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**FILTER TESTING AND DEVELOPMENT FOR PROLONGED
TRANSURANIC SERVICE AND WASTE REDUCTION**

MASTER

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FILTER TESTING AND DEVELOPMENT FOR
PROLONGED TRANSURANIC SERVICE
AND WASTE REDUCTION

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INTRODUCTION

The life of High Efficiency Particulate Air (HEPA) filters used in transuranic service is influenced greatly by the gaseous and particulate matter to which the filters are exposed. The most severe conditions encountered at Rocky Flats are at the ventilation systems serving the plutonium recovery operations in Bldg. 771.

A project titled "Filter Testing and Development for Prolonged Transuranic Service and Waste Reduction," was formally initiated at Rocky Flats on July 1, 1975. The project is directed toward improving filtration methods which will prolong the life of HEPA filter systems without sacrificing effectiveness. Another important aspect of the project is to reduce the volume of HEPA filter waste shipped from the plant for long-term storage.

An initial report of the work performed on this project was issued during March 1976 and covered the period from July 1, 1975 to December 31, 1975. Because of the Federal changes in the fiscal reporting periods, the present report covers activities for a nine-month period from January 1, 1976 to September 30, 1976. Subsequent reports will be issued on a six-month basis, beginning with October 1, 1976.

The reporting format follows the description of tasks as outlined in the program plan described in the form 189c.

proposal as originally submitted to the Waste Management Section of the Nuclear Fuel Cycle and Production Division, ERDA, Washington.

The work on this project uses the personnel and the very considerable resources of the Rocky Flats Plant located near Golden, Colorado. In-service filter studies are conducted in actual production facilities devoted to plutonium recovery and fabrication. All branches of the Analytical Laboratories are available and have been responsible for all of the analytical data included in this report. Production of hand sheets and mechanical testing of filter media have been accomplished in the Rocky Flats Filter Certification Laboratory, and work on new components has received the time and attention of personnel of the Component Development Laboratory.

Mr. Humphrey Gilbert, formerly of the Health & Safety Division of the Atomic Energy Commission has served as consultant on this program since its inception.

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A. LITERATURE SEARCH - K. Terada

The literature search for all studies on HEPA filters is kept current by regular perusal of the pertinent periodicals. Remaining up to date on filtration literature is relatively simple due to good communication between investigators of filtration science and technology.

A search for literature pertaining to materials used for separators in the HEPA filters has been initiated. This search is in regard to finding a replacement for asbestos in the separator used for the Rocky Flats-type HEPA filter.

B. ANALYSES OF EFFLUENTS - R. W. Woodard

The plan to sample exhaust air at various locations in the chemical plutonium recovery system, Bldg. 771, was mentioned in the first progress report¹.

A sketch of the exhaust system showing the sample points is shown in Figure 1. All of the sample points mentioned in the discussion immediately following are references to this Figure.

Figure 1

LOCATION OF TYPICAL
SAMPLING POINTS IN BLDG. 771

(● - Sample Point)

The glovebox line available for these studies is used for leaching residues containing plutonium. Nitric acid containing a small concentration of fluoride ion is used in the leaching process. Air in the box is relatively high in concentration of chemical and particulate components.

Sampling and analyses of effluents for chemical components were carried out at sample points E, F, and G (Figure 1) using two methods:

1. The sample was collected in a trap cooled by liquid nitrogen. The sample was then warmed to volatilize gaseous components into a mass spectrometer for identification. Residue remaining in the trap was dissolved in a known volume of water and analyzed by means of specific ion electrodes to determine concentrations of chloride, fluoride, and nitrate ions. Use of the specific ion electrode technique to determine the concentration of nitrate, was found impractical because of the high minimum detectable limit.
2. A second method, limited to determining the concentration of NO_x , utilized an Environmetric Multi-Gas Analyzer. The analyzer utilizes a sensor in which the electrocatalytic oxidation or reduction of NO_x generates a current under diffusion limited conditions giving a linear output relative to the NO_x concentration.

Samples taken at point E (inside the glovebox enclosure) gave the concentrations of chemicals (Vol. ppm) shown in Table I.

TABLE I.
ANALYSES OF
SAMPLES FROM INSIDE GLOVEBOX
(POINT E, LINE 24 - FIG. 1)

<u>Date</u> <u>Sampled</u>	<u>Method of</u> <u>Sampling and Analyses</u>	<u>NO_x</u>	<u>F⁻</u>	<u>Cl⁻</u>	<u>H⁺</u>
1/22/76	LN ₂ Trap + Mass Spec.	76.3			
1/27/76	" " " " "	20.4			
1/27/76	" " " " "	18.3			
1/28/76	" " " " "	182.0	2.53*	21.3*	2.9*

*Specific Ion Electrode on trap rinse to determine concentration of F⁻, Cl⁻, and H⁺

The Environmetrics instruments was used to determine the concentration of NO_x in the glovebox (point E) and exhaust header (point F) immediately downstream from the glovebox.

In Table II, concentrations shown were obtained by switching the sample gas flow to the instrument between locations E and F to provide an indication of the effect of the glovebox exhaust filter.

Figure 2 is a photograph of a glovebox line (Line 24) in which the plutonium is leached from refractory residues.

TABLE II
NO_x CONCENTRATION IN
GLOVEBOX (E) AND
GLOVEBOX EXHAUST HEADER (F)
 (Figure 1)

<u>Date</u>	<u>Time</u>	NO _x (Vol. ppm) at Locations	
		<u>E</u>	<u>F</u>
4/21/76	10:30 A.M.	18	
	12:30 P.M.	12	
	2:45 P.M.	9	
4/22/76	8:50 A.M.	114	
	2:45 P.M.	171	160
4/29/76	11:00 P.M.	3	2
	2:30 P.M.	13	8
4/30/76	8:00 A.M.	2	2
	10:10 A.M.	23	15
	12:40 P.M.	1	5
	2:45 P.M.	1	1
5/4/76	8:30 A.M.	0	0
	10:10 A.M.	1	0
	1:00 P.M.	90	30
	2:45 P.M.	0	0
5/5/76	8:20 A.M.	54	15
	10:10 A.M.	30	10

These data show a tendency of lower concentration of NO_x in the exhaust after passing through the glovebox filter.

Figure 2
Plutonium Glovebox

Both mass spectrometric and the Environmetric Analyzer were used to determine NO_x concentration at sample point G (See Figures 1 and 3). Results of analyses are shown in Table III.

TABLE III
 NO_x CONCENTRATION AT
COOLING CHAMBER EXHAUST (G)
(Figure 1)

<u>Date</u>	<u>Analytical Method</u>	<u>NO_x Conc. (Vol. PPM)</u>
11/19/75	LN_2 Trap + Mass Spec.	0.36
11/20/75	" " " " "	1.76
11/24/75	" " " " "	1.37
2/9/76	Environmetrics Analyzer	1.00 to 6.00
2/10/76	" "	4.00 to 6.00
2/25/76	" "	0.50 to 2.00
2/27/76	" "	0.50 to 1.00
3/1/76	" "	0.50 to 1.20
3/2/76	" "	0.50 to 1.00
3/3/76	" "	0.50 to 2.50
3/4/76	" "	1.00 to 1.20
3/5/76	" "	0.50 to 1.00

The low concentrations of NO_x observed in the exhaust from the cooling chamber is explained by the fact that

Figure 3
Cooling Chamber
(Note Sample Point "G")

exhaust air from all glovebox lines in the production recovery areas converge in the chamber. This has a dilution effect since many of the lines do not contribute NO_x , thus lowering the overall concentration of this component.

Membrane filters Millipore[®] (AA 0.8 μm) were used to collect samples of particulates at points E and F. Table IV exhibits results of the sampling.

TABLE IV

ALPHA ACTIVITY UPSTREAM AND DOWNSTREAM
OF GLOVEBOX EXHAUST FILTER (LINE 24)

(Figure 1)

<u>Alpha Activity</u> <u>in Box (E)</u> <u>(d/m/m³)</u>	<u>Alpha Activity in</u> <u>Exhaust Header (F)</u> <u>(d/m/m³)</u>	<u>Removal of</u> <u>Alpha Activity</u> <u>(%)</u>
3.65 x 10 ⁷	1.7 x 10 ⁵	99.54
7.52 x 10 ⁶	4.0 x 10 ⁴	99.47
5.73 x 10 ⁶	2.0 x 10 ³	99.97
3.14 x 10 ⁷	4.0 x 10 ⁴	99.87
1.58 x 10 ⁷	2.8 x 10 ⁴	99.82
Average:		
1.94 x 10 ⁷	6.2 x 10 ⁴	99.68

[®] Millipore is the registered trademark of Millipore Corp., Bedford, Mass., U.S.A.

The distribution of the particle size of material collected on membrane filters at point E was determined using a Quantimet 720 particle size analyzer which combines optical and electronic counting and sizing systems. Table V and Figure 4 present particle size data.

TABLE V
DISTRIBUTION OF PARTICULATES SAMPLED
IN GLOVEBOX LINE 24
(Point E - Figure 1)

<u>Size of Particulate</u> <u>(Micrometres)</u>	<u>% of</u> <u>Total Count</u>
< 0.4	10.2
0.4 - 0.7	23.2
0.8 - 1.3	36.7
1.4 - 3.4	23.1
3.5 - 6.8	5.4
6.9 - 13.6	1.3
> 13.7	.1

Most of the mass of the particulate is associated with the larger particles. A prefilter effective enough to filter out the larger particles would be expected to retain most of the plutonium at the glovebox.

FIGURE 4. PARTICLE SIZE DISTRIBUTION

C. HAND SHEET PREPARATION - C. D. Skaats

The filter medium used in the fabrication of HEPA filters is produced on Fourdrinier paper-making machines in continuous strips which are wound into rolls weighing about 50 lbs. Sampling and testing of the production run is difficult because of the need for the full width of the continuous fiber sheet.

For testing and development purposes, however, paper of comparable characteristics can be produced in small quantities which are known in the industry as "hand sheets."

Rocky Flats has developed a capability for the production of hand sheets which is presently operated in conjunction with the Filter Certification Laboratory.

The filter medium used for absolute filters is prepared from very fine glass fibers which, at present, are supplied by only one manufacturer. Presently, all fibers are produced from a glass combination known as Type 475. Other glass formulations have been developed and tested but have not gained the overall acceptance of the Type 475 glass. The fine cotton-like fibers are classified in codes according to a range of fiber diameter. The code most commonly used for absolute filter media are listed below:

<u>Code</u>	<u>Diameter</u>	
104	.2 - .499 micrometer	
106	.5 - .749	"
110	1.6 - 2.590	"
1/4" Chopped Strand	Approx. 14	"
1/2" Chopped Strand	Approx. 14	"

In the preparation of hand sheets, fibers are selected according to the filtration properties required in the finished product. After the fibers are selected and weighed in quantities equivalent to a one-square-foot hand sheet, the fibers are placed in a mixing container to which has been added 2,750 ml of water and 3 ml of 2 normal sulfuric acid. This quantity of acid promotes a pH of approximately 3. The acid content aids in the dispersion of the fibers and acts also as a wetting agent. Fibers are mixed 10 - 15 minutes until a smooth milky slurry is produced. At this point, the slurry is quickly poured into the head box of the sheet mold shown in Figure 5. The head or deckel box contains an additional eight gallons of water and 25 ml of 2 normal sulfuric acid. If the finished hand sheet is to contain asbestos, it is added at this point. Upon opening the foot valve of the head box piping, the water drains rapidly and deposits the fibers uniformly over the 62 x 80 mesh wire screen.

Figure 5
Operator transferring fiber
slurry into deckel box

Drying Process

The hand sheet must now have additional water removed to allow transfer from forming screen to a dryer. This is done by use of standard desk-type blotters. Two blotters are placed over the hand sheet and allowed to remain there until the blotters are saturated. The blotting is repeated until all excess moisture is removed

as indicated by adherence of the hand sheet to the blotter. The hand sheet and blotter are now carefully lifted off the forming screen and placed on the electrically heated dryer. No attempt is made to remove the blotter until the hand sheet is completely dry. The hand sheet may appear to be dry in 15 - 25 minutes; however, maximum tensile strength will not be reached until the sheet has dried for 30 - 40 minutes.

Filter Paper Testing Procedures

Tensile test - Hand sheets and medium are tested for tensile strength as follows: 1" x 6" strips are taken from the sheet and placed with ends held by spaced jaws of the Instron Tensile Tester. The action of the Instron tears the sample by the jaws pulling in opposite directions. The force required to break the paper is measured by electronic load cells and recorded on strip charts. A tensile strength of two pounds per inch of width for hand sheets is considered near maximum and is presently used as an objective.

Thickness Test - Thickness testing is done with an electronic micrometer with dial readout. Acceptable range on thickness in inches is between 15 - 20 thousandths, and 18 thousandths is considered ideal.

DOP Penetration - The penetration test is done on the Q127 penetrometer (product of ATI Industries, Baltimore, Md.) as follows: One 6" x 6" sample is taken from each

sample sheet and placed in the chuck of the Q127. When the chuck is closed, DOP smoke is drawn by vacuum through the sample being tested. The amount of smoke (%) passing through the sample is determined by a forward light scattering photometer. The calibrated dial reading is assigned as the penetration value for that sample. Penetration above .030 is not acceptable. The particle size of DOP smoke is held at .3 of a micrometre. This test is conducted with airflow carefully maintained at 32 litres per minute.

Resistance Test - The resistance to airflow through the medium sample is also determined at the same time as the penetration test. A resistance of 30 - 33 mm of Hg is the objective for hand sheets. The resistance is determined through an area of 100 sq. centimetres at an airflow of 32 litres per minute. Resistance in excess of 40 mm is unacceptable.

Hand sheets prepared by the method described above, possess all the filtration characteristics of Fourdrinier-produced media, where the same paper formulations are used. After testing, representative sheets are forwarded to the Bldg. 881 facility to permit exposure tests in acid atmospheres.

After an exposure period of two to three weeks, the exposed samples are returned to the test facility, dried, and retested for the same characteristics as described earlier.

Comparisons of the two sets of test results, as well as observation of photographs derived from a scanning electron microscope, provide information on the effect of the attack of the acid upon the fibers composing the hand sheet.

D. LABORATORY FILTER TEST STUDIES - K. Terada

Chemical exposure studies on experimental filter media have been continued in the test chamber described in the earlier report¹. The first phase of this laboratory study to develop a more chemically resistant HEPA filter involved the effect of different percentages of South African Blue Asbestos fiber on chemical resistance to 50 percent relative humidity and HNO_3 -HF atmosphere. Except to relieve the plugging effect of increasing asbestos fiber concentrations, the relative percentages of the different types of glass microfibers used in the formulations were kept constant in the series of tests. These microfiber types differ in fiber thickness and length.

HNO_3 and HF were selected for the corrosive agents since they are the most chemically active materials to which the HEPA filters are exposed. On the basis of analytical studies of their concentrations in Bldg. 771 exhaust ducts, concentrations of .56 and 40 ppm by volume of HF and HNO_3 , respectively, were established for the acid environment. A solution containing this approximate concentration of

these reagents is placed in a 25-gallon reservoir and is sprayed into the test chamber through an atomizing nozzle.

To determine the actual concentrations of the acid in the test atmosphere, it is periodically analyzed. In the analytical procedures, sampling is by either cryogenic trapping, bubbling through NaOH solution, or direct analyses. For direct analysis, the test atmosphere is drawn from the chamber directly through a commercial NO_x analyzer. NO_x is also analyzed by mass spectrometry. The fluoride ion concentrations are determined by means of a specific ion electrode. These techniques were discussed more fully in the first report. The analytical results are shown in Table VI.

The analyses show the NO_x concentrations to be generally considerably below the desired 40 ppm. The CO₂ analysis, which is used as a rough standard, indicated that there was no gross error in the sampling. CO₂ in the air varies from 300 - 500 ppm and all the samples were either within this range or only slightly below.

The analyses also show significant variations in fluoride ion concentrations but they tend to vary on both sides of the intended .56 ppm. It has not been established at this time whether the variations are actually due to fluctuations in the concentrations or entirely analytical shortcomings. Undoubtedly, there are some analytical problems

TABLE VI

ANALYSES OF ATMOSPHERE IN FILTER TEST CHAMBER

(Results are in ppm by volume)

<u>Sampling Data</u>	<u>HF</u>	<u>NO_x</u>	<u>NO_x/HF</u>	<u>Total Acidity</u>	<u>CO₂</u>	<u>Sampling* Method</u>
Apr. 18, '76	0.18	40.00	222.00		271	A
"	0.34	1.60	4.70		274	A
Apr. 9, '76	50.00	0.95	0.19		285	A
"	0.45	4.39	9.80		420	A
May 10, '76		< 1.00				C
"	0.33	0.34	1.00	0.12	375	A
"	0.35	0.42	1.20	0.04	374	A
May 12, '76	51.00					B
May 17, '76	0.23					B
May 19, '76	< 0.01	0.07				B
Sept. 13, '76	1.29			N.D.		B
Sept. 14, '76	0.58			N.D.		B
Sept. 15, '76	0.15			4.90		B
Sept. 16, '76	0.08			14.40		B
Sept. 17, '76	0.10			6.10		B
Sept. 20, '76	1.30	0.47	0.36	29.90	363	A
"	1.43	0.33	0.23	7.20	377	A

*A = Cryotrap

B = NaOH Bubbler

C = Environmetrics NO_x Analyzer

N.D. = Not Detectable

since the ratio of HF to HNO_3 is 1 to 71 but is analyzed as much less with one exception. One source of error that has been identified is that for both the NO_x analyzer and mass spectrometry, all the HNO_3 is assumed to be in the vapor stage as NO_x . No provision was made for HNO_3 which is present in the test atmosphere.

Table VII lists the results of acid exposure on the various filter samples. Although a mass of data has been collected, it would be premature to make any sweeping conclusions before the results of the planned series of tests have been completed. However, it would be appropriate to make some observations on the data accumulated thus far.

The data show better precision or agreement when they are taken in groups of four. Samples are exposed in the test chamber four at a time and they are separated from other groups in Table VII by double lines. While there is good agreement in the test results within groups, there appear to be significant variations between groups. These variations indicate that, although the environment to which they were exposed should have been the same, there were significant differences to profoundly alter some results. For example, for some groups the tensile strength of the hand sheets increased after exposure while it decreased in others. Earlier observations^{2,3} have shown that filter

media subjected to some acid environments containing HF gain tensile strength after a slight initial loss. Continued exposure results in a sharp loss of strength. The relative differences in tensile strength listed in Table VII may be the result of the samples having received different amounts of acid exposure during the same exposure time.

The first two groups of samples (1 - 8) (Table VII) show significant degradation. This is probably a reflection on the lack of control of the corrosive environment during the first weeks of testing. Although subsequent results show much better consistency, there is still an uncertainty from test to test whether the tensile strengths have increased or decreased.

Scanning electron micrographs have been taken of each sample and two of them are shown in Figures 6 and 7, along with a micrograph of an unexposed hand sheet. They are shown as types of chemical attack under seemingly identical conditions. The bead and web-like features in micrographs (Figures 6 and 7) suggest that attack by a liquid phase was involved at least during some stage of the test. The presence of liquid on the filter medium during the test was not unexpected. Although the liquid aerosol generated at the opposite end of the test chamber from the sample filters is invisible, a photometric particle sensor indicated the presence of aerosol upstream of the filters. Apparently, the atomized solution is not completely vaporized. As the acid aerosol vaporized, the

TABLE VII
TESTS ON FILTER MEDIA

Sample #	% Asbestos	Exposure Time	% Humidity	Tensile (psi)		Bulk (in.)		Resistance (mm Hg)		% Penetration	
				Before	After	Before	After	Before	After	Before	After
01	5	1 Wk.	50	1.88	1.10	18.75	18.50	32	20.32	.008	.920
02	5	"	"	1.88	1.15	18.75	18.30	32	21.59	.008	.557
03	5	"	"	1.88	1.05	18.75	18.50	32	25.40	.008	.180
04	5	"	"	1.88	1.05	18.75	18.00	32	21.59	.008	.532
05	5	1 Wk.	50	1.90	1.09	18.78	15.00	33	15.44	.014	.778
06	5	"	"	1.90	1.08	18.78	18.30	33	25.40	.014	.0165
07	5	"	"	1.90	.80	18.78	17.50	33	22.86	.014	.0693
08	5	"	"	1.90	1.28	18.78	18.16	33	27.94	.014	.011
09	5	1 Wk.		2.07	1.20	19.07	18.48	33	33.00	.008	.003
10	5	"		1.98	1.21	18.48	18.70	33	35.00	.008	.002
11	5	"		1.76	1.28	18.84	18.58	33	33.00	.008	.003
12	5	"		1.67	1.27	18.93	18.62	33	35.00	.008	.002
13	5	1 Wk.	50	1.41	1.88	18.40	19.00	33	45.00	.003	.006
14	5	"	"	1.78	1.89	18.35	18.65	33	45.00	.003	.006
15	5	"	"	2.02	2.24	18.85	18.70	33	Lost	.003	Lost
16	5	"	"	1.96	2.26	18.78	18.88	33	45.00	.003	.004
17	5	1 Wk.		1.53	1.71	18.68	19.13	33	31.00	.008	.004
18	5	"		1.38	1.39	18.30	18.65	33	30.00	.008	.006
19	5	"		2.06	1.58	18.46	18.83	33	30.00	.008	.008
20	5	"		1.82	1.57	18.83	18.05	33	30.00	.008	.008
21	4	1 Wk.	50	1.95	1.43	19.10	18.80	32	32.00	.005	.004
22	4	"	"	1.88	1.57	18.75	18.65	32	33.00	.005	.002
23	4	"	"	1.96	1.53	18.80	18.80	32	32.00	.002	.002
24	4	"	"	1.90	1.60	19.05	18.65	32	32.00	.002	.004

TABLE VII (Cont'd)
TESTS ON FILTER MEDIA

Sample #	% Asbestos	Exposure Time	% Humidity	Tensile (psi)		Bulk (in.)		Resistance (mm Hg)		% Penetration	
				Before	After	Before	After	Before	After	Before	After
25	4	1 Wk.	50	1.82	1.90	19.13	19.80	31	35.00	.004	.004
26	4	"	"	1.65	2.11	18.80	19.35	31	35.00	.004	.006
27	4	"	"	1.90	2.16	18.60	19.40	31	33.00	.004	.004
28	4	"	"	1.80	2.00	19.05	19.65	31	35.00	.004	.006
29	4	1 Wk.	50	2.04	2.13	19.00	19.45	33	35.00	.004	.006
30	4	"	"	2.01	2.43	18.83	19.45	33	35.00	.004	.007
31	4	"	"	2.04	2.21	19.15	19.13	33	35.00	.004	.008
32	4	"	"	1.90	2.46	19.05	19.50	33	38.00	.004	.009
33	4	2 Wks.	50	2.19	1.74	19.20	19.20	32	35.00	.006	.006
34	4	"	"	2.11	1.82	19.10	19.20	32	33.00	.006	.005
35	4	"	"	2.03	1.70	19.00	19.48	32	35.00	.006	.004
36	4	"	"	1.94	1.76	18.80	19.20	32	33.00	.006	.006
37	4	2 Wks.		1.78	2.20	18.93	19.30	35	40.64	.005	.004
38	4	"		1.73	2.09	19.23	19.25	35	38.10	.005	.004
39	4	"		1.75	1.84	19.03	19.08	35	40.64	.005	.006
40	4	"		1.95	2.18	19.18	19.73	35	38.10	.005	.005
41	4	2 Wks.		1.83	1.78	19.33	19.68	33	38.00	.006	.002
42	4	"		2.22	1.91	19.95	20.30	33	38.00	.006	.002
43	4	"		2.22	1.76	19.25	19.65	33	38.00	.006	.002
44	4	"		2.10	1.80	19.65	19.40	33	38.00	.006	.003

New (1000 X)

Exposed (2000 X)

Figure 6.

Comparative photomicrographs of new (1000 X) and exposed (2000 X) fibers in hand sheet showing effects of HNO_3 and HF vapors.

New (1000 X)

Exposed (2000 X)

Figure 7.

Comparative photomicrographs of new (1000 X) and exposed (2000 X) fibers in hand sheet showing effects of HNO_3 and HF vapors.

azeotropic effect increased the acid concentration and, consequently, decreased the vapor pressure of the aerosol to delay complete vaporization. Currently there is no visual evidence of the presence of vapors on the filters during and after the tests. The walls and the floor of the test chamber remain dry and the filters are dry to the touch.

Future Work

Analytical studies of the chamber atmosphere will be continued. The nitric acid concentrations tend to be consistently low. This may be due to condensation of the acid in the collection tube leading to the cryotrap or NaOH bubbler. New sampling techniques will be tried to eliminate this source of error. Accurate nitric acid analyses would show whether the fluctuations in fluoride concentrations are due to analytical limitations or actual changes in the chamber atmosphere.

The tests on the effect of humid acid environment on filter media containing different percentages of asbestos will be continued. Additional instrumentation will be installed to detect and record any changes which could affect the test chamber atmosphere. A controller is also being added to insure a constant airflow through the filters. The goal is to maintain a relative humidity of 50 ± 5 percent.

In conjunction with the investigation of the effluents in the exhaust ducts of the plutonium processing facility, attempts will be made to continually record the humidity of the air in front of the first filter bank. In order to obtain an understanding of the mechanism of filter degradation, it is essential to know the range of humidities to which the filters are exposed over a span of at least one year. Also, the possibility of distinguishing solid from liquid aerosols will be explored.

Scanning electron microscopy studies of the filter exposed to corrosive environments will be continued. An electron microprobe attachment will be used in an effort to identify the compositions of the web and bead-like features on the filter media.

E. VOLUME REDUCTION OF CONTAMINATED HEPA FILTERS - K. Terada and O. I. Buttedahl

The present Rocky Flats system of packaging the 2' x 2' x 1' contaminated filters for disposal consists of crushing the filters in a press and packing them in a 4' x 4' x 7' fiberglass reinforced polyester (FRP) coated plywood boxes. Approximately 20 - 27 of the filters are currently shipped in each box which costs about \$230.00 apiece. Considering all the costs from procurement, handling, and transportation to the storage site, each filter results in an expenditure of approximately \$415.00.

This does not include the cost of retrievable storage which has been estimated as high as \$30.00 per cubic foot.

In an effort to reduce this cost, the feasibility of compacting the filter media is being investigated. As a first step of this program, a device consisting of a hydraulically operated punch, rams, and extruding die were designed and constructed to compact the filter media and separators of 8" x 8" x 6" HEPA filters. The device is shown in Figure 8.

A standard 5,000 psi hydraulic pump (1) in Figure 8 is connected through a series of valves to three cylinders (2, 3, and 4) which are operated and controlled independently. A ram is attached to the piston rod of each cylinder, each of which has a specific function. The combination of cylinder (2) and ram, punches the filter medium out of the frame. A force of about 2,000 pounds is required to separate the medium from the frame. The medium is then transferred by the ram attached to cylinder (3) into the main chamber. The main cylinder (4), which has a capacity of 25 tons of force, is used to extrude the filter medium through the pelletizing die (5). An additional cylinder (not shown) is used to flatten the filter frames.

Different configurations of dies were tested. Early dies were designed to extrude the media in 1/2" diameter

FIGURE 8. EXPERIMENTAL HEPA FILTER COMPACTOR

cylindrical pellets. However, because of the poor flow characteristics of the filter medium, it could not be forced through the tapered circular openings. The die currently used has square openings with very slight taper from a 2" square at the knife edge to 1 3/4" square, 1" into the 2" thick die. This is shown in Figure 8. The overall dimension of the inside of the die is 4" and this is divided into four equal sections. The leading edge of the divider comes to a knife edge where the filter media is sheared.

Before the filter is placed in the compactor, it is thoroughly soaked with water. Without it, the extruded pellets tend to re-expand. The major contribution of water is in wetting the filter medium so that the compacted pellets will retain their size and shape. Water appears to have little or no lubricating properties. However, a possible function which will be investigated might be as a rinse to partially wash off contamination. Most of the moisture is squeezed out of the medium during compaction and no free liquid exudes from the compacted pellet. In the existing laboratory atmosphere, the exterior of the pellet is visibly dry within 24 hours. There is no re-expansion during the drying. An 83 percent volume reduction of the medium is obtained. A greater overall volume reduction of the HEPA filter will be obtained when the wooden filter frame is incinerated as planned at Rocky Flats. A compacted filter medium is shown in Figure 9.

Figure 9 - Compacted Media and Frame
From 8" HEPA Filter

The Rocky Flats Waste Management group has been kept informed and their input solicited throughout the feasibility study. Present plans call for the eventual use of the prototype compactor for 2' x 2' x 1' HEPA filters, which is currently in the design stage, to compact spent contaminated filters. Discussions with Nuclear Safety have not revealed any serious criticality problems

associated with the compacting and proposed packaging of contaminated filter media. In packaging the pellets for waste shipment, the possibility is being explored of placing them in voids that are usually present in plywood boxes filled with other types of waste. This procedure could eliminate the shipment of boxes devoted to contaminated filters. Excess weight would not be a problem at Rocky Flats since the average shipping weight of a crate is about 4,000 pounds and the maximum allowable is 5,000 pounds. Rocky Flats currently discards about 3,000 2' x 2' x 1' filters a year. This requires approximately 120 waste boxes. Adding the shipping cost to that of the box raises the expenditure per box to \$500.00. A potential savings of \$60,000 a year could be achieved at this discard rate.

As stated earlier, design for a new scaled up compactor to handle the 2' x 2' x 1' HEPA filters is in progress. The current schedule calls for the preliminary design to be completed by April 1977. Construction and tests of the compactor should be completed by July and September 1977, respectively.

After development and testing, it is planned to enclose the new unit in a glovebox and test it in actual use with contaminated filters. The system will be automated with the addition of flow control and sequencing valves so that it can be operated remotely.

By 1979, it is planned to have a system in operation which will substantially reduce the the handling and disposal costs of waste HEPA filters. Also, by operating the filter compaction system remotely, the potential hazard will be reduced of contaminating operating personnel who currently package the filters in a hot room protected by supplied air suits.

F. IN-SERVICE FILTER TESTING - R. W. Woodard

1. Study of Filters Used in 1st and 3rd Stages of Chemical Exhaust Plenum, Bldg. 771

The previous progress report¹ described results of analytical studies on new HEPA filter components and components which had been exposed in the 1st stage of the booster plenum (see Figure 1, page 6). Subsequent to this work, studies were made on HEPA filter components which had been in service in the 3rd stage of a booster plenum.

Table VIII presents comparative data on filter components when new, in service in the 1st stage, and in service in the 3rd stage of the booster plenum.

Samples of filter and separator material were examined using a Cambridge S-4 Stereoscan Scanning Electron Microscope. Both photomicrographs and electron microprobe analyses were made on samples of the media and separator

materials. The media and separator samples were taken from the same filters which had been in service 2 1/2 months and 10 months and subjected to tests shown in Table VIII.

TABLE VIII
COMPARATIVE ANALYSES OF FILTER COMPONENTS
AFTER USE UNDER DIFFERENT SERVICE CONDITIONS

Service:	New		1st Stage		3rd Stage	
Time in Service:	0		2 1/2 Mos.		10 Mos.	
Component:	<u>Media</u>	<u>Separator</u>	<u>Media</u>	<u>Separator</u>	<u>Media</u>	<u>Separator</u>
Volatiles by TGA (1) to 1000°C (%)	4.00	25.00	18.00	47.10	3.90	61.40
Water leach						
pH (2)	8.90		3.90	3.90	3.15	3.40
F- (3)	.06		2.20	.22	.45	.24
NO ₃ - % (4)	.09		9.80	19.60	1.60	36.50
Mass Spectral Outgas (to 400°C)						
Major	None	CO, CO ₂ , H ₂ O	SiF ₄ , H ₂ O, NO, CO	H ₂ O, NO, N ₂ O, CO ₂	H ₂ O	H ₂ O, NO ₂ , NO, N ₂ O, CO
Minor	--	--	HF, NH ₃ , CO ₂	SiF ₄	NH ₃ , SiF ₄ , NO, N ₂ O, DOP	--
Trace	H ₂ O, CO, CO ₂	CH ₃ OH, HCHO	--	HF, HCl, HNO ₃	NO ₂ , HCl, CO, CO ₂ , HF, Fluoro-silanes	SO ₂ , HC

- (1) Volatile content determined by thermogravimetric analysis (TGA). An airflow of 80 cc per minute was passed over samples while heating at rate of rise of 20°C per minute to 1000°C.
- (2) pH is determined on leach of weighed component with 100 ml distilled water.
- (3) Weight percent based on weight of component sample analyzed.
- (4) Analysis by Specific Ion Electrode.

Figure 10 is a photomicrograph of 1st stage medium in service 2 1/2 months and shows a heavy collection of particulate matter. Electron microprobe data indicated silicon as the most plentiful element followed by calcium, iron, sodium, and potassium. These elements are principally those contained in glass fibers. Sodium is the lowest atomic weight element detected by the electron microprobe method and, therefore, presence of nitrogen and fluoride components are not detected.

Figure 10
1st Stage Filter Medium - 1000 X
(2 1/2 Mos. Service)

Figure 11, a photomicrograph of the asbestos separator material, reveals the presence of crystalline material. The major elements detected were silicon and magnesium with substantially lesser amounts of iron, calcium, and potassium.

Figure 11
1st Stage Separator - 1000X
(2 1/2 Mos. Service)

Figures 12 and 13 show medium and separator components from 3rd stage filters in service for 10 months. Note that the medium is quite free of particulate matter since it would have been filtered out by 1st and 2nd stage filters.

Figure 12

3rd Stage Medium - 900 X
(10 Mos. Service)

Figure 13
3rd Stage Separator - 900X
(10 Mos. Service)

The lighter colored crystals seen on the separator in Figure 13 contain major concentrations of sodium, magnesium, and silicon components.

The trends noted by the analytical work reveal that fluoride in the exhaust gas preferentially adsorbs or reacts with the glass filter media, whereas the nitrate reacts with substances making up the asbestos separator. The partitioning is more evident in the 3rd stage filters where essentially no deposition of particulate matter takes place but nitration of the separator is extensive.

The concentration of fluoride in the 3rd stage filter media is lower than on the 1st stage, even after longer exposure, suggesting depletion of the fluoride as it passes through a number of stages of filter media.

The presence of nitrate in media is relatively high only on the 1st stage filters where it combines with, or is a part of, the particulate matter being filtrated. Nitrate in the separator has been identified to be predominately magnesium nitrate. Since magnesium nitrate is deliquescent, its presence would be expected to influence the absorption of water by the filter.

2. Study of Filters Used in Six Stages of Chemical Exhaust Plenum.

A study was also made on samples taken from six stages of filters which had been in service in a booster plenum used to exhaust air from glovebox lines used for chemical operations. All stages of the filters were changed within a two-week period. The filters in stages 1, 2, 3, and 4 had been in use for four months; those in stages 5 and 6 for approximately one year.

Grab samples of medium and separator were taken from one filter in each of the six stages and submitted for analyses. (Note: Because of the friable nature of the exposed filter separator material, mixing of the media and separator components occurred in some samples.) The results of analytical work are presented in Table IX. Weight loss on heating,

weight loss on water leaching, and fluoride and nitrate content follow a pattern similar to that noted in the comparison of 1st and 3rd stage samples discussed earlier in the report.

TABLE IX

ANALYSES OF MEDIA AND SEPARATOR SAMPLES
TAKEN FROM SIX STAGES OF HEPA FILTERS

<u>Stage</u>	<u>Sample Ident.</u>	<u>Weight Loss</u> <u>(%) to (°C)</u>		<u>Solubility</u> <u>(%)</u>	<u>Fluoride</u> <u>(%)</u>	<u>Nitrate</u> <u>(%)</u>
1	Media	9.3	550			
	Media + Sep.* Separator	37.7	950	24.6 Avg.	.38 Avg.	5.8 Avg.
2	Media	6.6	950	7.1 "	.24 "	1.7 "
	Separator	63.9	700	63.8 "	.05 "	30.0 "
3	Media					
	Media + Sep.* Separator	15.0	970	26.7 "	.16 "	13.8 "
4	Media	8.1	950			
	Media + Sep.* Separator	56.0	900	3.6 "	.18 "	2.6 "
5	Media	6.6	960	18.2 "	.15 "	1.7 "
	Separator	48.5	900	55.8 "	.06 "	26.1 "
6	Media	4.5	960	24.0 "	.11 "	1.3 "
	Separator	58.1	900	55.0 "	.06 "	28.8 "

* Sample crushed, media and separator mixed during sampling.

An additional study was carried out on a filter removed from the 6th stage at the same time the sample, discussed above, was taken. The filter was sufficiently free of

plutonium contamination to permit handling without special precautions. Observations relating to the filter are presented in Table X.

TABLE X

DATA ON FILTER REMOVED FROM 6TH STAGE

Manufacturer: Flanders Filters, Inc.

Tested: Hanford 3/18/74 File No. 1083

Penetration: 100% flow .006% (.78" W.C. Δ P)

20% flow .004%

Date Filter Installed: 4/19/74

Time Filter in Active Service (Plenum FU-2B): 1 Year

Date Filter Removed: 8/18/76

Retests on Filter at Rocky Flats Filter Certification Lab:

Gross Wt.: 67 Lbs.

Penetration: 100% flow .004%

20% flow .020%

Retest on Medium Taken From Filter:

Resistance: 42 mm W.C. @ 32 lpm thru 100 cm²

Tensile strength:

Machine direction 7.42 lbs. per sq. in.

Cross direction 5.27 lbs. per sq. in.

Bulk (thickness): .023 inch

After completion of the physical tests, the filter was further dismantled to permit chemical and radiological studies. Samples of media and separator were removed from three

locations in the filter. Since these samples could be handled carefully, no mixing of media and separator occurred. The frame was also sampled. Chemical tests run on the components are reported in Table XI.

TABLE XI

ANALYSES OF SAMPLES
TAKEN FROM 6TH STAGE FILTER

<u>Sample Description</u>	<u>Weight Loss</u> <u>(%) to (°C)</u>		<u>Water Soluble</u> <u>(%)</u>	<u>Fluoride</u> <u>(%)</u>	<u>Nitrate</u> <u>(%)</u>
Media	5.2	920	2.7		
	3.6	950	2.7	.10	1.0
	3.5	830	2.7		
Separator	61.7	850	65.5		
	61.0	840	68.3	.07	35.8
	60.7	850	62.4		
Frame	91.3	925	10.4	.004	1.9

Note that the fluoride content of separator and media for this analysis does not show as significant partitioning effect as previously observed. The nitrate ion partitioning was more pronounced.

A sample of the media was submitted for iron assay to determine the crocidolite asbestos content. The concentration of iron was 0.34 percent which is equivalent to 1.1 percent asbestos.

The weight of the filter as noted in Table X was 67 pounds. A new filter averages about 47 pounds. The increase in filter weight, estimated at 20 pounds, is attributed to reaction of ingredients in the separator with nitric acid and/or NO_x fumes, along with absorption of water. Evidence of the nitration reaction is depicted in the photograph shown in Figure 14 where crystals of magnesium nitrate are evident on the surface of separator material viewed under low power magnification.

Samples of media and separator from the 6th stage filter were also investigated using alpha and fission track techniques. (Note: See section in this report "Plutonium Particulate Penetration and Size Studies," for description of method.) Plutonium particulate was found in the range of $.07 \mu\text{m}$ - $0.19 \mu\text{m}$ assuming plutonium as plutonium oxide (PuO_2). However, uncertainty exists on whether the presence of the activity is due to penetration or due to contamination during construction activity. Further work is planned to resolve this point.

Figure 14

Photomicrograph (15X) of Magnesium Nitrate on
Separator Sample Removed from 6th Stage Filter.

3. Test of Separatorless Filters.

A technique used to a limited extent for in-service filter testing, was that of taking pictures of separatorless filters in a highly contaminated production filter plenum. Pictures taken under these conditions utilized a Kodak[®] Instamatic[®] camera loaded with a Kodacolor[®] film cartridge. A technician wearing a supply air suit took the photographs. Another technician opened air lock doors, handled hoses, etc., so that the man taking pictures would minimize contamination of the camera. After taking pictures, the camera was bagged out of the plenum and removed to a glovebox where the film cartridge was carefully removed.

Although photography under these conditions requires considerable effort and cooperation, it was demonstrated to be a useful technique when there is a need to observe a filter or component during its service life.

Using the method described above, a Flanders glass-asbestos medium Super-Flow[™] (separatorless) filter was installed in the 1st stage of a chemical exhaust plenum on April 19, 1976 and photographed on April 20 and May 13. No significant change was observed during the period as shown in Figures 15 and 16.

[®] Kodak, Instamatic, and Kodacolor are trademarks of the Eastman Kodak Company, Rochester, New York

[™] Super-Flow is a trademark of Flanders Filters, Inc. Washington, N. C.

Figure 15
Flanders Super-Flow Filter Glass-Asbestos
Media Separatorless - Installed on 4/19/76
Photo on 4/20/76

Figure 16

Flanders Super-Flow Filter Glass-Asbestos
Media Separatorless - Photo 5/13/76

The photographs show that no change in the filter took place during one month. The filter was changed on August 3, 1976. The use of separatorless filters has obvious advantages, both in regard to handling weight and reducing volume of waste. The service life, however, is subject to further evaluation.

G. PREFILTER DEVELOPMENT - R. W. Woodard

WATERWEB[®]

In the last progress report¹, a material called WATERWEB was described as a potentially useful prefilter media. Limited testing of this material was performed during the current reporting period.

For the first tests, 8 x 8 x 1-inch pieces of WATERWEB (PVC coated) were cemented to 8 x 8 x 5-inch particle board frames. A completed unit is shown in Figure 17.

The tests were conducted by installing one of the WATERWEB prefilters in a glovebox (Line 24) and allowing the exhaust air to pass through the WATERWEB medium. The first prefilter was placed in service on July 15, 1976. On August 10, the prefilter was taken down, inspected, and washed. At that time it was visually observed that the

[®] WATERWEB is the trademark of Heat Systems Ultrasonics, Inc., Plainview L.I., New York

Figure 17

Prefilter made from WATERWEB demister medium
in wooden frame adapted for 8" filter holder.

WATERWEB medium had not been degraded but the particle board frame was severely attacked on the inside surface.

Particulate matter on the exposed face of the WATERWEB was washed away by backflowing water through the medium. When the unit was reinstalled, the pressure drop across the filter remained relatively high which may indicate the washout of particulate from the medium was not complete.

A second test was conducted using another WATERWEB (8 x 8 x 1-inch PVC) prefilter. The exhaust gas was sampled downstream of the prefilter with about 1.5×10^4 d/m/m³ α activity observed.

Since results using the WATERWEB were encouraging, two more prefilters were fabricated. These units are constructed from an 8 x 8 x 6-inch stainless steel frame in which a piece of 1 1/2-inch thick polypropylene WATERWEB is cemented. A front and back view of the unit is shown in Figure 18. These units are awaiting testing in a production line.

ACS Demister

Another type of 8 x 8 x 6-inch size prefilter was constructed using Mistermesh[®] media. Stainless steel frames,

[®]Mistermesh is the trademark of ACS Industries, Woonsocket, R.I.

Figure 18
Prefilter Construction of WATERWEB Demister
Media in Stainless Steel Frame

see Figure 19, were constructed to accommodate different thicknesses of the demister media. In these prefilters, the Mistermesh is fabricated from multi-filament glass with parallel knit polypropylene. The medium is friction fitted into the frame and is held in place by a slip frame. When the unit is assembled it is approximately six inches thick.

Gore-Tex®

Two 8 x 8 x 6-inch filters were fabricated by Flanders Filters, Inc., using Gore-Tex media supplied by W. L. Gore & Associates. The filters are shown in Figure 20. Tests on the unit by the Filter Certification Laboratory gave results shown in Table XII below:

TABLE XII

TEST DATA ON 8 x 8 x 6-INCH FILTERS WITH GORE-TEX MEDIA

<u>Filter No.</u>	<u>Test Flow (CFM)</u>	<u>Resistance (In.-W.G.)</u>	<u>DOP Penetration %</u>
482826 (5 oz.)	50	.52	98
482828 (8 oz.)	50	.52	98

These filters will be placed in service in a production line to observe performance. When plugging occurs, an attempt will be made to wash the media.

® Gore-Tex is the trademark of W. L. Gore & Associates, Inc., Elkton, Md. 21921

Figure 19
Prefilters Constructed of Stainless Steel
Frames and ACS Mistermesh Media

Figure 20

Two 8 x 8 x 6-inch filters fabricated by
Flanders Filters, Inc. using Gore-Tex Media.

H. PLUTONIUM PARTICULATE PENETRATION AND SIZE STUDIES -

J. A. Hayden and R. W. Woodard

During the reporting period, a study was initiated to determine to what extent HEPA filter media in chemical exhaust service is penetrated by plutonium particulate. The study has made use of techniques of detecting and sizing plutonium particles based on alpha and fission activity. A short discussion of the methods used follow:

Alpha Track (α T)

Alpha active matter, in this case weapons-grade plutonium, is collected or deposited on the surface of a filter. The sample is covered with thin (10-micrometre) polycarbonate film overlaid with cellulose nitrate film. This "sandwich" of sample and films is lightly compressed and left undisturbed for a known period of time.

During the exposure time, alpha particles emitted by the plutonium pass through the thin polycarbonate film and penetrate the nitrate film. When the exposure period is ended, the nitrate film is leached for a short time in warm sodium hydroxide solution (6N), then rinsed and dried. At the points in the film where an alpha particle penetrated the film, the film dissolves more rapidly and "tracks" may be observed under low power magnification. The tracks, originating from a point source, e.g., a particle containing plutonium, are star-like. By counting the tracks in a "star" and knowing the exposure time, geometry, rate of

decay, etc., the size of the particle can be estimated. Usually, not every track or star is counted, only those entering the field of vision as the film is scanned while it is moved from one side to the other. If very few stars are present, additional scans are made.

Fission Track (FT)

When using the fission track method of detecting plutonium and estimating particle size, advantage is taken of the fact that plutonium will undergo fission when exposed to slow neutrons. A determination is made by pressing polycarbonate film (10-micrometre thick) against the surface where plutonium is present. The sample is then exposed to a neutron flux in a small training reactor. Heavy nuclei, released when plutonium undergoes fission, penetrates the polycarbonate film. Leaching the film reveals the tracks made by the fission particles. The tracks of primary interest are those originating from a common point to form "stars."

The number of tracks in a star, along with values of other exposure conditions, make calculations possible to estimate the size of the plutonium particle. An advantage of the fission track over the alpha track method, is that it is more sensitive and thus requires less exposure time to "see" the plutonium particulate.

The techniques described above were applied to study the size of particulate penetrating samples of HEPA filter

media. Samples of media (37 mm in diameter) were mounted in a Millipore plastic field monitor constructed as shown in the exploded sketch (Figure 21).

Air taken from the glovebox exhaust system at point G (Figure 1) was pulled through the filter holder at a flow of about three cubic feet per hour (CFH). At this flow rate the velocity of air passing through the samples of media is five feet per minute or 2.5 centimetres per second.

HEPA filter media identified in Figure 21 as A, B, C, D and the Millipore back-up filter, E, were then examined by means of either the alpha track or fission track method, depending on the level of activity.

A relatively large amount of particulate collects on the "A" filter. The alpha track (α T) method was used to determine the size of the plutonium particulate based on the assumption that it is present as the oxide PuO_2 . A small portion of the medium from the filter in the "A" location was washed in an ultrasonic agitated bath of water containing detergent. An aliquot of the wash water was evaporated on 0.8 μm Millipore filter which was then examined by the α T technique. The data obtained from three runs are presented in Table XII.

FIGURE 21. EXPLODED CROSS SECTION OF HOLDER
USED TO STUDY PARTICLE PENETRATION

TABLE XII

PARTICLE SIZE DATA
BASED ON ALPHA TRACK METHOD

<u>Run</u>	<u>Filter</u>	<u>No. of Scans</u>	<u>Number of Tracks in Stars (Particle Diameter μm as PuO_2)</u>					
			<u>5 (.105)</u>	<u>10 (.132)</u>	<u>25 (.179)</u>	<u>50 (.226)</u>	<u>100 (.285)</u>	<u>150 (.326)</u>
5576	A*	3	39	31	31	10	5	2
6976	A*	3	9	18	32	20	22	15
61776	A*	3	9	30	29	20	20	24

*See Figure 18

Log normal plots are shown in Figure 22. Two of the runs, 6976 and 61776, show the count mean diameter (CMD) of the plutonium particulate as $.19 \mu\text{m}$ while the plot of 5576 data indicates CMD of $.11 \mu\text{m}$.

In another experiment, plutonium particulate was detected which had collected on the discs of HEPA filter media in locations B, C, and D (Figure 18). The procedure based on counting fission tracks was employed to estimate the size of particles detected on these filters. The limited data from these determinations appear in Table XIII and log normal plots in Figure 23.

TABLE XIII

PARTICLE SIZE DISTRIBUTION BASED ON
FISSION TRACK METHOD - RUN 6976

<u>Location</u> <u>Filter*</u>	<u>No. of</u> <u>Scans</u>	Number of Tracks in Stars (Particle Diameter μm as PuO_2)				
		5 (.075)	10 (.089)	25 (.12)	50 (.15)	100 (.2)
B	17	64	36	6	3	0
C	17	43	14	2	1	2
D	18	41	23	4	0	0
E**	16	0	0	0	0	0

* See Figure 18

** Millipore® Back-Up Filter

The size distribution places the CMD at about .07 μm or less. In addition to the star patterns, many single tracks were also observed.

The work described on particle sizing is in the early stage. Much remains to be done on establishing the extent of penetration, particularly as it is related to conditions such as variations in humidity, chemical degradation of media, separators, etc.

FIGURE 22. PARTICLE SIZE DISTRIBUTION BY ALPHA TRACK METHOD

FIGURE 23. PARTICLE SIZE DISTRIBUTION BY FISSION TRACK METHOD

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