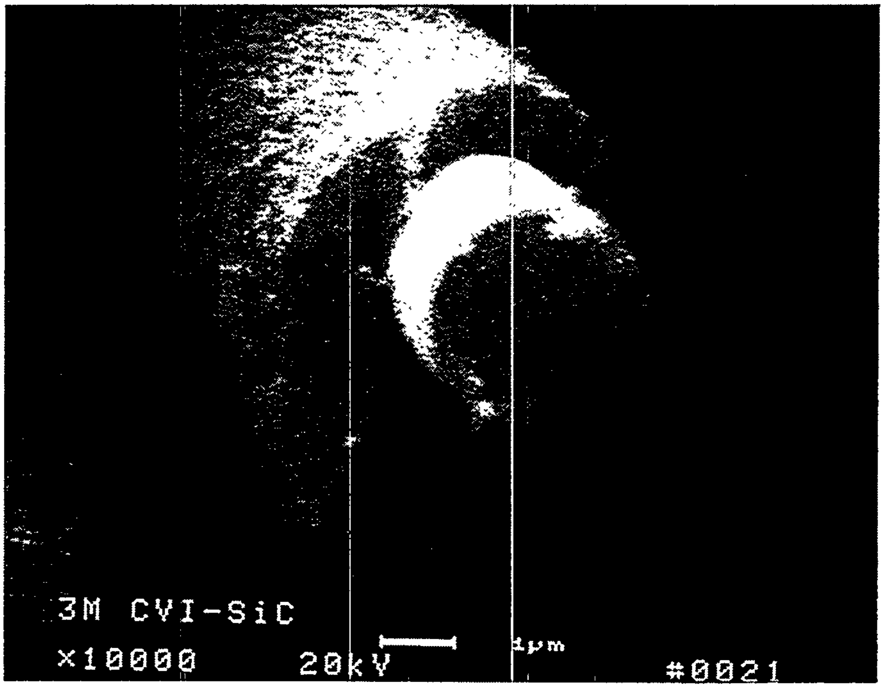
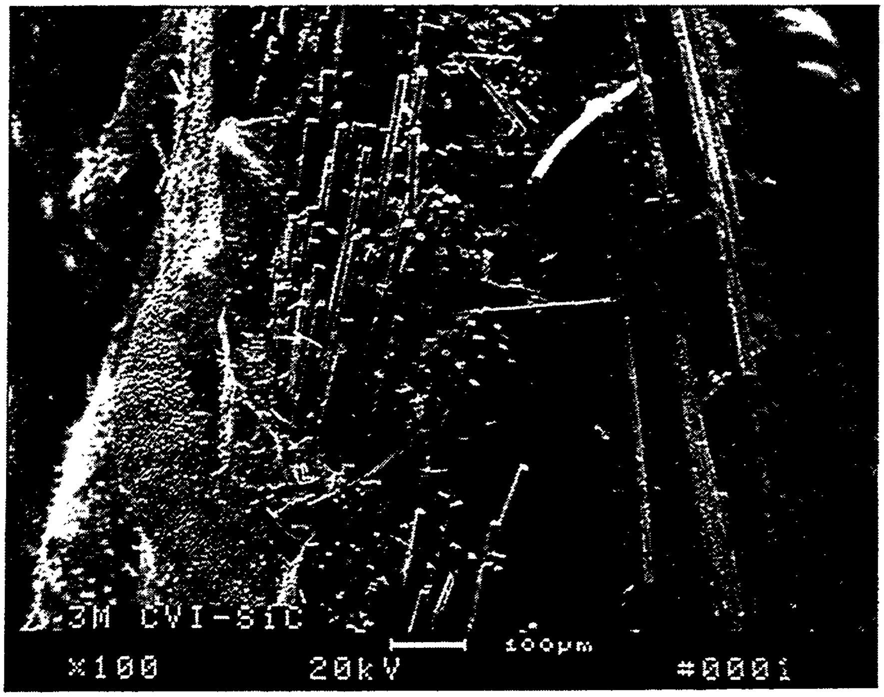


Figure 5f — Additional Micrographs Illustrating The Morphology Of The Filtration Mat Fibers In The As-Manufactured 3M CVI-SiC Composite Filter Matrix



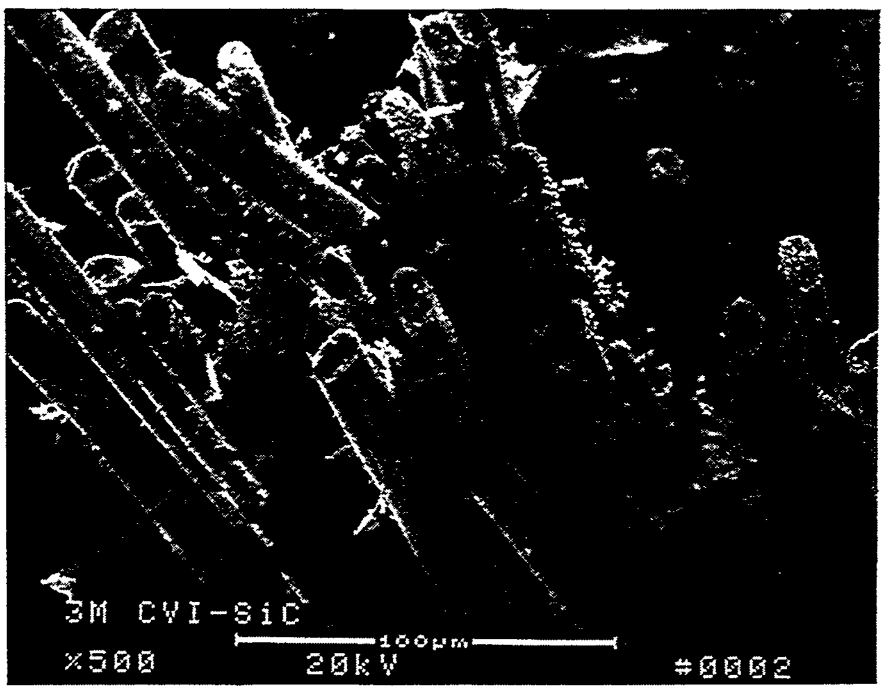


Figure 6a – Scanning Electron Micrographs Illustrating The Fiber Bundles In The ~100 μm Thick CVI-SiC Coated Triaxial Braid Support Matrix In The As-Manufactured 3M Composite Filter Matrix

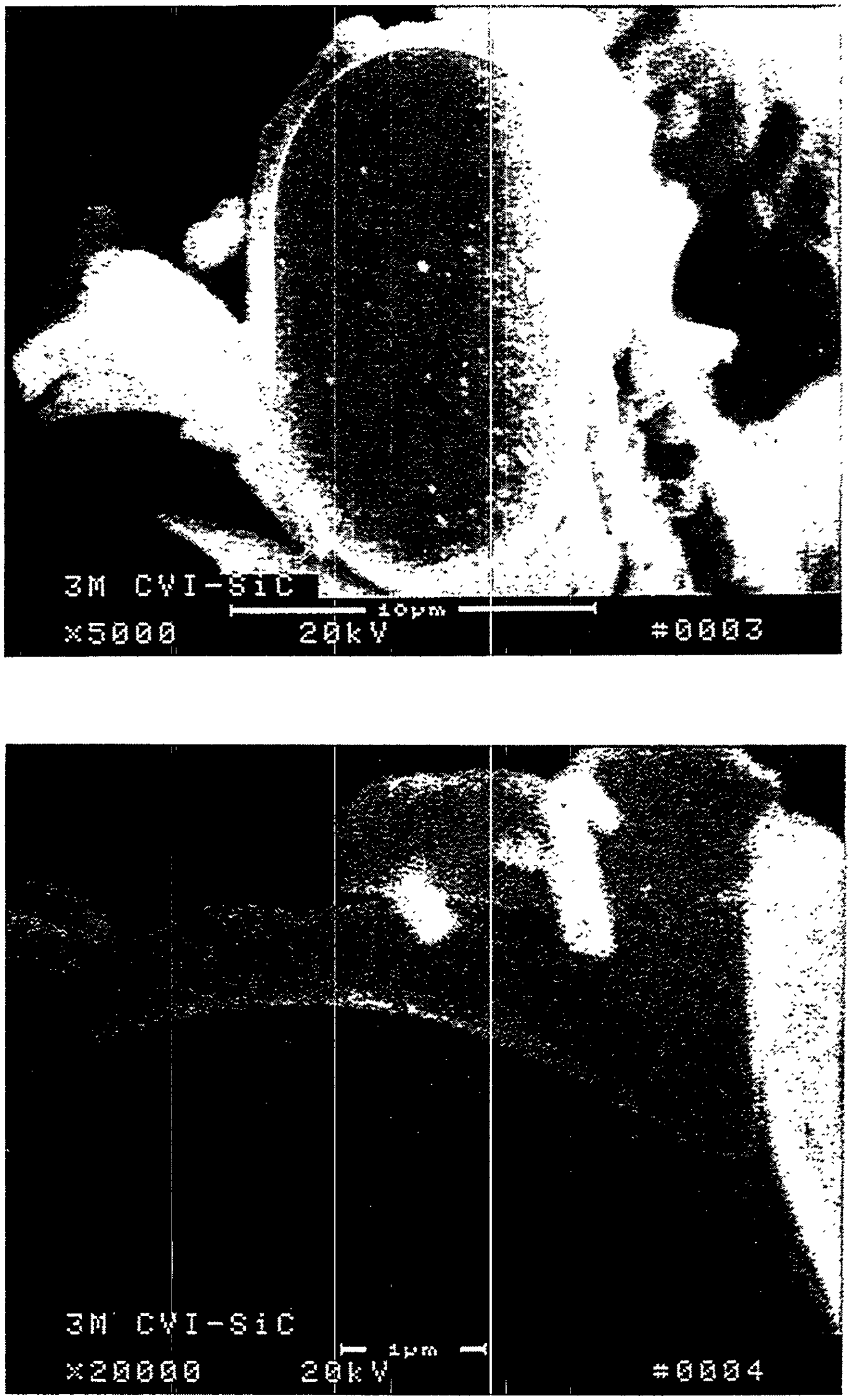


Figure 6b – Morphology Of An Individual Fiber In The Triaxial Support Matrix

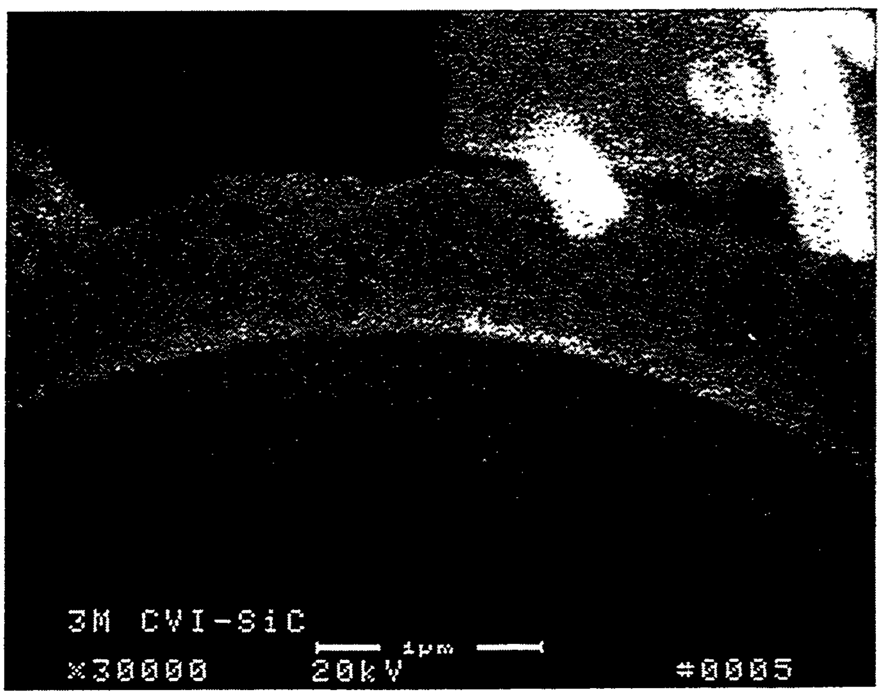
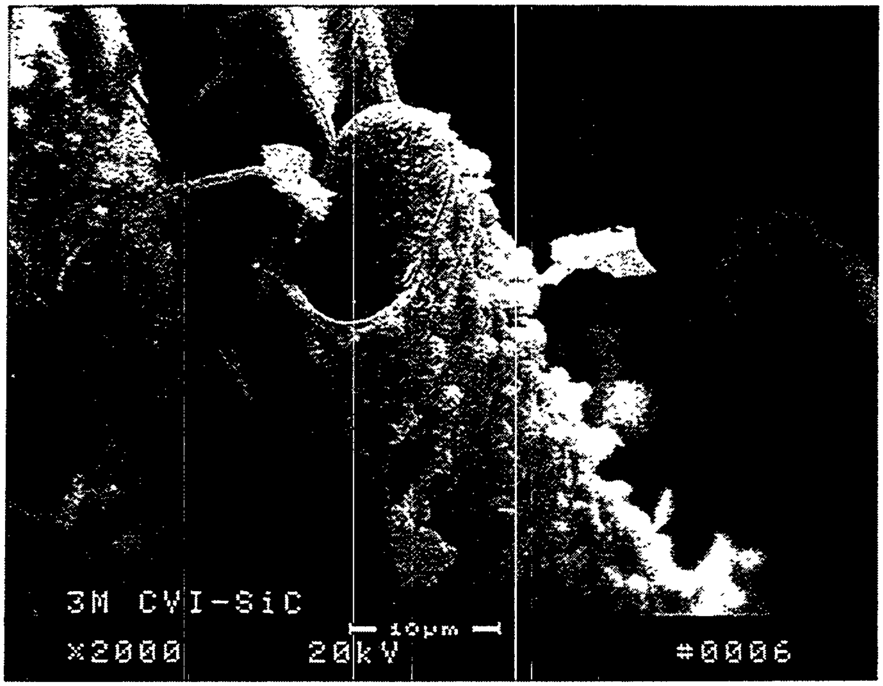


Figure 6c — Higher Magnification Micrograph Illustrating The CVI-SiC Surface Coating Which Was Deposited Along The Surface Of The Nextel^{TM} 312 Fiber In The Triaxial Braid Support Matrix



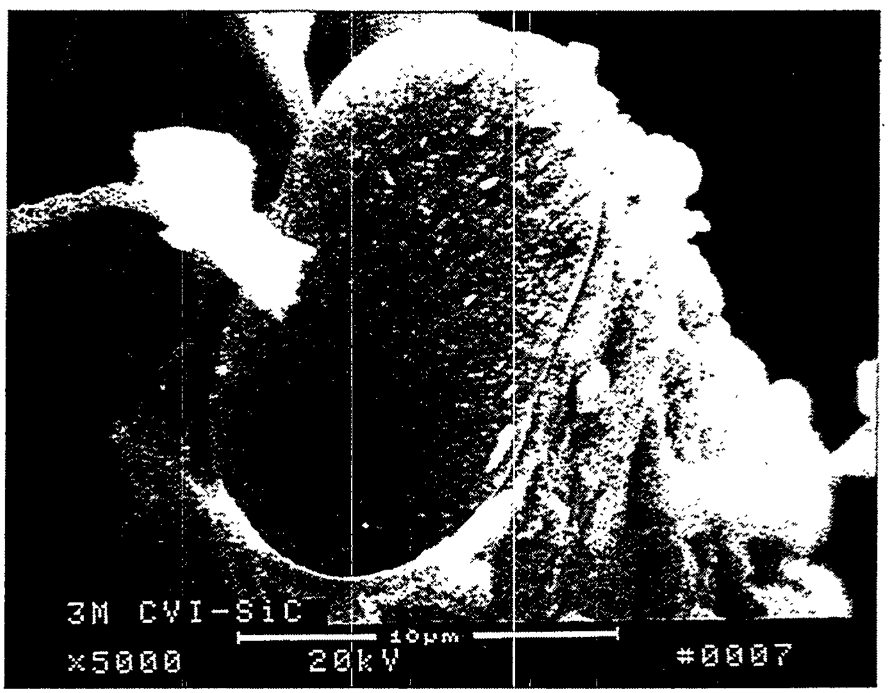


Figure 6d -- Additional Micrographs Illustrating The Morphology Of Individually Coated Nextel^{TM} 312 Fibers In The Triaxial Braid Support Matrix

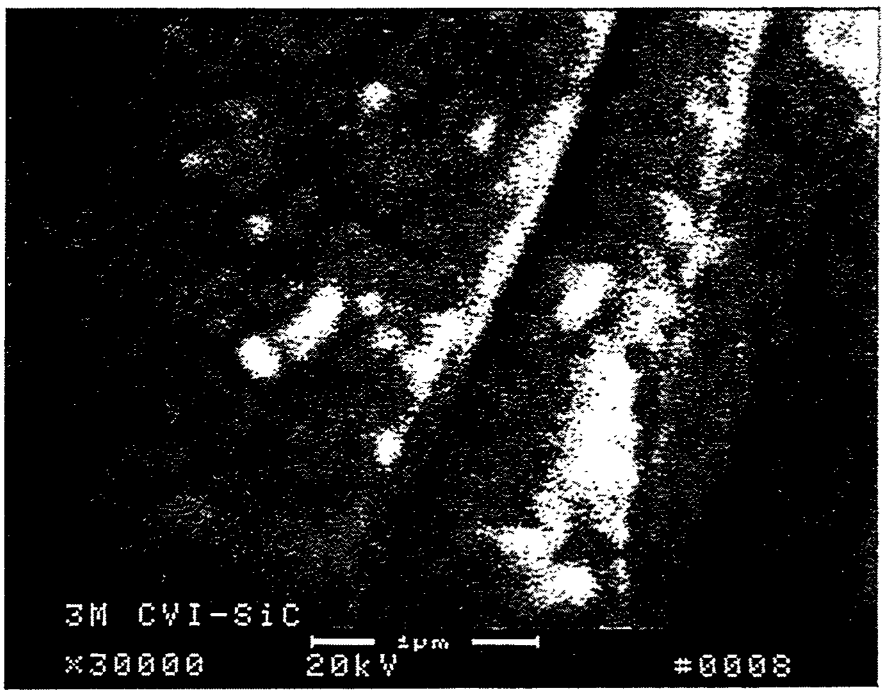


Figure 6e — High Magnification Micrograph Of the CVI-SiC Coating Along The Surface Of The Nextel™ 312 Fibers In The Triaxial Braid Support Matrix

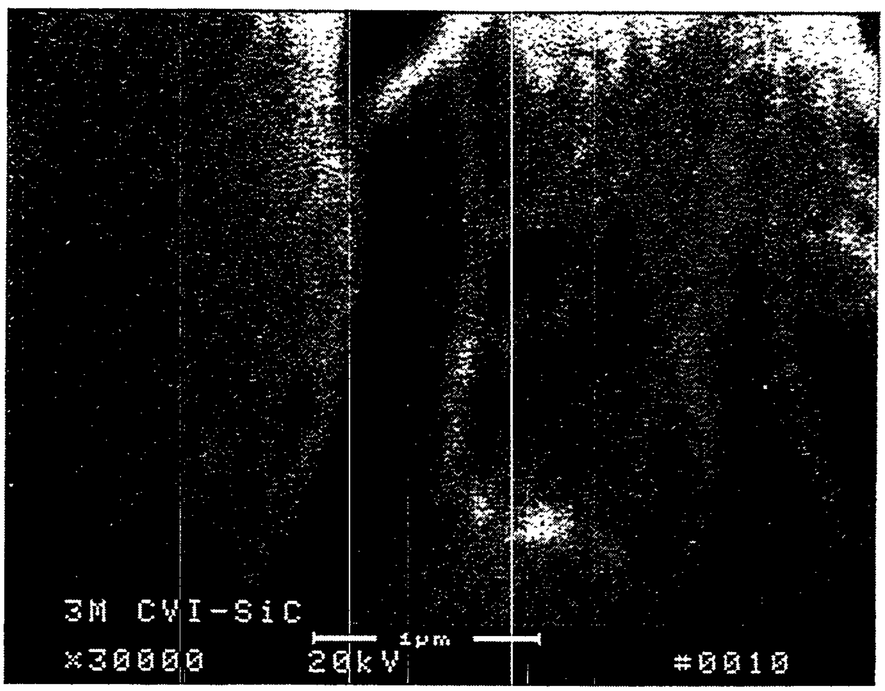
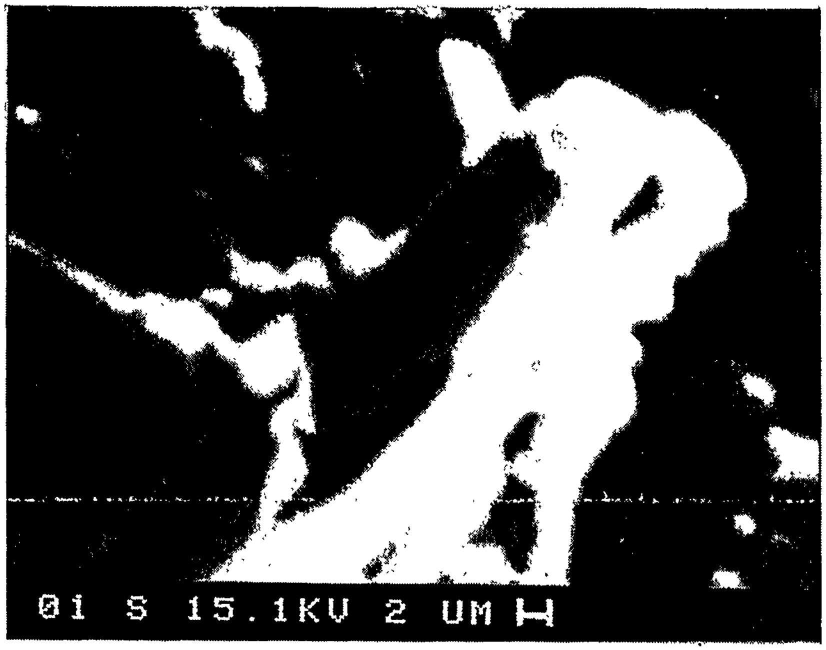
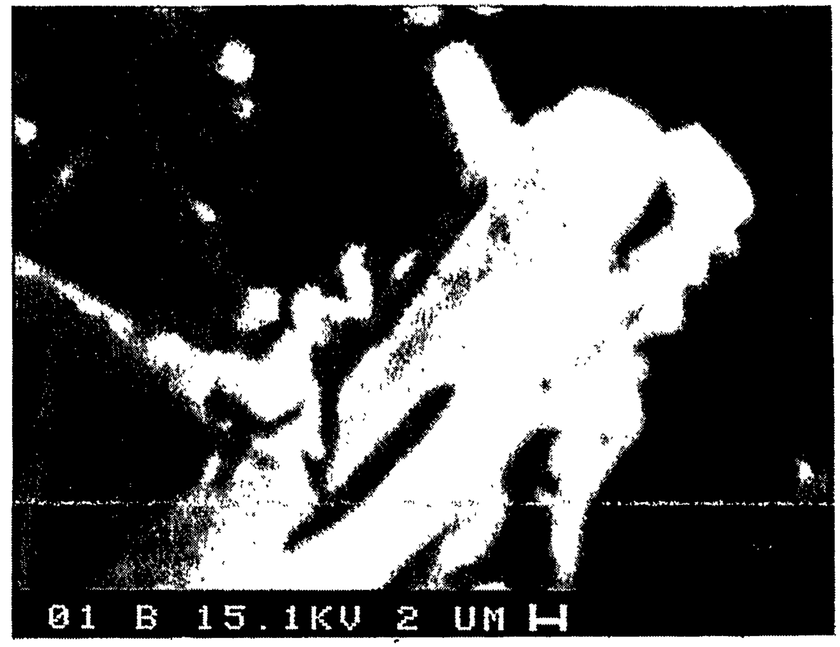


Figure 6f — Additional Scanning Electron Micrographs Illustrating The Morphology Of The CVI-SiC Coated Nextel^{TM} 312 Fibers In The Triaxial Braid Support Matrix

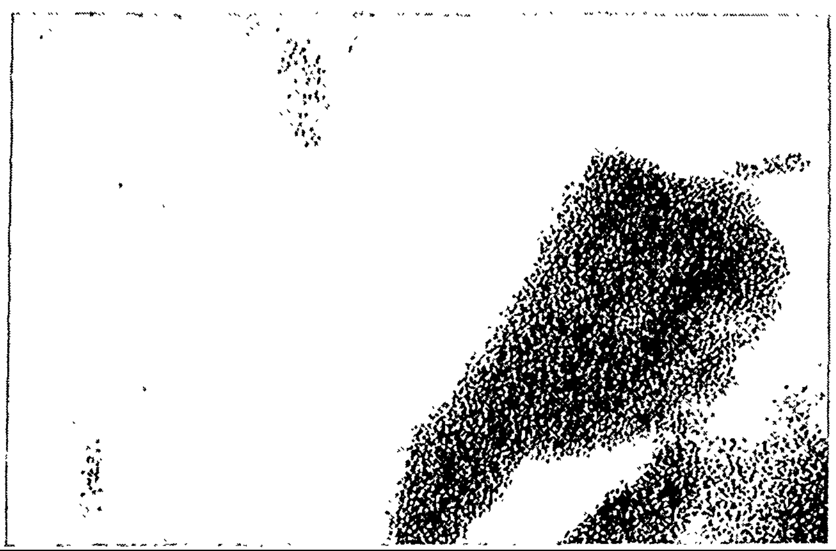
SEM



BSE



Si



Al

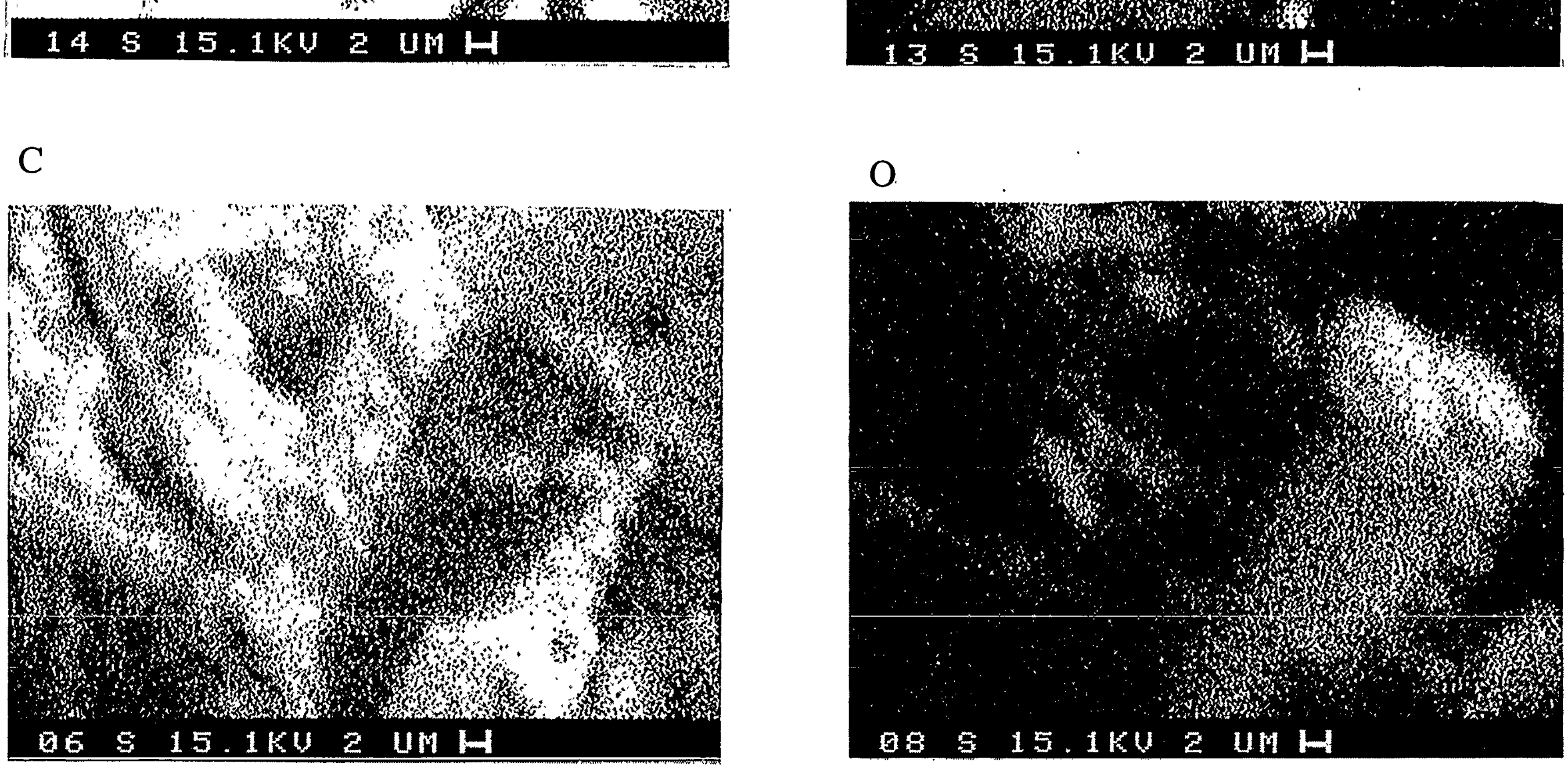
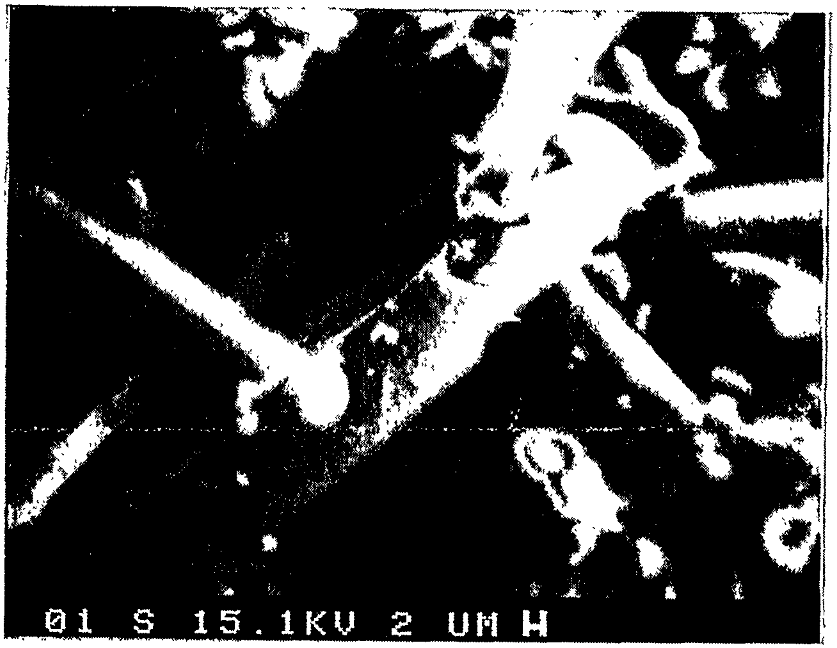
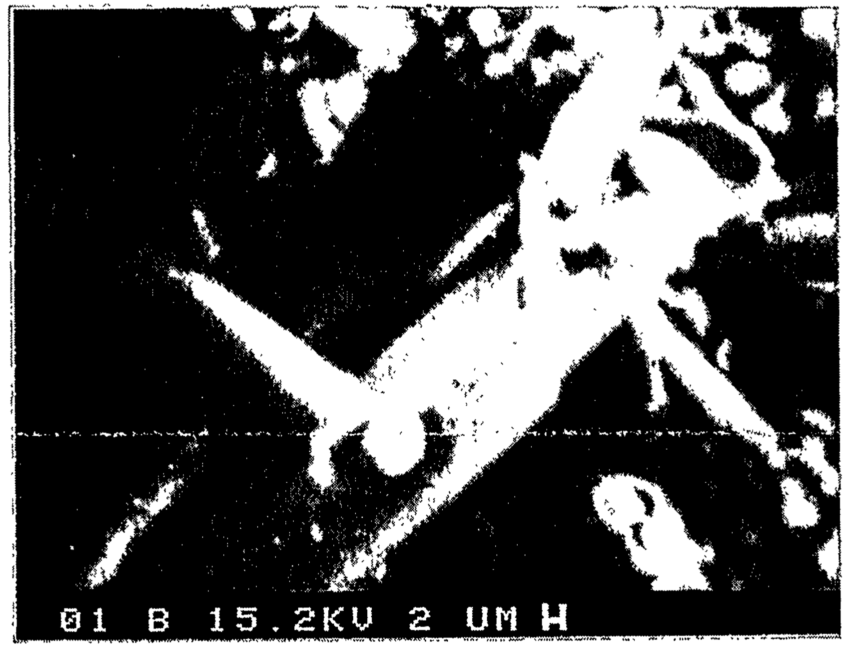


Figure 7a – Elemental Microprobe Analyses Of The CVI-SiC Coated Fibers In The As-Manufactured Triaxial Braid Support Matrix In The 3M Composite Filter

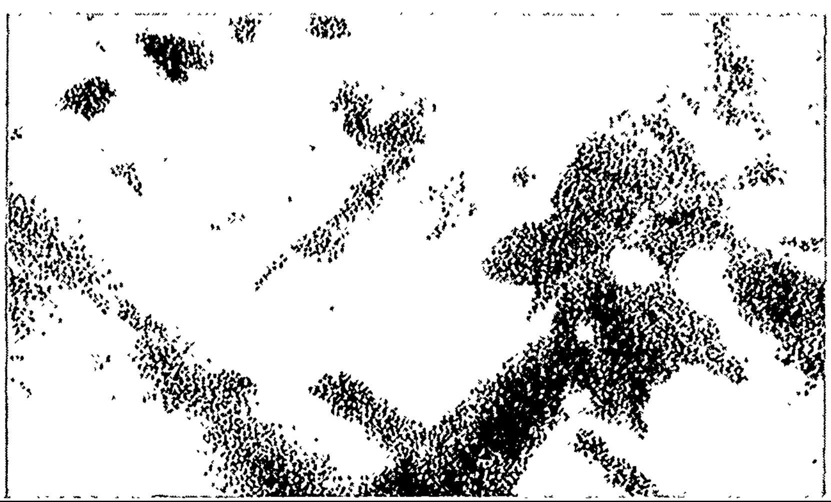
SEM



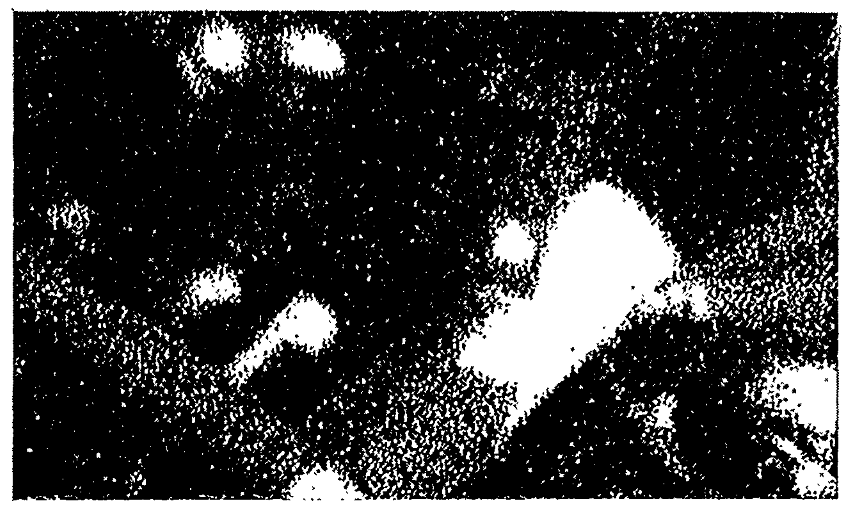
BSE

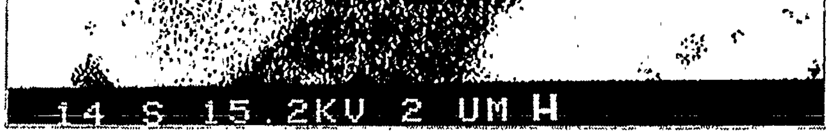


Si



Al





C

O

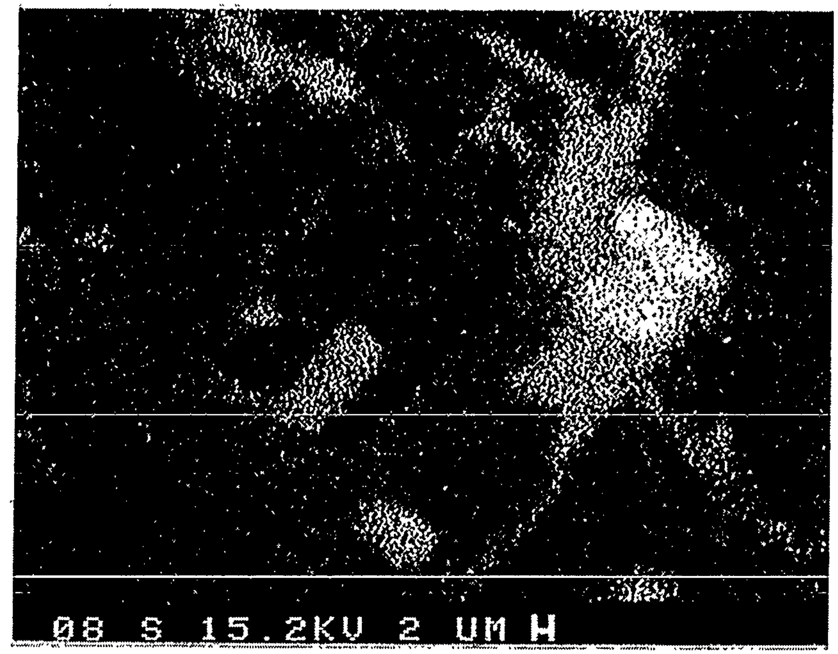
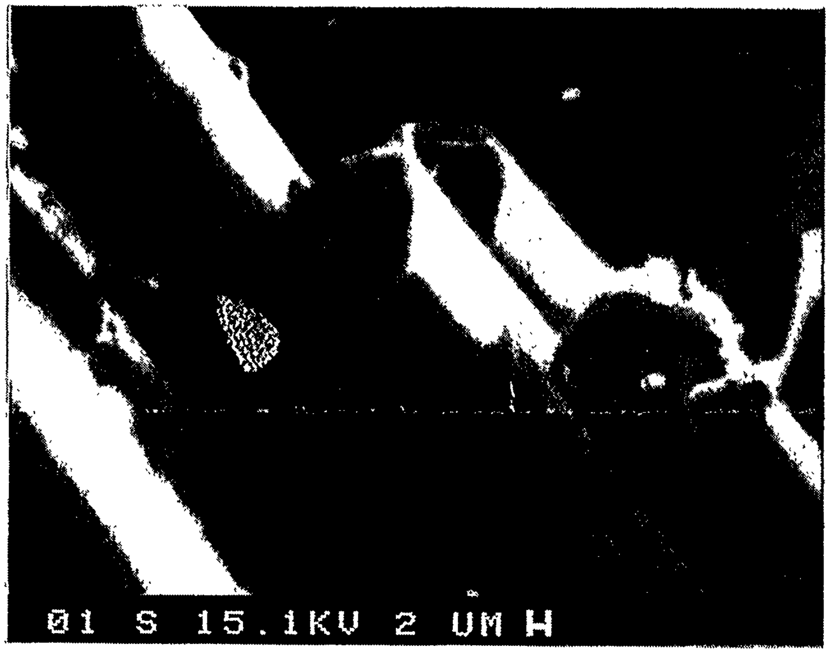


Figure 7b – Elemental Microprobe Analyses Of The CVI-SiC Coated Fibers In The As-Manufactured Triaxial Braid Support Matrix In The 3M Composite Filter

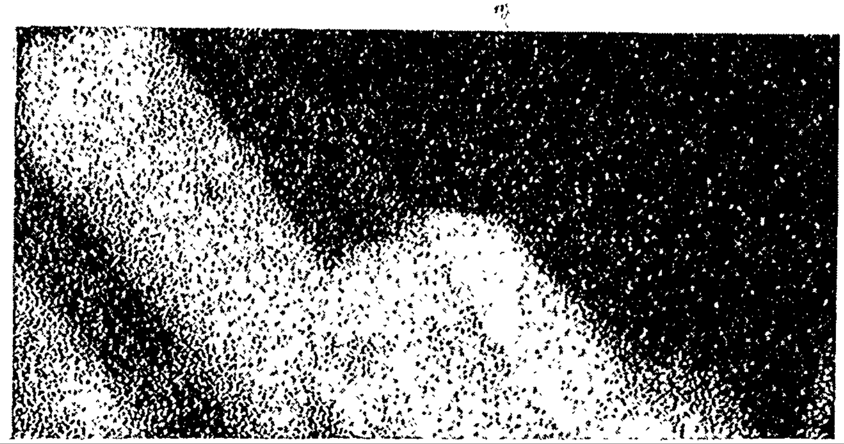
SEM



BSE

Si

Al



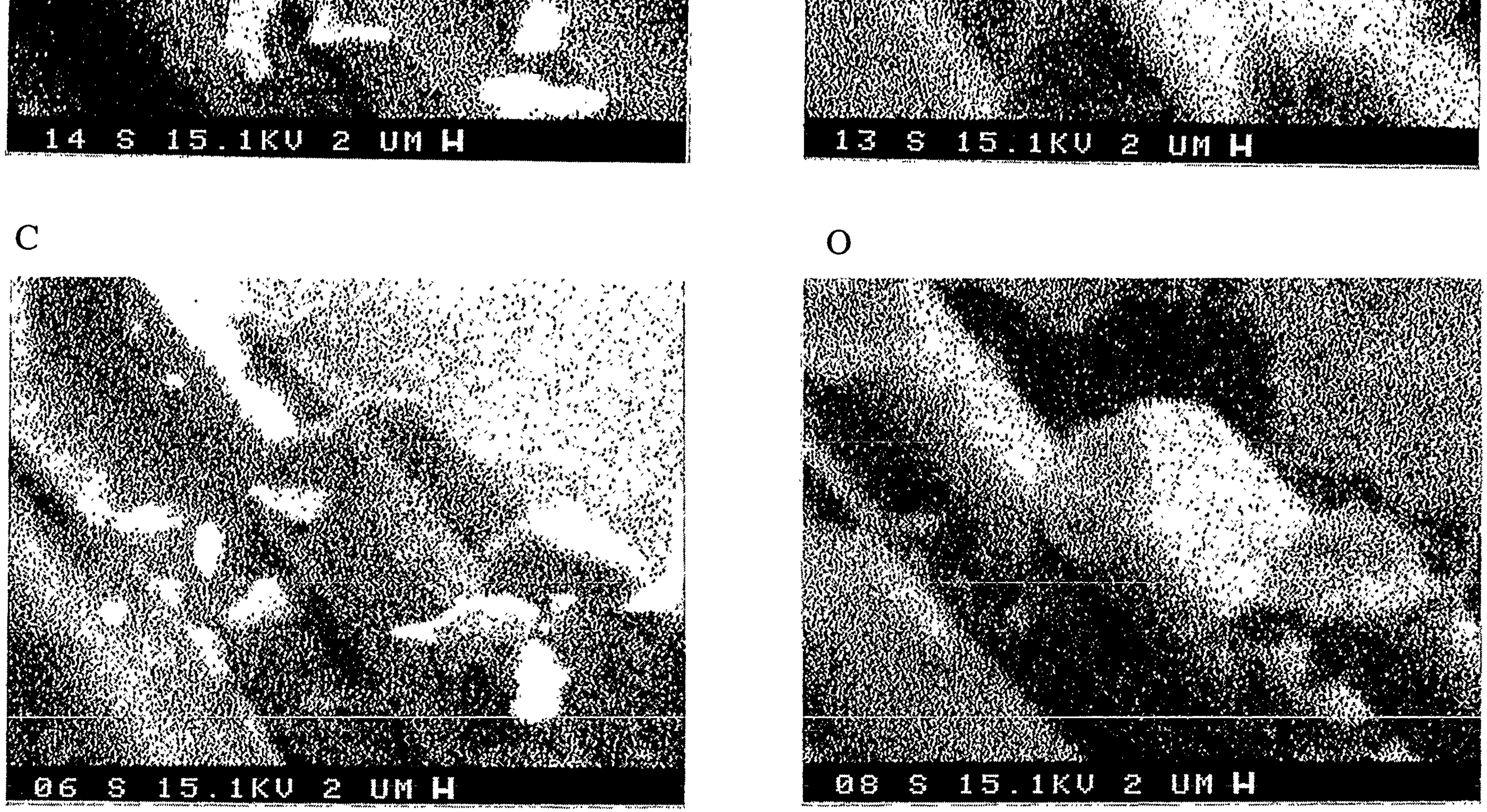
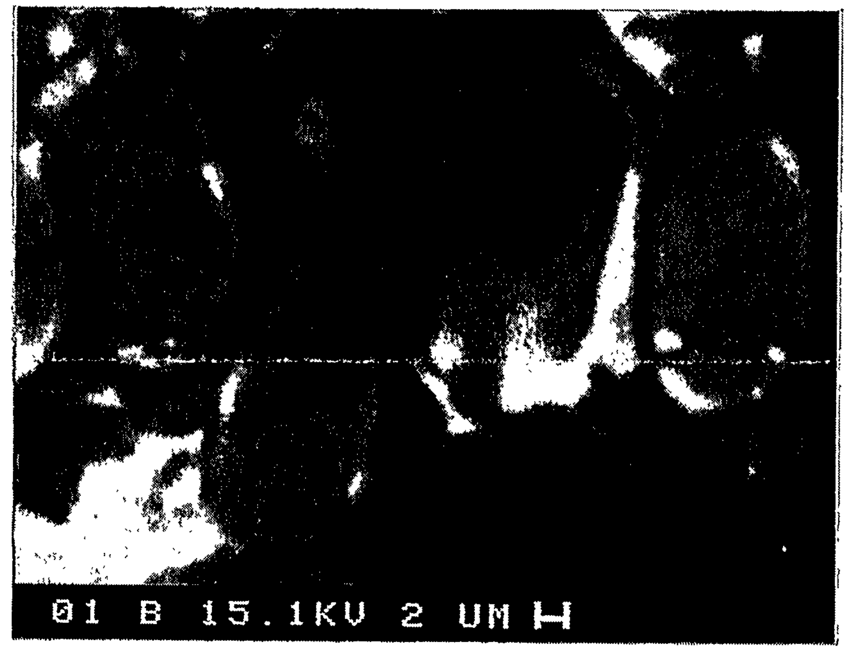


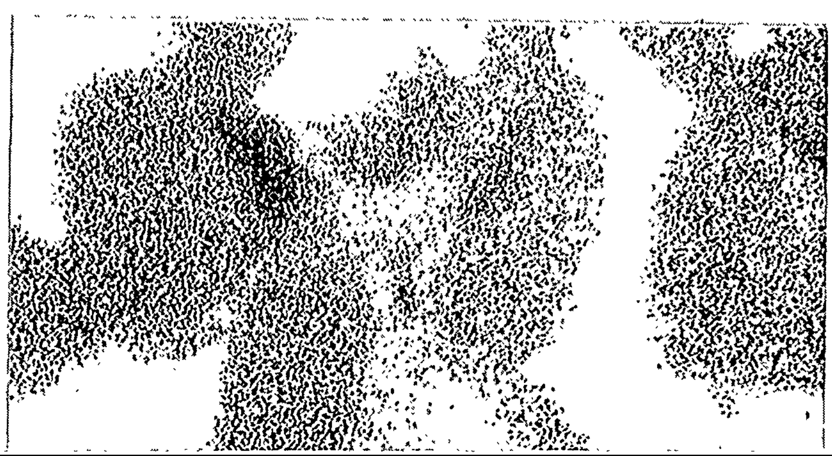
Figure 7c – Elemental Microprobe Analyses Of The CVI-SiC Coated Fibers In The As-Manufactured Triaxial Braid Support Matrix In The 3M Composite Filter

SEM

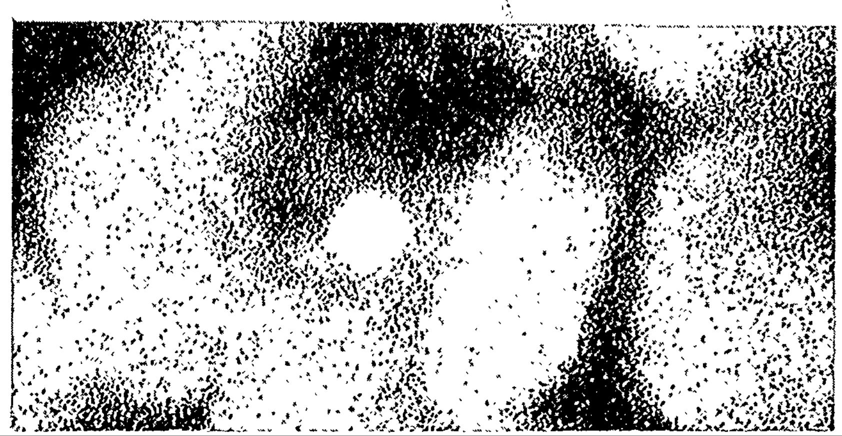
BSE

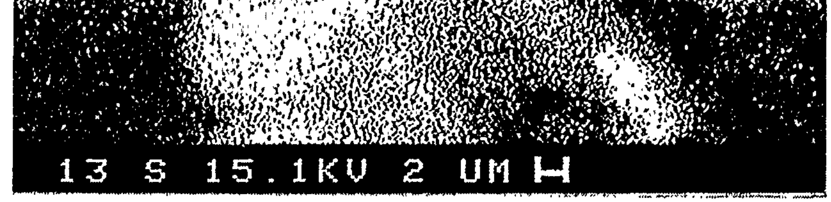


Si

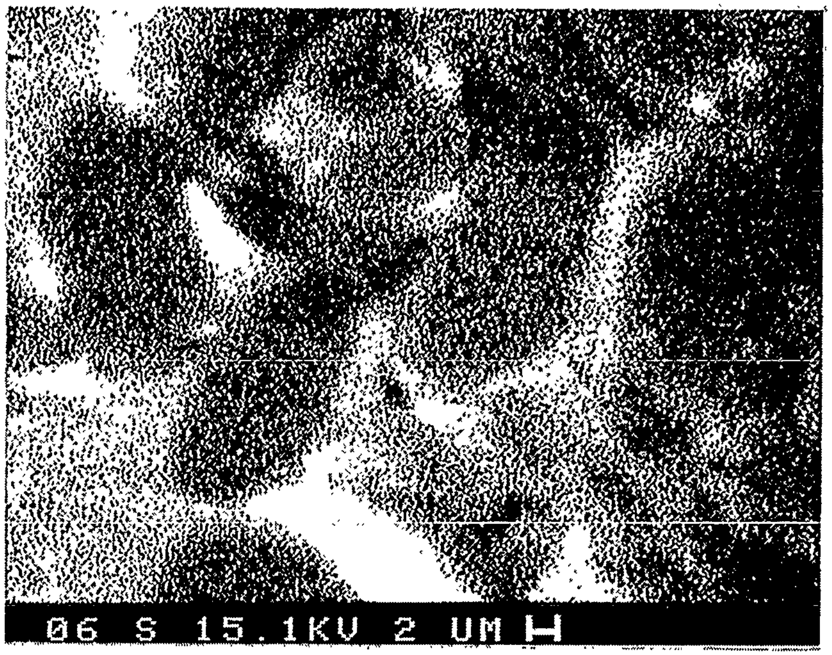


Al





C



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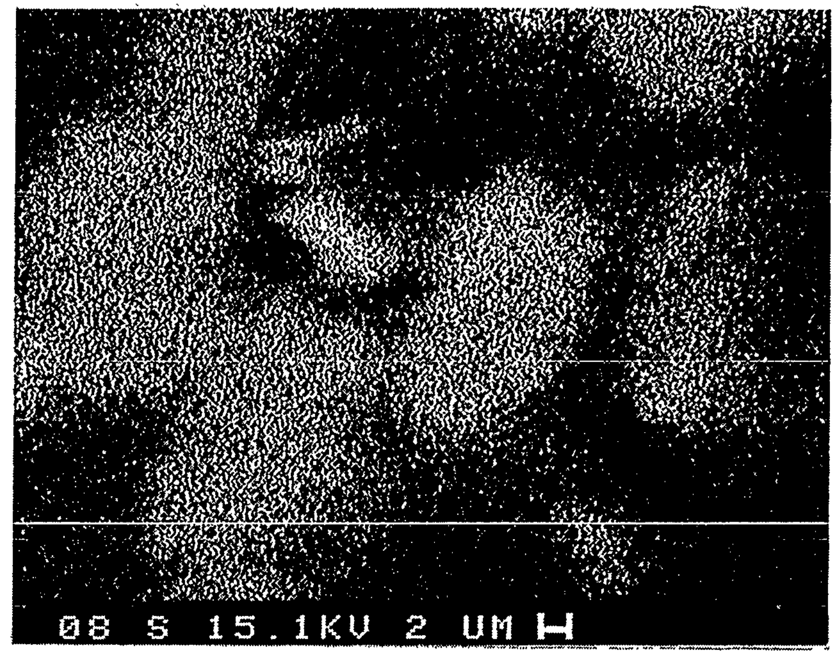

Figure 7d – Elemental Microprobe Analyses Of The CVI-SiC Coated Fibers In The As-Manufactured Triaxial Braid Support Matrix In The 3M Composite Filter

PFBC EXPOSED 3M COMPOSITE FILTER MATRIX

Three 1.5 m 3M CVI-SiC candle filters (No's 43-1-6 (B/M-15); 43-2-5 (B/M-16); 43-1-5 (B/M-17) were installed in Westinghouse's Advanced Particulate Filtration (W-APF) system in June 1994, and testing was initiated in the pressurized fluidized-bed combustion (PFBC) gas environment in July 1994. The borescope inspection on September 22, 1994 of the W-APF internals indicated that all three of the 3M composite filter elements remained intact during the first 1015 hours of test operation. Testing continued for a total of 1705 hours after which time testing was terminated, and the W-APF filter internals were removed from the pressure vessel. Post-test inspection indicated that two of the 3M CVI-SiC composite filter elements had failed. Fracture of these elements had clearly occurred at the transition section of the composite filter matrix (see discussion below). The third filter element remained intact throughout the entire 1705 hours of test operation.

Figure 8 shows the flange section of the failed 3M filter element. Due to the thin wall construction of the 3M composite filter matrix, mounting of the filter was accomplished via the use of a metal insert and gasket which were used to tightly capture the flange area of the filter element in the existing filter holder, as well as to provide the primary dust seal surface. Generally dust was seen to be trapped between the metal insert and the inner wall of the 3M composite filter (i.e., below the thick inner gasket; Figure 9). Similarly dust had compacted between the filter holder mount and the outer surface of the 3M composite filter (i.e., below the thick outer gasket; Figure 9). As shown in Figure 10, the outer gasket sleeve extended below the metal holder which contained the failed 3M composite filter elements. The metal holder in turn, extended below the fractured filter body, both of which extended below the metal insert which is required for installation and use of the 3M composite filter body.

During construction of the 3M composite filter element, an additional layer of Nextel™ 312 fabric is placed along the outside surface of the flange in order to provide additional strength in this area. After cleaning the failed section of the 3M composite filter, it was clearly evident that failure had occurred where the double layer of fabric terminated, and where the single layer of the filter body continued (Figure 11). Remnants of the failed 3M filter matrix which had been retrieved after passing through the ash hopper and screw conveyor are shown in Figure 12. Only shards of the 3M composite filter matrix remained.

The remaining intact 3M CVI-SiC composite filter (No. 43-1-6 (B/M-15) was removed and inspected, and prepared for further material characterization. As shown in Figure 13, various sections along the filter body were identified for characterization by

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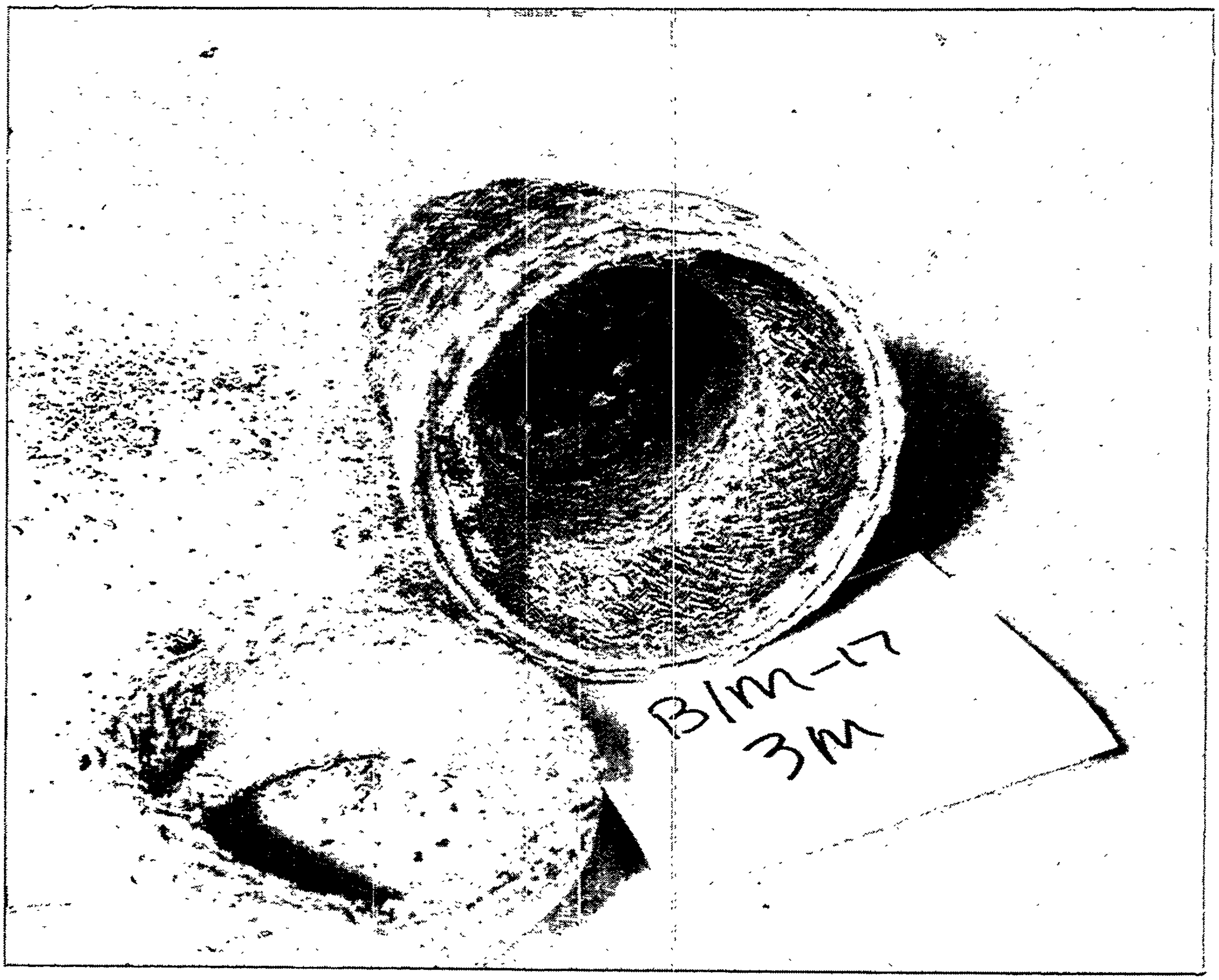


Figure 8 — Flange Section Of The Failed 3M Composite Filter

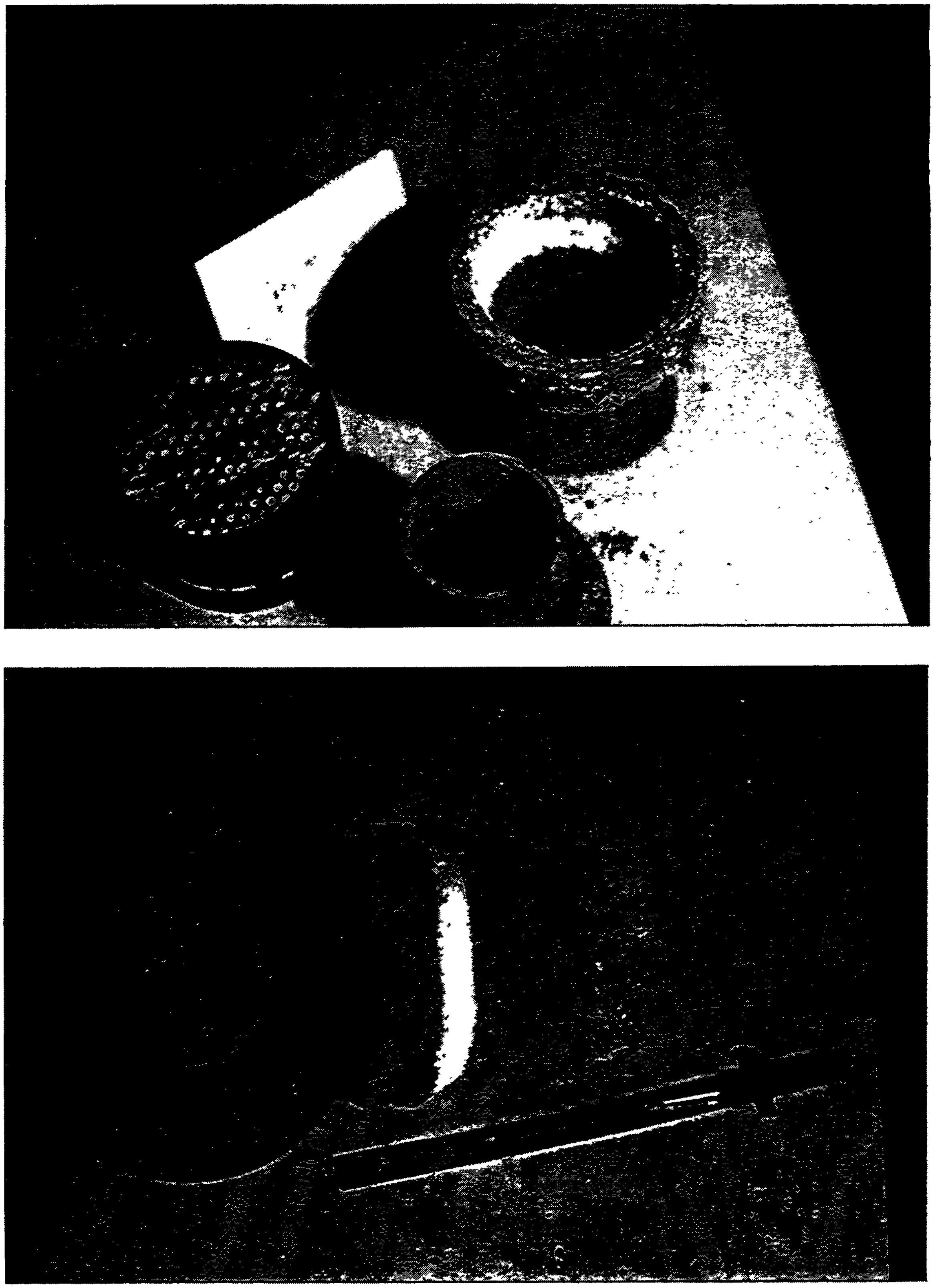
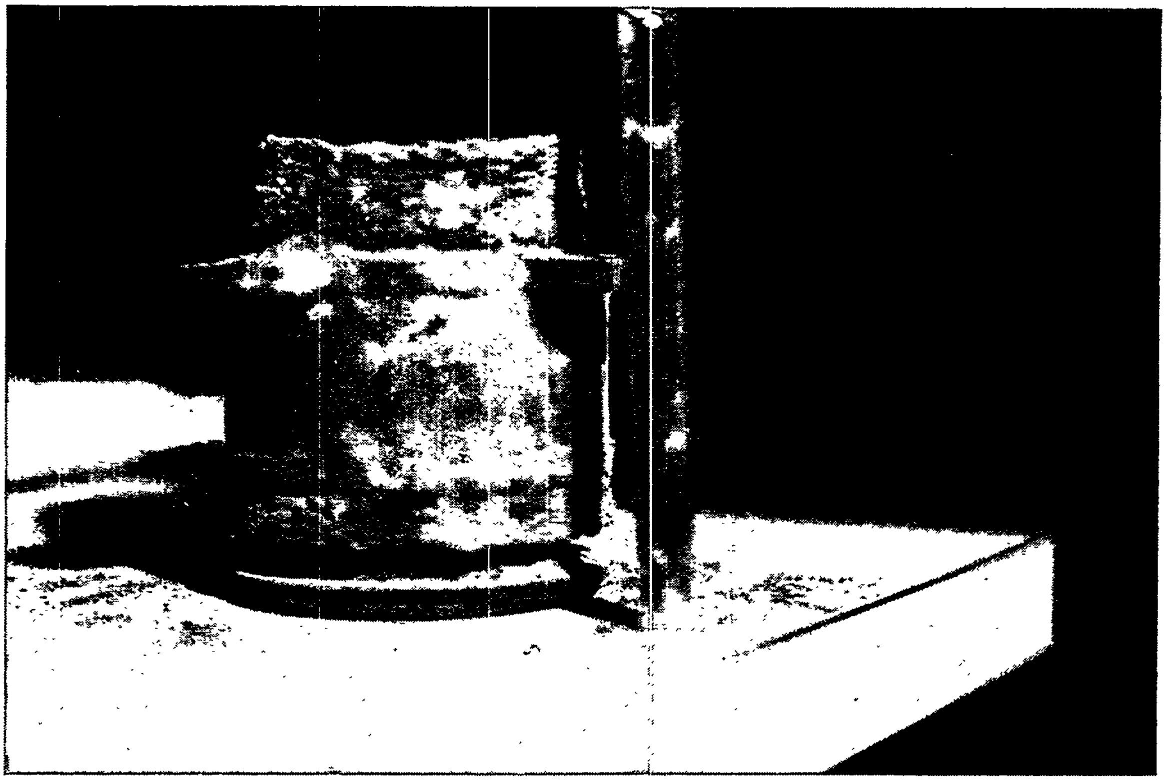


Figure 9 — Photographs Illustrating Dust Cake Accumulation Along The Flange Area Of The Failed 3M Composite Filter



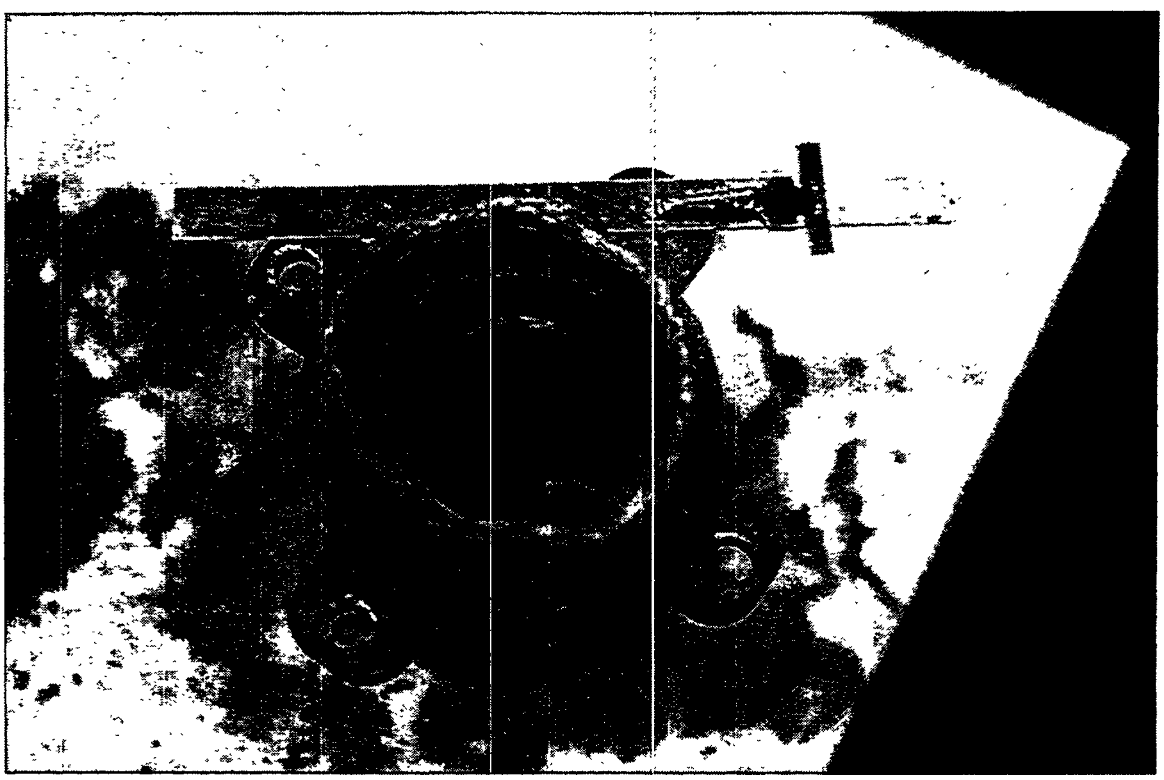


Figure 10 – Location Of The Fractured Area Of The Failed 3M Composite Filter Relative To The Filter Holder Mount And Metal Insert

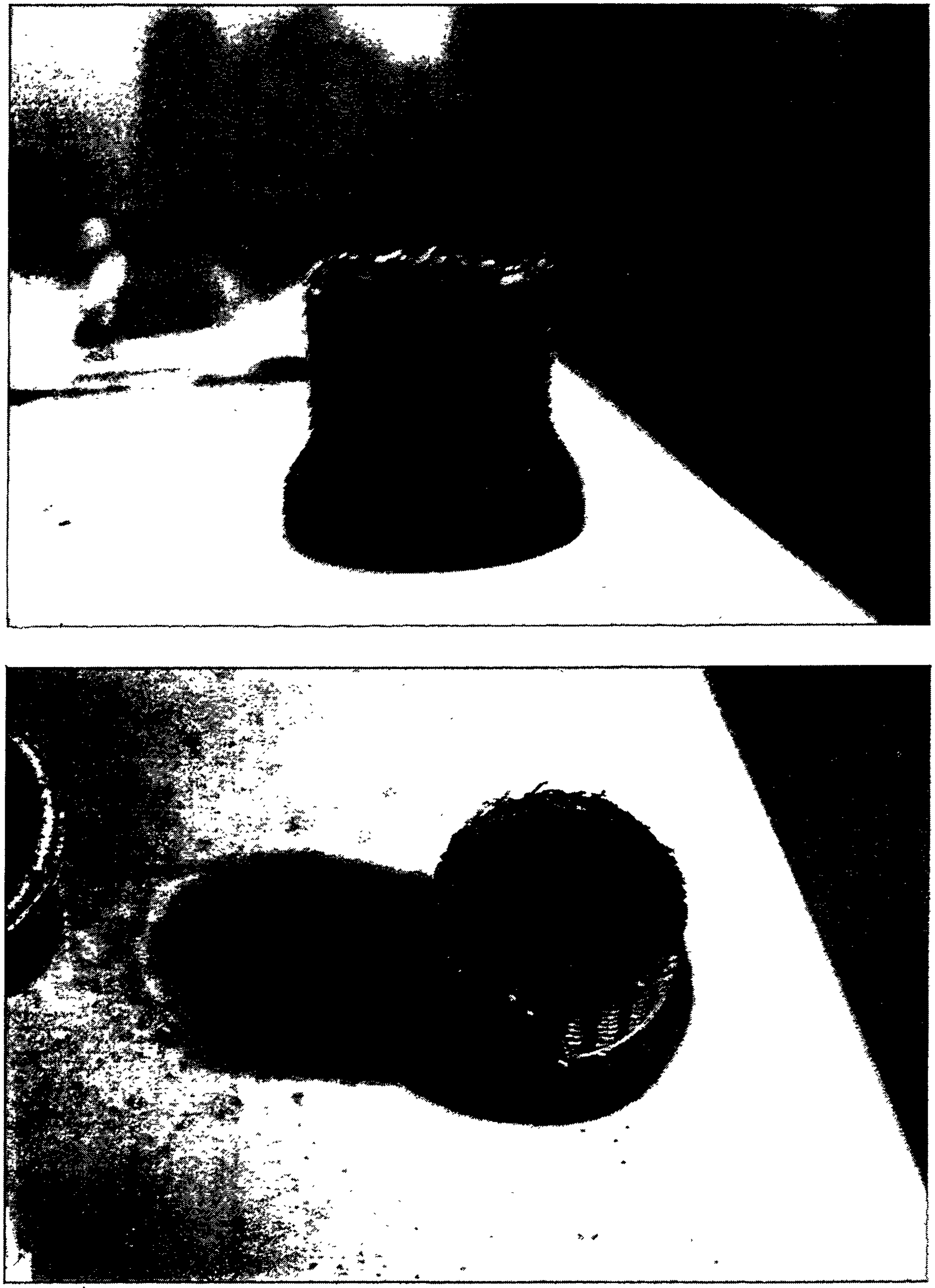


Figure 11 – Flange Section Of The Failed 3M CVI-SiC Composite Filter

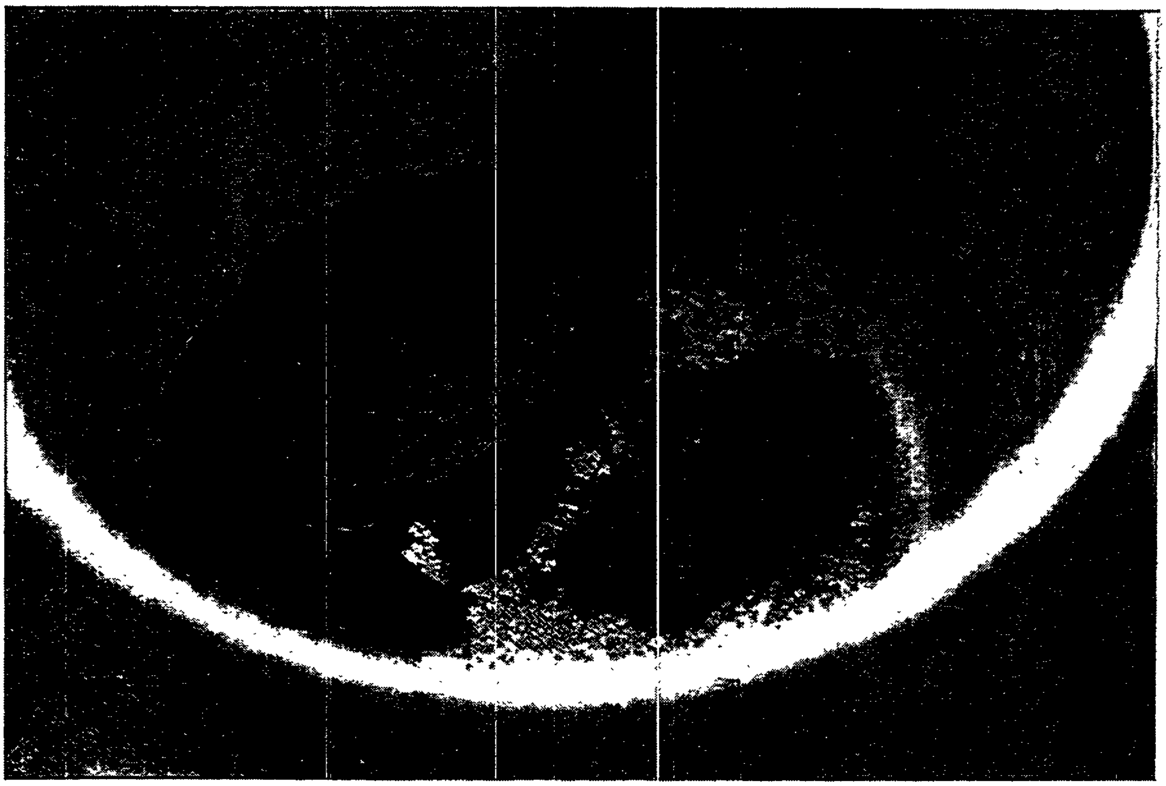


Figure 12 – Remnants Of the 3M Composite Filter Matrix After Passing Through The Ash Hopper And Screw Conveyor In The W-APF System

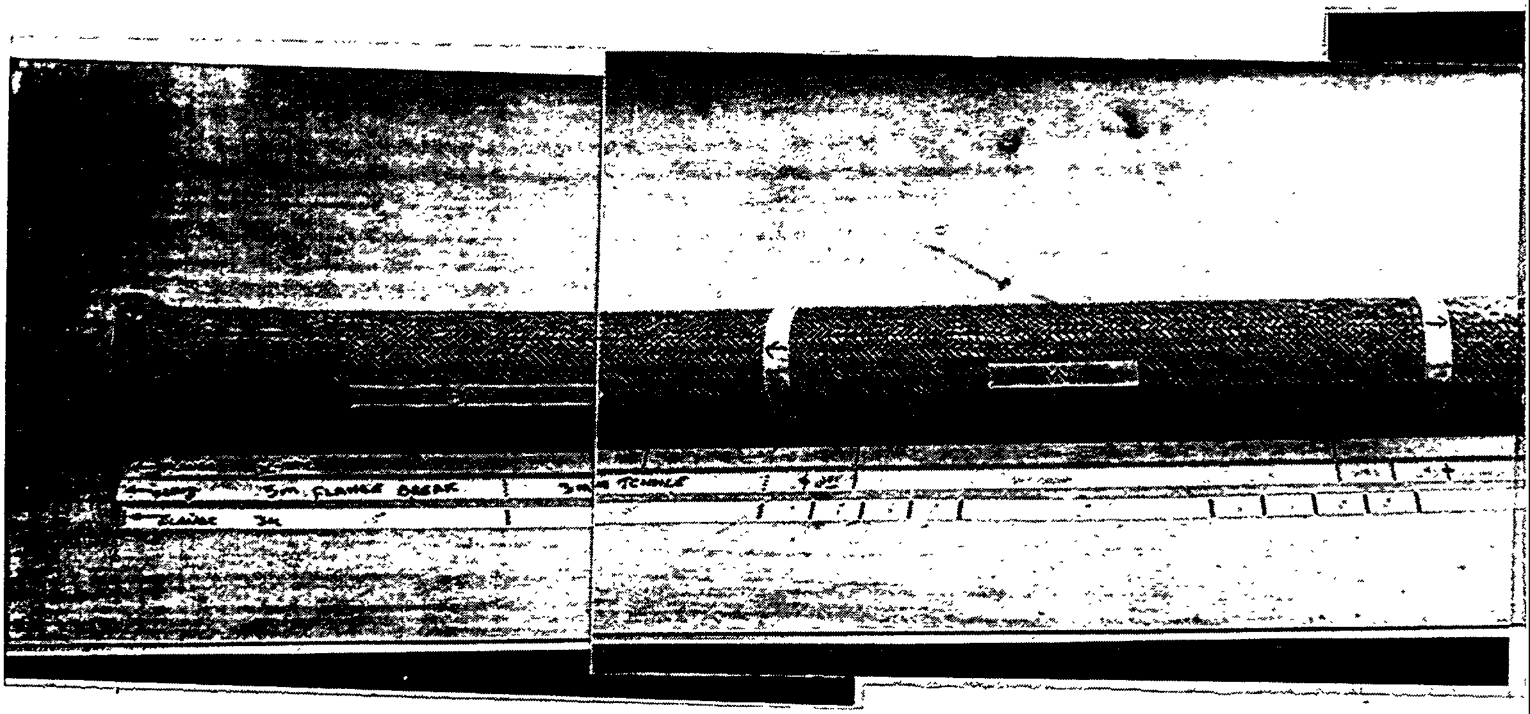
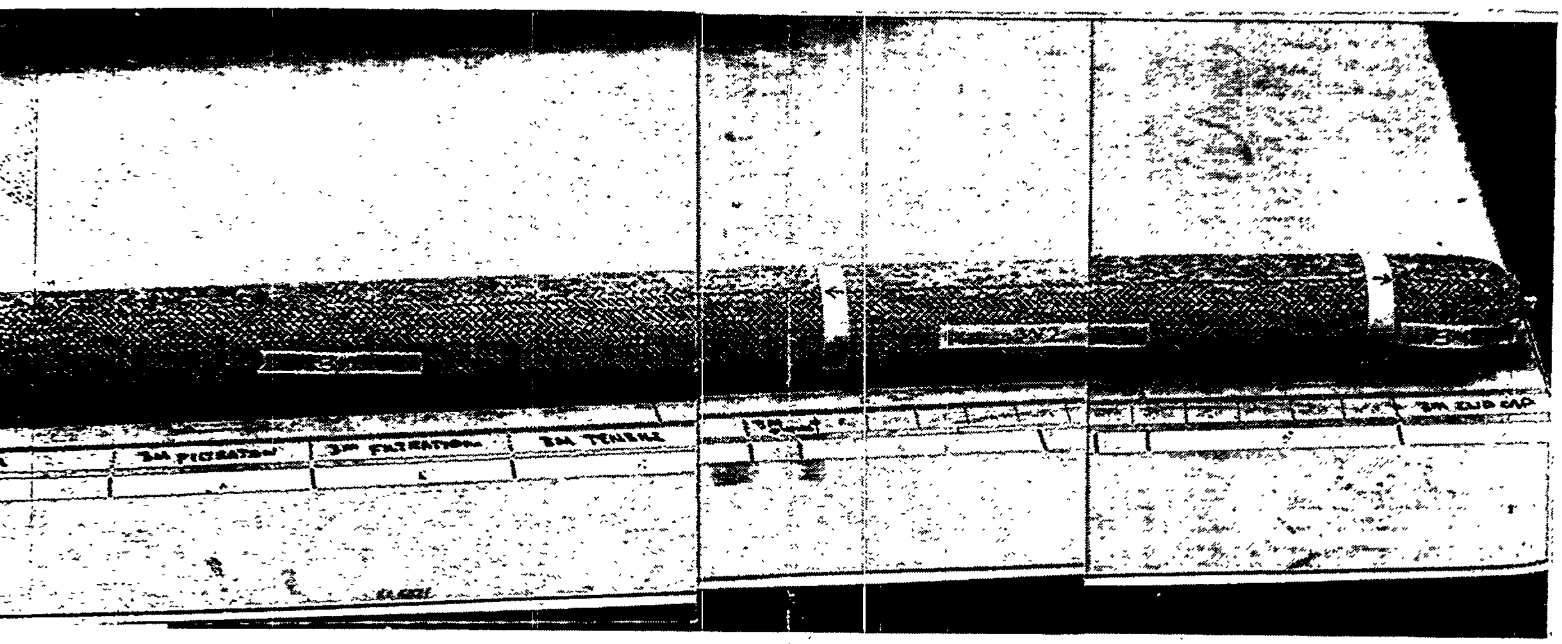


Figure 13 – Locations Identified Along The Intact 1705
Composite Filter For Materials Evaluation
Westinghouse Personnel



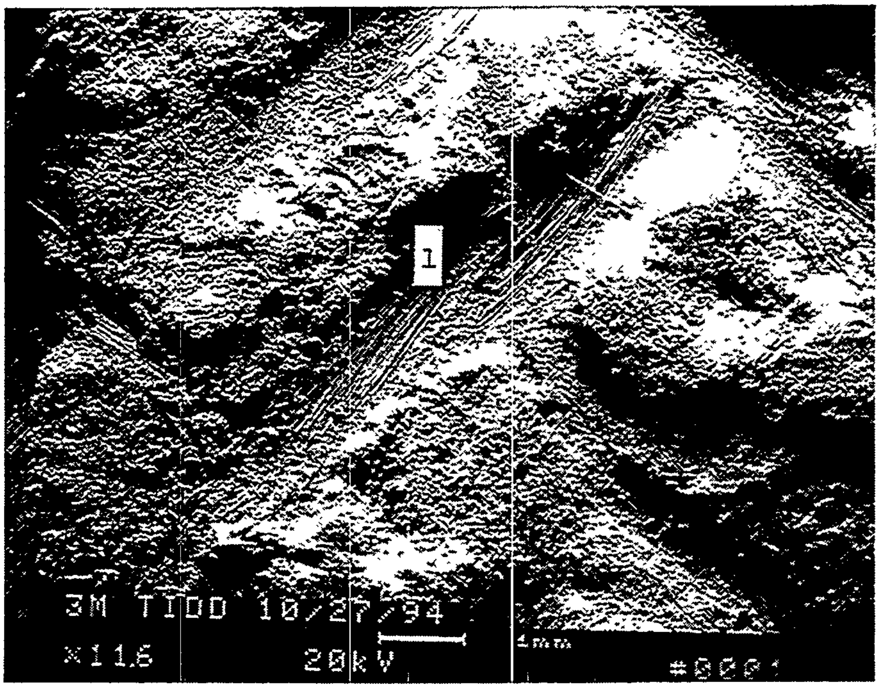
lour PFBC Exposed CVI-SiC
onducted By 3M And

3M, as well as Westinghouse personnel. 3M received the flange section, the mid-section of the filter, and the end cap. Westinghouse received a section which was removed between the flange and mid-section of the filter body, and a section between the mid-section of the filter body and the end cap.

Scanning electron microscopy/energy dispersive x-ray analyses (SEM/EDAX) and elemental microprobe analyses (EMA) were conducted at Westinghouse along a section of the 1705 hour PFBC exposed 3M CVI-SiC composite filter matrix. As shown in Figure 14, the open mesh confinement layer of the PFBC exposed filter matrix is filled with ash. Area 1 in Photo 1, Figure 14a illustrates an area of the PFBC exposed fibers in the confinement layer, and Photo 2, Figure 14a illustrates the morphology of these fibers at higher magnification. Frequently empty shells of the SiC coating are evident which initially housed the Nextel^{TM} 312 fibers in the confinement layer (Area 1, Photo 3, Figure 14b). Figure 14c provides a higher magnification micrograph illustrating the morphology of the CVI-SiC coating along a Nextel^{TM} 312 fiber in the confinement layer after 1705 hours of hot gas filtration in the PFBC gas environment.

Figures 14d and 14e illustrate the morphology of the CVI-SiC coated Nextel^{TM} 312 fibers at an alternate location in the PFBC exposed confinement layer. The outer surface of the CVI-SiC coating appears to have a "grainy" or textured appearance. The fractured outer CVI-SiC coating is rather jagged which has resulted presumably during sample preparation. In the areas where the CVI-SiC coating is removed, the underlying Nextel^{TM} 312 fiber is exposed. In the micrographs shown in Figure 14d, a gap may be present between the CVI-SiC coating and the underlying Nextel^{TM} 312 fiber. The gap is shown at higher magnification in Figure 14e.

As we move into the ~1 mm filtration mat layer, dense packing of fibers and ash fines are evident (Figure 15a). "Melt-like" features are apparent along or at the ends of the CVI-SiC coated filtration mat fibers (Photo 4, Figure 15b). The outer surface of the CVI-SiC layer is "grainy" or textured, similar to the morphology of the SiC coated filtration mat fibers in the as-manufactured filter matrix (Photo 5, Figure 15b; Photo 16, Figure 5c and Photo 17, Figure 5d). Figure 15c illustrates the resulting morphology along a cross-sectioned filtration mat fiber. Area 1 shown in Photo 6, Figure 15c contains the ~1-2 μm SiC coating, while Area 2, Photo 6, Figure 15c contains the aluminum, silicon, and oxygen enriched fiber (i.e., an aluminosilicate matrix). The rather mottled appearance of the fractured surface of the PFBC exposed filtration mat fiber is similar to that of the as-manufactured filtration mat fibers shown in Figures 5c and 5f. A distinct separation between the CVI-SiC outer coating and the filtration mat fiber, and/or the expected interface layer is not evident.



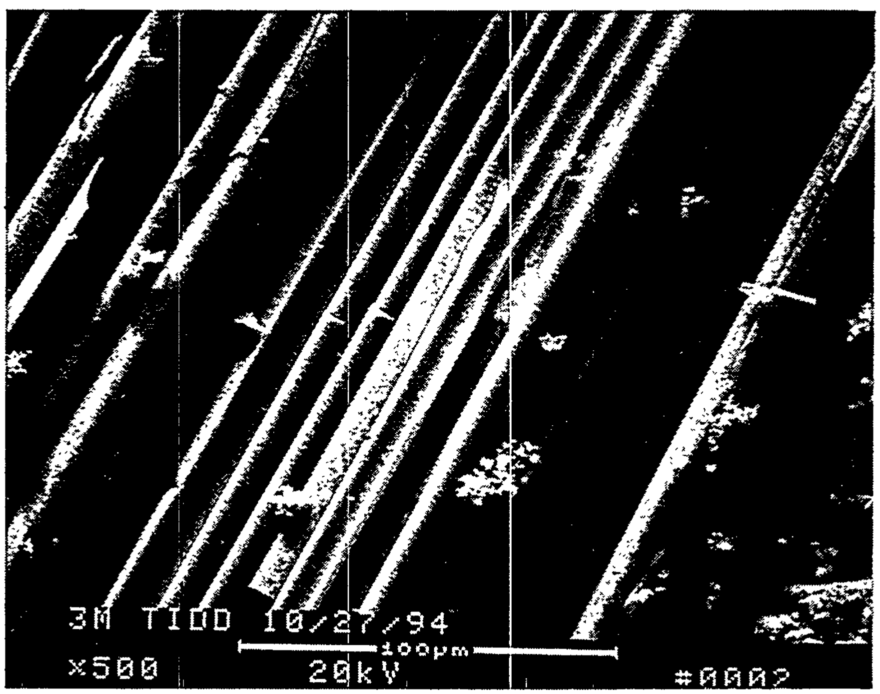


Figure 14a – Morphology Of The CVI-SiC Coated Nextel™ 312 Fibers In The Confinement Layer Of The 1705 Hour PFBC Exposed 3M Composite Filter Matrix

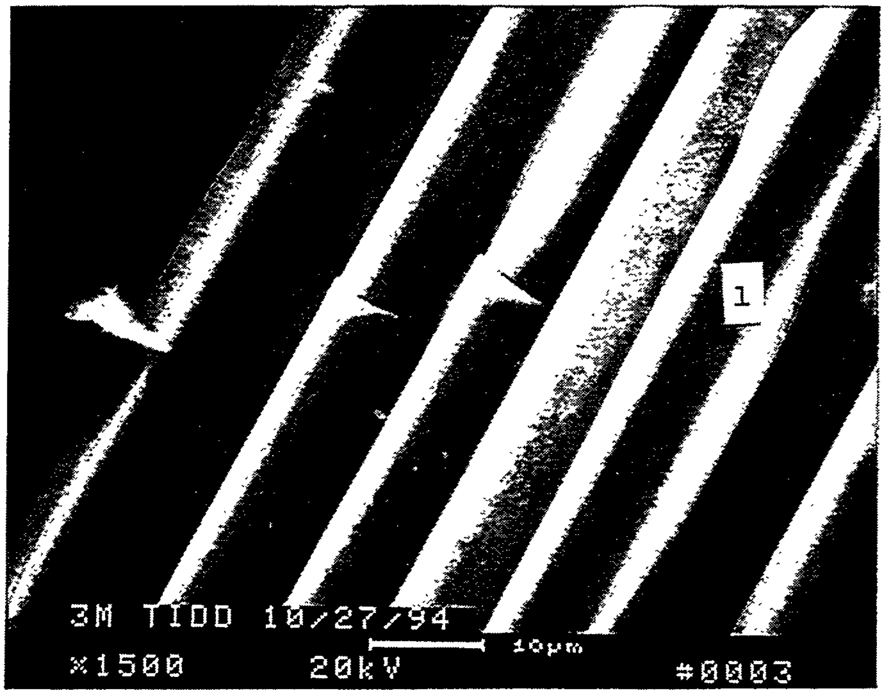


Figure 14b – Higher Magnification Micrographs Of The Confinement Layer Fibers

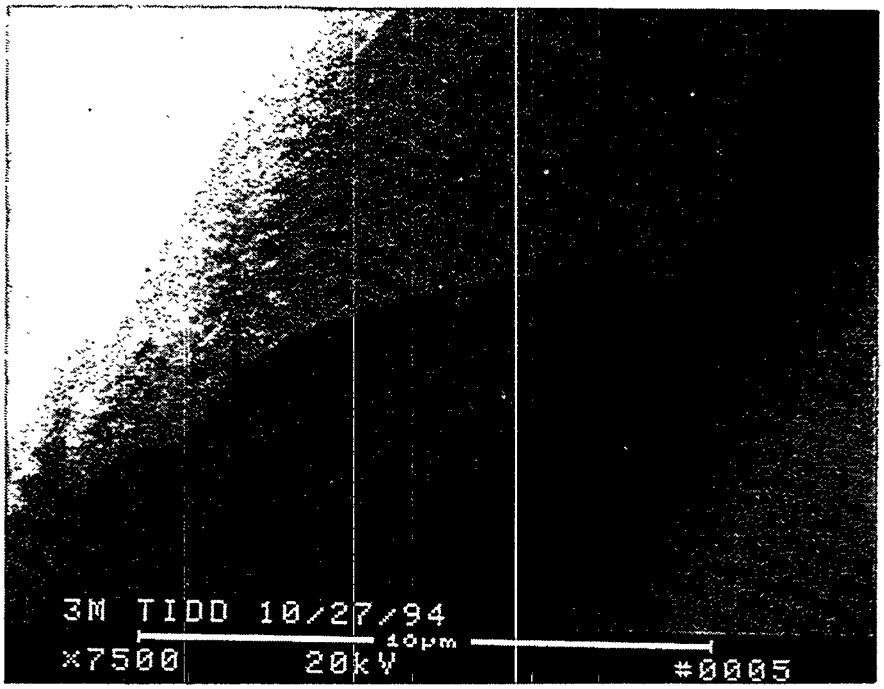


Figure 14c – Higher Magnification Micrograph Of The Confinement Layer Fibers

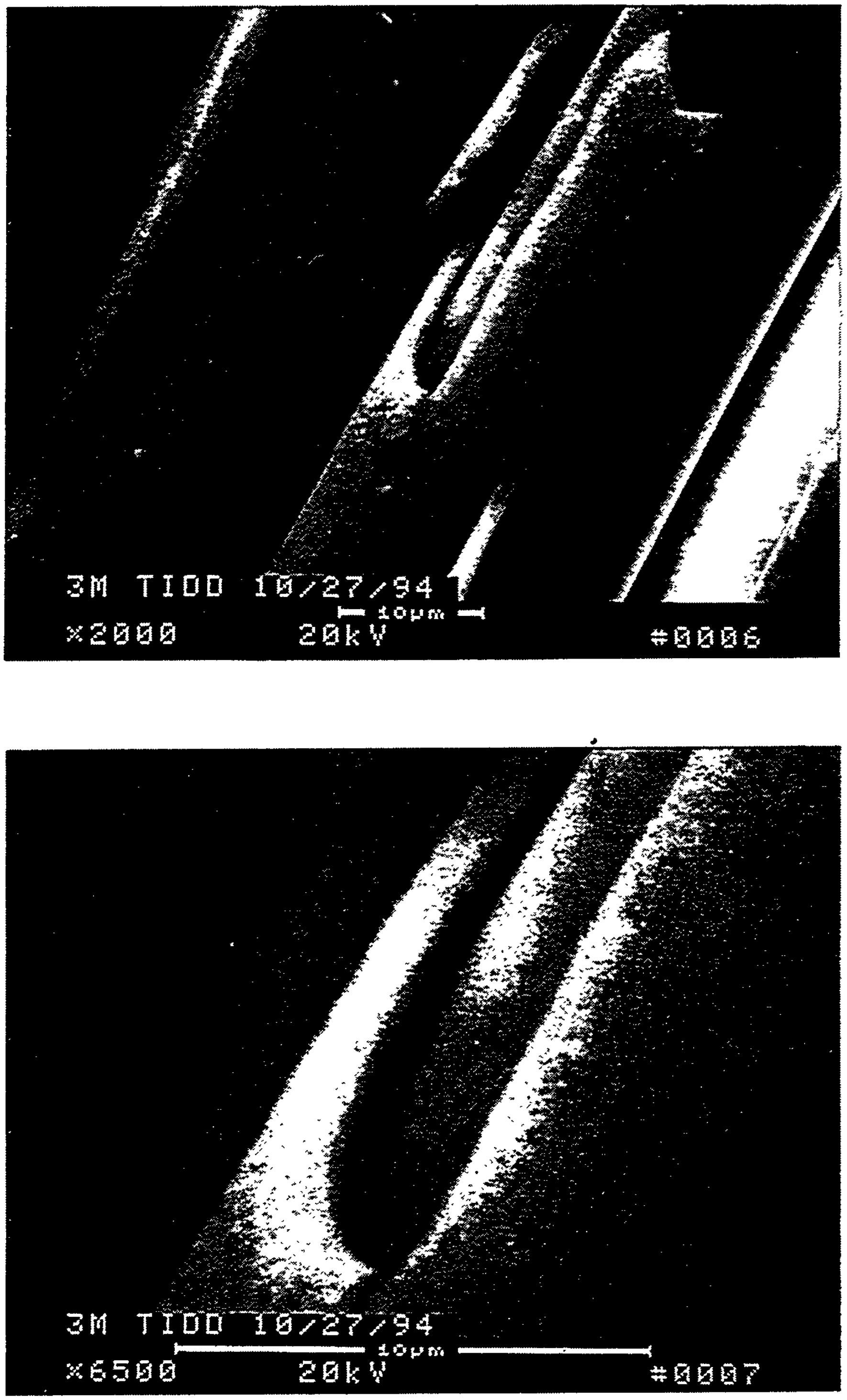


Figure 14d – Micrographs Illustrating The Morphology Of the 1705 Hour PFBC CVI-SiC Coated Nextel™ 312 Fibers In The Confinement Layer Of The 3M Composite Filter

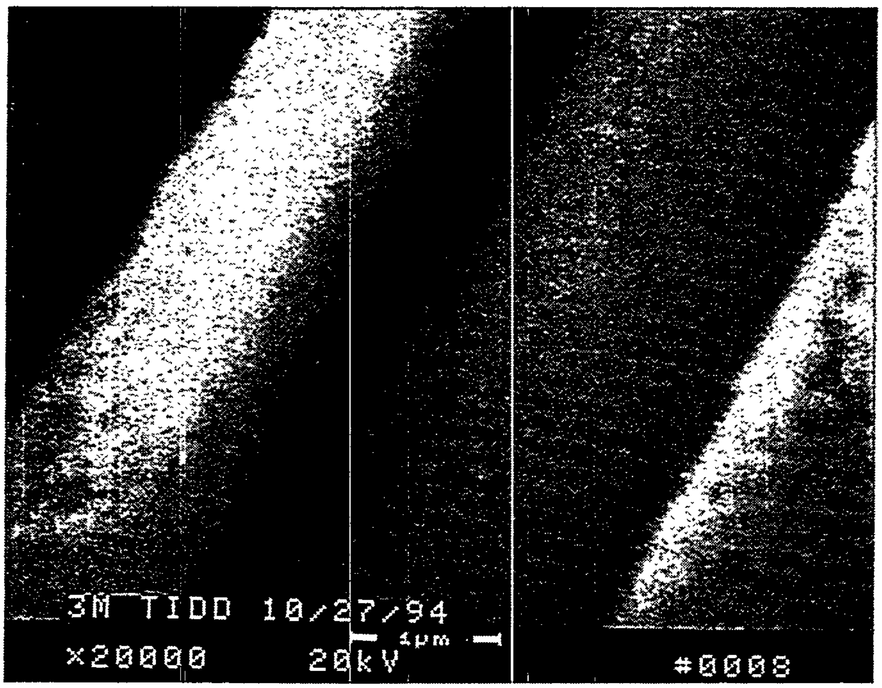


Figure 14e – Higher Magnification Micrograph Of The CVI-SiC Coated Nextel™ 312 Fibers In The Confinement Layer Of The PFBC Exposed 3M Composite Filter

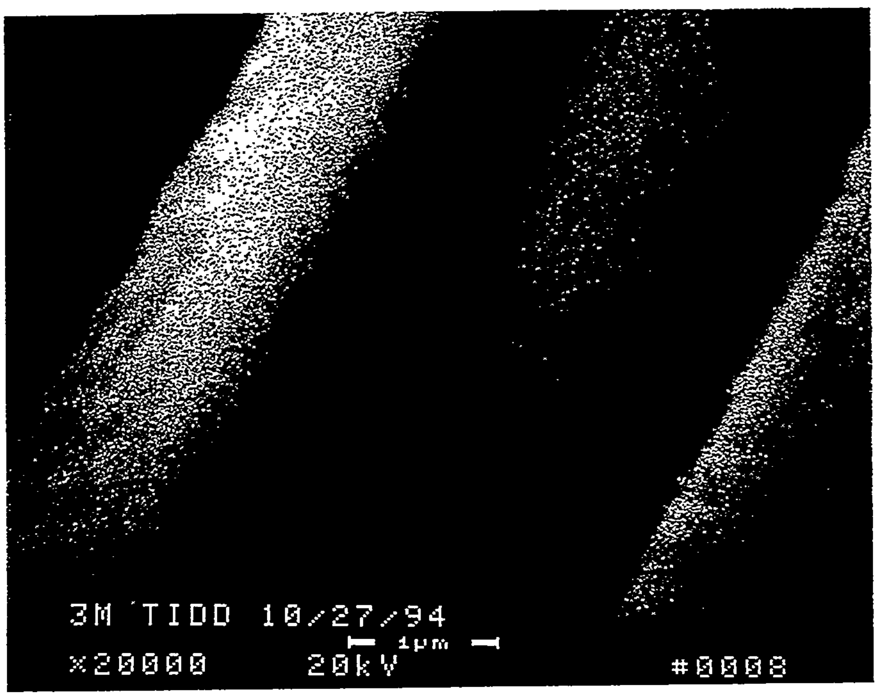
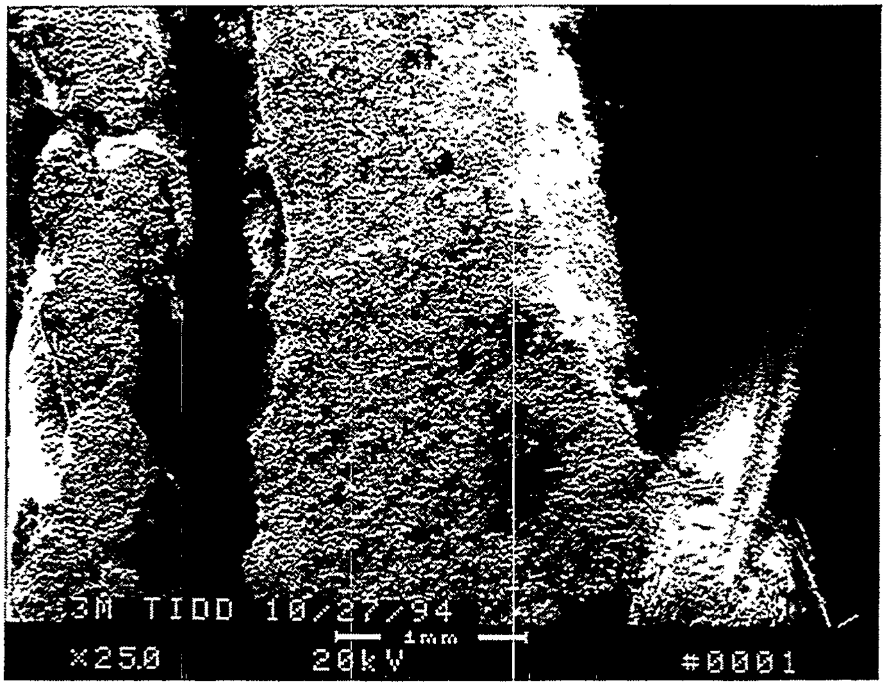


Figure 14e – Higher Magnification Micrograph Of The CVI-SiC Coated Nextel^{TM} 312 Fibers In The Confinement Layer Of The PFBC Exposed 3M Composite Filter



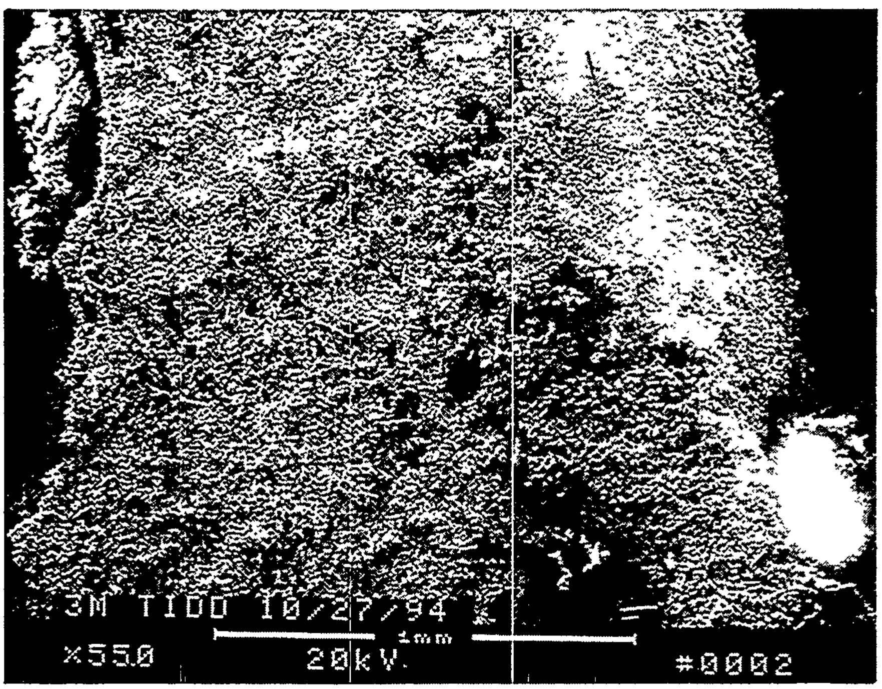
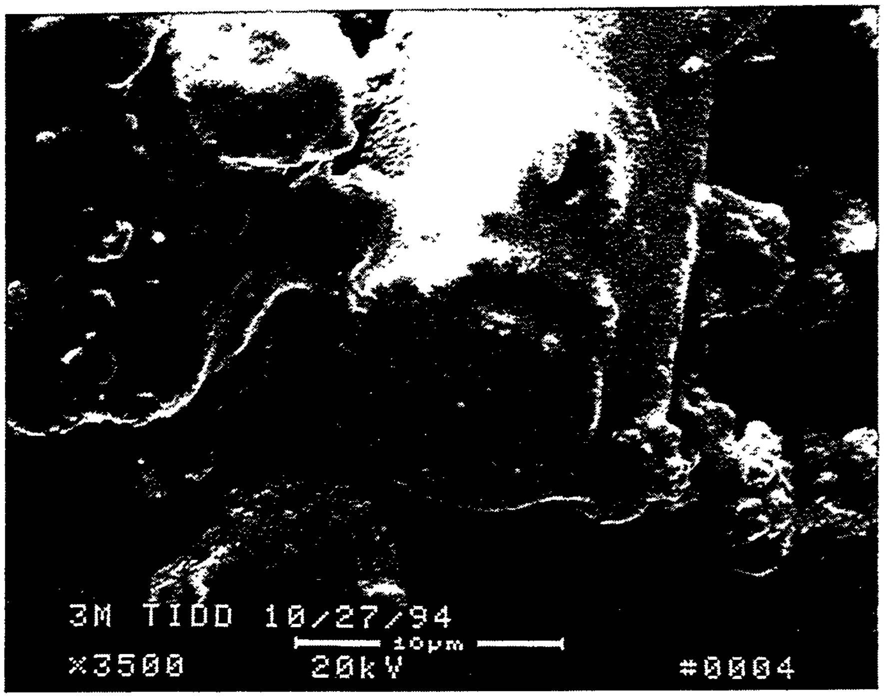


Figure 15a – Filtration Mat Layer In The 3M CVI-SiC Composite Filter That Was Exposed For 1705 Hours In The PFBC Gas Environment



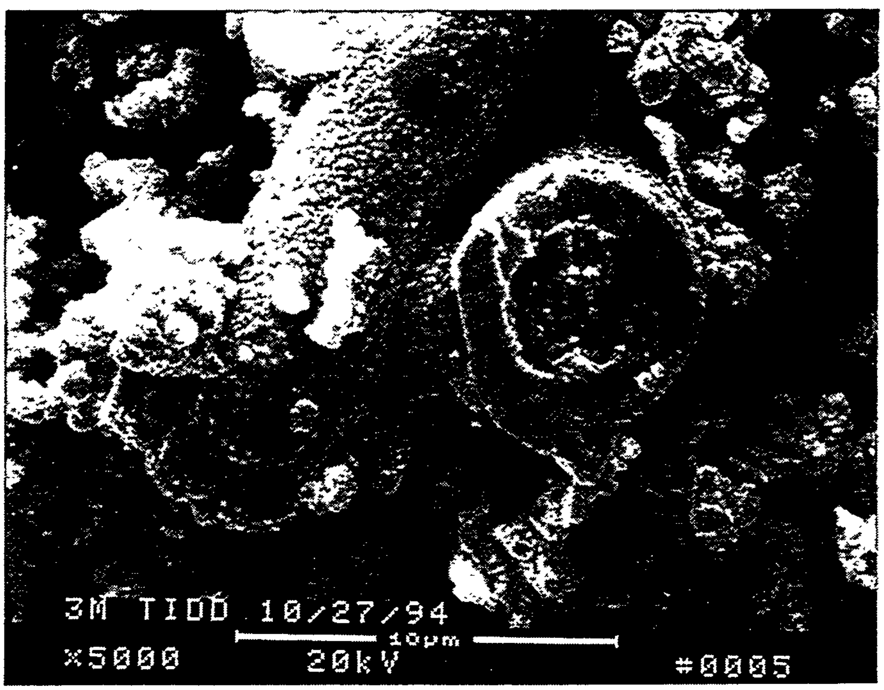
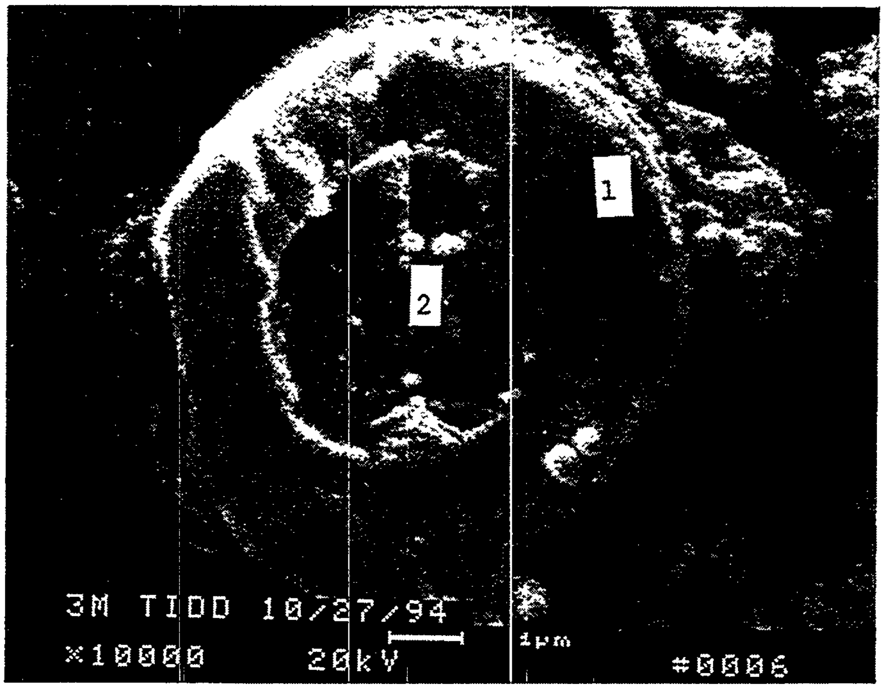


Figure 15b – Morphology Of The Filtration Mat Fibers After PFBC Exposure



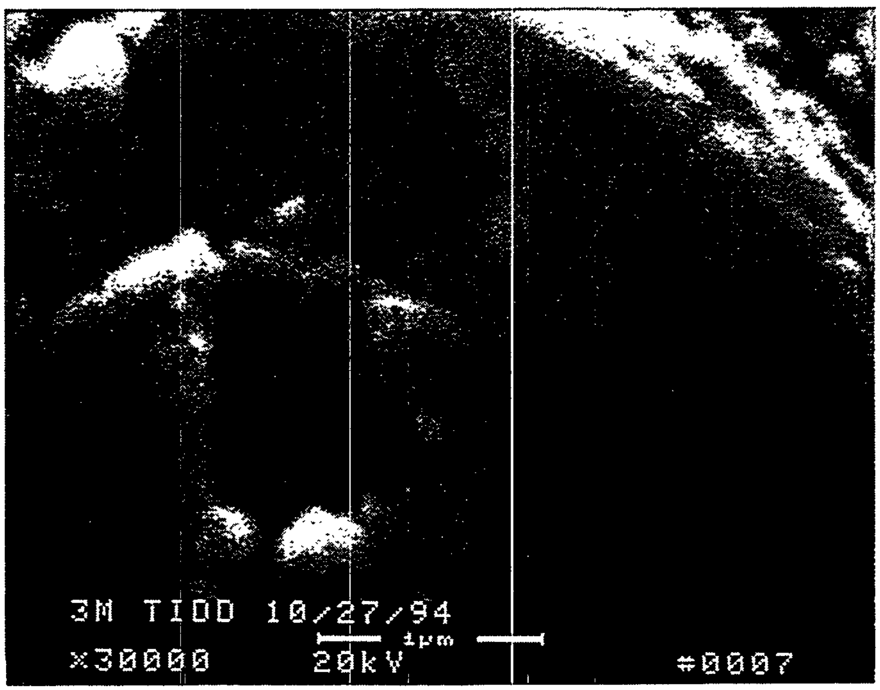


Figure 15c — Higher Magnification Micrographs Illustrating The Morphology Of A Cross-Sectioned Filtration Mat Fiber After 1705 Hours Of Exposure To The PFBC Gas Environment

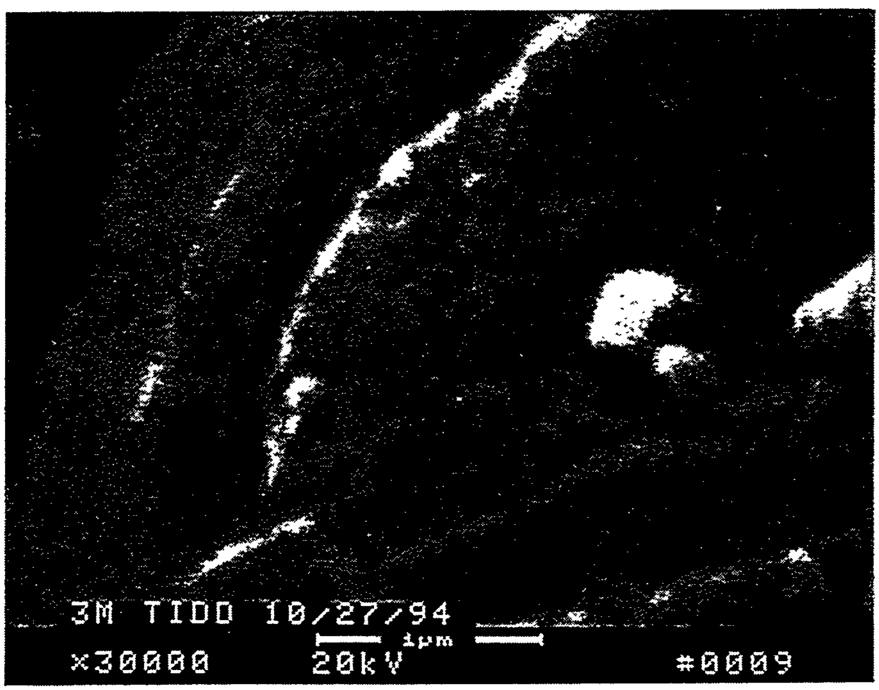
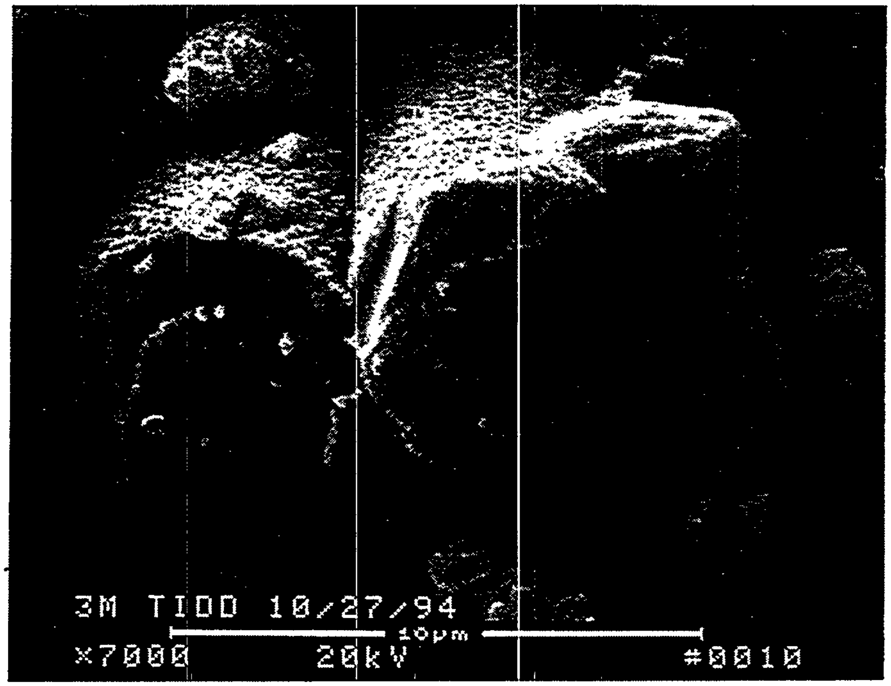


Figure 15d – Additional Higher Magnification Micrographs Illustrating The Morphology Of A Cross-Sectioned Filtration Mat Fiber After 1705 Hours Of Exposure To The PFBC Gas Environment



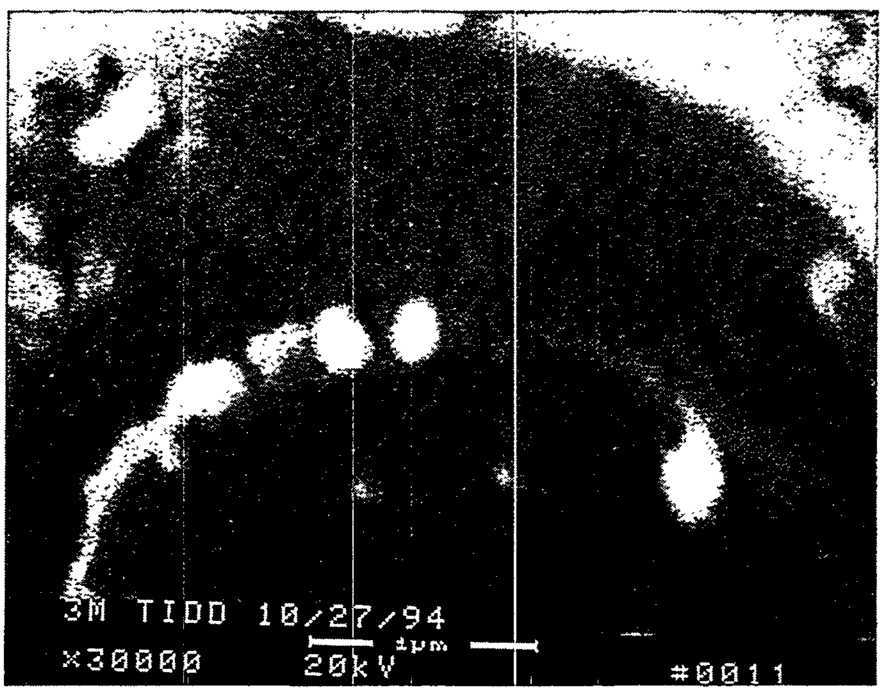


Figure 15e — Additional Higher Magnification Micrographs Illustrating The Morphology Of A Cross-Sectioned Filtration Mat Fiber After 1705 Hours Of Exposure To The PFBC Gas Environment

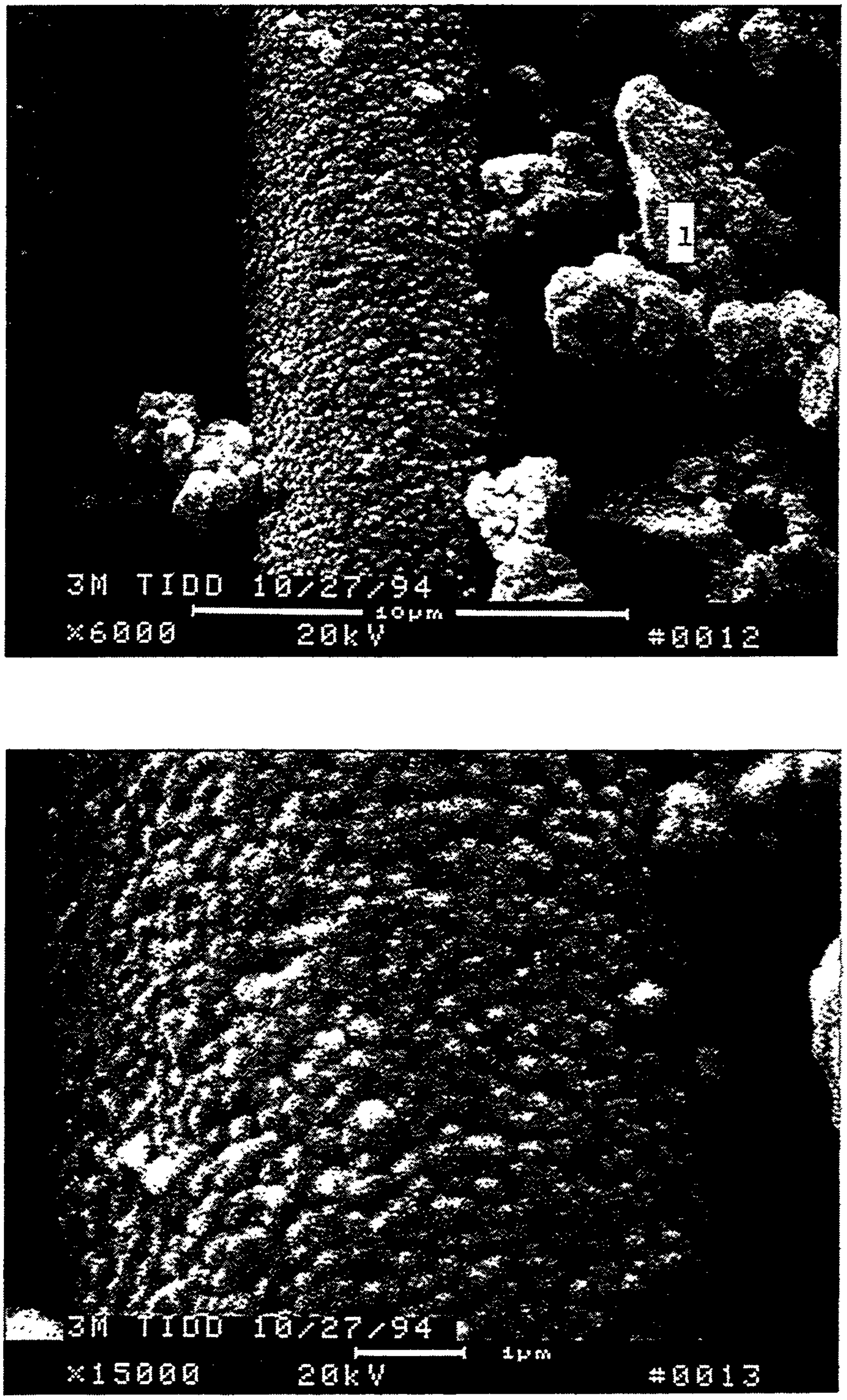


Figure 15f – Morphology Of The CVI-SiC Surface After 1705 Hours Of Exposure In The PFBC Gas Environment

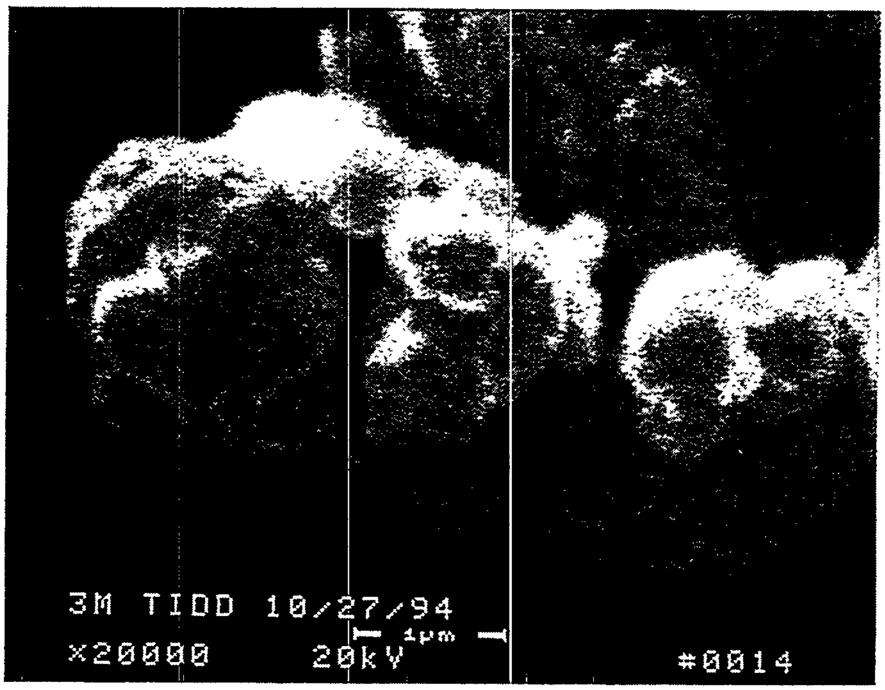


Figure 15g — Ash Particulate Captured In The Filtration Mat Layer Of The 3M CVI-SiC Composite Filter Matrix

The morphology of another fiber in the 1705 hour PFBC exposed filtration mat layer is shown in Figure 15d and in Figure 15e. Again the outer surface of the CVI-SiC coating along these fibers is rather mottled.

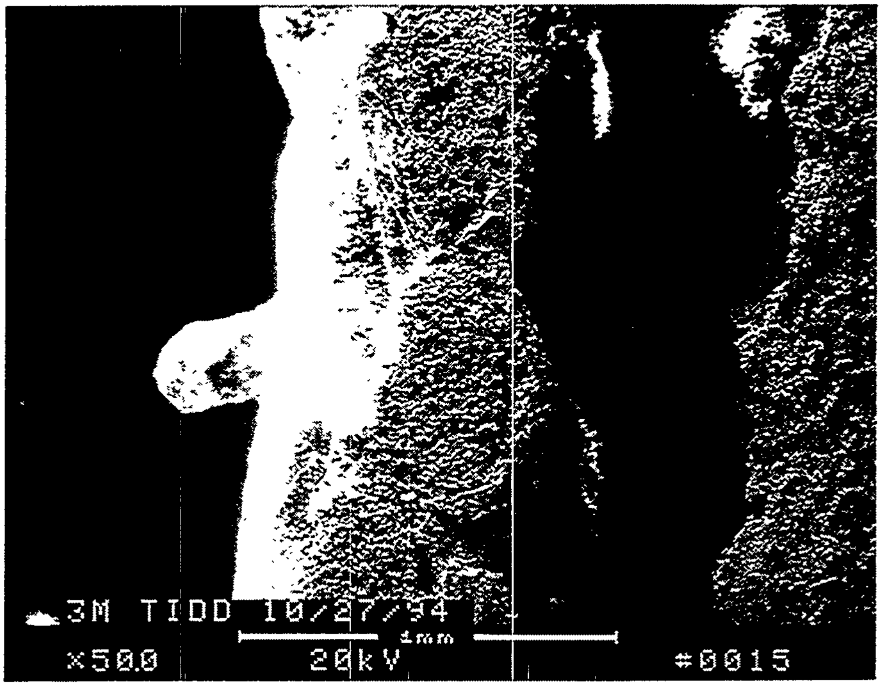
The morphology of the mottled CVI-SiC surface coating is also shown in Figure 15f. Since EDAX analyses were not performed along the surface of the CVI-SiC coating, we cannot state with certainty whether oxidation of the SiC surface has occurred during the 1705 hours of exposure in the PFBC gas environment.

Ash fines which were in contact with the filtration layer are shown in Area 1, Photo 12, Figure 15f and in Figure 15g. As identified by EDAX, the ash fines typically contain aluminum, silicon, calcium, iron, and oxygen. Since gold was used to coat the sample during preparation for SEM/EDAX analysis, the presence of sulfur in the ash fines was not detected.

The cross-sectioned triaxial braid, structural support layer that was in contact with the filtration mat layer is shown in Figures 16a and 16b. The fiber bundles which are present in the triaxial braid contain elliptical Nextel™ 312 fibers which appeared to be individually coated with SiC (Figures 16c, 16d, and 16e). As shown in Figures 16d and 16e, the SiC coating has fractured and is lifted above the Nextel™ 312 fiber in the triaxial support braid. The surface of the Nextel™ 312 fibers appears to contain raised formations. Clear resolution of the raised areas along the "patchy" or mottled surface that remained along the Nextel™ 312 fiber surface (Photos 7 and 8, Figure 16e) could not be obtained. Similarly, compositional analyses were not generated via EDAX characterization in this area. Additional efforts using Auger analysis are recommended to define the composition of the possible phase changes that may have resulted along the surface of the Nextel™ 312 fibers after 1705 hours of exposure in the PFBC gas environment.

The columnar microstructure of the CVI-SiC matrix is clearly evident along the outside surface of the CVI-SiC coating that encapsulates the triaxial braid (Figure 17a). Retention of ash fines is also apparent along the outside surface of the columnar SiC matrix (Figure 17b).

Figure 17c illustrates the morphology of the columnar SiC matrix at an alternate location along the triaxial braid. At higher magnification the morphology of the columnar SiC matrix and possibly ash fines are apparent (Figure 17d). EDAX analysis of Area 1, Photo 8, Figure 17d indicates the presence of 62.50% O, 36.53% Si, 0.40% Na, 0.31% Fe,



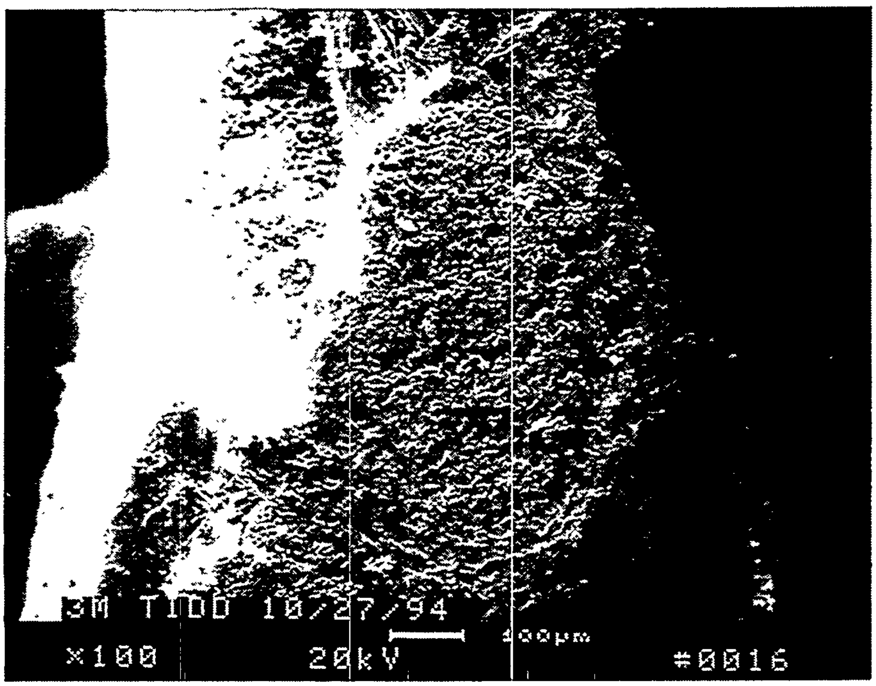


Figure 16a — Cross-Sectioned Triaxial Support Braid In The 1705 Hour PFBC Exposed 3M CVI-SiC Composite Filter Matrix

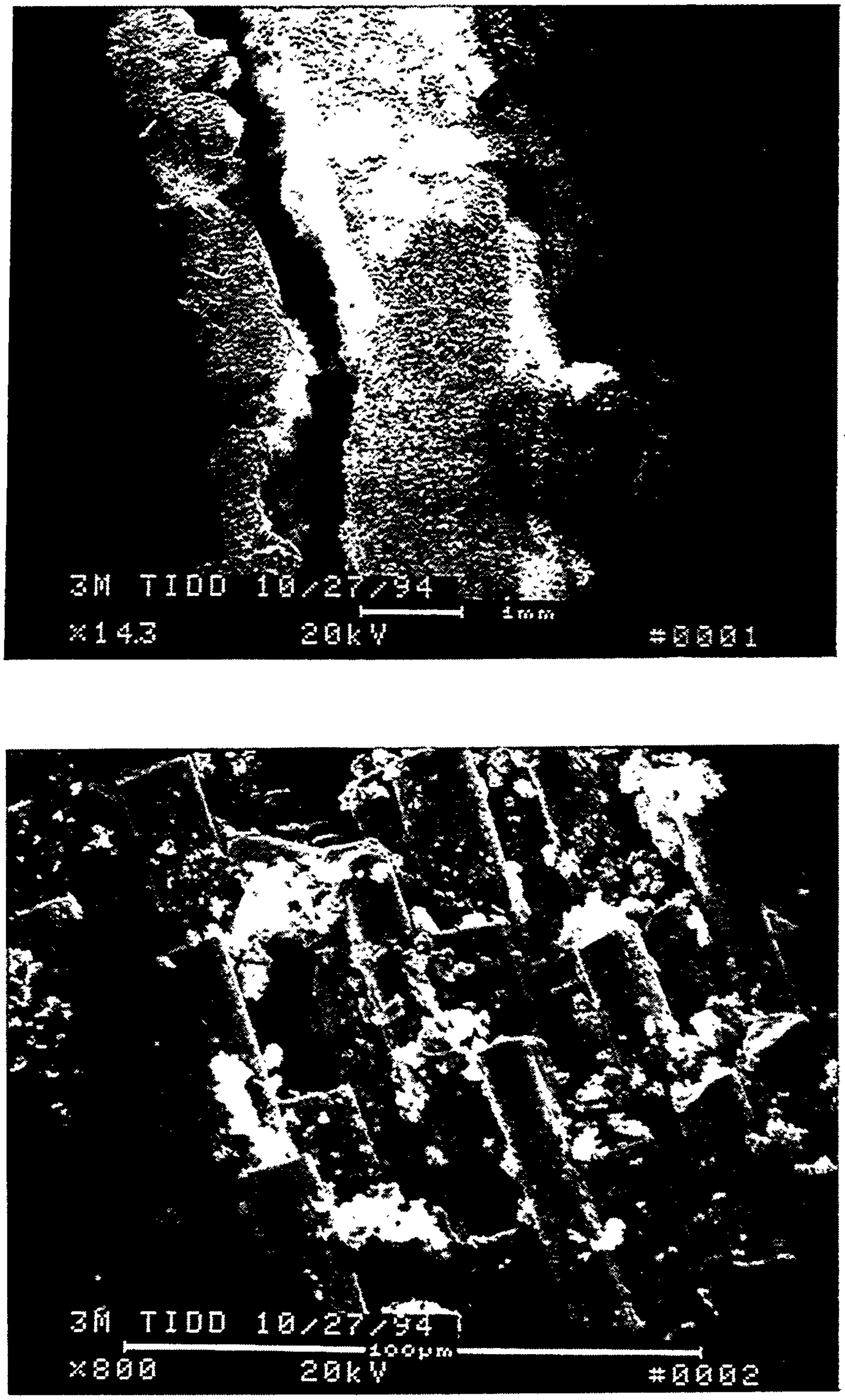
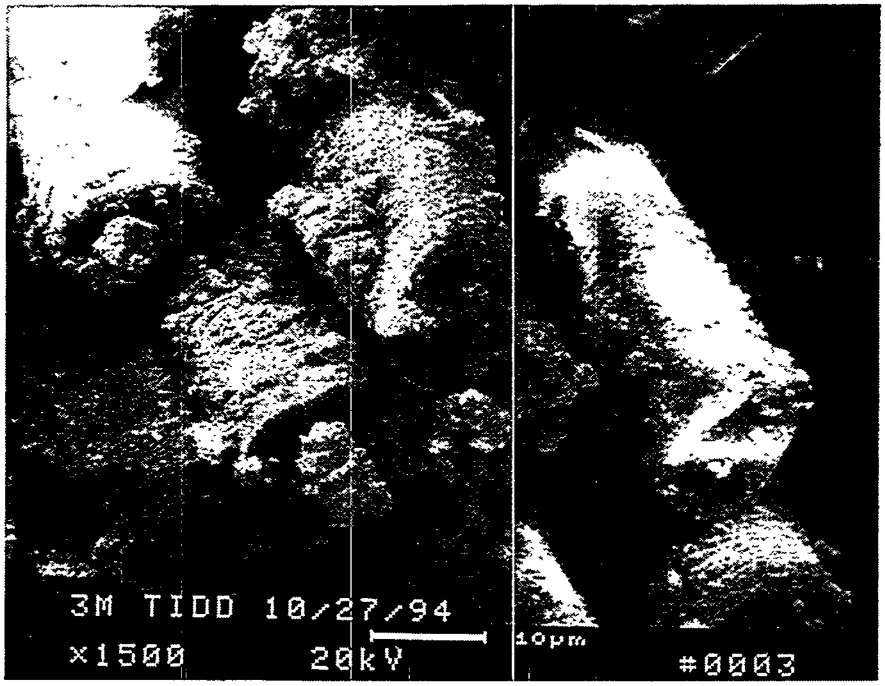


Figure 16b — Fibers Present In The Cross-Sectioned Triaxial Support Braid In The 1705 Hour Exposed 3M CVI-SiC Composite Filter Matrix



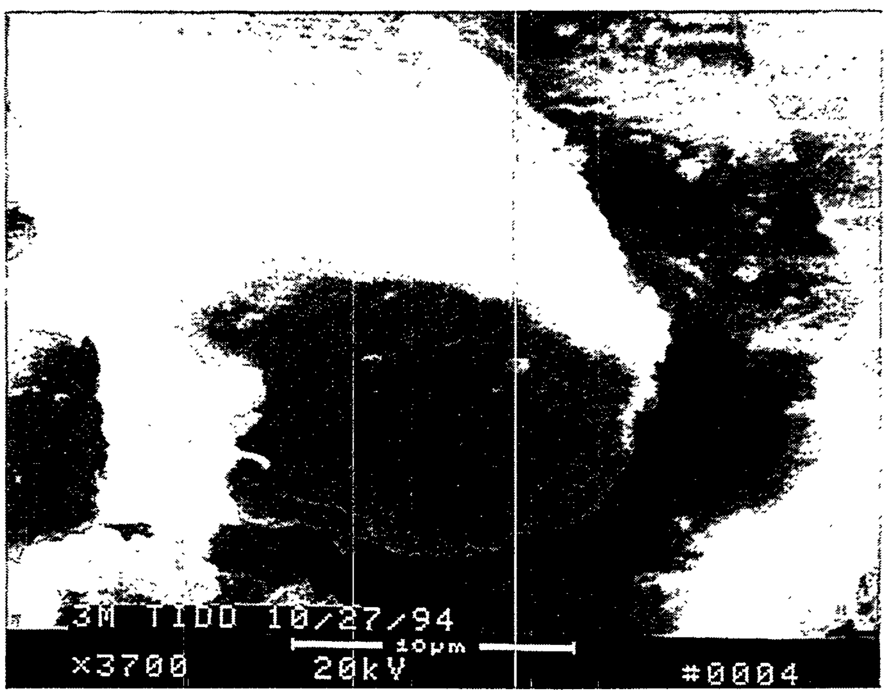


Figure 16c — Micrographs Illustrating The Morphology Of The Individual Fibers In The Triaxial Support Braid

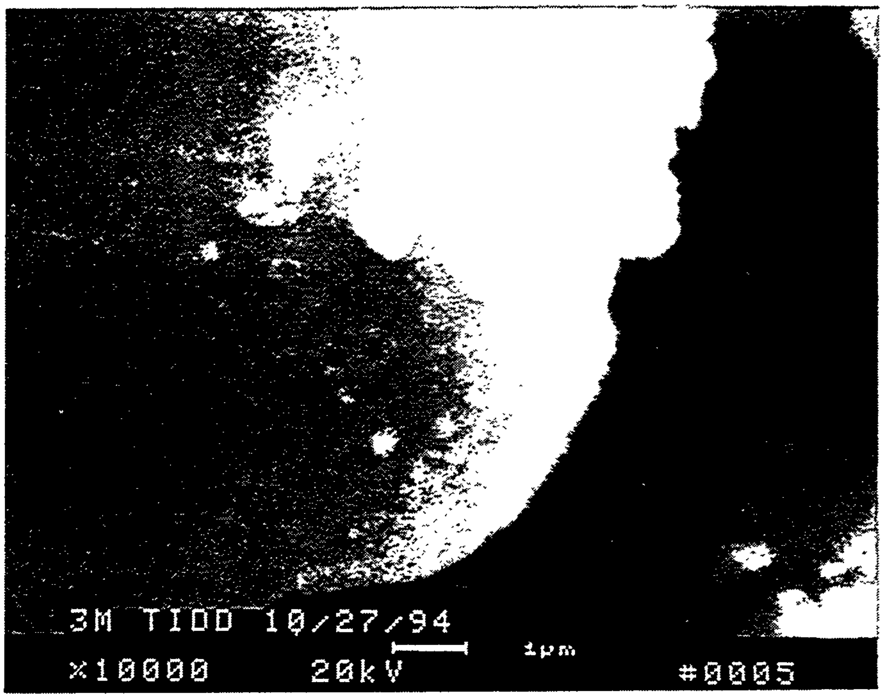
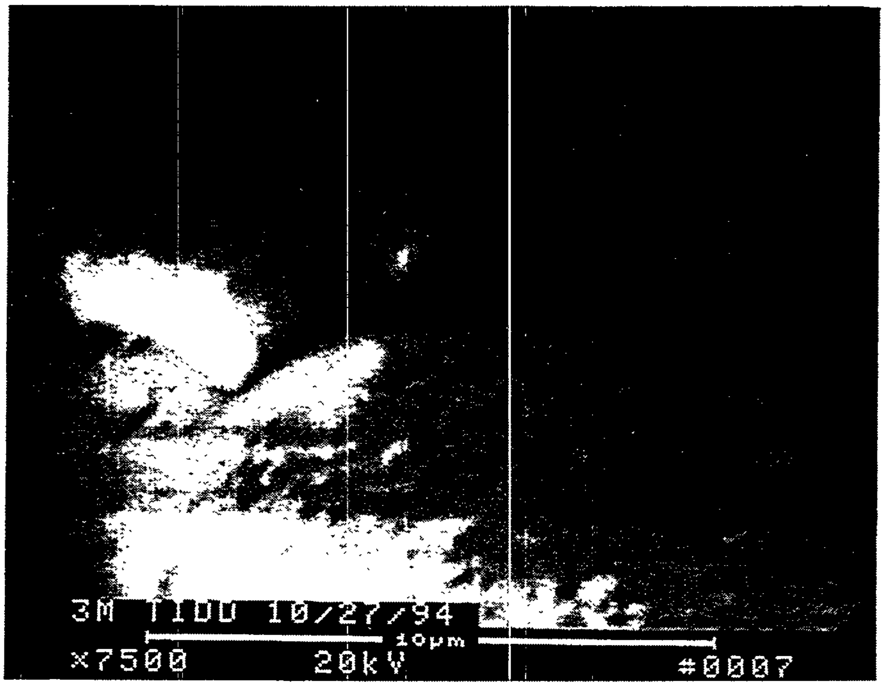


Figure 16d — Higher Magnification Micrograph Illustrating The Tight Bond Between The CVI-SiC Coating That Encapsulates The Individual Nextel™ 312 Fibers In The Triaxial Support Braid, As Well As A Micrographs Which Illustrates Fracturing Of The CVI-SiC Coating Along The Surface Of The Nextel™ 312 Fiber



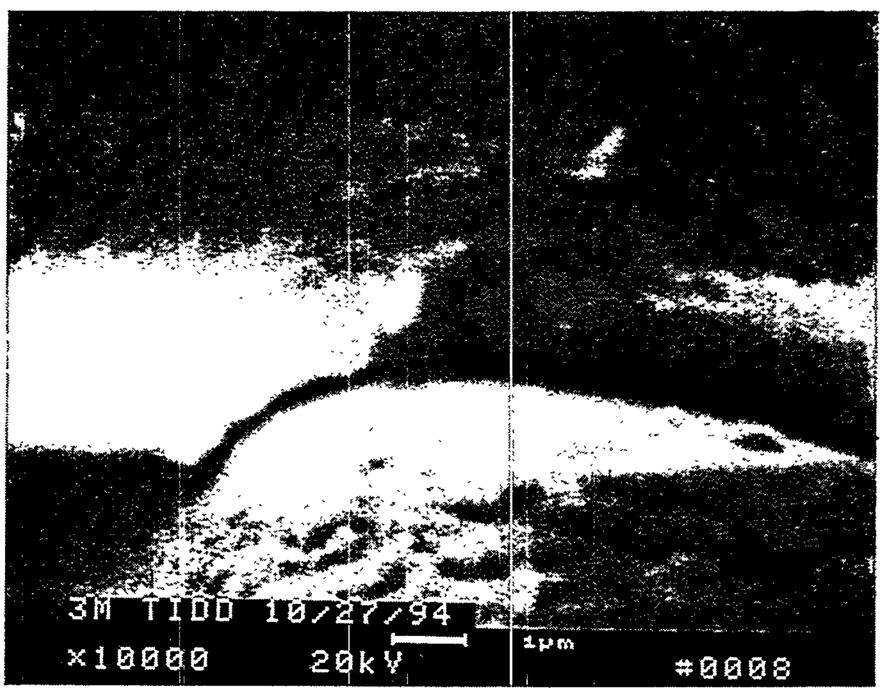


Figure 16e — High Magnification Micrographs Illustrating The Mottled Surface Of The Nextel™ 312 Fibers That Results Below The CVI-SiC Deposit Layer After 1705 Hours Of Exposure To The PFBC Gas Environment

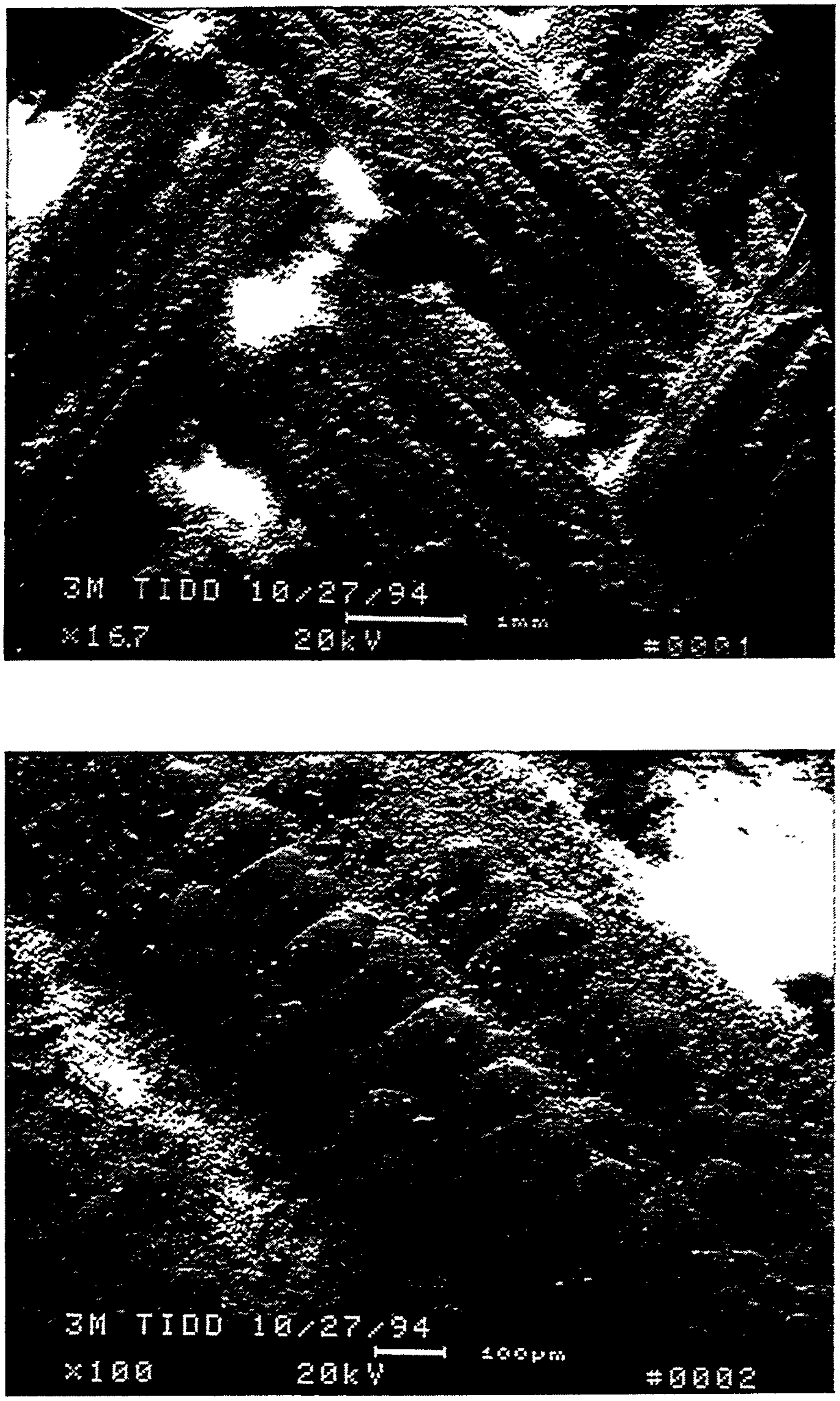


Figure 17a – Morphology Of The Outer Surface Of The CVI-SiC Coated Triaxial Braid After 1705 Hours Of Exposure In The PFBC Gas Environment

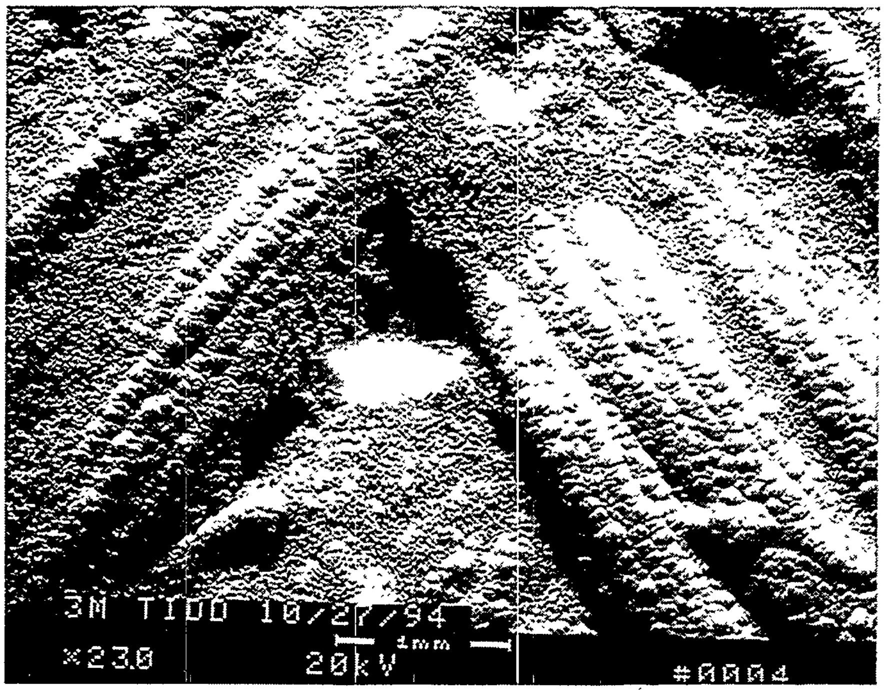
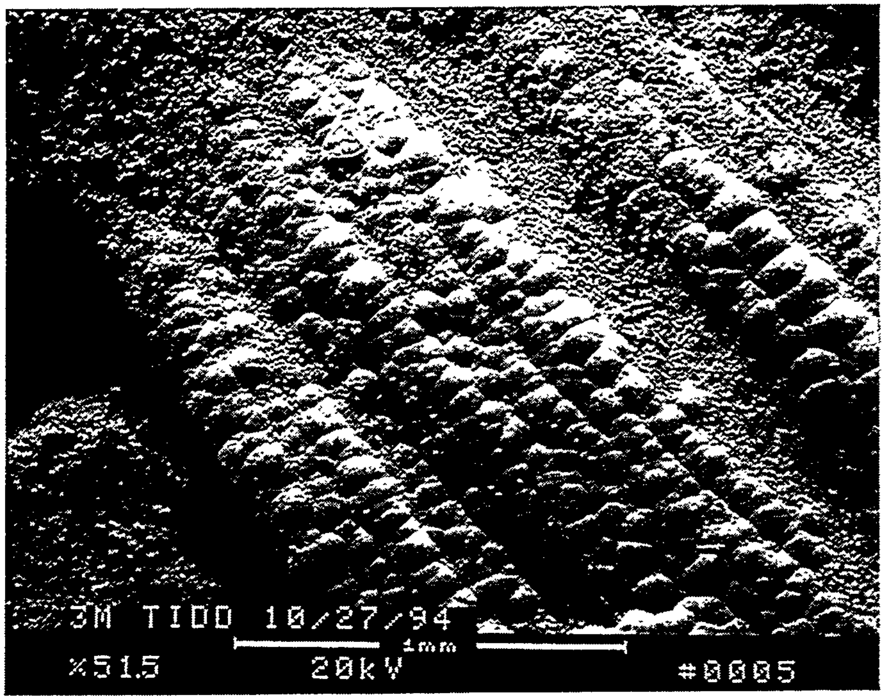


Figure 17b — Adherence Of Ash Fines Along The CVI-SiC Coated Triaxial Braid



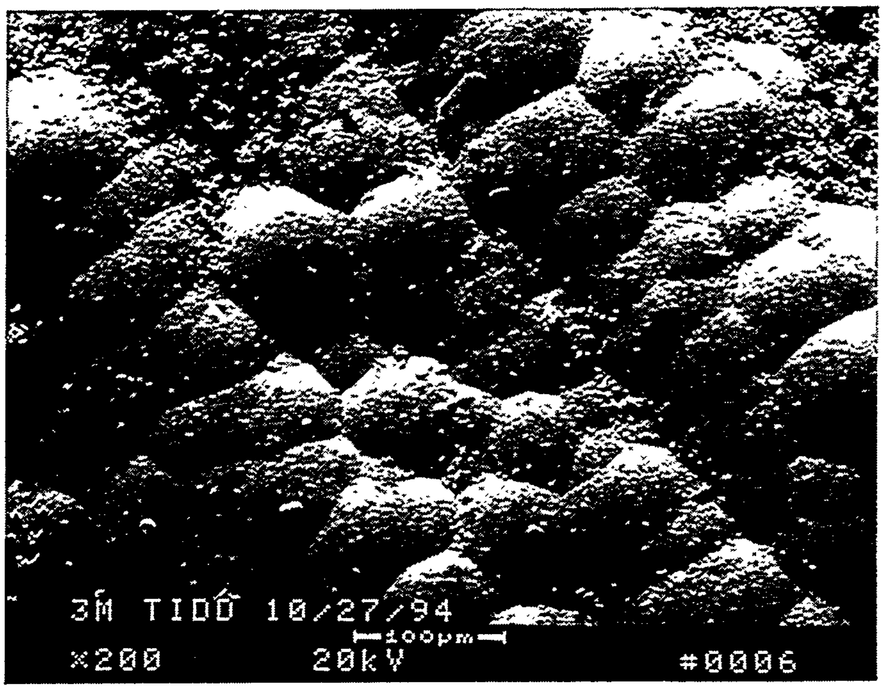


Figure 17c — Additional Micrographs Illustrating The Adherence Of Ash Fines Along The Triaxial Braid Support Matrix In The 1705 Hour PFBC Exposed 3M CVI-SiC Composite Filter Matrix

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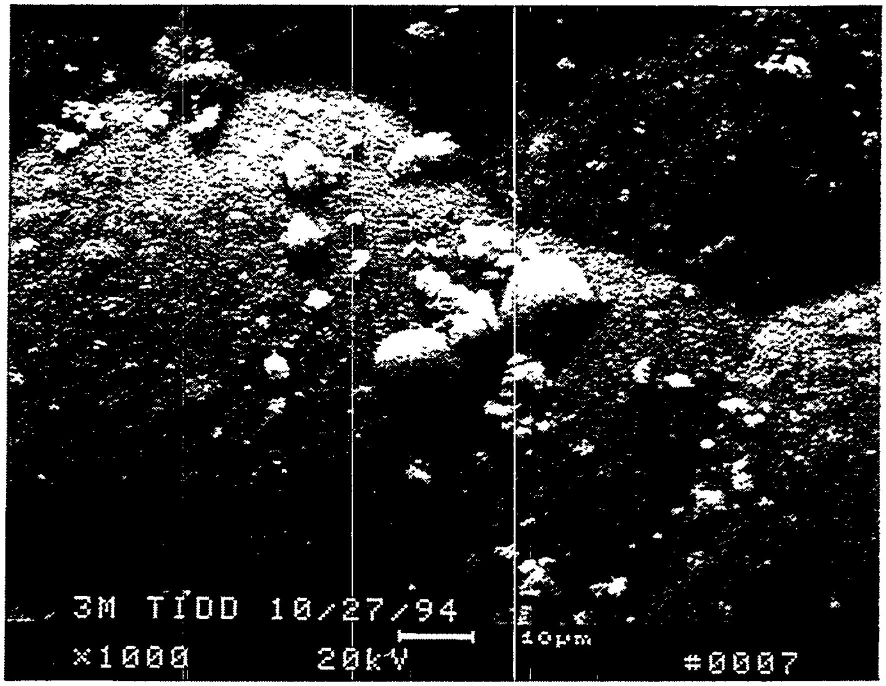


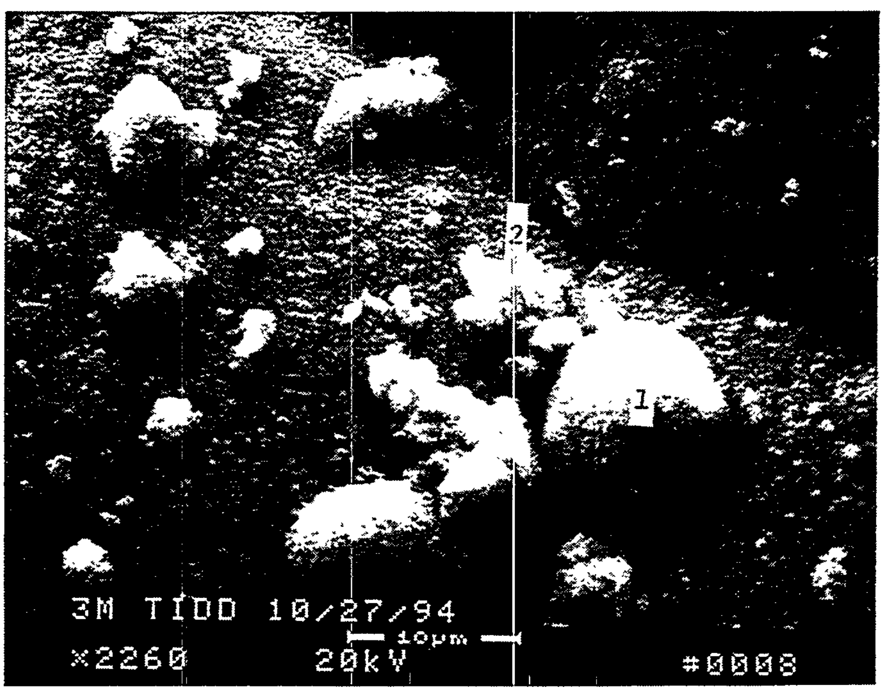


Figure 17d — Higher Magnification Micrographs Illustrating The Morphology Of The CVI-SiC Coated Triaxial Braid

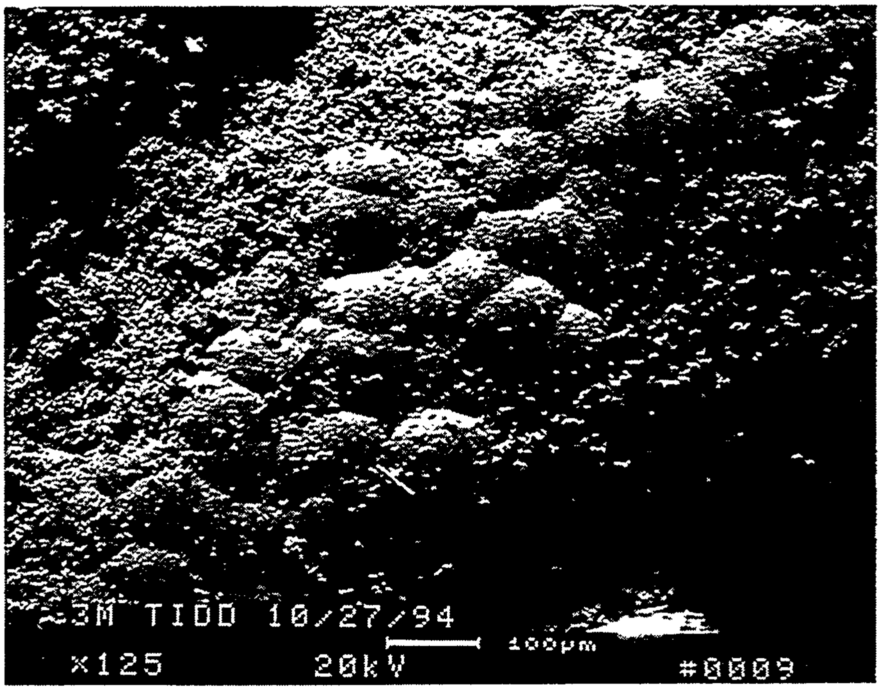


Figure 17e – Additional Micrograph Illustrating The Adherence Of Ash Fines Along The Triaxial Braid

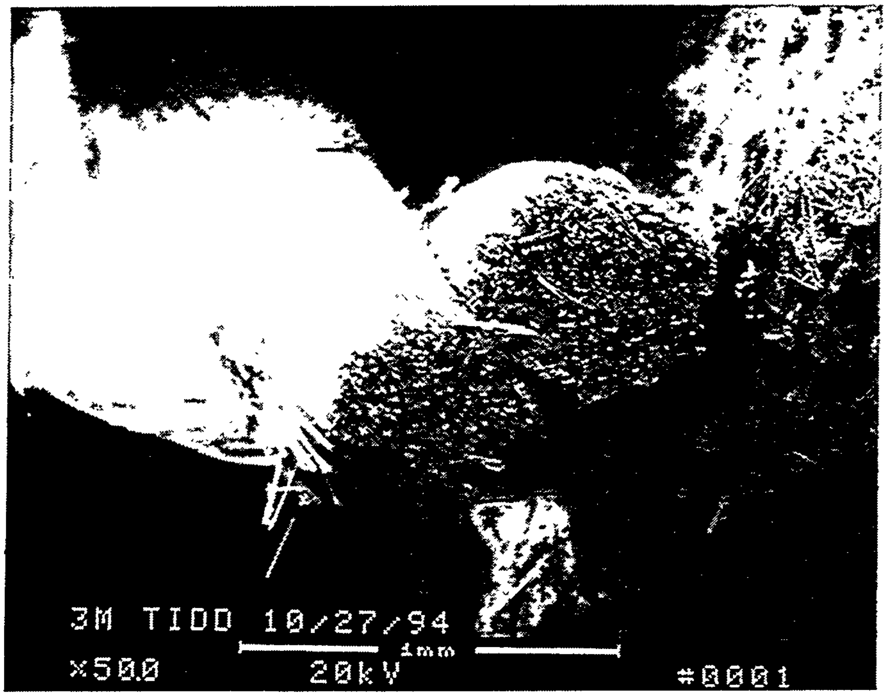
0.14% Ca, and 0.11% Al (i.e., atomic percent basis). Although the matrix in this area is silica-rich, we believe that Area 1 may contain ash due to the presence of sodium, iron, calcium, and aluminum. Since gold was used during sample preparation, the presence of sulfur cannot be detected which would provide further evidence that Area 1 contained ash particles.

Area 2 in Photo 8, Figure 17d was also subjected to EDAX analysis which indicated the presence of 62.31% O, 27.33% Si, 4.13% Al, 1.76% K, 1.42% Na, 1.15% Mg, 0.82% Cl, 0.74% Fe, and 0.35% Ca. Clearly Area 2 in Photo 8, Figure 17d contains ash which remained attached to the CVI-SiC matrix. Figure 17e provides a final micrograph which shows the presence of ash fines at an alternate location along the CVI-SiC coating which encapsulates the triaxial braid structural support layer in the 1705 hour PFBC exposed filter matrix.

Since ash was retained in the 3M CVI-SiC composite filter matrix, a section of the matrix was washed and subjected to further SEM/EDAX analyses. The washed fiber bundles in the outer confinement layer of the 1705 hour PFBC exposed filter matrix are shown in Figures 18a and 18b. Figure 18b attempts to capture an isolated fiber, which when shown at higher magnification in Figure 18c is seen to contain raised particles along the surface of the uncoated Nextel^{TM} 312 fibers. Additional micrographs indicate the presence of the raised or nodular growths along the surface of alternate fibers in the open mesh confinement layer (Figure 18d).

Figure 18e illustrates the morphology of the confinement fibers at an alternate location. Separation between the outer CVI-SiC coating and the Nextel^{TM} 312 fibers is minimal. In several areas, <1 μm gap is evident between the CVI-SiC coating and the underlying fiber (Figure 18f and 18g). The surface of the thin ~2 μm CVI-SiC coating frequently appears to be mottled as shown in Figure 18g.

Due to the apparent thinness and complete "mottling" through the entire layer of material which is shown in Area 1 of Photo 14, Figure 18h (i.e., higher magnification in Photo 15, Figure 18h and in Photo 17 in Figure 18i) questions are raised as to whether this area actually contains the original CVI-SiC coating, or a phase which has resulted along the outer surface of the Nextel^{TM} 312 fiber during exposure to the PFBC gas environment. Similarly Area 2 in Photo 14, Figure 18h is shown at higher magnification in Photo 15, Figure 18h and in Photo 16, Figure 18i. This area also begs the question of whether the matrix is a remnant of the CVI-SiC coating, or a phase which has formed along the Nextel^{TM} 312 fiber surface.



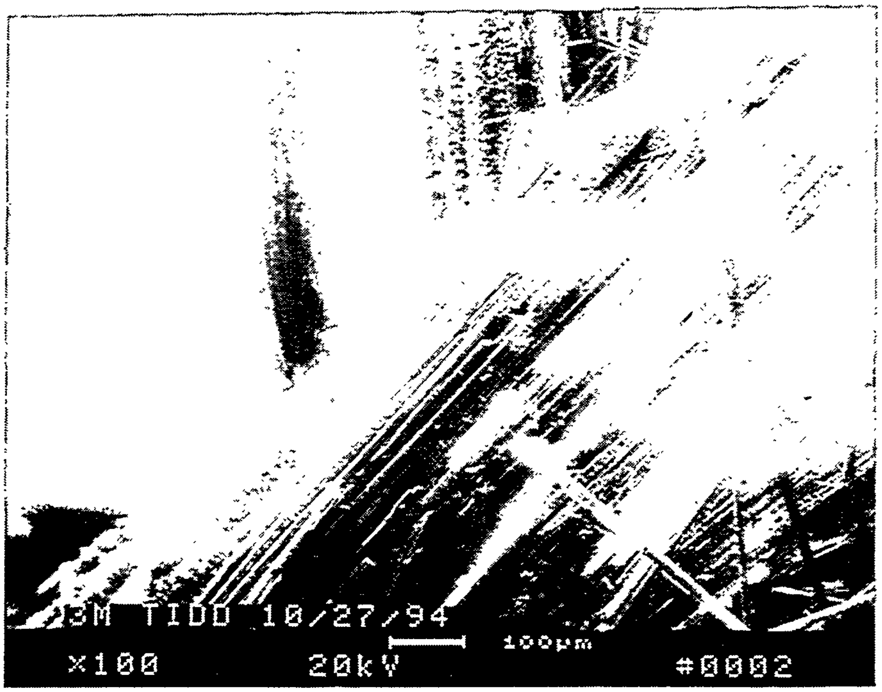
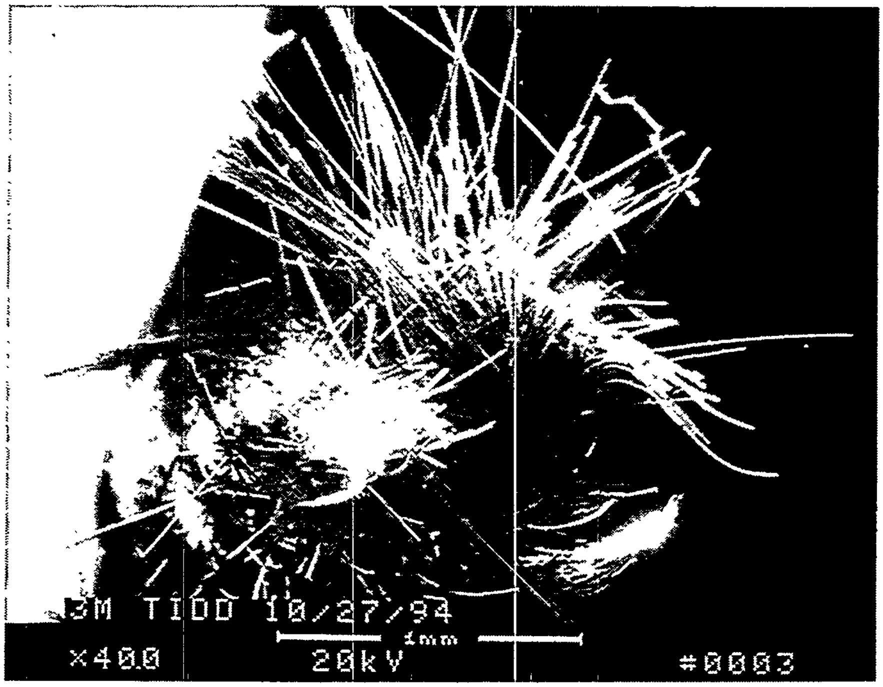


Figure 18a – Morphology Of the 3M Confinement Layer After Washing



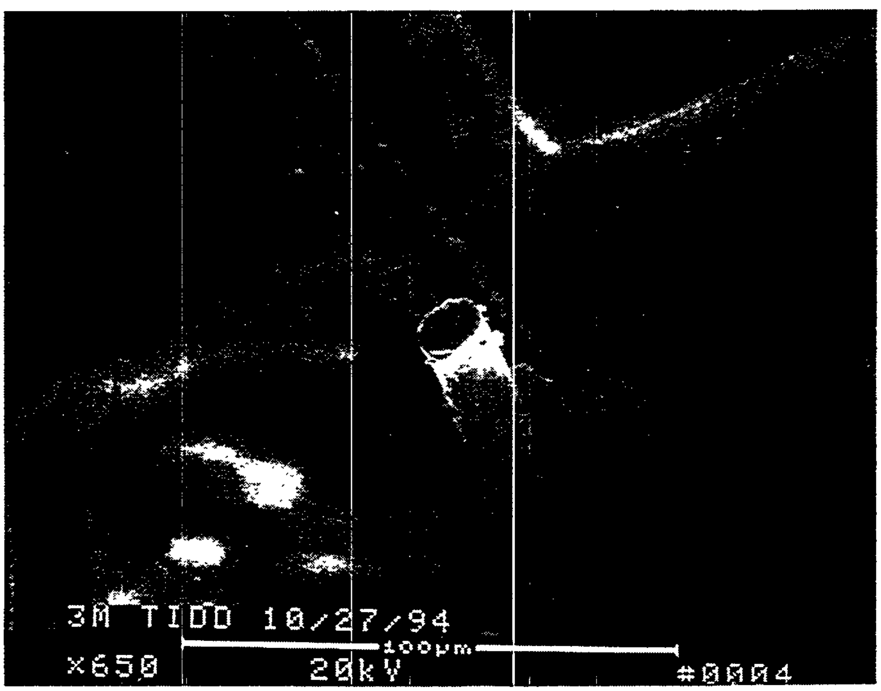


Figure 18b – Micrographs Illustrating The Morphology Of The Confinement Fibers

Figure 18c — Higher Magnification Micrographs Illustrating The Surface Features Of The Nextel™ 312 Fiber In The Confinement Layer After 1705 Hours Of Exposure To The PFBC Gas Environment

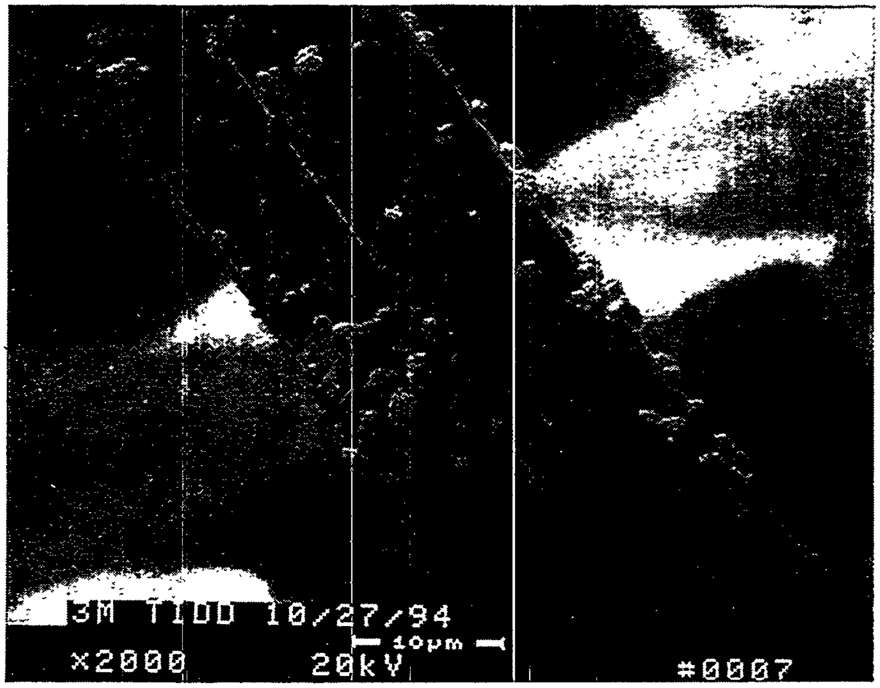


Figure 18d – Additional Micrographs Illustrating The Surface Features Of The Nextel™ 312 Fiber In The Confinement Layer After 1705 Hours Of Exposure To The PFBC Gas Environment

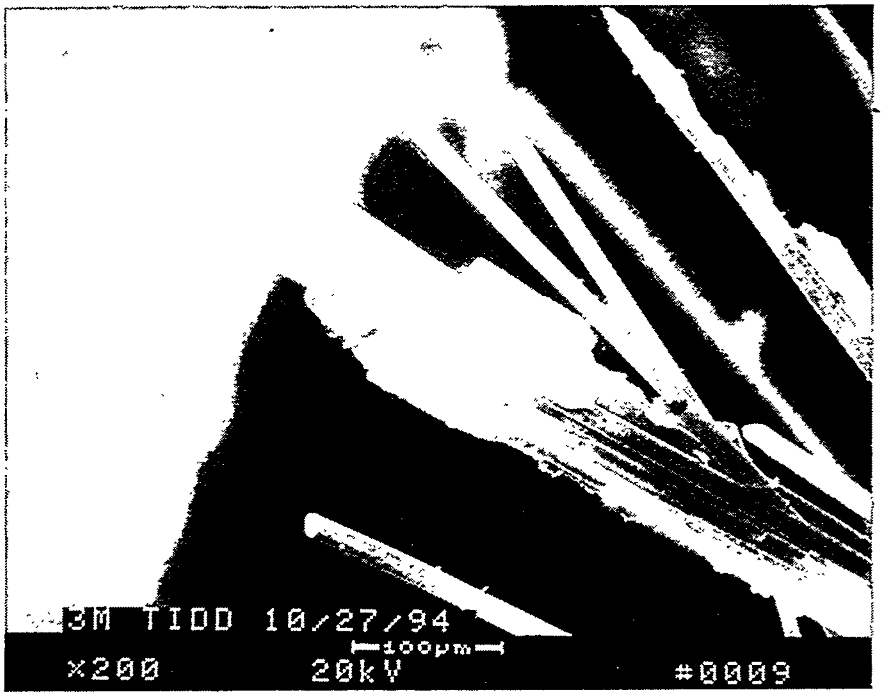
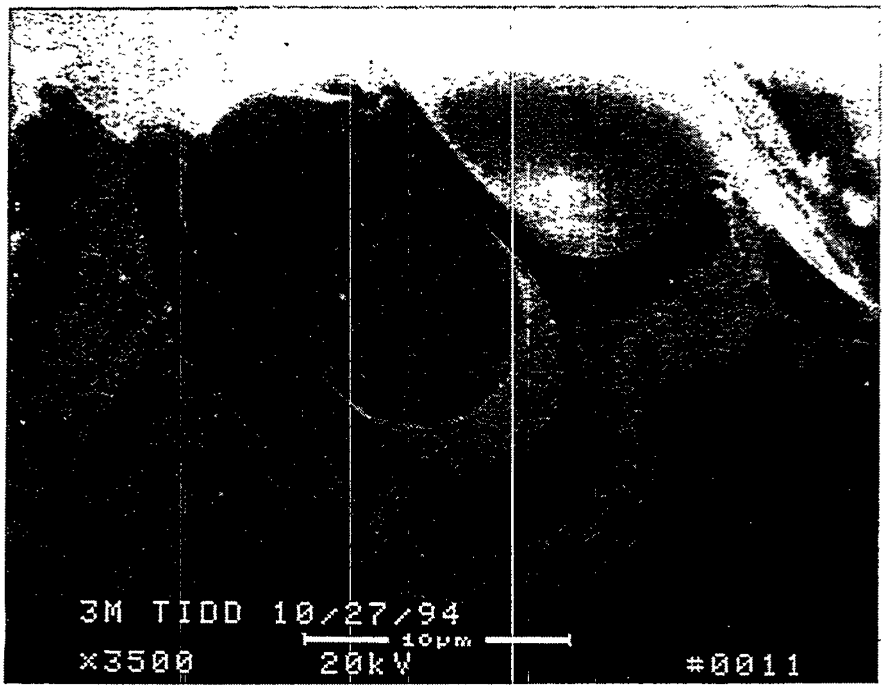


Figure 18e — Additional Micrographs Illustrating The Morphology Of The Confinement Fibers In The 3M CVI-SiC Composite Filter Matrix After 1705 Hours Of Exposure To The PFBC Gas Environment



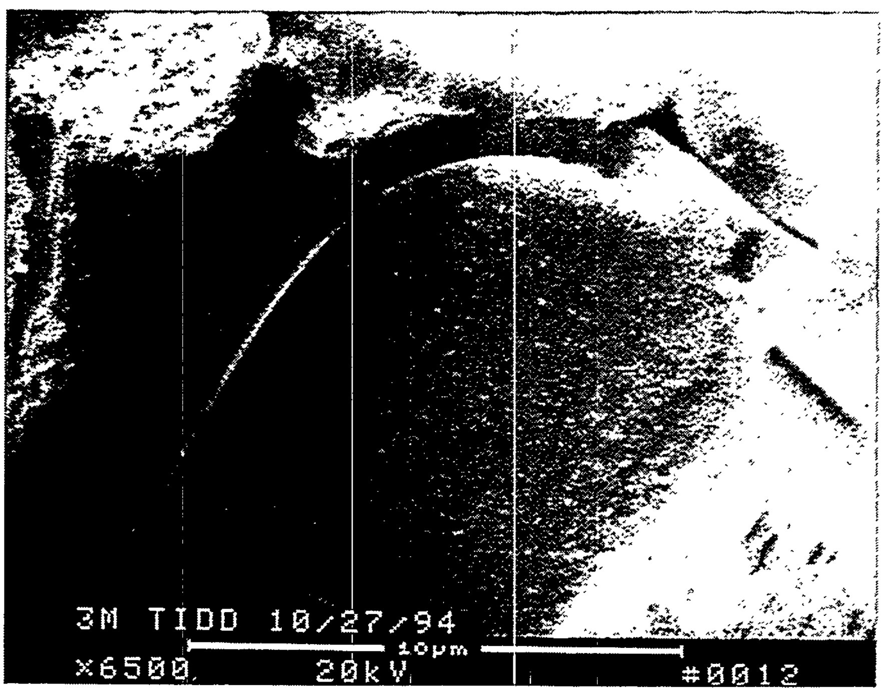


Figure 18f — High Magnification Micrographs Illustrating The Surface Coating Of The CVI-SiC Layer Along The Nextel™ Fibers In The Confinement Layer Of The 3M Composite Filter Matrix

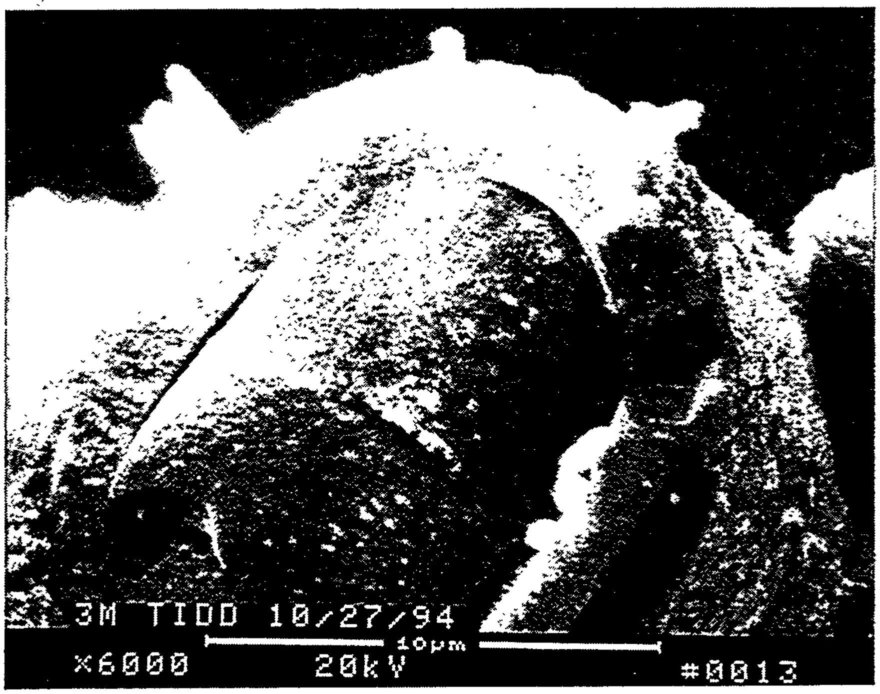
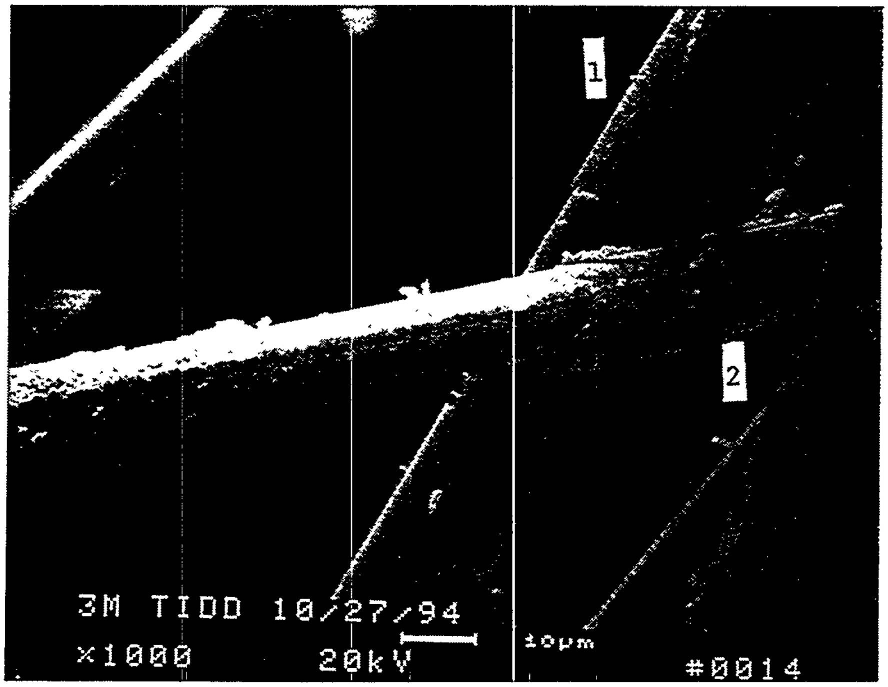


Figure 18g – Higher Magnification Micrograph Illustrating The Morphology Of The Cross-Sectioned Confinement Layer Fiber



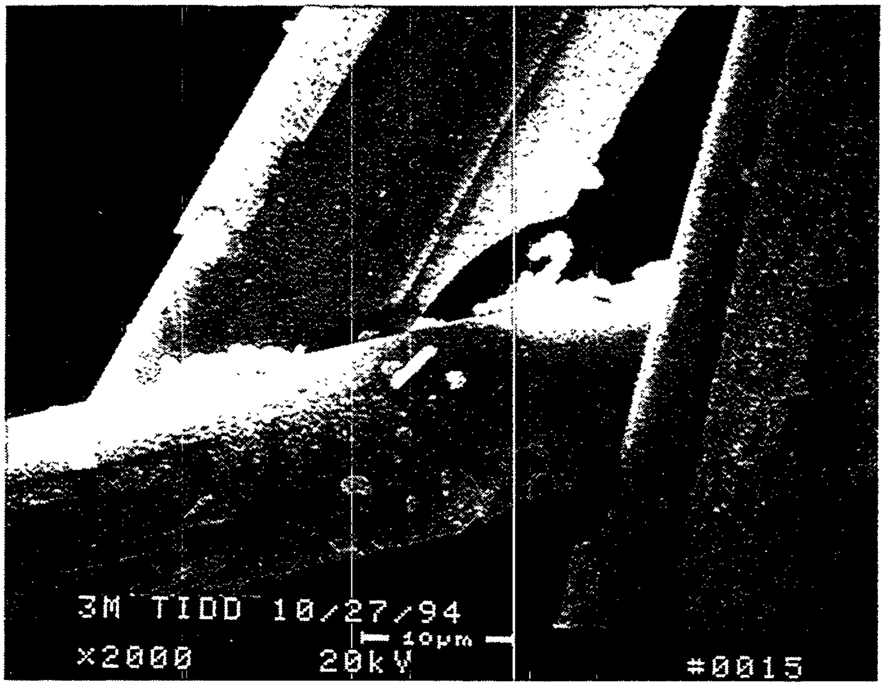


Figure 18h — Additional Micrographs Illustrating The Morphology Of The Confinement Layer Fibers After 1705 Hours Of Exposure In The PFBC Gas Environment

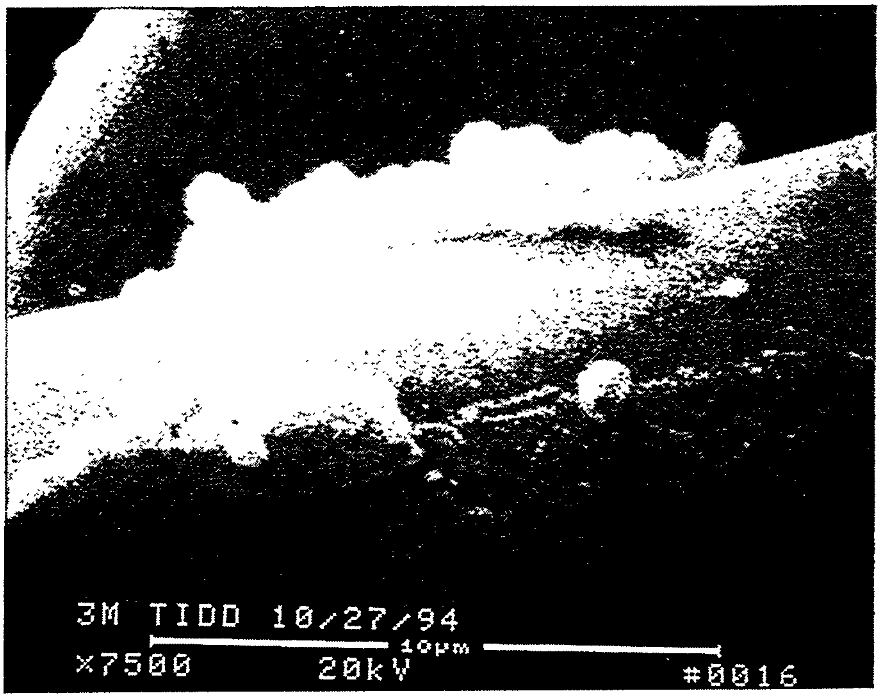


Figure 18i – Additional Micrographs Illustrating The Morphology Of The Confinement Layer Fibers

Moving to the filtration mat layer, we can clearly see that the 4-5 μm diameter fibers which are present in the filtration mat layer are coated with an ~1-2 μm SiC outer layer (Figure 19a). Again the surface morphology of the CVI-SiC coating is mottled. Surface mottling is also evident along the fractured filtration mat fibers. Both the outer CVI-SiC coating and the fractured filtration mat fibers are shown at higher magnification in Figure 19b.

As we move to the triaxial braid, the ~100 μm thick CVI-SiC coating is seen to encapsulate the underlying Nextel™ 312 fiber bundles (Figure 20a). In the fiber bundles, areas are evident which contain the empty SiC shells, as well as areas which contain the elliptical Nextel™ 312 fibers which retain remnants of the CVI-SiC coating (Figure 20b). The raised nodular appearance of the CVI-SiC coating is shown at higher magnification in Figure 20c. Due to the relatively uniform appearance of the matrix, we believe the nodules are part of the originally deposited CVI-SiC matrix.

Figure 20d provides another montage illustrating the separation of the CVI-SiC shell from the underlying Nextel™ 312 fibers. Again raised, nodular areas are evident along the outer surface of the CVI-SiC coating.

The thick CVI-SiC coating that encapsulates the triaxial braid is shown in Photo 27, Figure 20e. Fibers that are in direct contact with the thick CVI-SiC coating are shown in Photo 28, Figure 20e, and in Photo 29, Figure 20f.

Figure 20g illustrates the layering of SiC during the CVI deposition process. During manufacturing of the composite filter body, the initial ~100 μm thick CVI-SiC coating is deposited along the triaxial braid to form the structural support matrix. After the filtration mat and open mesh confinement layers are applied, an additional ~2-5 μm CVI-SiC layer is deposited throughout the composite matrix, which leads to the formation of two distinct layers along the thick SiC layer which encapsulates the triaxial braid.

The outer surface of the CVI-SiC coating which encapsulates the triaxial braid is shown in Figure 20h. Columnar growth of the CVI-SiC matrix is evident. Frequently in the valleys or crevices of the CVI-SiC matrix are areas which appear to contain "melt-like", mud crack areas (Figure 20i).

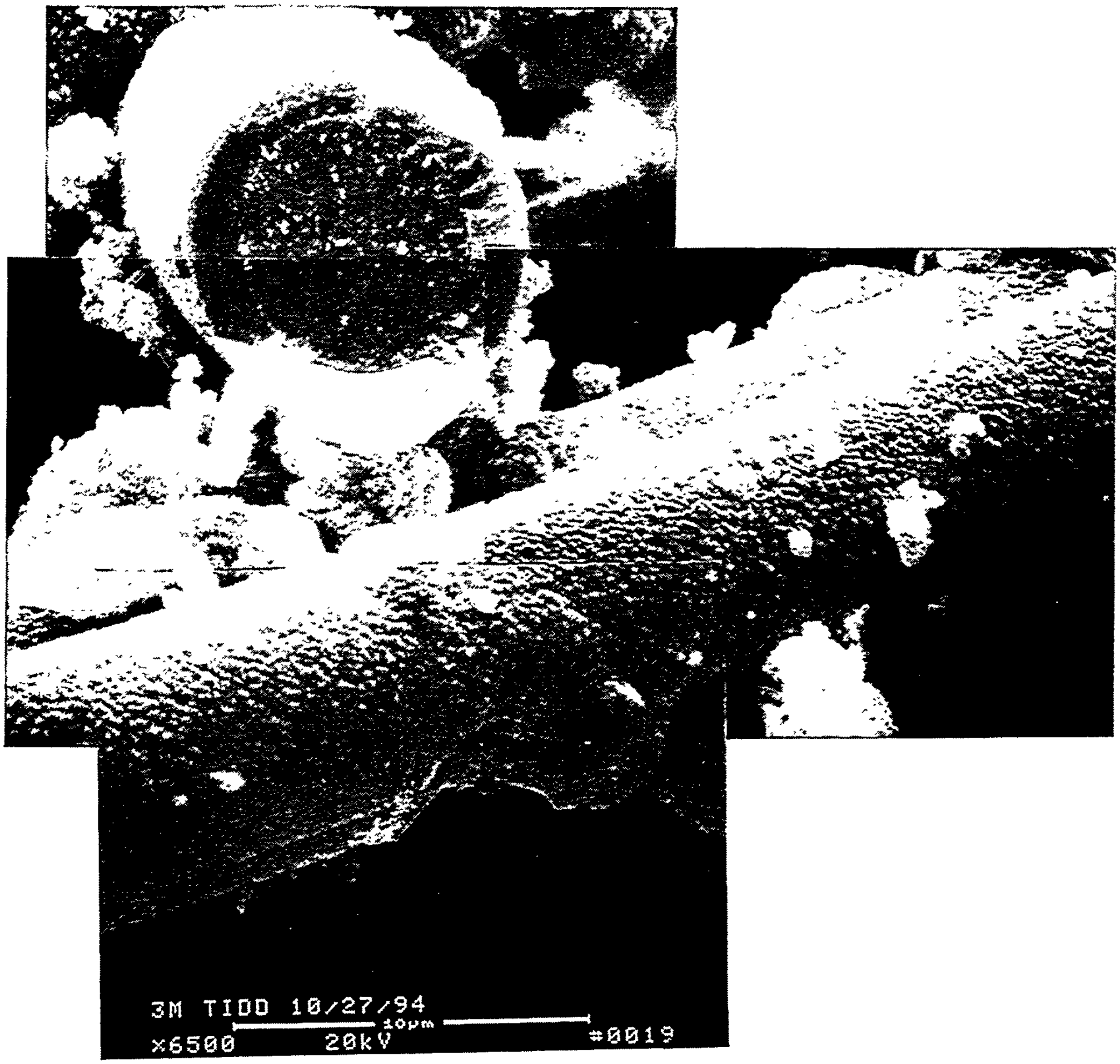


Figure 19a — Morphology Of The Filtration Mat Fibers

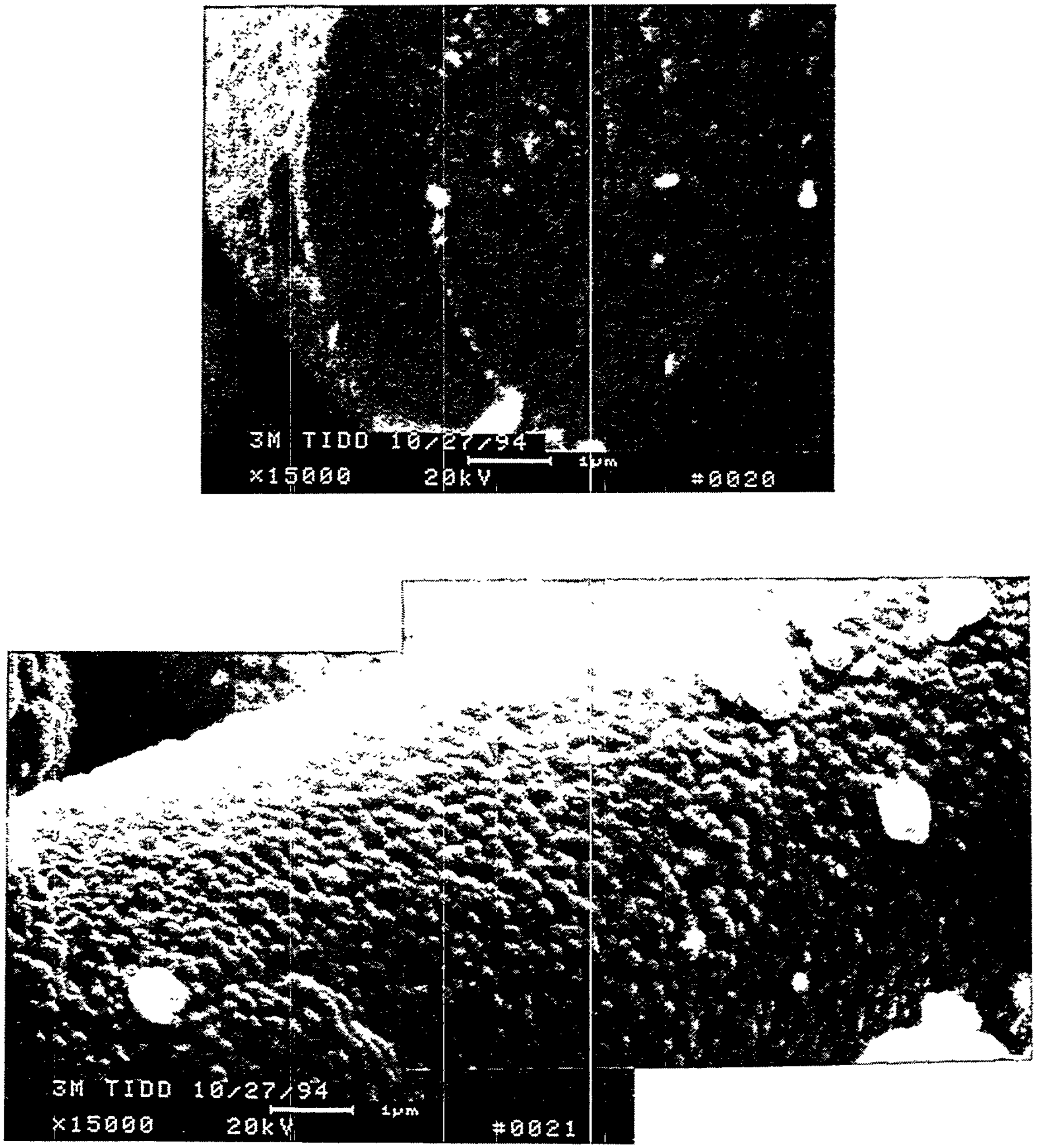
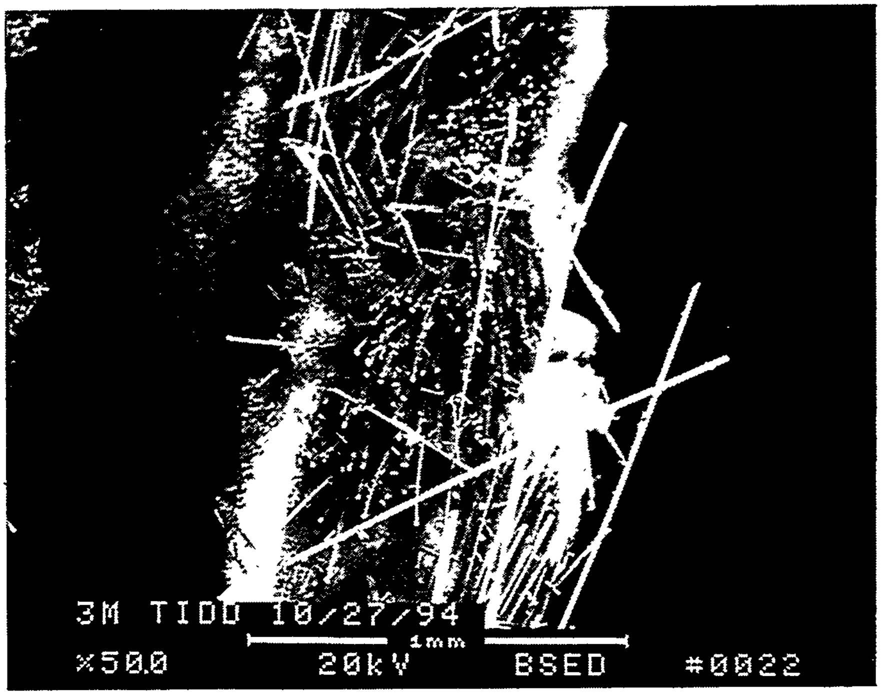


Figure 19b — Higher Magnification Micrographs Illustrating The Morphology Of The Cross-Sectioned Filtration Mat Fibers And The Outer Surface Coating Of The CVI-SiC Layer



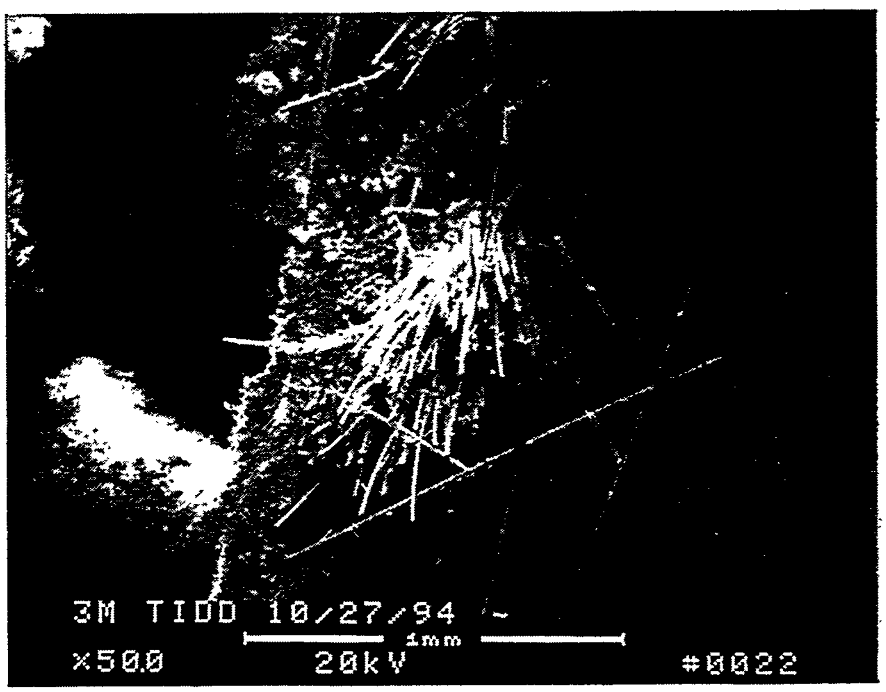
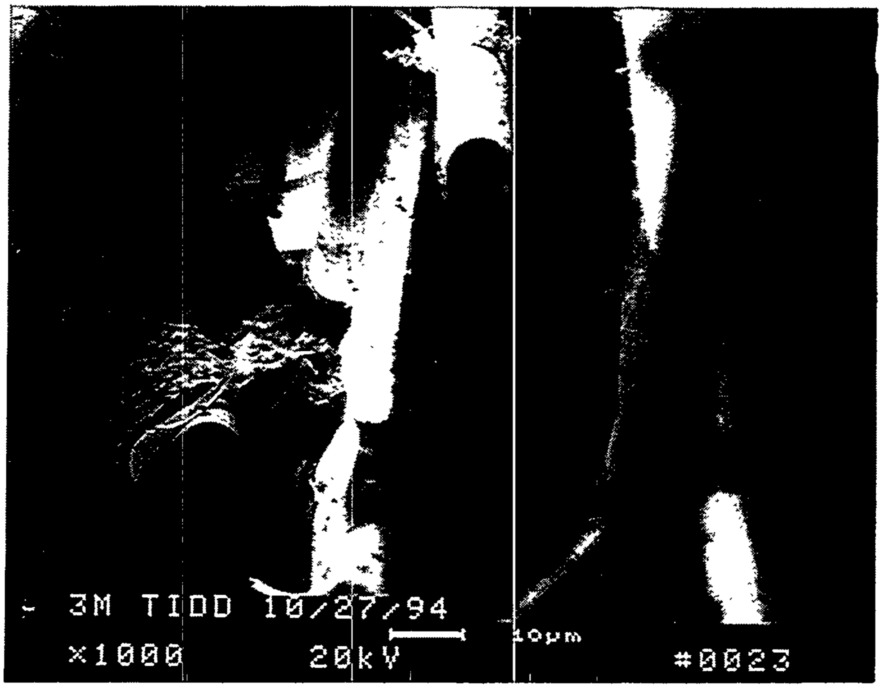


Figure 20a – Micrographs Illustrating The Morphology Along The Cross-Sectioned Triaxial Braid In The 3M Composite Filter Matrix



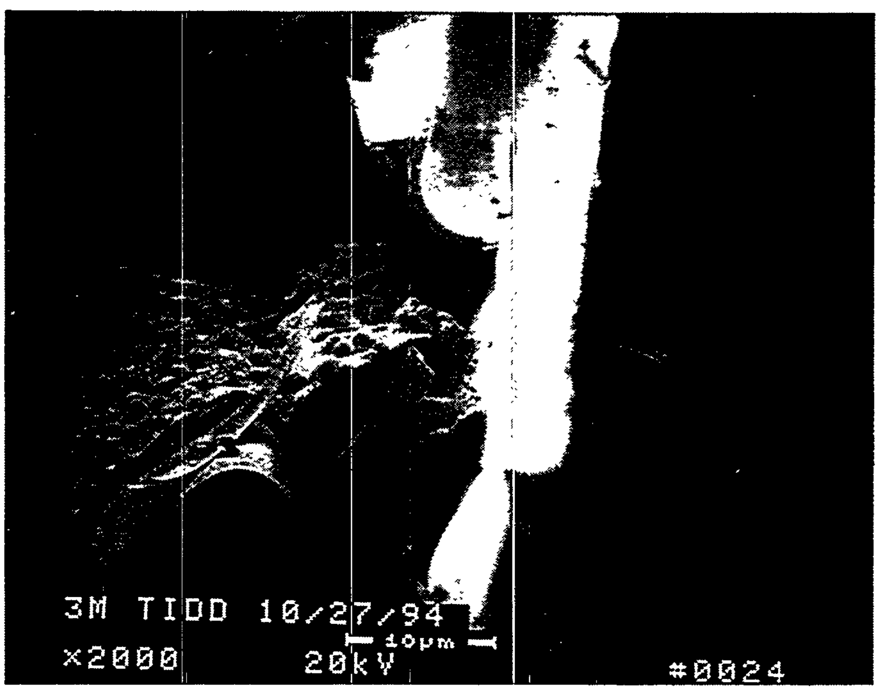


Figure 20b — MIcrographs Illustrating The Morphology Of The Individual Fibers In The Triaxial Braid

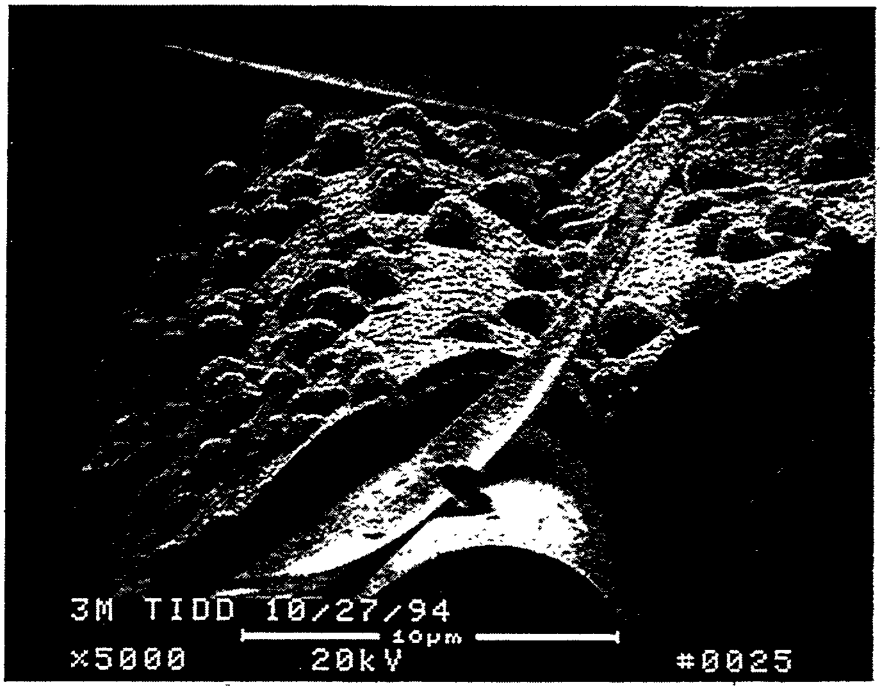


Figure 20c – Raised Nodular Formations Along The CVI-SiC Layer Which Encapsulates The Nextel™ 312 Fibers In The Triaxial Braid After 1705 Hours Of Exposure In The PFBC Gas Environment

Figure 20d — Additional Micrographs Illustrating The Morphology Of The Individual FIbers In The Triaxial Braid Of The 3M Composite Filter Matrix

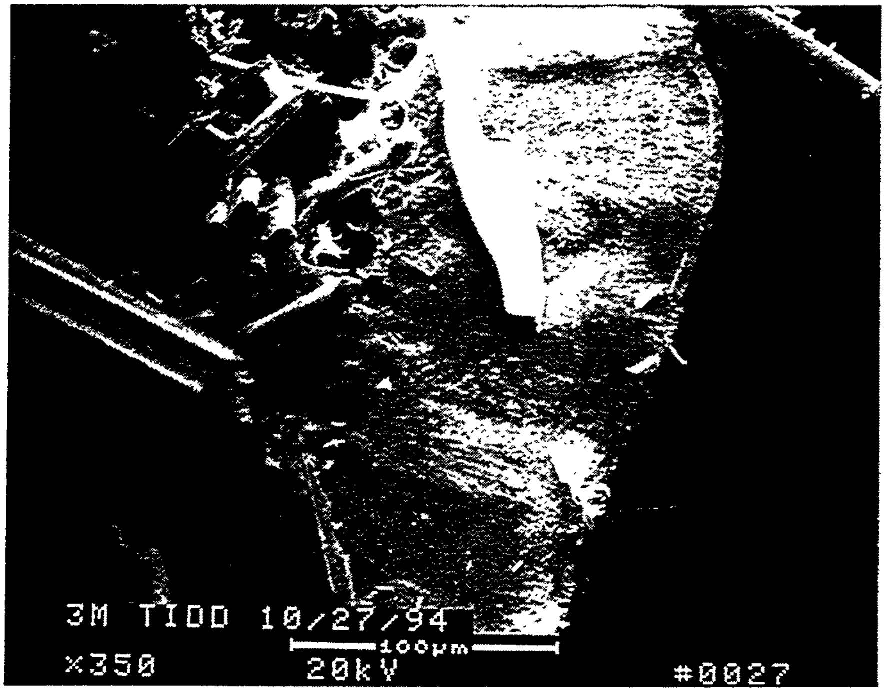


Figure 20e – Micrographs Illustrating The Thick SiC Coating Which Encapsulates The Triaxial Braid, As Well As Fibers Which Were In Direct Contact With The Thick CVI-SiC Layer

Figure 20f — Additional Micrograph Of The Fibers Near The Thick CVI-SiC Deposit Layer Along The Triaxial Support Braid

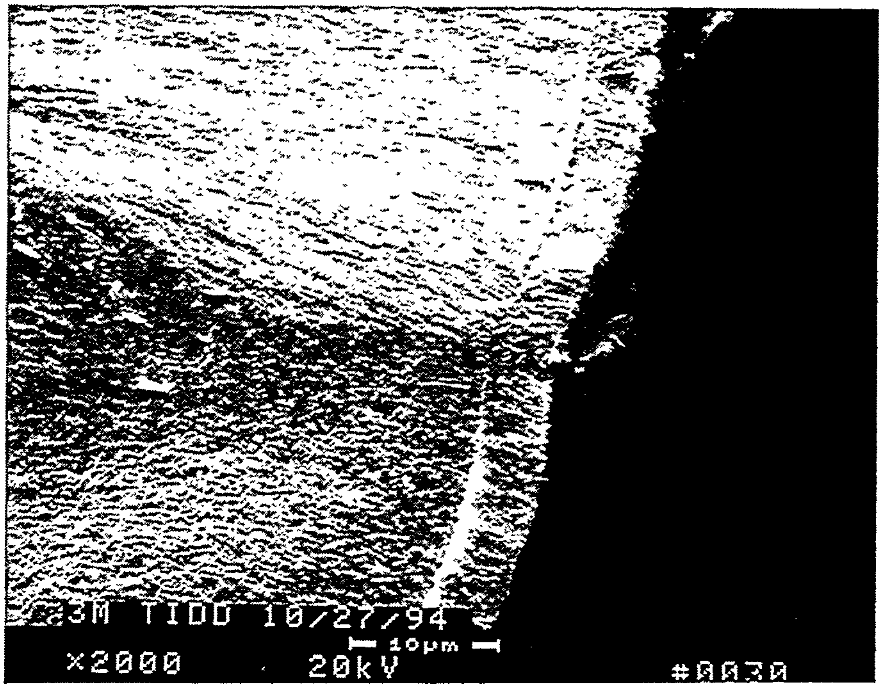
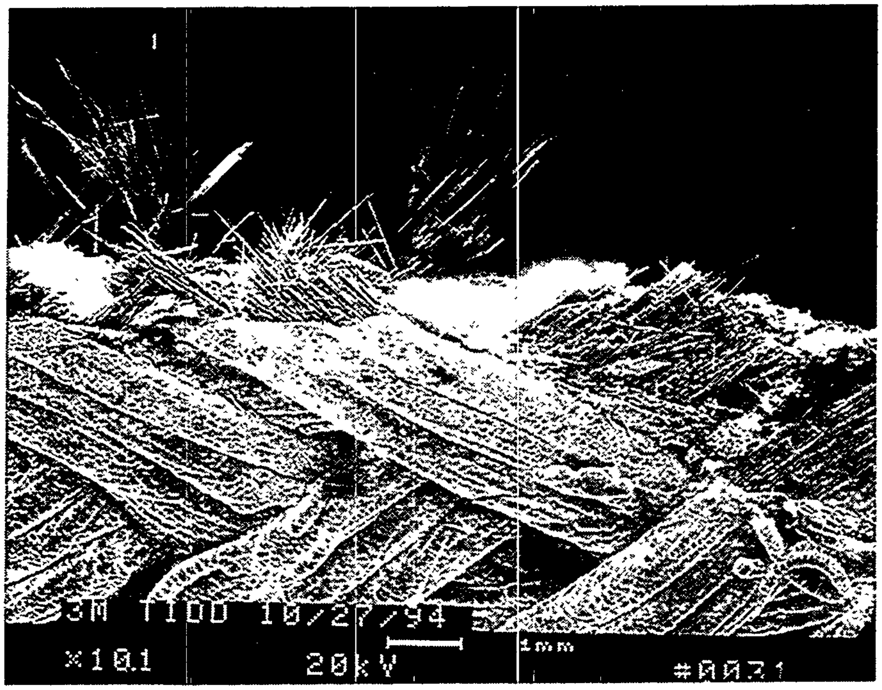


Figure 20g – Cross-Sectioned CVI-SiC Coating Along The Triaxial Braid



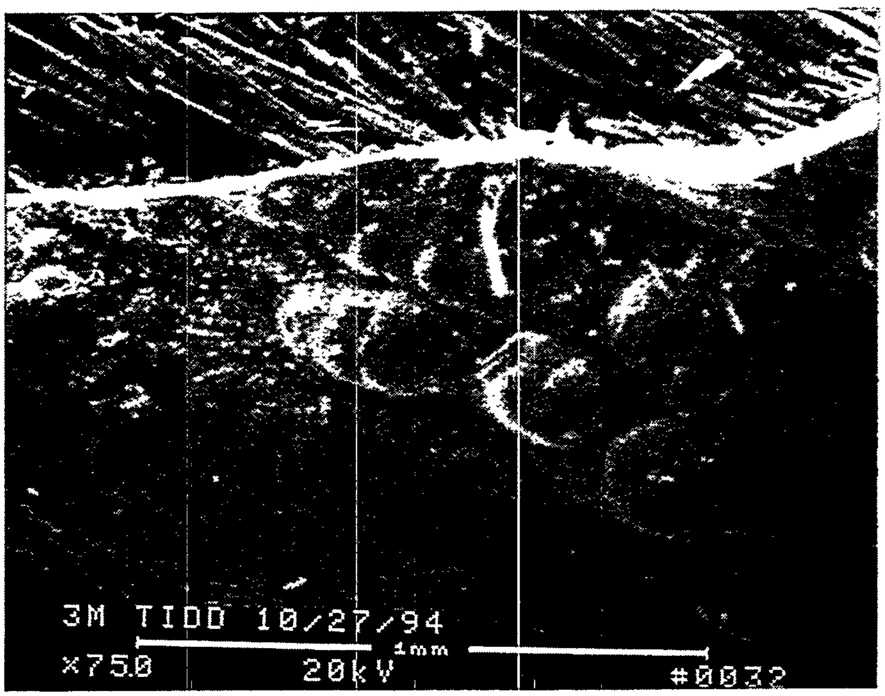
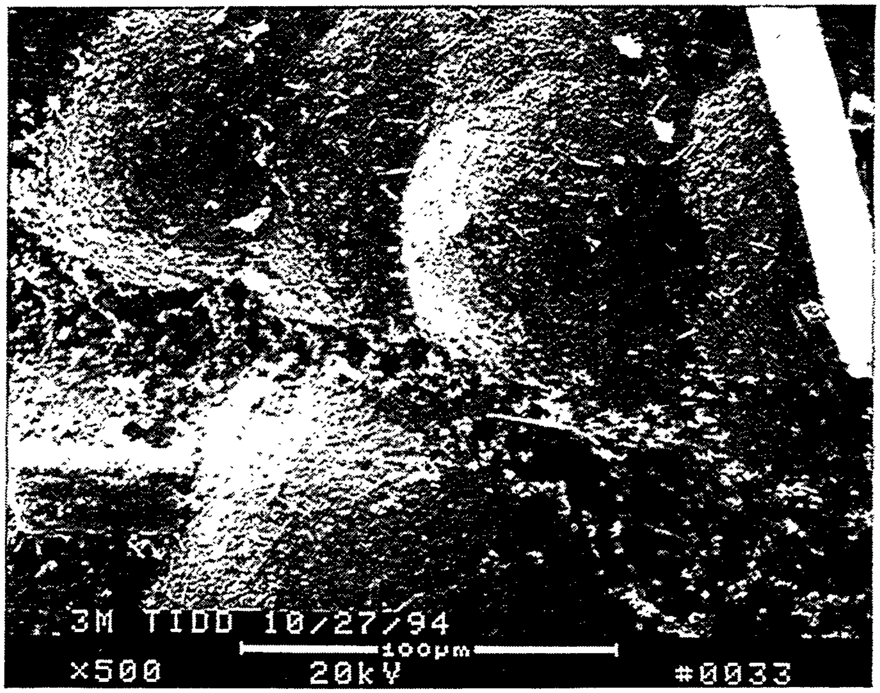


Figure 20h – Columnar CVI-SiC Growth Along The Triaxial Braid



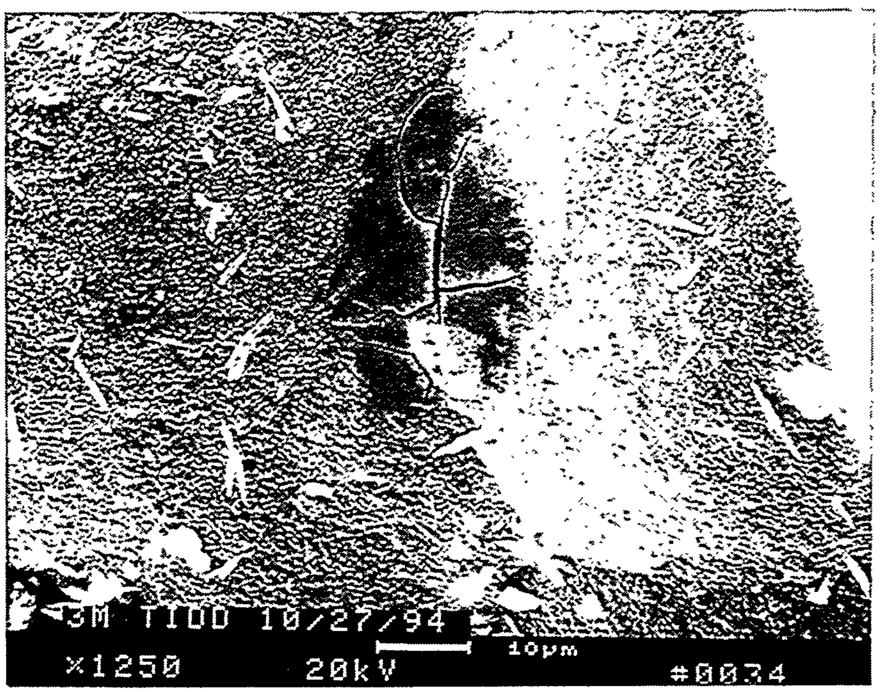


Figure 20i — High Magnification Micrographs Of The Columnar CVI-SiC Surface Which Encapsulates The Triaxial Braid

Elemental microprobe analyses were also conducted along the various layers in the PFBC exposed and washed 3M CVI-SiC composite filter matrix. The data generated in the EMA analyses were comparable to the data presented in the above SEM/EDAX discussions.

Figure 21 provides scanning electron micrograph montages across the filtration mat layers in the as-manufactured filter matrix, as well as across the PFBC exposed and wash 3M CVI-SiC composite filter matrices. Clearly ash fines collected throughout the filtration mat layer during operation in the high temperature PFBC gas environment. Washing the 3M CVI-SiC filter matrix assisted in ash removal from the filtration mat layer.

SUMMARY

- Scanning electron microscopy revealed little changes in the morphology of the 3M CVI-SiC composite filter matrix after 1705 hours of operation in the PFBC gas environment. Further effort would be required (i.e., Auger analysis; x-ray diffraction analysis) to discern whether oxidation had actually occurred along the surface of the chemical vapor infiltrated SiC matrix in the PFBC exposed 3M composite filter. Additional effort would also be needed to discern whether phase changes also resulted along the surface of the Nextel™ 312 fiber, beneath the interface and/or CVI-SiC coating after operation in the PFBC gas environment.

- Based on the techniques used in this study, detection of the as-manufactured interface layer between the CVI-SiC coating and the underlying Nextel™ 312 fibers is difficult. This is mainly the result of the thin <1 μm interface coating (i.e., 0.1-0.2 μm) which is applied during production of the filter matrix. Elemental microprobe line traces and possibly Auger analysis along the cross-sectioned fibers may be capable of detecting the presence and composition of the interface layer. A gap or separation was considered to be evident between the CVI-SiC coating and underlying Nextel™ 312 fibers in several areas of the PFBC exposed 3M composite filter matrix. Oxidation of the interface layer in the combustion gas environment may be responsible for the formation of the gap or separation between the CVI-SiC coating and underlying Nextel™ 312 fibers.

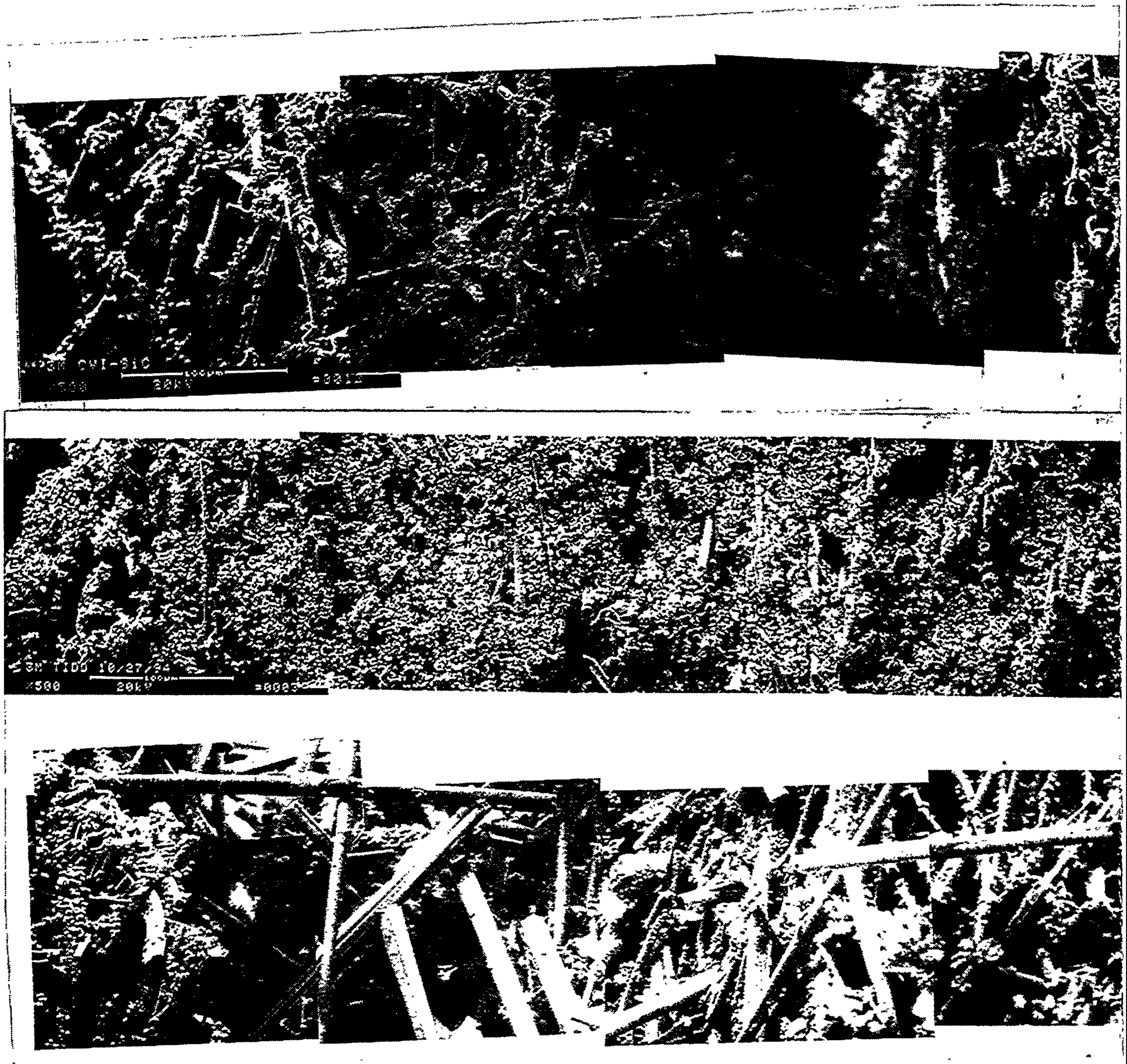
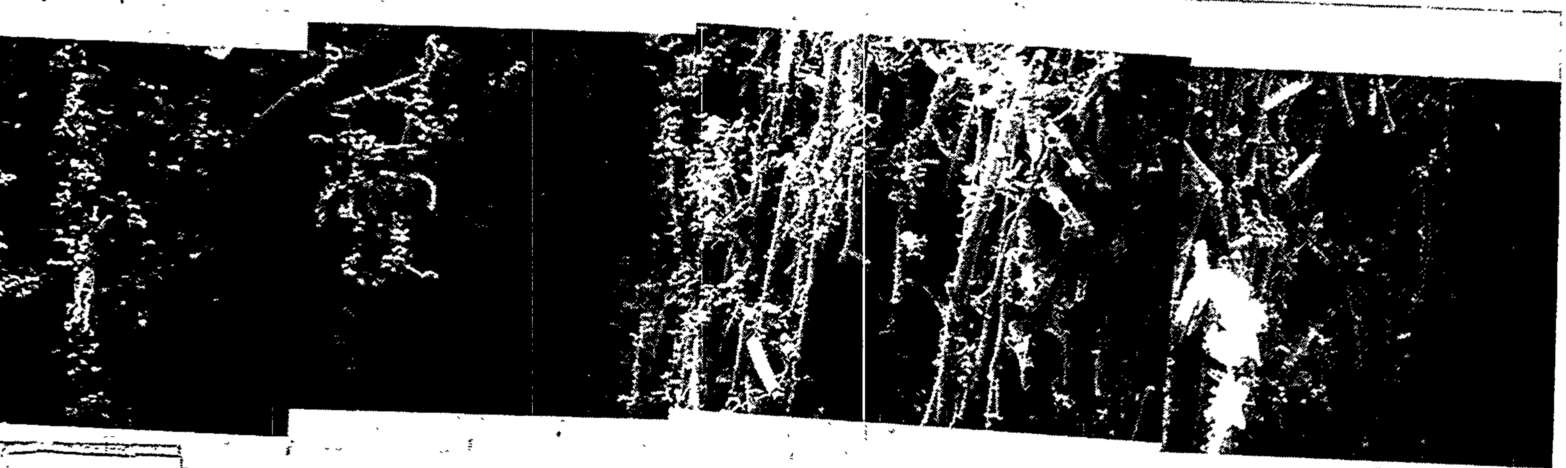
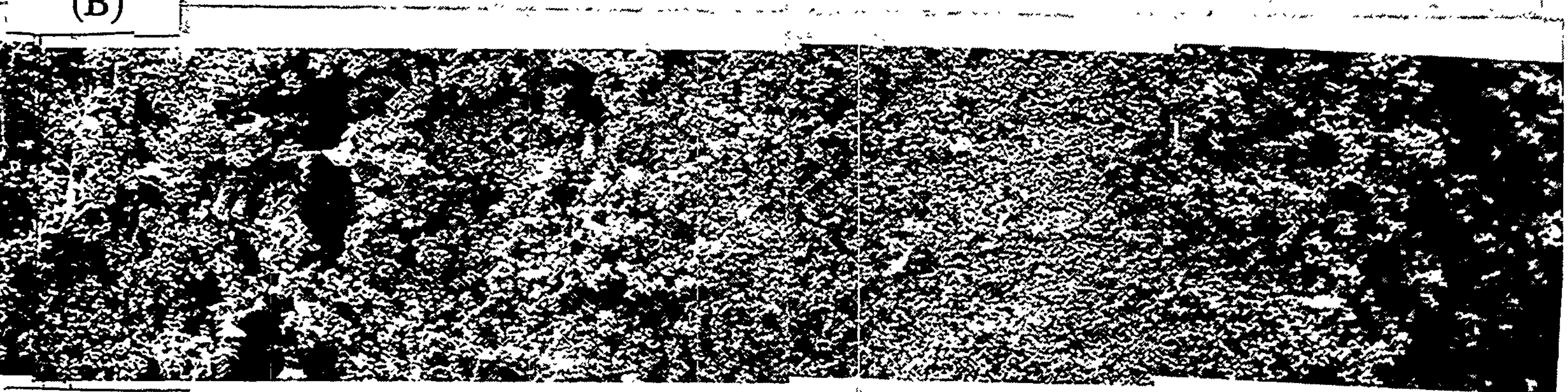


Figure 21 — . Montages Illustrating Th
(a) As-Manufactured 3M
(b) PFBC Exposed 3M C
(c) Washed PFBC Expos

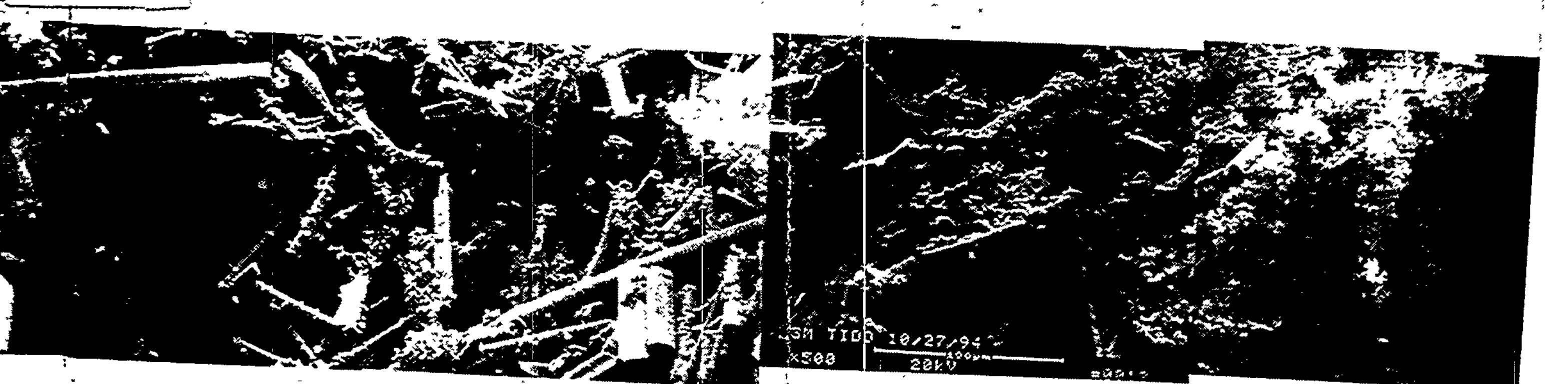
(A)



(B)



(C)



Iorphology Of Various Filtration Mat Layers
VI-SiC Composite Filter Matrix
-SiC Composite Filter Matrix
3M CVI-SiC Composite Filter Matrix

MATERIALS CHARACTERIZATION OF THE 3M CVI-SiC COMPOSITE FILTER MATRIX

AS-MANUFACTURED FILTER MATRIX

The as-manufactured strength of the 3M CVI-SiC composite filter matrix was evaluated via diametral O-ring compression strength testing at Westinghouse STC. Candle filter 43-1-2 was dry cut into 0.57 in (15 mm) and 0.965-0.990 in (~25.4 mm) O-rings in an attempt to discern whether the width of the test specimen has an impact on the resulting strength of the material. As shown in Table 1, the applied ultimate load to initiate fracture in the 0.57 in (15 mm) 3M composite sample was ~1/2 that needed to initiate fracture in the 0.965-0.990 (~25.4 mm) 3M composite sample. Utilizing the entire composite thickness (i.e., outer confinement layer; filtration mat layer; triaxial support layer), the resulting high temperature strength (i.e., 732°C; Tidd nominal operating temperature) of the 3M CVI-SiC matrix was 1011 psi for the 0.57 in (15 mm) O-ring versus 849-943 psi for the 0.965-0.990 in (~25.4 mm) O-ring. Since the outer confinement layer is primarily utilized to contain the lapped filtration mat sublayer, and the function of the filtration mat is to prevent fines penetration directly into the clean gas stream, both are considered to provide little strength to the overall composite matrix. With this in mind, estimates of the overall strength of the as-manufactured 3M CVI-SiC composite filter matrix utilizing only the support triaxial support braid were 9569 psi for the 0.57 in (15 mm) O-ring, and 9196-10217 psi for the 0.965-0.990 in (~25.4 mm) O-ring.

Variable cross-head test speeds have typically been utilized by various investigators. Westinghouse has continuously used a cross-head test speed of 0.05 in/min throughout the development of our materials characterization database. In a preliminary attempt to discern whether the rate that the load is applied to the test sample has an impact on the fast fracture characteristics and ultimate strength of the 3M CVI-SiC composite filter matrix, and additional ~1 in (~25.4 mm) O-ring was tested with a cross-head speed of 0.157 in/min, as recommended by 3M personnel. The resulting high temperature strength of the entire composite was calculated to be 898 psi, and 9913 psi for the support triaxial braid when the matrix was tested with a cross-head speed of 0.157 in/min. These values fall within the strength values established for the O-ring samples which were tested with a cross-head speed of 0.05 in/min.

TABLE 1
AS-MANUFACTURED HIGH TEMPERATURE O-RING STRENGTH

-- Candle Filter No. 43-1-2 --

Cross-Head Speed, in/min	Temp., °C	Sample Width, in	Applied Ultimate Load, lbs	Composite * Strength, psi	Support Braid Strength, psi
0.050	732	0.990	9.10	849	9196
0.050	732	0.577	5.50	1011	9569
0.157	732	0.988	9.80	898	9913
0.050	732	0.965	9.85	943	10217

* Composite: Outer Confinement, Filtration Mat, And Triaxial Braid Support Layer.

Figures 22 through 25 provide the resulting load versus deflection curves for all four samples tested at 732 °C. The typical graceful load transfer/fiber pull-out characteristics are evident for the as-manufactured 3M CVI-SiC composite filter matrix.

Based on the above data,

- Little difference was observed in the resulting high temperature strength of the 3M CVI-SiC composite filter matrix when either 0.57 in (15 mm) versus ~1 in (~25.4 mm) O-ring samples of the material were tested at temperatures of 732 °C.

- Little difference was observed in the resulting high temperature strength of the 3M CVI-SiC O-ring samples which were tested in compression using cross-head speeds of either 0.05 in/min or 0.157 in/min.

In an effort to characterize the entire composite filter body, additional 0.57 in (15 mm) and ~1 in (~25.4 mm) O-rings were dry cut from the as-manufactured 3M CVI-SiC filter element. These were tested in compression at room temperature, as well as at 732 °C (i.e., nominal filter operating temperature at Tidd).

One ~1 in (~25.4 mm) O-ring section was removed directly below the flange of the 3M CVI-SiC composite filter and was strength tested at 732 °C in order to establish the load bearing capability of the double layered, densified flange area of the filter element. As shown in Table 2, the densified section required a 24.7 lb load to initiate fracture, while the remainder of the body required loads of 7 to 12.4 lbs to initiate fracture. The resulting strength along the densified flange area was calculated to be 1232 psi for the entire composite thickness (i.e., one layer of the support triaxial braid; an overlay of tightly braided material; the filtration mat layer; and the confinement open-mesh weave layer), while the calculated overall strength of the triaxial and densified braid was 6473 psi.

During conduct of the strength tests, O-rings which were removed from the filter body were oriented in the test fixture with the lapped seam positioned at 45°, 135°,

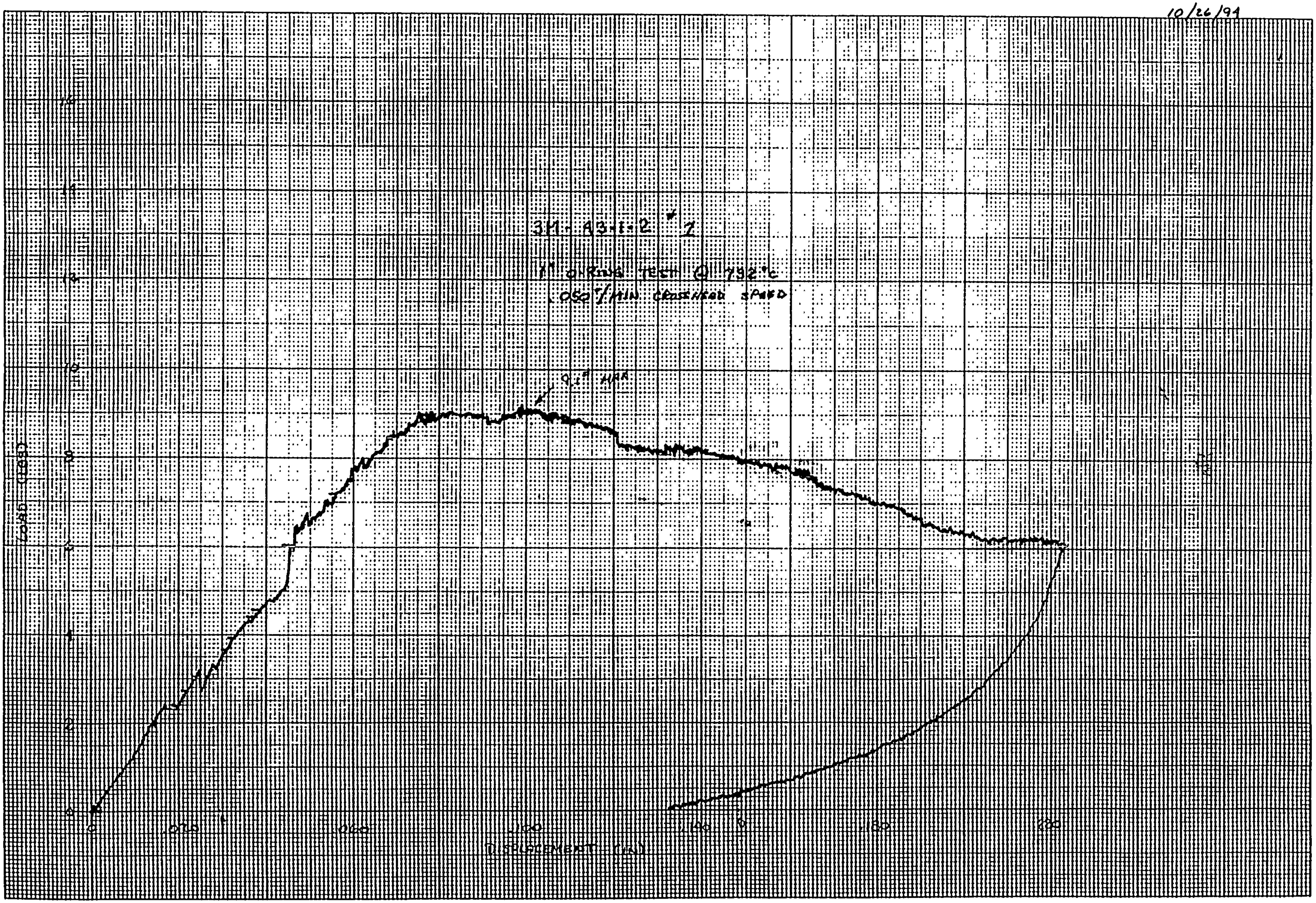


Figure 22 — Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample No. 1 (0.990 inch O-ring; Cross-Head Speed: 0.05 in/min)

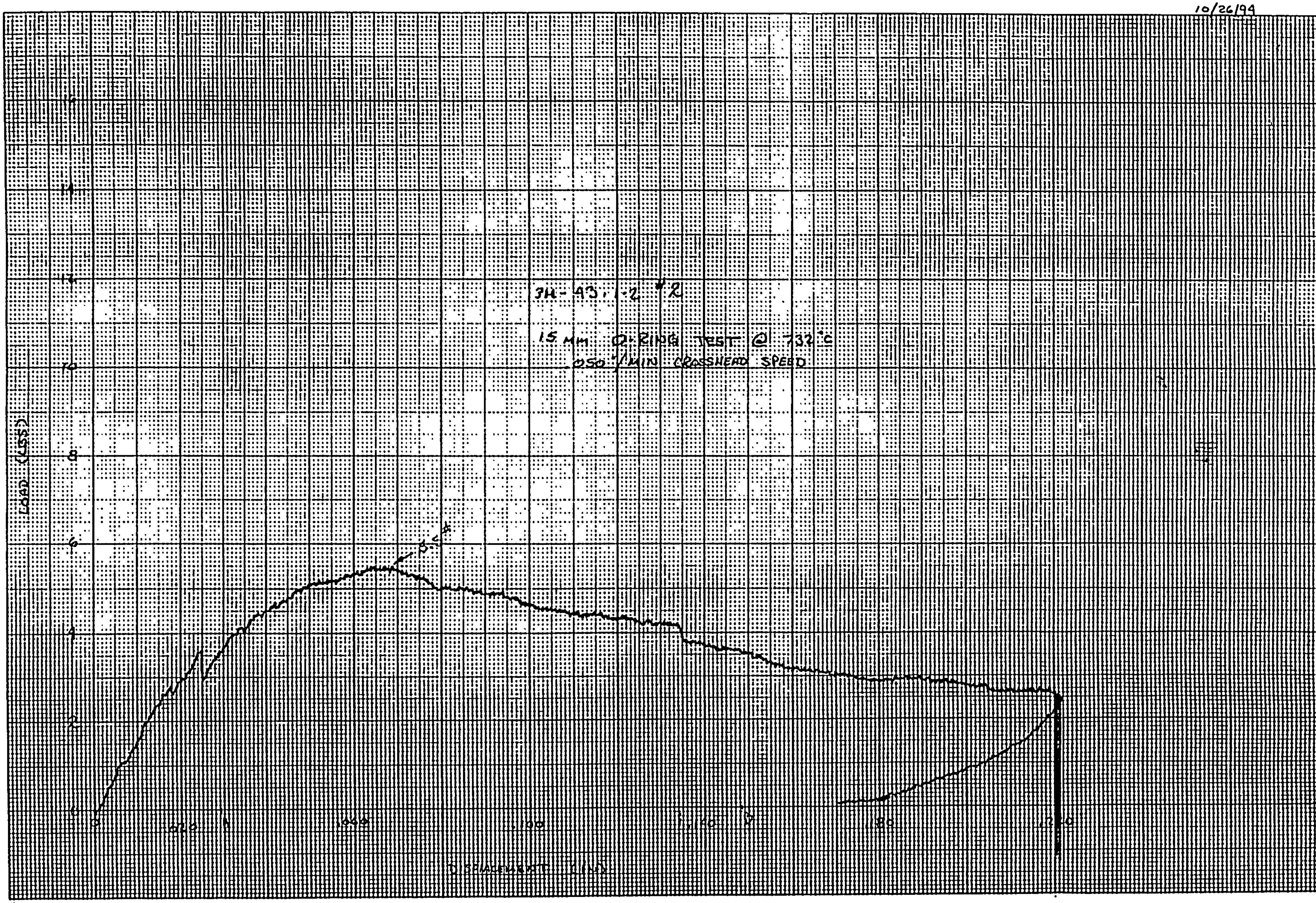


Figure 23 — Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample No. 2 (0.577 inch O-ring; Cross-Head Speed: 0.05 in/min)

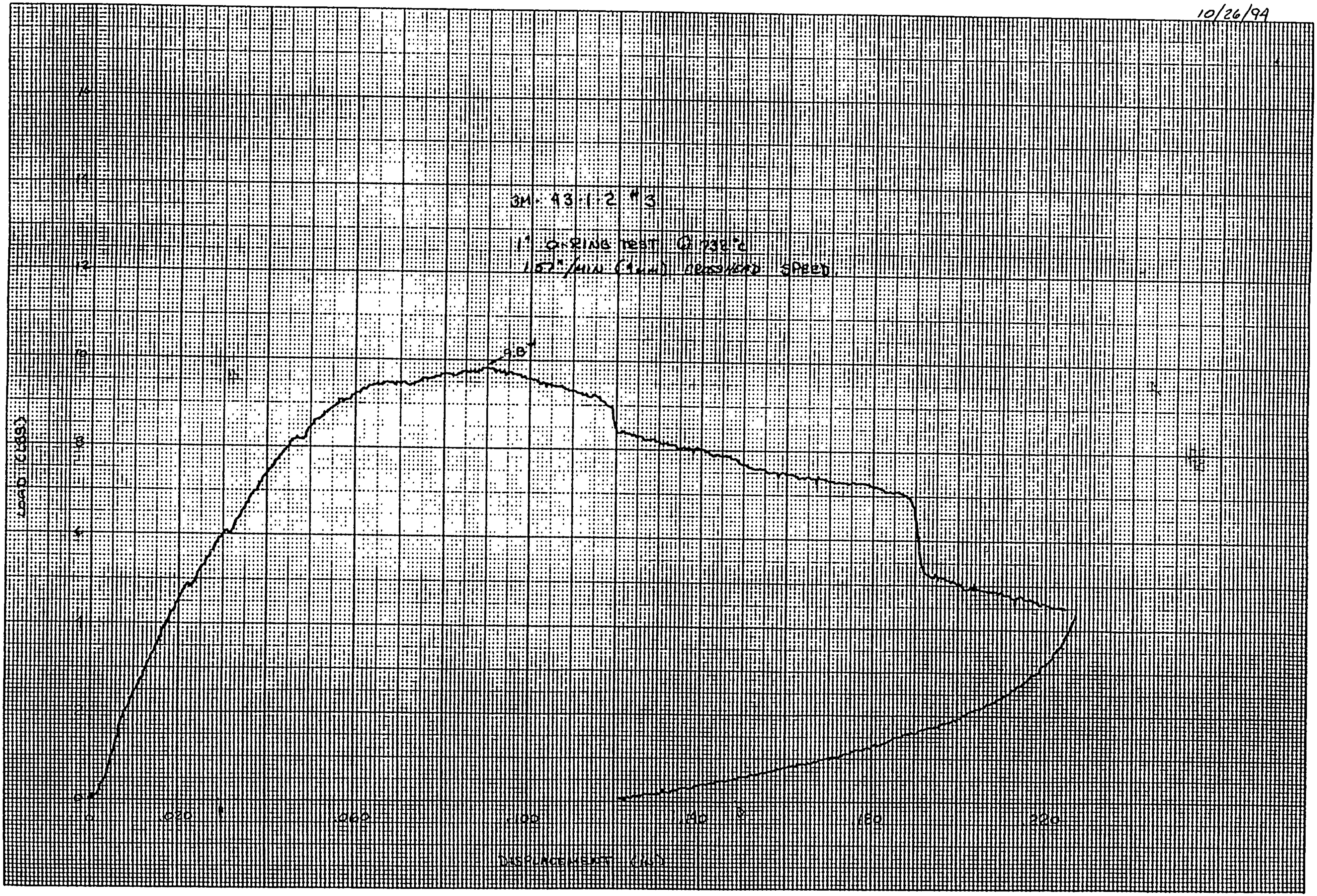


Figure 24 — Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample No. 3 (0.988 inch O-ring; Cross-Head Speed: 0.157 in/min)

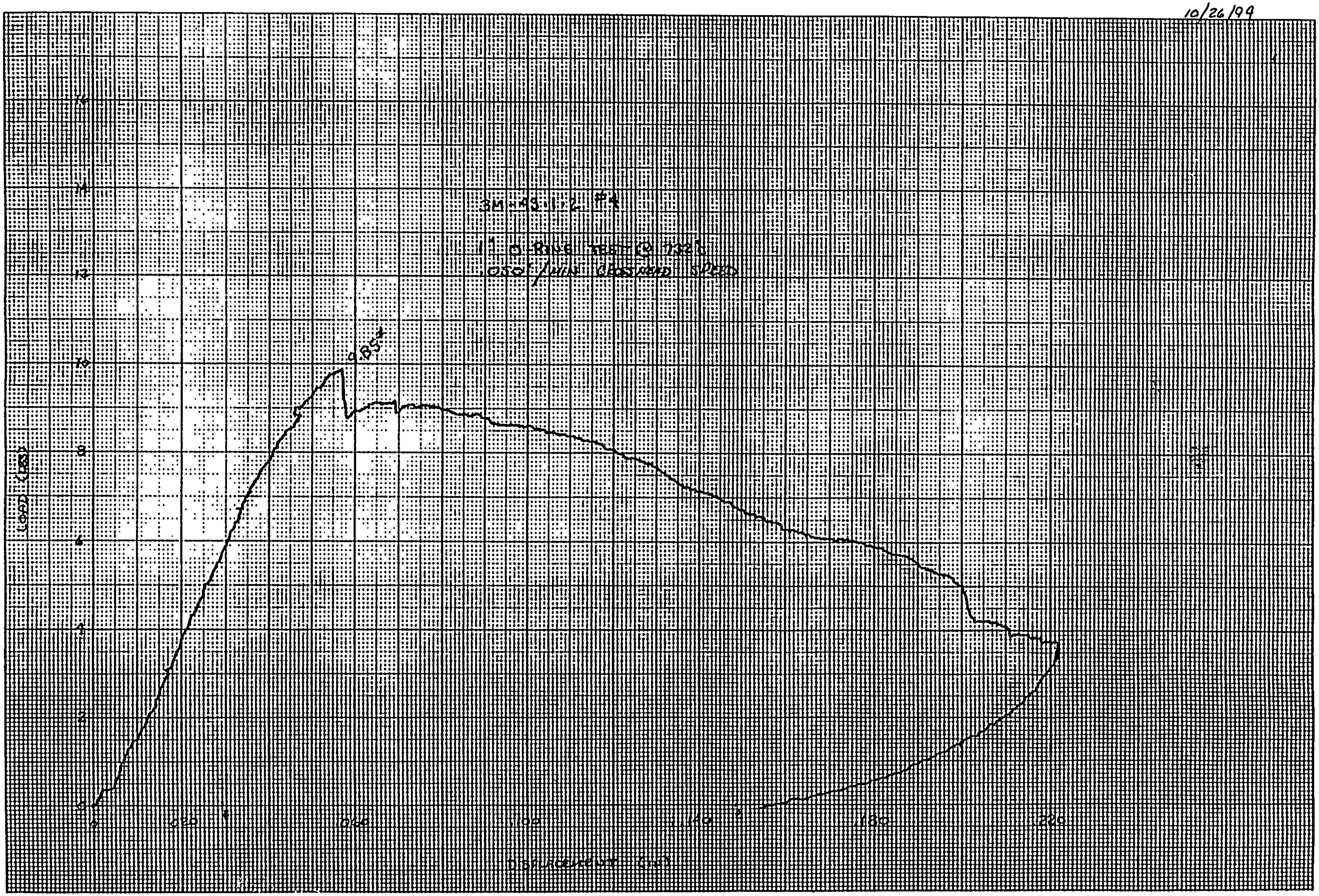


Figure 25 — Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample No. 4 (0.965 inch O-ring; Cross-Head Speed: 0.05 in/min)

TABLE 2
AS-MANUFACTURED DIAMETRAL STRENGTH

-- Candle Filter No. 43-1-2 --
O-Ring Compression

Sample No.	Cross-Head Speed, in/min	Temp., °C	Sample Width, in	Applied Ultimate Load, lbs	Composite Strength, psi	Support Braid Strength, psi
9	0.05	RT *	0.980	9.8	905	9999
12	0.05	RT	0.992	12.7	1175	12808
16	0.05	RT	0.966	15.1	1617	15738
20	0.05	RT	0.977	15.3	1507	15690
26	0.05	RT	0.977	13.1	1227	13551
30	0.05	RT	0.961	15.0	1527	15692
34	0.05	RT	0.976	12.7	1125	13069
38	0.05	RT	0.981	13.0	1339	13310
42	0.05	RT	0.970	13.0	1253	13494
46	0.05	RT	0.981	16.5	1737	16910
1**	0.05	732	0.967	24.7	1232	6473
2	0.05	732	0.996	8	661	8071
3	0.05	732	0.997	7.7	670	7784
5	0.05	732	0.969	9.9	993	10201
7	0.05	732	0.979	8.8	883	8948
18	0.05	732	0.981	12.4	1346	12751
22	0.05	732	0.965	11.7	1235	12189
28	0.05	732	0.960	9.8	919	10288
32	0.05	732	0.986	11.9	1152	12163
40	0.05	732	0.980	11.5	1118	11797
44	0.05	732	0.967	12.4	1147	12923
48	0.05	732	0.993	12.1	1199	12244
49	0.05	732	0.979	12.3	1236	12619
50	0.05	732	1.010	11.2	1214	11181

* RT: Room Temperature.
** Double Layered Strengthened Section Within The Densified Flange Area.

TABLE 2 (Continued)
AS-MANUFACTURED DIAMETRAL STRENGTH

-- Candle Filter No. 43-1-2 --
O-Ring Compression

Sample No.	Cross-Head Speed, in/min	Temp., °C	Sample Width, in	Applied Ultimate Load, lbs	Composite Strength, psi	Support Braid Strength, psi
8	0.05	RT	0.593	6.1	1039	10321
13	0.05	RT	0.572	7.5	1245	13143
17	0.05	RT	0.585	8.2	1283	14085
21	0.05	RT	0.594	8.0	1708	13573
27	0.05	RT	0.584	7.7	1297	13334
31	0.05	RT	0.582	7.4	1321	12864
35	0.05	RT	0.579	7.4	1147	12925
39	0.05	RT	0.576	7.0	1216	12254
43	0.05	RT	0.590	9.1	1464	15559
47	0.05	RT	0.589	8.6	1430	14701
4	0.05	732	0.572	4.8	808	8416
6	0.05	732	0.582	4.7	753	8047
14	0.05	732	0.572	11.5	1973	20143
15	0.05	732	0.576	6.1	1130	10699
19	0.05	732	0.588	6.1	1044	10445
23	0.05	732	0.585	4.5	776	7764
29	0.05	732	0.573	5.9	1050	10433
33	0.05	732	0.602	6.6	1189	11103
41	0.05	732	0.583	7.4	1234	13361
45	0.05	732	0.574	6.9	1087	12091

225° and 315° from the point of the applied load. In this manner, the entire filter body could be evaluated in terms of its as-manufactured strength, as opposed to selectively characterizing a uniaxial section along the length of the composite filter matrix. Table 2 provides the results of the diametral O-ring compression strength tests which were conducted at both room temperature and 732° C for the ~0.6 in (15 mm) and ~1 in (~25.4 mm) test samples. The manner in which the data are reported indicate the position of the samples which were removed from the filter body relative to the flange. These data seem to indicate that the matrix is slightly weaker below the flange in comparison to the remainder of the filter body.

Table 3 summarizes the resulting strength data of the as-manufactured 3M CVI-SiC composite filter matrix based on the diametral O-ring compressive strength values shown in Table 2. Very little difference was identified between the resulting O-ring strength values for either the ~0.6 in (15 mm) or ~1 in (~25.4 mm) O-rings when tested at either room temperature or at temperatures of 732 ° C. Future testing is therefore recommended to be conducted with 0.6 in (15 mm) thick samples as opposed to 1 in (25.4 mm) test samples in order to obtain more information which is necessary to generate statistically significant strength results.

Review of the data provided in Table 3 indicates that the strength of the 3M CVI-SiC composite matrix appears to be somewhat lower at 732° C in comparison to its strength at room temperature. This is similar to the data generated for the alternate monolithic filter materials. Note, however, that a 10-30% 1-σ range resulted in the strength of the 3M CVI-SiC composite matrix, indicating that significant scatter or non-homogeneity exists in the filter body. As shown in the data presented in Table 1, the resulting strength values for the entire composite filter matrix (Table 3) are ~1/10 of the calculated strength of the triaxial braid or support layer.

Five C-rings were removed from various locations along the as-manufactured 3M CVI-SiC composite filter body. The C-rings were tested in compression at room temperature and at 732° C. It is rather interesting that the 0.6 in (15 mm) C-ring room temperature composite strength was calculated to be 1343 psi, while the structural support triaxial braid layer was calculated to have a strength of 13187 psi (Table 4). These data are clearly comparable to the 0.6 in (15 mm) O-ring strength values shown in Table 3

TABLE 3

SUMMARY OF THE AS-MANUFACTURED DIAMETRAL O-RING COMPRESSIVE STRENGTH VALUES FOR THE 3M CVI-SiC COMPOSITE FILTER MATRIX

Sample Thickness, in	Matrix	Room Temp. Strength, psi	High Temp. Strength (732 °C), psi
0.57	Composite *	1315± 186	1104± 350
0.57	Support **	13276±1417	11250±3595
0.99	Composite	1314± 254	1060± 219
0.99	Support	14026±2012	11012±1795

Cross-Head Speed: 0.05 in/min.
* Composite: Entire Filter Matrix.
** Support: Triaxial Braid Layer.

TABLE 4
AS-MANUFACTURED C-RING COMPRESSIVE STRENGTH

-- Candle Filter No. 43-1-2 --

Sample No.	Cross-Head Speed, in/min	Temp., °C	Sample Width, in	Applied Ultimate Load, lbs	Composite Strength, psi	Support Braid Strength, psi
25	0.05	RT	0.590	2.5	1343	13187
24	0.05	RT	0.980	5.4	1635	17012
37	0.05	732	0.574	2.6	1352	13444
10	0.05	732	0.668	2.0	964	8926
36	0.05	732	0.980	5.1	1425	16857

which indicate a room temperature strength of the composite of 1315±186 psi, and a structural support strength of 13276±1417 psi. The resulting room temperature strength for the ~1 in (~25.4 mm) C-ring was, however, higher than the ~1 in (~25.4 mm) room temperature O-ring value, and similarly the 0.6 in (15 mm) and ~1 in (~25.4 mm) 732°C C-ring strength values were higher than the 0.6 in (15 mm) and ~1 in (~25.4 mm) O-ring strength values. Since the C-ring data were based on one test sample, further effort would be required to test additional samples prior to concluding whether there is actually a difference between the reported O-ring versus C-ring strengths. Additional testing would also be required to establish the C-ring tensile strength for the 3M CVI-SiC composite filter matrix.

A 254 mm (10 in) section of material was removed from the as-manufactured 3M CVI-SiC composite filter matrix. Two 90° strain gage rosettes were installed on both inside, as well as outside surface of the matrix, at approximately the center of the test sample (i.e., 5 inches from either end). A water filled bladder was pressurized to determine the hoop strength of the filter composite matrix. Failure of all three composite layers (i.e., ~3-4 inch crack formation) occurred at one end of the burst sample.

As shown in Figure 26, both inside and outside strain gages tracked comparably prior to ~110 psi pressure. After ~110 psi, a slight deviation resulted between the strain readings along the outside versus inside filter surfaces. This deviation is considered to result from "debonding" of the confinement layer with the underlying support and filtration mat. The resulting hoop strength as shown in Table 5 is 1.01 ksi for the entire composite matrix, while 3.30 ksi is projected for the structural support. The 1.10 ksi burst strength is comparable with the 0.6 in (15 mm) and ~1 in (~25.4 mm) room temperature and 732°C O-ring strength values shown in Table 3.

Based on the strain gage data shown in Figure 26, the 3M CVI-SiC composite filter matrix has an elastic modulus of 2.96-3.38 x 10^6 psi. The Poisson's ratio for the as-manufactured 3M CVI-SiC composite filter matrix was calculated to range between 0.14 (i.e., inside strain gage data along the triaxial support braid layer) and 0.27 (i.e., outside strain gage data along the open mesh confinement layer).

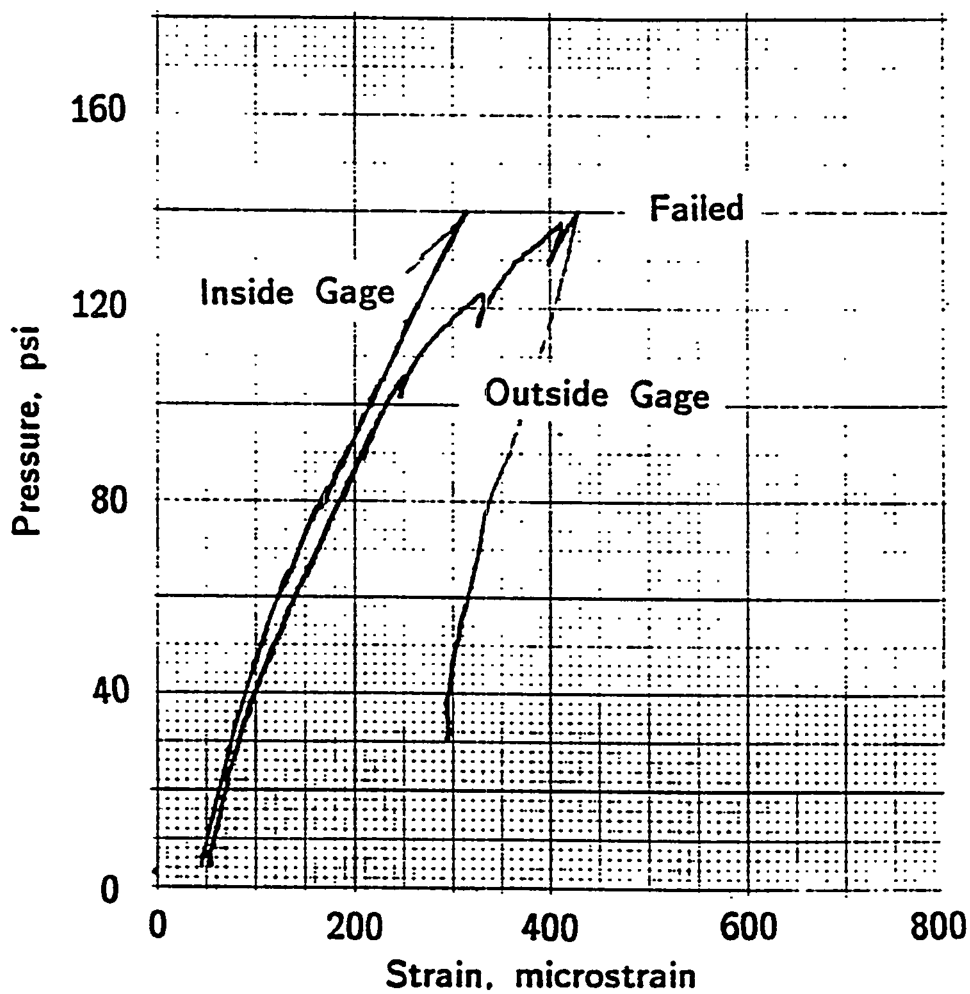


Figure 26 — Pressure Versus Strain Curve For The As-Manufactured 3M CVI-SiC Composite Filter Matrix (Filter No. 43-1-2)

TABLE 5
BURST STRENGTH AND ELASTIC MODULUS OF THE
AS-MANUFACTURED 3M COMPOSITE FILTER MATRIX

-- Candle Filter No. 43-1-2 --

Burst Strength

Wall Thickness, inch	Hoop Strength, ksi
0.044	3.30
0.149	1.01

Elastic Modulus

Measurement Location	Elastic Modulus	Poisson's Ratio
Inside	3.38×10^6	0.14
Outside	2.96×10^6	0.27

PFBC EXPOSED FILTER MATRIX

After removal from the W-APF system, room temperature air flow resistance was measured through the 1705 hour PFBC exposed 3M CVI-SiC composite candle filter (No. 43-1-6; B/M-15). As shown in Figure 27 and Table 6, the filter exhibited high gas flow resistance in either its as-received dust-laden or cleaned vacuumed state (i.e., Δp = 221.44 iwc at 10.57 fpm at room temperature). The high gas flow resistance through the 3M CVI-SiC composite filter matrix was attributed to the extensive ash cake along the surface of the filter, as well as ash fines which had penetrated into the various layers of the composite matrix.

After the candle had been sectioned for materials evaluation at 3M and Westinghouse (Figure 13), an ~1 inch O-ring section was dry cut from the filter body and weighed. The PFBC exposed O-ring section weighed 3.75 g in comparison to a comparable ~1 inch O-ring section from an as-manufactured composite filter which weighed 1.84 g. The filter matrix nearly doubled its initial weight during hot gas filtration, primarily as the result of ash accumulation within the composite layers.

The O-ring was then washed with water to remove the entrapped ash fines. After washing, the O-ring was dried overnight in a muffle furnace at temperatures of ~100 °C. Examination of the O-ring sample after drying indicated that the matrix appeared to remain intact. The lapped seam of the filtration mat layer remained bonded together, and similarly all three layers of the filter matrix appeared to remain bonded tightly to each other. Separation of the three layers was not evident in the wash ~1 inch O-ring sample.

Additional ~1 inch O-rings were removed from the 1705 hour PFBC exposed 3M CVI-SiC composite filter matrix which were subsequently subjected to room temperature and process temperature O-ring diametral compression testing. As shown in Figure 28, the PFBC exposed composite filter exhibited more brittle fracture characteristics during room temperature and process temperature diametral O-ring compression testing in comparison to the graceful fiber pull-out (i.e., fracture toughened matrix) which was demonstrated for the as-manufactured composite matrix.

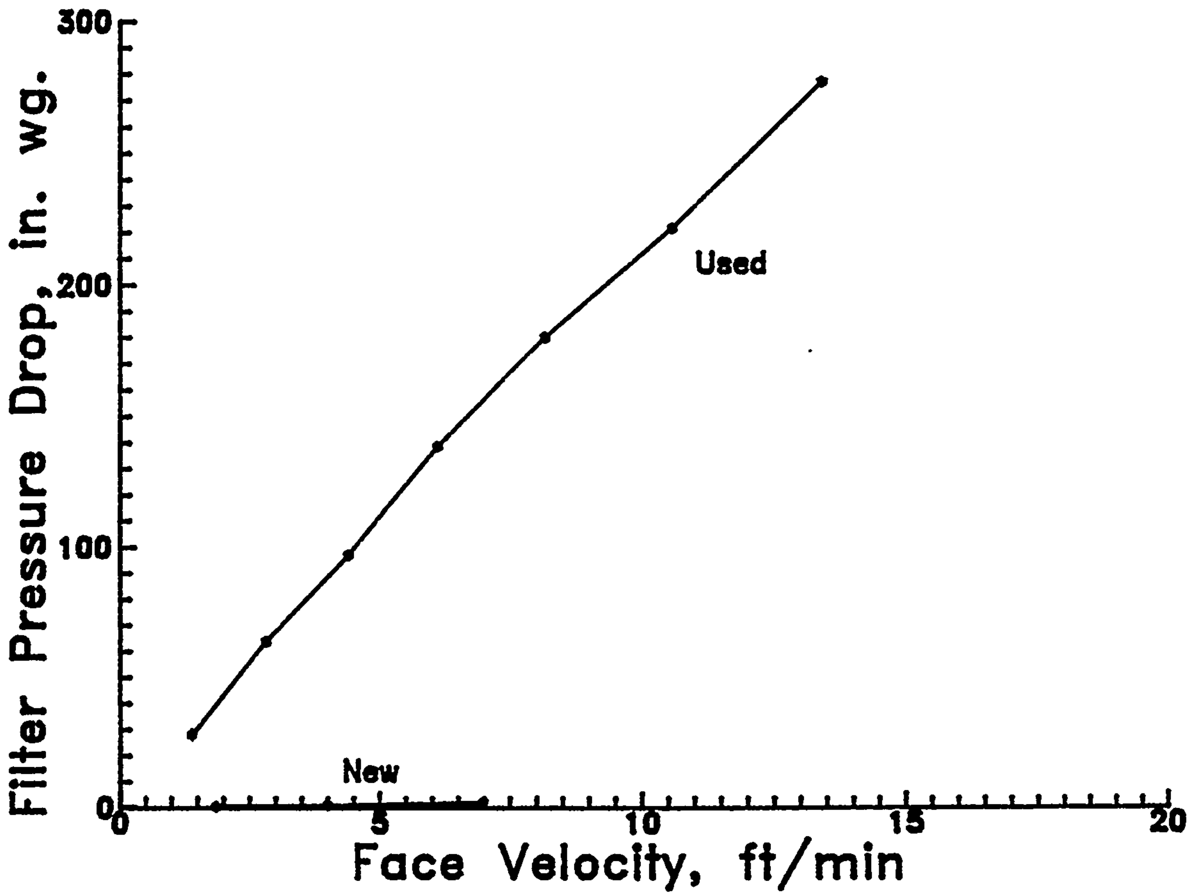


Figure 27 – Gas Flow Resistance Through The As-Manufactured And PFBC Exposed 3M CVI-SiC Composite Candle Filters

TABLE 6
GAS FLOW PERMEABILITY OF THE AS-MANUFACTURED AND PFBC EXPOSED
3M CVI-SiC COMPOSITE CANDLE FILTERS

Ident.	Flow %	Flow scfm	Pressure psig	Velocity fpm	delta P iwc	delta P @1550 deg iwc
B (CTC 93265-1)	10	3.22	1.5	1.21	0.1	0.19
	20	6.43	2	2.45	0.19	0.37
	30	9.65	3	3.78	0.3	0.58
	40	12.86	5	5.32	0.5	0.97
	50	16.08	7	6.98	0.8	1.56
	60	19.29	10.5	9.02	1.2	2.34
	70	22.51	16	11.62	1.8	3.51
C (CTC 93265-2)	10	3.22	1.5	1.21	0.09	0.18
	20	6.43	2	2.45	0.15	0.29
	30	9.65	3	3.78	0.29	0.56
	40	12.86	4.8	5.29	0.45	0.88
	50	16.08	7	6.98	0.7	1.36
	60	19.29	11	9.11	1.2	2.34
	70	22.51	16	11.62	1.8	3.51
D (CTC 93287-1)	10	3.22	1.5	1.21	0.1	0.19
	20	6.43	2	2.45	0.2	0.39
	30	9.65	3	3.78	0.35	0.68
	40	12.86	4.8	5.29	0.6	1.17
	50	16.08	7	6.98	0.9	1.75
	60	19.29	10.5	9.02	1.4	2.73
	70	22.51	16	11.62	2.1	4.09
E (CTC 93287-3)	10	3.22	1.5	1.21	0.1	0.19
	20	6.43	2	2.45	0.2	0.39
	30	9.65	3	3.78	0.3	0.58
	40	12.86	4.8	5.29	0.5	0.97
	50	16.08	7	6.98	0.8	1.56
	60	19.29	10.8	9.07	1.2	2.34
	70	22.51	16	11.62	1.8	3.51
F (CTC 93287-4)	10	3.22	1.5	1.21	0.1	0.19
	20	6.43	2.1	2.45	0.2	0.39
	30	9.65	3	3.78	0.35	0.68
	40	12.86	4.8	5.29	0.55	1.07
	50	16.08	7	6.98	0.85	1.66
	60	19.29	10.8	9.07	1.35	2.63
	70	22.51	16	11.62	2.1	4.09

TABLE 6 (Continued)
GAS FLOW PERMEABILITY OF THE AS-MANUFACTURED AND PFBC EXPOSED
3M CVI-SiC COMPOSITE CANDLE FILTERS

Ident.	Flow %	Flow scfm	Pressure psig	Velocity fpm	delta P iwc	delta P @1550 deg iwc
G (CTC 93263-3)	10	3.22	1.5	1.21	0.1	0.19
	20	6.43	2	2.45	0.2	0.39
	30	9.65	3	3.78	0.35	0.68
	40	12.86	4.8	5.29	0.55	1.07
	50	16.08	7	6.98	0.85	1.66
	60	19.29	10.5	9.02	1.35	2.63
	70	22.51	15.9	11.60	2.05	3.99
3m 43-16		5	2	1.84	0.2	0.39
		10	5	3.99	0.75	1.46
		15	12	6.97	1.9	3.70
AFTER USE AT TIDD						
As Received	10	3.57	2.5	1.38	27.68	53.90
	20	6.99	4	2.81	63.66	123.98
	30	10.24	6.5	4.39	96.88	188.67
	40	13.45	9	6.10	138.40	269.52
	50	16.80	12.5	8.16	179.92	350.38
	60	20.15	17	10.57	221.44	431.24
	70	23.77	22	13.41	276.80	539.05
Vacuumed	10	3.57	2.5	1.38	35.98	70.08
	20	6.99	4.2	2.83	69.20	134.76
	30	10.24	6.5	4.39	105.18	204.84
	40	13.45	9	6.10	138.40	269.52
	50	16.80	13	8.24	179.92	350.38
	60	20.15	17	10.57	221.44	431.24
	70	23.77	22	13.41	276.80	539.05

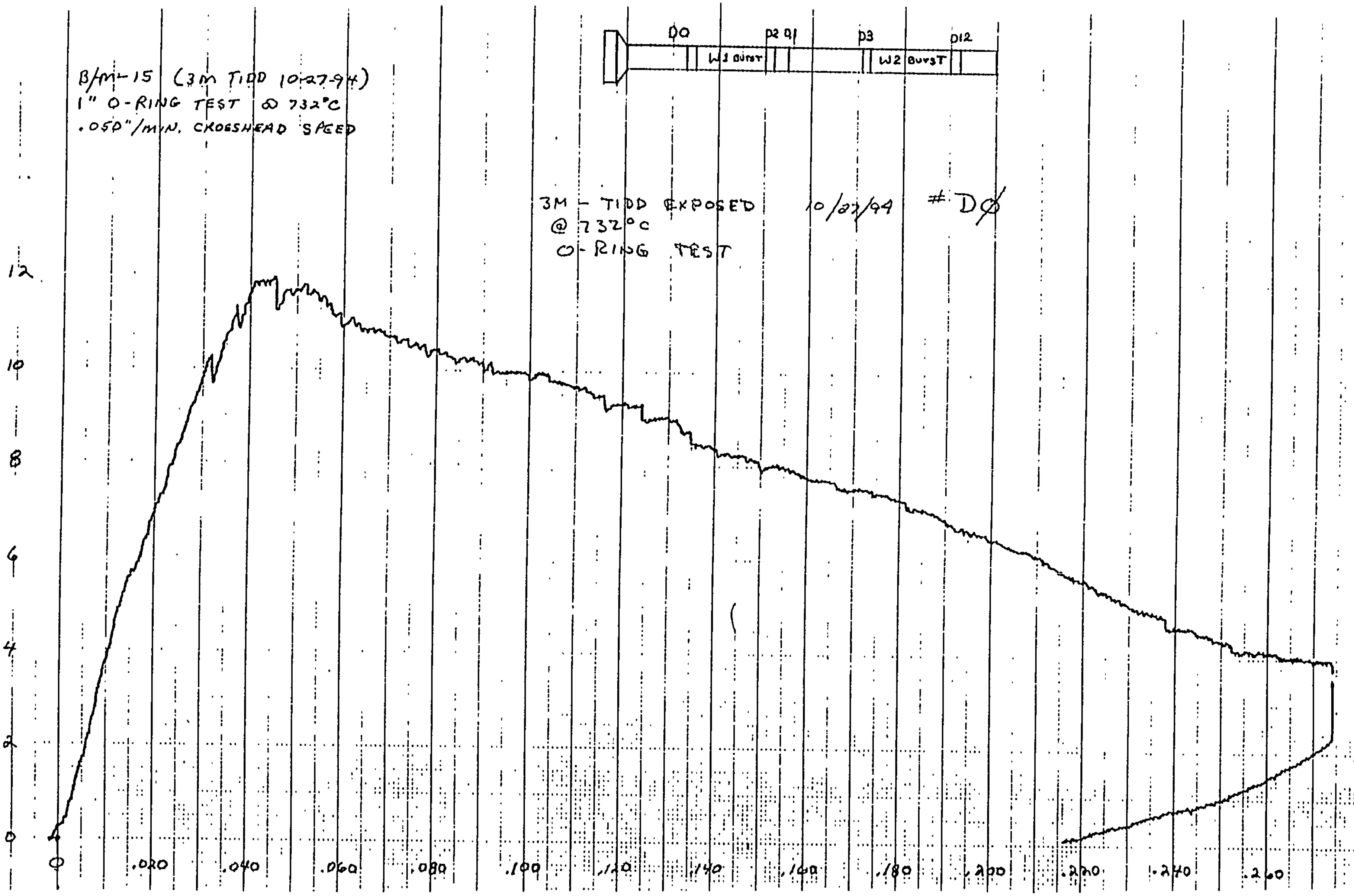


Figure 28a — High Temperature (732 ° C) Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D0 (0.994 inch O-Ring; Cross-Head Speed: 0.05 in/min)

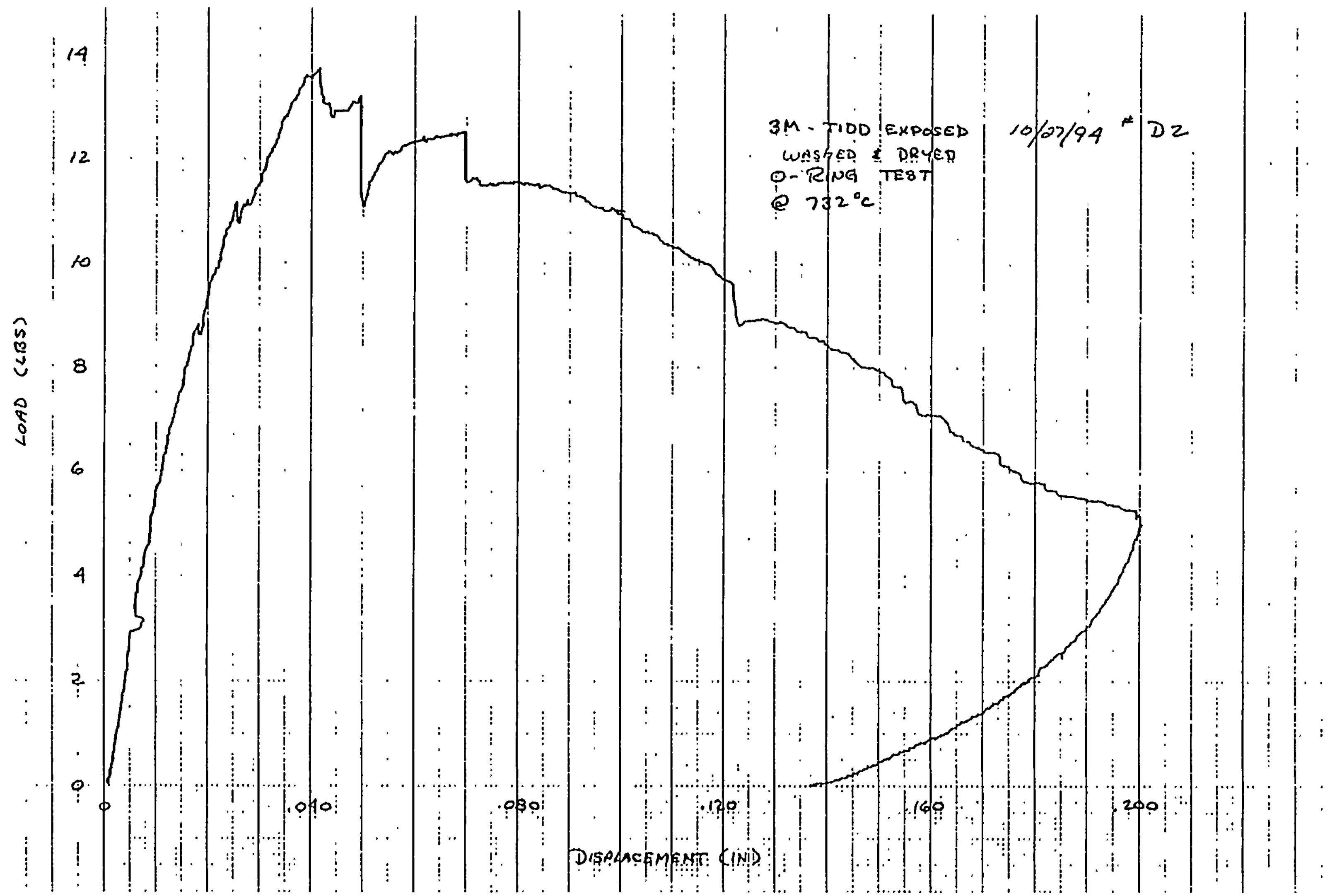


Figure 28b — High Temperature (732 ° C) Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D2 (1.008 inch O-Ring; Cross-Head Speed: 0.05 in/min)

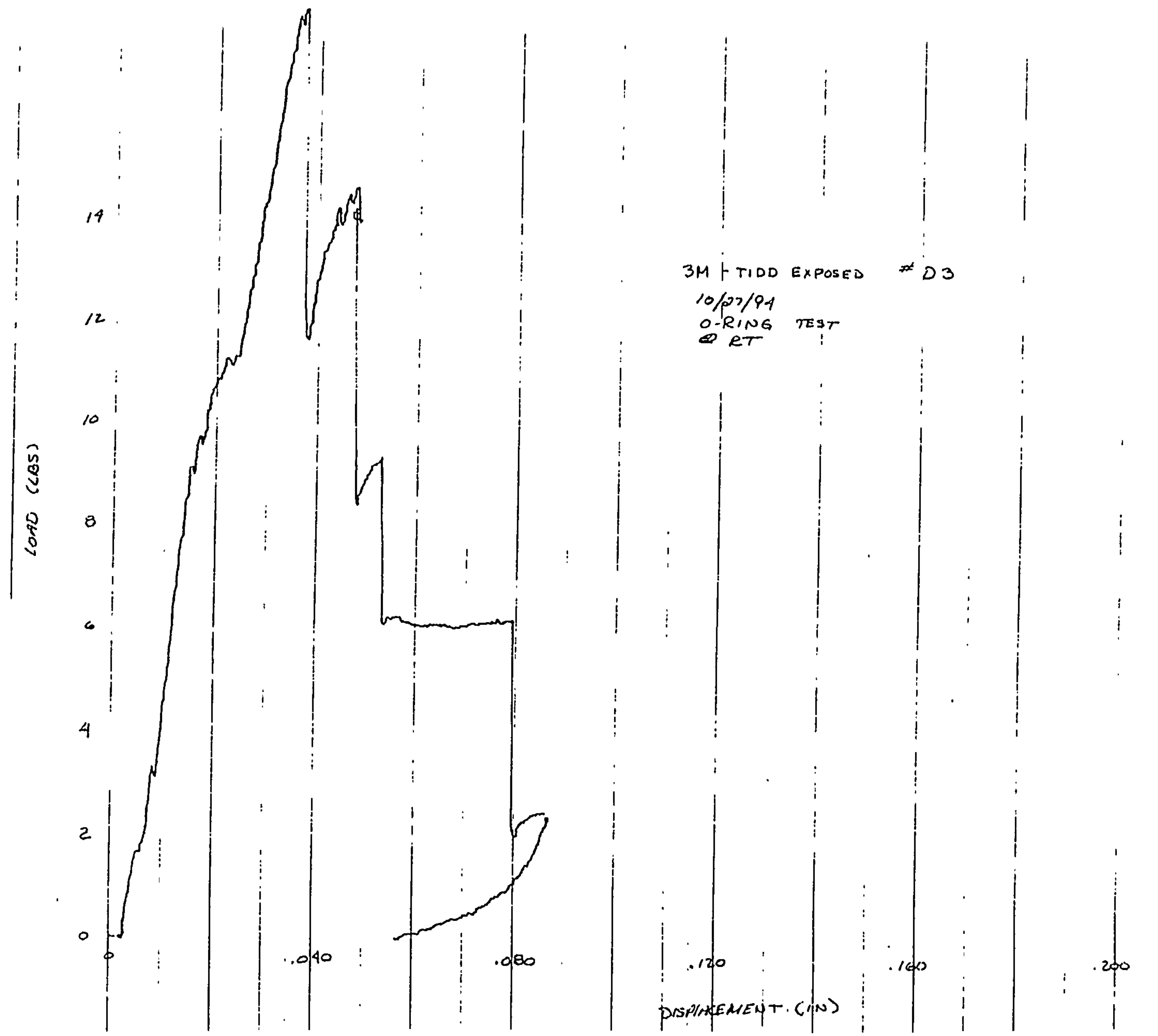


Figure 28c — Room Temperature Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D3 (0.993 inch O-Ring; Cross-Head Speed: 0.05 in/min)

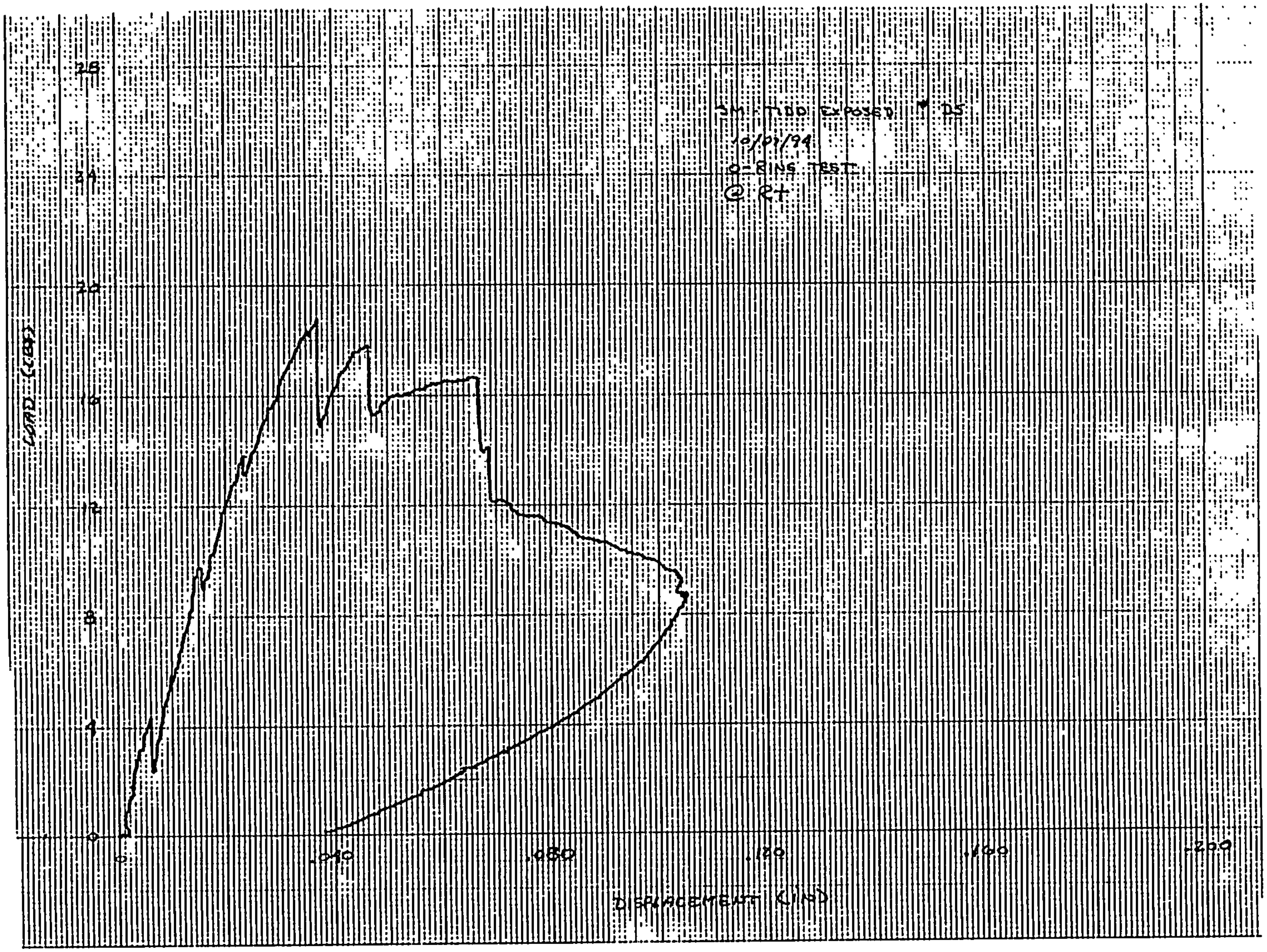


Figure 28d — Room Temperature Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D5 (0.993 inch O-Ring; Cross-Head Speed: 0.05 in/min)

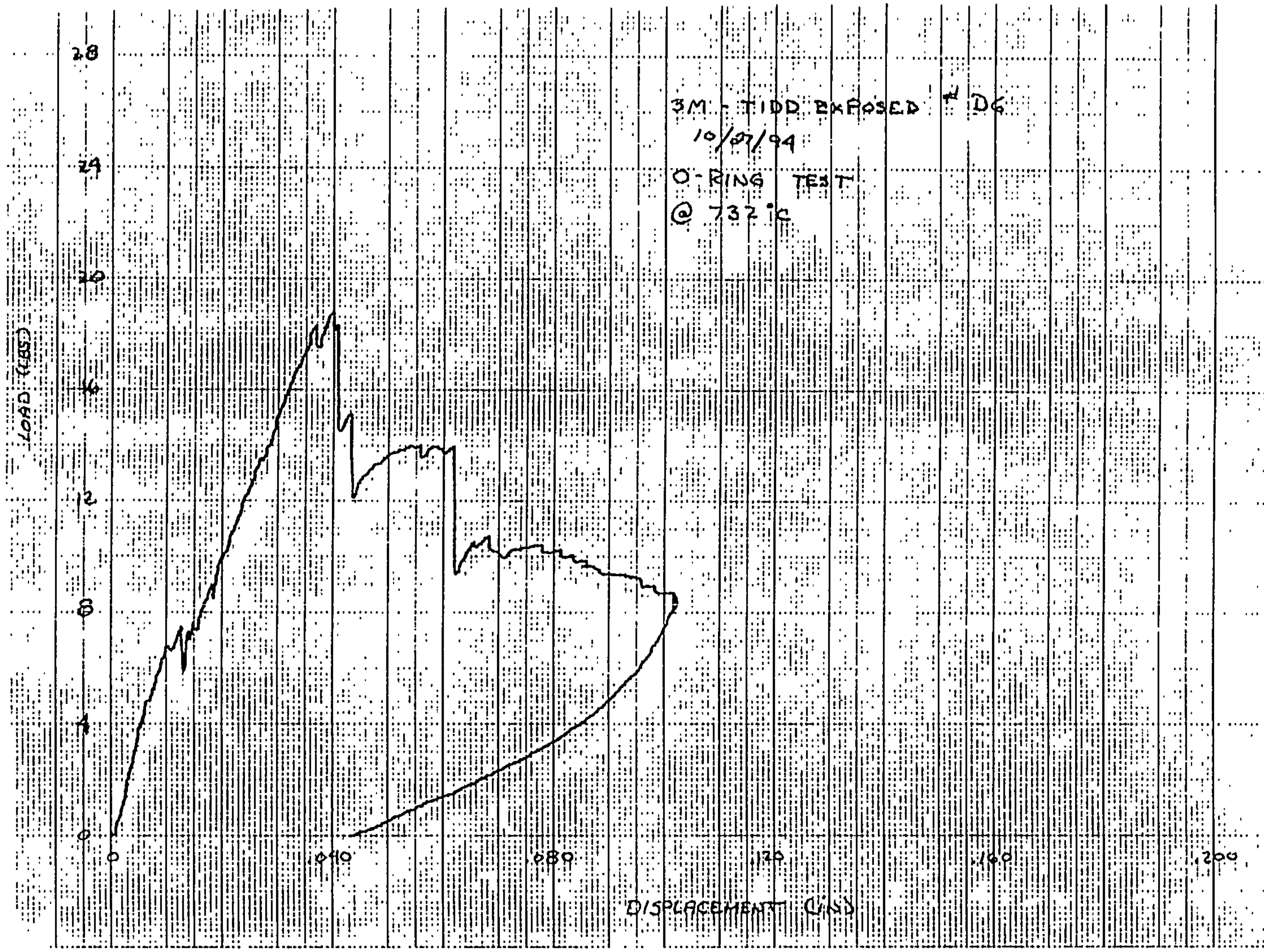


Figure 28e — High Temperature (732 ° C) Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D6 (0.993 inch O-Ring; Cross-Head Speed: 0.05 in/min)

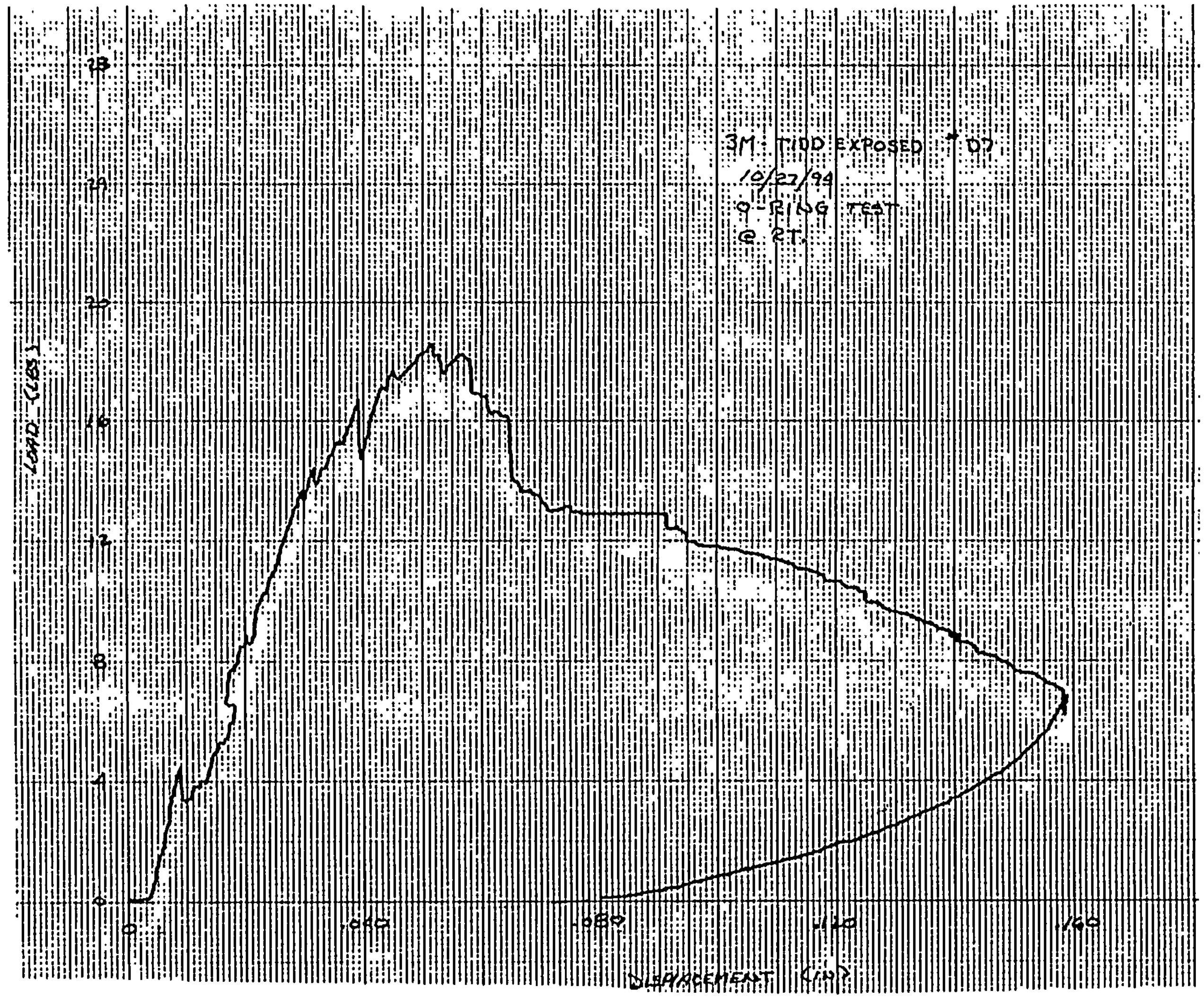


Figure 28f — Room Temperature Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D7 (1.002 inch O-Ring; Cross-Head Speed: 0.05 in/min)

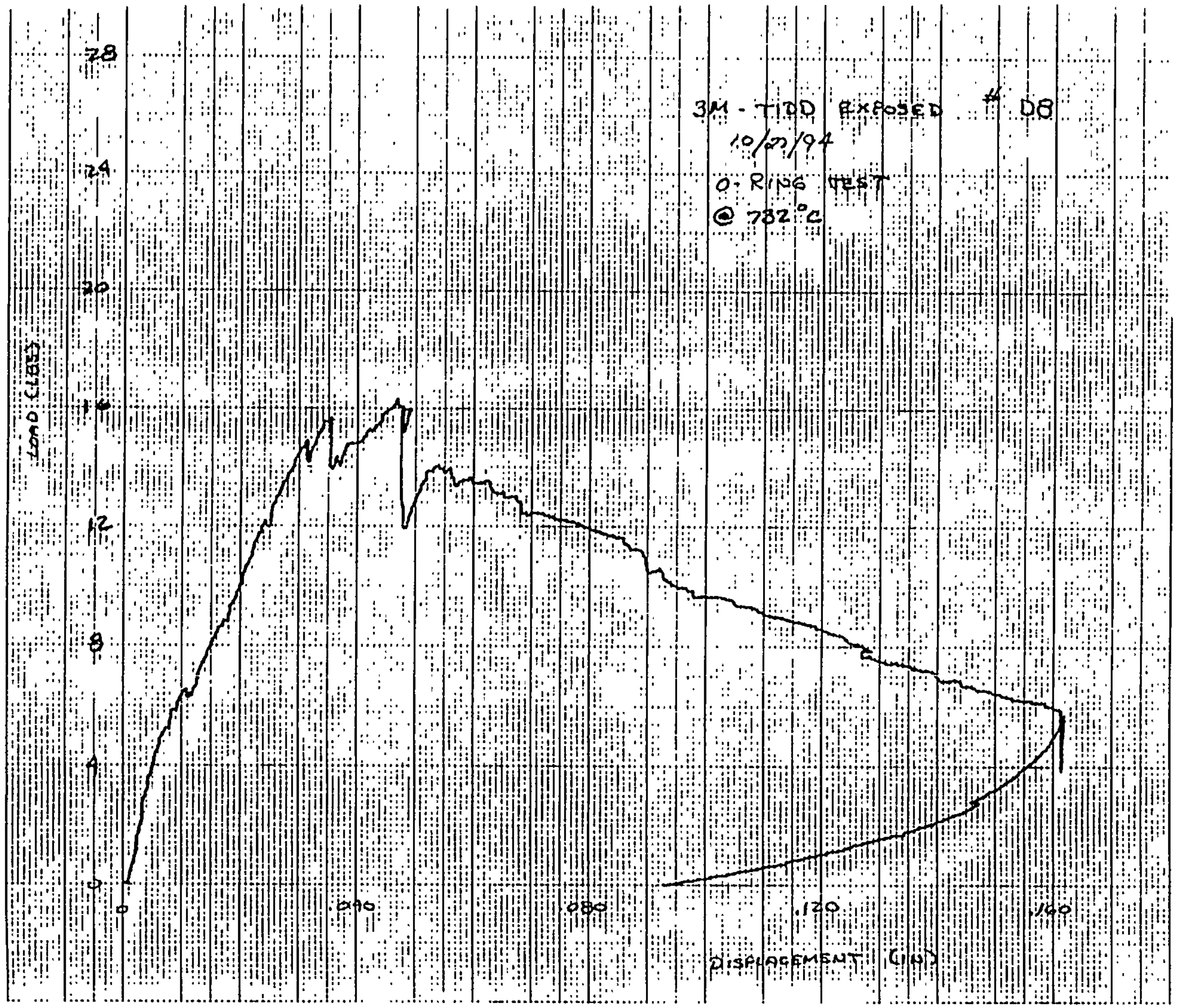


Figure 28g — High Temperature (732 ° C) Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D8 (1.001 inch O-Ring; Cross-Head Speed: 0.05 in/min)

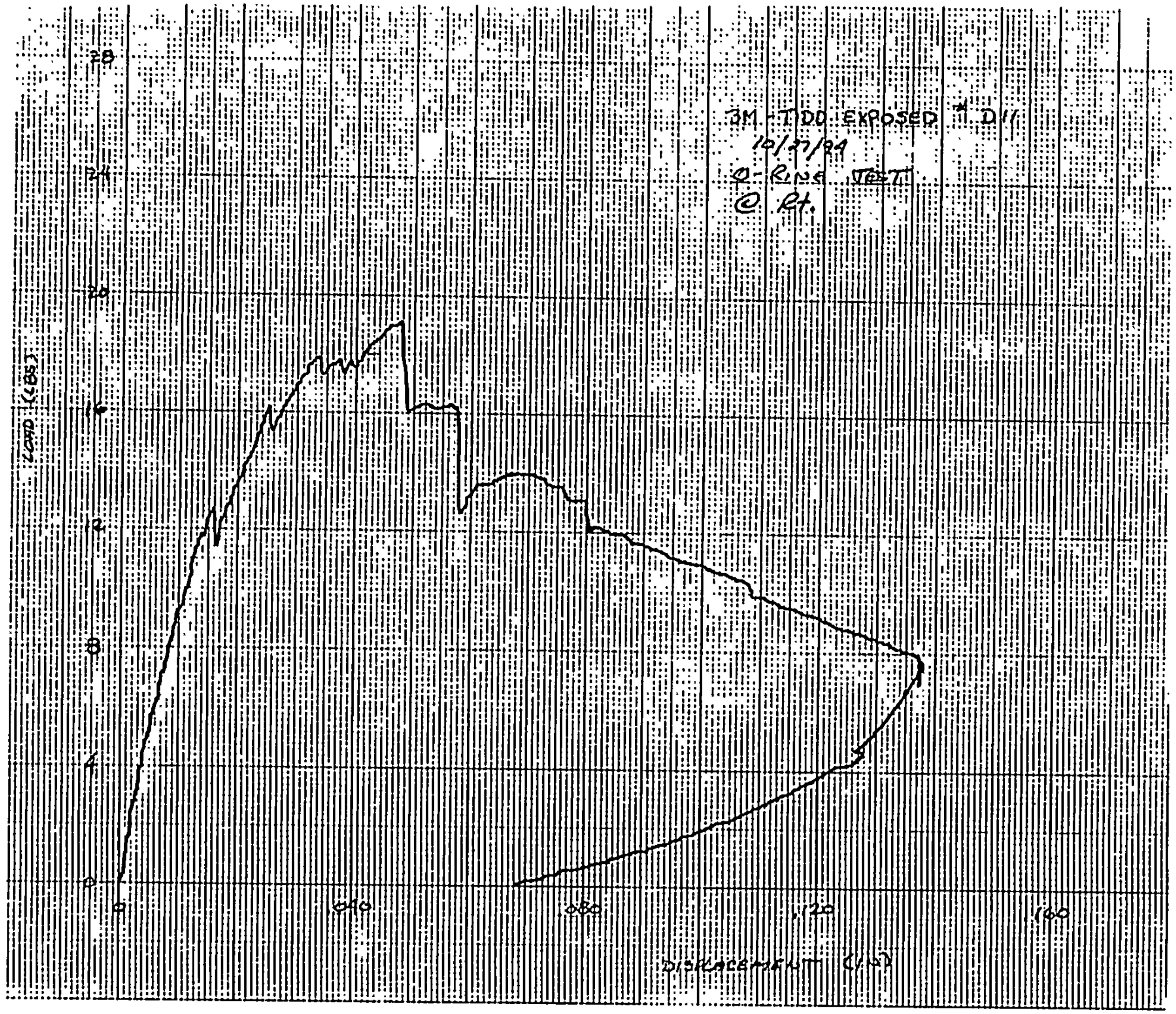


Figure 28h — Room Temperature Load Versus Deflection Curve For The 3M CVI-SiC Composite Filter Matrix - Test Sample D11 (1.015 inch O-Ring; Cross-Head Speed: 0.05 in/min)

Utilizing a cross-head speed of 0.05 in/min, the average room temperature strength of the 3M CVI-SiC composite matrix after exposure in the PFBC gas environment was calculated to be 1696±195 psi for the entire composite, and 18220±1356 psi for the triaxial braid or structural support layer (Tables 7 and 8). At process operating temperatures of 732°C, the resulting strengths of both the composite and structural support layers are somewhat lowered -- 1429±159 psi and 15599±2246 psi, respectively.

With respect to the load bearing capabilities of the PFBC exposed 3M CVI-SiC composite filter matrix, only 18.4±1.29 lbs was needed to be applied in order to fracture the composite at room temperature, while 15.41±2.22 lbs was needed at temperatures of 732°C. These loads are somewhat higher than the 10.75±1.71 lbs and 13.62±1.90 lbs needed to fracture the as-manufactured 3M CVI-SiC composite filter matrix.

Several factors may be responsible for the increased strength of the 3M CVI-SiC composite filter matrix after 1705 hours of operation in the PFBC gas environment. These include:

- Crystallization of the amorphous phase which is expected to be initially present in the as-manufactured Nextel^{TM} 312 fibers, particularly in the triaxial braid or structural support matrix.

- As suggested by 3M personnel, accumulation of fines with the PFBC exposed filter matrix which tend to "wedge" in between the coated fibers, limiting "crushing" of the filter matrix.

A 254 mm (10 inch) section of material was removed from the PFBC exposed 3M CVI-SiC composite filter matrix. Two 90° strain gage rosettes were installed on both the inside, as well as outside surface of the matrix at approximately the center of the test sample (i.e., 5 inches from either end). A water filled bladder was pressurized to determine the hoop strength of the filter composite matrix. Failure of the matrix (i.e., ~2-3 inch crack formation) occurred through all three layers of the 3M composite filter matrix near the center of the 254 mm (10 inch) burst sample.

TABLE 7
PFBC EXPOSED 3M CVI-SiC COMPOSITE FILTER MATRIX

-- Candle Filter No. 43-1-6 (B/M-15) --
O-Ring Compression

Sample No.	Cross-Head Speed, in/min	Temp., °C	Sample Width, in	Applied Ultimate Load, lbs	Composite Strength, psi	Support Braid Strength, psi
D1	0.05	732	0.588	7.0	1025	11986
D3	0.05	RT	0.993	18.3	1860	18609
D5	0.05	RT	0.993	18.8	1666	18996
D7	0.05	RT	1.002	18.6	1524	18726
D9	0.05	RT	1.013	15.9	1498	15811
D11	0.05	RT	1.015	19.1	1934	18956
D0	0.05	732	0.994	11.9	1218	12107
D2	0.05	732	1.008	13.7	1254	13671
D4	0.05	732	0.999	16.6	1498	16763
D6	0.05	732	0.993	18.8	1637	19024
D8	0.05	732	1.001	16.3	1358	16379
D10	0.05	732	0.981	15.8	1576	16200
D12	0.05	732	0.988	14.8	1465	15052

TABLE 8
SUMMARY OF THE DIAMETRAL O-RING COMPRESSIVE STRENGTH VALUES FOR THE PFBC EXPOSED 3M CVI-SiC COMPOSITE FILTER MATRIX

Sample Thickness, in	Matrix	Room Temp. Strength, psi	High Temp. Strength (732 °C), psi
0.59	Composite *	ND	1025
0.59	Support **	ND	11986
1.00	Composite	1696± 196	1429± 159
1.00	Support	18220±1356	15599±2246

Cross-Head Speed: 0.05 in/min.
* Composite: Entire Filter Matrix.
** Support: Triaxial Braid Layer.
ND: Not Detected.

As shown in Figure 29 both inside and outside strain gages tracked comparably during burst strength testing. The resulting hoop strength as shown in Table 9 is 1.18 ksi for the entire composite filter matrix, while 3.85 ksi is projected to the structural support or triaxial braid. The 1.18 ksi hoop strength for the PFBC exposed 3M matrix is comparable to that of the 1.10 ksi hoop strength value for the as-manufactured filter matrix. In contrast the hoop strength for the structural support layer after exposure in the PFBC gas environment increased by ~0.55 ksi. Again crystallization of the amorphous phase in the Nextel™ 312 fibers and/or wedging of the ash fines in the matrix as suggested by 3M personnel may be responsible for the observed increase in strength of the 3M CVI-SiC composite filter matrix. Further efforts would be needed to verify whether amorphous phase crystallization of the Nextel™ 312 fibers has indeed occurred (i.e., x-ray diffraction analyses), and whether additional phase changes have occurred within the silicon carbide coating which encapsulates the triaxial braid, filtration mat, or open mesh confinement layer fibers.

Based on the strain gage data shown in Figure 29, the PFBC exposed 3M CVI-SiC composite filter matrix has an elastic modulus of 2.5-3.33 x 10^6 psi. The Poisson's ratio for the PFBC exposed matrix was calculated to range between 0.05 (i.e., inside strain gage data along the triaxial support braid layer), and 0.12 (i.e., outside strain gage data along the open mesh confinement layer (Table 9).

TABLE 9
BURST STRENGTH AND ELASTIC MODULUS OF THE
PFBC EXPOSED 3M COMPOSITE FILTER MATRIX

-- Candle Filter No. 43-1-6 --

Burst Strength

Wall Thickness, inch	Hoop Strength, ksi
0.044	3.85
0.152	1.18

Elastic Modulus

Measurement Location	Elastic Modulus	Poisson's Ratio
Inside	3.33×10^6	0.05
Outside	2.50×10^6	0.12

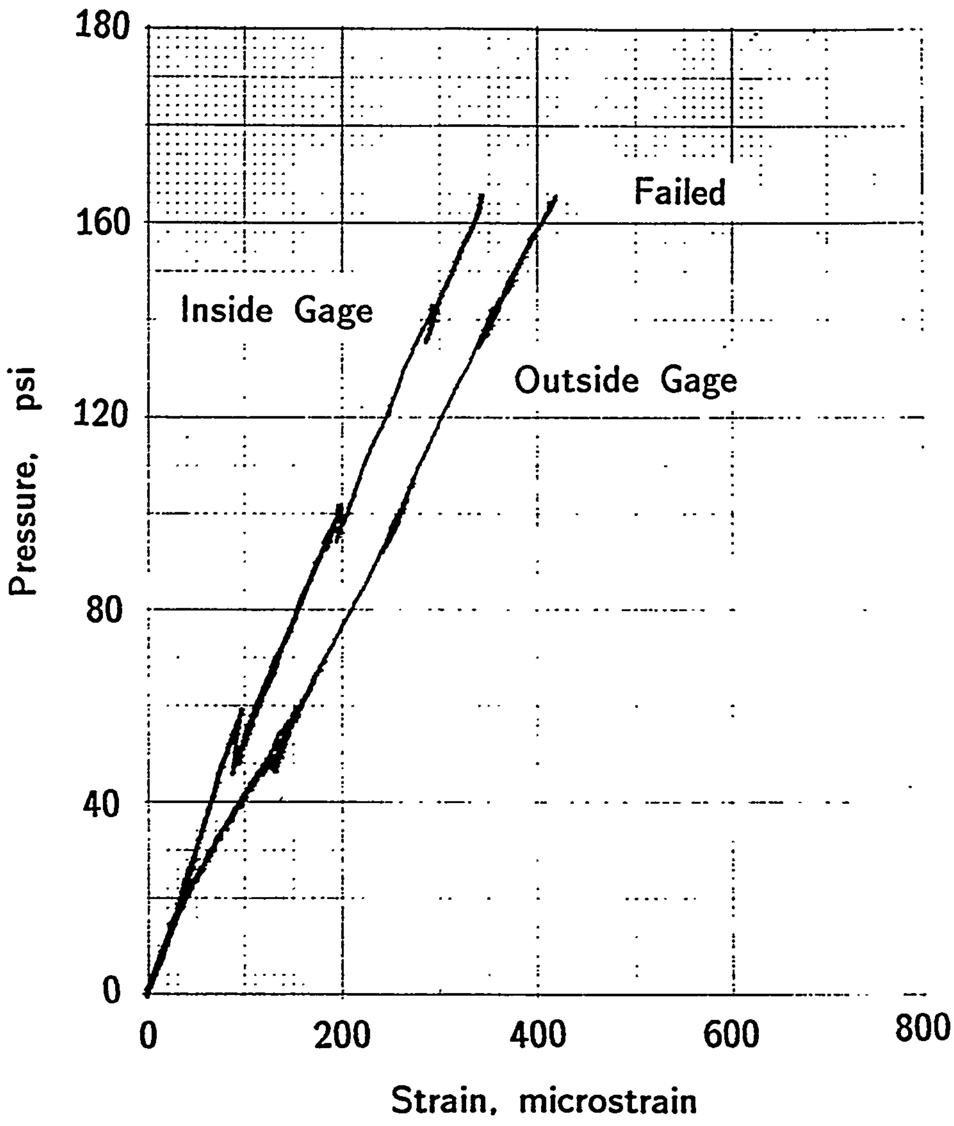


Figure 29 — Pressure Versus Strain Curve For The PFBC Exposed 3M CVI-SiC Composite Filter Matrix (Filter No. 43-1-6; B/M-15)

APPENDIX I

STRENGTH CHARACTERIZATION OF THE FIRST AND SECOND GENERATION CANDLE FILTERS AFTER 1705 HOURS OF PFBC OPERATION AT TIDD

M.A.Alvin

STRENGTH CHARACTERIZATION OF THE FIRST AND SECOND GENERATION CANDLE FILTERS AFTER 1705 HOURS OF PFBC OPERATION AT TIDD

M. A. Alvin
December 22, 1994

ABSTRACT

Previously Westinghouse has monitored the residual strength of the porous ceramic filter elements after operation in the pressurized fluidized-bed combustion (PFBC) gas environment at Tidd. Typically residual strength has been measured via both room temperature and process temperature compressive and tensile strength testing (i.e., C-ring or O-ring), as well as burst strength measurements. In this report a summary of the residual strengths and load bearing capabilities of the first and second generation porous ceramic filter elements after 1705 hours of hot gas filtration in the PFBC gas environment is provided.

STRENGTH CHARACTERIZATION

Between July and October 1994 (Test Segment 4), the Westinghouse Advanced Particulate Filtration (W-APF) system was operated for an additional 1705 hours, bringing the total number of operational hot gas filtration hours for the system to 4734. During this segment of testing, advanced or second generation candle filters were installed in either the B/M or C/M filter arrays. The advanced or second generation candles included eight Coors P-100A-1 alumina/mullite filters, eight Pall Vitropore 442T filters, three DuPont PRD-66 filters, three 3M CVI-SiC composite filters, and eight Schumacher Dia Schumalith FT20 filters. In addition, four Schumacher Dia Schumalith F40 surveillance filters were positioned in the following locations: A/B-16 (S228/318B; 3038 hrs), B/B-16 (S422/322B; 3038 hrs), C/B-16 (S492/322B; 3038 hrs), and B/T-16 (S328/314C; 2572 hrs). All remaining candles which were reinstalled in the top and middle plenums were either new filter elements or elements which had undergone previous testing at Tidd. The filters which were positioned in the lower plenums during this segment of testing had neither been removed nor cleaned after the June 1994 inspection period. These filters had been initially installed and operated in Test Segment 3 for a period of 1268 hours.

Post-test inspection of the W-APF in October 1994 indicated that with the exception of two of the 3M CVI-SiC composite filters, all advanced second generation candles remained intact. Room temperature and process temperature (i.e., 732 °C) strength testing was conducted on one as-manufactured and one PFBC exposed filter from each filter element type. Similarly three Schumacher Dia Schumalith F40 filter elements (i.e., a surveillance candle (4734 hrs total); a previously used filter (2973 hrs total); and a newly installed candle (1705 hrs total)) were also subjected to strength testing.

C-ring compressive and tensile testing was conducted on the Coors P-100A-1 alumina/mullite, Pall Vitropore 442T, DuPont PRD-66, Schumacher Dia Schumalith F40 and FT20 filter matrices, while O-ring diametral compressive strength testing was conducted on the 3M CVI-SiC composite filter matrix. Table 1 summarizes the results of the room temperature and process temperature (i.e., 732 °C) compressive and/or tensile strength tests. Generally the Coors P-100A-1 alumina/mullite filter matrix experiences a slight loss of material strength after 1705 hours of PFBC operation. A greater reduction in strength is experienced by the Pall Vitropore 442T candles during the same operating period. The aged Schumacher Dia Schumalith F40 candles have generally retained their conditioned strength during continued operation in the W-APF system. A slight increase in strength is evident along the ID wall of the Schumacher Dia Schumalith FT20 filter matrix after experiencing 1705 hours of hot gas filtration. Both the DuPont PRD-66 and 3M CVI-SiC composite filter matrices appeared to strengthen during the 1705 hour test period. Crystallization of the amorphous phase in each of these matrices may be responsible for the apparent strength increase. Alternately since both filter matrices were filled with ash, fines may have wedged between the fibers or fiber bundles, stiffening the matrix, and preventing the matrix from fracturing at a lower load.

Table 2 provides a summary of the loads that were applied to fracture the various filter matrices. Note that the data shown in Tables 1 and 2 for the 3M CVI-SiC composite filter matrix were generated via diametral O-ring compressive strength testing, while data for all other filter materials were generated via C-ring compressive and/or tensile testing. Although not directly comparable, we see that the load bearing capabilities of the DuPont PRD-66 and 3M CVI-SiC composite matrices are lower in comparison to the Coors P-100A-1 alumina/mullite, Pall Vitropore 442T, and Schumacher Dia Schumalith F40 and FT20 filter matrices. Currently diametral O-ring strength testing is being conducted on all materials, such that a direct comparison of the load bearing capabilities of the first and advanced or second generation filter materials can be made.

Table 3 provides a summary of all of the strength testing that has been conducted at Westinghouse STC for the Schumacher Dia Schumalith F40 filter matrix since the beginning of this test program. Similarly Table 4 identifies the percent strength retention in the Schumacher Dia Schumalith F40 matrix as a function of manufacturing or

TABLE 1
RESIDUAL STRENGTHS OF THE VARIOUS POROUS CERAMIC CANDLE FILTERS

Filter Matrix	Candle ID No.	W-APF Location	Room Temperature Strength, psi		High Temperature (732°C) Strength, psi	
			C-Ring Compression	C-Ring Tension	C-Ring Compression	C-Ring Tension
Coors P-100A-1 Alumina/Mullite						
	DC-013	---	2575±182	2721±415	3107±276	3353±231
	DC-003	B/M-16	2475±189	2903±289	2738±161	3291±246
Pall Vitropore 442T						
	R2-325	---	2857±186	2574±177	3430±221	3029±149
	R5-325	B/M-20	2311±231	2034±139	2453±187	2138±180
Schumacher Dia Schumalith F40						
	S442/322B	B/B-16	870±145	816±112	1031±105	1139±160
	S1742/348C	B/B-17	1491±158	1326±157	1687± 87	1595±132
	S2129/355C	B/B-18	1553± 83	1678±526	1478±124	1480±257
Schumacher Dia Schumalith FT20						
	S199/315E	---	2296±261	2268±167	3043±148	2708±360
	S039/312E	C/M-15	2283±184	2370±238	3041±238	3102±272
DuPont PRD-66						
	D-99	---	1219±162	1265±188	1277±178	1304±327
	D-132	B/M-7	1830±238	1725±320	1884±142	1642±401
	D-123	B/M-8	1946±206	1841±232	2023±197	1769±234

Brittle Fracture Characteristics Exhibited By All Filter Matrices At Both Room Temperature And At Process Temperature.

TABLE 1 (Continued)
RESIDUAL STRENGTHS OF THE VARIOUS POROUS CERAMIC CANDLE FILTERS

Filter Matrix	Candle ID No.	W-APF Location	Room Temperature Strength, psi		High Temperature (732 °C) Strength, psi	
			O-Ring Diametral Composite	Triaxial Braid	O-Ring Diametral Composite	Triaxial Braid
3M CVI-SiC Composite						
	43-1-2	---	1341±254	14026±2012	1060±219	11012±1795
	43-1-6	B/M-15	1696±195	18220±1356	1429±159	15599±2246

Graceful Fracture Toughened Failure Characteristics Were Exhibited By The As-Manufactured 3M CVI-SiC Composite Filter Matrix.
The PFBC Exposed 3M CVI-SiC Composite Filter Matrix Exhibited Brittle Failure Characteristics.

TABLE 2
ULTIMATE APPLIED LOAD PRIOR TO FAILURE

Filter Matrix	Candle ID No.	W-APF Location	Room Temperature Load, lbs C-Ring Compression	Room Temperature Load, lbs C-Ring Tension	High Temperature (732 °C) Load, lbs C-Ring Compression	High Temperature (732 °C) Load, lbs C-Ring Tension
Coors P-100A-1 Alumina/Mullite						
	DC-013	---	42.8±2.4	31.4±4.9	52.2±4.7	38.1±2.5
	DC-003	B/M-16	41.7±4.7	33.9±2.7	47.0±4.7	38.5±3.7
Pall Vitropore 442T						
	R2-325	---	60.5±5.9	35.5±1.8	71.9±3.5	41.7±2.9
	R5-325	B/M-20	48.9±6.1	27.6±2.2	51.8±2.8	29.5±2.0
Schumacher Dia Schumalith F40						
	S442/322B	B/B-16	47.0±10.8	21.6±3.2	55.6±8.4	30.2±4.8
	S1742/348C	B/B-17	83.4±10.2	36.8±4.4	96.2±9.0	44.2±5.8
	S2129/355C	B/B-18	85.9±5.3	46.3±15.7	82.1±7.6	41.1±9.1
Schumacher Dia Schumalith FT20						
	S199/315E	---	44.2±4.8	29.2±2.9	59.5±4.0	34.6±4.6
	S039/312E	C/M-15	45.5±4.6	31.1±3.1	60.0±3.9	40.2±4.9
DuPont PRD-66						
	D-99	---	9.2±1.0	7.3±1.3	9.8±1.3	7.5±1.9
	D-132	B/M-7	14.7±1.4	10.3±1.8	14.8±1.0	9.9±2.3
	D-123	B/M-8	15.6±1.5	11.4±1.3	16.4±1.7	10.8±1.5

TABLE 2
ULTIMATE APPLIED LOAD PRIOR TO FAILURE

Filter Matrix	Candle ID No.	W-APF Location	Room Temperature Load, lbs: C-Ring Diametral Composite	Room Temperature Load, lbs: C-Ring Diametral Triaxial Braid	High Temperature (732 °C) Load, lbs: O-Ring Diametral Composite	High Temperature (732 °C) Load, lbs: O-Ring Diametral Triaxial Braid
3M CVI-SiC Composite						
	43-1-2	---	13.6±1.9	-----	10.8±1.7	-----
	43-1-6	B/M-15	18.1±1.3	-----	15.4±2.2	-----

TABLE 3

SUMMARY OF THE STRENGTH DATA FOR THE CLAY BONDED SILICON CARBIDE SCHUMACHER F40 MATERIAL AFTER EXPOSURE IN THE PFBC GAS ENVIRONMENT AT AEP

Filter ID	Filtration Time, Hrs	Room Temperature C-Ring Compression psi *	Room Temperature C-Ring Tension psi *	Process Temperature C-Ring (732°C) Compression psi *	Process Temperature C-Ring (732°C) Tension psi *	Ultimate Hoop Stress, psi	Youngs Modulus, psi x 10^6	Full Body 4-Pt Flex Strength, psi	Full Body Elastic Modulus, psi x 10^6
As-Manufactured 1991									
S/APF-131/317B	---	1285±197	NA	1120±104 (1)	NA	1491	5.07	NA	NA
S/APF-153/317B	--- •	1300±213	1907±111	1416±127	2328±228	1447, 1905	5.13, 5.67	NA	NA
S/APF-441/322B	---	NT	NT	NT	NT	1089	NA	NA	NA
Ash Hopper	464	966±120	NT	1018±114	NT	1492	5.40	NA	NA
Segment	464	1147±134	1372±122	1114±114	1635±321	NA	NA	NA	NA

(1) Strength Tested At 870°C
(2) Bowed Candle.
(3) Data In Parentheses Provided By Schumacher GmbH.
(4) 1991 Or 1992 Fabrication Lot And Corresponding Exposure Period Cannot Be Determined For The Broken Candle Sections Removed From The Ash Hopper In September 1993.

* 9-12 C-Rings Tested Per Reported Value.
** One Ring Tested.
*** Two Rings Tested.

NA: Not Available.
NT: Not Tested.
TBD: To Be Determined.

• Poissons Ratio: 0.17.
•• Fractured Candles.

TABLE 3 (continued)

SUMMARY OF THE STRENGTH DATA FOR THE CLAY BONDED SILICON CARBIDE SCHUMACHER F40 MATERIAL AFTER EXPOSURE IN THE PFBC GAS ENVIRONMENT AT AEP

Filter ID	Filtration Time, Hrs		Room Temperature C-Ring Compression psi *	Room Temperature C-Ring Tension psi *	Process Temperature C-Ring (732°C) Compression psi *	Process Temperature C-Ring (732°C) Tension psi *	Ultimate Hoop Stress, psi	Youngs Modulus, psi x 10^6	Full Body 4-Pt Flex Strength, psi	Full Body Elastic Modulus, psi x 10^6
Full Candles - 1991 Production Lot										
S/APF-504/322B	464	B/T-1	1120±123	NA	1226±116	NA	1309 (1088)(3)	4.58	NA	NA
S/APF-436/321B	464	B/M-1	1096±116	NA	1172±134	NA	1178 (1073)(3)	4.99	NA	NA
S/APF-193/318B	464	B/B-1	1147±119	NA	1245±108	NA	1149 (1261)(3)	5.49	NA	NA
S/APF-065/314B	464	A/B-6	940± 60	NA	1056±131	NA	1122 (986)(3)	4.84	NA	NA
S/APF-106/317B	464	B/B-45	1180± 98(2)	NA	1230±127	NA	1282 (1233)(3)	5.19	NA	NA
S/APF-324/319B	464	B/B-9	1083±148	1438±108	1137±101	1778±246	1363	5.36	1128	4.62
S/APF-109/317B	464	B/B-41	1140±120	1424±162	1132±112	1873±174	1327	5.06	1179	4.67
S/APF-215/378B	1760	B/M-22	908± 72	1117± 91	1064± 72	1418±122	1206	4.56	NA	NA
S/APF-447/322B	1760	A/T-22	794± 50	709± 71	1028± 94	973±121	1056	4.30	NA	NA
S/APF-455/322B	1760	B/T-22	793± 58	711± 89	989± 77	885± 54	1006	3.42	NA	NA
S/APF-523/322B	1760	C/T-22	793± 39	1016±134	968± 96	1252±241	1075	4.40	NA	NA
S/APF-418/321B	3038	B/T-16	720± 57	944±172	890± 65	1284±199	NA	NA	NA	NA
S/APF-442/322B	4734	B/B-16	870±145	816±112	1031±105	1139±160	NA	NA	NA	NA
Fractured Candles - 1991 Production Lot ••										
S/APF-427/321B	1760	B/M-19	586± 62	835±110	802± 67	1104±170	NA	NA	NA	NA
S/APF-755/317B	1760	A/M-38	718± 29	970±162	856± 57	1194± 63	NA	NA	NA	NA

(1) Strength Tested At 870°C
(2) Bowed Candle.
(3) Data In Parentheses Provided By Schumacher GmbH.
(4) 1991 Or 1992 Fabrication Lot And Corresponding Exposure Period Cannot Be Determined For The Broken Candle Sections Removed From The Ash Hopper In September 1993.

* 9-12 C-Rings Tested Per Reported Value.
** One Ring Tested.
*** Two Rings Tested.
• Poissons Ratio: 0.17.
•• Fractured Candles. Sections That Remained In The Flange Were Characterized.

NA: Not Available.
NT: Not Tested.
TBD: To Be Determined.

Fail-Safe/Regenerator Was Included Above S/APF-418/321B During The Final 1278 HOurs Of Test Operation.

TABLE 3 (continued)
SUMMARY OF THE STRENGTH DATA FOR THE CLAY BONDED SILICON CARBIDE SCHUMACHER F40 MATERIAL AFTER EXPOSURE IN THE PFBC GAS ENVIRONMENT AT AEP

Filter ID	Filtration Time, Hrs	Room Temperature C-Ring Compression psi *	Room Temperature C-Ring Tension psi *	Process Temperature C-Ring (732°C) Compression psi *	Process Temperature C-Ring (732°C) Tension psi *	Ultimate Hoop Stress, psi	Youngs Modulus, psi x 10^6	Full Body 4-Pt Flex Strength, psi	Full Body Elastic Modulus psi x 10^6
As-Manufactured 1992									
S/APF-482/315C	---	1790±112	2308±275	2064±204	3519±285	NA	NA	1666	5.87
Ash Hopper Segment	1296-1760(4)	759± 39	979 **	933±100	1427±402 ***	NA	NA	NA	NA
	1296-1760(4)	784± 49	NT	874± 89	NT	NA	NA	NA	NA
	1296-1760(4)	739± 46	935 **	727± 94	NT	NA	NA	NA	NA
Full Candles - 1992 Production Lot									
S/APF-452/315C	1296 B/B-22	1277± 85	1298±189	1430±125	1628±324	1152	5.96	NA	NA
S/APF-494/315C	1296 A/B-22	1012± 48	1166± 77	1416± 70	1380± 86	1341	5.42	NA	NA
S/APF-460/315C	1278 B/M-17	1253± 72	1275±134	1612±103	1809±251	NA	NA	NA	NA
S/APF-528/315C	2574 B/B-16	941± 40	1150±195	1333±108	1733±124	NA	NA	NA	NA
S/APF-638/325C	1278 C/T-38	1165±135	1073±213	1705± 91	1669±283	NA	NA	NA	NA
S/APF-291/314C	1278 B/T-17	1176± 73	1354± 88	1660± 55	1777±233	NA	NA	NA	NA
S/APF-316/314C	1278 A/T-17	1149± 67	1151±164	1520±105	1639±144	NA	NA	NA	NA
S/APF-563/316C	1278 C/T-17	1243± 84	1422±182	1937± 71	1906±148	NA	NA	NA	NA

(1) Strength Tested At 870°C
(2) Bowed Candle.
(3) Data In Parentheses Provided By Schumacher GmbH.
(4) 1991 Or 1992 Fabrication Lot And Corresponding Exposure Period Cannot Be Determined For The Broken Candle Sections Removed From The Ash Hopper In September 1993.
* 9-12 C-Rings Tested Per Reported Value.
** One Ring Tested.
*** Two Rings Tested.
• Poissons Ratio: 0.17.
•• Fractured Candles. Sections That Remained In The Flange Were Characterized.

NA: Not Available.
NT: Not Tested.
TBD: To Be Determined.

TABLE 3 (continued)

SUMMARY OF THE STRENGTH DATA FOR THE CLAY BONDED SILICON CARBIDE SCHUMACHER F40 MATERIAL AFTER EXPOSURE IN THE PFBC GAS ENVIRONMENT AT AEP

Filter ID	Filtration Time, Hrs	Room Temperature C-Ring Compression psi *	Room Temperature C-Ring Tension psi *	Process Temperature C-Ring (732°C) Compression psi *	Process Temperature C-Ring (732°C) Tension psi *	Ultimate Hoop Stress, psi	Youngs Modulus, psi x 10^6	Full Body 4-Pt Flex Strength, psi	Full Body Elastic Modulus psi x 10^6
As-Manufactured 1993									
S/APF-1788/348C	---	1470± 96	1971±367	1861±138	2381±271	NA	NA	NA	NA
S/APF-2097/352C	---	1451± 83	1843±239	1450±100•	2374±213•	NA	NA	NA	NA
S/APF-2187/355C	---	1540±173	1821±266	1961±117	2026±351	NA	NA	NA	NA
Full Candles - 1993 Production Lot									
S2134/355C	1268	1053± 39	1300± 87	1231± 48	1534±141	NA	NA	NA	NA
S1742/348C B/B-17	1705	1491±158	1326±157	1687± 87	1595±132	NA	NA	NA	NA
S2129/355C B/B-18	2973	1553± 83	1678±526	1478±124	1480±257	NA	NA	NA	NA

* 9-12 C-Rings Tested Per Reported Value.
• Strength Tested At 843°C.

TABLE 4
PERCENT RESIDUAL STRENGTH RETENTION IN THE SCHUMACHER DIA SCHUMALITH F40 FILTERS

			Room Temperature		Hot Strength, 732 °C	
Candle ID F-40 1991	Temp., °C	Time, Hrs Test Segment	% Compression C-Ring	% Tension C-Ring	% Compression C-Ring	% Tension C-Ring
S504/322B	732	464 A	87	NA	97	NA
S436/321B	732	464 A	85	NA	92	NA
S193/318B	732	464 A	89	NA	98	NA
S065/314B	732	464 A	73	NA	83	NA
S106/317B	732	464 A	91	NA	97	NA
S324/319B	732	464 A	84	75	90	76
S109/317B	732	464 A	88	75	89	81
S215/378B	732	1760 A,B	70	59	84	61
S447/322B	732	1760 A,B	61	37	81	42
S455/322B	732	1760 A,B	61	37	78	38
S523/322B	732	1760 A,B	61	53	76	54
S418/321B	732	3038 A,B,C	56	50	70	55
S422/322B	732	4734 A-D	67	43	81	49

NA: Not Available.
A: Test Segment 1
B: Test Segment 2
C: Test Segment 3
D: Test Segment 4

TABLE 4 (Continued)
PERCENT RESIDUAL STRENGTH RETENTION IN THE SCHUMACHER DIA SCHUMALITH F40 FILTERS

			Room Temperature		Hot Strength, 732 °C	
Candle ID F-40 1992	Temp., °C	Time, Hrs Test Segment	% Compression C-Ring	% Tension C-Ring	% Compression C-Ring	% Tension C-Ring
S452/315C	732	1296 B	71	56	69	46
S494/315C	732	1296 B	57	51	69	39
S460/315C	732	1278 C	70	55	78	51
S528/315C	732	2574 B,C	53	50	65	49
S638/325C	732	1278 C	65	47	83	47
S291/314C	732	1278 C	66	59	80	51
S316/314C	732	1278 C	64	50	74	47
S563/316C	732	1278 C	69	62	94	54

A: Test Segment 1
B: Test Segment 2
C: Test Segment 3
D: Test Segment 4

TABLE 4 (Continued)
PERCENT RESIDUAL STRENGTH RETENTION IN THE SCHUMACHER DIA SCHUMALITH F40 FILTERS

Candle ID F-40 1993	Temp., °C	Time, Hrs Test Segment	Room Temperature % Compression C-Ring	Room Temperature % Tension C-Ring	Hot Strength, 732 °C % Compression C-Ring	Hot Strength, 732 °C % Tension C-Ring
S2134/355C	732	1268 C	71	69	70	68
S1742/348C	732	1705 D	100	71	96	71
S2129/355C	732	2973 C,D	104	89	84	66

A: Test Segment 1
B: Test Segment 2
C: Test Segment 3
D: Test Segment 4

production lots, as well as operating time in the PFBC environment. For completeness, percent strength retention in the various advanced or second generation filter elements is provided in Table 5.

FILTER LENGTH MEASUREMENTS

The lengths of three Schumacher Dia Schumalith F40 candle filters, one Schumacher Dia Schumalith FT20 candle filter, and one Pall Vitropore 442T candle filter were measured after the elements had been removed from the W-APF in October 1994. As shown in Table 6, only one filter element had its original length reported based on the filter identification number recorded during candle installation and the inspection sheet data provided by the various candle filter suppliers.

After 4734 hours of operation in the PFBC gas environment at Tidd, the Schumacher Dia Schumalith F40 filter may be experiencing elongation as seen by the difference of ~3 mm from its as-manufactured length. The slight increase in length may have resulted from either the inclusion of ash residue along the flange or end cap, or possibly variations in the measurement techniques used by Schumacher and Westinghouse personnel. Clearly, elongation of the clay bonded silicon carbide Schumacher Dia Schumalith F40 matrix is virtually non-existent at the nominal Tidd operating temperatures of 732 °C in comparison to the ~26 mm elongation experienced by the clay bonded silicon carbide Pall Vitropore 442T candles in the 830 °C circulating pressurized fluidized-bed combustion (CPFBC) gas environment at the Ahlstrom test facility in Karhula, Finland.(1)

SUMMARY

Exposure of the advanced or second generation, fiber reinforced filters to 1705 hours of hot gas filtration in the PFBC gas environment resulted in a strengthening of the filter matrices. The apparent strengthening was attributed to crystallization of the amorphous phases which may be present in the as-manufactured filter elements. Westinghouse has previously encountered strengthening of the porous ceramic filter matrices when the original Coors P-100A alumina/mullite matrix was exposed to simulated PFBC environments.(2,3) This primarily resulted from crystallization of the amorphous phase in the P-100A alumina/mullite filter matrix which led to the production of anorthite, as well as an increase in the strength of the filter matrix. Modifications which were made to the alumina/mullite matrix eliminated the initial amorphous content, and decreased the raw material particle size which assisted in strengthening the P-100A-1 alumina/mullite filter matrix. Extended operating time of the DuPont PRD-66 and 3M

TABLE 5
PERCENT RESIDUAL STRENGTH RETENTION
IN THE MONOLITHIC AND SECOND GENERATION FILTERS
AFTER EXPOSURE AT TIDD

Candle ID	Temp., °C	Time, Hrs Test Segment	Room Temperature % Compression C-Ring	Room Temperature % Tension C-Ring	Hot Strength, 732 °C % Compression C-Ring	Hot Strength, 732 °C % Tension C-Ring
Coors P-100A-1 Alumina/Mullite						
DC-003	732	1705	96	107	88	98
Pall Vitropore 442T						
R5-325	732	1705	81	79	72	71
Schumacher Dia Schumalith FT20						
S039/312E	732	1705	99	105	100	115
DuPont PRD-66						
D-132	732	1705	150	136	148	126
D-123	732	1705	160	146	158	136

TABLE 5 (continued)
PERCENT RESIDUAL STRENGTH RETENTION
IN THE MONOLITHIC AND SECOND GENERATION FILTERS
AFTER EXPOSURE AT TIDD

Candle ID	Temp., °C	Time, Hrs Test Segment	Room Temperature % O-Ring Compression Composite	Room Temperature % O-Ring Compression Braid	Hot Strength, 732°C % O-Ring Compression Composite	Hot Strength, 732°C % O-Ring Compression Braid
3M CVI-SiC Composite						
43-1-6	732	1705	127	130	135	142

TABLE 6

FILTER LENGTH MEASUREMENTS

Filter ID No.	Location In The W-APF	Operating Hours	Initial Length, mm	Final Length, mm
S422/322B	B/B-16	4734	1516	1518.8
S1742/348C	B/B-17	1705	NG	1514
S2129/355C	B/B-18	2973	NG	1514.5
S039/312E *	C/M-15	1705	NG	1516
R5-325	B/M-20	1705	NG	1503.3

NG: Not Given.
* Radiused End Cap.

CVI-SiC composite filters in the PFBC environment will be needed to identify whether additional strengthening of the fiber reinforced matrices results. Similarly x-ray diffraction analyses are recommended to be performed in order to verify whether the assumed mechanism for matrix strengthening is valid.

In contrast to the second generation filter materials, the first generation monoliths initially lose strength during operation in the PFBC gas environment. Although the binder phase of the clay bonded Schumacher Dia Schumalith F40 matrix was shown to crystallize during the 3038 hours of operation at Tidd, forming what was considered to be a conditioned state,[4] the matrix appeared to maintain a relatively constant strength throughout the remainder of testing in Test Segment 4.

The strength data presented to date indicate that porous ceramic candle filters which have strengths as low as 800 psi can remain intact and functional during extended operation in the Tidd PFBC environment.

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2. M. A. Alvin, D. M. Bachovchin, T. E. Lippert, R. E. Tressler, and K. R. McNerney, "Thermal/Chemical Stability of Ceramic Cross Flow Filter Materials," Twelfth Annual Gasification and Gas Streams Cleanup Systems Contractors Review Meeting, Morgantown, WV, September 15-17, 1992.

3. M. A. Alvin, T. E. Lippert, D. M. Bachovchin, and R. E. Tressler, "High Temperature Filter Materials," Ninth Annual Coal-Fueled Heat Engines, Advanced Pressurized Fluidized Bed Combustion and Gas Stream Cleanup Systems Contractors Review Meeting, Morgantown, WV, October 27-29, 1992.

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APPENDIX J

FILTERS USED IN THE DECEMBER 1994 RECANDLING EFFORT AT TIDD

M.A.Alvin

FILTERS USED IN THE DECEMBER 1994 RECANDLING EFFORT AT TIDD

M. A. Alvin

December 27, 1994

The attached figure schematically provides the locations of the various filter elements which were installed in the Westinghouse Advanced Particulate Filtration (W-APF) at Tidd during November and December 1994. First generation monolithic, as well as advanced second generation filter elements were used during this installation. The following provides a preliminary summary of the various filter types that were used in each of the plenum arrays:

Plenum Location	Filters
A/T	21 Coors Alumina/Mullite P-100A-1 1 Schumacher F40 (Surveillance)
A/M	22 Coors Alumina/Mullite P-100A-1
A/B	52 Coors Alumina/Mullite P-100A-1
B/T	22 DuPont PRD-66
B/M	3 Coors Alumina/Mullite (Test Segment 4) 3 Pall Vitropore 442T (Test Segment 4) 3 Schumacher F40 (Test Segments 3 and 4) 13 Pall Vitropore 442T
B/B	1 Schumacher F40 (Surveillance) 5 3M CVI-SiC Composite 46 Pall Vitropore 442T
C/T	5 3M CVI-SiC Composite 17 Pall Vitropore 442T
C/M	22 Pall Vitropore 442T
C/B	52 Pall Vitropore 442T

All candles unless otherwise stated were newly manufactured filter elements.

Templates showing the filter identification numbers and locations will be provided for all five recandling efforts at Tidd. Similarly, comments regarding the detection of dust along the ID of the filters and holder mounts which resulted during Test Segment 4 (July-October 1994) will also be provided.

During candle installation and removal, filter identification numbers were frequently transposed, were misread (i.e., the European 1 was read as a 7; a 4 became a 9; a 2 became a 7, etc.), duplicated, or were unreadable based on the manner or location that the vendor initially marked the filter elements. During disassembly, array A/B became B/A which fortunately is an obvious fix. Tracking the filter elements based on the vendor inspection sheet information helps to circumvent many of these errors, but when redundant or transposed candle identification numbers are recorded, identifying an actual candle and monitoring its history becomes clearly difficult. With this in mind, caution should be exercised when using the 1728 filter identification numbers and their respective locations [(384 x 3) + (288 x 2)] which will be provided. Specifically tracking only a small number of filter elements (i.e., the surveillance candles) is expected to alleviate this problem, but limits candle progression and life in the event of failure as during an ash bridging or thermal transient event.

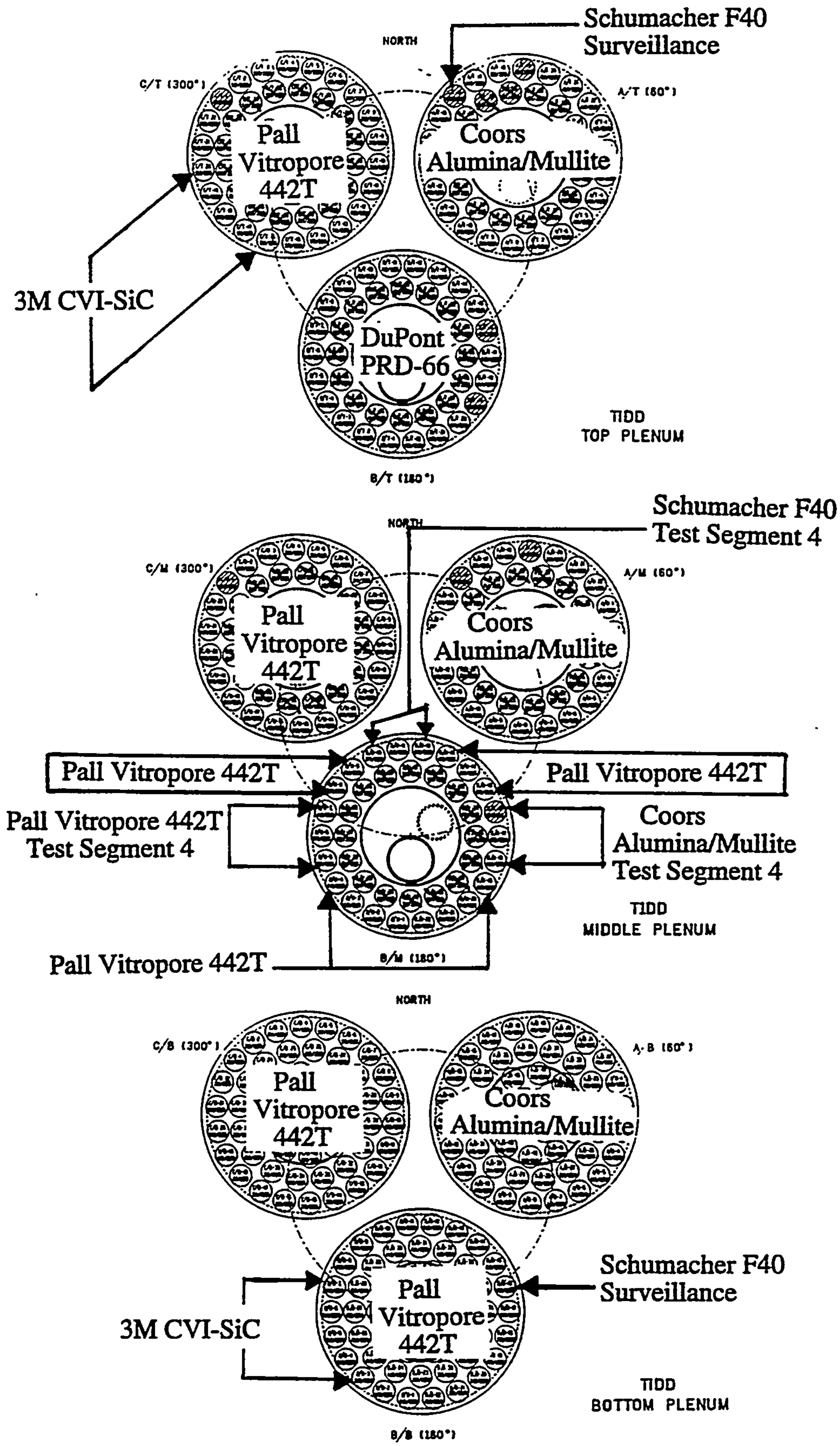

Figure 1 – Filter Locations During The December 1994 Recandling Effort