

SESSION XI

ENGINEERING DESIGN OF AIR CLEANING SYSTEMS FOR  
PLUTONIUM FACILITIES: ROUND TABLE

Thursday, August 31, 1972

CHAIRMAN: R. Yoder

PANELISTS:

G. A. Schurr, E.I. duPont de Nemours  
Engineering Considerations for  
Filter Selection

H. Ettinger, Los Alamos Scientific Laboratory  
Size Characteristics of Plutonium Aerosols  
Co-authors: John C. Elder  
Manuel Gonzales

W. E. Domning, Dow Chemical Company  
Water Spray Heat Exchangers for HEPA  
Protection in Accidents (Heat Removal  
Requirements and the Effect of Smoke and  
Water on HEPA Filters)

J. L. Russell, Jr. C. F. Braun and Company  
Engineering Aspects of Plutonium Facility  
Air Cleaning Installations

OPENING REMARKS OF SESSION CHAIRMAN:

This round table discussion will cover many aspects of air cleaning system design for plutonium facilities and for other facilities handling transuranic elements. As an outgrowth of new AEC criteria for the design and construction of plutonium facilities, there has been increased emphasis on fire protection, particularly for air cleaning systems. Interest in this area has intensified as a result of the Rocky Flats fire a few years ago plus increased national concern with environmental protection.

At least three solutions to the protection problem have been proposed, or identified. The first, is protection of HEPA filters by using water sprays or other means of cooling the air to reduce its temperature at the filter and to prevent hot particles, which may burn holes in the medium, from reaching the filter. Some work has demonstrated that this is a feasible concept; at least in the laboratory. The other two methods require installing sand filters or deep bed glass fiber filters. Both offer fire resistance but their use has generated many questions with regard to their performance parameters. I hope the panel will address these areas this morning.

ENGINEERING CONSIDERATIONS FOR FILTER SELECTION

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The design of a high efficiency filtration system for cleaning air in plutonium facilities must provide containment protection for both "normal" operation and any excursion from normal. In Du Pont, it is recognized that each facility has special requirements necessitating separate evaluations for each application. At present the deep-bed sand and glass fiber filters and the HEPA type facility operated independently or in combination are generally considered for each application. Considerable operating experience has been gained at the Savannah River Plant on both sand and HEPA operation. The test work discussed in the paper presented yesterday compared some of the important variables of the sand and glass fiber filters. The strengths and weaknesses of these filters must be evaluated against the requirements of the application. Judgment and experience enter into the weighting of importance of the various fabrication, collection, and expected life performance factors.

In the broadest sense, our experience and test data shows the deep-bed sand or glass fiber filters to be long-lived, easily maintained, and highly efficient units. The sand filter is considered the easiest to fabricate and the most inert in face of most anticipated excursions from normal. The HEPA type installation requires maintenance and is generally difficult to maintain at high efficiencies. Its cost advantage makes it attractive for applications where back-up is provided in the event of an incident likely to breach the filter. Where size requirements may be important, either HEPA or glass fiber deep bed construction requires less space than sand.

## SIZE CHARACTERISTICS OF PLUTONIUM AEROSOLS

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Abstract

A program is in progress to measure size characteristics and activity concentrations (source term) of plutonium aerosols generated by typical operations handling significant quantities of plutonium. This will provide a basis for generating similar aerosols in the laboratory to study the effectiveness of multiple stages of HEPA filtration. Initial data shows Pu concentrations ranging up to  $16.5 \times 10^6$  dpm/m<sup>3</sup>, with the following aerodynamic size characteristics:

aerodynamic activity median diameter (aamd) = .52 to 5.5  $\mu$ m

geometric standard deviation ( $\sigma_g$ ) = 1.5 to 6.60

I. Introduction

Increased concern regarding the potential release of radioactive particulates to the atmosphere has resulted in new stringent air cleaning requirements for facilities handling plutonium. These include proposals to require decontamination factors of  $10^9$  to  $10^{12}$ . This can be attained by use of multiple High Efficiency Particulate Aerosol (HEPA) filters, which singly can provide decontamination factors of  $10^3$  to  $10^4$ . While extensive test data is available to substantiate this level of performance for individual HEPA filters, and filtration theory predicts multiple filter installations will provide the overall protection required, quantitative substantive data is not available. There is also concern that filter performance against laboratory test aerosols, such as DOP, is not fully representative of performance against plutonium aerosols. Because of this interest in realism, a field sampling program was designed to measure size characteristics and activity concentrations (source term) of plutonium aerosols generated by typical operations at several AEC facilities handling significant quantities of plutonium. Definition of these aerosols would provide a basis for generating similar aerosols in the laboratory to study the effectiveness of multiple stages of HEPA filtration.

Initially three plants, representing different production and research operations, utilizing both  $^{238}\text{Pu}$  and  $^{239}\text{Pu}$ , were selected to provide air sampling data to characterize plutonium source terms under a variety of operating conditions. Wide variations of activity concentration and size characteristics were expected due to: (1) differences in the amount of material handled, and mechanical and chemical operations at each site; and (2) aerosols incident on the main

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exhaust filters may undergo previous stages of filtration at the glovebox. Therefore, sampling data would be represented as ranges of values to describe aerosol concentration and size characteristics. Due to the nature of some operations performed in these plants, sampling locations and operational processes are identified only in these general terms:

1. research and development (r and d)
2. recovery (chemical operations)
3. production (mechanical operations)

The following discussion will primarily be directed at the size characteristics of plutonium aerosols, with only brief mention of activity levels. Data presented is preliminary, and was summarized only for presentation at the Round Table Discussion at this Air Cleaning Conference.

### II. Sampling Procedures

The 8-stage Andersen impactor<sup>(1)</sup> was selected to be the primary sampler for particle size analysis. This device is simple, easy to operate in the field, provides size separation over a fairly wide range of particle diameters on the basis of the inertial properties of the aerosol, and its calibration is well documented.<sup>(2,3)</sup> The impactor backup membrane filter and the eight impaction plates are alpha counted for analysis. Net count rate is proportional to the mass of particles deposited on each plate if two assumptions are made: (1) absorption of alpha particles in the particle (self-absorption) is negligible, and 2) specific activity (dpm/gm) is constant. A 5 MeV alpha particle has a range of at least 10  $\mu\text{m}$  in  $\text{PuO}_2$ <sup>(4)</sup> compared to a physical diameter of 3 to 4  $\mu\text{m}$  collected on the first stage of the impactor. Therefore, an alpha particle emitted anywhere within a 4  $\mu\text{m}$   $\text{PuO}_2$  particle should emerge from the particle with sufficient energy to be counted. Spectroscopy samples support this hypothesis for the particle size range of interest in this study. However, one of the three facilities discharges a mixture of  $^{238}\text{Pu}$  and  $^{239}\text{Pu}$  in highly variable ratios. Therefore, data obtained to date have only been defined in terms of aerodynamic activity median diameter (aamd) and geometric standard deviation ( $\sigma_g$ ) rather than mass median diameter. The aamd probably relates most closely to the performance of an air cleaner against these aerosols.

Previous evaluation of the Andersen impactor has indicated a potential error due to particle rebound.<sup>(5,6)</sup> If the particle does not adhere to the first plate it contacts, but deposits on the next stage, or rebounds from all succeeding stages to be collected by the backup filter, the indicated aerosol size characteristics are in error. Use of a "sticky" impaction surface would interfere with alpha counting procedures and was not acceptable. An alternate technique is the application of membrane filter media to the surface of the impactor plates.<sup>(6)</sup> In tests now under way, adjacent impactor sampling streams have been installed at one sampling site, and samples obtained covering the plates of one impactor with vinyl metricel

membrane filters (MF) leaving the plates of the other impactor bare. By alternating the MF coating on each impactor each day, data indicating rebound (or no rebound) can be developed despite possible slight differences between the two sampling streams. Alpha spectroscopy has provided information on the potential error associated with absorption of the alpha particles by the filter media applied to impactor plates as an anti-rebound agent. Preliminary analysis of the vinyl metrical media showed very little absorption and indicate its suitability as an impactor anti-rebound agent.

Sampling locations at each plant were selected to monitor the more contaminated air streams in each plant, and sampling systems were designed to provide isokinetic sampling conditions. Samples are collected for varying lengths of time, depending on the activity in the duct. For convenience of handling, counting, and shipping, activity per sample is limited to about  $10^5$  dpm, therefore, the time required to collect a sample of this order of magnitude varies greatly for each sampling location. Sampling periods are selected at times when normal activities in the building are underway; i.e., not at lunch time or break time or near quitting time.

A gas flow proportional counter is used to count alpha activity on each sample. This counter is approximately 33% efficient for bare samples and 22% efficient for standard sources covered with a .00025" mylar film. The mylar film is used to cover each impactor plate and filter to minimize contamination problems. Net count rate is determined for each sample and utilized as previously discussed in determining cumulative percent smaller than a stated aerodynamic particle size. Net count rates and the corresponding effective cutoff diameters (ECD)<sup>(7)</sup> are submitted for computer analysis as a data set of 8 values to be fit by minimum chi-squares method<sup>(8)</sup> and plotted on a log probability grid.<sup>(9)</sup> This analysis defines aerodynamic activity median diameter (aamd) and geometric standard deviation ( $\sigma_g$ ) for the aerosol, and the deviation of each data point from the best fit line. The latter value can be utilized in a test to confirm or reject the assumption of log normality of the distribution. A range of aamd and ( $\sigma_g$ ) describes variations in the size characteristics of typical Pu aerosols.

To provide a frame of reference, Table 1 summarizes the operational characteristics associated with each sampling site. Table 2 indicates the variations in total activity at each sampling site. Concentration data was obtained using both Andersen impactors and adjacent membrane filters. Major variations between week-day and week-end samples are apparent for site A. Even greater variations between site A and sites B and C are, also indicated.

### III. Aerosol Size Characteristics

Size characteristics of the Pu aerosols defined by the Andersen impactors are summarized in Table 3, which also indicates the significance of the rebound problem. Arithmetic mean values of aerodynamic activity median diameter (aamd) and geometric standard deviation ( $\sigma_g$ ) are listed along with their extremes. Variations are apparent, which is not too surprising considering the large number of different

aerosol-producing operations conducted in these plants.

Somewhat surprising was the size distribution of the Pu aerosol at Location B. Size characteristics of the aerosol measured here are distinctive due to the high percentage of very small particles in the distribution. In the 14 impactor measurements made to date, the cumulative percent smaller than  $0.43 \mu\text{m}$  (final impactor stage ECD) has averaged 60%; that is, 60% of total activity measured in the impactor sampler passed through the impactor and was collected on the backup membrane filter. A distribution of this type is not readily characterized by the Andersen impactor, and these results have not been considered in this presentation.

Figures 1 through 6 are included as log probability representations of typical plutonium size distributions, and the extremes. Figure 1 represents a sample which closely approximates the mean aerosol at Location A (aamd =  $1.70 \mu\text{m}$  and  $\sigma_g = 2.33$ ). Figures 2 and 3 represent two extremes of  $\sigma_g$  for this sampling location. Figures 4 through 6 show typical size distributions for locations C, D and E. In each figure a best fit line defined by the chi-squares method<sup>(8)</sup> is provided. Examination of the data in Table 3 reveals no significant particle rebound. Had the uncoated plates displayed a consistently lower aamd and higher  $\sigma_g$  than coated plates, or larger amounts of activity on the backup filter, a rebound problem would be suggested. Preliminary results of rebound tests conducted with twin impactors has also indicated no rebound problem.

Spectroscopy of several samples has shown the presence at Location A of  $^{238}\text{Pu}$  and  $^{239}\text{Pu}$  in similar quantities which complicates measurement of size characteristics. The  $^{238}\text{Pu}$  and  $^{239}\text{Pu}$  particles contributing to the total alpha activity on each impactor plate probably originate at different unrelated operations resulting in two distinct size distributions as indicated in Fig. 7. Samples to investigate the makeup of composite distributions using alpha spectroscopy have been obtained, and are undergoing analysis. Impactor samples will provide  $^{238}\text{Pu}$  to  $^{239}\text{Pu}$  ratios for each stage, relating isotope concentration to aerodynamic size.

#### IV. Acknowledgment

The cooperation, guidance, and assistance of many people and groups at Rocky Flats Div, Dow Chemical Co.; Mound Laboratories, Monsanto Research; Los Alamos Scientific Laboratory is gratefully acknowledged.

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Table 1  
Sampling Locations

<u>Location</u>	<u>Plutonium Isotope</u>	<u>Major Operation</u>
A	238 & 239	r & d
B	239	recovery
C	239	production
D	238	r & d
E	238	production & recovery

Table 2

Activity Concentrations of Pu Aerosols (dpm/m<sup>3</sup>)

<u>Description</u>	<u>Location</u>	# <u>Samples</u>	<u>A<sub>1</sub> (direct MF)</u>			<u>A<sub>S</sub> (Impactor + MF<sub>2</sub>)</u>		
			<u>Mean</u>	<u>Max</u>	<u>Min</u>	<u>Mean</u>	<u>Max</u>	<u>Min</u>
Weekdays	A	65	11,388	34,590	286	9,980	36,325	198
Weekends	A	15	988	4,579	51	1,505	4,798	44
Weekdays	B	19	8.10x10 <sup>6</sup>	16.5x10 <sup>6</sup>	3.87x10 <sup>6</sup>	6.72x10 <sup>6</sup>	15.2x10 <sup>6</sup>	4.06x10 <sup>5</sup>
Weekdays	C	26	1.27x10 <sup>5</sup>	7.86x10 <sup>5</sup>	1,814	0.98x10 <sup>5</sup>	6.79x10 <sup>5</sup>	2,611
Weekdays	D	12	12,020	0.1x10 <sup>6</sup>	138	4,124	32,537	4
Weekdays	E	11	31,084	0.303x10 <sup>6</sup>	12	24,913	2.43x10 <sup>5</sup>	25

Table 3  
Andersen Impactor  
Size Characteristics of Pu Aerosol

<u>Description</u>	<u>Location</u>	# <u>obs.</u>	<u>aamd (<math>\mu\text{m}</math>)</u>			<u><math>\sigma_g</math></u>		
			<u>mean</u>	<u>max</u>	<u>min</u>	<u>mean</u>	<u>max</u>	<u>min</u>
Weekdays, no coating	A	63	1.70	3.30	.52	2.33	4.94	1.53
Weekends, no coating	A	12	1.92	3.32	1.03	2.37	3.20	2.03
All Samples, DM-800 coating	A	5	2.10	2.50	1.25	2.09	2.61	1.74
All Samples, AA coating	A	10	1.86	2.70	.92	2.38	3.37	1.83
Weekdays, AA coating	B	14	*					
Weekdays, no coating	C	6	2.83	3.53	1.96	3.03	6.40	1.98
Weekdays, AA coating	C	11	2.37	3.25	1.61	2.98	6.6	2.06
Weekdays, DM-800 coating	D	9	3.20	5.51	1.80	3.11	4.36	2.13
Weekdays, DM-800 coating	E	11	1.87	2.99	.57	2.21	2.63	1.58
All samples (excluding B)		127	--	5.51	0.52	--	6.60	1.53

\*60% smaller than last impaction stage; not amenable to analysis using Andersen impactor.

DM-800-Gelman vinyl metrical membrane filters (.8  $\mu\text{m}$  pore size)

AA-Millipore Filters (.8  $\mu\text{m}$  pore size)

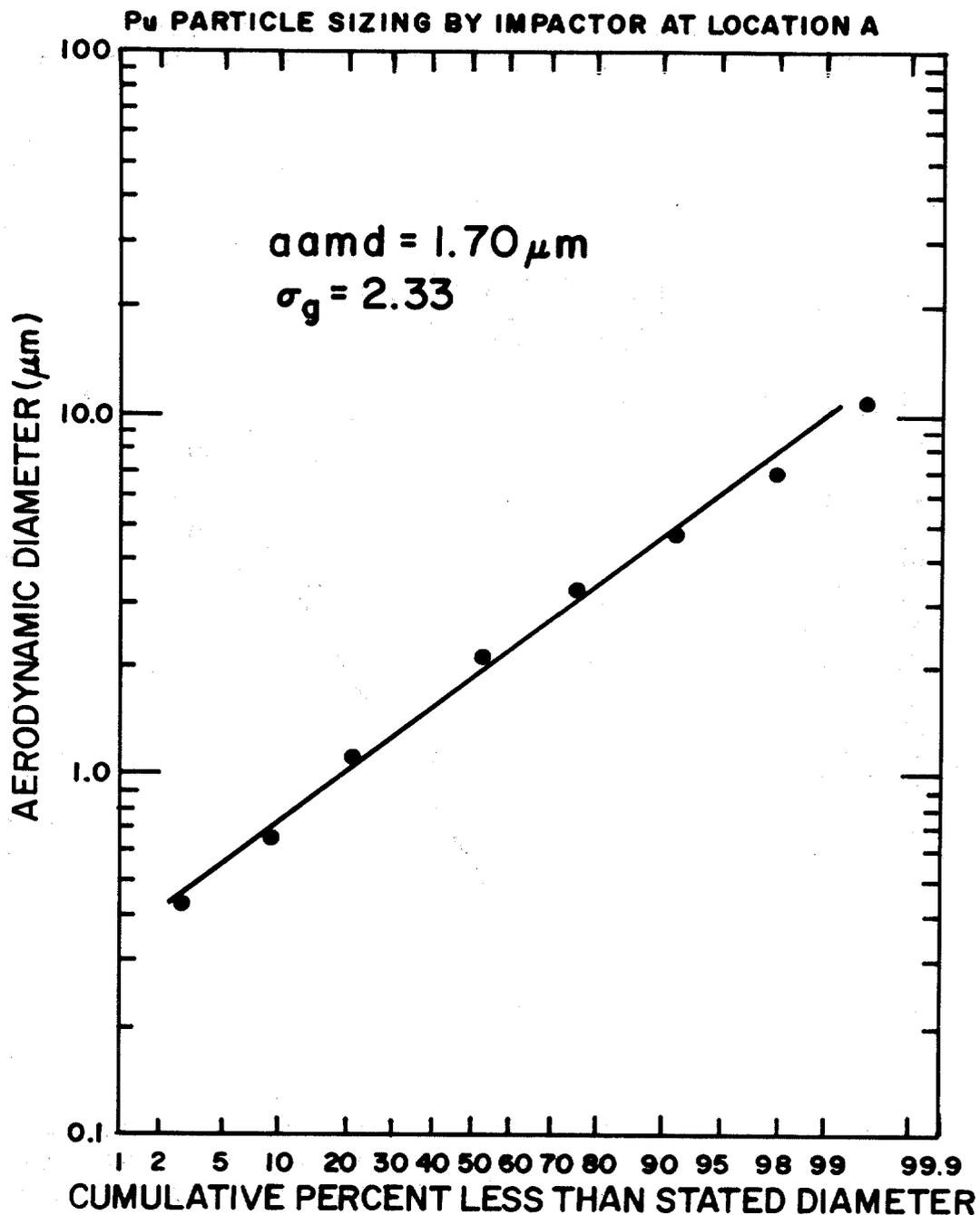


Figure 1: Size Characteristics of Pu Aerosol--  
 Representative of Mean aamd and  $\sigma_g$ .  
 LOCATION A

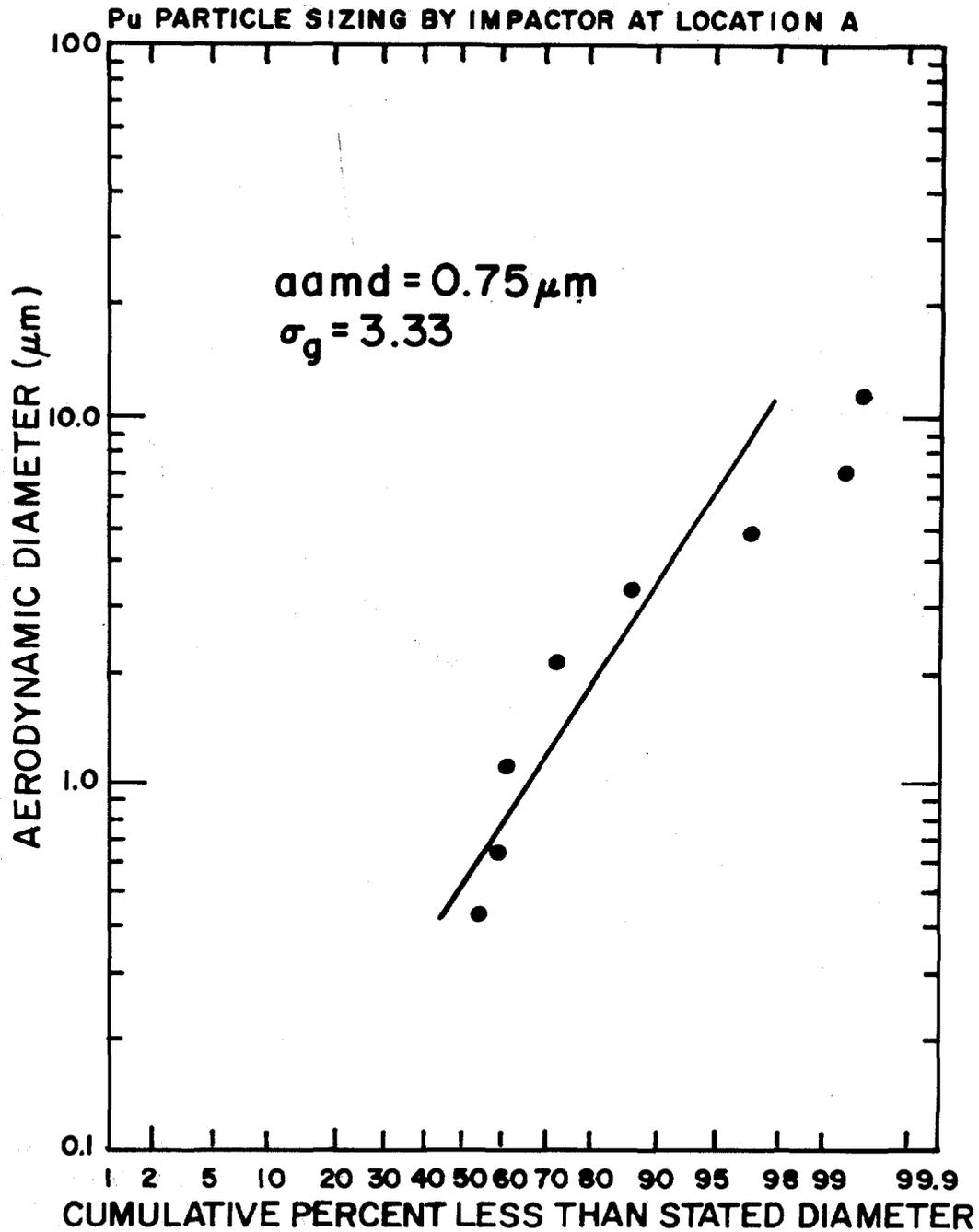


Figure 2: Size Characteristics of Pu Aerosol--  
 Representative of Distribution With High  $\sigma_g$ .  
 LOCATION A

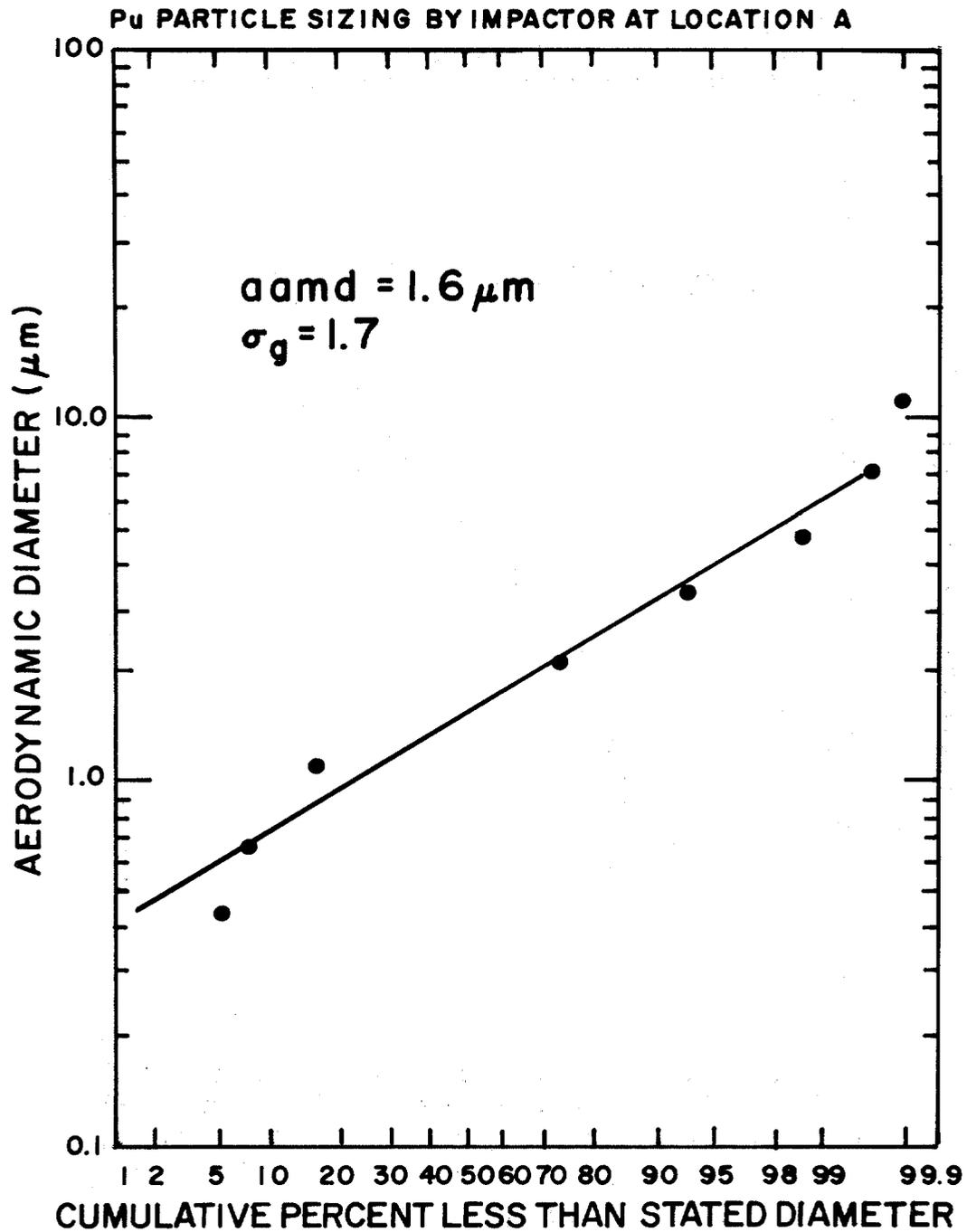


Figure 3: Size Characteristics of Pu Aerosol--  
Representative of Distribution with Low  $\sigma_g$ .  
LOCATION A

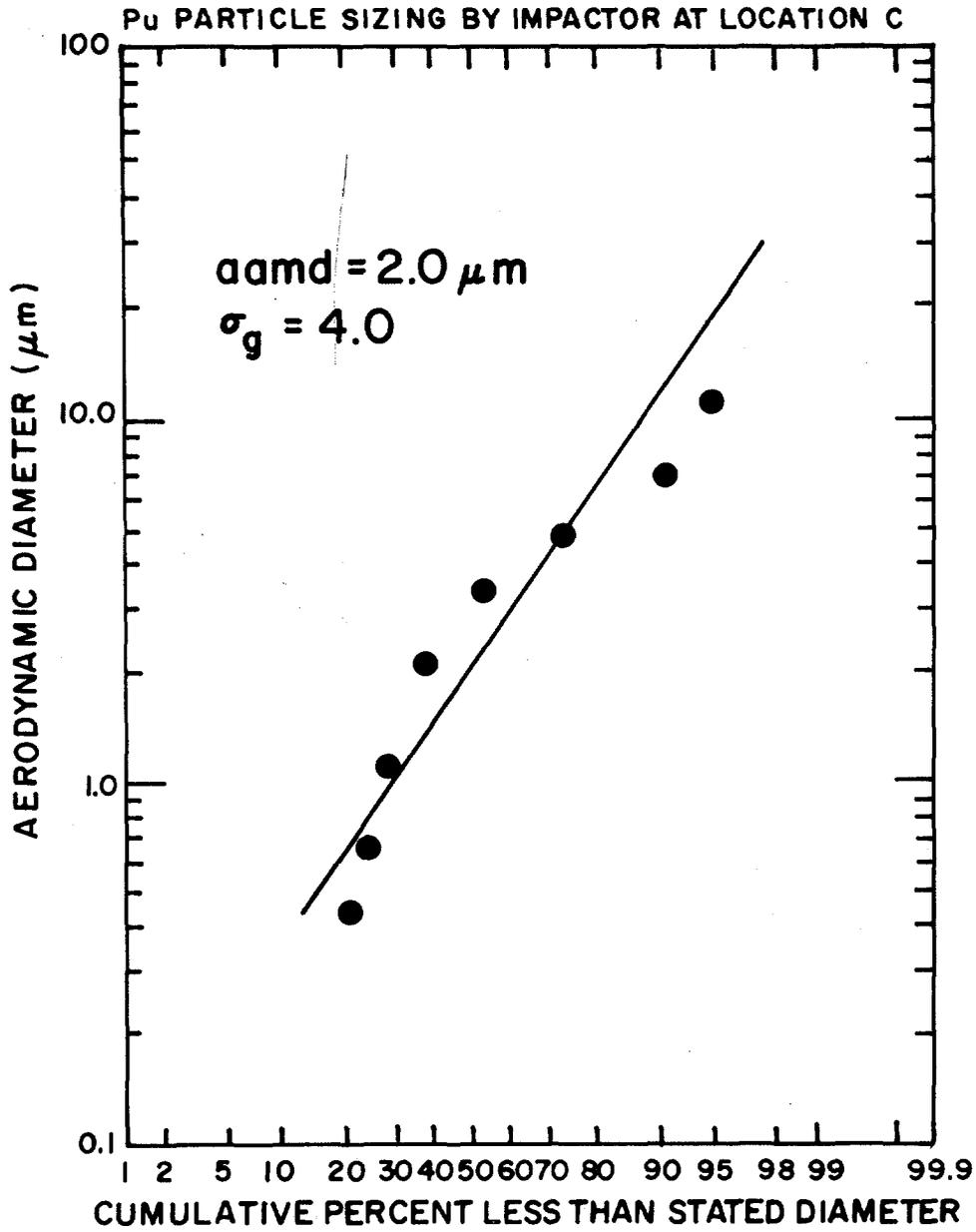


Figure 4: Size Characteristics of Pu Aerosol -- Typical Distribution - Location C

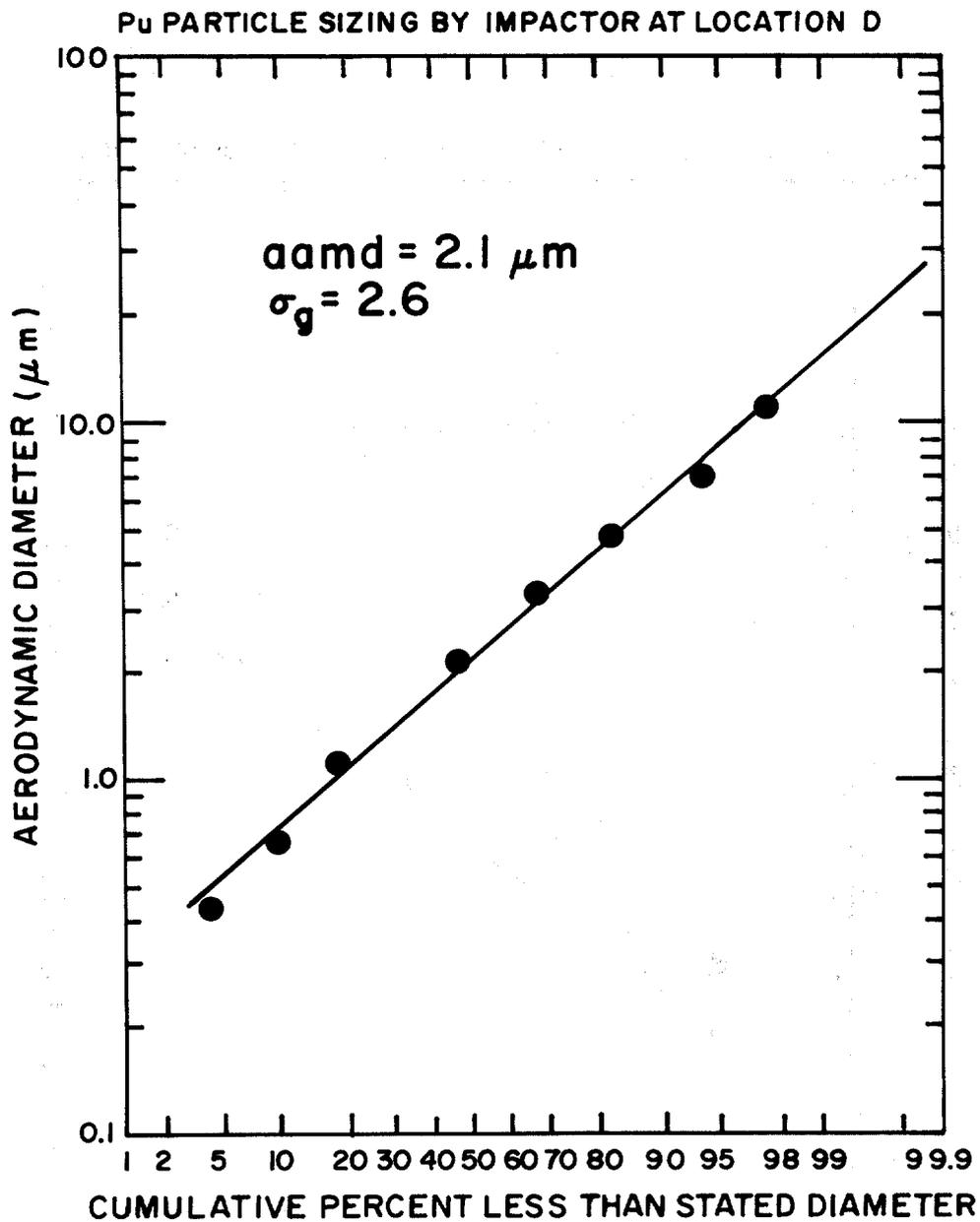


Figure 5: Characteristics of Pu Aerosol --  
Typical Distribution - Location D

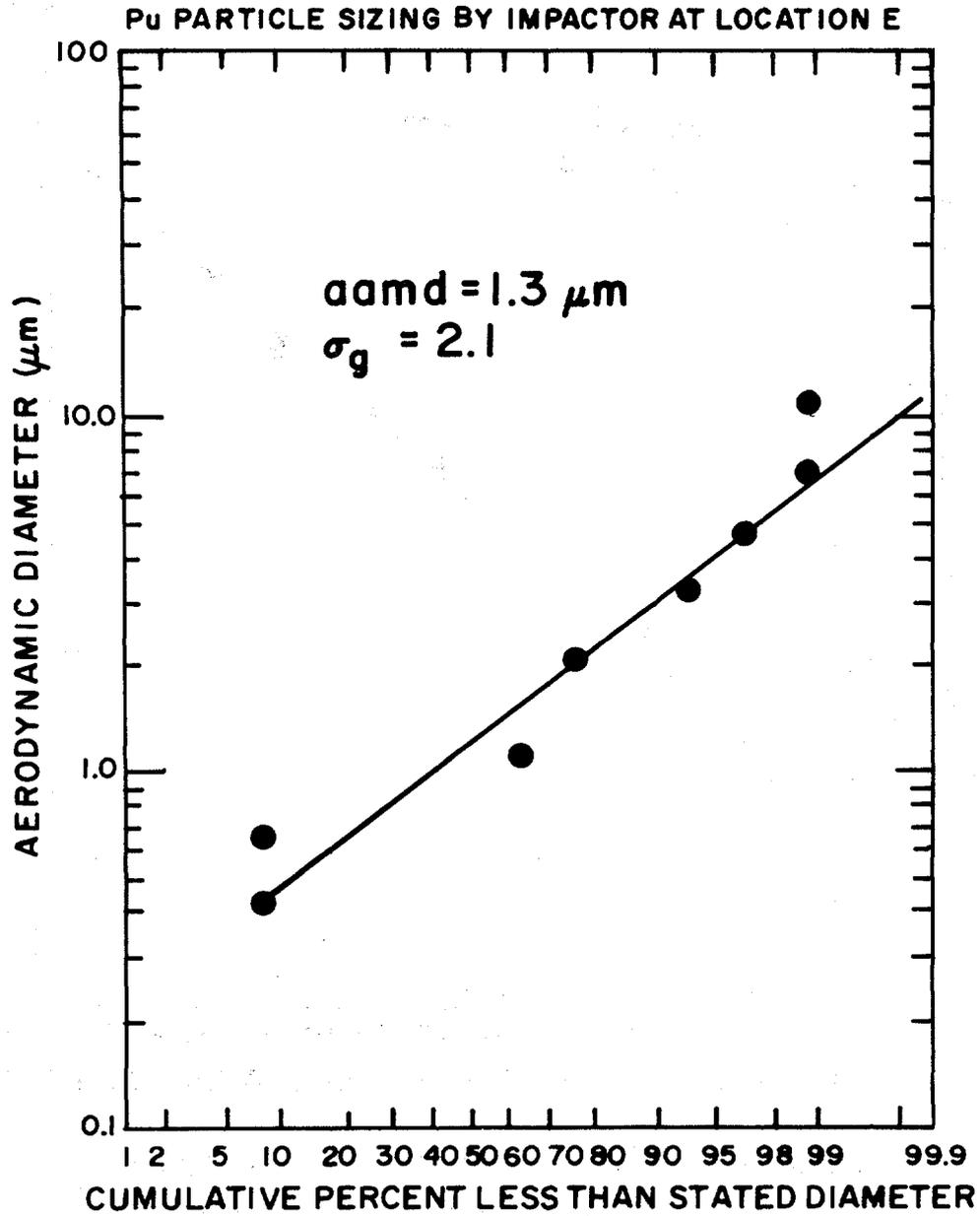


Figure 6: Size Characteristics of Pu Aerosol -- Typical Distribution - Location E

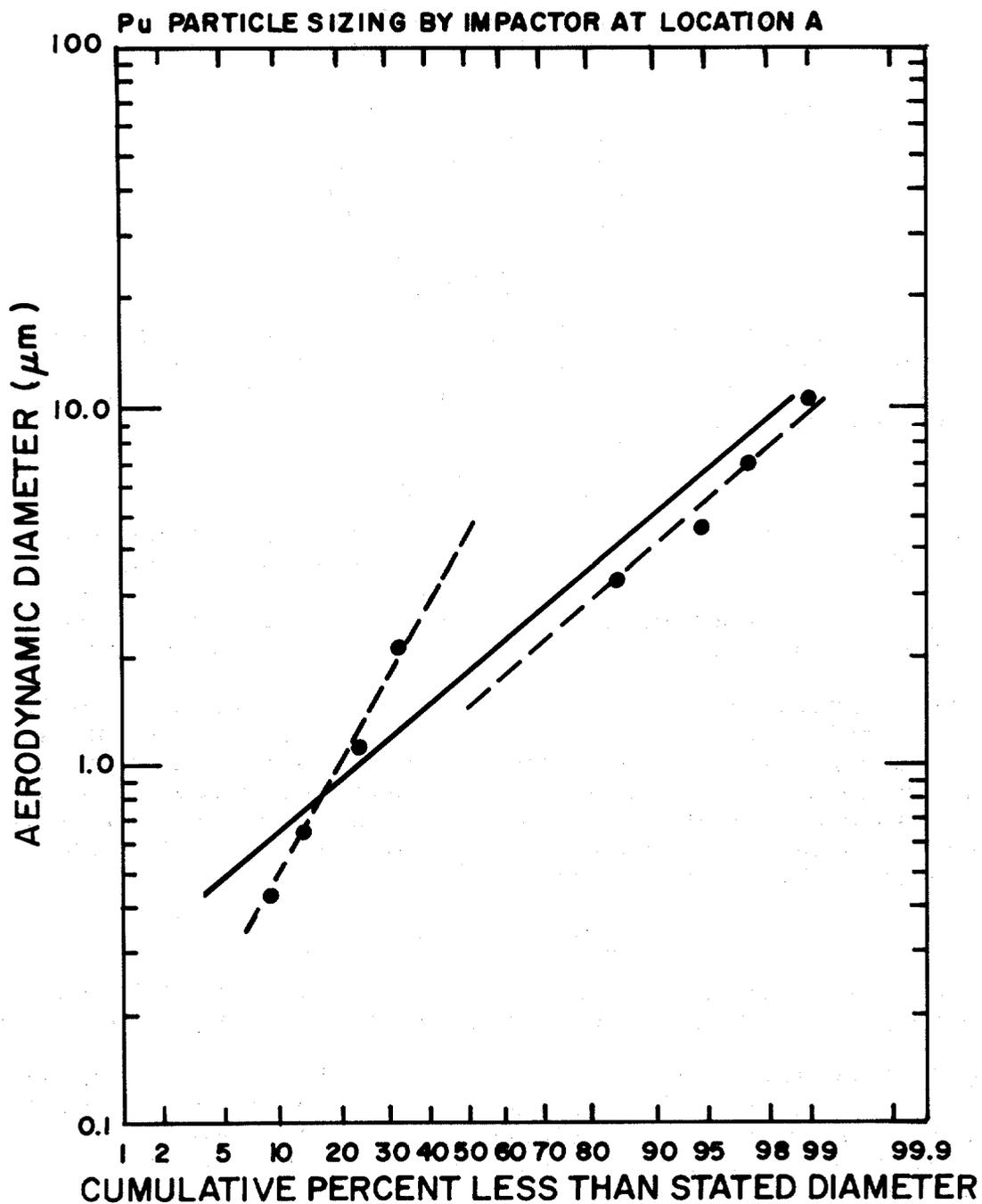


Figure 7: Size Characteristics of Pu Aerosol--  
Representative of Composite Distribution.

WATER SPRAY HEAT EXCHANGERS  
FOR HEPA PROTECTION IN ACCIDENTS  
(HEAT REMOVAL REQUIREMENTS AND THE EFFECT  
OF SMOKE AND WATER ON HEPA FILTERS)

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Abstract

The bulk air temperature as the result of a credible glovebox fire was calculated to be 226°F for a Rocky Flats room module. Experiments performed showed water spray on HEPA filter media to have a greater effect on plugging than smoke.

I. Introduction

The smoke and heat from fire occurring within a radiochemical processing facility must be vented through the buildings' high efficiency particulate air (HEPA) filtration system, as shown in Figure 1. This filtration system must continue to function under fire conditions, even though smoke can plug the filters and heat can damage them<sup>1</sup>.

In order to maintain the integrity of the building and its filtration system, a device is needed which will both abate the smoke and exchange the heat from the exhausting air. Such a device, consisting of a water-cooled heat exchanger, has been described in an earlier paper<sup>2</sup>. In order to design this device, some prediction of the inlet air temperatures are necessary. In addition, the effectiveness of smoke removal should be determined.

II. Experimental Results

Tests have been run to simulate the effect of fire with full-size gloveboxes<sup>3</sup>. Figure 2 shows a typical scene during these tests.

Figure 3 shows the temperature of the glovebox ventilation air during a fire. The reason for the different rates of rise is that the air flow varied between tests. Figure 4 shows the temperature of the air surrounding the burning glovebox. The step in these curves is due to sprinkler discharge.

Using temperatures of 1600°F for the glovebox ventilation air and 1000°F for the air surrounding the glovebox, calculations have been made which show that for a credible glovebox fire, the bulk temperature of the air entering the filtration system will be 226°F.

Two experiments were performed in the fire test facility at Rocky Flats<sup>4</sup> to study the effects of water and smoke on filters.

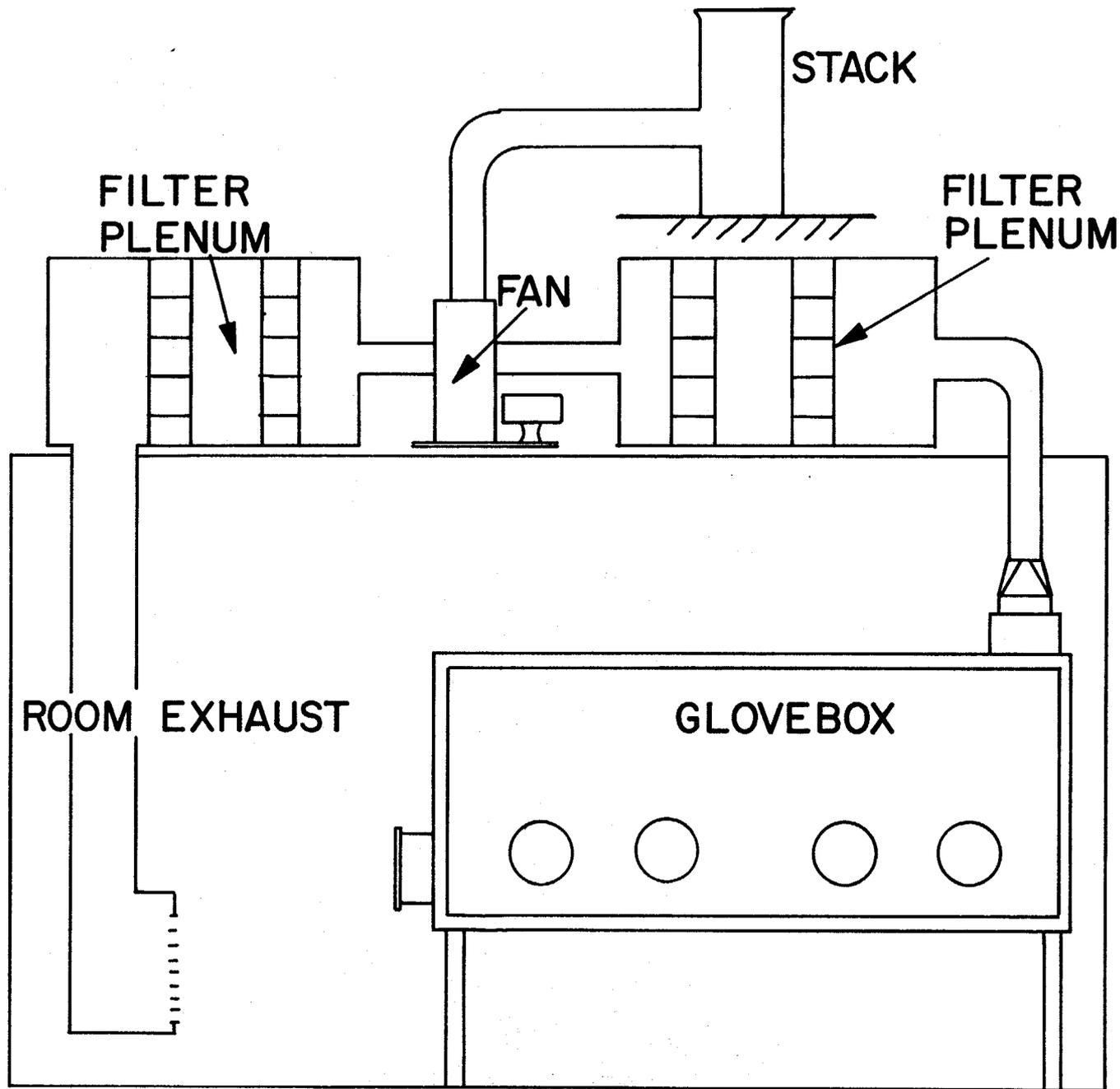


FIGURE 1 Glovebox System

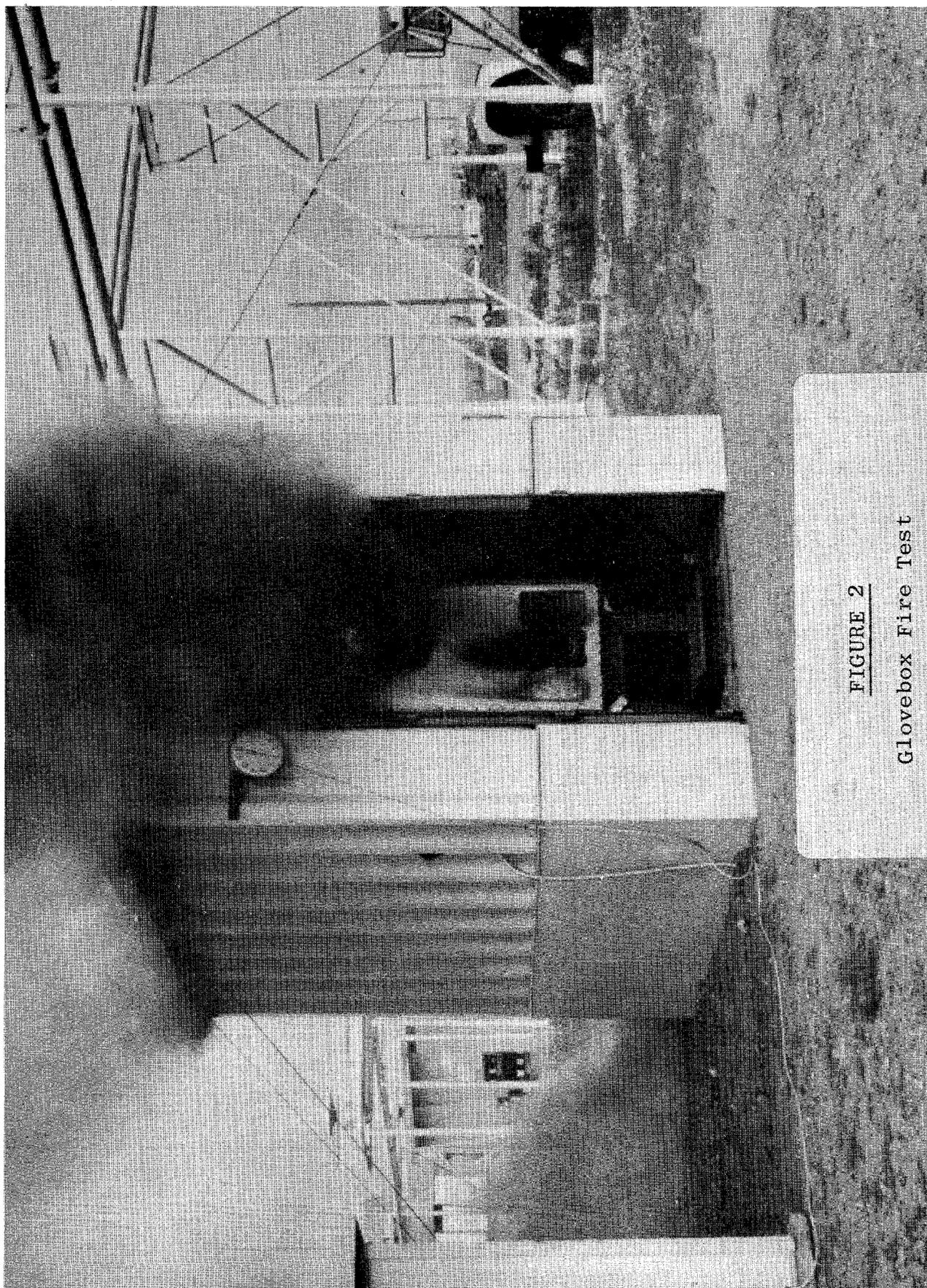


FIGURE 2  
Glovebox Fire Test

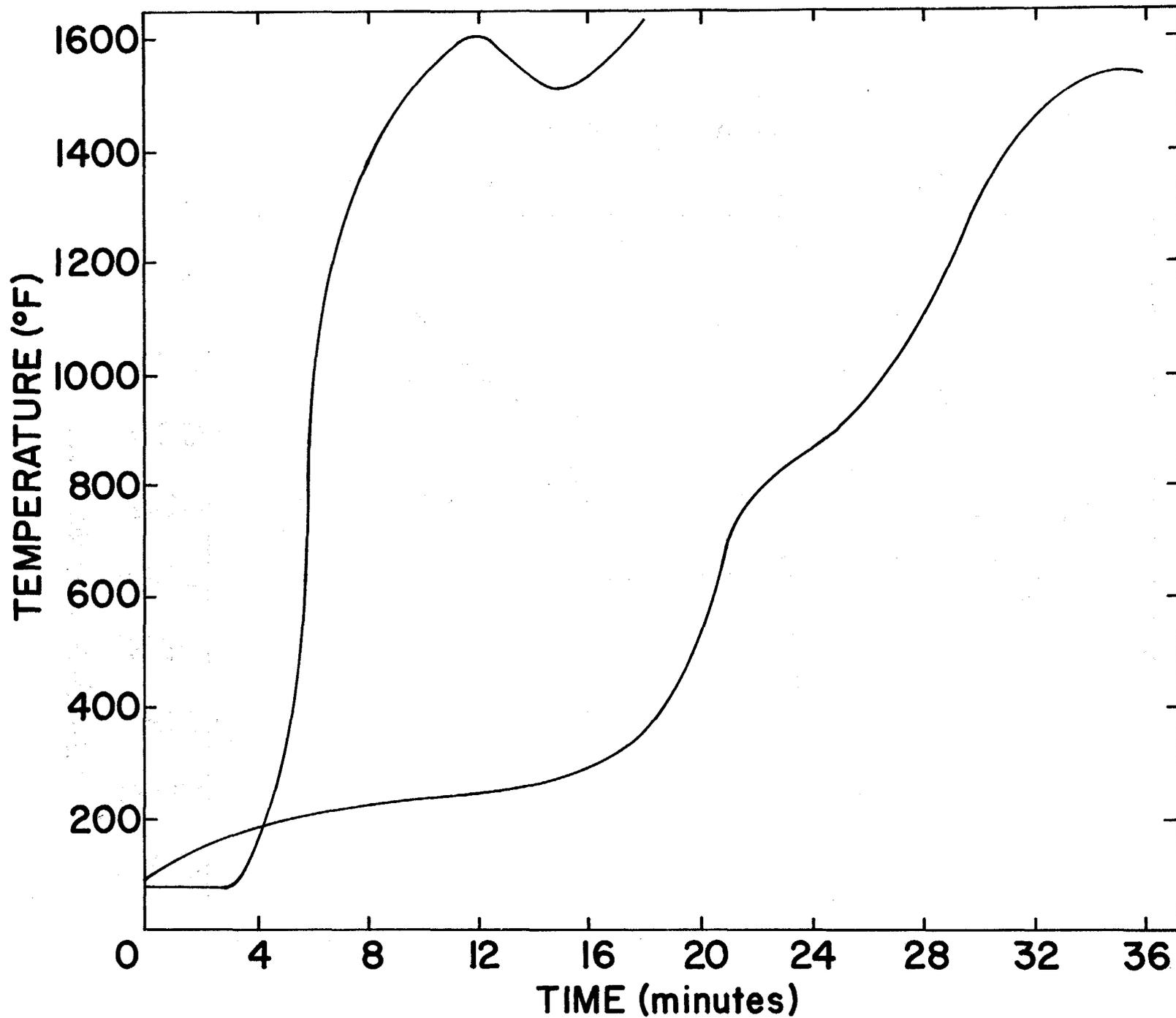


FIGURE 3 Air Temperatures Within Glovebox

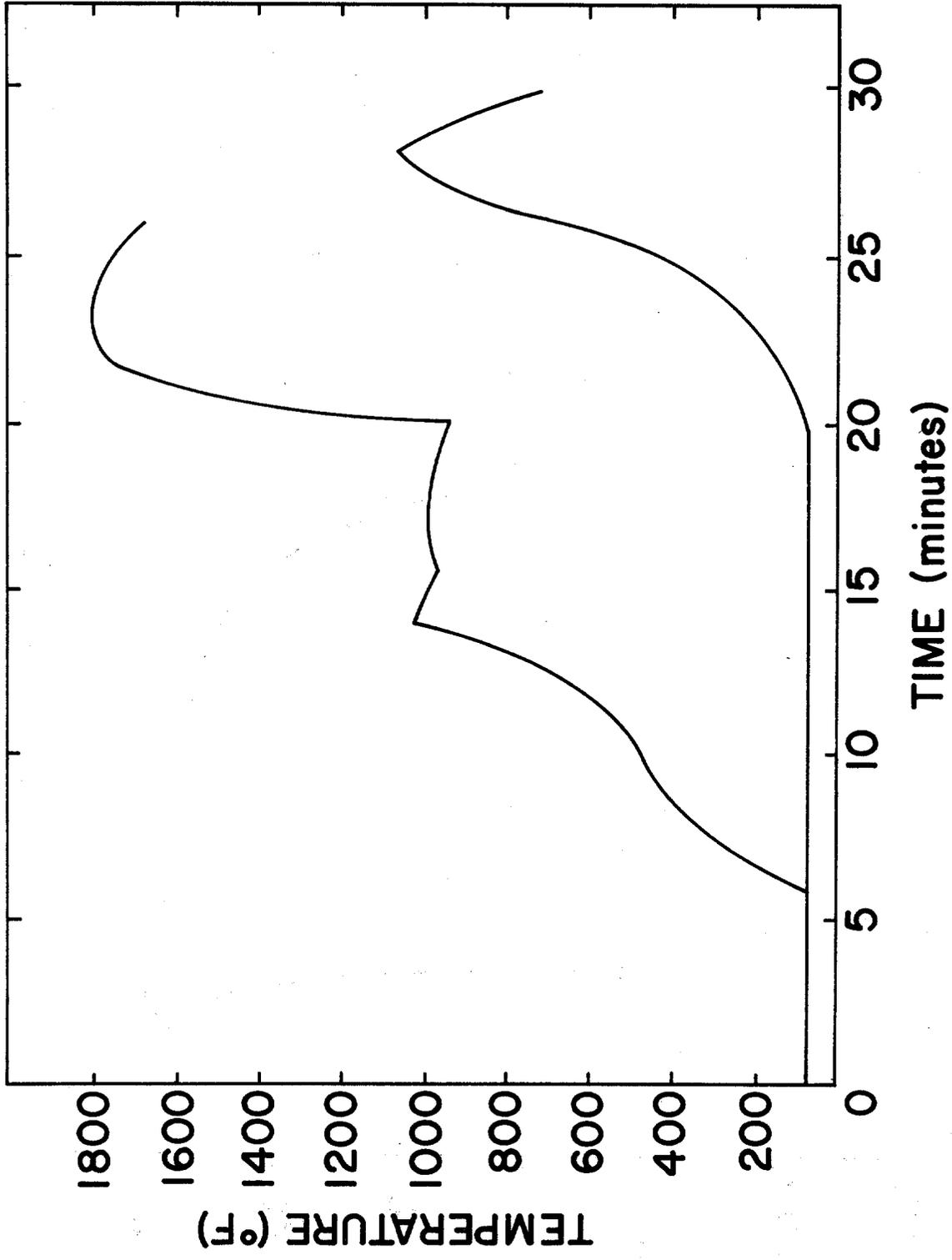


FIGURE 4 External Temperature of Glovebox

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The experimental arrangement for the initial test of this series is shown in Figure 5. The inlet duct was fitted with a 2 X 2 foot deflector located eight inches from the end of the duct as shown in Figure 6.

The test consisted of building a wood and paper fire in the incinerator and adjusting the air flow to 5400 CFM. The water flow was activated when the filter face temperature reached 70°C. Table I and Figure 7 contain the data obtained in this test.

TABLE I

Smoke and Countercurrent Water Spray

Time (Min. - Sec.)	Pressure Drop Across Filters (Inches of Water)
0	0.29
2:20	0.26
8:00	0.5
16:00	0.36
32:00	0.52
38:00	0.52
60:00	0.52

The nozzle used for the fire test was a Viking Model A2-120°. The total gallorage of water delivered was 790 which yields a water density of 12 gallons per minute or 0.25 gallons per minute per square foot of filter area.

The air flow through each filter was measured with an Alnor Velometer and the results of these measurements are summarized in Figure 8. The flows are expressed in cubic feet per minute, uncorrected for altitude or temperature; however, the temperature was the same (4.5°C) when all the measurements were taken. The row (Figure 8) marked "CFM Dry" was the air flow established through a new set of filters. The row "CFM Wet" was the air flow measured after the experiment was performed and the filters were wet from the carried-over spray. The remaining row shows the air flow existing after 14 hours of air-drying at 5400 CFM.

Twelve new filters were used for these tests and a DOP (polydisperse) in-place test showed the installation to be 93 percent effective. Immediately after the test, the filters were in-place tested and found to be 97 percent efficient. The reason for the increase could be that a crack between the filter frames and plenum ceiling was located and

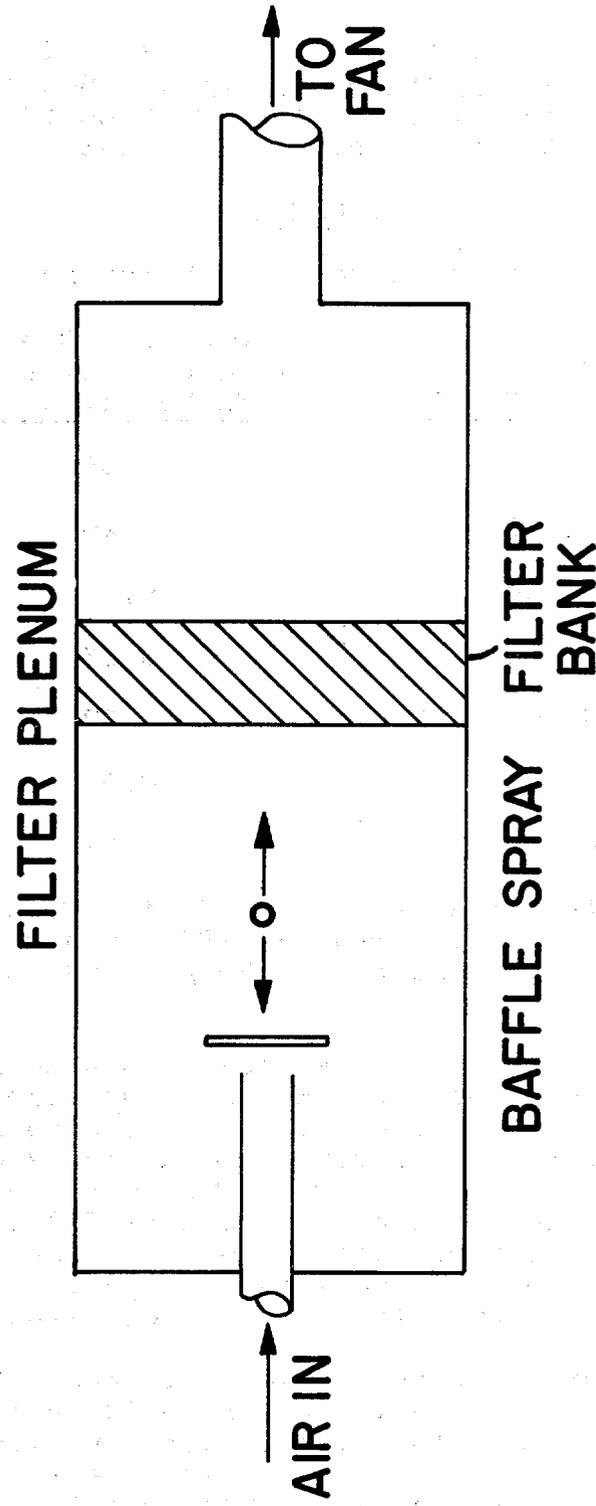


FIGURE 5 Plenum Configuration

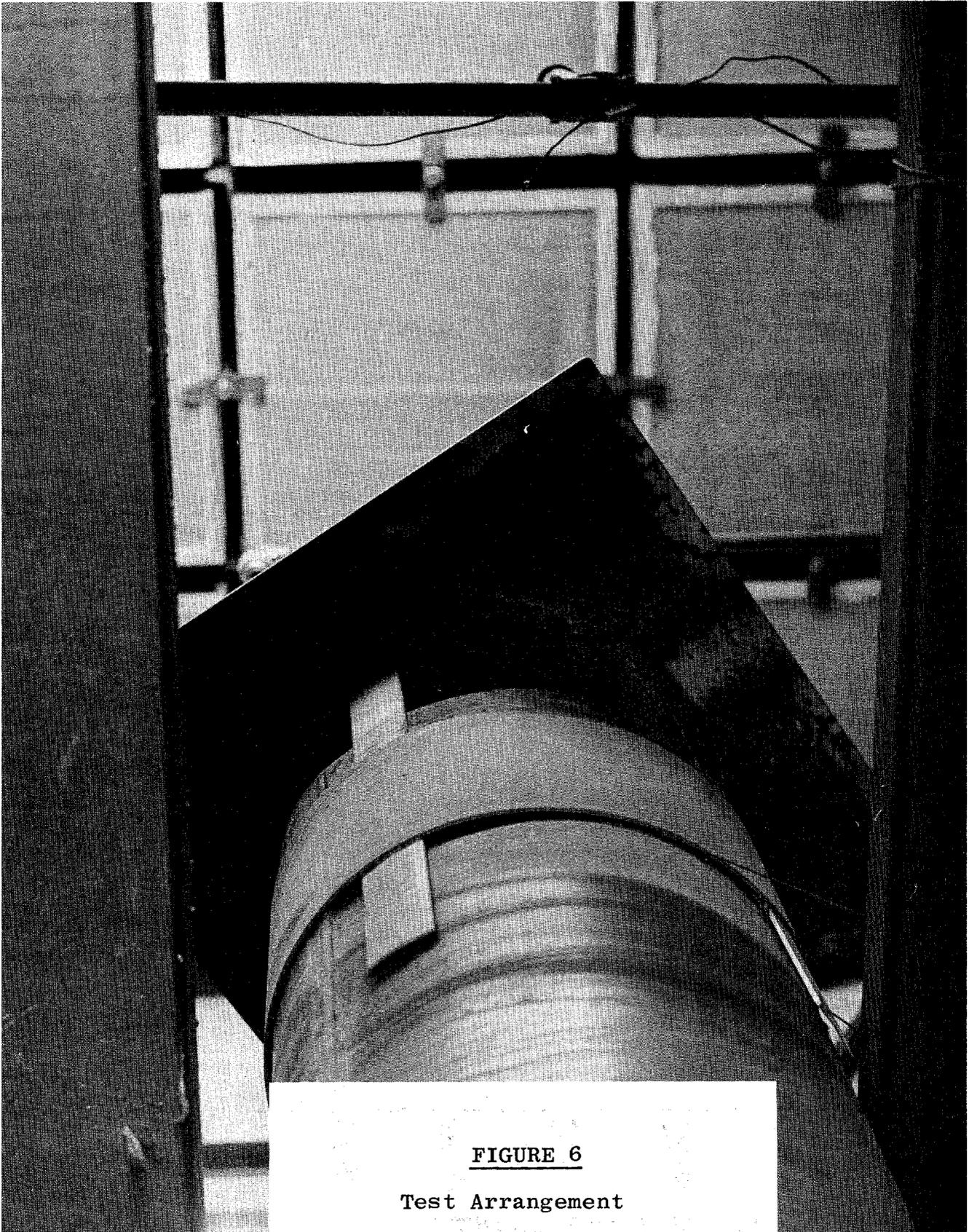


FIGURE 6  
Test Arrangement

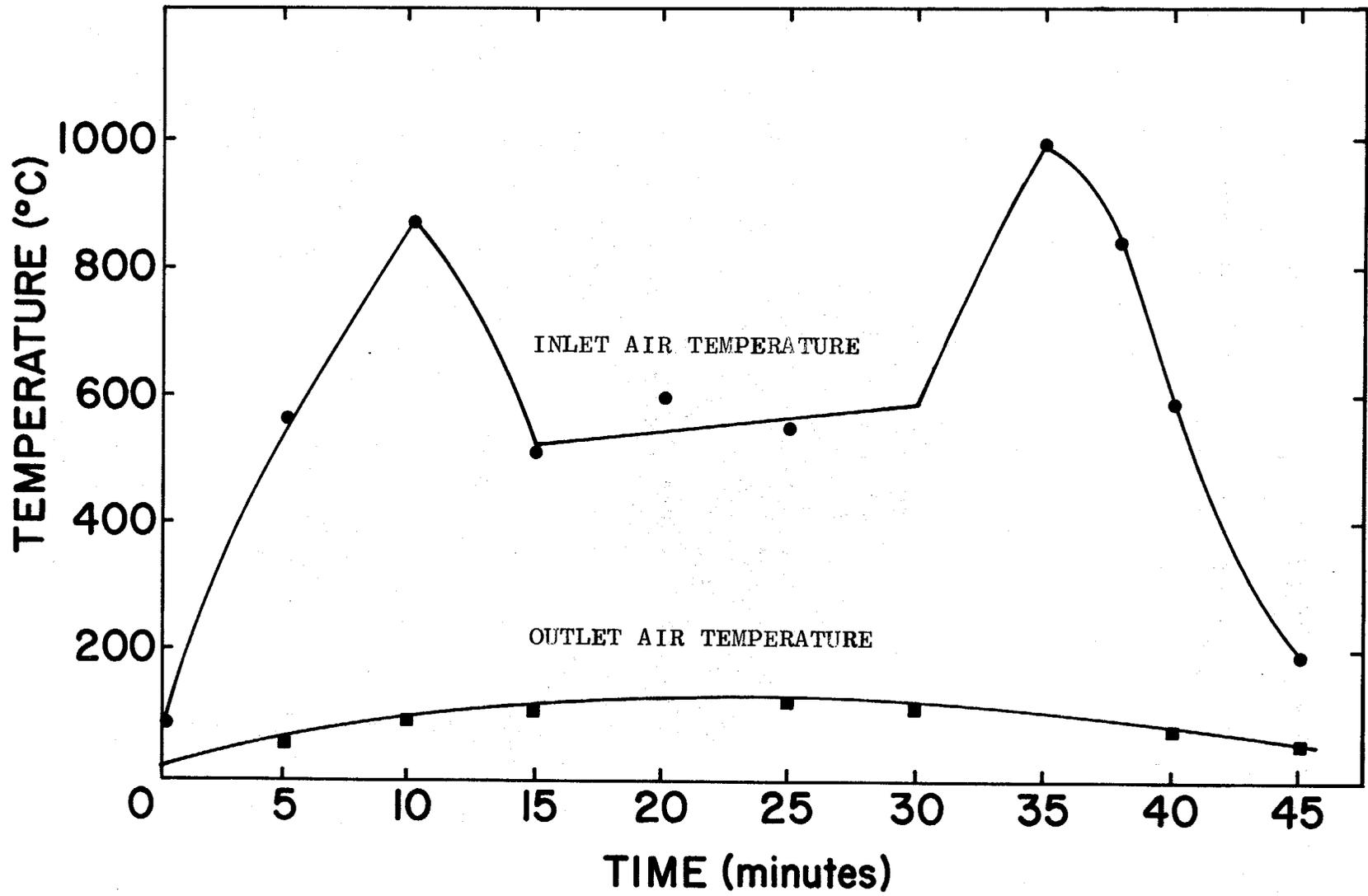


FIGURE 7 Inlet and Outlet Air Temperatures

FILTER NO. CFM DRY CFM WET CFM DRIED	1 440 320 400	2 480 300 320	3 540 320 360
FILTER NO. CFM DRY CFM WET CFM DRIED	4 400 280 320	5 400 340 420	6 440 260 336
FILTER NO. CFM DRY CFM WET CFM DRIED	7 440 300 380	8 460 280 380	9 440 280 320
FILTER NO. CFM DRY CFM WET CFM DRIED	10 420 300 340	11 420 300 300	12 400 360 320

FIGURE 8

Air Flow Rates

patched. Three of the filters were individually DOP tested for efficiency. The data for these tests are tabulated in Table II. The filter numbers refer to location indicated by an upstream view of the filter frame as shown in Figure 8.

TABLE II

Filter Efficiency After Fire Test

<u>Filter No.</u>	<u>DOP Efficiency</u>
1	99.996
5	99.998
2	99.998

Inspection of the interior of the plenum showed that fire residue, ash, soot, and smoke particles were deposited on the plenum walls at the point of impingement of the water spray. No damage to the media was noted either by visual or DOP inspection. Figure 9 has been constructed from data of Table I and Figure 3 to show the relationship between pressure drop and flow for the 12-filter bank in the plenum.

An experiment was performed by spraying water directly upon 12 clean, 24" X 24" X 11 7/8" HEPA filters from a Viking A-2 sprinkler positioned three feet from the filters at a rate of 0.25 gallons per minute per square foot of filter face. During this experiment, the fan inlet valve remained at a constant setting and the pressure drop was allowed to vary.

Since the fire was not used in this experiment, there was no effect from smoke on the change in pressure drop. The data are presented in Table III and show the increase in pressure drop, due to the water spray, to be 0.18 of water for the 30.5 minutes of spray.

TABLE III

Water Spray Data

<u>Time (Minutes)</u>	<u>Pressure Drop Across Filter Bank (Inches of Water)</u>
1.0	0.27
6.0	0.31
12.0	0.36
18.0	0.40
24.0	0.42
30.5	0.44

Figure 9 and Table III have been used to construct Figure 10 which shows the relationship between flow through a filter and time of exposure to water.

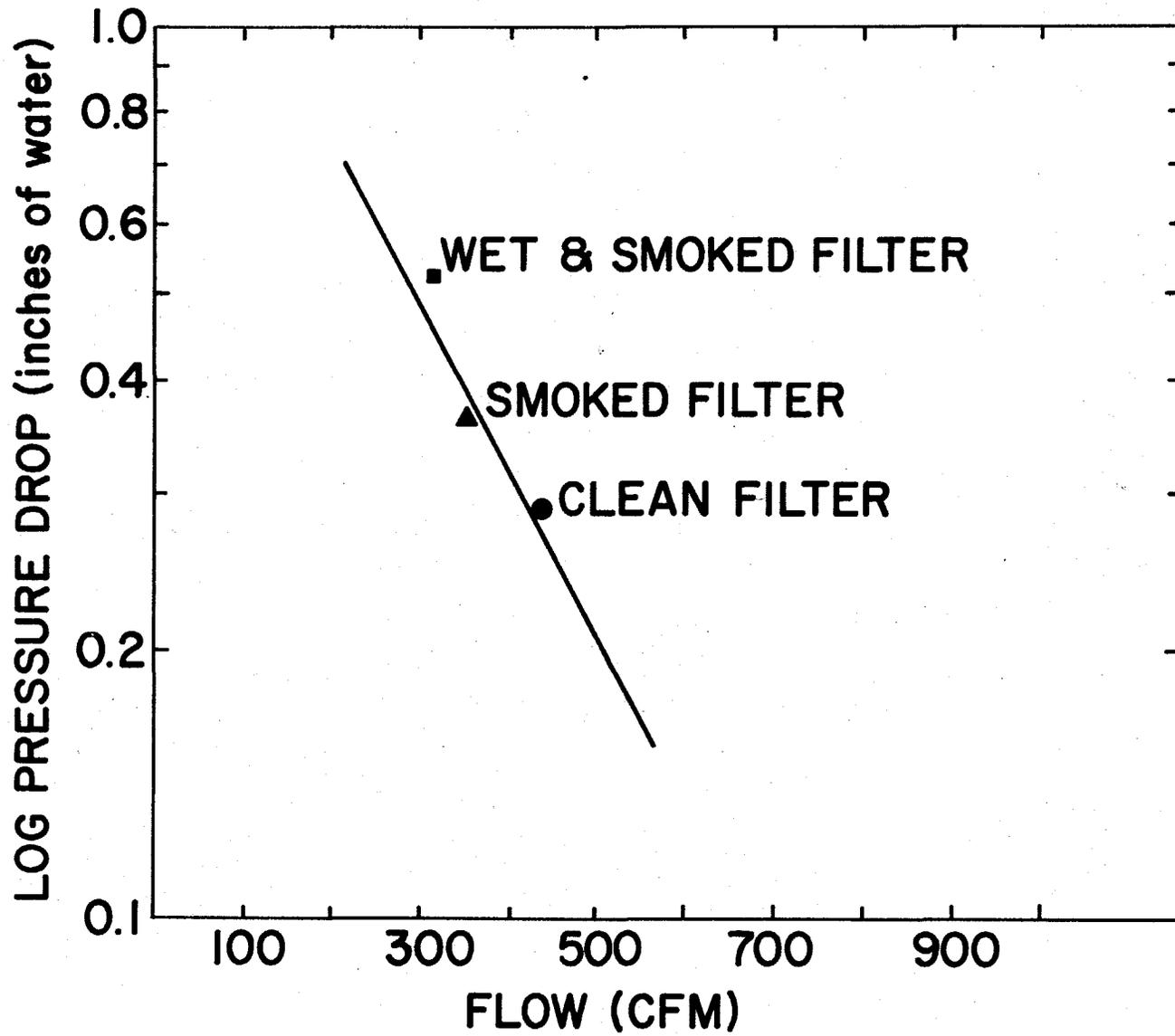


FIGURE 9 Pressure Drop - Flow Correlation

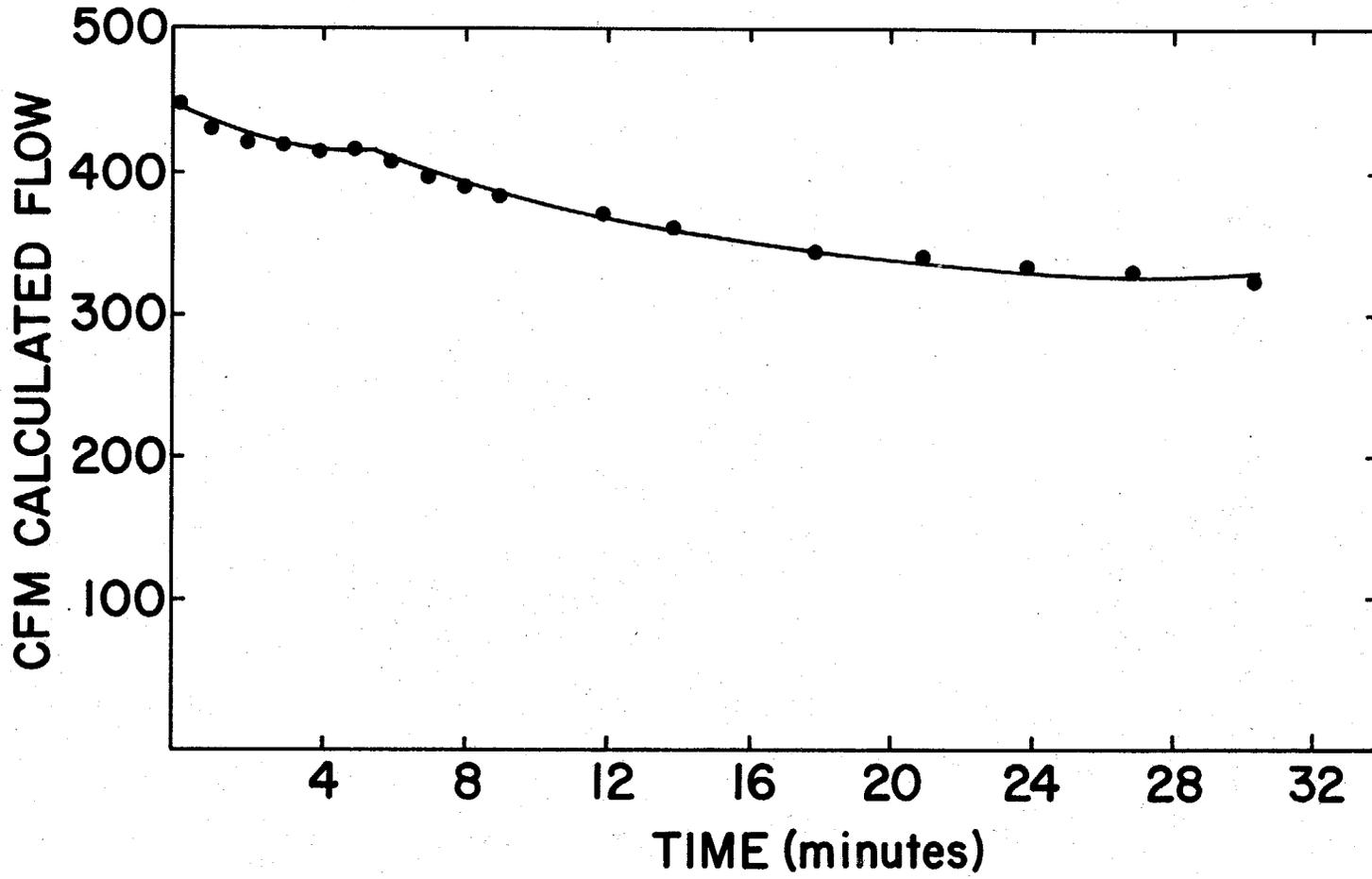


FIGURE 10 Water Plugging of HEPA Filters

III. Discussion

With restricted air exhaust, a glovebox fire fueled by Plexiglas and rubber gloves will reject the greater proportion of its heat to the surrounding module air. The predicted bulk air temperature of 226°F assumes that perfect mixing of the module air occurs. This would not be the case however, and it might be possible for 1000°F air to impinge upon some of the overhead areas of the module. Design of the filter plenum heat exchanger should use an inlet temperature between these numbers.

The average flow through the dry filters was 440 CFM per filter at a pressure drop of 0.29 inches of water. After 60 minutes of the paper and cardboard fire, the pressure drop had increased to 0.52 inches of water. The average air flow rate at this time was 303.3 CFM per filter. The filters were dried and the average flow rate became 349.6 CFM per filter, and the pressure drop had decreased to 0.37 inches of water.

By subtraction, the pressure drop due to smoke plugging became 0.08 inches of water, and that due to water, 0.15 inches of water.

These data show that smoke plugging from a fire to be less an effect than water plugging as determined from the pressure drop across the filters.

Referring to Table I, the system was run one minute and 30 seconds before the water was turned on. However, smoke was entering the system for this period of time. Unfortunately, the pressure drop was not recorded at the time the water spray was activated, but 50 seconds later, the pressure drop with the water spray going had decreased. Therefore, it may be safe to assume that the initial rate for smoke plugging is small.

In the second filter plenum experiment, the pressure drop increase of 0.18 inches of water is of the same order of magnitude when compared with the pressure drop of 0.15 inches of water reported in the first experiment. In the first experiment, the water spray was counter-current to the air flow for one hour and in this experiment, it was co-current to the air stream for one-half hour. However, when the pressure drop time relationship (Tables I and III) are compared at the 30 minute time, a similar pressure drop is obtained; 0.50 inches of water versus 0.44 inches of water.

That the pressure drop did not rise after 32 minutes as shown by the data of Table I suggests that the filters had become saturated with water. The smoke was being scrubbed from the air stream.

A water-cooled heat exchanger used to protect a HEPA filter system should be designed to handle an incoming air temperature of 1600°F from glovebox exhaust, and air in the 300-1000°F range rooms.

At half-rated air velocities, smoke is scrubbed at a sufficient rate to prevent a serious rise in pressure drop through filters. In the experiments reported, water spray was shown to have a greater effect on plugging than smoke.

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## 12th AEC AIR CLEANING CONFERENCE

### ENGINEERING ASPECTS OF PLUTONIUM FACILITY AIR CLEANING INSTALLATIONS

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Our task as the architect-engineer is to apply the knowledge gained by the research scientist, and the experience gained by the operators to provide safer and more efficient plutonium handling facilities. It is a team effort. No one member of the team can function adequately without the full benefit of the others' contributions. The end responsibility is equally shared and must be so recognized.

Release concentration limits for plutonium are well established, but are still under evaluation. These may change in the foreseeable future from concentrations to total quantities. The problem of plutonium is its long half-life, approximately 24,000 years, its relative indestructibility, and its apparent radiotoxic effect on animal life, even in minute quantity. The result of these is that our design goal is to control release of plutonium to the lowest practicable level below the established limits. And this comes at a time when our total quantity of plutonium in process is on the verge of a large increase because of reactor fuel needs.

Providing adequate and safe ventilation clean-up systems for plutonium facilities starts with an adequate knowledge of the quantity and physical characteristics of the materials to be controlled, particularly the plutonium.

More complete knowledge of the plutonium aerosol size range and the mass contribution by size will greatly aid us in applying more effective collection systems for specific operations such as manufacturing and chemical processing. An important related factor is that of the determination of the most effective means of collecting (electrostatic, nucleation) the sub-micron size plutonium aerosol. Today we rely mostly on the sand and HEPA filters, but we suspect they have limits to their effectiveness in the sub-micron aerosol range. We know that plutonium aerosols exist in size below 0.01 microns, particularly in fires which we must control and contain

We have already experienced the need for, and have achieved plutonium aerosol mass reduction ratios of greater than  $10^7$  in normal operation. Fires have resulted in greater reduction needs. Greater mass reduction ratios may be required when large scale plutonium reactor fuel reprocessing plants are built.

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I believe that new, and very positive means of collecting the aerosol are required. These should be applicable as close to the source of the aerosol generation as possible, in the fume collection system in a chemical process, for example, to keep them as small as possible. The ventilation system filters should be solely to protect the out-of-doors from an inadvertent failure within the primary collection system.

The HEPA and the deep bed sand fiberglass filters are our best tools in this area today, but each has its weakness which must be compensated for. The HEPA filter is subject to damage by fire and chemical attack, and is fragile and potentially damaged by upsets in the air system such as might be caused by tornado forces and system pressure excursions. Protection from these damaging effects must be provided. How far can we afford to go to effectively protect these from all possible dangers?

Deep bed sand and fiberglass filters cannot alone provide the necessary mass reduction ratios. They are good only to about  $10^4$ , based on 0.3 microns. Sand filters have been damaged by chemical attack. These filters were not originally conceived and designed for purely plutonium service. Experience is therefore limited. How much plutonium can we load into one of these filters? What are their nuclear safety limits? How do we assure we are safe after years of operation? How do we dispose of them after they are loaded to the limit or no longer needed? What happens to their efficiency after a severe earthquake? These are the type of questions we must now answer before we apply them.

Both large scale HEPA and deep bed filters pose a difficult testing problem once in operation. Any such future installation are going to require periodic performance testing. We need new, more simple and efficient testing methods. How valid is a cold generated DOP aerosol test (mean particle size 0.7 - 0.8 micron) when our problem may be the 0.01 aerosol. How frequently can we afford such tests when we know it will soon plug our filters? What alternatives have we?

I have here tried to point out some of the problems that I as a system designer have seen, and to project these into the future growth of this industry. I am certain they can be resolved. Some may already be so. I hope such information is forthcoming.

DISCUSSION

FREEMAN:\* In comparing deep bed fiber filters with sand filters in ventilation systems it has always been assumed that the former would be operated dry. However, deep bed fiber filters are more often operated wet, either as a mist eliminator or deliberately sprayed so as to irrigate them.

A ventilation system utilizing commercially available deep bed fiber filters of a type currently used in process industries was evaluated by Mound Laboratory and it appears they would be a useful tool for the engineer in special cases.

A typical system would include the following:

1. A deluge chamber for cooling the air stream.
2. A deep bed fiber filter with an efficiency of 100% for particles above 3 microns to remove large particles of smoke and large droplets of water.
3. Deep bed fiber filters with an efficiency of 99.97% for particles .03 micron in size to remove fine particulate and fine mists in the sub-micron range. These filters would be irrigated to keep the filters clean.
4. Standard HEPA filters downstream as an added precaution and additional filter efficiency.

This system would operate with high pressure drops similar to sand filters but the self-cleaning feature would provide almost unlimited loading.

\* This communication submitted after the Conference.

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MURROW: There has been a lot of talk the last several days about deep bed sand filters and HEPA filters. Has anyone given consideration to combining the two? For example, by using a deep bed filter with, perhaps, not as much sand. It might have more of the coarser materials to provide fire and over-pressure protection plus time for agglomeration. It could, then, be followed by HEPA filters to take out the small particles that, inevitably, would go through the sand filter; particularly if the layers of fine sand that are normally used were omitted.

SCHURR: We've considered this. We have looked at combinations of roughing sand filter and roughing fiberglass filters backed by deep bed fiberglass filters, or by HEPA-type filters. If you define the job you want to do, i.e., the efficiency you think you can obtain and the kind of particulate matter you want to catch, you can evaluate a number of these systems. It then becomes an economic decision as to which of the suitable alternatives is the most economical.

RUSSELL: We have looked specifically at that case in our study because of the safety aspect of the sand filter, which won't burn and cannot be destroyed by earthquake, tornado or any natural forces we know of. But it will not accomplish the necessary decontamination. A problem I encountered was that information is available only for an 8-foot deep sand filter. Not being an aerosol scientist, I was not in a position to design a different one, myself. Therefore, my studies had to be predicated on the sand filter we know. We looked at combination filters with HEPA filters ahead of a sand filter and behind a sand filter. My dilemma is that I don't know what large quantities of plutonium will do to a sand bed, so I chose putting them ahead of the sand filter.

BARLOW: I'm curious about your last remark, that an earthquake would have no effect on a deep bed sand filter. I think it would tend to compound the problem.

RUSSELL: The analysis that we have indicates that the filter will get more efficient because it will tend to compact the sand bed. You can develop a structure which will withstand an earthquake in most areas. I understand some shock testing has been done on small-scale model sand beds and that compacting tends to increase efficiency.

BARLOW: I was thinking more of the containment of the sand, rather than breaking up of the filter housing, itself.

RUSSELL: We did not do an extensive analysis on structural collapse, but the sand filter is a fairly substantial

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concrete structure, built below the earth. It appears feasible to design it to withstand an earthquake.

DOMNING: I have a comment to make about the sand filter, particularly at our location. We're about 20 miles from rapidly growing Denver and we're seeing houses come over the hill that, eventually, will surround us. This means that a sand filter, put underground at our location, will have to be picked up and moved, or, possibly, processed. We could not abandon it in place. This is probably a problem that is unique to us. Also, the Governor of Colorado has said there will be no plutonium buried in the State.

RAY: I will address this primarily to Bill Domning. Until he mentioned that water for fire suppression plugged a filter worse than smoke, I was going to suggest the possibility of using electrostatic precipitators (perhaps to come on only during a fire) to eliminate plugging. I wonder if water-plugging is due to solids dissolved in the water that remain after the spray evaporates or whether it is just moisture in the sand bed?

Before you answer that, I might also suggest the possibility of using electrostatic precipitators following filters, particularly after a sand filter if changing regulations result in its not quite meeting requirements.

DOMNING: In the case of water plugging the filters, about two years ago Jack Murrow did the exact experiment that I did, except at twice the rate of flow; he ran the filters at 1,000 cfm and I ran them at 500 cfm. We used the same spray at about the same distance from the filters. Murrow's results showed the filters plugged rapidly and dramatically. My results showed the opposite. There's a conflict here.

I calculated the energy of the particle reaching the filter in each case. In Murrow's work, particle energy exceeded the surface energy of the particle by a factor of 10. In my work, the kinetic energy of the water droplet reaching the filter did not exceed the surface energy of the particle; again by a factor of 10. In other words, there were two orders of magnitude difference in the energy of the particle reaching the filter. This indicates to me that when you accelerate a particle fast enough, it breaks up and penetrates the media, causing pluggage. When it does not break up, it agglomerates and runs off as a stream.

For the second question: Jack Russell reported 39 grams of plutonium on a HEPA filter at our installation. That's not an uncommon number for us. I wish we had electrostatic precipitators ahead of the filter to cut the loading down. The air entering these filters comes from a chemical processing operation in which we dissolve plutonium oxide in mixtures of nitric and hydrofluoric acids. Quite a bit of the moisture comes from the large amount of steam used in the steam-sparged dissolvers. We have been looking into methods of suppressing steam and reducing relative humidity in the vent, but it

is a difficult engineering problem. Therefore, I am going to consider electrostatic precipitation seriously. However, we have a problem at Rocky Flats because we are located at 6,000 feet and there is little information on electrostatic precipitator performance at this elevation. With reports of 39 g of plutonium on HEPA filters at our installation, electrostatic precipitators would be desirable ahead of the filter to reduce the loading.

RAY: I had some experience operating a spray-type scrubber in a system that required HEPA filtration. Being concerned about condensation in the filter paper, I put the blower between the scrubber and the HEPA filter, using the heat of compression produced in the blower to reduce relative humidity of the gas. That worked quite satisfactorily except when the scrubber flooded and liquid water blew through.

DOMNING: I might mention that we, too, are trying to use a scrubbing tower and, at times, it gives us a rainstorm in the filter plenum. Our setup is similar to yours.

FREEMAN: I would like to suggest another combination. An irrigated, self-cleaning, roughing-type fiber bed filter efficient, say, to 3 micron size, followed by a fiber bed filter, also self-cleaning with an efficiency equivalent to a HEPA filter, and both followed by a HEPA filter. This combination would allow you to deluge the air with a sufficient amount of water to cool it and to handle any amount of sub-micron particles, either smoke or moisture.

YODER: I'd like to ask Harry Ettinger a question. Would you comment on the effect of aerosol concentration on filter efficiency for both HEPA and sand filters? How does the entering aerosol concentration vary when one uses several stages of filtration?

ETTINGER: We haven't looked at systems under accident conditions. What we have, is information for "normal operating conditions," and it's worth using these data to predict how multiple HEPA filters will act under normal operating conditions.

Plutonium loading is relatively light. We have data for five facilities which show from 200 to 0.001 grams per month per thousand cfm filter. This shows that the amount of plutonium, in terms of a mass loading, is relatively light. There is only one facility that has significant quantities of plutonium under normal operations. The assertion that multiple HEPA filters in series will not work because of a change in aerosol characteristics and agglomeration, does not seem to apply. The number concentration of plutonium particles is relatively small. For agglomeration to be significant, the number would have to be several orders of magnitude higher. The mass loading of plutonium is also relatively light.

With reference to the question of whether multiple HEPA filters will operate effectively, there have been no experimental data to show that a second HEPA filter, or a third HEPA filter, will be

99.97% efficient. We ran a series of tests to estimate whether putting a second HEPA filter in series does any good. We generated a very concentrated DOP aerosol and passed it through two HEPA filters in series. The first HEPA was just deluged with the DOP; it was not measureable by any technique that we tried to use. But, we did get sufficient material through the first HEPA filter so that the aerosol passing to the second HEPA filter gave a reading on the order of 1% in a standard light scattering photometer. We then measured what passed through the second HEPA filter to find out if it was significantly less than 99.9% or 99.95%. The concentration downstream of the second HEPA filter measured zero. We assumed that a zero reading on the instrument indicated less than 5% of full scale. This is not an unreasonable assumption with reasonably good electronics. Using this assumption, we calculated efficiency to be greater than 99.9% for each of the six or seven HEPA filters we tested. These are the only numbers I've seen indicating a minimum efficiency of 99.9, or 99.95% for a second HEPA filter. Field data show that aerosol mass concentrations are relatively light, except for one facility. Certainly, conditions during an accident will be entirely different, but we have not studied these conditions yet.

I would also like to make a comment regarding combinations of sand filters and other filters. I think that a sand filter has many advantages, e.g., it doesn't burn and it's earthquake resistant. But, I think a sand filter is not going to provide the level of protection needed for air cleaning. If you wish to reach decontamination factors of  $10^9$  to  $10^{15}$ , a sand filter will be no better than one HEPA filter if it is even that good. This means that the sand filter must be backed up with several stages of HEPA filtration. The sand becomes a pre-collector to protect the HEPA filters. I've only seen two sets of data where sand filters perform at 99.95% or so; one is Dr. Schurr's and the other is from ZPPR in Idaho Falls. When we talk about sand, we must talk about sand backed up or preceded by fibrous filters. I believe "backed up" is preferable but, in any case, sand in combination with several HEPA filters, or, possibly, deep bed fiberglass filters. Certainly not a sand filter by itself. This means that the cost of future filtration systems will be increased by adding on sand filters as another stage. I would appreciate Dr. Schurr's comments on this topic.

SCHURR: A discussion of filter efficiency must include the entire filter system. For the HEPA filter, this means the filter cartridge and support structure. Whereas the cartridge itself is efficient, I don't consider the HEPA system operated singly to be as reliably efficient as our operating sand filters.

Our operating experience with HEPA filters has shown that, in place, in operation, monitored day after day, the single HEPA filter is not necessarily a highly efficient system. In banks of parallel filters, of course, statistics improve.

I have to agree with Harry Ettinger, when talking in terms of very high protection levels, that a single sand filter of our operating design is not adequate. One can design a sand filter which is

more efficient if given enough money. One can design a sand filter to be just about as efficient as it has to be. Cost differential, of course, becomes much greater. But, I don't think that any single filter system provides the protection level that Ettinger is talking about. We would like to think of a sand filter's main advantage as being the last line of defense, where its mass is an advantage. HEPA's are very good for preliminary filtration and, if they are maintained and operated correctly, they are reasonably efficient, but it's the inertness of the sand filter that offers its principal advantage. When talking about very high levels of containment, I don't think you can talk about one filter operated alone. I agree that multiple filtration levels are required.

FISHER: A loading reported by Russell of 39 grams in, I presume, a 2' x 2' filter has been mentioned by Domning. Is that an upper limit? If so, our experiences at NUMEC must be uniquely different. This has implications upon Ettinger's work. He appears to see relatively light dust loadings. In contrast, we get so much plutonium to some of our 12" x 12" glove box filters, which were preceded by a pink fiberglass batting prefilter, that we had to institute a program of monitoring with a gamma scanner. Counting geometry was very poor and non-reproducible. When we got a reading of over 10 MR it indicated that the filter (a 12" x 12" x 12", nominally rated at 100 CFM) contained at least 10 grams of plutonium and might contain as much as 100 grams. We instituted this program when we had indications that some filters contained greater than 250 grams of plutonium. Those were from boxes where very dusty operations were being carried out. One more thing, I think that most of the criticism of absolute filters, i.e., leaking and inefficiency, is somewhat misleading. I don't believe they leak appreciably through the paper unless they are damaged or defective. The manufacturer tests them all. I think they leak from poor mountings. Our experience with filters that have a nozzle on each end, i.e., where bypassing of the filter is almost impossible, is that air downstream from a filter containing 100 grams of plutonium oxide is almost within breathing limits.

DOMNING: I didn't mean to say the 39 g is our upper limit for the loading of filters. I have seen 8" x 8" filters that contained up to 100 grams of plutonium. This value can be related to the loading of a 24' x 24' in a similar operation. I mentioned the 39 g figure because that is an average experience for us. As I mentioned earlier, we have a fellow in our group who is particularly concerned about materials of construction. This is an area which gets into filter integrity as well as fire protection. At least most of our fire protection problems can be solved by the use and control of better materials. I would like to suggest that one of our larger problems during the 1969 fire was the presence of a particular plastic which depolymerized to the monomer. From TGA analysis, it also turns out that the fire retardant in this plastic volatilizes prior to depolymerization. In other words, a fire retardant is present in the plastic but it is ineffective under ventilation conditions. This is an example of the mousetrap that you can build for yourself. I think that, with proper emphasis on material selection, you can minimize

fire intrusion in the HEPA filter.

Conversely, I would like to reiterate that not all the materials that go into the HEPA filter are totally satisfactory. This is particularly the case for the rubber gasket. Yesterday, you saw some of the radiation damage to the rubber that occurs at high radiation exposures. There will be materials coming on the market within the next year, particularly chlorinated polyethylene, which preliminary results indicate to be about twice as resistant to radiation as regular neophrene. I don't think we should quit the search for better materials to make and seal filters.

ETTINGER: I would like to make a comment that parallels Dr. Fisher's regarding our experience with HEPA filters. We have found them to be reliable when properly installed and maintained. When not properly installed and maintained, they are useless. Our experience has been that if you want to have a HEPA filter bank properly installed, you must put an engineer at the site during installation. Workmen do not understand that their fingernails can ruin a filter while lifting it up to get it out of the box. We have several HEPA filter installations for a plutonium facility. It is a relatively small system by other plant standards; on the order of 10 to 20 thousand cfm. It is tested routinely by an in-place DOP test and we get operating data from health physics monitoring day-to-day. These measurements indicate that the filters consistently meet the AEC decontamination factor which is now being talked about; i.e.,  $10^3$  for HEPA filters. I think that a good HEPA filter installation will provide excellent protection. When measurements showing that a HEPA filter is only 90 percent efficient, or less, as some people have indicated, it does not mean that the HEPA filter is inadequate, but, rather, that the installation is inadequate. It's likely to be an installation that was not properly supervised. It does not take very much to ruin a HEPA filter.

I think that HEPA filter systems have to be designed with the intention of testing them. To build a system which is not testable, is wrong.

I would like to take this opportunity, since we brought up the question of the integrity of HEPA filter systems, to ask Humphrey Gilbert if he would like to comment on his general experience on the performance of HEPA filter systems. He has probably seen more of these under various conditions than anyone else.

GILBERT: Harry Ettinger is perfectly right that filter system must be designed properly. When the atomic energy program began, high-efficiency filter systems were not used. With the introduction of high-efficiency filtration, the systems were merely added, like the tail on a dog. To a great extent this type of design has persisted ever since and it's about time for a change. There should be a limit on the number of filters in a plenum in order to make it possible to test the installed system. Test probes should be built in for this purpose. In other words, permanent sampling probes should be connected to permanent sampling lines and led outside where

the test instrument can be connected. It becomes very difficult, otherwise, to maneuver through 200 yards of an exhaust air tunnel, towing an instrument, to test the system.

A lot of this, of course, is past history from which we have learned proper design. We've also learned over the years that the high-efficiency filter has a lot of weaknesses and technology has not yet brought us to the point where these weaknesses can be overcome completely. As has been pointed out, the seal is the most vulnerable component of the filter. A variety of gasket materials have been tried. We've had difficulty with non-elastomeric materials. More recently, a non-elastomeric silicone seal appears to be a reliable substitute for rubber but this seal must be evaluated with consideration for potential problems of contamination and disposal which might be faced in a system filtering the exhaust of a plutonium operation.

Rubber certainly hardens under radiation and decomposes under abnormally high dosage. However, we expect, from laboratory examination, that although the gasket will harden, it should remain intact during a major accident. I believe that this conclusion stems from the work that Lyle Cheever reported. We can use materials which may not harden and disintegrate but experience, unfortunately, has shown that such materials, with exception of the new silicone seal, do not provide the required reliability in sealing the filter to its mounting. I consider that, all in all, we have, today, the best filter that technology can provide and this gives us a very good offgas purification system when it is properly designed. Proper design must include limiting the number of filters installed in one filter plenum. This design affords more strength and integrity and provides a testable installation.

LAUSHKIN: Minimum design criteria specify that a ventilation system must be operable for two hours under fire conditions. Have you considered the possibility of plugging the pre-filters of filters under fire conditions within this time limit and rendering the ventilation system inoperative?

RUSSELL: We have looked at AEC minimum criteria for plutonium facilities and we find that ventilation systems must operate continuously for a minimum of two hours throughout the worst fire that can be hypothesized for a facility. In most cases, we use pre-filters in the ventilation system to confine material releases as close as possible to the source. This means the use of HEPA filters as pre-filters in glove box exhaust outlets and use of normal types of pre-filters in room exhaust pickups. We make no attempt to protect any of these filters from fire. We consider them expendable if the fire gets bad. We have more than one route for exhaust air. If a filter plugs, air can be diverted to go through other routes. Generally, room filters are not fire resistant. In our analysis of fires for our facility, we have been unable to postulate a fire severe enough to give us a serious problem. We haven't analyzed thoroughly the situation of a loaded filter. If it ruptures, so what? Our fans will pull it through.

DOMNING: I have something to add to that. When you postulate a two-hour fire, you should be very certain that you know what is going to burn and what the products of combustion will be. Some of you may have been disturbed over Harry Lee's paper the other day when he reported that a few pounds of kerosene will plug a filter. When we tested a postulated fire in our filter plenum facility by burning all the materials in the same proportions that we expect to be present in such a fire, we noticed little buildup. I think the pressure drop increased about two-tenths of an inch of water over the two-hour period. With the spray scrubber going, during this two-hour period, we did not intrude the first stage of filtration or the second stage of filtration.

I did an analysis of a burning glove box using temperatures that might be expected for our module which is 20 by 40 feet. I assumed good mixing of the air because our filter outlet is at the floor and the fire will push the hot air up. On this basis, I can predict that the average temperature leaving the module will be about 300°F. Protection from this type of fire is simple if you have 50 or 60 feet of duct run and the heat capacity of the plenum to protect the filter. However, you can't always bank on this. The maximum temperature of the air dumped to the room from the burning box is about 1,000°F.

METZGER: I am sure we are all aware that HEPA filters do an excellent job of containing contamination as long as the integrity of the system is maintained. Even though a lot of advances have been made over the past few years, HEPA filters are still subject to problems caused by acid vapors, caustics, smoke, heat, pressure created by explosion or tornado, etc. I would like the panel's opinion on how well the presently-envisioned systems can be protected from these problems and where the most critical needs are for more work.

RUSSELL: We have this particular problem in the design of the new plutonium reprocessing facility at Rocky Flats, where there is extensive use of chemicals in the reduction of the material, in separation, fluorination, calcination, and a number of processes which generate fumes, caustics, and other problems that we have to solve. But this material does not go directly onto the HEPA filters. That isn't the best thing for their long life. We have considered a number of possibilities. There are devices such as mist eliminators and separators that can be put in the immediate vicinity of the process, where the ventilation air is picked up. Reflux condensers and scrubbers can be used. There are a number of things which are better than a HEPA filter in the immediate area of high level fume, acid, or caustic service. As a matter of fact, you don't want to put a HEPA anywhere near there, and there is information available to that effect, although not a lot. I would like to see a lot more information on the effectiveness of scrubbers for handling highly contaminated plutonium acid fume, i.e., what is the efficiency; how much plutonium does a scrubber remove as it neutralizes the nitric acid? Our objective now, when using a scrubber, is only to neutralize a chemical. We

do not attempt to take credit for the removal of plutonium, although we know that quite a bit of plutonium is retained in the scrubber. This must be taken into account in the design of sumps, i.e., they must be critically safe in plutonium service and they must be monitored and serviced fairly frequently. This is an area that needs a lot of attention because, as I see it, the demand for chemical processing is going to grow in the coming years.

SCHURR: I think I would have to agree. I think our current philosophy is that there is no adequate way to protect HEPA systems operated alone or in series against all the incidents that we can dream up. Certainly, one has to look at the most economic and efficient way to protect the system. We are not convinced that the optimum system has been designed yet but we are looking at things like scrubbers and prefilters. Another philosophy is to have a filter as the final line of defense that you don't ever expect to use. After the bulk of activity has been removed with prefilters, the sand filter will be in the line. In case of an accident, it is always ready, a passive element, with tremendous holding capacity for most of the incidents one can dream up.

YODER: George Schurr, do you have any experience with the performance of sand filters in acid atmospheres?

SCHURR: We have found by experience that a sand filter contained in a concrete structure may be subject to structural failure although the sand beds are stable. We have sand filters that were designed to operate for 10 years that have been operating for 18 years. We have had some mechanical difficulties in maintaining these filters, i.e., structure-type problems rather than problems with the filter beds, themselves. Also, when one uses sands that have significant percentages of acid leachables, crystal growth can occur within the sand and cause problems. Nevertheless, the comforting thing about a sand filter is that as long as the structural integrity of the filter is maintained, operating efficiencies may go down in terms of power requirements but collection efficiencies always tend to improve. The first day a sand filter is turned on is probably its least efficient day of operation. That's one of its inherent strengths; it always tends towards higher efficiency over a reasonable operating lifetime.

DOMNING: One of the things we're beginning to see is a system where a large percentage of the air is recirculated. The applicability of a sand filter for this service is somewhat uncertain. Although we are limiting our discussion to once through systems, I think we will see more and more pressure for recirculating systems. Regarding process problems, I think we, as air cleaning experts, must get a little tougher. I agree with Humphrey Gilbert that we ought to start telling process designers that the process has to take into account air filtration problems. The process design must be compatible with our air cleaning system. I would like to see some process people sitting in on these conferences.

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ETTINGER: I will just say that recirculation doesn't refer to process air. I don't think anyone is contemplating doing enough air cleaning on process air to recirculate it, as a general rule.

RUSSELL: I was talking about tornado protection and emptying room air. How do we prevent it if we are going to use sand filters for everything?

SCHURR: I might comment that no one advocated sand filters as the only filters. I don't think we have a sand filter without preliminary filtration by some other device. Hopefully, we won't have to ask the final filtration system to do any work; it just sits there as a safety factor.

THOMAS, J: Harry Ettinger and Jack Russell were talking about efficiencies of sand filters, and I got the impression they don't think they could be made to achieve decontamination factors better than  $10^4$  or  $10^5$ . On the other hand, Dr. Schurr said they could be made as efficient as desired; is this correct?

SCHURR: That is right; if you are willing to pay a power premium.

THOMAS, J: The work Bob Yoder and I did in '56 is old stuff, but I think it is still good. With a monodisperse aerosol and no channeling, the decontamination factor is exponential with bed depth. If an 8 foot bed gives a decontamination factor of  $10^4$ , a 16 foot bed will give  $10^8$ , etc. Furthermore, if decontamination factors are determined with an aerosol size giving maximum penetration, the bed is going to be more efficient than that on every other size. As far as I remember, the size for maximum penetration at reasonable velocities is of the order of a few tenths of a micron.

SCHURR: About 0.30 to 0.35  $\mu\text{m}$ , I believe.

THOMAS, J: Yes, particles smaller or bigger are removed more efficiently. When particles get as small as 0.01  $\mu\text{m}$  there is no trouble removing them. The only thing to worry about is getting the required decontamination factors on volatile materials which evaporate from the sand after collection. I agree with Dr. Schurr that you can make sand filters as efficient as you wish; even if  $10^{50}$  is required, it can be obtained.

SCHURR: If you have enough money.

ETTINGER: I want to say that, whereas theory predicts the relationship cited by Jess Thomas, data on sand filtration are limited and inconsistent. I would not be willing to build a facility on the basis that because five feet of sand gives you a decontamination factor of  $10^3$ , 10 feet will give  $10^6$ . The data that have been published seem to me to be anomalous. There is little hard information on the basic parameters involved in sand filter performance.

Jess Thomas and Bob Yoder did some basic work at Oak Ridge to develop optimum size penetration data. Dr. Schurr developed data on sand filters, also. When he took a little bit of sand off the top layer, he got a significant reduction in penetration. Although, theory can be useful for extrapolation, sand filter theory has not been confirmed adequately to predict whatever protection factor you wish. The only operational deep bed sand filter performing at a decontaminated factor of  $10^3$  to  $10^4$  is at Idaho Falls. Most of the others discussed in the review paper by Kessey from Argonne National Laboratory are operating at 99%, more or less. Therefore, I believe that, whereas, in theory, it is possible to extrapolate data to any extent you like, the design factors aren't well enough defined to lend confidence to the calculation. Iowa sand must be used to obtain the desired performance because we don't know yet what causes real differences in sands. Maybe it is the moisture content. Maybe it is something else, such as the shape of the sand. I believe we know more about predicting the performance of fibrous filters but even here, theory does not agree well with experiment, although we have more experimental data for fiber filters than we have for sand filters. We should know more about sand because sand filters have the very distinct advantage that they do not burn and are sounder physically. They can't be destroyed as readily as fibrous media.

OWEN: I would like to remind you that sand filters, identical to those described at Savannah River, were built at Hanford in 1947 and that I've sampled those sand filters over many years. For example, at the Redox Facility sand filter, entering air samples read several rads per hour, whereas exit samples showed no activity, using a Geiger counter. I am sure this reduction was  $10^5$ , or better. The material entering was ruthenium tetroxide that plates out very easily on any kind of a filter. For the deep bed or fiberglass, filters at Purex, I have seen efficiencies as low as 97% when inlet activity was low and 99.9% when inlet activities were high. I have seen as high decontamination factors across sand filters as are being reported here. There are identical sand filters at T-plant, U-plant, and Redox that have been in operation from 10 to 20 years. This is quite a bit of operating experience. Unfortunately, little data have been documented for them. I would like to ask if anyone can compare DOP test results with filter efficiency for materials like plutonium which have a high density. Does DOP truly represent these other materials?

ETTINGER: The answer is that DOP does not represent the materials you are concerned about. No air cleaning system that I know of is designed to remove DOP because of hazard control. But then, I don't know of any facilities built to remove sodium chloride, fluorescein, or uranine that are also used as test aerosols. That is the reason we were asked by Humphrey Gilbert to get some information on the characteristics of plutonium aerosols. That's the negative side of the coin. In theory, one extrapolates using DOP strictly as a tracer. In theory, the fact that plutonium has a density of 10, or so, and DOP has a density of 1 is compensated for by using aerodynamic size. That takes into account density and shape of the particle,

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as well as geometric size. The aerodynamic size indicates how the particle moves in an air stream. In addition to the fact that DOP is not an aerosol that must be removed in a practical system, it is liquid instead of solid. There are experimental data for some filter media showing that efficiency is higher for solids than for DOP of the same aerodynamic size, indicating that DOP may be a conservative test aerosol. This work was not done with high efficiency media because of instrumentation limitations.

DORMAN: I may be digressing a bit, but with the limited knowledge I have of the subject, it seems that one of the major problems is knowing the particle size distribution at any particular time. Has any work been done on sampling so that rapid routine checks can be made to assess particle size?

RUSSELL: I don't know that there has been any attempt to come up with standardized procedures or testing points. In our experience, the operating people, through experience with a given system, and by taking samples and comparing them on a continuous basis to measured conditions, have developed some general guides as to where to set the probes. What standards? There are none that I know of.

ETTINGER: I think it is a very good point because, formerly, health physics people were concerned only with what was released. For many years, at Los Alamos, we had very good data detailing what was being released from the stacks. As an afterthought, someone put an air sampler upstream of the filter so we would have some idea of the material incident on the filter. We found that it was possible to calculate filter efficiency as a function of operating time, but after noting sampling errors, it was necessary to rationalize the result because of a poor sampling location. We have modified our procedures and are trying to get a reliable sample upstream and downstream of the filter bank. This is for a much simpler system than at Rocky Flats. They handle about 100,000 cfm to my 10,000 cfm. What I can do easily, is a difficult project for Jack Russell. We are now getting data continuously to define the efficiency of the HEPA filter system. It is complicated by the fact that there is an order of magnitude difference between the hot upstream sample and the downstream sample. Therefore, we take daily upstream samples and a weekly downstream samples. I think it would be very valuable for all operating facilities to generate data like these although they can't be obtained quickly; i.e., only one sample a day, or one a week. It would provide answers to questions about the relationship between filter efficiency for DOP and for plutonium.

KEIGHER: Sand seems to be getting a lot of recognition, today, because of its non-combustible properties but this is an over-simplification. Whatever the nature of the incombustible material, whether sand, fiberglass, or 15 mil paper, the material that holds it together, be it metal, or concrete, can be affected by heat. I think the merit of a sand filter or a deep bed filter, from the standpoint of fire protection, is that they are usually located remotely from a building and are underground. If you put a HEPA

filter bank in the same location, it would have many of the same attributes. With all of these systems, dynamic fire protection is sought rather than passive fire protection. It is pleasing to hear no remarks during the discussion today about four-hour and six-hour construction in plutonium facilities because I consider that concept to be old fashion and expensive. Fire protection is needed at every level and protection must be designed in-depth. I think Mr. Domning mentioned earlier that you must go back to the source of the fire. We don't want to fight the fire only at the "hole in the wall".

STEINBERG: I believe that we have to attack the problem of test aerosols more basically. I am a backer of DOP as a test aerosol, or of anything else that will give us an idea of what is happening, such as finding leaks in gaskets. Based on all our experience, filters, by and large, don't leak when properly installed. Nevertheless, we have to understand the nature of the particulate matter that must be removed in practice. There is no sense challenging a filtration system with 0.3  $\mu\text{m}$  particles if all it has to take out are 50  $\mu\text{m}$  particles; and there is no sense in the reverse. Mr. Ettinger, I would like to know the size range of the particulate matter you are finding in your studies.

ETTINGER: This was shown briefly in the first slide. We started the program in April and have been generating data, since. Although we used an Anderson impactor it has caused us concern and has given us many problems. The data will be in the proceedings as will a detailed description of our sampling procedures. We're not sure that five sampling locations at three facilities will be adequate or whether we should look at different types of operations.

YODER: I regret that all of you who had questions or comments didn't get to present them. Summarizing this session, we've ranged through different types of filter systems, their construction, problems of their performance, and problems of their evaluation. I think that one of the most important conclusions is that we don't have all the answers; that there are questions which need more work. These include Harry Ettinger's work on plutonium aerosol properties; the work that George Schurr is doing with sand filters; and the work that Bill Domning and Jack Russell are doing on filter fire protection. Selection of filter materials can be improved by better performance data on the materials we now have available. I wish to thank the members of the panel and conference attendees for the vigorous interchange that we've had.