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OPERATING MANUAL FOR THE ELECTROSTATIC GLOVE BOX PREFILTER
INSTALLED INSIDE THE FILTER GLOVE BOX, NO. 046
AT ROCKY FLATS, BUILDING 776

W. Bergman, R. C. Kaifer, H. D. Hebard, R. D. Taylor,
B. Y. Lum, and R. M. Boling
Lawrence Livermore Laboratory

G. I. Buttedahl, R. W. Woodard, and K. Terada
Atoms International Division, Rocky Flats Plant

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CONTENTS

Abstract	1
Introduction	2
Responsibility	3
Theory of the Electrostatic Filter	4
Description of Glove Box Number 046	7
Description of the Electrostatic Prefilter	12
Operating Procedure	20
Introduction	20
Hazards Warning	20
Flow-System Adjustment	21
First Test: HEPA Filter Alone	22
Second Test: HEPA Filter and Standard Disposable Prefilter	25
Third Test: HEPA Filter and Standard Reusable Prefilter	35
Fourth Test: HEPA Filter and Electrostatic Disposable Prefilter	37
Fifth Test: HEPA Filter and Electrostatic Reusable Prefilter	47
Particle-Size Distribution Measurements	50
Flow-Meter Calibration	53
Long-Term Maintenance and Durability	53
Electrical Engineering Safety Note	56
High-Voltage Operational Hazard of Electrostatic Prefilter	56
Testing of Safety Devices	58
Radiation Safety Review	60
Acknowledgments	60
Engineering Drawings	61
Data Sheets	70

ILLUSTRATIONS

1. Two electrical-capture mechanisms of the electrostatic filter responsible for increasing the filter efficiency	5
2. Schematic of possible explanation for the decreased-pressure drop observed when electric fields are used to enhance filtration	5
3. Two of the four cartridge filters housed inside the glove box	8
4. Side-view of the glove box used as a vacuum cleaner to remove fine dust from molten salt and electro-refining operations	9
5. End-view of the glove box	10
6. Electrostatic prefilter mounted on the end-plate, fully assembled	13
7. Front latch opened and the ground electrode swung open to expose the prefilter medium	14
8. Prefilter medium removed, exposing the high-voltage electrode	15
9. Rear latch opened, and the electrostatic-prefilter unit swung away to expose the HEPA filter	16
10. HEPA filter removed from its holder top and pointed in the opposite direction	17
11. Electrostatic-prefilter housing removed from the mounting flange on the HEPA-filter holder	18
12. Rear-view of the electrostatic prefilter showing the high-voltage connection, the sample probe, and pressure tap . .	19
13. Schematic of sample filter-holder assembly	28
14. Cylindrical-sampling chamber housing the two sample-filter holders that are used to determine the efficiency of the electrostatic-filter unit	29
15. An operator removes one of the inline filters	32
16. Front panel of the modified Hipotronics power supply	42
17. Calibration curves for the three orifice plates to be used in calibrating the Hastings velocity meter	54

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W. Bergman, R. C. Kaifer, H. D. Hebard, R. D. Taylor,
B. Y. Lum, and R. M. Boling, Lawrence Livermore Laboratory
O. I. Buttedahl, R. W. Woodard, and K. Terada *

ABSTRACT

A manual is presented for evaluating the electrostatic glove-box prefilter found inside the filter glove box number 046 at Rocky Flats, Building 776. The objective of the evaluation is to evaluate the effectiveness of the electrostatic prefilter in prolonging the life of HEPA (high-efficiency particulate-air) filters. The names and phone numbers of the personnel responsible for the safe operation of the glove box and the prefilter evaluation program are included. The theory of the electrostatic filter is reviewed, and Glove Box Number 046 is described in detail, followed by a description of the electrostatic prefilter used in the present application. Engineering drawings of the electrostatic prefilter are included. The procedure for evaluating the electrostatic prefilter includes the steps for conducting five different tests: evaluating (1) the HEPA filter alone, (2 and 3) the HEPA filter with a standard prefilter treated both as disposable and reusable, and (4 and 5) the HEPA filter with the electrostatic prefilter, again treated as disposable and reusable. Procedures for flow-meter calibrations and measurements of particle-size distributions are also included. Long-term maintenance of the system during the evaluation program is outlined, and estimates of component durability are given. An electrical engineering safety note describes the high-voltage operational hazard of the electrostatic prefilter and the testing of safety devices (the current-overload trip circuit, the filter-door-interlock system, and the current-limiting resistor).

* Atomics International Division, Rocky Flats Plant, permanent address.

INTRODUCTION

The evaluation of the electrostatic glove-box prefilter at the Rocky Flats Plant is a joint effort of the independent research programs at Rocky Flats and Lawrence Livermore Laboratory (LLL) to reach the common objective of developing technology for prolonging the life of HEPA (high-efficiency particulate-air) filters. Although the technology of electrostatic prefilters was developed at LLL, it could not be tested there satisfactorily because the clean environment at LLL was not representative of the major users of HEPA filters. Several factors were responsible for evaluating the electrostatic prefilter at Rocky Flats:

- (1) they are the largest user of HEPA filters within the DOE family, which not only would make the evaluation very realistic, but would also provide them with a strong incentive to implement this technology wherever possible;
- (2) the programs at LLL and Rocky Flats are both sponsored by the Airborne Waste Management Program Office of DOE;
- (3) Rocky Flats already has a program to investigate prefilters for prolonging the life of HEPA filters; and
- 4) they also have a filter certification laboratory, which may provide additional support when needed.

This manual was reviewed by the Hazards Control Department of Lawrence Livermore Laboratory to insure that all reasonable safety precautions have been taken. A safety review committee at Rocky Flats also concluded that the electrostatic filter and operating procedure meet their safety requirements.

RESPONSIBILITY

<u>Direct Responsibility</u>		<u>FTS phone numbers</u>
Supervisor	Richard Franchini	322-4151
Operator	Steve Brighton	322-2227

The responsibility for the safe operation of the electrostatic glove-box filter rests entirely with the Rocky Flats personnel. Richard Franchini is the supervisor in charge of the facility where the electrostatic filter, which is installed inside the filter glove-box number 046, is being evaluated. All work inside the glove box or changes in its operation must be approved by Franchini. He has assigned Steve Brighton to perform the evaluation and to maintain a data log on the filter-evaluation and glove-box activities.

<u>Rocky Flats Coordinator</u>		<u>FTS phone numbers</u>
	Olaf Buttedahl	322-2261
Alternates	R. Woodard	322-2536
	K. Terada	322-4966

Olaf Buttedahl will have the primary responsibility at Rocky Flats for the filter-evaluation program. He is responsible for overseeing the evaluation and coordinating all related operations, such as counting the activity on the filters and repairing or modifying electrical or plumbing fixtures. His alternates are R. Woodard and K. Terada.

<u>LLL Coordinator</u>		<u>FTS phone numbers</u>
	Werner Bergman	532-5227
Alternates	R. Taylor	532-5146
	H. Hebard	532-5219

Werner Bergman of LLL is responsible for planning the filter-evaluation program and training personnel to perform this evaluation. It is important to notify Bergman of any unforeseen events or deviations in the planned evaluation. His alternates are R. Taylor and H. Hebard.

THEORY OF THE ELECTROSTATIC FILTER

A conventional fibrous filter can be converted to an electrostatic filter by applying an external electric field across the filter medium. This can be accomplished by sandwiching a sheet of filter medium between two conductive screens and applying high voltage to one and grounding the other. The resulting electrostatic filter will have a higher efficiency and a higher dust-loading capacity than the standard filter.

The higher efficiency results from two additional capture mechanisms that capture particles when the electric field is applied. These capture mechanisms, shown in Fig. 1, are due to the interaction between a polarized fiber and a charged particle, and the interaction between a charged fiber and a charged particle. (Almost all particles are charged.) When an external electric field is first applied to the filter, the only additional capture mechanism is due to the forces between a polarized fiber and a charged particle. The electric field instantly polarizes the fiber, which then attracts charged particles. The charged particles that deposit on the fiber then gradually build up a fiber charge and introduce the second capture mechanism. This mechanism is based on the force between charged fibers and charged particles. A steady state is eventually reached with both of the electrical capture mechanisms in Fig. 1 causing a large increase in the filter efficiency.

The higher dust-loading capacity for the electrostatic filter compared to a standard filter is due to the difference in particle deposits for these two cases. Figure 2 shows a schematic of how particles may deposit on the fibers of a standard filter (no electric field) and an electrostatic filter (electric field). For standard filters, the particle deposit grows in a random fashion and tends to bridge between neighboring fibers. In contrast, the electrical capture mechanisms that increase the filter efficiency also cause the particles to be attracted toward the fiber. This attraction causes the particles selectively to form deposits around the fiber rather than in a random fashion. Comparing the two-particle deposits in Fig. 2 shows that the deposits for the electrostatic filter do not block the air nearly as much as

FIG. 1. Two electrical-capture mechanisms of the electrostatic filter responsible for increasing the filter efficiency. The larger and smaller circles represent the cross sections of the fiber and the charged particle, respectively. The solid lines are the electrical lines of force while the dashed lines are the particle trajectory for the two capture mechanisms.

FIG. 2. Schematic of possible explanation for the decreased-pressure drop observed when electric fields are used to enhance filtration. The larger and smaller circles represent cross sections of the fibers and particles, respectively.

the deposits from a standard filter. The decreased obstruction-to-air flow significantly increases the dust-loading capacity for the electrostatic filter. For a more extensive theoretical discussion, see the paper by Bergman, et al. in Proc. 15th DOE Air Cleaning Conference (Boston, Mass., 1978).

DESCRIPTION OF GLOVE BOX NUMBER 046

The filter glove box identified by the number 046 is located in Building 776 at the Rocky Flats Plant. This glove box encloses the filter portion of a vacuum-cleaning system used to remove dust from a group of other glove boxes that extract plutonium in molten salt and electro-refining operations. The vacuum-cleaning system consists of suction hoses inside the other glove boxes, which connect plumbing that leads to four cartridge filters and a vacuum turbine. Figure 3 shows two of the four cartridge filters housed inside the glove box. Dust swept up from the other glove boxes is split into two parallel paths, each of which have two cartridge filters in series, as shown in Fig. 3. The only time dust is generated inside the glove box occurs when the cartridge filters are cleaned or replaced.

Figure 4 shows a side-view of the glove box with the vacuum turbine extending from the rear-end plate. The glove box is approximately a cube with three feet on a side. One of the four cartridge filters can be seen through the side window. The glove box is maintained at a negative pressure for safety precautions in case a leak develops. A Magnehelic gauge provides a measure of the glove box ΔP . Figure 4 also shows a portion of the electrostatic prefilter between the two glove ports. The sampling chamber, mounted on top of the glove box, houses two in-line filters that sample dust before and after the electrostatic prefilter for efficiency measurements. This chamber is completely enclosed and has its own ventilation system to prevent contamination. A vacuum pump, mounted on a cart, provides the vacuum for taking the filter samples. High voltage to the electrostatic prefilter is provided by the power supply.

Figure 5 shows the front-end plate with its bag-out port and housing for the HEPA filter. The electrostatic prefilter, not seen in this figure, is mounted inside the glove box in front of the HEPA filter. Exhaust from the glove box passes through the electrostatic prefilter and HEPA filter, and exits through the exhaust pipe. A butterfly valve controls the exhaust flow, which can vary between 4 and 11 cfm. The exhaust flow, which is measured with a Hastings velocity meter, is determined by the exhaust vacuum source and the

FIG. 3. Two of the four cartridge filters housed inside the glove box.

FIG. 4. Side-view of the glove box used as a vacuum cleaner to remove fine dust from molten salt and electro-refining operations. The basic components of the vacuum cleaner are the cartridge filters and the vacuum turbine. Also shown are the electrostatic prefilter and its accessories, which consist of a sampling chamber, power supply, and sampling pump cart.

FIG. 5. End-view of the glove box.

total resistance due to the electrostatic prefilter, HEPA filter and butterfly valve. Since the maximum exhaust vacuum is normally 1-in. w.g., the exhaust flow will decrease as the total pressure drop across the two filters and the butterfly valve increases. When the total pressure drop equals the 1-in. source vacuum, then the exhaust flow rate is zero.

Since the efficiency and pressure drop across any filter is a function of the face velocity of the gas being filtered, it is important to maintain a constant exhaust flow rate. Since it is not possible to maintain a fixed flow rate during the evaluation, the flow rate was held within a range indicated on the velocity meter. The butterfly valve is used to bring the exhaust flow within the defined range. Note that a constant Magnehelic reading for the glove box ΔP (Fig. 4) does not guarantee a constant flow rate through the electrostatic prefilter and HEPA filter. The pressure drop across the HEPA filter and the prefilter are determined with the Magnehelic gauges seen in Fig. 5.

The selection of this glove box for evaluating the electrostatic prefilter was based on the following:

- Large quantities of plutonium dust are generated over short time periods, thus accelerating the filter evaluation.
- Since cleaning or replacing the cartridge filters is the only work performed in this glove box, the electrostatic-prefilter evaluation will not interfere with normal operations.
- The atmosphere of the glove box is essentially pure nitrogen, very dry and at room temperature. Although the probability of the electrostatic prefilter for producing sparks and a consequent fire is very low, even in an oxygen atmosphere, the nitrogen atmosphere eliminates this possibility. The very dry atmosphere also provides a favorable test condition since high humidity will make the filter fibers conductive and thus reduce or eliminate the electrostatic effects.

DESCRIPTION OF THE ELECTROSTATIC PREFILTER

The electrostatic prefilter described in this manual is an experimental prototype of units expected to find widespread application in glove boxes for the nuclear industry. The flat screen design is simple, occupies very little space, and can be economically mass-produced. However, a number of design features, like the type of filter medium, material of construction, and a low-cost, low supply, must be selected or developed before the unit is ready for commercialization.

Figure 6 shows the prototype prefilter attached to the end-plate of the glove box in Fig. 5. This prototype prefilter is much larger and more complicated than a production unit because it has built-in probes to sample aerosols, before and after the prefilter, for efficiency measurements. A plastic shroud was also added around the inlet of the prefilter to obtain isokinetic samples. Without this shroud, erroneously low inlet aerosol concentrations are obtained because the aerosols will by-pass the sample probe. If aerosol samples were not required, the thickness of the electrostatic prefilter in Fig. 6 could be reduced to less than 2 inches. Important design features of the electrostatic prefilter are the two latches that secure the hinged portions of the filter and provide easy access to the prefilter and HEPA filter. The main body of the prototype unit is made from polyethylene to provide good electrical insulation and give it strength. However, a metal reinforcement was required on the front plate to prevent distortion when the latch was closed. Figure 6 also shows the high voltage cable and pressure lines. Additional pictures of the electrostatic prefilter in various stages of disassembly are shown in Figs. 7 through 12.

The grade of fiberglass medium used in this test, AF-18, obtained from Johns-Manville, is relatively poor. Using a less efficient filter medium reduces the evaluation time since more aerosols would reach the HEPA filter and cause it to plug up faster. The increase in the HEPA life, when using a less efficient filter medium as a standard prefilter or an electrostatic prefilter, can therefore be determined in less time than it would take when using a very efficient filter medium.

FIG. 6. Electrostatic prefilter mounted on the end-plate, fully assembled. The clear-plastic shroud that extends from the filter unit provides a uniform flow to the filter and a representative inlet sample. Also shown are the sample and pressure-lines and the high-voltage cable.

FIG. 7. Front latch opened and the ground electrode swung open to expose the prefilter medium.

FIG. 8. Prefilter medium removed, exposing the high-voltage electrode. Although the high-voltage electrode is shown as insulated wire, only non-insulated electrodes will be used in the evaluation.

FIG. 9. Rear latch opened, and the electrostatic-prefilter unit swung away to expose the HEPA filter. The sample probe and pressure tap downstream of the prefilter can be seen. Note the incorrect insertion of the HEPA filter: the arrow should be on top and should point in the opposite direction.

FIG. 11. Electrostatic-prefilter housing removed from the mounting flange on the HEPA-filter holder.

FIG. 12. Rear-view of the electrostatic prefilter showing the high-voltage connection, the sample probe, and pressure tap.

OPERATING PROCEDURE

INTRODUCTION

This chapter describes the safe operating procedure for evaluating the electrostatic prefilter installed in the filter glove-box number 046, located in Building 776 at Rocky Flats. The evaluation will determine how effective the electrostatic prefilter is in extending the life of a HEPA filter mounted downstream of the prefilter. To make this assessment, three different configurations will be tested: (1) a HEPA filter alone; (2) a HEPA filter with a standard prefilter; and (3) a HEPA filter with an electrostatic prefilter. Each of these tests consists of loading the filters with radioactive aerosols and evaluating the filters at various stages of clogging.

For each of the two configurations using prefilters, two separate tests will be performed. In one test, the prefilter will be treated as a disposable filter; in the other test, it will be cleaned and re-used. The evaluation of the electrostatic prefilter will therefore involve a total of five different tests.

HAZARDS WARNING

It is important to recognize that the electrostatic prefilter uses high-voltage electrodes and may, therefore, have an occasional corona discharge across the filter. This occurrence is extremely unlikely since we have never observed a corona discharge at 10 kV in over 100 tests. A corona discharge does not occur until the applied voltage exceeds 13 kV. However, if a corona discharge would present an undesirable safety hazard, the electrostatic prefilter should not be used. This device should never be used in potentially explosive environments. In considering the potential hazard from an occasional corona discharge, keep in mind that only a single discharge will occur before the power supply automatically shuts down. Most combustible materials cannot sustain combustion with a single corona discharge. For a more detailed discussion of the electrical safety analysis, see the section entitled Electrical Engineering Safety Note.

Evaluation of the electrostatic prefilter also involves a potential radiation hazard when changing the sample filter holders in the sampling chamber. To minimize the possibility of contamination during this operation, you must carefully follow the procedure for changing the sample filter holders.

FLOW-SYSTEM ADJUSTMENT

One of the most important requirements for the tests in this manual is to maintain a constant gas-flow rate through the HEPA filter and prefilter. Unless this is rigorously followed, it will be impossible to interpret the test results. A flow meter, mounted in the exit tubing downstream of the prefilter and HEPA filter, provides input to an analog meter. Two lines on the face of the meter define the allowable range of the flow rate that must be maintained at all times. The needle on the analog meter must fall within this allowable range. The flow rate is adjusted with a butterfly valve (see Fig. 5) installed in the exit tubing close to the glove box. If the proper flow cannot be obtained even with the valve wide open, then the prefilter should be either cleaned or changed, depending on the specific test being performed. It is important to recognize that the criterion for cleaning or replacing the prefilter or HEPA filter is an exhaust flow rate below the defined minimum when the butterfly valve is wide open.

FIRST TEST: HEPA FILTER ALONE

NOTE: Since this test does not require a prefilter or high voltage, disconnect the high voltage cable at the power supply and remove the prefilter. The power supply should remain OFF during this test. Enter all data on the data sheets provided.

The HEPA-filter test will provide the baseline data for evaluating the improvement in the HEPA service life when a standard prefilter is used. The test consists of periodic filter evaluations at increasing levels of filter clogging. The procedure is as follows:

HEPA Filter Installation

1. Bag-in a new HEPA filter in the glove box. Only those HEPA filters that have been pre-dried to a constant weight may be used.
2. Weigh the HEPA filter using the balance inside the glove box. The pan and weights should always be dusted clean prior to weighing. The metal cylinder weighs 1908.5 g.
3. Install the HEPA filter in its holder. Note the direction of the air flow on the filter. The correct installation will have the arrow on top and pointed away from the glove box. (The installation in Figs. 9 and 10 is not correct.) Proceed directly to the Evaluation, Steps 4 through 7.

Evaluation

NOTE: The measurements in Steps 4 through 7 should be made under low dust conditions, either before every fourth cleaning, or three hours after every third cleaning of the filter cartridge. Adjust the butterfly valve until the exhaust flow velocity falls within the defined range.

4. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum. The pressure drop across the prefilter should be nearly zero since there is no prefilter in this test. Also record the reading on the velocity meter.
5. Remove the HEPA filter from its holder and weigh it, using the balance inside the glove box. The pan and weights should always be dusted clean prior to weighing. The metal cylinder weighs 1908.5 g.
6. Install the HEPA filter in its holder, again noting the direction of the air flow on the filter. The correct installation will have the arrow on top and pointed away from the glove box. (The installation in Figs. 9 and 10 is not correct.)
7. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove box vacuum, and the reading on the velocity meter.

Filter Cartridge Cleaning

8. Repeat Step 7 each time before cleaning the cartridge filters. Adjust the butterfly valve to bring the exhaust flow velocity within the defined range.
9. If the exhaust flow velocity falls within the defined range on the velocity meter then repeat Steps 4 through 7 after every third cleaning of the cartridge filters.

HEPA Filter Removal

10. When the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, take the measurements in Step 7. Then remove the HEPA filter, weigh it, and try to shake off the particle deposits into the pan. The pan should be dusted clean and

weighed to get a tare weight. After all of the dust has been shaken from the HEPA filter into the pan, weigh the HEPA filter and the pan.

11. Install the HEPA filter in its holder and take the measurements in Step 7. This concludes the first test.

SECOND TEST: HEPA FILTER AND STANDARD DISPOSABLE PREFILTER

Note: Since this test does not require high voltage, the power supply should be turned off and the high voltage cable disconnected. Enter all data on the data sheets provided.

This test will provide data for evaluating the effectiveness of a standard prefilter in extending the life of a HEPA filter. It also provides baseline data for evaluating the additional improvement in the HEPA service life when an electrostatic prefilter is used instead of a standard prefilter. As in the test with the HEPA filter alone, this test consists of periodic filter evaluations at increasing levels of filter clogging. The procedure is as follows:

HEPA Filter and Prefilter Installation

1. Bag-in a new HEPA filter and a supply of prefilters. Only those HEPA filters that have been pre-dried to a constant weight may be used.
2. Weigh the HEPA filter using the balance inside the glove box. The pan and weights should always be dusted prior to weighing. The metal cylinder weighs 1908.5 g.
3. Install the HEPA filter in its holder. Note the direction of air flow on the filter. The correct installation will have the arrow on top and pointed away from the glove box. (The installation in Figs. 9 and 10 is not correct.)
4. Take two new prefilters from the supply bag and weigh them on the balance.
5. Install the two prefilters in the prefilter holder so that the fluffy side of both filters is facing upstream (Figs. 7 and 8). If the prefilters are installed correctly, the fluffy side can be seen inside the glove box. Proceed directly to the Evaluation, Steps 6 through 22.

Evaluation

NOTE: The measurements in Steps 6 through 22 should be made under low dust conditions, either before every fourth cleaning or three hours after every third cleaning of the filter cartridges. Adjust the butterfly valve until the exhaust flow velocity falls within the defined range.

6. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum. Also record the reading on the velocity meter.
7. Remove the HEPA filter from its holder and weigh it, using the balance inside the glove box. The pan and weights should always be dusted clean prior to weighing. The metal cylinder weighs 1908.5 g.
8. Install the HEPA filter in its holder, again noting the direction of the air flow. The correct installation will have the arrow on top and pointed away from the glove box. (The installation in Figs. 9 and 10 is not correct.)
9. Remove the prefilters from their holder and weigh them using the balance inside the glove box. Use the grounded forceps with the insulated handle to remove the prefilter medium, being very careful not to knock off any dust from the filter surface. The pan and weights should always be dusted clean prior to weighing.
10. Install the prefilters in the prefilter holder so that the fluffy side of both filters is facing upstream (Figs. 7 and 8). If the prefilters are installed correctly, the fluffy side can be seen inside the glove box.
11. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.

12. Prepare two sample filter holders for sampling the dust before (B) and after (A) the prefilter. The schematic of the sample filter-holder assembly is shown in Fig. 13. The filter holder is prepared by placing a membrane filter (0.2 μ m-pore size) on the holder base. The shiny side of the filter should be facing up. Then place the O-ring over the membrane filter and finally screw on the cap. The cap should be tightened about 1/4 turn beyond the point where there is friction in turning. Use a non-erasable pen to mark "B" on one holder and "A" on the other.
13. Leak-check the filter holders using the small vacuum pump with rotometer (not shown). Place the Tygon tubing from the vacuum pump over the hose nipple marked "to absolute filters" in Fig. 13. Then turn on the vacuum pump and place a finger over the hose nipple marked "to sample" in Fig. 13. If the ball on the rotometer does not drop to zero, there is a leak. The leak will have to be corrected or a new filter holder assembled. To illustrate a zero-leak condition, place a finger over the Tygon tubing leading to the vacuum pump.
14. Leak-check the glove-box sampling system. This test should only be conducted when no dust has been generated inside the glove box for at least three hours. Begin by turning on the sample pump (Fig. 4) and adjust the two rotometers on the sampling chamber (Fig. 14) to 2 lpm. Then pinch the two Tygon tubes (inside the glove box) that sample the dust before and after the prefilter. If the two balls on the rotometers (Fig. 14) drop to the bottom, then there are no leaks. The large rotometer mounted on the sample pump (Fig. 4) should also drop to the bottom if there are no leaks. If a leak exists in one or both of the lines, then the following additional checks must be made.

- a. Get a health physicist to monitor radiation.

NOTE: A respirator and gloves must be worn whenever opening the access door of the sampling chamber (Figs. 14 and 15).

FIG. 13. Schematic of sample filter-holder assembly.

FIG. 14. Cylindrical-sampling chamber housing the two sample-filter holders that are used to determine the efficiency of the electrostatic-filter unit. Note that the correct position of the plastic filter holder has the male portion on top. The sample line continues past the plastic filter holder, an absolute filter, a rotometer, a valve and finally to the vacuum pump. The latched doors provide access for changing the filter holders.

- b. Open the sampling chamber (Fig. 14) and, with an appropriate radiation survey meter, check the chamber for contamination. If the sampling chamber is contaminated, connect the vacuum cleaner to the exhaust duct of the sampling chamber and turn it on.
- c. For the line having a leak, disconnect the sample filter holder from the Tygon tubing at the end leading to the absolute filters. (The other end, leading to the glove-box sample, is hot.) Close the needle valve on the other sample line so that all of the flow will go through the open line.
- d. Turn on the sampling pump and place a finger over the open Tygon tubing.
- If the ball in the rotometer drops to the bottom, the leak is due to the filter holder. Turn off the pump. The leaky filter holder should then be replaced with one that has been recently leak-checked in Step 13. After installing the new filter holder, the sampling system should be checked for leaks again in Step 14. Close the access doors of the sampling chamber and survey the surrounding area for radiation.
 - If the ball does not drop to the bottom, then the leak is outside the sampling chamber (most likely the cylindrical absolute filter). This condition should be corrected immediately in case the contamination was able to bypass the absolute filter.
- e. If the large rotometer on the sampling pump (Fig. 4) indicates a leak while the small rotometers (Fig. 14) do not, then a leak exists somewhere in the sampling line beyond the absolute filter. This is not a serious condition, although the leak should be found and corrected.

15. Generate dust in the glove box by removing the upstream-filter cartridge (Fig. 3) and gently shaking out the deposit. Do not generate any more dust than is normally produced during a cartridge cleaning.
16. Allow the dust to settle for one minute.
17. Turn on the sampling pump (Fig. 4) for two minutes. Make sure that both rotometers (Fig. 14) indicate 2 lpm. Turn off the sample pump after two minutes.
18. Open the sampling chamber, and with an appropriate radiation-survey meter, check the chamber for contamination. A respirator and gloves must always be worn when entering the sampling chamber (Fig. 15). If the sampling chamber is contaminated, connect the vacuum cleaner to the exit duct of the sampling chamber and turn it on.
19. Replace the two sample filter holders, one at a time, with the two filter holders recently leak-checked. This step has a potential for radiation contamination and should therefore be carefully followed. Make sure that the filter holder marked "B" goes on the red-sample line and the filter holder marked "A" goes on the yellow-sample line (Fig. 14). Also make sure that the correct installation is obtained as shown in Fig. 14. (The installation in Fig. 15 is incorrect.)

NOTE: The greatest contamination hazard occurs when disconnecting the Tygon tubing from the filter holder on the sample side (bottom side). Be careful not to touch the end of either the Tygon tubing or the filter holder. The side leading to the absolute filters should normally not be contaminated.

Place the contaminated filter holder in a container for later shipment to the counting lab.

20. After checking the sampling chamber for radioactivity, close the chamber door. Also check the operator and the surrounding area for radiation.

FIG. 15. An operator removes one of the inline filters. Note that the filter holders are installed upside down.

21. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
22. Fill out the request form for having the two filter samples counted and ship the container to the counting lab. Write the number of the chemical request on the data sheet.

Filter Cartridge Cleaning

23. Repeat Step 21 each time before cleaning the cartridge filter. First adjust the butterfly valve until the exhaust flow velocity falls within the defined range.
24. If the exhaust flow velocity falls within the defined range on the velocity meter, then repeat the evaluation Steps 6 through 22 after every third cleaning of the cartridge filters.

Prefilter Replacement

25. When the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, and at least three hours have passed since dust was last generated in the box, replace the dirty prefilter with a new one.
 - a. Take the measurements in Step 21.
 - b. Use the grounded forceps with the insulated handle to remove the prefilter medium. Be very careful not to knock off any dust from the filter surface.
 - c. Weigh the dirty prefilter and set it on a clean spot in the glove box.
 - d. Take two new prefilters from the supply bag and weigh them on the balance.

- e. Install the two new prefilters in the prefilter holder so that the fluffy side of both filters is facing upstream. If the prefilters are installed correctly, the fluffy side can be seen inside the glove box (Figs. 7 and 8). Adjust the butterfly valve until the exhaust flow velocity falls within the defined range.
 - f. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
26. Shake off the particle deposits on the used prefilter into the pan. The pan should be dusted clean and weighed to get a tare weight. After all of the dust has been shaken from the prefilter into the pan, weigh the prefilter and the pan.
27. If the exhaust flow velocity falls within the defined range, repeat Steps 6 through 26.

HEPA Filter Removal

28. If the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, take the measurements in Step 21. Then remove the HEPA filter and weigh it and try to shake off the particle deposits into the pan. The pan should be dusted clean and weighed to get a tare weight. After all the dust has been shaken from the HEPA filter into the pan, weigh the HEPA filter and the pan.
29. Install the HEPA filter in its holder and take the measurements in Step 21. This concludes the second test.

THIRD TEST: HEPA FILTER AND STANDARD REUSABLE PREFILTER

This test will provide data for evaluating the advantages to be gained in cleaning and reusing the prefilters compared to discarding the used prefilters. All of the steps and notes in this evaluation, except for Steps 25 and 26, are identical to those in the second test, describing the HEPA filter and standard disposable prefilter.

Prefilter Cleaning

25. Clean the dirty prefilter after replacing it with a temporary prefilter when the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open. Allow at least three hours to pass since dust was last generated in the box before proceeding with this step. This is described in detail in the following steps:

- a. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
- b. Use the grounded forceps with the insulated handle to remove the dirty prefilter medium. Be very careful not to knock off any dust from the filter surface.
- c. Weigh the dirty prefilter.
- d. Install a temporary prefilter in the prefilter holder. This temporary prefilter can be either a clean or used filter, but once selected, the same filter should be used in this step for the remainder of the test. The only purpose of this temporary filter is to prevent the HEPA filter from collecting some of the dust created in the next step.

- e. Shake off the particle deposits on the dirty prefilter into the pan. When shaking the prefilter, be very careful not to tear the filter or be excessively rough, since it will be reused in the test. However, try to remove as much of the deposit from the filter as possible. The pan should be dusted clean and weighed to get a tare weight. After all of the dust has been shaken from the prefilter into the pan, weigh the prefilter and the pan. Wait for at least one hour for the dust to settle in the box before proceeding to the next step.
 - f. Replace the temporary prefilter in the holder with the prefilter cleaned in the previous step. Store the temporary prefilter in a plastic bag until the next time the prefilter is cleaned in Step 25. Adjust the butterfly valve until the exhaust flow velocity falls within the defined range.
 - g. Record the Magnehelic readings for the HEPA and prefilter and the glove box vacuum and the reading on the velocity meter.
 - h. If the exhaust flow velocity falls within the defined range on the velocity meter, go to Step 26.
 - i. If the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, discard the prefilter. Then take two new prefilters from the supply bag and weigh them on the balance. These filters should be installed in the prefilter holder.
26. If the exhaust flow velocity falls within the defined range on the velocity meter, repeat Steps 6 through 26. If not, this completes the third test.

FOURTH TEST: HEPA FILTER AND ELECTROSTATIC DISPOSABLE PREFILTER

This test will provide data for evaluating the effectiveness of the electrostatic prefilter in extending the life of a HEPA filter. The test is very similar to the previous test using a standard prefilter except that an electric field will be applied across the filter. High voltage will be applied to the filter only when aerosols are generated inside the glove box and for three hours after, and should be off at all other times. Do not open the prefilter- or HEPA-filter holder or attempt to change these filters while the high voltage is on. The test consists of periodic filter evaluations at increasing levels of filter clogging. The procedures is as follows:

NOTE: Enter all data on the data sheets provided. Have a sign prominently displayed by the glove box stating: "High voltage should be turned on whenever any dust is generated and for three hours thereafter."

HEPA and Prefilter Installation

1. Bag-in a new HEPA filter and a supply of prefilters. Only those HEPA filters that have been pre-dried to a constant weight may be used.
2. Weigh the HEPA filter using the balance inside the glove box. The pan and weights should always be dusted prior to weighing. The metal cylinder weighs 1908.5 g.
3. Install the HEPA filter in its holder. Note the direction of air flow on the filter. The correct installation will have the arrow on top and pointed away from the glove box. (The installation in Figs. 9 and 10 is not correct.)
4. Take two new prefilters from the supply bag and weigh them on the balance.
5. Install the two prefilters in the prefilter holder so that the fluffy side of both filters is facing upstream (Figs. 7 and 8). If the prefilters are installed correctly, the fluffy side can be seen inside

the glove box. Proceed directly to the evaluation in Steps 6 through 23.

Evaluation

NOTE: The measurements in Steps 6 through 22 should be made under low dust conditions, either before every fourth cleaning or three hours after every third cleaning of the filter cartridge. Adjust the butterfly valve until the exhaust flow velocity falls within the defined range.

6. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
7. Remove the HEPA filter from its holder and weigh it using the balance inside the glove box. The pan and weights should always be dusted clean prior to weighing. The metal cylinder weighs 1908.5 g.
8. Re-install the HEPA filter in its holder, again noting the direction of the air flow. The correct installation will have the arrow on top and pointed away from the glove. (The installation in Figs. 9 and 10 is not correct.)
9. Remove the prefilters from their holder, and weigh them using the balance inside the glove box. Use the grounded forceps with the insulated handle to remove the prefilter medium. Be very careful not to knock off any dust from the filter surface. The pan and weights should always be dusted clean prior to weighing.
10. Install the prefilters in the prefilter holder so that the fluffy side of both filters is facing upstream (Figs. 7 and 8). If the prefilters are installed correctly, the fluffy side can be seen inside the glove box.

11. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
12. Prepare two in-line Gelman filter holders for sampling the dust before (B) and after (A) the prefilter. The schematic of the filter assembly is shown in Fig. 13. The filter holder is prepared by placing a membrane filter (0.2 μ m pore size) on the holder base. The shiny side of the filter should be facing up. Then place the O-ring over the membrane filter and finally screw on the cap. The cap should be tightened about 1/4 turn beyond the point where there is friction in turning. Use a nonerasable pen to mark "B" on one holder and "A" on the other.
13. Leak-check the filter holders using the small vacuum pump with rotometer. Place the Tygon tubing from the vacuum pump over the hose nipple marked "to absolute filters" in Fig. 13. Then turn on the vacuum pump and place a finger over the hose nipple marked "to sample" in Fig. 13. If the ball on the rotometer does not drop to zero, there is a leak. The leak will have to be corrected or a new filter holder assembled. To illustrate a zero-leak condition, place a finger over the Tygon tubing leading to the vacuum pump.
14. Leak-check the glove-box sampling system. This test should only be conducted when no dust has been generated inside the glove box for at least three hours. Begin by turning on the sample pump (Fig. 4) and adjust the two rotometers on the sampling chamber (Fig. 14) to 2 lpm. Then pinch the two Tygon tubes inside the glove box that sample the dust before and after the prefilter. If the two balls on the rotometers (Fig. 14) drop to the bottom, there are no leaks. The large rotometer mounted on the sample pump (Fig. 4) should also drop to the bottom if there are no leaks. If a leak exists in one or both of the lines, then the following additional checks must be made.
 - a. Get a health physicist to monitor radiation.

NOTE: A respirator and gloves must be worn whenever opening the access door of the sampling chamber. (Figs. 14 and 15).

- b. Open the sampling chamber (Fig. 14) and, with an appropriate radiation survey meter, check the chamber for contamination. If the sampling chamber is contaminated, connect the vacuum cleaner to the exhaust duct of the sampling chamber and turn it on.
- c. For the line having a leak, disconnect the sample filter holder from the Tygon tubing at the end leading to the absolute filters. (The other end, leading to the glove-box sample, is hot.) Close the needle valve on the other sample line so that all of the flow will go through the open line.
- d. Turn on the sampling pump and place a finger over the open Tygon tubing.
 - If the ball in the rotometer drops to the bottom, the leak is due to the filter holder. Turn off the pump. The leaky filter holder should then be replaced with one that has been recently leak-checked in Step 13. After installing the new filter holder, the sampling system should be checked for leaks again in Step 14. Close the access doors of the sampling chamber and survey the surrounding area for radiation.
 - If the ball does not drop to the bottom, then the leak is outside the sampling chamber (most likely the cylindrical absolute filter). This condition should be corrected immediately in case the contamination was able to bypass the absolute filter.
- e. If the large rotometer on the sampling pump (Fig. 4) indicates a leak while the small rotometers (Fig. 14) do not, then a leak exists somewhere in the sampling line beyond the absolute filter. This is

not a serious condition, although the leak should be found and corrected.

15. Turn on the high voltage power supply to 10 kV. First, check that the high voltage cable is continuous from the hv output on the power supply to the connector on the glove box. Use the following steps and Fig. 16 to turn on the high voltage.
 - a. With the AC POWER initially off, turn the VOLTAGE RANGE selector to HIGH, then turn the RAISE VOLTAGE selector to 0 and the OUTPUT CURRENT selector to X1 on DC.
 - b. Flip the toggle switch on the AC POWER to ON. Then press in the HIGH VOLTAGE ON button. The high voltage should be on at this time and the yellow warning light should be flashing. If the high voltage does not come on, then there is either a short across the prefilter electrodes or the interlock system is not closed. The most probable cause is the interlock system. Check that both of the electrostatic filter doors are closing the interlock relays located in the box mounted on top of the power supply (Fig. 4). When the doors are properly closed, the relays give an audible click. If the relays occasionally stick, a slight tap on the relay box would then turn on the high voltage. If the failure to obtain high voltage appears to be due to a short across the prefilter electrodes, then remove the prefilter medium and look for any apparent cause, such as moisture or excessive particle build-up. If this condition cannot be corrected, notify one of the people listed in the beginning of this manual.
 - c. Once the high voltage is on, turn the RAISE VOLTAGE knob until the needle on the AC DC KILOVOLT meter indicates 10 kV.
 - d. To turn off the power supply, press the HIGH VOLTAGE OFF button, and then flip off the AC POWER toggle switch.
 - e. If the overload circuit has been tripped and the high voltage is

Voltage range
low • med • high

Output current

hv output

FIG. 16. Front panel of the modified Hipotronics power supply.

turned off, before the high voltage can be turned on again, turn the RAISE VOLTAGE knob to zero and press in the OVERLOAD RESET button.

16. Generate dust in the glove box by removing the upstream filter cartridge (Fig. 3) and gently shaking out the deposit. Do not generate any more dust than is normally produced during a cartridge cleaning.

NOTE: The high voltage power supply should remain on for at least three hours after dust has been generated in the glove box.

17. Allow the dust to settle for one minute.
18. Turn on the sampling pump (Fig. 4) and sample for two minutes. Make sure that both rotometers (Fig. 14) indicate 2 lpm. Turn off the sample pump after two minutes.
19. Open the sampling chamber and, with an appropriate radiation survey meter, check the chamber for contamination. A respirator and gloves must always be worn when entering the sampling chamber (Fig. 15). If the sampling chamber is contaminated, connect the vacuum cleaner to the exit duct of the sampling chamber and turn it on.
20. Replace the two sample filter holders, one at a time, with the two filter holders that were recently leak-checked. This step has a potential for radiation contamination and should therefore be carefully followed. Make sure that the filter holder marked "B" goes on the red sample line and the filter holder marked "A" goes on the yellow sample line (Fig. 14). Also make sure that the correct installation is obtained as shown in Fig. 14. (The installation in Fig. 15 is incorrect.)

NOTE: The greatest contamination hazard occurs when disconnecting the Tygon tubing from the filter holder on the sample side (bottom side). Be careful not to touch the end of either the Tygon tubing or the filter holder. The side leading to the vacuum pump should normally not be contaminated.

Place the contaminated filter in a container for later shipment to the counting lab.

21. After checking the sampling chamber for radioactivity, close the chamber door. Also check the operator and the surrounding area for radiation.
22. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
23. Fill out the request form for having the two filter samples counted and ship the container to the counting lab. Write the number of the chemical request on the Data Sheet.

Filter Cartridge Cleaning

24. Repeat Step 21 each time before cleaning the cartridge filter. Turn on the high voltage power supply to 10 kV as described in Step 15 at least five minutes before the filter cartridges are cleaned. The high voltage must remain on for at least three hours after the cleaning is completed.
25. If the exhaust flow velocity falls within the defined range on the velocity meter, then repeat the evaluation Steps 6 through 23 after every third cleaning of the cartridge filters.

Prefilter Replacement

26. When the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, and at least three hours have passed since dust was last generated in the box, replace the dirty prefilter with a new one.
 - a. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.

- b. Use the grounded forceps with the insulated handle to remove the prefilter medium. Be very careful not to knock off any dust from the filter surface.
 - c. Weigh the dirty prefilter and set it on a clean spot in the glove box.
 - d. Take two new prefilters from the supply bag and weigh them on the balance.
 - e. Install the two new prefilters in the prefilter holder so that the fluffy side of both filters is facing upstream. If the prefilters are installed correctly, the fluffy side can be seen inside the glove box (Figs. 7 and 8). Adjust the butterfly valve until the exhaust flow velocity falls within the defined range.
 - f. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and glove-box vacuum, and the reading on the velocity meter.
27. Turn on the hv power supply to 10 kV as described in Step 15.
28. Shake off the particle deposits on the used prefilter into the pan. The pan should be dusted clean and weighed to get a tare weight. After all of the dust has been shaken from the prefilter into the pan, weigh the prefilter and the pan. Leave the hv power supply on for three hours after shaking off the dust from the prefilter.
29. If the exhaust flow velocity falls within the defined range, repeat Steps 6 through 28.

HEPA Removal

30. If the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, take the measurements in Step 26f. Then remove the HEPA filter, weigh it, and try to shake

off the particle deposits into the pan. The pan should be dusted clean and weighed to get a tare weight. After all of the dust has been shaken from the HEPA filter into the pan, weigh the HEPA filter and the pan.

31. Install the HEPA filter in its holder and take the measurements in Step 26f. This concludes the fourth test.

FIFTH TEST: HEPA FILTER AND ELECTROSTATIC REUSABLE PREFILTER

This test will provide data for evaluating the advantages to be gained in cleaning and reusing the prefilter compared to discarding the used prefilter. All of the steps and notes in this evaluation, except for Steps 26 through 29, are identical to those in the fourth test, describing the HEPA filter and electrostatic disposable prefilter.

Prefilter Cleaning

26. Clean the dirty prefilter after replacing it with a temporary prefilter when the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open. Allow at least three hours to pass since dust was last generated in the box before proceeding with this step. This procedure is described in detail in the following steps:
 - a. Record the Magnehelic readings for the pressure drop across the HEPA filter, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
 - b. Use the grounded forceps with the insulated handle to remove the prefilter medium. Be very careful not to knock off any dust from the filter surface.
 - c. Weigh the dirty prefilter and set it on a clean spot in the glove box.
 - d. Install a temporary prefilter in the prefilter holder. This temporary filter can be either a clean or used filter, but once selected, the same filter should be used in this step for the remainder of the test. The only purpose of this temporary filter is to prevent the HEPA filter from collecting some of the dust created when the dirty prefilter is cleaned.
27. Turn on the hv power supply to 10 kV as described in Step 15. Allow five minutes for the filter to become energized before starting the next step.

28. Shake off the particle deposits on the dirty prefilter into the pan. The pan should be dusted clean and weighed to get a tare weight. After all of the dust has been shaken from the prefilter into the pan, weigh the prefilter and the pan. Wait for at least one hour with the hv power supply on before proceeding to the next step.

- a. Replace the temporary prefilter in the holder with the prefilter cleaned in the previous step. Store the temporary prefilter in a plastic bag until the next time the prefilter is cleaned in Step. 26. Adjust the butterfly valve until the exhaust flow velocity falls within the defined range.
- b. Record the Magnehelic readings for the HEPA, prefilter, and the glove-box vacuum, and the reading on the velocity meter.
- c. If the exhaust flow velocity falls within the defined range on the velocity meter, go to Step 29.
- d. If the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, discard the prefilter. Then take two new prefilters from the supply bag and weigh them on the balance. These filters should then be installed in the prefilter holder. Adjust the butterfly valve until the exhaust flow velocity falls within the desired range.

29. If the exhaust flow falls within the defined range repeat Steps 6-28.

HEPA Removal

30. If the exhaust flow velocity falls below the defined minimum on the velocity meter with the butterfly valve wide open, take the measurements in Step 28b. Then remove the HEPA filter, weigh it, and try to shake off the particle deposits into the pan. The pan should be dusted clean and weighed to get a tare weight. After all of the dust has been shaken from the HEPA filter into the pan, weigh the HEPA filter and the pan.

31. Install the HEPA filter in its holder and take the measurements in Step 28b. This concludes the fifth test.

PARTICLE-SIZE DISTRIBUTION MEASUREMENTS

The size distribution of the aerosols generated in the glove box has a major effect on the performance of the electrostatic filter. Periodic measurements of the size distribution will then be made using an Andersen impactor, which will separate an aerosol sample into different size fractions and collect them on collection plates representing these size fractions. There is a glass fiber backup filter to collect any particles that were not collected by the impactor plates. The procedure is as follows:

1. Clean the impactor, collection plates, and backup-filter holder in an ultrasonic-water bath. Let the various parts dry and then measure the radioactivity. If the residual radioactivity is sufficiently high, the impactor will have to be assembled in a hood or glove box.
2. Assemble the impactor plates beginning with the bottom plate, which supports the filter holder. Place one of the stainless-steel disks on the supports of the bottom plate. Then place a glass-fiber filter on the stainless-steel disk and stack a new stage, 7, over the entire assembly. Repeat the process by placing a new stainless-steel plate, then a glass-fiber filter, and finally, another stage, 6, over the previous assembly. This process is continued until the last stage, 1, is placed on top of the resulting stack. Make sure the O-rings are properly seated in each of the stages when the impactor is assembled. After all the stages are stacked up, bolt them together using the threaded rods and nuts. Place rubber nipples over the ends of the rods to prevent tearing bags during the bag-in and bag-out operations.
3. Place a new glass fiber filter in the backup-filter holder and attach the filter holder to the impactor stage.
4. Check the impactor assembly for leaks by placing a stopper in the impactor inlet and monitor the downstream flow when a vacuum is

applied. Zero downstream flow indicates no leaks. If leaks are present, they must be eliminated before using the impactor. The rubber stopper should remain in the impactor.

5. Bag-in the impactor assembly inside the glove box and place it next to the inlet of the electrostatic prefilter.
6. Disconnect the sample line at the glove-box end-plate that measures the inlet concentration to the electrostatic prefilter. Connect the vacuum line from the impactor to this connector on the end plate. Turn the rotometer valve, on the upstream sample line, completely off and open the ball valve on the other end of the tee. This will make a connection between the Andersen impactor inside the glove box and the vacuum pump outside. Replace the B filter holder from the red sample line (Fig. 14) with a straight 1/4" tube.
7. Remove the stopper from the impactor and turn on the sample pump. Make flow adjustments to obtain 1-cfm flow. Turn off the sample pump and replace the stopper.
8. Generate aerosols by removing a filter cartridge and shaking it gently. Do not generate any more dust than is normally produced during a cartridge cleaning. Let the dust settle for one minute before taking the impactor sample.
9. Remove the stopper from the impactor and turn on the sample pump. Make flow adjustments to obtain 1 cfm flow. Take a sample for two minutes.
10. Turn off the sample pump, insert the stopper in the impactor inlet and bag-out the impactor assembly for dismantling.
11. Carefully disassemble the impactor and place each of the glass-fiber filters into a glass dish with a cover identified by a number

corresponding to the impactor stage. Also, place the backup filter in a glass dish with a cover.

12. Count the radioactivity on each of the filters as two blanks for the glass-fiber filters and one blank for the membrane filter.

FLOW-METER CALIBRATION

A Hastings flow meter, mounted in the exhaust pipe downstream of the HEPA filter, provides a measurement of the flow through the filter system. This flow meter will be periodically calibrated with a series of plates that fit into the prefilter holder. Each plate has a different size hole in its center and, consequently, produces a different pressure drop at a given flow rate. These plates have been previously calibrated to relate the pressure drop to a given flow rate. When the plate is installed in the filter holder, the flow indicated by the Hastings meter can be related to the true flow, using the pressure drop-flow relationships shown in Fig. 17. The curves in Fig. 17 are not corrected for the lower atmospheric pressure in Denver.

LONG-TERM MAINTENANCE AND DURABILITY

The electrostatic prefilter is designed to operate maintenance-free for periods up to six months. At this time, the MSA inline filters that are mounted on top of the sampling chamber should be replaced. In addition to this, the electrostatic-filter holder, high-voltage electrodes, and the HEPA filter holder should be thoroughly wiped clean after each of the five evaluations described. The Tygon tubing inside the glove box and the sampling chamber should also be replaced after each of these five evaluations. No maintenance is expected for any of the electrical components of the system.

Tests on the electrical safety devices, described in the following Electrical Engineering Note, should be conducted every six months.

A similar evaluation of the electrostatic prefilter was performed at LLL in a glove box containing UO_2 and BeO aerosols. However, since there was no HEPA filter immediately downstream of the prefilter, the evaluation consisted of only the prefilter portion of the second and fourth tests. The prefilter was operated every working day from March 8, 1978, to June 16, 1978, and performed satisfactorily.

Efficiency measurements were made at least once a month during this period with applied voltages of 0, 5, 10, and 15 kV; each high voltage setting

FIG 17. Calibration curves for the three orifice plates to be used in calibrating the Hastings velocity meter.

was on for about one hour. In addition to these evaluations, a filter was tested for 19 working days from May 2, 1978 to May 26, 1978 with a continuous applied voltage of 10 kV. During the entire evaluation, no corona discharge was observed, and the system functioned satisfactorily without much maintenance. The only maintenance required was occasionally to brush off the particle deposits from the electrodes.

ELECTRICAL ENGINEERING SAFETY NOTE

NOTE: Refer to Engineering Drawing A, page 62, when reading this chapter.

HIGH-VOLTAGE OPERATIONAL HAZARD OF ELECTROSTATIC PREFILTER

Filter-Assembly High-Voltage Sparking

At 10 kV dc, the wire mesh is operating in the corona region, and it may be necessary to reduce the voltage when operated at high altitude. However, experiments performed at LLL with a filter in place showed no visible indication of a corona discharge until the voltage exceeded 13 kV and breakdown occurred. This system should not be used in an application where a small amount of sparking cannot be tolerated. The energy in a spark is reduced by the current-limiting series resistor, which decouples the filter system from the remainder of the charged cable and power supply.

The hv power supply has a current overload circuit to shut down power to the hv transformer when the load current exceeds 40 μ A. In the event of a spark, the current through the series resistor will be approximately $10^4 \text{ V} / 10^7 \Omega = 10^{-3} \text{ A}$, or 25 times that required for tripping the circuit. The overload circuit requires a thyatron to trigger and a relay to pull in, to turn off the hv power supply. Because of the importance of overload sensing to prevent repeated or prolonged sparking, a redundant-overload circuit has been added to the hv power supply.

Attempting to Change Filters with High Voltage Left On

The flashing-yellow-warning light (Fig. 4) keeps the user alert to the fact hv is energized. A relay that operates the light is connected directly across the primary of the high-voltage transformer. The relay was necessary because, without it, the surge current for the light would cause periodic drops in the Sola voltage. The flashing light is powered through the relay contacts from

the primary side of the Sola transformer, which is connected to the flasher box by a special cable. Thus, it is ensured that the light is on the same circuit as the Sola.

If one attempts to open the latches that allow access to either the prefilter or HEPA filter, sealed-magnetic-reed switches will operate through an interlock circuit to de-energize the hv supply. The reed switches will open and remove power from redundant relays, whose contacts in series also open, thereby de-energizing the hv supply. There are two reed switches on each door, thus providing redundancy in the event one switch fails to open.

The power supply does not have an output-shorting solenoid.

NOTE: When the hv power supply is de-energized, the voltage will not go to zero immediately. It will decay with an exponential time constant of 2.5 s through the metering circuits, associated resistors, and neon bulbs. The decay can be observed on the voltmeter.

If the supply is shut down after operating at 10 kV, the voltage will fall to 67 V in 12.5 s. It is good policy to observe the operation of the voltmeter during shutdown as it falls to zero.

As stated in the operating procedure, the grounded forceps, with an insulated handle, must be used in lieu of a grounding hook to remove the filter and then short the mesh to ground. This will eliminate any residual charge that has not drained from the high-voltage electrode.

Disconnection Of hv Cables with High Voltage Energized

Although it should never be done, the Reynolds cable connectors are designed to be disconnected under no-load conditions with hv on. They are rated at 20 kV, unmated, and the hv center conductor is recessed so as to be inaccessible unless a tool such as a pencil or screwdriver is stuck into the connector.

NOTE: It is very important to have the hv power supply securely connected to the building ground and to have the ground system complete as shown in the system diagram.

The ground braid in the glove box should not be flexed unnecessarily. Proper grounding greatly minimizes the shock hazard even with faulty hv cable or connectors.

HV Power Supply

There are a number of modifications to the power supply. Some have been mentioned in previous sections, including the second overload circuit and the flashing yellow light that operates when power is applied to the transformer primary. The hv dc-output connector has been changed to a Reynolds rated at 20 kV. Only the dc output is to be used. The ac-output connector must be left capped.

Since the power supply is not regulated, a Sola constant-voltage transformer was added to make the hv output more independent of line voltage changes. Any fast transient increases in line voltage that the Sola cannot handle will cause the overload circuits to trip.

TESTING OF SAFETY DEVICES

Current Overload Trip Circuits

An additional overload sensing circuit has been added to the hv power supply. These circuits both have a fixed sensitivity of 40 μ A, which is slightly lower than the lowest level at which the original variable control could be set. A dummy load of 20 $M\Omega$ is provided in a minibox, which, when connected, should cause the power supply to trip out at approximately 800 V. In order to test the overload circuits individually for proper operation, it is necessary first to disable one circuit and then the other. This is performed by holding

the momentary switch (rightmost switch of the OVERLOAD functions in Fig. 16) in either test position while increasing the hv from zero to the trip level with the other hand. In the normal center position of the switch, both circuits are able to sense an overload.

Filter-Door-Interlock System

Two reed switches, in series, are imbedded in each door to provide redundancy. However, to be sure the switches are both open when the doors are open, it is necessary to check them every six months with an ohmmeter. Access to the switches is obtained by disconnecting the interlock cable attached to the Varian feedthrough (Fig. 5).

There is also redundancy in the relays that open the interlock circuit of the hv power supply. To check that they have both opened, disconnect the interlock cable and measure with an ohmmeter between pins A and B and pins C and D.

Current-Limiting Resistor

The current-limiting resistor, mounted to the right of the HEPA filter housing (Fig. 5) should be checked periodically with an ohmmeter to verify that its resistance is within $\pm 20\%$ of 10 M Ω .

See Engineering Drawings B and C for the power supply and the flasher-warning light, respectively, on pp. 63 and 64.

RADIATION SAFETY REVIEW

The Health Physics Group at LLL has reviewed the sampling procedure and equipment for the electrostatic prefilter that is being evaluated at Rocky Flats. They concluded that the sampling methods, if properly performed, appear to be safe and should not cause any significant release of radioactive materials outside the box. The sampling techniques and procedures have been carefully considered and designed to give acceptable experimental results. However, filter changes should be made only by personnel familiar with the equipment to avoid contamination of filters, equipment, or personnel. When properly handled, they concluded the sampling arrangement is safe and meets reasonable health physics practices.

ACKNOWLEDGMENTS

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ENGINEERING DRAWINGS

- A. Enhanced filtration system diagram.
- B. Power supply.
- C. Flasher-warning light.
- D. End-plate weldment of filter glove box.
- E. Sampling chamber.
- F. Assembly of the electrostatic prefilter.
- G. Front-door sub-assembly of the electrostatic prefilter.
- H. Filter body.

Eng. dwg. B

63

- 1. UNLIMITED LATERAL BRANCHING
- 2. INTERIOR THERMOSTATIC VALVES
- 3. SWIFT - AND SHIMMING - EXTREME - NOISE REDUCTION
- 4. UNLIMITED THERMISTOR - ALL - RESISTANCE - AND - 100 - 100

PROJECT	1. UNLIMITED LATERAL BRANCHING
DESCRIPTION	2. INTERIOR THERMOSTATIC VALVES
DESIGNER	3. SWIFT - AND SHIMMING - EXTREME - NOISE REDUCTION
CHECKED	4. UNLIMITED THERMISTOR - ALL - RESISTANCE - AND - 100 - 100
DATE	1964-8-21
BY	1. UNLIMITED LATERAL BRANCHING
DATE	1964-8-21
BY	2. INTERIOR THERMOSTATIC VALVES
DATE	1964-8-21
BY	3. SWIFT - AND SHIMMING - EXTREME - NOISE REDUCTION
DATE	1964-8-21
BY	4. UNLIMITED THERMISTOR - ALL - RESISTANCE - AND - 100 - 100
DATE	1964-8-21

MS 312ZE14-19P

Eng. dwg. C

NOTE:
PULSING CHIME POWER AVAILABLE
AT TB1 PIN 3 (HOT) AND FB PIN 3 (NEUT).

DIV/GROUP
ORIGINATOR
DATE
CHECKED
DATE
APPROVED
DATE

C	ADDED J2 MS NUMBER	5/79	REV
B	REVISED	5/79	REV
REV	ZONE DESCRIPTION	DATE	DRAWN APPROVED
TITLE FLASHER WARNING - GHT ZERO CRO-ING			
LAWRENCE LIVERMORE LABORATORY ELECTRONICS ENGINEERING DEPARTMENT University of California, Livermore California		GROUP BASIC PACKAGE NO LE-78-2149	SHEET TYPE REV 0 - C
APPROVED		SHEET OF	

Eng. dwg. D

NOI 11:

- 1 3 MEMPHIS AND
"ORANGE" ARE THE
AMERICAN AIR
- 2 POSITION. ARE FROM
"ORANGE" APP. 100
REAR, 80% OF "ORANGE" ARE
- 3 "ORANGE" ARE THE
AND - 80%
- 4 68
1 100%
- 5 "ORANGE" ARE THE
100% 75% ARE
- 6 "ORANGE" ARE THE
"ORANGE" ARE THE
"ORANGE" ARE THE

2-10 DRAWING SET

NOTES:

IDENTIFY WITH APPROX. 1/4" - 3/4"
NUMBERS APPROX. WHERE SHOWN.

2 AFTER INSTALLING TEM 3 EPOXY TEM 5
TO SAME, NOTE ORIENTATION.

3 POSITION TEM 4 ABOUT 250 Ø HOLE,
PRESS TEM 3 INTO TEM 4 PLACES.

3

20	FLAT HD SCR #8-32 UNC x 3/16 LG	36	NUT
19	FLAT HD SCR #8-32 UNC x 3/16 LG	4	NUT
18	RD HD SCR #8-32 UNC x 5/16 LG	15	ST
17	RD HD SCR #8-32 UNC x 3/16 LG	15	ST
16			
15	1/4" POLYPROPYLENE FITTING 404-4		JACOPEO
14	MAGNETIC FEED SENS - MRR-2-95	2	MANUAL
13	LATCHING DEVICE		5340-4620
12	WIRE 20 GAGE, TINED COPPER	A R	
11	FIBER GLASS Ø 5/16" AF 10	1	PERMANENT
10	DOWEL, Ø 1/2" STOCK x 3/16 LG	2	ST
9	HIGH VOLTAGE FEED THRU		PERMANENT
8			
7	7B-12390 MOUNTING FRAME		
6	7B-12391 PRESSURE TAP		
5	7B-12392 FRONT DOOR SUB-ASSY.	1	
4	7B-12393 KNOB	1	
3	7B-12394 DOWN STREAM SAMPLING TUBE	1	
2	7B-12395 WIRE FRAME	1	
1	7B-12396 FILTER BODY	1	

A	P.Y.	28	2/74
REV	DATE	BY	REVISION
1	10/1/74	WJ	1

DR. F. TRIESTI 24		THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LIBRARY UNIVERSITY OF CALIFORNIA LIBRARY 400 UNIVERSITY AVENUE BERKELEY, CALIF. 94720-1500 REPRODUCTION PROHIBITED UNLESS PERMITTED BY THE UNIVERSITY OF CALIFORNIA LIBRARY		DRAWN BY CHECKED BY APPROVED BY DATE	
LABORATORY ENGINEERING DEPARTMENT		PROJECT NO.		DRAWING NO.	
BILL OF MATERIALS REVISED		ASSEMBLY		PART NO. 112398-0A	

(3) "A" = 0.92; "B" = 0.87; "C" = 0.82

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 99. W-10
 100. W-10

[illegible]

#8-32 UNC-2B THRU
5 PLACES

1117A-112M3-00

NOTES:

1. DIMENSIONS AND TOLERANCES ARE PER ANSI Y14.5, M3.
2. POSITIONAL AND FORM TOLERANCES APPLY HERE REGARDLESS OF FEATURE SIZE.
3. SURFACE TEXTURE PER ANSI-B.
4. ✓ UNLESS OTHERWISE NOTED
5. BREAK CORNERS AND EDGES

#8-32 UNF-2B
1.500 DIA DEPT T-0
4 PLACES

#8-32 UNF-2B
1.500 DIA DEPT T-0
2 PLACES

2

NOTES:

1. DIMENSIONING AND TOLERANCES ARE PER ANSI-Y14.5, Q13.
2. POSITIONAL AND FORM TOLERANCES APPLY RFS (REGARDLESS OF FEATURE SIZE)
3. SURFACE TEXTURE PER ANSI-B46.
4. ✓ UNLESS OTHERWISE NOTED
5. BREAK CORNERS AND EDGES .05 MAX

250 1.00S @ THRU
3 PLACES NEAR WALL
870 1.00S @ 1.50 1.03 DEEP
REF. -A- 3 PLACES

- 3 -

8-32-60-2B
 500 Y L DEFE -D
 6 2-4-65

08-32 UP, 22
X.500 M.N. FEPS
THD, 2 P.A. 66

-23 = 03 MAY
6 2-4-88

25 - 22 542
4 2 845

500 : .010

.750 : .010

၂၁၈

 0.375 ± 0.00

7.250 1,2 2

250 = 005 @ THRU

.750 : 005 Ø THRU

- 1,125 ± 0.0

1. 25 ± 0.10 Ø CBORE
* 502 ± 0.10 DEEP

3

[illegible]

DATA SHEETS

Four data sheets are included in this section. The first, Data Sheet I, is for the First Test, the HEPA filter alone. The second is an example of a filled-in data sheet for the Fourth Test, the HEPA filter and electrostatic disposable prefilter. This serves as an example for filling out the next two sheets; Data Sheet II is for the case of the disposable prefilter (Second Test and Fourth Test), and Data Sheet III is for the case of the reusable prefilter (Third Test and Fifth Test). Both Data Sheets II and III can be used for either the standard or electrostatic mode.

These sheets should be photocopied for actual use.

HEPA Filter Test (No prefilter and no electric field)

Measurements taken:

[illegible]

DATA SHEET EXAMPLE

HEPA Filter and Disposable Prefilter Test

Measurements taken:

Date	Before weighing	After weighing	After sampling	Before cleaning cartridge	Before prefilter replacement	Other	[] No electric field		[x] Electric field, 10 kV/cm		Velocity meter	Comments	
							HEPA mass	ΔP	Prefilter mass	ΔP			Glove box ΔP
3/5						X	21018		9.0			NEW HEPA + PREFILTER INSTALLED	
3/5	X							0.05		0.5	70	40	
3/5		X					21019	0.05	9.1	0.6		42	
3/5			X					0.05		0.7	0	0	CHEMICAL REQUEST 05031
3/7				X				0.05		0.7	0.7	46	
3/9				X				0.05		0.7	0.7	48	
3/13				X				0.12		0.46	0.87	0	
5/2	X							0.60		0.85	0.85	70	
5/2		X					2108	0.68	18.5	8.0	0.85	70	
5/2								0.60		0.82	0.85	70	CHEMICAL REQUEST 05019
5/2								0.62	9.0	7.0	0.85	70	7.04 Request 7.04 Prefilter Request 05019
5/2													HEPA and Prefilter Request 05019

11

100

0.0001

[illegible]

HEPA Filter and Reusable Prefilter test

☐ No electric field

[] Electric field, 10 kV/cm

[illegible]