A METHOD OF CHANGING ALPHA AND GAMMA CONTÁMINATED FILTERS WITHOUT INTERRUPTING EXHAUST

by

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Abstract

This method consists of pushing a filter into its working position in a tunnel as an initial step and then pushing it on through with a new filter. Special gaskets on the filter keep it sealing the openings at all times. The seal is maintained during transfer into the disposal container. The transfer can be accomplished by remote operation using gamma shielding.

Introduction - The need for a simple mechanical method to change highly alpha and gamma contaminated filters is becoming more apparent as fabrication and reprocessing of reactor fuel is required. The possibility of higher gamma activity in the filter due to fire and methods of cutting and fabrication which generate small air-borne particles makes it necessary that the prefilters be highly efficient and possibly shielded. Details of the shielding of the filter housing and filter disposal container are not included in this paper. It is always desirable to maintain a radioactive area under a slight negative pressure which means an uninterrupted exhaust. Filters which can be changed without shutting off the blowers and without losing filtration of the exhaust air are desirable.

The one way push-through method requires a continuous tunnel so that filters are inserted successively on one end only and pushed through the tunnel by the following clean filter to the collecting end (the container). The working position is intermediate between the ends of the tunnel. At the working position, the contaminated air is collected in the filter as the air passes from an upper plenum to a lower plenum. A seal is maintained on the openings of the tunnel by each successive filter. The air is filtered at all times during the transfer.

A mockup was set up, using the 24" x 24" x 12" AEC filters. In most installations the new high efficiency glass media filters of the same size will be used particularly where a fire hazard exists or chemical elements are injurious to the filter media. Experimental testing of the mockup was required to study the following problems. It was important to observe the physical characteristics of the seal in operation and also to determine the optimum deflection of the seal. The effectiveness of the seal and the force necessary to propel filters through the tunnel was also information desired from the mockup.

Design - The filter with its seal and a typical metal container are shown in Fig. 1. The ring gasket with 1 inch radius corners mounts to the top and bottom of the wooden filter frame. This gasket seals on the upper and lower plates of the tunnel.

The main section of the seal material[a] is a 5/8" diameter neoprene covered sponge rubber core. The round section has a mounting leg of wire and cord mesh covered with neoprene. This mounting leg is 1/16 inch thick and extends about 1-1/8 inches from the center of the 5/8 inch diameter. The wire mesh leading into the sponge rubber center gives the gasket some support. The seal material is very smooth on the outer surfaces.

The wooden frame of the filter was notched on a shaper at the outer edges with 1 inch radius at the corners. The continuous gasket vulcanized at the joint was cemented into the recess and a steel strap tightened over the mounting leg. Wood screws fastened the steel at 4 inch intervals. Aluminum support strips were placed on the leading and trailing edges to support the 5/8 inch diameter section. This support is especially needed while passing the opening at the working position.

Another advantage of this sealing material is the great deformation of the seal without substantial increase in the sealing force. The seals and sliding surfaces are coated with a Silicone Pneumatic grease.[b] The wiping force is thus held to a minimum. The seal due to its flexible neoprene skin seems to conform to irregular surfaces maintaining a seal without ground or honed surfaces. The seals are compressed about 1/8" for best wiping and sealing action.

Figure 2 shows the experimental setup with the clean filter at the left ready to push the dirty filter on through to the right into a container not shown. The hydraulic ram pushing on the clean filter propels the dirty filter into a container attached as shown in Fig. 3.

The container to receive the filter is bolted to the tunnel. The container can be shielded. The bolts to mount the container can be operated by long-handled wrenches through the back end of a shielding pot. The cover to the container would be fastened to the sliding gate of the shielding pot and after loading of the container, it would be lowered in front of the container. The same bolts would then be used to fasten the cover on the container. During this sealing of the container, the filter is sealed by the top and bottom of the container--but there will be suspect contamination in the grease.

[a]Bridgeport Fabrics Company, Bridgeport, Conn. (Catalog #HD-604N-1).
[b]USAF 3515 Spec. MIL-G-4343 Dow Corning Corporation, Midland, Michigan.

The ring gasket, top and bottom mounted to the filter frame, seals on the upper and lower plate of the tunnel. The gasket on the leading edge of the clean filter and the gasket section on the trailing edge of the dirty filter come together to form one wiping seal as they travel over the openings in the upper and lower plates. The air to be filtered enters the filter at the top and is exhausted at the bottom. The contaminated particles on the top side of the filter cannot fall off onto the track during transfer. The wooden sides of the filter are roughly guided just below the center so that the rounded cross section of the gasket riding in the apex of the corner is uniformly deformed. Tests show it required a maximum force of 500 lbs. tó move the two filters through the tunnel. The surfaces of contact and the seals are coated with a grease to reduce friction and to fix contamination which is spread by the wiping action of the seals.

Testing - The following experimental tests were conducted: the burning of uranium to test the spread of contamination; fluorescent powder was used to observe the wiping action of the seals; and leakage tests on the seals were attempted.

The filters used in the leakage test are only available with a wooden frame. Testing of the filter seals was attempted in the tunnel but the wooden frame, even after coating with paraffin, was too porous. A metal container inserted in the tunnel, open on the top with a seal similar to the upper seal of the filter, held 42 inches of water pressure for a few hours testing without loss. The seal, compressed 1/8" on the rough ground stainless steel plates, was considered sufficient for the present filters. The filter leakage, of course, will be offset by the negative pressure established by the blower which should be operating during the filter change.

Using the hood to the left of the upper plenum of the mockup (Fig. 2), a test was made burning 150 grams of uranium while drawing 200 to 250 cfm of air through the filter and hood. The background air tests showed a little over one microgram of uranium per cubic meter. The air count during the burning and during the filter push through into the container remained the same as background. The air suction tube for this test was placed under the parting line between the tunnel and the attached container. Smear tests were made on the top leading edge of the test filter gasket before and after the uranium burning. The contamination increased from 2 to 136 micrograms of uranium. A smear test across the top leading edge gasket of a second filter unit, pushed through the working position on out so that a smear could be taken, measured 144 micrograms. The smear test on the bottom front edge of the receiving container showed no gain in contamination when tested before and after the push through. This showed that the filter did a good filtration job and the lower plate was not contaminated. We would conclude that some contamination was spread by the wiping action of the seal but was fixed in the lubricating grease. Contamination did not escape at the joint between the tunnel and the container. Smears made on the inner sides of the container before and after the uranium burning showed no increase as a result of air displacement by the filter insertion.

To further test the efficiency of the wiping seal, a 1" x 24" strip of yellow fluorescent powder was applied to the lower plate of the mockup about 8 inches from the opening toward the clean end. Using a black light detector, after passage of the first filter unit, it was observed that the powder had been spread from the original one-inch wide band to a three-inch wide band about one third the original brilliancy. None of the powder was detected as having fallen into the opening; the powder that was picked up by the wiping action of the seal was retained in the grease. A second filter passed through picked up very little of the powder and did not visibly spread the band. As with the uranium burn test, we conclude that the contamination that was spread by the wiping action of the seal was contained in the grease and would not fall out when passing over joints or openings.

Conclusions - This method of filter changing can be done in a fairly short period of time compared to some of the cover taping and bagging methods now being used. It can be adapted to remote control because of the simple load and push through feature which might have to be done behind gamma shielding. The greased seal contains the contamination during the wiping action. With the exhaust operating at all times during the change, the chance for the spread of contamination in the handling area is kept at a minimum. All leakage is into the exhaust as our wooden filter frames are not well sealed. The filter will, of course, be sealed in the container during transfer to processing or disposal areas.

Acknowledgment - The authors are grateful for the cooperation of members of the Remote Control Engineering Division, especially Hubert Judkins for his work in the assembly and testing of the push-through filter change mockup. The uranium burning experiments were directed by Donald P. O'Neil of the Industrial Hygiene & Safety Division, who also helped in evaluating the merits of the proposed method.

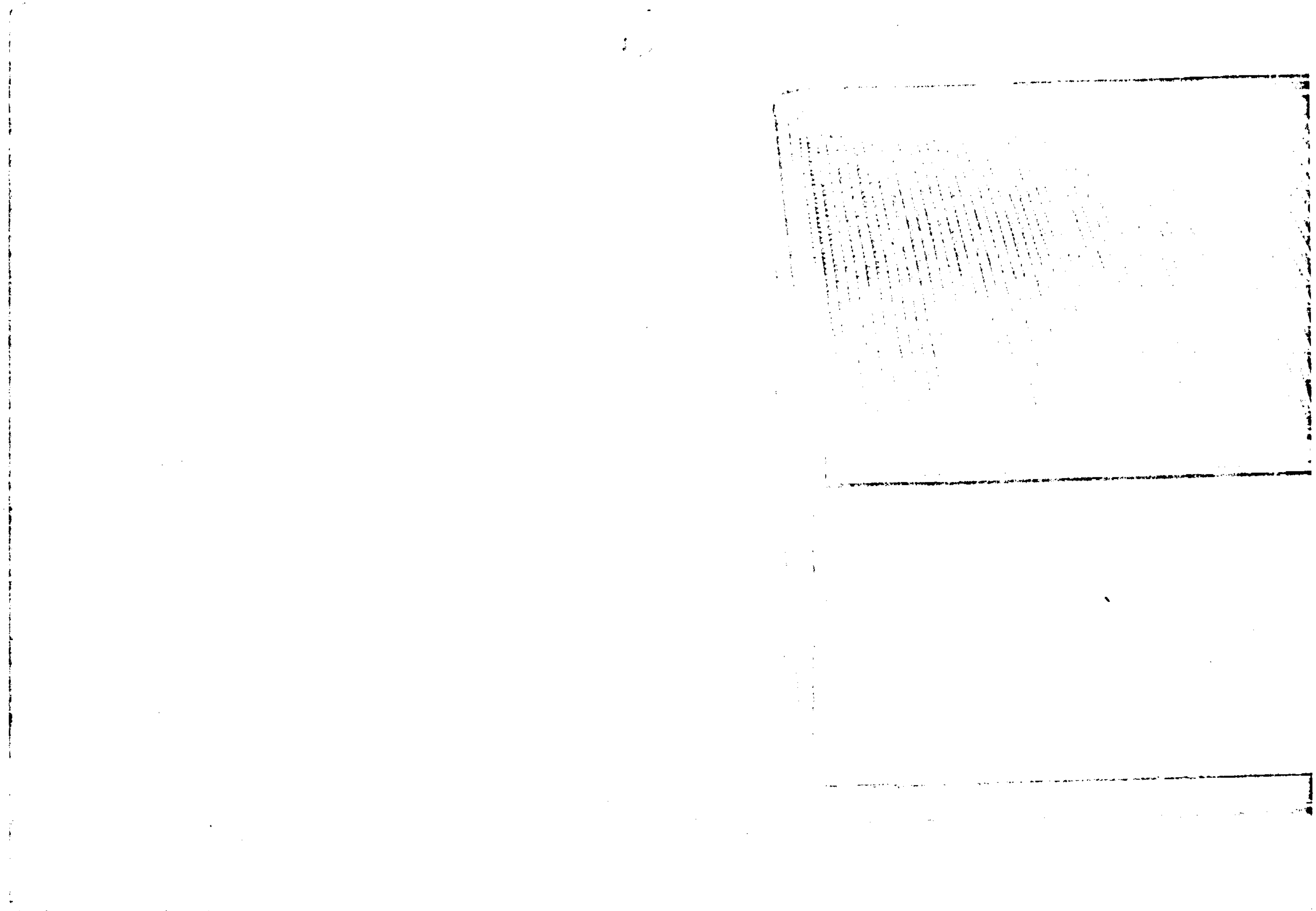

Fig. 1. Container and Filter with Ring Gasket Top and Bottom.

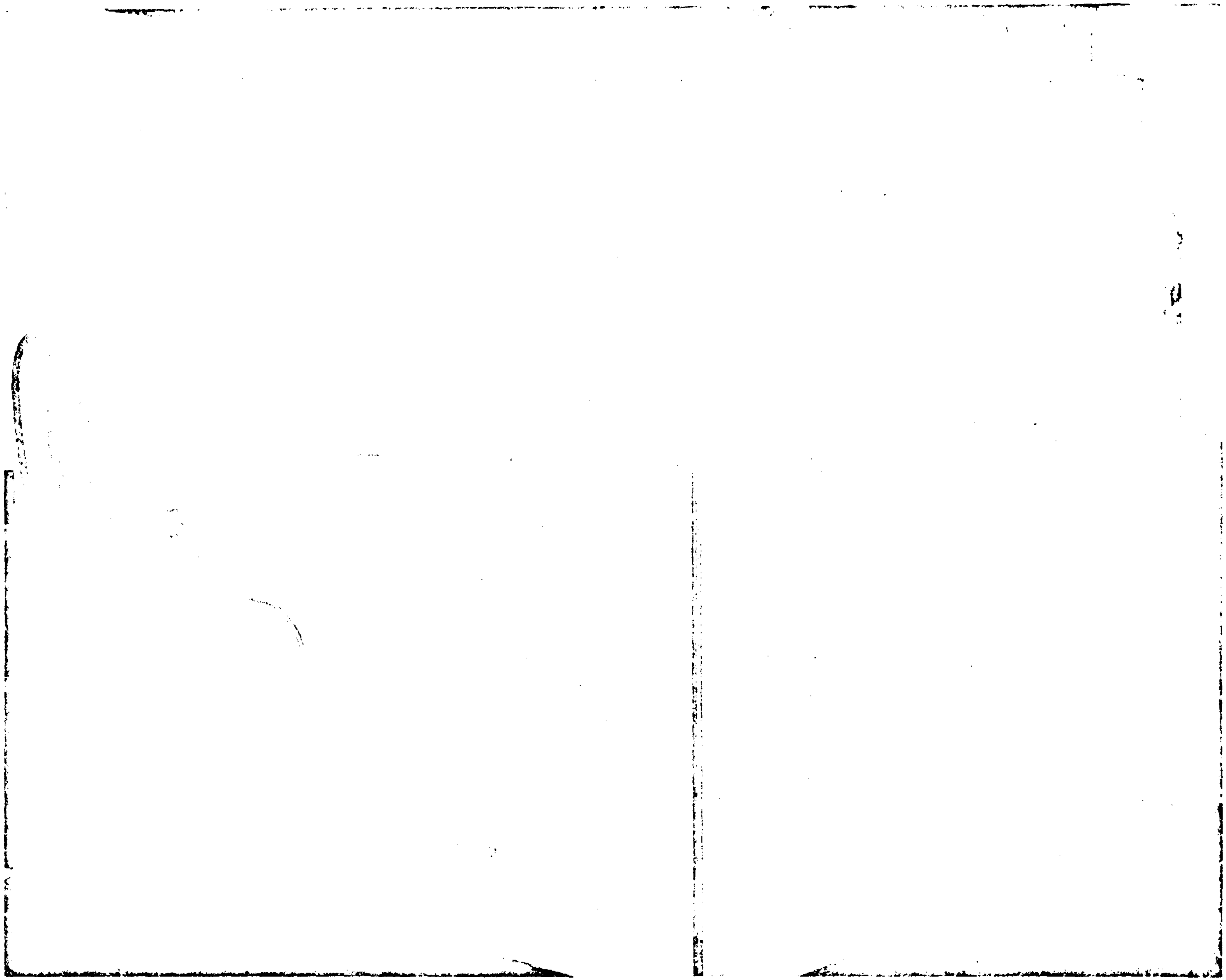

Fig. 2. Mockup of Push Through Filter Change Method for High Level Caves.

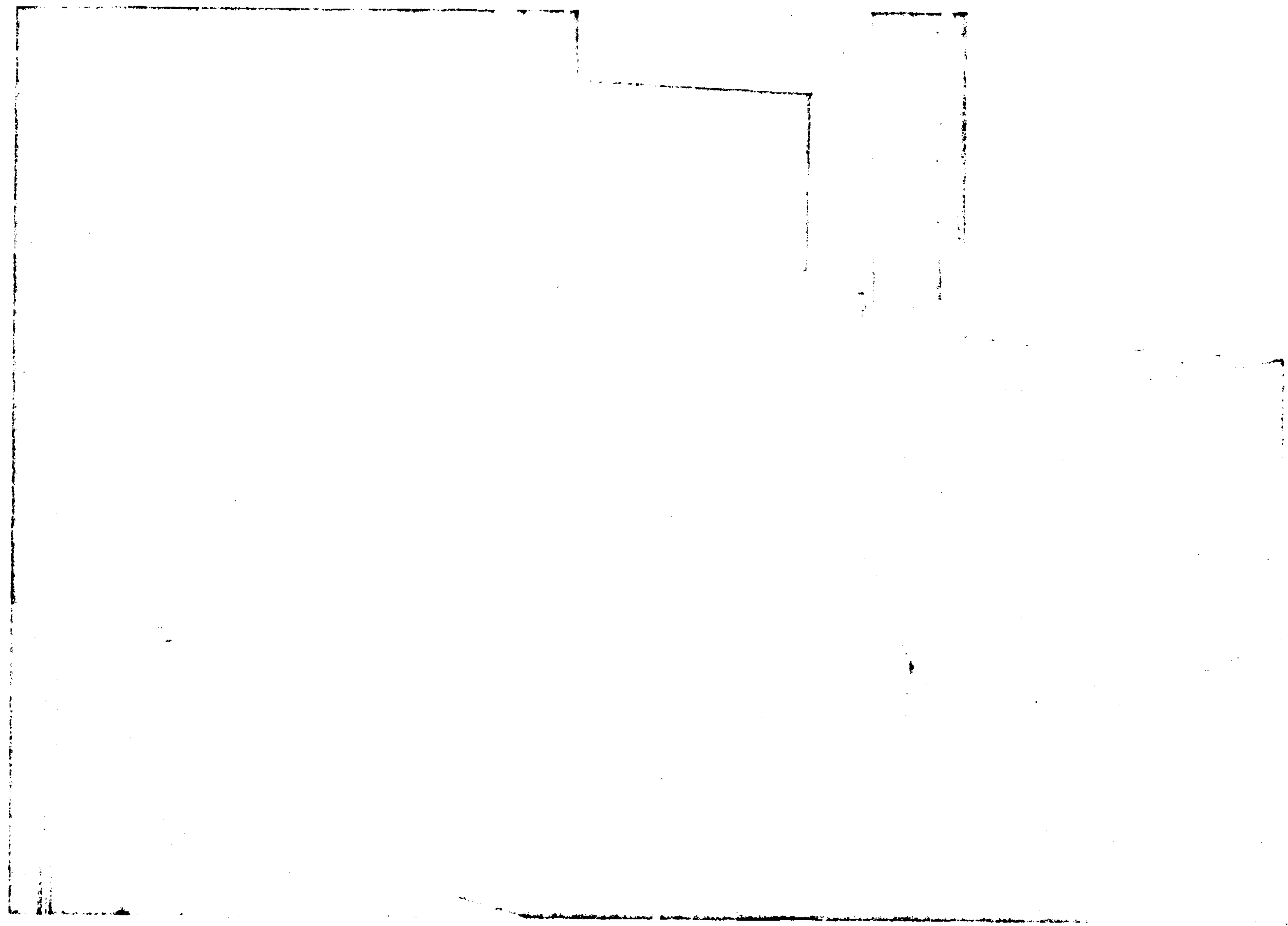

Fig. 3. Container for Contaminated Filter Attached to Mockup for Push Through Filter Change Method.

COLLECTION EFFICIENCY OF AIR CLEANING AND AIR SAMPLING FILTER MEDIA IN THE PARTICLE SIZE RANGE OF 0.005 to 0.1 MICRON

J. J. Fitzgerald

C. G. Detwiler

Abstract

The Hollingsworth and Vose-70 filter medium and the air cleaning filter media, (CC-6, MSA-1106-B, AEC-1) tested in these experiments are significantly more efficient in the collection of submicron particles than the Whatman-40 and 41 filter papers. However, with a proper selection of the face velocity, relatively high collection efficiencies can be achieved even with the use of the Whatman filter papers.

In these filter efficiency studies, all air sampling filter media investigated were more efficient for the collection of liquid $KMnO_4$ particles in the size range of 0.01 to 2.1 microns than for corresponding sizes of solid duraluminum particles.

In the size range of 0.005 to 0.1 micron, the Whatman-40 and 41 filter papers are more efficient in the collection of solid duraluminum particles than in the collection of $KMnO_4$ particles.

The optimum particle size for penetration through air cleaning and air sampling filter media was detected or indicated in each of the studies conducted. The optimum particle sizes for penetration through Whatman-40 and 41 filter papers occurred at approximately 0.03 and 0.02 microns, respectively at a velocity of 150 cm/sec (the minimum efficiency under these conditions was 90%). These results are in good agreement with the theory of Davies and Green.

Introduction

Chemically toxic and radioactive particles and gases may of their very essence emanate from mechanical, chemical and reactor operations in an atomic energy laboratory. At the Knolls Atomic Power Laboratory, an air cleaning and air sampling program* was initiated to provide adequate cleaning of the laboratory air and the air discharged to the environs. Particles emanating from laboratory operations are collected in a variety of air cleaning equipment such as electrostatic and cyclone precipitators, caustic scrubbers, and Dustop and high efficiency filter units. A total of 475,000 cfm of laboratory air is cleaned prior to discharge to the environs. High efficiency air filter units (predominantly CWS-6) clean 80% of the filtered air discharged in the environs. To assure adequate control of air-borne material and the proper operation of air cleaning equipment, 20,000 air samples are taken yearly and analyzed for their chemically toxic and radioactivity content.

Whatman-40 and Hollingsworth and Vose-70 filter papers are used to collect chemically toxic (beryllium) and radioactive particulate material, respectively in the Laboratory and the environs. Cascade impactors, electrostatic and thermal precipitators and Millipore Filters have been used to determine the particle size distribution of materials emanating from operations in the metallurgy, chemistry and physics laboratories at KAPL. These particle size distributions have included analyses of the particles under a light and an electron microscope.** Autoradiographic studies have been conducted using a stripping film technique** to evaluate the size distribution of radioactive particles in a heterogenous mixture of radioactive and non-radioactive particles.

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* KAPL-1014, KAPL Air Cleaning Program, L. J. Cherubin, J. J. Fitzgerald.

** KAPL-1015, Evaluation of the KAPL Separations Process Stack Effluent, J. J. Fitzgerald.

An evaluation of the effectiveness of an air cleaning program requires not only a knowledge of the particle size distribution but also the efficiency of the filter media used to collect these particles. To provide an adequate evaluation, one must know the collection efficiencies of the filter media primarily as a function of the particle size, particle velocity in the air stream and the type of particles used. In an earlier report by Fitzgerald and Detwiler,* collection efficiencies were determined for the H-70, W-40, W-41, CC-6, MSA-1106-B and AEC-1 filter media in the particle size range of 0.1 to 2.1 micron at face velocities of 0.5 to 150 cm/sec using a duraluminum aerosol. This study in itself was not adequate for a complete evaluation of the filter media. A complete evaluation of a filter medium requires a knowledge of the collection efficiency in the size range of 0.005 to 0.1 micron for the following reasons:

1. The majority of the particles in the air, upon which radioactive material may be deposited, are in this size range.**
2. The average particle size emanating from the KAPL separation process operation was 0.05 micron.***
3. The maximum penetration of particles, theoretically, occurs in this particle size range when the particle velocity is greater than 1 cm/sec.****
4. There is no doubt that particles in this size range will be retained with relatively high efficiency in the aveolar from Brownian movement in the respiratory system.*****

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* Fitzgerald, J. J., and Detwiler, C. G., "Collection Efficiency of Air Cleaning and Air Sampling Media", American Industrial Hygiene Association Quarterly, June 1955

** Wilkening, M. H., Natural Radioactivity as a Tracer in Sorting Aerosols According to Mobility. Review of Scientific Instruments, Vol. 23 No. 1, Jan. 1952.

*** KAPL-1015, Evaluation of KAPL Separations Process Stack Effluent, J. J. Fitzgerald

**** Proc. Inst. Mech. Engr. (London), B 1 185 (1952) pg 203, H. L. Green

***** Brit J., Industr. Med., 1952, 9, 120, C. N. Davies, "Dust Sampling and Lung Disease."

In this report the following experimental results will be discussed:

1. The collection efficiencies of air sampling (W-40, W-41 and H-70) and air cleaning (CC-6, AEC-1 and MSA-1106-B) filter media in the particle size range of 0.005 to 0.1 micron will be presented.
2. The theoretical and experimental optimum particle sizes for penetration through the filter media will be discussed.
3. A comparison will be made of the efficiencies obtained using atmospheric dust, solid duraluminum and liquid $KMnO_4$ aerosols.

Discussion of Parameters Affecting Filter Efficiency

Theoretically, aerosols are collected in fiber filter media by several methods; inertia, interception, electrostatic forces, settling, and diffusion. These factors have been discussed in detail in many reports.* For a given fiber radius or standardized filter medium, the filter efficiency is predominantly a function of the particle size and the velocity of the particle in the air stream for a specific aerosol. In some instances, the electrical charge of the fiber and the aerosol may have a significant effect on the collection efficiency. The collection efficiency of a filter medium varies with particle size and face velocity in the manner presented in Table 1.

Table 1. Variation of Collection Efficiency with Particle Size and Face Velocity

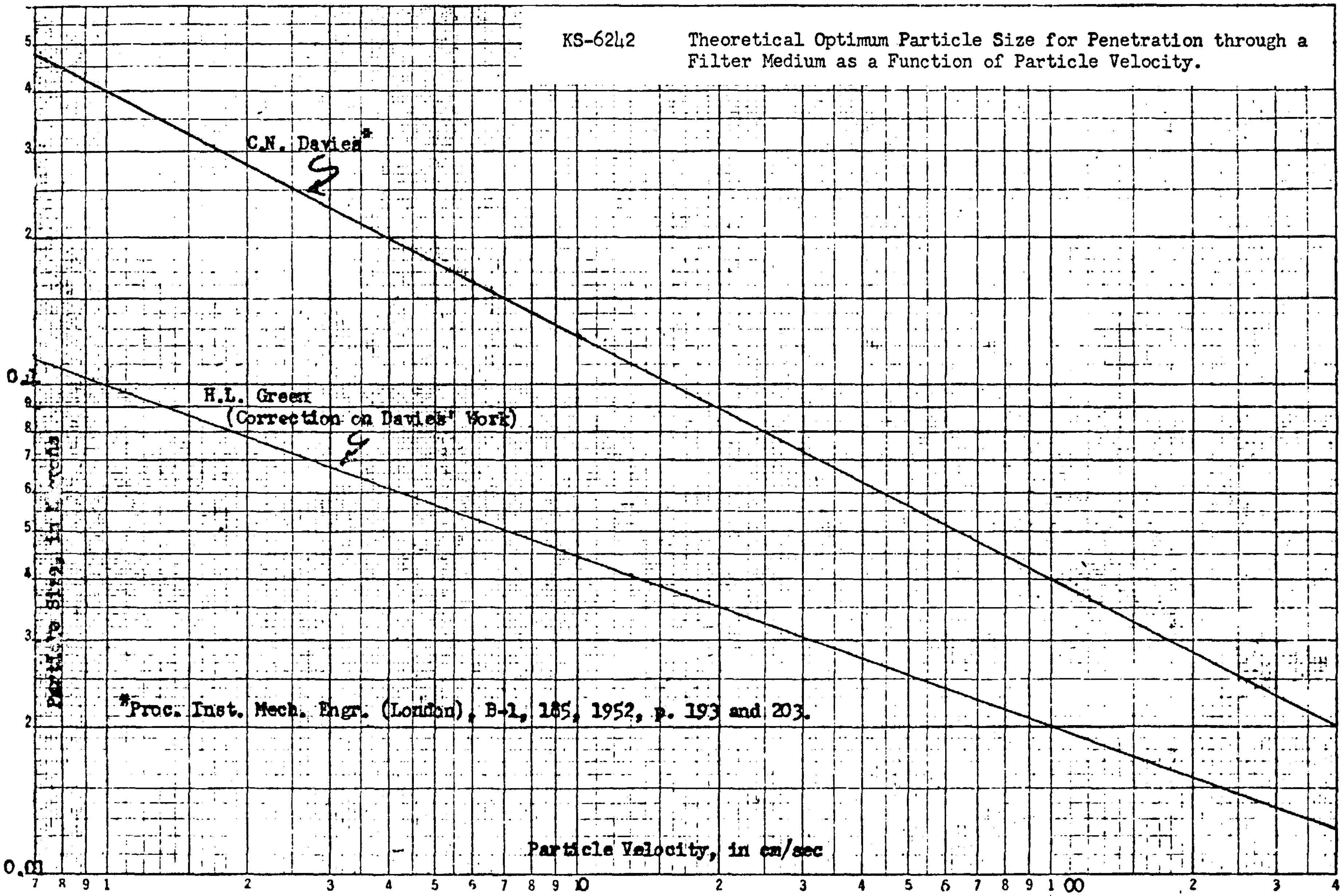
Collection Efficiency Parameters	Relationship of Particle Size, Dp and Face Velocity, v with Collection Efficiency E
Inertial Impaction	$E \sim v\, D_p^2$
Direct Interception	$E \sim D_p$
Electrical Attraction by Charges	$E \sim (v\, D_p)^{-1}$
by Induction	$E \sim v^{-1}\, D_p^2$
Diffusion	$E \sim (v\, D_p)^{-1}$
Gravitational	$E \sim v^{-1}\, D_p^2$

* NYO-512, Studies on Filtration of Mondispersed Aerosols, V. K. La Mer

NYO-1594, Electrostatic Mechanisms in Fiber Filtration of Aerosols, A. T. Rossano, Jr., L. Silverman.

Handbook of Aerosols, U. S. AEC Washington, D. C., 1950, Chapter 9, Filtration of Aerosols, W. H. Rodebush.

SO-1004, The Impaction of Aerosol Particles on Cylindrical and Spherical Collectors, W. E. Ranz.



KS-6242 Theoretical Optimum Particle Size for Penetration through a Filter Medium as a Function of Particle Velocity.

For large particle sizes and high particle velocities, the inertial impaction parameter is an important factor in determining the total efficiency of the filter medium. For small particle sizes and low particle velocities, the diffusion parameter becomes an important factor in determining the total efficiency of the filter unit for the collection of the particles. Collection by direct interception is independent of particle velocity and depends fundamentally on the ratio of the particle size to the filter fiber size. Collection by gravity is important when the particle size is large and the particle velocity is small.

Several theories based on these relationships have indicated that each filter medium will yield a point of maximum penetration for a certain particle size at a given face velocity. This theory of maximum penetration evolves from the fact that for a given particle velocity, fiber size (or filter media) and test aerosol, the efficiency of collection by the diffusion mechanism increases with a decrease in particle size whereas the efficiency for collection by inertial impaction and direct interception decreases with a reduction in particle size. Perhaps, the most recent and complete theory has been promulgatea by C. N. Davies. In his theory, the optimum particle size, D_p in cm for a maximum penetration through a given filter medium at a specified velocity of v, cm/sec may be approximated in Equation (1).

$$D_p^2 v = 4 \times 10^{-9.4} \qquad (1)$$

In a review of Davies' Theory, H. L. Green pointed out that using Davies' final equation, the optium penetration sizes did not occur at the above relationship. The optium penetration sizes using Equation (1) and the corrected values of Green are given in Figures KS-(1).

Davies' Theory did not consider the gravitational and electrostatic parameters in the determination of the optimum penetration size. In general, the contribution of these parameters in the total collection of particles is negligible for the particle sized and velocities considered. However, the electrostatic effects of some aerosols and filter medium may be sufficient to alter substantially the optimum penetration sizes as stated by Davies and Green. In the final analysis, the experimental determination of the optimum penetration sizes is of greatest significance at this time until more reliable assumptions can be made with respect to theoretical considerations.

Experimental Procedure

Test Aerosol

In previous studies,* duraluminum was used as the test aerosol for determining filter efficiencies in the particle size range greater than 0.1 micron in diameter. The duraluminum aerosol concentration was too low, however, to permit the production of satisfactory electron micrographs for studies in the particle size range of 0.005 to 0.1 micron in diameter. General atmospheric dust was found sufficiently abundant to use as the test aerosol for some of the less efficient filters. The general atmospheric dust concentration in the particle size range of 0.1 to 2.1 microns was approximately one order of magnitude greater than the duraluminum aerosol concentration but was too low for satisfactory electron micrographs in the air cleaner filter efficiency studies in the lower particle size range.

An effort was then made to produce a highly concentrated and suitable aerosol with respect to particle density, detection under the light microscope, physical state and particle shape. Lauterbach's improved aerosol generator** was modified by increasing the size of his aerosol generation chamber to 13 inches in diameter. With this modification, and with the use of a saturated solution of $KMnO_4$, the aerosol concentration was approximately three orders of magnitude greater than when duraluminum was used. Suitable electromicrographs for the filter efficiency studies in the sub-micron size range were obtained with the $KMnO_4$ aerosol.

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* Fitzgerald, J. J., and Detwiler, C. G., "Collection Efficiency of Air Cleaning and Air Sampling Media," American Industrial Hygiene Association Quarterly, June 1955.

** UR-377, "An Improved Aerosol Generator," by K. E. Lauterbach, et al, July 12, 1955, p. 4-6.

The modified $KMnO_4$ aerosol generator is shown in Figure KS-4911. The letter "A" designates the aspirator and aerosol production chamber. The $KMnO_4$ reservoir is located at "B". The operating principles of this aspirator type aerosol generator are described in detail by Lauterbach, et al, in UR-377*. With a saturated $KMnO_4$ solution, the generator produced 1.1 x 10^9 particles/ft^3, as determined with light microscope. The particle size distribution was characterized by a geometric mean size of 0.3 micron and a geometric standard deviation fo 1.9; based on light microscope particle size measurements.

Standard Filter Sample Collection

The aerosol was released into the test equipment illustrated at "A" in Figure KH-9A 1064. The particles larger than approximately three microns in diameter were collected on the impaction plate at "C", and the particles less than three microns passed into chamber "F". The details of this system were reported in KAPL-1068 and the American Industrial Hygiene Association Quarterly.**

Equal quantities of the test aerosol were taken isokinetically from the aerosol chamber at sampling ports, "H". The fractions of the test aerosol taken at the sampling ports, "H" were shown experimentally to be equal within the statistical limits of the procedure.

Referring to Figure KS-2714, the filter under test was held between flanges at the right of "B". The desired face velocity for each filter efficiency test was obtained by the insertion of retainer rings between the test filter flanges. The retainer rings had aperatures which varied in diameter, (from 0.46 to 6.52 cms) depending on the desired face velocity.

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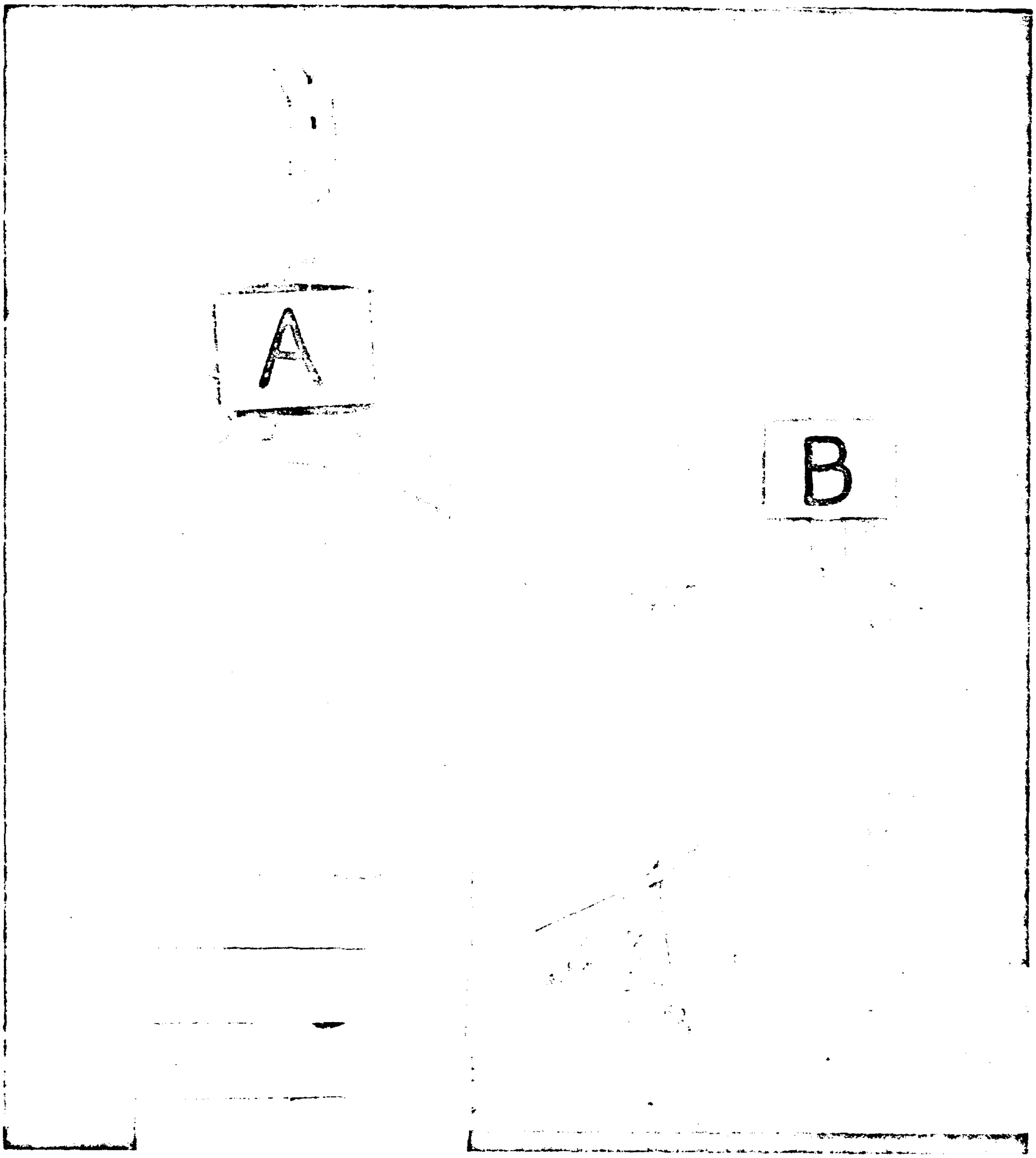
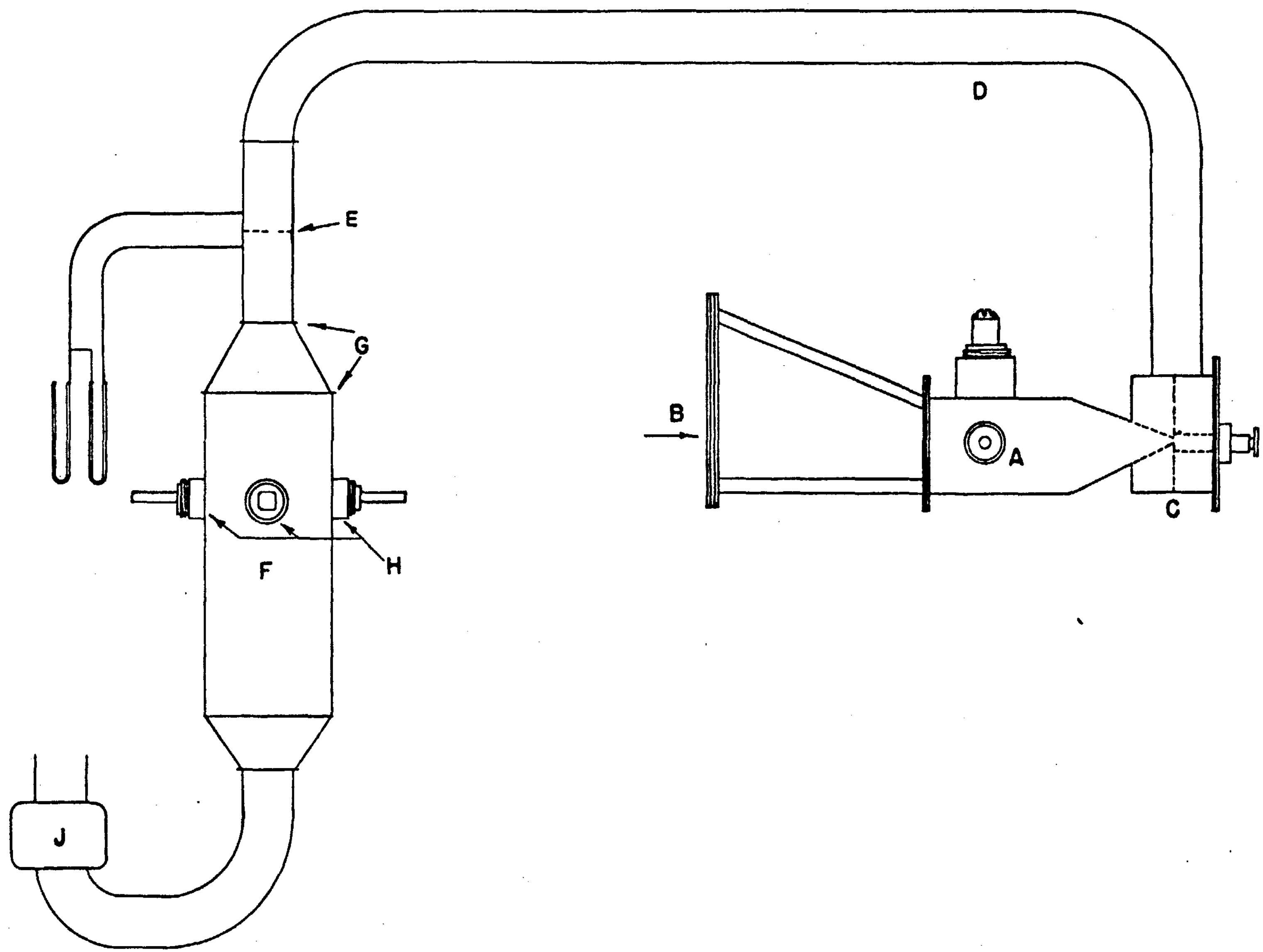
* UR-377, "An Improved Aerosol Generator," by K. E. Lauterbach, et al, July 12, 1955, pg. 4-6.

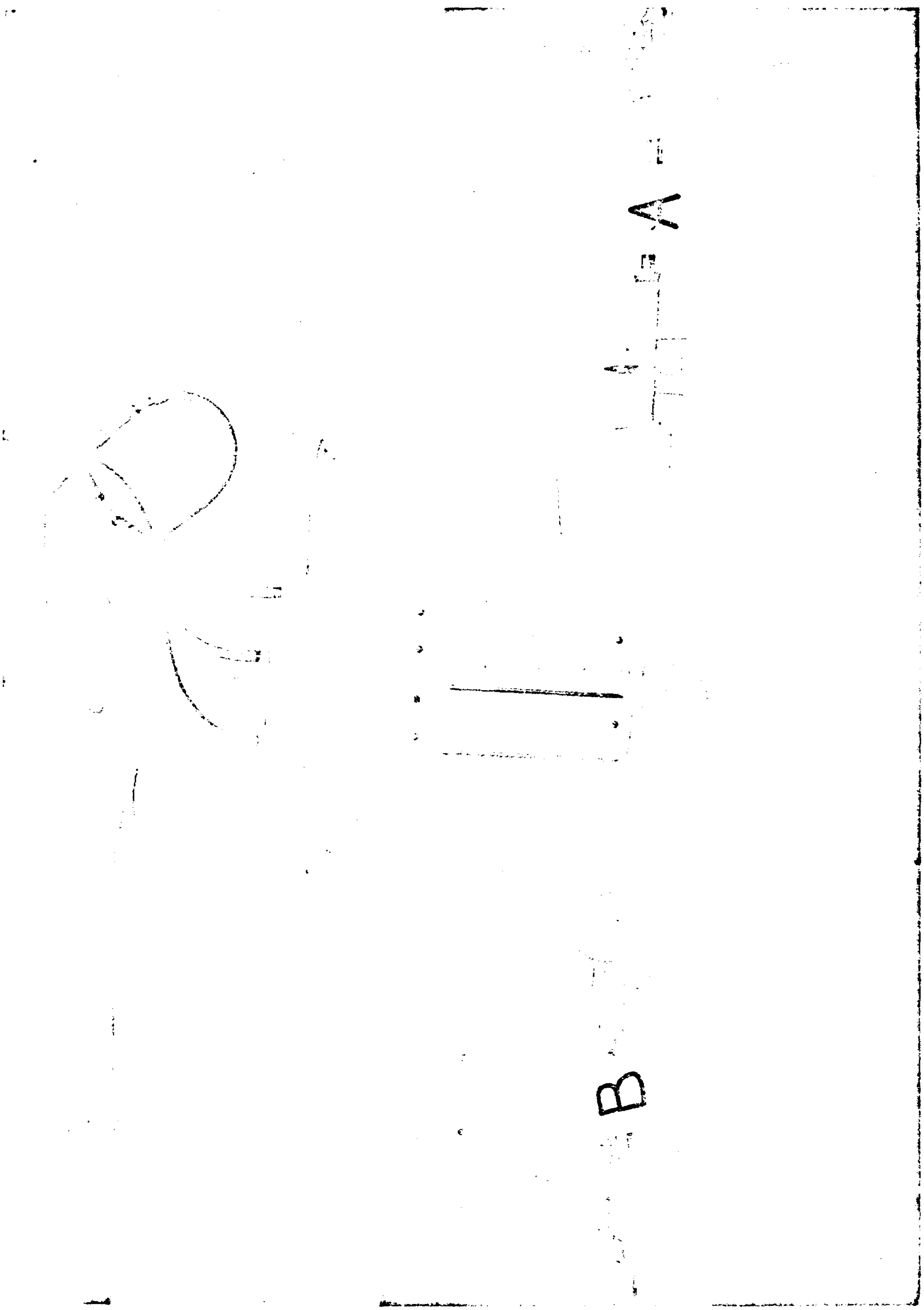
** Fitzgerald, J. J. and Detwiler, C. G., "Collection Efficiency of Air Cleaning and Air Sampling Filter Media," Am. Ind. Hyg. Ass'n. Quarterly, Vol. 16, No. 2, June 1955.



KS-4911 Modified $KMnO_4$ Aerosol Generator



KH-9A1064 Schematic Diagram of Test Unit



KS-2714 Aerosol Chamber

In these experiments, the size of the aperatures was varied while the flow-rate was held constant. The aerosol sample drawn into the standard filter (Type HA, Millipore Filter) at the right of "A" was equal to the aerosol sample exposed to the test filter. The standard filter to the left of "B" collected the aerosol that passed through the test filter. A comparison of the aerosol collected on the two standard filters permitted a determination of the particle collection efficiency of the filter under test.

Sample Analysis

The filter efficiency evaluations were accomplished in two phases. In the first phase, the particles deposited on the standard filter papers were analyzed under the light microscope. This phase involved the collection efficiency determinations of the filter media in the particle size range of 0.1 to 2.1 microns. In the second phase of these filter efficiency studies, the particles in the size range of 0.005 to 1.0 micron deposited on the standard filter papers were analyzed under an electron microscope.

In the light microscope phase of the evaluation, the Millipore Filter is impregnated with microscope immersion oil, which renders the filter transparent. A cover glass is placed over the sample and a standard size count is made. A comparison of the upstream and downstream size counts, corrected for scanning area, then yields the particle collection efficiency of the test filter for particles in the light microscope size range.

In the electron microscope phase of the efficiency evaluation, the Millipore Filter was treated for a size analysis by a silica replication* technique.

In the Silica Replication Method, the silica film is deposited on the filter by the rapid evaporation in a 0.1 micron vacuum of approximately 1.3 mg. of silicon dioxide or silicon monoxide from a coil tungsten filament. The filter is placed 10 cm. from the filament and normal to it. The evaporation must be done rather rapidly to avoid damaging the filter by the heat from the filament. Small pieces of the coated filter are then placed on microscope specimen screens, with the silica film in contact with the screen. The microscope specimen screen is placed on a 100 mesh screen forming a low table in a depression of a spot plate. Acetone

* KAPL-863, Semiannual Progress Report of Radiological Development Activities in the Health and Safety Unit, July - December 1952.

is placed under the table from a capillary pipette until the level of the liquid reaches the top of the table but does not cover the specimen screen holding the sample. Capillary action carries the acetone up to the filter. The level of acetone is maintained until the filter is dissolved.

Electron micrographs are made from the silica replicas after selecting fields representative of the particle size distribution and concentration. Size counts are made from the electron micrographs. The data are analyzed in the same manner, as the light microscope data were treated to establish the particle collection efficiencies.

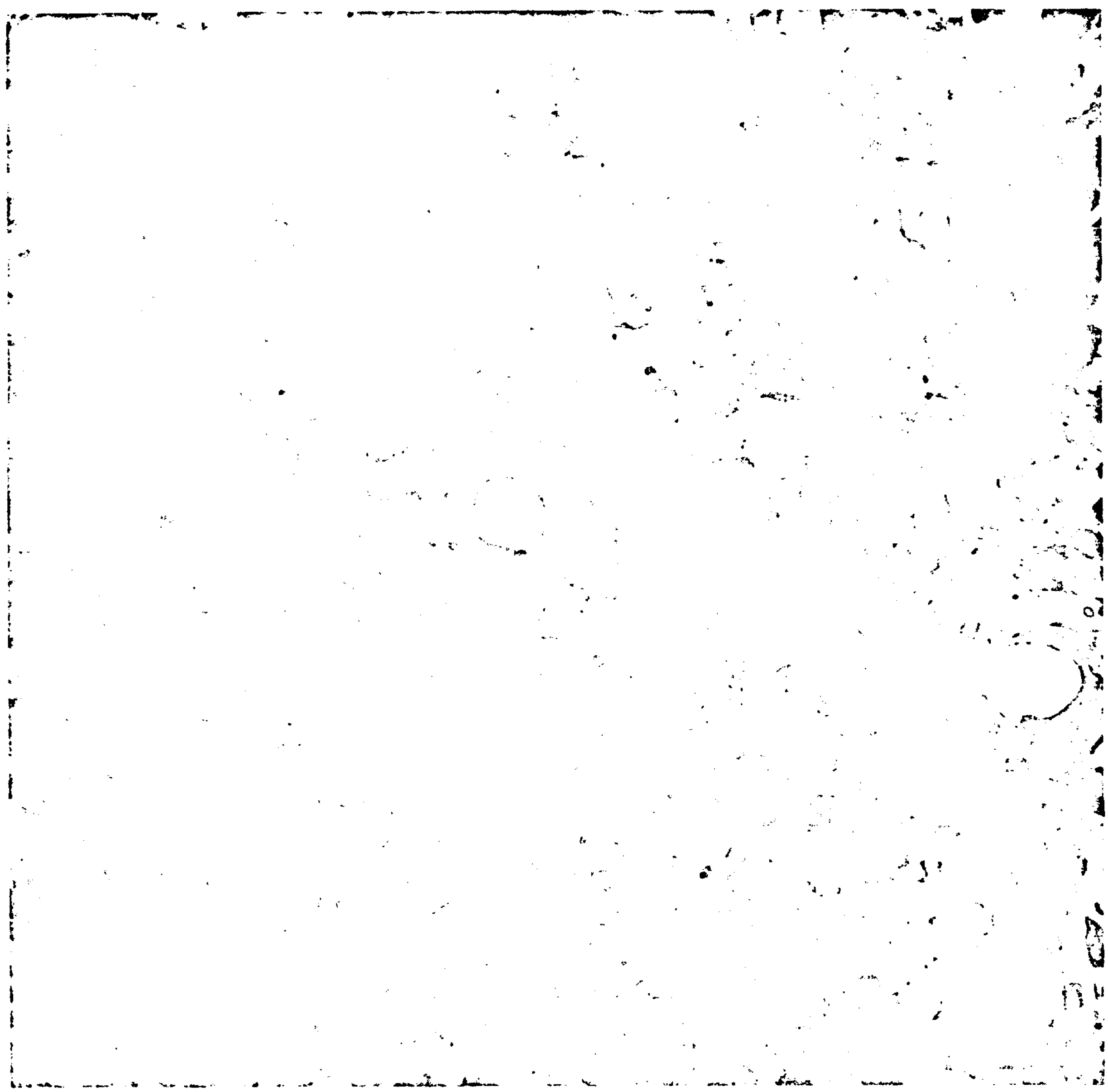
It was necessary to determine the particulate background on unexposed Millipore Filter papers prior to determining the significance of submicroscopic particles shown on the electron micrographs of Millipore Filters exposed to the atmosphere. An electron micrograph of an unexposed on control Millipore Filter is shown in Photograph 1121212. The surface of the filter paper is shown in replica form with a magnification of 15,000.

An electron micrograph of a Millipore Filter paper exposed to atmospheric test dust is shown in Photograph 1122162. The magnification is 20,000 and particles down to 0.005 micron are readily discernible even with the obstructing background. Some of this background, however, can be eliminated as shown in Photograph 1122161. There appears, however, to be some variation in the surface structure of the Millipore Filters which permits the reduction of the obstructing background rather than a variation in the technique applied in the preparation of the electron micrograph.

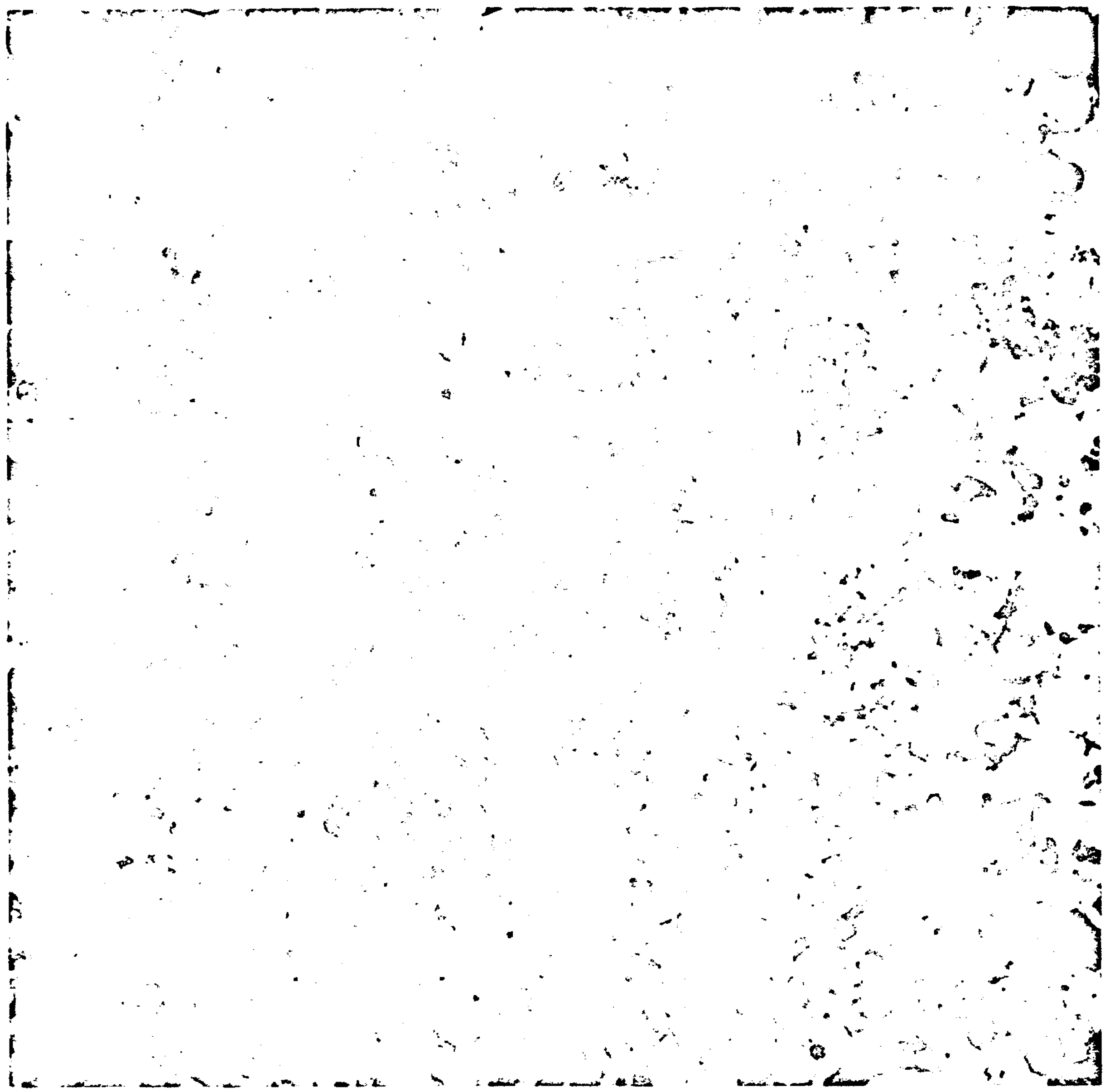
1121212

MILLIPORE FILTER UNEXPOSED-CONTROL FILTER

Magnification - 15000   Scale 0.5 micron



1122162
Millipore Filter, Type HA
Sample from downstream side of W-40 test filter
Magnification, 20,000X
Method of analysis, silica replication
Scale, 1 mm = 0.05 micron



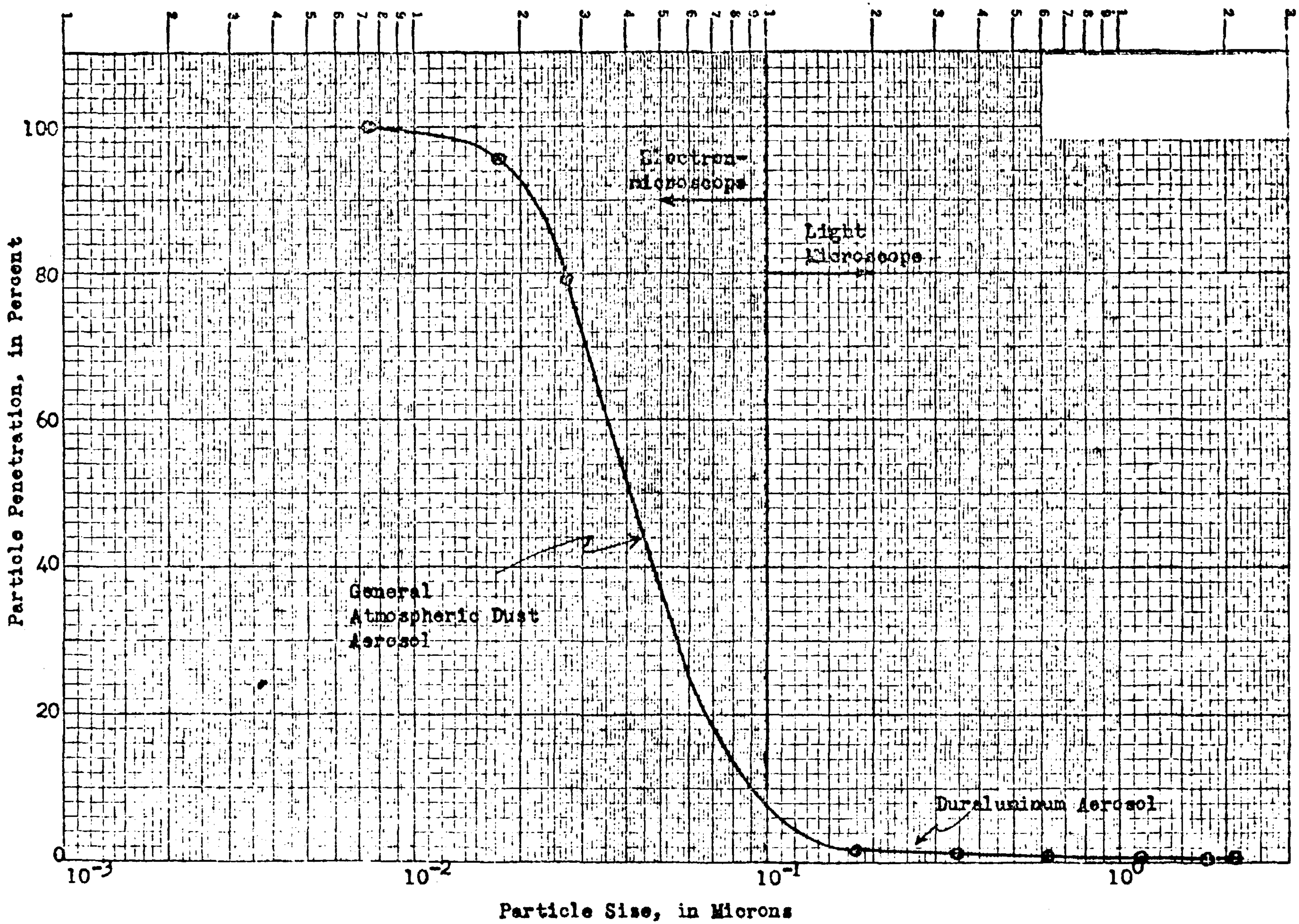
1122161
Millipore Filter, Type HA
Sample from upstream side of W-40 test filter
Magnification, 20,000X
Method of analysis, silica replication
Scale, 1 mm = 0.05 micron

EXPERIMENTAL RESULTS

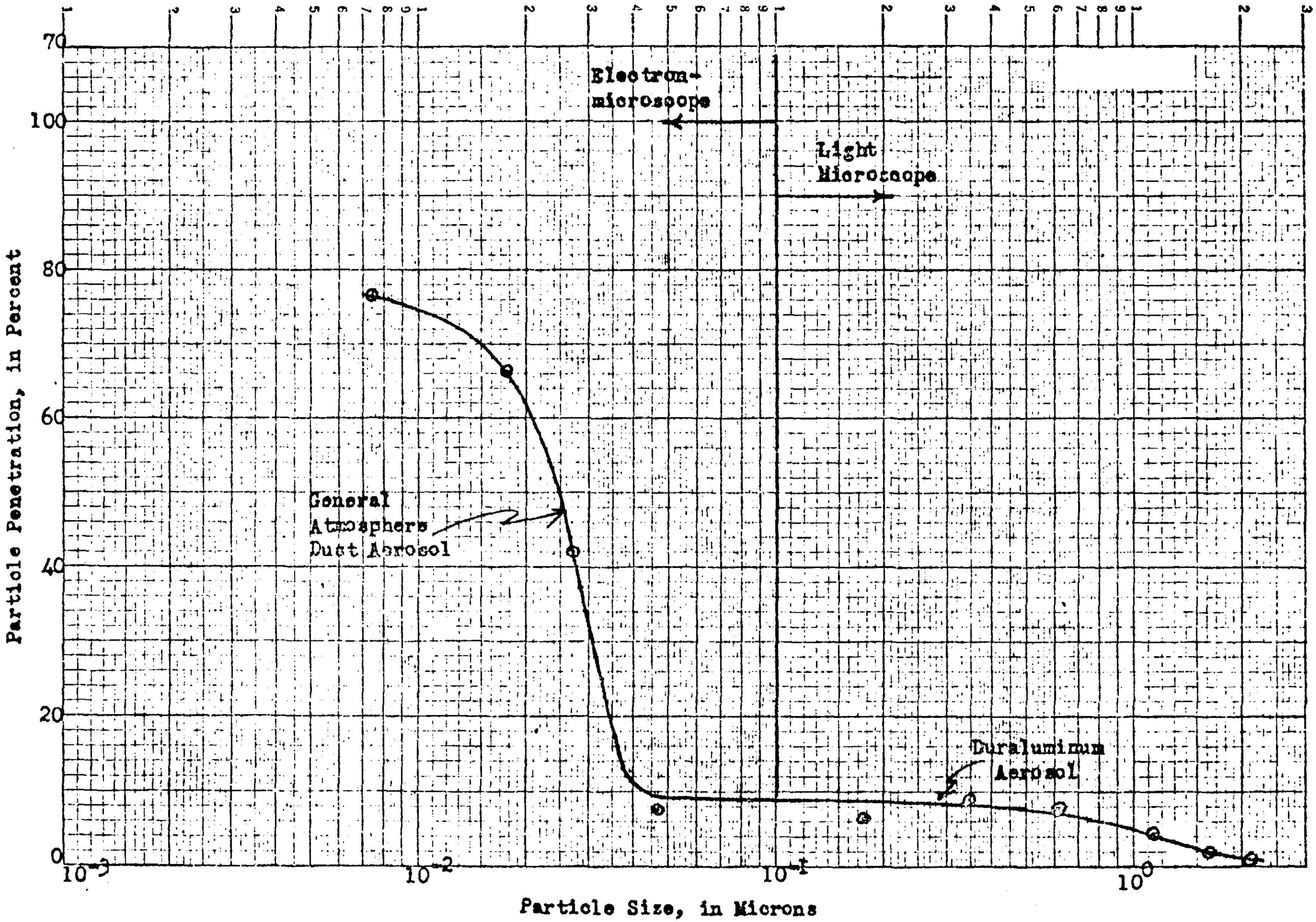
Air Sampling Filter Media

The collection efficiencies of the Whatman-40 and 41 filter papers decreased with particle size for particle velocities of 40 and 10 cm/sec, respectively, as shown in Figures KS-6126 and 6127. In these initial studies, duraluminum solid particles were used as the test aerosol in the light microscope particle size range. In the initial phases of this study it was not possible to produce sufficient quantities of the duraluminum aerosol in the lower particle size range. It was, therefore, necessary to use atmospheric dust which provided a larger number of the smaller particles for the study of the relatively low-efficient filter papers. The particle velocity chosen in these preliminary studies was one at which the collection efficiency was high in the light microscope particle size range. This choice was made to provide a maximum range in which the colledtion efficiency could vary as a function of particle size in the electron microscope range. Although a point of maximum penetration as previously defined was not detected in either of these initial studies, the shape of the curves indicated the possible existence of the point at the lowest detectable particle size.

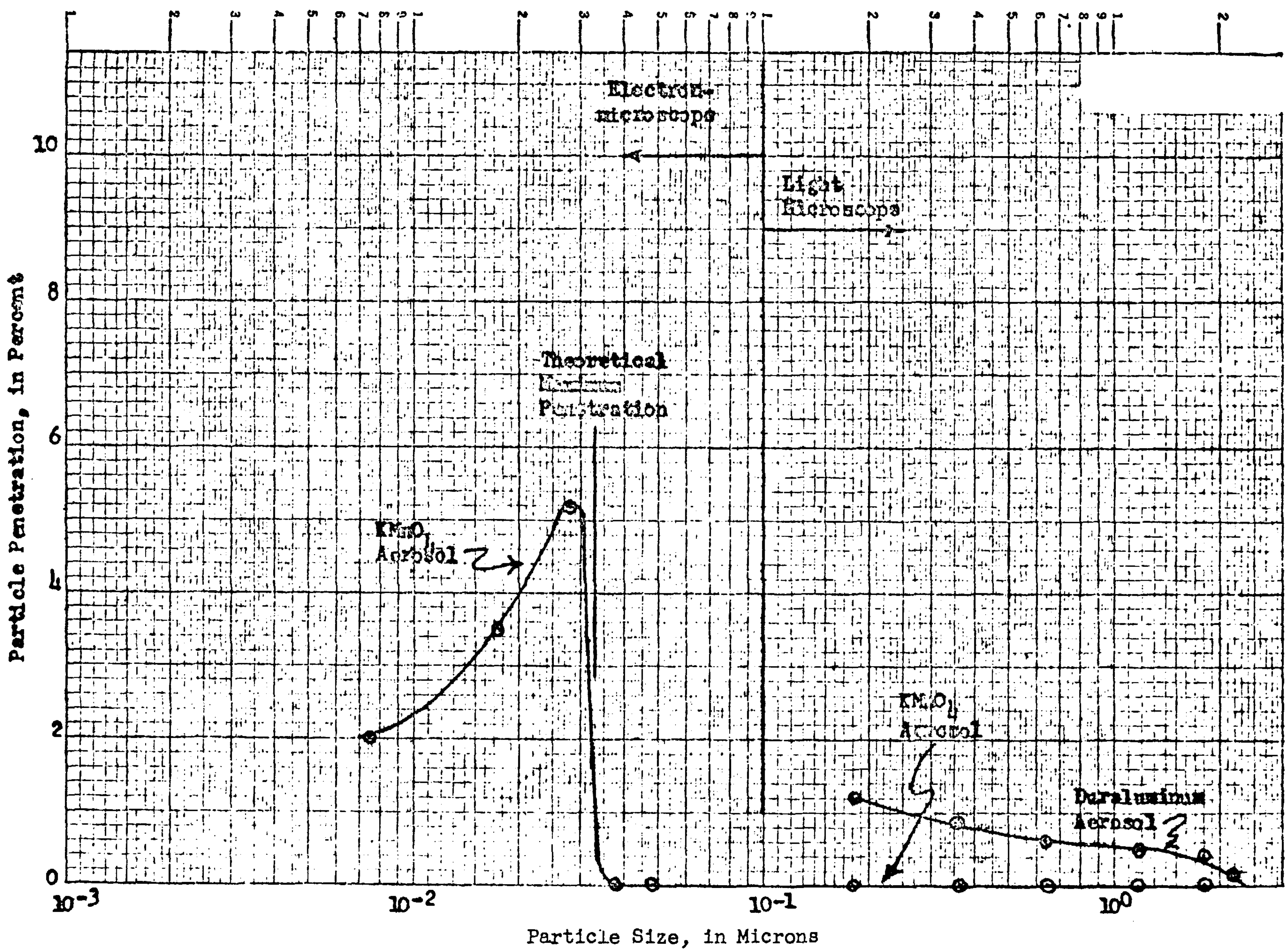
The modified liquid $KMnO_4$ aerosol generator provided sufficient quantities of the aerosol to determine the collection efficiency of Whatman-40 and 41 filter papers at a velocity of 150 cm/sec. This velocity was chosen to approximate the velocity used in the new Health Physics beryllium air samplers. As indicated in Figures KS-6179 and KS-6130, an optimum size for penetration through the filter papers was detected in the particle size range of 0.01 to 0.04 micron. Both of these points of maximum penetration are in good agreement with the theory of Davies and Green. The data also indicates that the Whatman-40 and 41 filter papers are greater than 90% efficient in the collection of KM_nO_4 aerosol over the entire



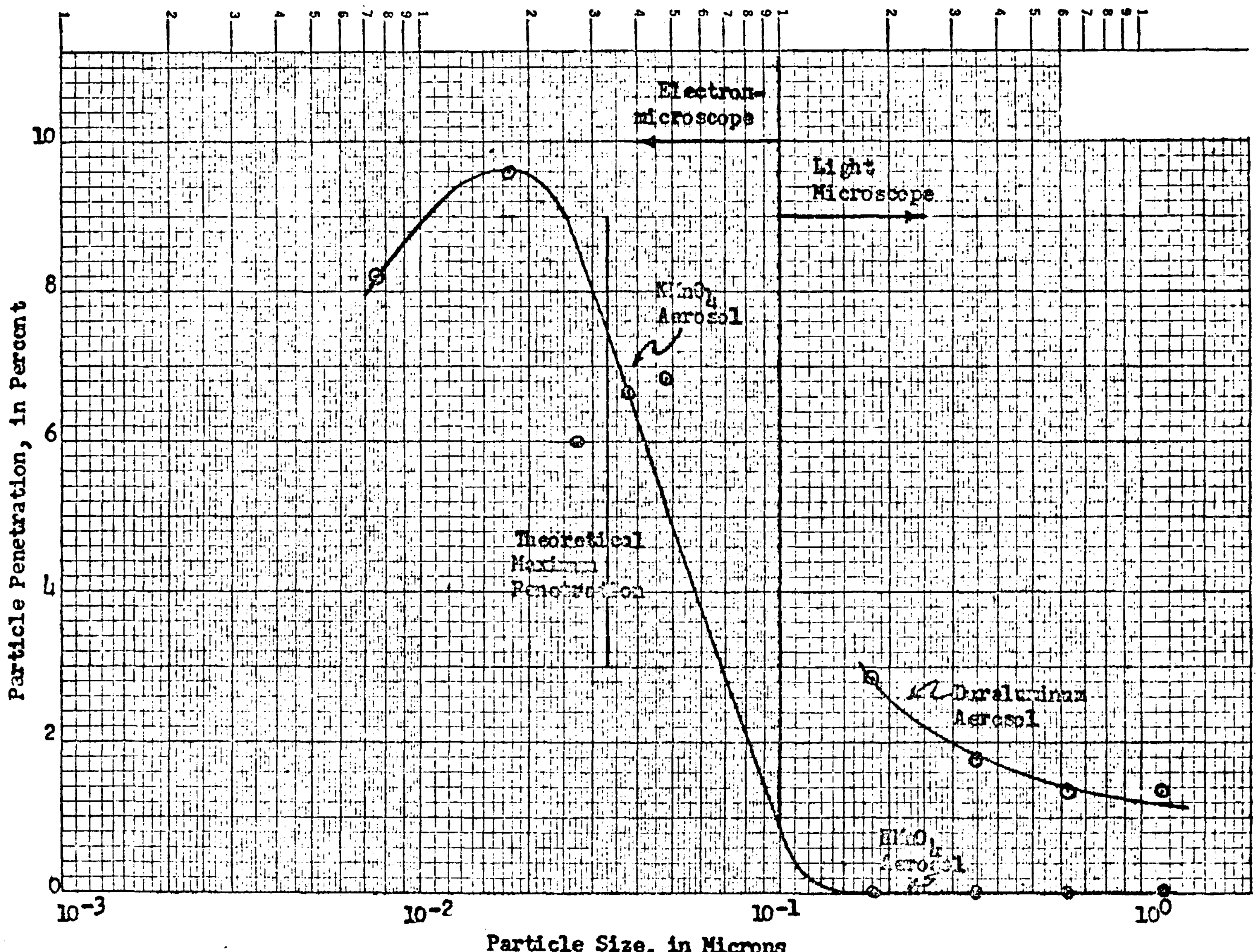
KS-6126 Filter Efficiency Whatman 40 (40 cm/sec)



KS-6127 Filter Efficiency Whatman 41 (10 cm/sec)



KS-6129 Filter Efficiency Whatman 40 (150 cm/sec)

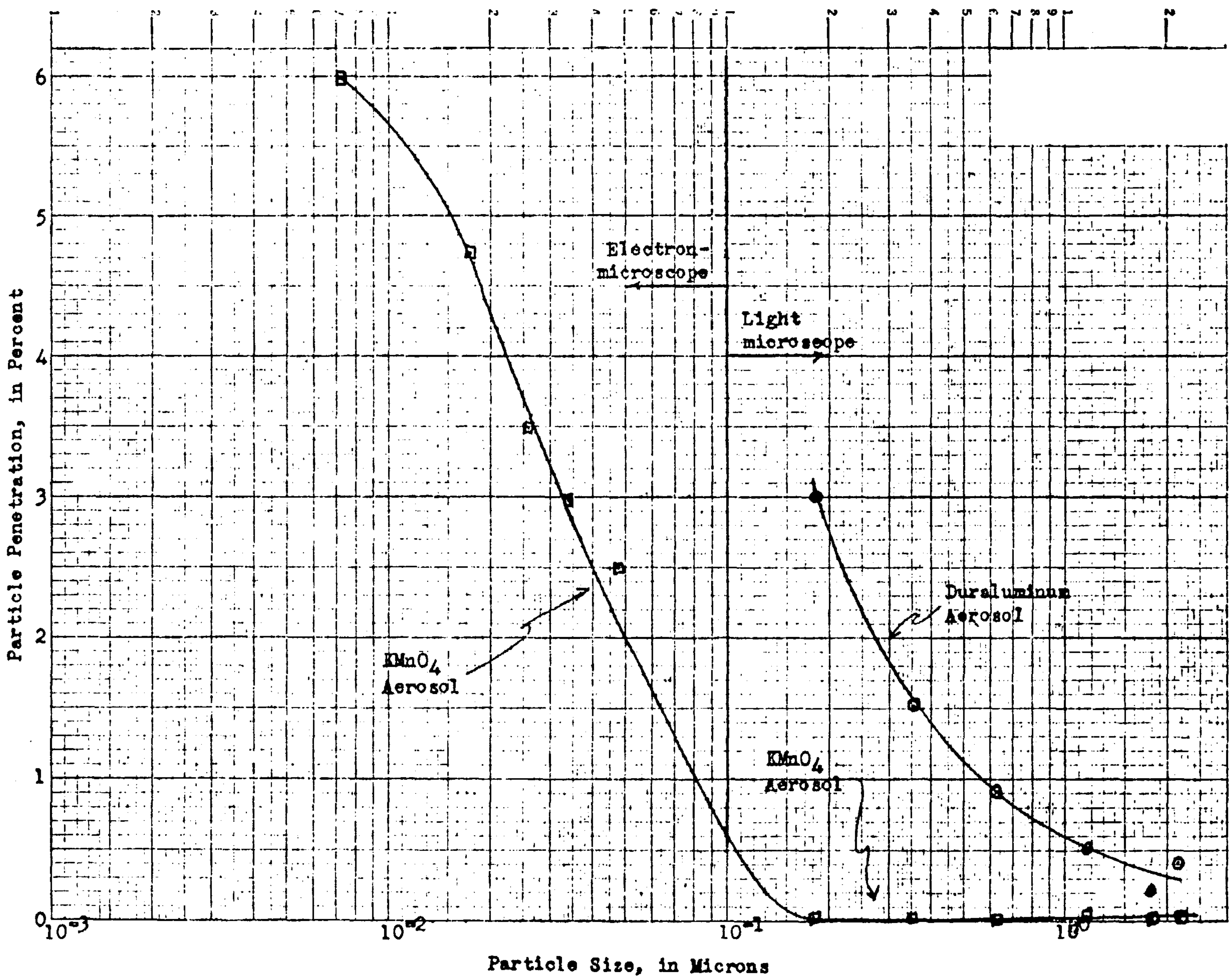


KS-6130 Filter Efficiency Whatman 41 (150 cm/sec)

particle size range. As illustrated in Figures KS-6129 and KS-6130, the Whatman filter papers were more efficient in the collection of liquid KM_nO_4 particles than for solid duraluminum particles in the light microscope particle size range. The most recent data obtained by the analysis of these filter papers indicate that the collection efficiency at 150 cm/sec is greater for the solid duraluminum aerosols than for the KM_nO_4 aerosols in the 0.005 to 0.1 micron particle size.

In a preliminary study using atmospheric dust, the efficiency of H-70 filter papers for the collection of particle sizes from 0.005 to 0.1 micron at a velocity of 80 cm/sec was very efficient. A determination of a point of maximum penetration was not possible in this study.

In subsequent collection efficiency determinations of the H-70 filter papers, a particle velocity of 10 cm/sec was chosen using the KM_nO_4 test aerosol. The collection efficiencies using solid duraluminum particles were relatively low at this velocity in the light microscope particle size range. Since the H-70 filter paper has relatively high efficiency for the collection of particulate material, the velocity corresponding to the point of minimum collection was chosen to increase the number of particles collected on the downstream test filter paper. As indicated in Figure KS-6128, the H-70 filter paper at a particle velocity of 10 cm/sec, was more efficient for the collection of KM_nO_4 particles than for duraluminum particles in the light microscope range. In addition, the collection efficiency over the entire particle size range (using the KM_nO_4 aerosol) was greater than 94%. While no optimum particle size for penetration through the filter media was clearly detected, the curve does indicate the possible existence of an optimum particle size range investigated.



KS-6128 Filter Efficiency Hollingsworth and Vose, H-70 (9mil) (10-cm/sec)

Air Cleaning Filter Media

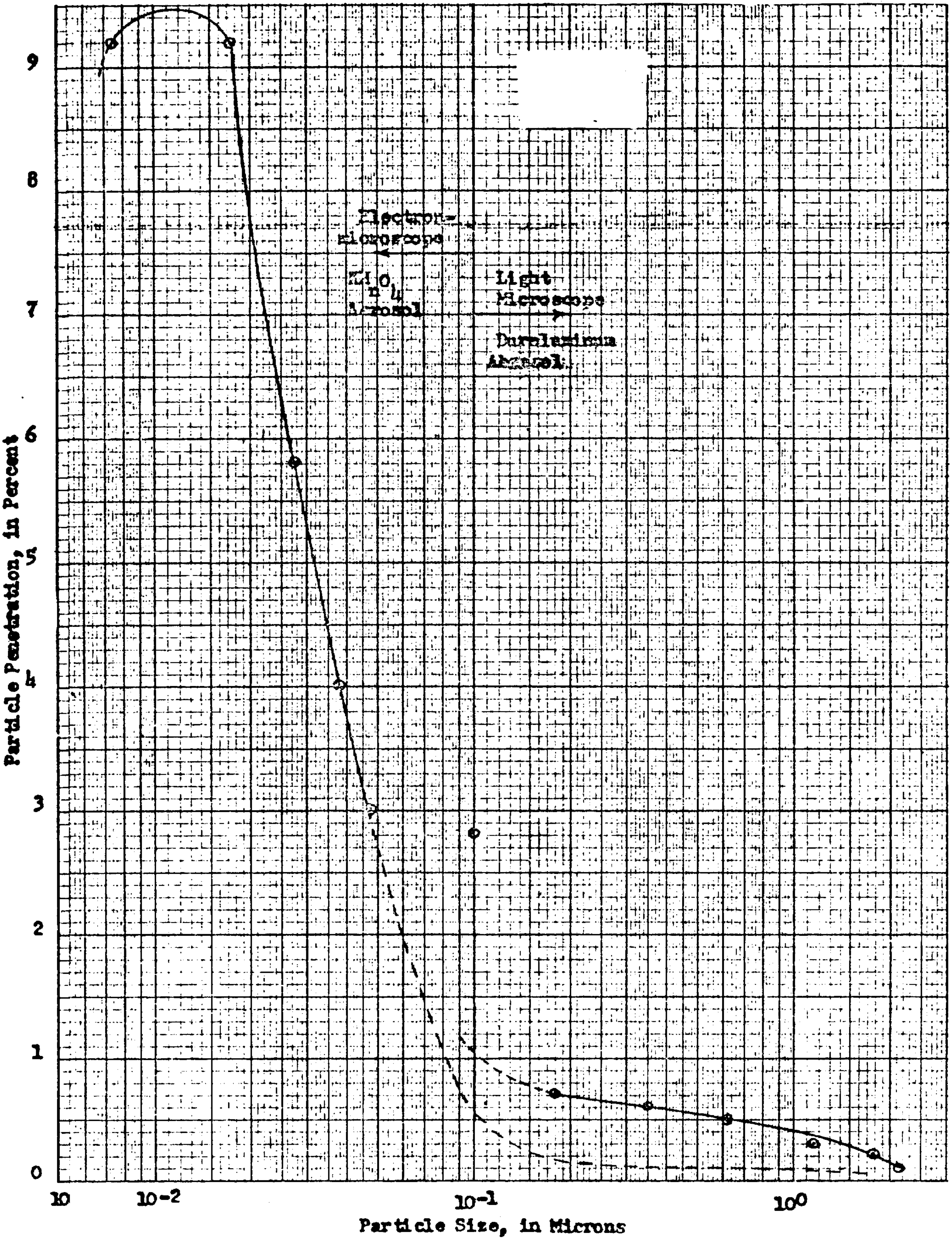
A point of maximum penetration was detected for each of the air cleaning filter media (AEC-1, MSA-1106-B, and CC-6) tested. The optimum particle sizes for AEC-1, MSA-1106-B and CC-6 filter papers as illustrated in Figures KS-6125, KS-6124 and KS-6123 were found in the particle size range of 0.01 to 0.02 micron. The efficiencies of the AEC-1, MSA-1106-B, and CC-6 for the collection of particles over the entire particle range was greater than 91.5, 93.0 and 93.0%, respectively. The estimated collection efficiencies for these filter media in the light microscope particle size range is indicated by the dashed line.

CONCLUSIONS

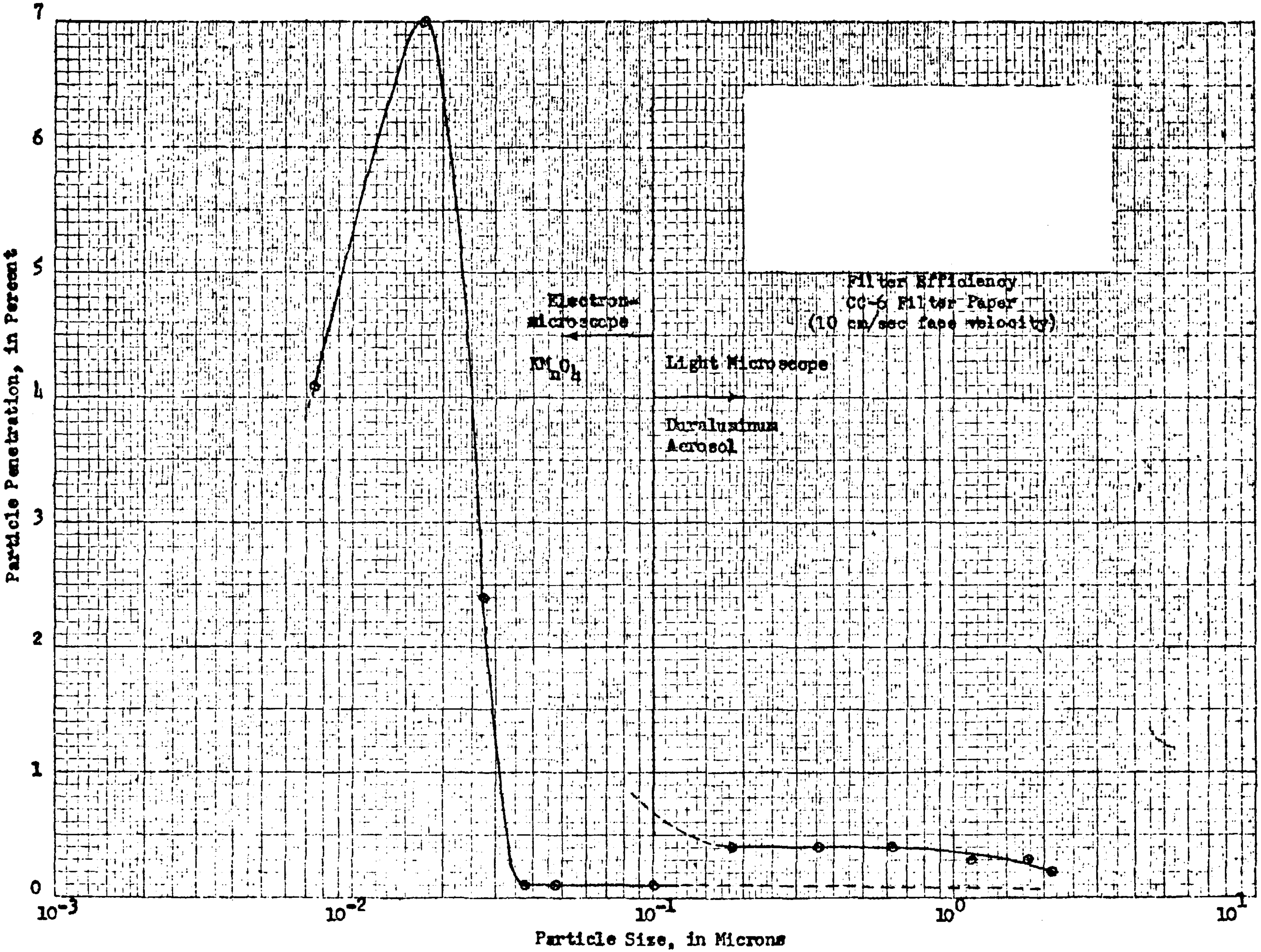
The Hollingsworth and Vose-70 filter medium and the air cleaning filter media tested in these experiments are significantly more efficient in the collection of submicron particles than the Whatman-40 and 41 filter papers. However, with a proper selection of the face velocity, relatively high collection efficiencies can be achieved with the use of the Whatman filter papers.

It has been demonstrated that the air sampling media used in these experiments are more efficient in the collection of the liquid KM_nO_4 particles than in the collection of the solid duraluminum particles. This statement is valid for particle sizes of 0.2 to 3.0 microns. In the particle size range of 0.005 to 0.1 micron, there is some indication that the Whatman-40 and 41 filter papers are more efficient for the collection of duraluminum than for KM_nO_4 particles. Since the collection efficiency varies significantly with the type of test aerosol used, one may question the reliability of applying the filter collection efficiency data to the collection of contaminated atmospheric dust having obtained the data using another type of aerosol.

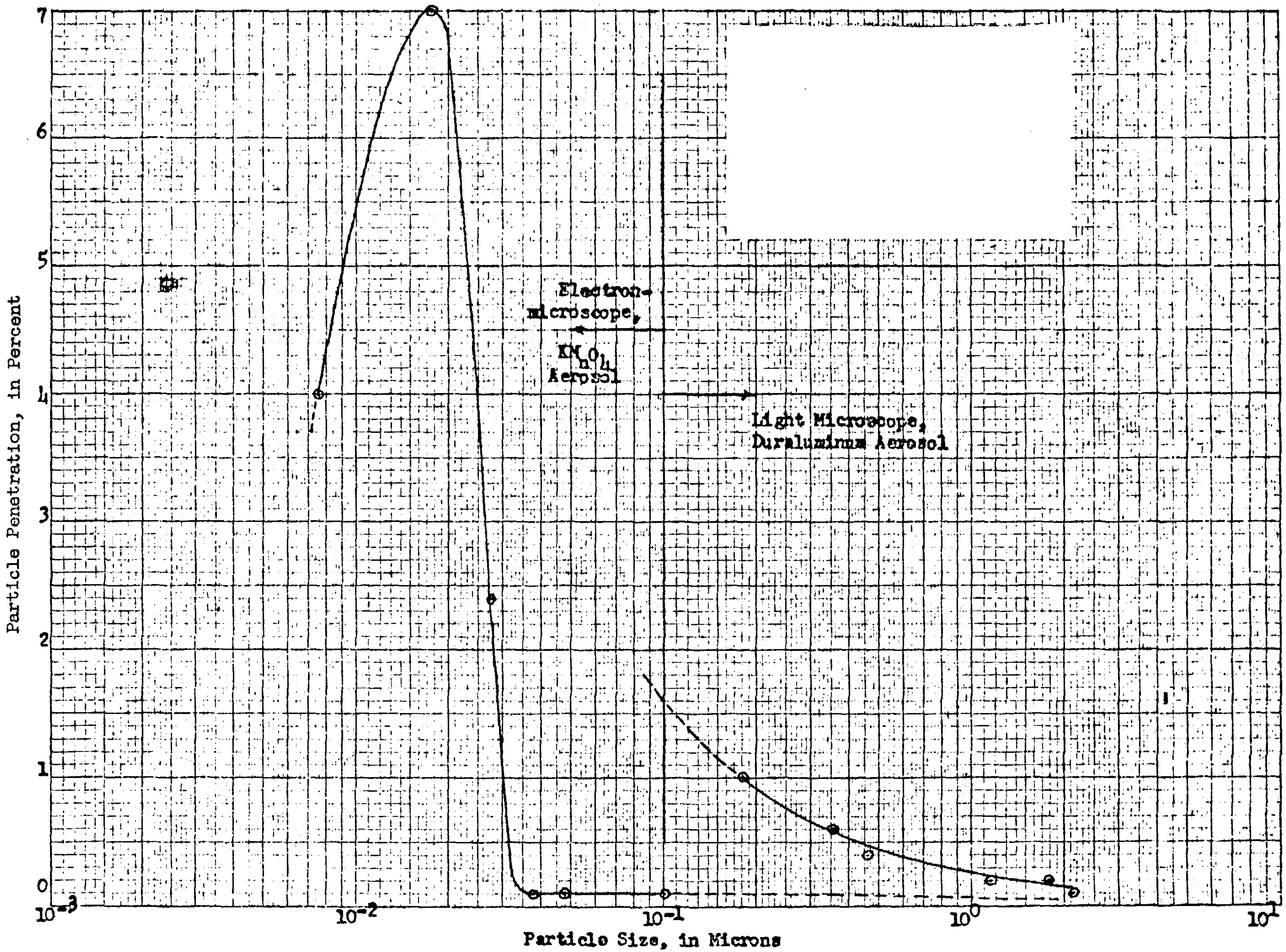
The optimum particle size for penetration through the air cleaning and air sampling filter media was detected or indicated in each of the studies conducted.



KS-6125 Penetration of Particles Through AEC-1 Filter Media (2 cm/sec)



KS-6123 Penetration of Particles Through CC-6 Filter Media (10 cm/sec)



KS-6124 Penetration of Particles Through MSA-1106-B Filter Media (10 cm/sec)

The optimum particle sizes for penetration through the Whatman-40 and 41 filter papers at a velocity of 150 cm/sec are in good agreement with the theory of Davies and Green.

With the experimental knowledge of these points of maximum penetration of particle sizes through the filter media; and with the knowledge of the complete collection efficiency of the filter media, one can choose more rationally the operational velocities for best utilization of the filter medium. With the above knowledge, a more reliable assessment of the air-borne concentrations can be made.

THE AEROSOL SIZE FOR MAXIMUM PENETRATION THROUGH FG-50 FILTER MATERIAL AND SAND

By J. W. Thomas and R. E. Yoder
Oak Ridge National Laboratory

The reality of the existence of an aerosol size for maximum penetration through mechanical filters has been a subject of controversy for 20 or 30 years. It is of fundamental importance to know that a size for maximum penetration does exist. Where extremely hazardous airborne alpha emitters are involved, it is not sufficient to know that the penetration of CC-6 filters is approximately 0.01% for 0.3 micron diameter DOP particles. We need to know that the filter provides protection against particulate material, even if the particles present are 0.01 micron diameter or less.

It is obvious that if the size for maximum penetration is known, one can have the assurance of protection against very small particles since below the size for maximum penetration, the smaller the particle, the less the filter penetration. Filters can then be designed whose performance can be guaranteed against all size particles, whether they are 1 mm diameter or single molecules (provided only that the incident particles stick to the filter and do not become re-entrained in the air stream).

Conceptions of aerosol filtration advanced by Langmuir, Stairmand, Davies, Ramskill and Anderson, LaMer, Johnstone, Ranz, Wong, Chen, etc., have been summarized recently in an article in Chemical Reviews by C. Y. Chen,[1] of the Illinois group. The theories of Langmuir, Davies, and Chen, especially, predict the existence of a size for maximum penetration. With the exception of limited experimental data of Chen, however, there has not been any recent experimental work confirming the theories. LaMer[2,3] (1951) and Ramskill and Anderson[4] (1951) did not find a size for maximum penetration.

FG-50 Filter Material Test

Results of this investigation (August 1955) are shown in Figure 1. The points on the curves were taken in random order to minimize any possible time dependence effects.[3] The DOP aerosol was generated in a LaMer type generator. The aerosols produced were presumably uncharged and reasonably homogeneous, as evidenced by 5 or 6 distinct color bands (for the large sizes). Particle size determinations were made using a lead shot column,[5] which had been previously calibrated with the polarization owl, the color-band owl, the diffusion battery[6] and by gravity settling in a convection free chamber.

The filter material used was FG-50, made by the American Air Filter Company. A microscopic examination of the filter showed most of the fibers to be about 1.25 micron diameter, as specified by the manufacturer. The filter pad, 10 cm diameter, was tested uncompressed and had a thickness of 1.2 cm. Porosity was 99.4% assuming the glass fibers to have a density of 2.5 g/cm^3.

Figure 2 shows a comparison of the results with the theories of Chen[8] and Davies.[7] The theories agree with our results to within a factor of 2. Both theories predict an increasing size for maximum penetration with decreasing face velocity. This is confirmed by the results, although there is less variation in the size for maximum penetration with velocity than predicted by either theory.

Sand Filter Tests

Although sand filters have been superseded, in some cases, by fibrous filters, they do have a unique utility for filtering low velocity air, when high temperatures and corrosive conditions are present. Figure 3 shows the sand placed in lucite holders for the aerosol penetration test. Figures 4 and 5 show typical results. The values of D_g, sand grain diameter, refer to average sizes calculated from sieves used to separate out the sand fractions. The sand having an average diameter of 0.161 cm was the fraction passing 8 mesh and caught on 20 mesh; 0.071 cm diameter, passing 20 mesh caught on 30 mesh; 0.036 cm diameter, passing 40 mesh and caught on 50 mesh. Void fractions were 0.41 for the Pennsylvania sands; 0.38 for the Clinch River sand.

The figures show the size for maximum penetration varies between 0.25 and 0.5 micron radius, depending on the size of the sand granule and the face velocity. Figure 5 is especially interesting in that it shows a large difference in penetration depending on the direction of flow through the bed with respect to gravity. Figures 4 and 5 show that for the sand filters, diffusion and gravity settling are the predominant mechanisms of aerosol filtration, since for even the largest particle size and highest velocity, penetration decreases with decreasing flow rate. We may assume that inertial impaction is playing a negligible part in this filtration process.

At the low velocities used in these tests, the diffusion effect is predominant for particles of 0.1-0.2 micron radius. As the particle size increases, the diffusion effect drops off and gravity settling becomes more effective. The combination of the two mechanisms of removal results in a size for maximum penetration at about 0.4 micron radius. Also, the column becomes increasingly more effective for downflow as compared to upflow. This difference in downflow and upflow efficiency is due only to the gravity mechanism of removal since the curves are convergent at the smaller particle sizes. The magnitude of the effect, however, is surprising. For particles of 0.8 microns radius, the columns can be 10 times as effective for downflow as compared to upflow.

The rough and irregular Clinch River sand showed better performance, by at least a factor of 2, then the nearly spherical Pennsylvania sand. This indicates the existence of a shape factor. It appears that the more irregular the sand grain shape, the better the filtration efficiency.

Summary

1. The existence of a size for maximum penetration through FG-50 fiber glass filter material has been established by the use of homogeneous DOP aerosols. It is 0.25μ radius for 0.94 cm/sec face velocity; 0.27 μ for 0.42 cm/sec face velocity; 0.29 μ for 0.21 cm/sec face velocity; and 0.35 μ for 0.094 cm/sec face velocity through the fiber glass material. The theories of Chen and Davies were confirmed to within a factor of 2.

2. Tests of sand filters have shown the existence of a size for maximum penetration. For large particle sizes and low velocities, filtration efficiency is much higher for downflow than for upflow.

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2. LaMer, V. K., P. Glendron, and R. Green, Nuclear Science Abstracts 5, No. 755 (1951).
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5. Thomas, J. W., and R. E. Yoder, Arch. Ind. Health (to be published).
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7. Davies, C. N., Proc. Inst. Mech. Engrs. (London) B1, 185 (1952).
8. Chen, C. Y., WASH-170, page 368 (1954).

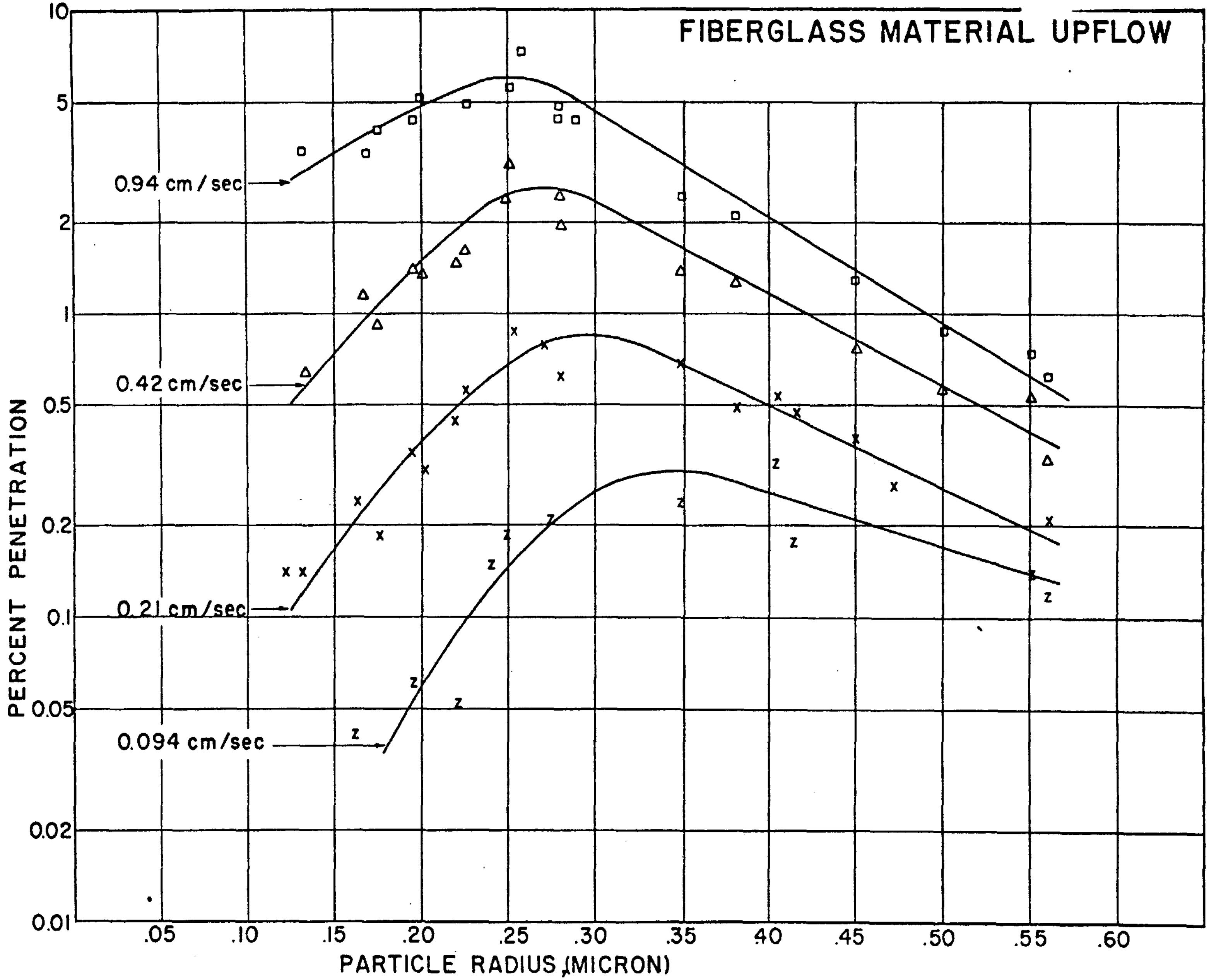

Fig. 1—DOP aerosol penetration through FG-50 filter material. Fiber diameter, 1.25 microns. Porosity, 99.43%. Filter thickness, 1.2 cm.

FACE VELOCITY IN FILTER MAT cm/sec	PARTICLE RADIUS FOR MAXIMUM PENETRATION, μ		
	CHEN'S THEORY 2μ FIBER	DAVIES' THEORY 2-20μ FIBER	EXPERIMENTAL RESULTS 1.25μ FIBER
0.94	0.12	~0.2	0.25
0.42	--	~0.3	0.27
0.21	--	~0.45	0.29
0.094	0.23	~0.65	0.34

Fig. 2—Comparison of theories and results.

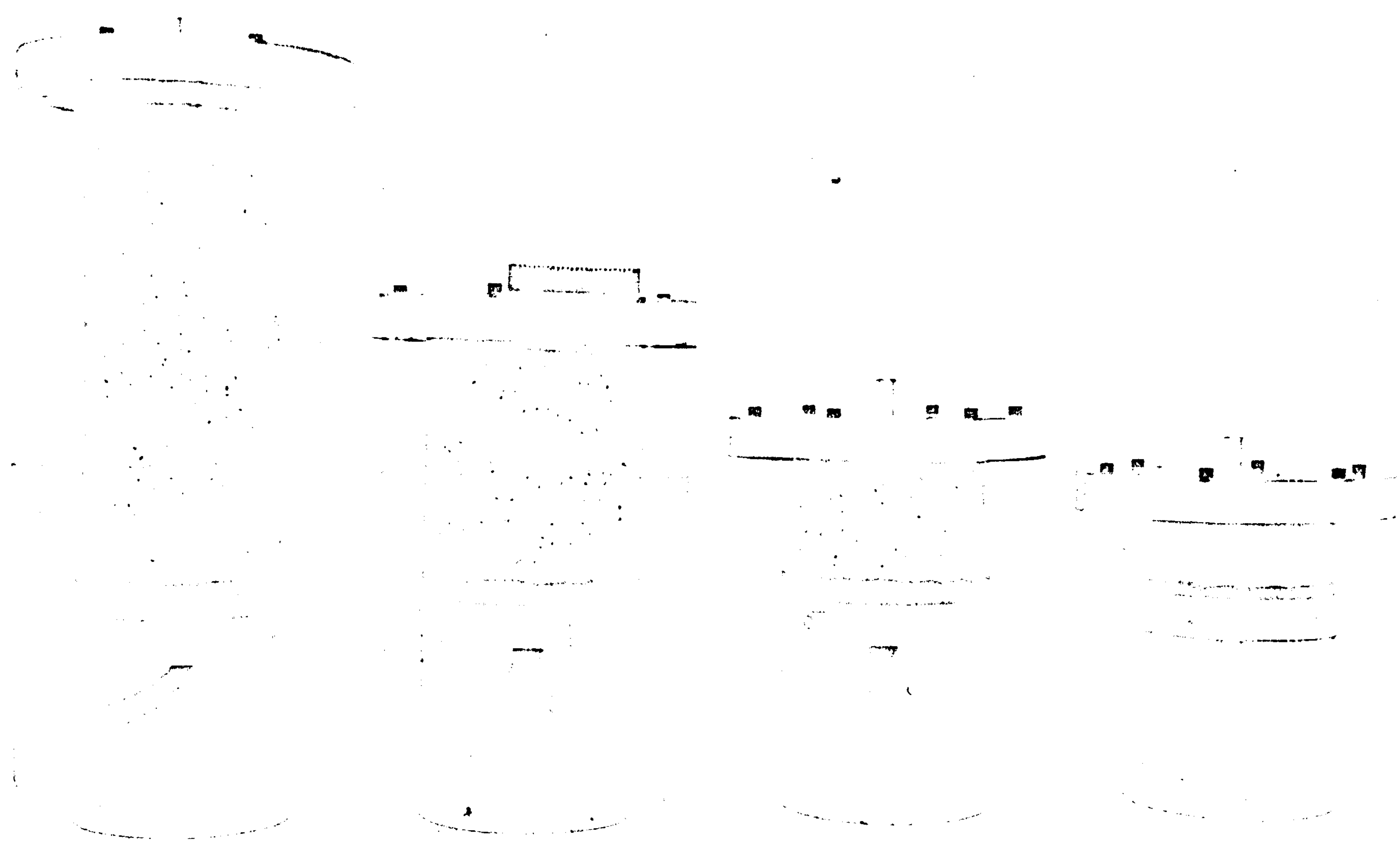

Fig. 3—Pennsylvania Sand in test holders.

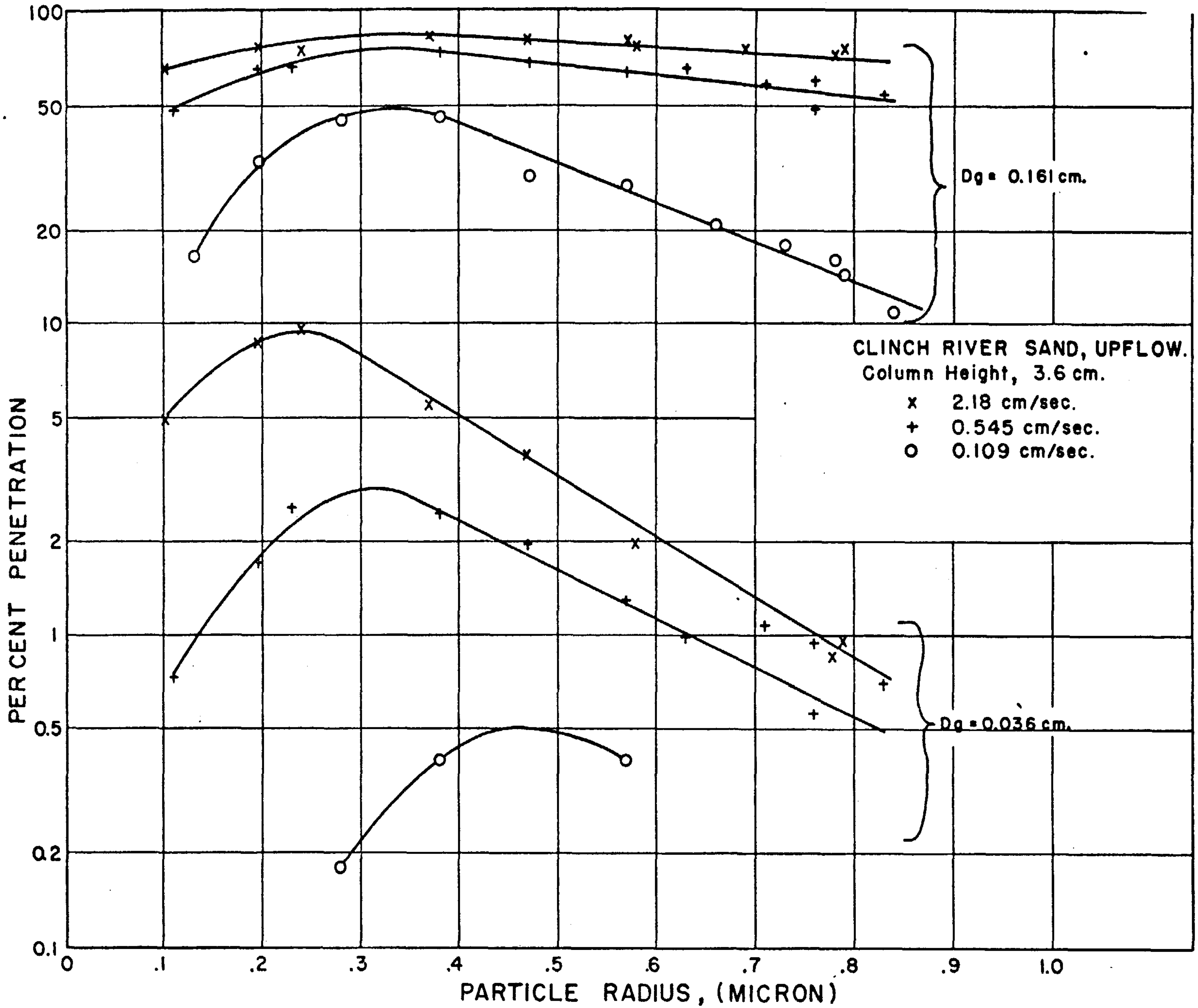

Fig. 4—DOP aerosol penetration through Clinch River Sand.

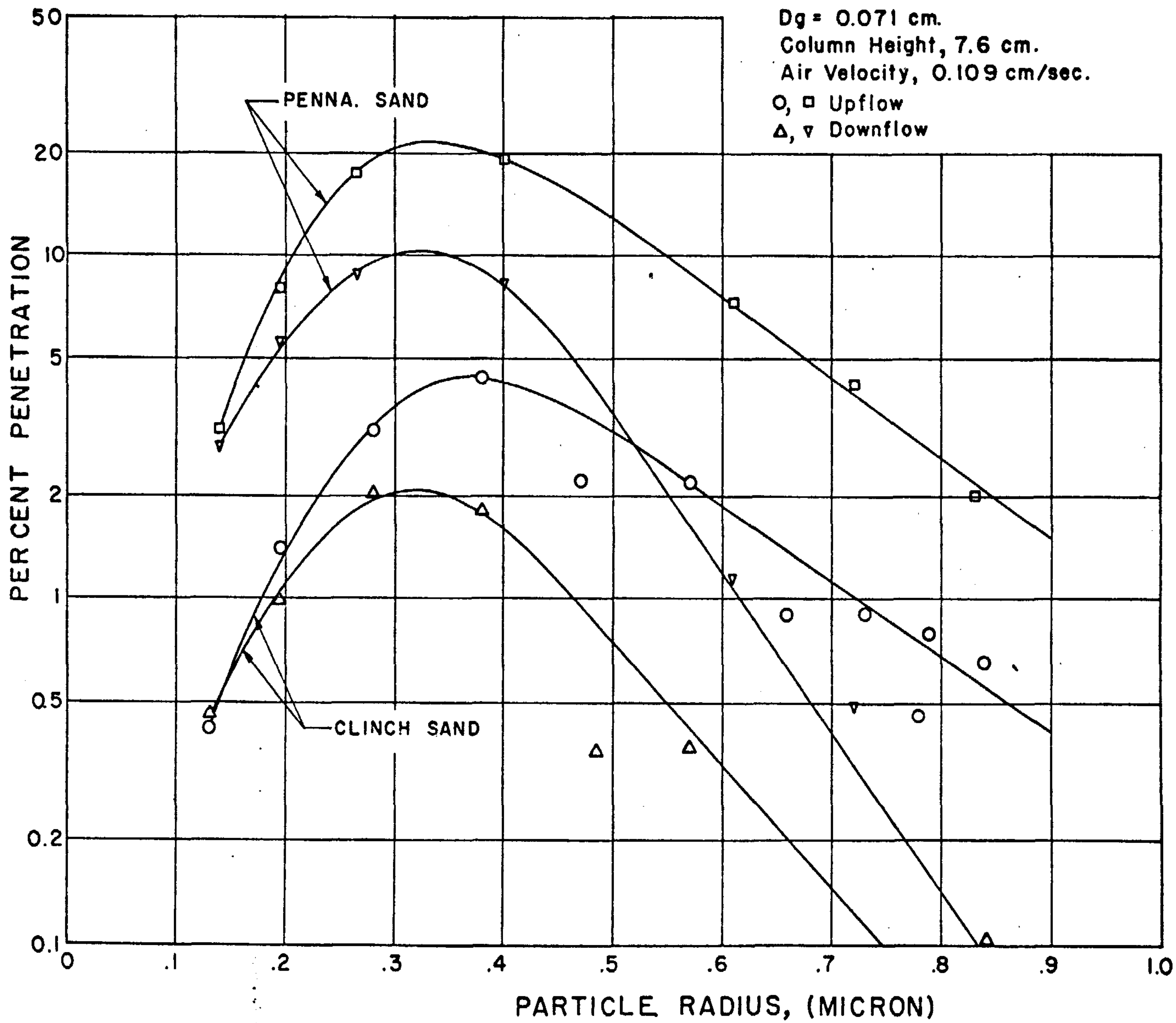

Fig. 5—DOP aerosol penetration Pennsylvania and Clinch River Sand (20-30 mesh sand, Dg = 0.071 cm).

A PRELIMINARY REPORT ON CONTAMINATION FROM UNCONTROLLED INCINERATION OF RADIOACTIVE PARTICULATES by W. B. Harris, New York Operations Office, U. S. Atomic Energy Commission.

Mr. Harris informally described preliminary results of an experiment in burning baled combustible material that was slightly contaminated with radioactivity. The information presented is being developed into a paper for presentation at the April 1956 meeting of the American Industrial Hygiene Association. The complete paper will be subsequently published in the "Quarterly," which is the official publication of the AIHA.

STATUS REPORT ON STANDARDIZATION OF AIR ASSAY PAPERS

by

Walter J. Smith
Arthur D. Little, Inc.

January, 1956

INTRODUCTION

Those of you who attended the last Air Cleaning Seminar (which was held at Los Alamos two years ago) will recall that we agreed steps should be taken to simplify or standardize on selection of air assay papers. Perhaps a quick review will refresh your memories. We had completed a survey at that time to determine what papers various laboratories were using for air assay work, what were the sampling requirements of those laboratories, and what conditions had to be met by the sampling papers. This survey revealed that twenty-two different media were in use among the laboratories canvassed. It was obvious that the number of media required could be reduced greatly without introducing any hardships or inconvenience.

Before making any firm recommendations, it was necessary for us to compare the characteristics of all the various media under a single set of test conditions. We gathered together samples of all the assay media that were reported in the survey and measured their properties as air filters. Results of this work were compiled into a paper that was issued at our last meeting. This paper was presented at an A.S.T.M. meeting by permission of the A.E.C. and was published in A.S.T.M. Proceedings for 1953. You may be interested to know, in passing, that there has been a very great interest in this subject even outside of this group. The number of requests for copies of the paper was a real surprise to us. We have had to make several printings and still we are out of copies. Hundreds of them have been distributed.

A careful review of the survey returns and consideration of the measured properties of the various media being used for air assay work has led us to conclude that nearly all of the needs of the Atomic Energy Commission and associated groups can be met by the following five available air filter materials:

1. Whatman Filter Paper No. 41
2. Whatman Filter Paper No. 44
3. Membrane-type Filters
4. HV 70 Paper 18 mil thickness
5. Glass-fiber Papers

These media would be used as follows:

1. Whatman No. 41

   Where it is desirable to do large-volume sampling, and where a high-sampling rate will provide good collection efficiency.

2. Whatman No. 44

   Where a low-ash paper of good collection efficiency is needed, especially at low-flow rates. This should be the general-purpose paper of the air-assay laboratory.

3. Membrane Filter (Example: Millipore Types AA and HA)

   These media should be used:

   a. For the quantitative collection of the very finest particles (submicron).

   b. For collection of particles that are to be viewed, counted, or measured on the filter directly under the microscope.

   c. Where the particles must be collected wholly at the surface (as in α counting). Here HA is preferred.

   d. When quantitative collection of very small particles is coupled with the need to ash the filter during analysis.

4. HV 70 Paper

a. For monitoring devices requiring a high-efficiency paper, and where ash content is of no concern.

b. In continuous monitoring stations requiring low-resistance, high-efficiency paper in roll form, where color or ash-content of the paper is not important.

5. Glass-fiber Papers

To be used where high-collection efficiency is required and where the use of cellulose is precluded. Sampling of high-temperature stack gases would be a case in point. MSA Paper No. 1106B (Mine Safety Appliances Company), or any equivalent paper, is recommended. Properties of such a paper are given in Table I of Appendix D[1] under the heading, "Hurlbut Glass Paper." The AEC all-glass, air-filter medium also may be used successfully for assay purposes. (Reference: Report NYO-4603, August 31, 1954, Columbia University)

I hope that it is not disappointing to you to see the number of media reduced from twenty-two to no fewer than five. However, it is a move in the right direction, and further reduction of the required number may yet be possible. At present there is no universal medium that can fill all requirements. We think that the final minimum number will be not less than three: a high-efficiency organic paper, a membrane filter, and a mineral-fiber paper.

It has been recognized for some time that an all-purpose air-assay paper is a distinct possibility and an item that would be of particular value to the operating areas of the Atomic Energy Commission. Such a paper, carefully made to meet definite specifications of properties and performance, could be the standard throughout all laboratories where air-sampling and-analysis are practiced. The ideal paper would have the following properties:

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[1]"Media for Air Cleaning and Air-Assay Purposes" summary report to A.E.C., October 3, 1955

a. High-collection efficiency on sub-micron size particles.

b. Usable for liquid or solid particles.

c. Low-flow resistance.

d. Low-ash content.

e. Low-radioactivity background.

f. Fine texture, with particle collection close to surface.

g. White--to be usable in discoloration tests.

h. Available in roll form.(For continuous analyzers.)

All of these properties would be met by an absolute-type filter material based wholly on cellulose or other organic fibers. High-efficiency filter papers require the presence of very fine fibers in the furnish. Achievement of this ideal assay paper, therefore, depends upon obtaining a reliable source of very fine organic fibers.

A program of experimental work has been carried out on the development of such a paper; some success has been attained on a laboratory scale.

We have considered two sources of the very fine fibers--fibrils from natural cellulose and superfine spun synthetic fibers.

When cellulose fibers are worked in a paper mill beater with light-to-moderate roll pressure, a progressive change occurs in the pulp. To the hand, the wet pulp acquires a softer and more gelatinous feel. If successive samples of pulp from the beater are examined under the microscope, fine fibrils can be seen that are being stripped away from the parent fiber.

Fibrils produced in the beating of natural cellulose fibers measure to less than a micron in diameter, and are in the size range suitable for high-efficiency, air-filter media. They should be ideal for making a low-ash, all-cellulose paper such as we are seeking.

However, the fibrils in the desired condition appear to be of transient existence only. Very quickly they are attacked by surrounding water, become gelatinous, and lose their fibrous character. The whole problem in making a fine filter with cellulose is to retain the fibrils while they are still fibrils. To accomplish this we must defeat the hydration which destroys them. Various ways of doing this were tried:

a. Beating in hot water.

b. Beating in salt solution.

c. Beating with dimethylol urea in the beater.

d. Beating with cationic agents in the beater.

e. Beating with cationic resins in the beater.

f. Beating with chrome complex agents in the beater.

g. Use of alcohol or alcohol-water in the beater.

h. Washing out the fibrils as they are formed.

i. Acetylation of the cellulose.

j. Pretreatment of the cellulose to promote fibrillation.

Cotton fibers are a particularly good source of fibrils, and most of the experimental work was done using cotton--either linter board or, more often, clean cotton fiber purchased as roll batting.

Despite our efforts we were never able to produce an outstanding paper based on fibrillation.

Our most encouraging results were obtained with mixed cellulose and fine synthetic fiber of which the following is an example.

A cotton linter fiber furnish was prepared in a laboratory beater at 1 per cent consistency to a freeness of 14 at 70°F (Schopper Riegler). Acrylonitrile fibers in the size range of 1.0 to 1.50 microns diameter were beaten at high speed in a Waring Blendor for four minutes to reduce fiber length. A mixture of the following composition was prepared in the blender:

80 parts acrylonitrile fiber
20 parts prepared cotton linter fiber
1.6 parts Daxad No. 11
42,000 parts water

This was diluted with water twofold and cast into a handsheet.

Performance of this sheet when tested at 28 linear feet per minute with DOP smoke was as follows:

Smoke penetration	- 0.32 per cent
Pressure drop	- 240 mm water
Value of E	- 1.1

This is far superior to any all-cellulose filters we have ever made, and far superior to any commercial all-cellulose paper of which we are aware.

Ash content of a paper so made is about 0.4 per cent. This may be reduced to something less than .04 per cent by treating the paper with mixed hydrochloric and hydrofluoric acids.

We believe that an air-assay paper based on cellulose fibers and fine synthetic organic fibers offers the best approach at present to a standard air-assay paper. All of the properties listed at the beginning of this section are well met with this type of paper. No plant, or even pilot plant runs were made because of limitation of funds. However, several manufacturers have expressed an interest in making the paper if a demand develops.

ARRESTANCE VALUES AND LOADING CHARACTERISTICS OF COMMERCIALLY AVAILABLE AIR FILTERS AGAINST 0-5 MICRON TEST DUST

By Ernest N. Hellberg and William R. Nehlsen
NAVCERELAB–USNCBC
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The subject of this paper is the Arrestance Values and Loading characteristics of Commercially available Air Filters as tested against an aerosol of 0-5 micron test dust classified from Arizona road dust. However, before I report on the various tests conducted at NAVCERELAB, I thought I might explain just what the word NAVCERELAB, as listed on your program, stands for and why we are involved in testing air filters. The word NAVCERELAB is an abbreviation for the Naval Civil Engineering Research and Evaluation Laboratory, located at Port Hueneme, California. You can easily understand why the abbreviation is used. This Laboratory is under the direction of the Bureau of Yards and Docks in Washington, D. C. and was set up to work on their many and varied problems. BuDocks has cognizance of all the shore establishments of the Navy, both in the States and abroad, and one of its many responsibilities is the protection of these bases and its people against the hazards of ABC Warfare.

Gas masks will provide protection against ABC Agents for most of the individuals located at these Bases during and right after the actual attack, but are only suitable for relatively short periods of time. For personnel located in special purpose shelters, such as command posts, hospitals and communication centers, which require absolute protection for long periods of time, the Chemical Corps Collective Protectors are the answer. However, the relatively high cost of these special purpose collective protectors limits their use to essential operations and makes it desirable to determine if a more economical filter is available which will provide sufficient protection under most conditions of service. It was also desirable to determine which of these filters would make good roughing filters for the more expensive absolute filters.

Therefore, the Bureau of Yards and Docks directed the Laboratory to test all of the commercially available ventilation air filters to determine which type of filter, if any, would provide some measure of protection to personnel located in the Naval Shore Establishments, and to determine which type of filter would make a good pre-filter for use on the collective protector.

To insure that no potentially valuable filter would be overlooked, a thorough search for all available brands and types was made and three or more of each type was purchased through regular commercial outlets. All filters purchased were 20 × 20 inch nominal size unless otherwise stated, and included the metal viscous-impingement filters; the fibrous viscous-impingement filters; the dry, normal velocity, fibrous filters; and several of the dry, low velocity, fibrous filters to give comparative data on the more expensive commercial filters which approach "absolute" filtration.

TEST PROGRAM

The large number of filters involved made it necessary to divide the test program into two phases. In the first phase, every filter purchased was tested clean to determine its resistance and dust arrestance at a wide range of face velocities. This provided information for comparing the many makes, types, and thicknesses and for selection of specimans for more complete testing. This also provided much general information on filter performance against fine dust. The second phase which is still under way, will provide information on the performance of selected filters as they are loaded with dust.

An air filter testing apparatus, see Fig. 1, patterned after that designed by the Farr Company in Los Angeles, was used for all of the tests. It consists of a square duct totaling approximately 19 ft in length connected by a short transition section to the intake of a blower exhausting to the atmosphere, and a 3-ft long detachable intake plenum on which the dust feeder is mounted. The blower is driven by a 25-HP variable speed motor so that a wide range of air flow rates can be obtained. The air filter test section, including the intake plenum, is 18¼ in. square and is in detachable sections for ease in installing test filters and taking dust samples. Filters from 20 in. to 24 in. square and almost any thickness can be accommodated in this section. The air measuring section downstream from the test section is approximately 28 in. square and accommodates a standard ASME nozzle between two perforated plates of 40 per cent open area. Four standard nozzles have been calibrated to accurately measure air flow at all ranges of the test duct.

The dust feeder consists of a grooved metal tray which moves forward slowly by means of a rack and pinion gear driven by a synchronous motor; a pickup and vibrating mechanism for the test dust; and four air-aspirated conveyor tubes. A weighed amount of test dust is spread in the four grooves of the tray and is fed by rotating brushes into the aspirating tubes conveying the dust to the injection point in the duct where it is mixed with the air stream in a manner designed to produce uniform distribution.

The test dust used for the arrestance (efficiency) tests reported here is the 0-5 micron fraction of Army Standarized Fine Air Cleaner Test Dust. This test dust was selected because it approximates the expected particle size range of a biological warfare aerosol and was fed into the air stream of the duct at the rate of 20 gm/hr. This amount is greater than any expected BW aerosol concentration and provides a severe test for the filters. The dust was obtained by processing the commercially available air cleaner test dust through a multiple cyclone dust classifier.

To obtain a measurement of the particle size distribution, several samples of the dust cloud were collected on membrane filters just ahead of a test filter. The membrane filter was examined at 970 magnifications after it had been rendered transparent with standard immersion oil. A calibrated Whipple disc was used in the eyepiece of the microscope for size determination. The approximate size distribution is tabulated below (no particles over ten microns were detected):

Particle size range	Per cent of total number of particles
1 micron or less	78
1 to 2 microns	12
2 to 3 microns	5
3 to 4 microns	2.5
4 to 5 microns	1.4
5 to 6 microns	0.4
6 to 8 microns	0.04
8 to 10 microns	0.03

The filter arrestance was determined by taking samples upstream and downstream from the filter.

The term "arrestance" used in reporting performance is recommended by the Air Filter Institute for laboratory test work. "Efficiency" is used by this institute to define performance under in-service conditions. The samplers used were the Crismon type consisting of a one inch diameter copper tube about 1½ inches long. One end of the tube is closed with a 50 mesh wire screen to retain the sample collecting media of densely packed fine fiber glass wool. The other end of the tube, at which the air sample enters, is open with a beveled knife edge corresponding to the inside diameter of the tube. The samplers are placed in the sampling tubes upstream and downstream from the filter and during the test, air is drawn into them from the duct at isokinetic velocity. The samplers are weighed before and after on an analytical balance and the weight of test dust collected is used to calculate the arrestance.

A total of 90 different filters were tested against the 0-5 micron test dust at flow rates of 800, 1200, 1600, 2000, 2400, and 3000 cubic feet of air per minute to determine their resistance and arrestance values. The flow rate of 800 cfm is equivalent to a filter face velocity of 346 fpm, 1200 cfm equal to 518 fpm, on up to 866 fpm at 2000 cfm and 1298 fpm at the 3000 cfm figure. These values were originally reported in NAVCERELAB Technical Memorandum M-099 Ventilation Air Filters; 0-5 Micron Dust Arrestance by E. N. Hellberg and W. R. Nehlsen. However, because of lack of time and space the tabular data on all of the filters will not be present here. The following figures summarize that data. Figures 2, 3, and 4 show the high, low, and average performance curves for all of the metal viscous-impingement filters tested; while Figures 5 and 6 show the high, low, and average performance curves for all of the fibrous type Viscous-impingement air filters tested. It should be noted here that the high and low arrestance curves and the high and low resistance curves are not necessarily from the same filter. Figures 7 and 8 show the performance curves for the two types of dry standard velocity fibrous filters tested. Figure 9 shows the performance curves for the four types of low velocity dry fibrous filters tested. Test 8A shows the performance of a one inch shredded polyethylene filter at face velocities up to 1038 fpm. The other three curves are for filters composed of fine glass fiber pads set in five wedge shaped pockets and have a very low face velocity—only 40 fpm at 200 cfm. These filters have a fairly high arrestance as compared to the other types but the resistance increases rapidly as the load increases.

These curves, especially the ones showing the high, low and average performance of the filters, show very well the wide range of results that can be obtained with any particular type of filter. The results of the tests on the metal viscous-impingement filters at face velocities up to 2½ times the design figure indicates that there is no appreciable gain in arrestance over 1⅓ times the design figure.

The test dust used for loading the various selected air filters in the second phase was the Air Filter Institute (AFI) Standard Test Dust. This comprises of a mixture of 72% standardized air cleaner test dust, fine; 3% cotton linters, Wiley Mill Ground; and, 25% K-1 Carbon Black. It was selected because it was readily available from the James H. Herron Company in Cleveland, Ohio and provided a means of loading the filters within a reasonably short period of time, with an acceptable test dust. This test dust was fed into the air stream of the test duct at a rate of 40 gms/hours in the same dust feeder as described above.

The loading tests are continuing at this time; however, enough data has been collected to provide some interesting observations. Approximately fifteen selected filters representing all types will eventually be tested under this phase of the program. Each selected filter is tested in the Filter Test Duct at 800, 1200 and 1600 cubic feet of air per minute and is loaded until its resistance reaches 1.0 inches of water or until 1000 grams of dust has been fed into the air stream, whichever occurs first. Because of the time element, these limits had to be set. We only hope that this was long enough. Each filter is tested against 0-5 micron test dust to determine its arrestance at the start of each run and is again determined after each 40 grams of AFI Standard Test Dust has been fed to it. In this way a running account of its arrestance and resistance change is obtained. All of the 1-in., 2-in., and 4-in. metal viscous-impingement filters tested acted in approximately the same manner, in that there was no complete breakdown of the filter after 1000 grams of dust had been fed to them. As an example, Figure 10 shows how the 2-inch Farr 44 Filter performed. Neither the resistance nor the arrestance changed by any great amount during the test. Figure 11 shows how the American HV-2 performed. Both the resistance and arrestance increased at an accelerated rate as the load increased. The explanation as to why both curves for the 800 cfm run crosses the 1200 and 1600 cfm curves is probably that the lower velocity allows a greater build-up on the filter with the consequent higher arrestance and resistance values. All I can say is "we calls them as we sees them." I also have no idea as to which of these filters would be the best in the long run. Certainly both filters have their good and bad points.

There are no slides available at this time which show the loading characteristics of the other filters tested, but I can describe briefly some of the results. For the dry, standard velocity, fibrous type, the filter life was shorter. For instance, the arrestance of the aluminum wool filter dropped rapidly at all air flows after less than 100 grams of dust had been fed to it, and at the 1200 and 1600 cfm air flow the resistance increased rapidly right from the start. The arrestance of the shredded polyethylene filter dropped off rapidly as soon as the dust load started to build up while the resistance increased at about the same rate. The resistance was over 1-inch at the 1600 cfm air flow so no tests were conducted. The arrestance of the dry glass wool filter dropped to nothing in all cases before 300 grams of test dust had been fed.

Of the two 2-in Fibrous Viscous-Impingement (Throwaway) Filters tested, the Hair filter showed excellent results, holding steady at about 62% arrestance at 800 cfm until the resistance reached 1 inch after about 750 gms of dust had been fed to it. The resistance of the hair filter increased much more rapidly at 1200 and 1600 cfm air flows as the load increased. The arrestance of the glass wool filter with a light oil coating dropped off rapidly at all air flows after only a relatively small amount of dust had been fed.

The arrestance of the low face velocity, dry, fibrous type filter composed of fine glass-fiber pads arranged in wedged-shaped pockets approached 100% for all the air flows tested; however, the resistance was extremely high,—which proves, I guess, that you can't always get something for nothing.

The loading tests are continuing on several other types of filters and several reruns are being made to check some of the results. A report will be issued in the near future and will include new data collected on the arrestance of various filters tested since the last report was issued and a summary of the data obtained on the dust loading tests.

Since the dust loading tests are not complete, it is probably too early to say definitely which type of filter will be best. But, I think we can safely say that the certain popular brands of the metal viscous-impingement filters will offer a higher arrestance at a reasonable resistance for a longer period of time than any of the other types tested.

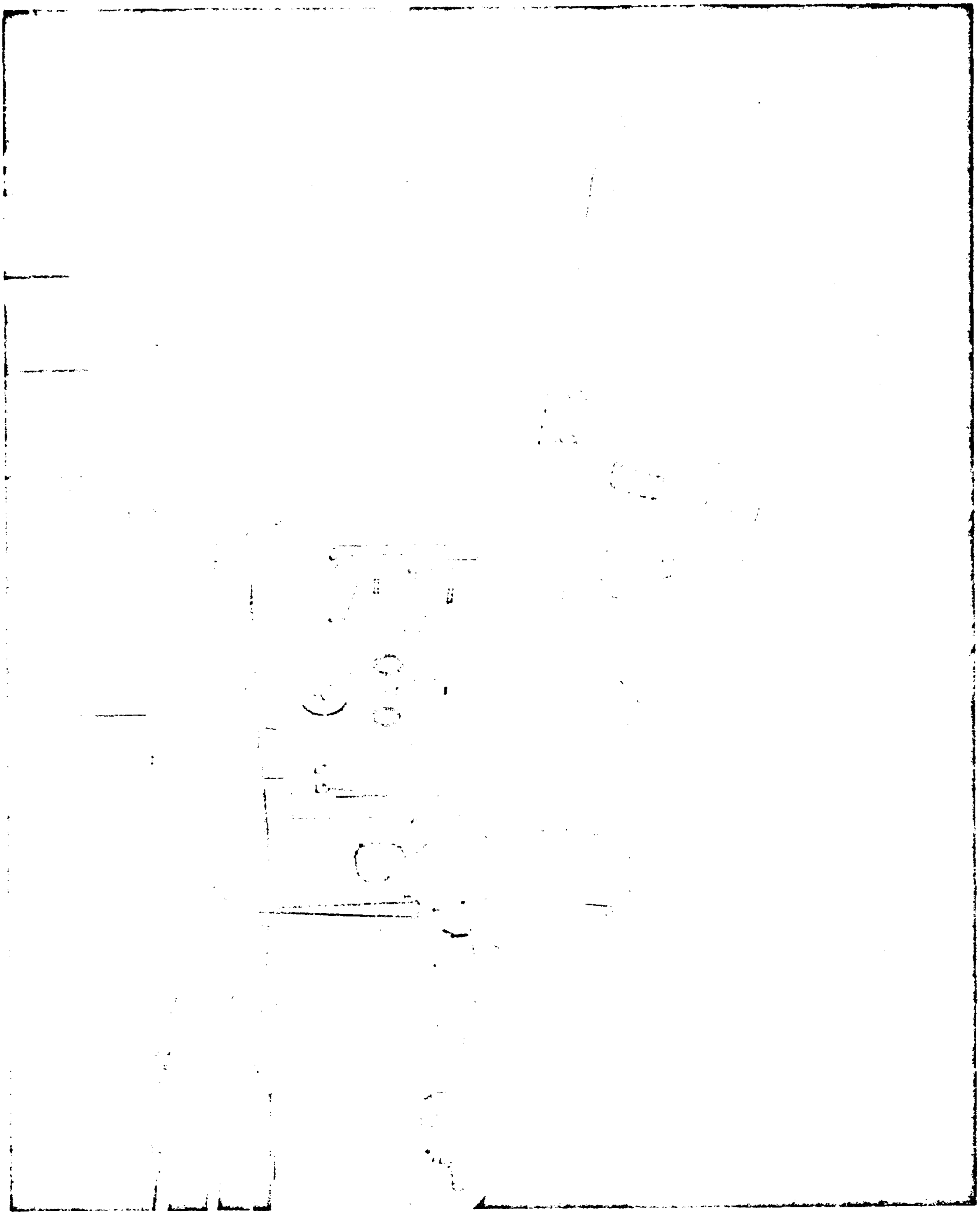

Fig. 1—Filter Test Duct.

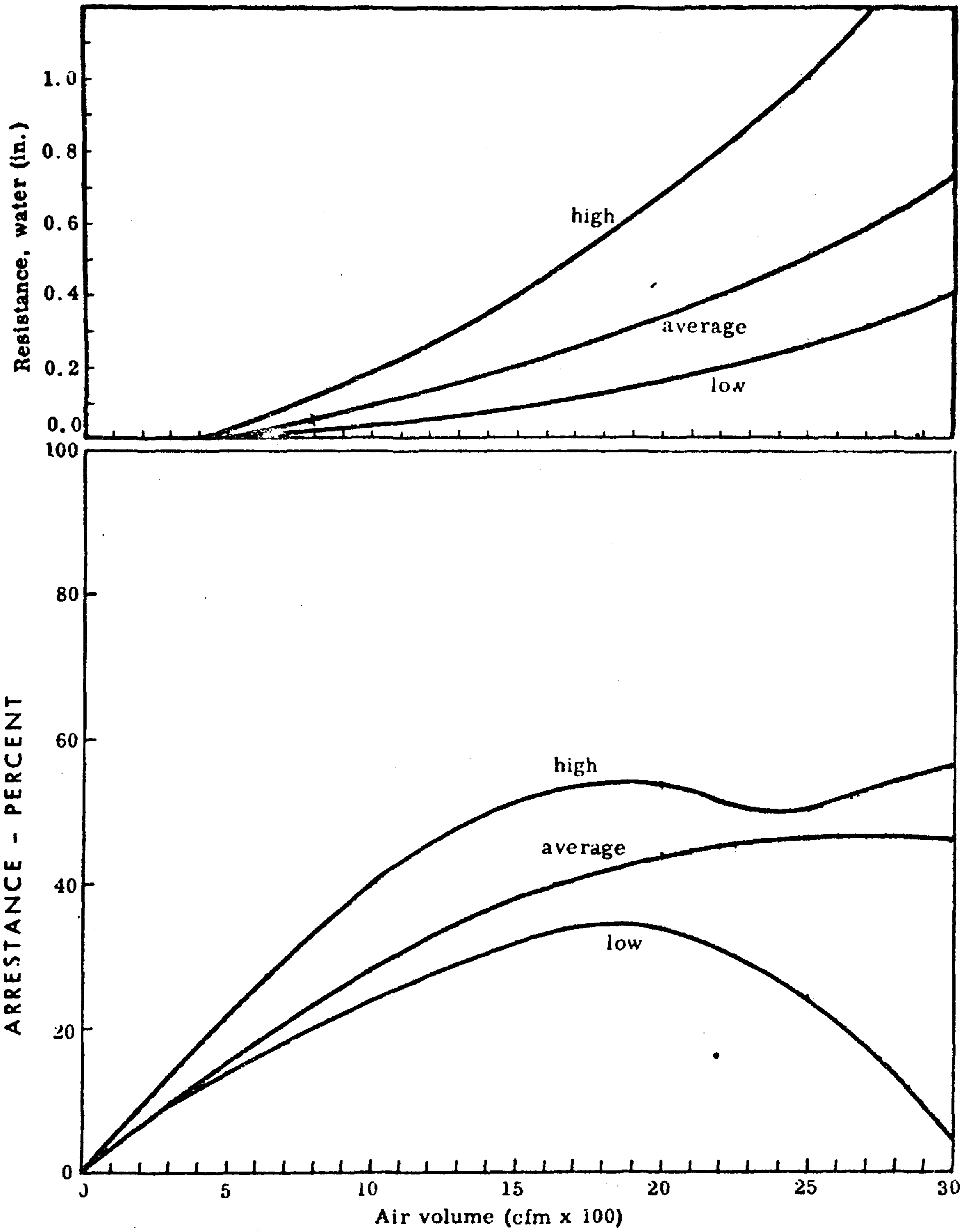

Figure 2. High, low and average performance curves for the 10 1-in. metal viscous impingement filters tested. The high and low performance curves do not represent the performance of individual filters. They are composites of the highest or lowest arrestances of any filters here tested.

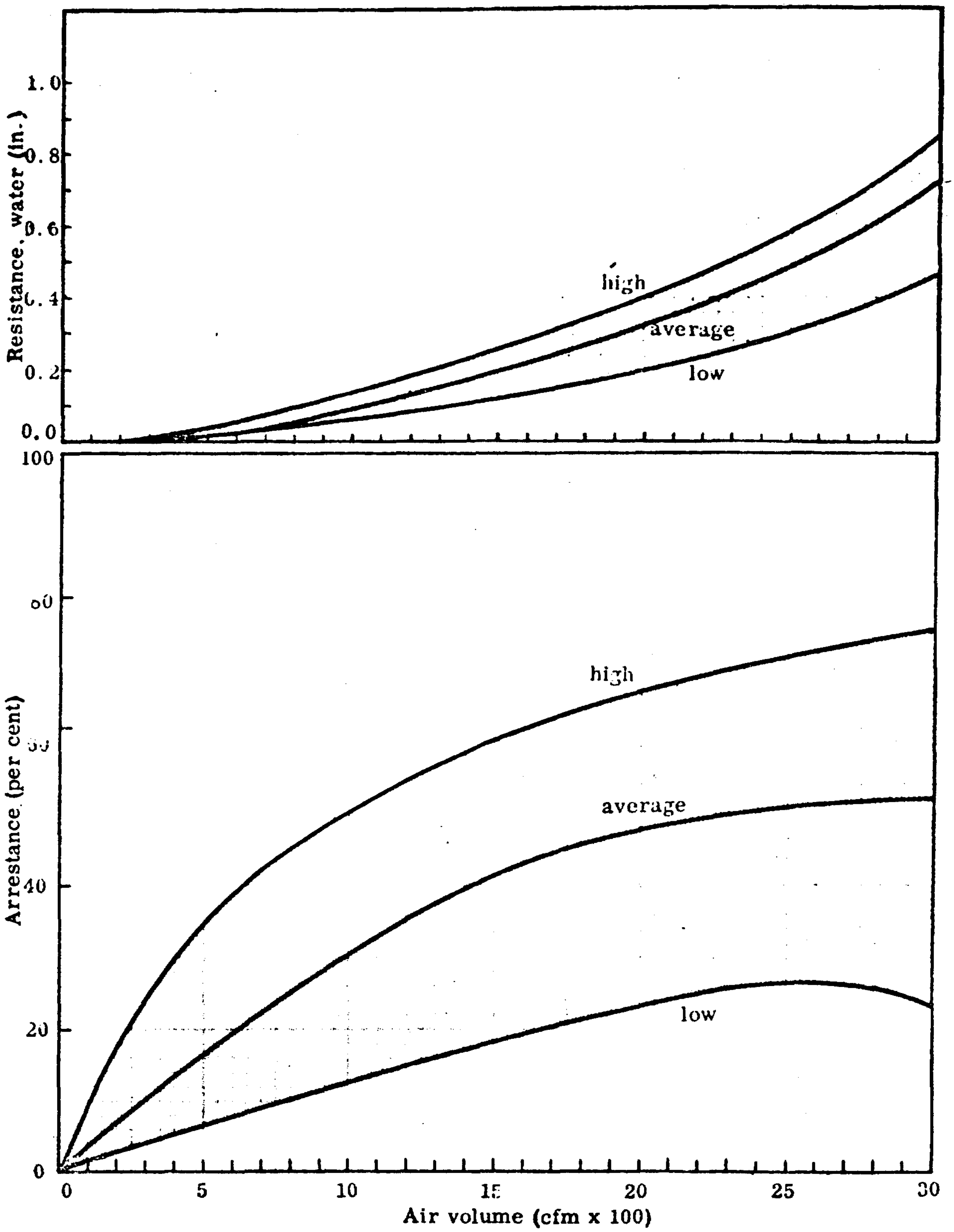

Figure 3. High, low, and average performance curves for the 22 2-in. metal viscous impingement filters tested. The low performance curve does not represent the performance of an individual filter. It is a composite of the low arrestances of any of the filters here tested.

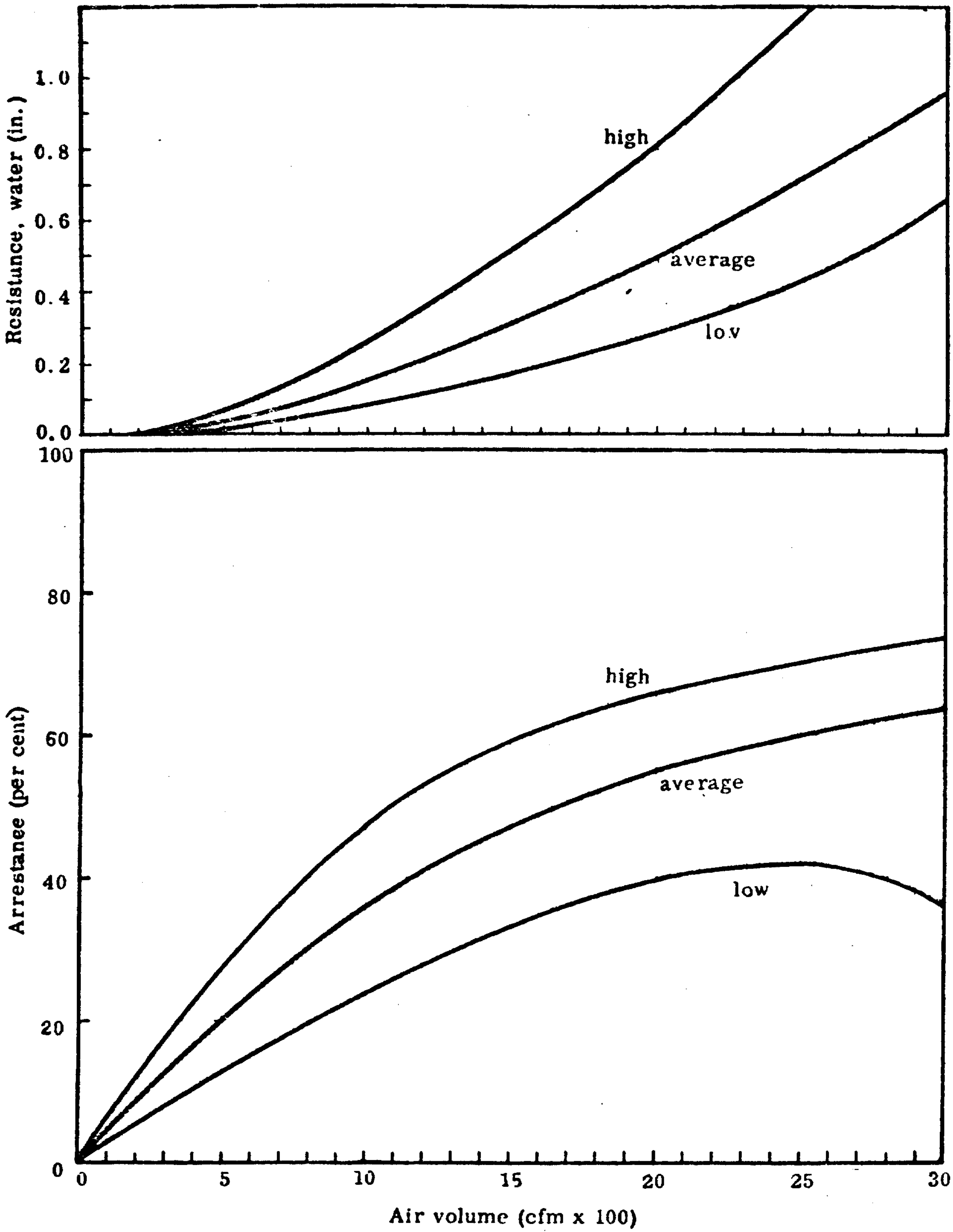

Figure 4. High, low, and average performance curves for the 18 4-in. metal viscous impingement filters tested. The low performance curve does not represent the performance of an individual filter. It is a composite of the low arrestances of any of the filters here tested.

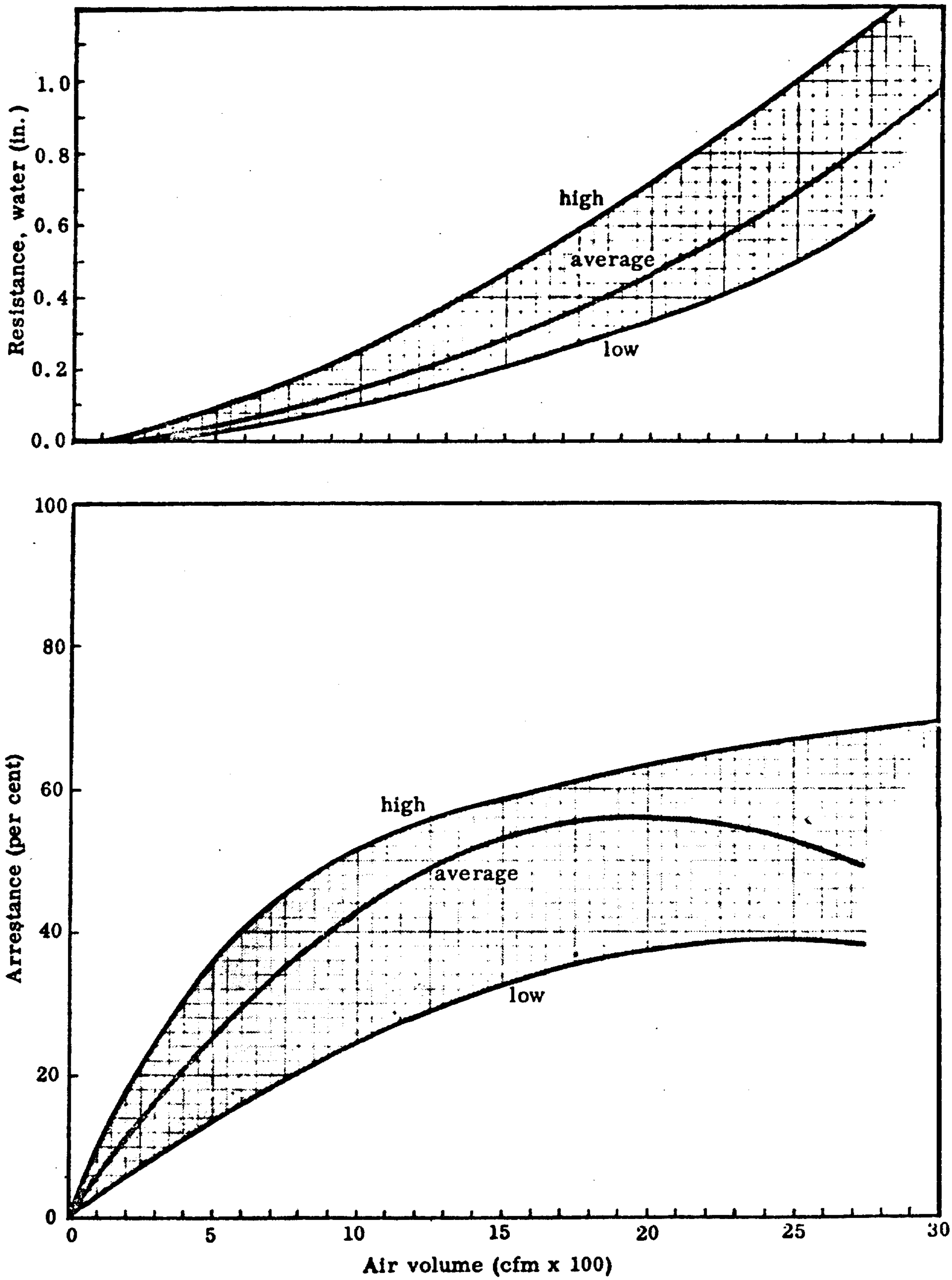

Figure 5. High, low and average performance curves of 8 1-in. fibrous viscous impingement filters tested.

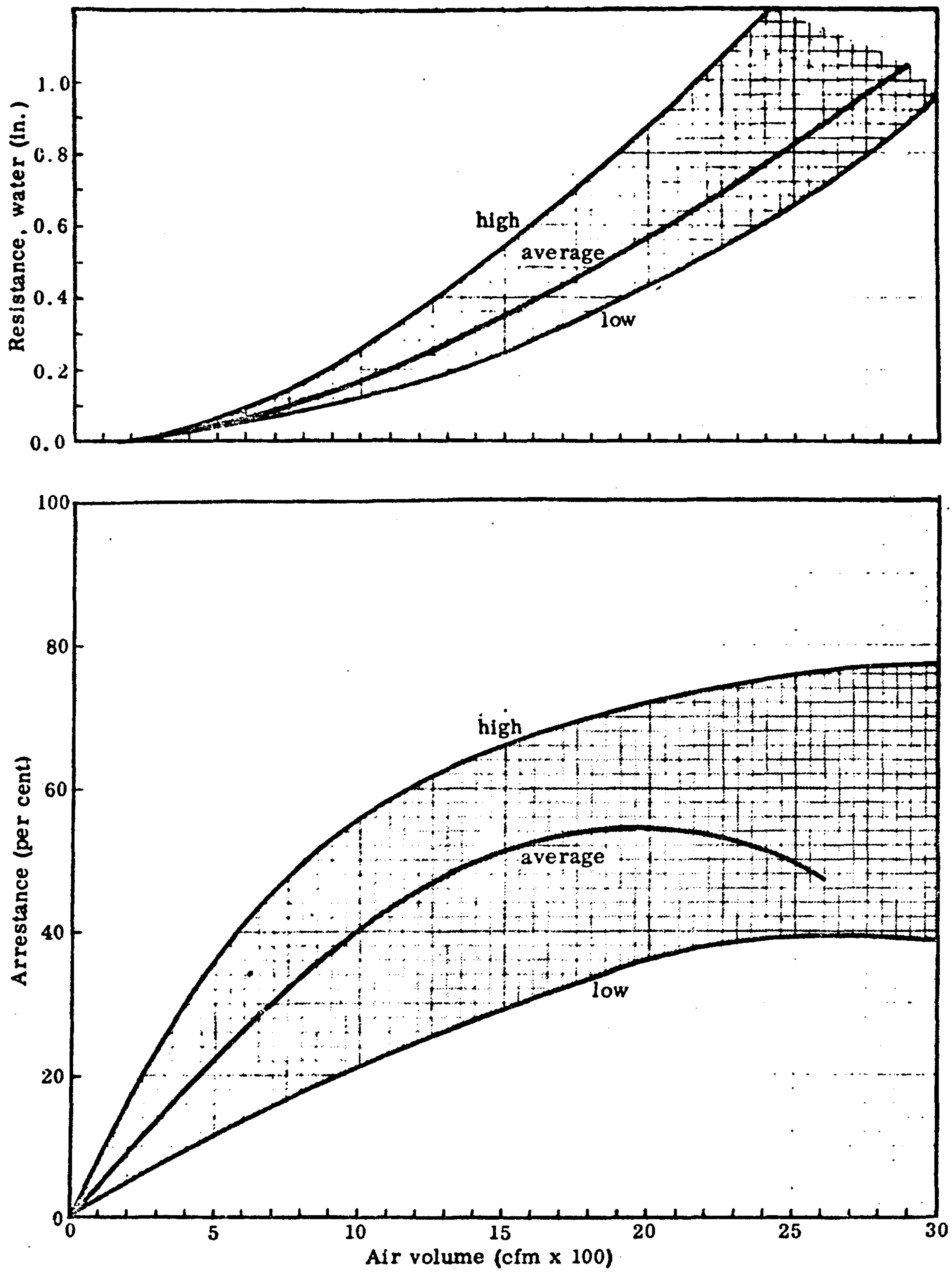

Figure 6. High, low, and average performance curves for the 9 2-in. fibrous viscous impingement filters tested.

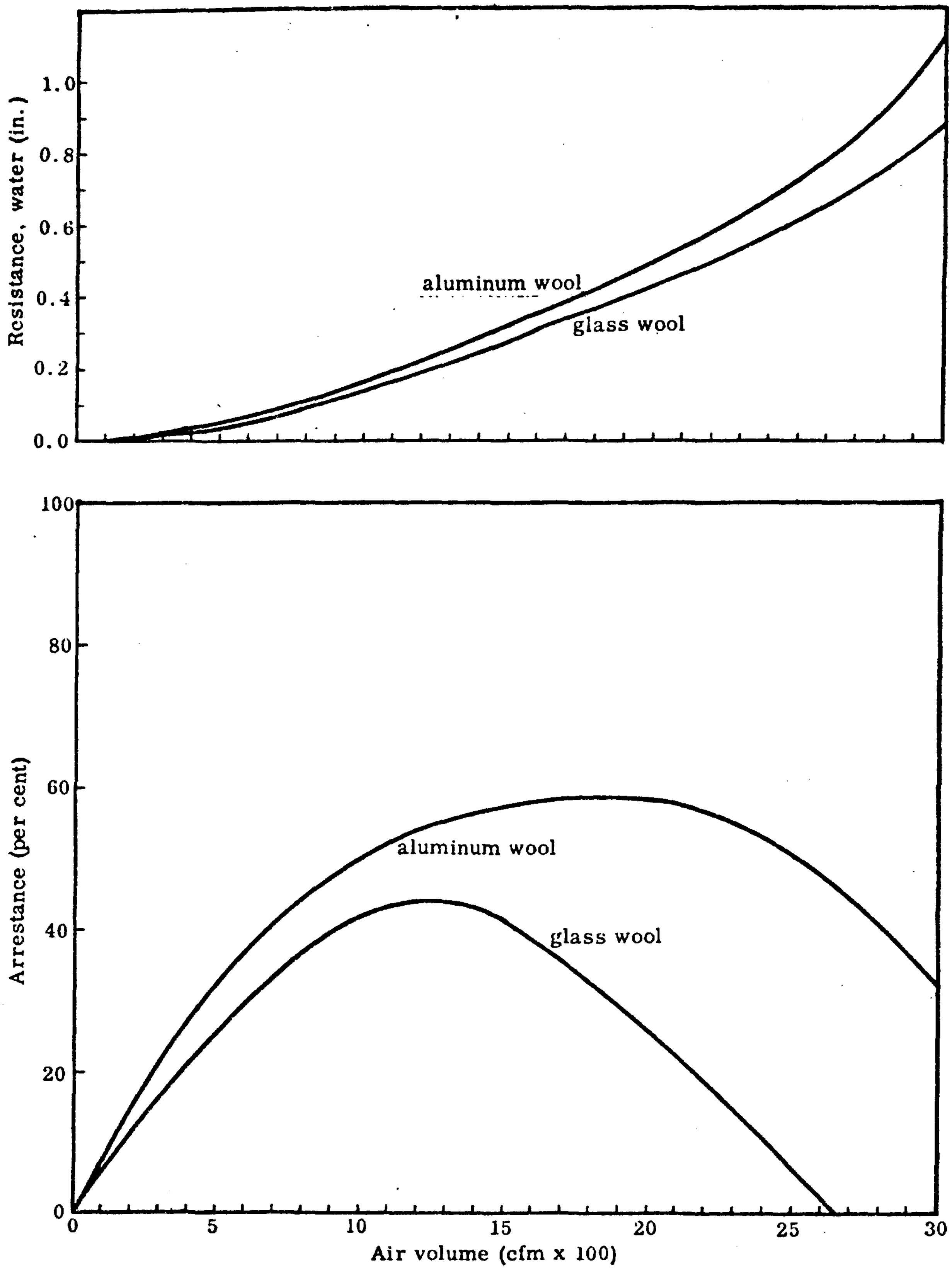

Figure 7. Performance curves for the 2 1-in dry standard fibrous filters tested.

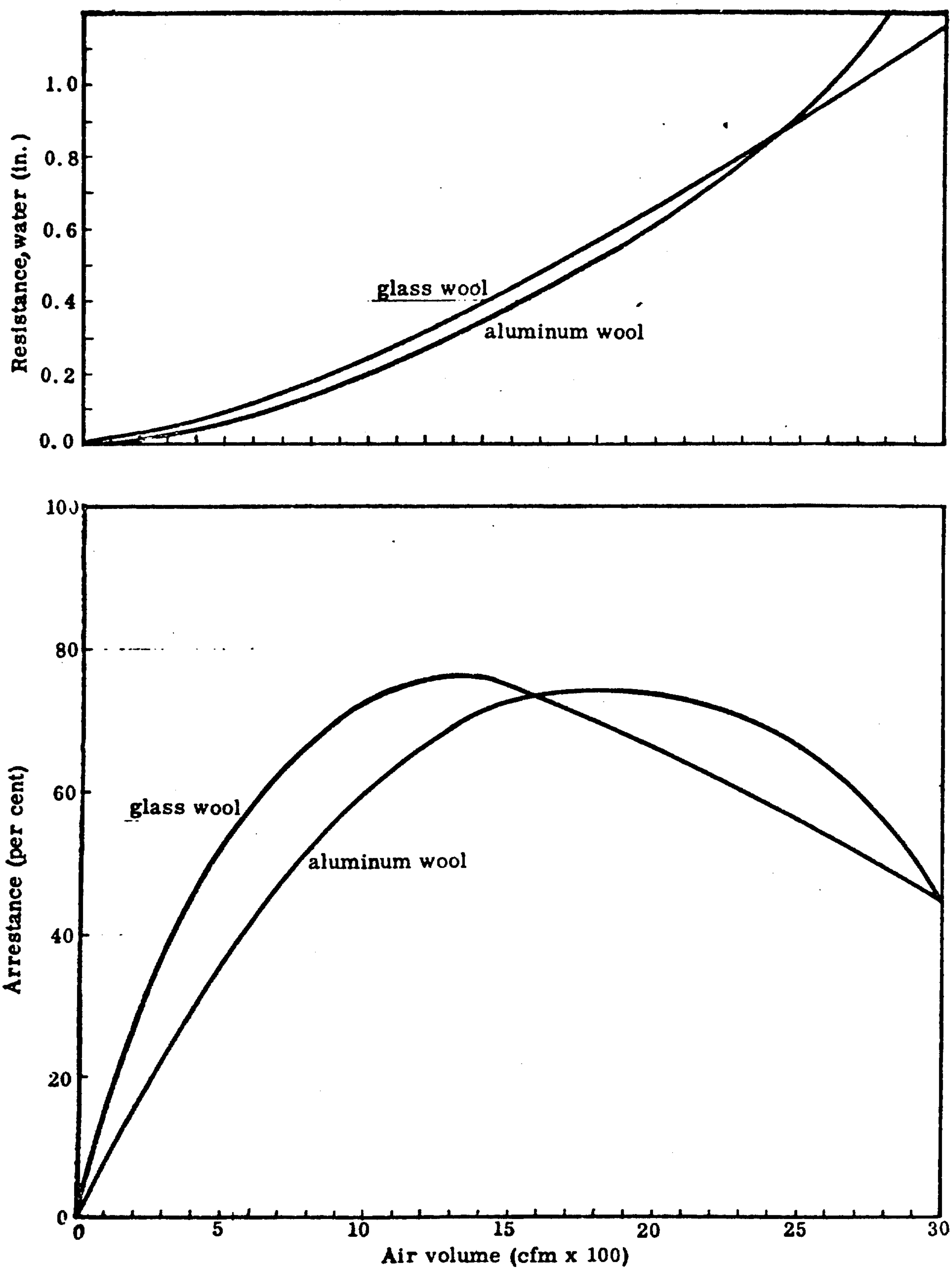

Figure 8. Performance curves for the 2 2-in. dry standard fibrous filters tested.

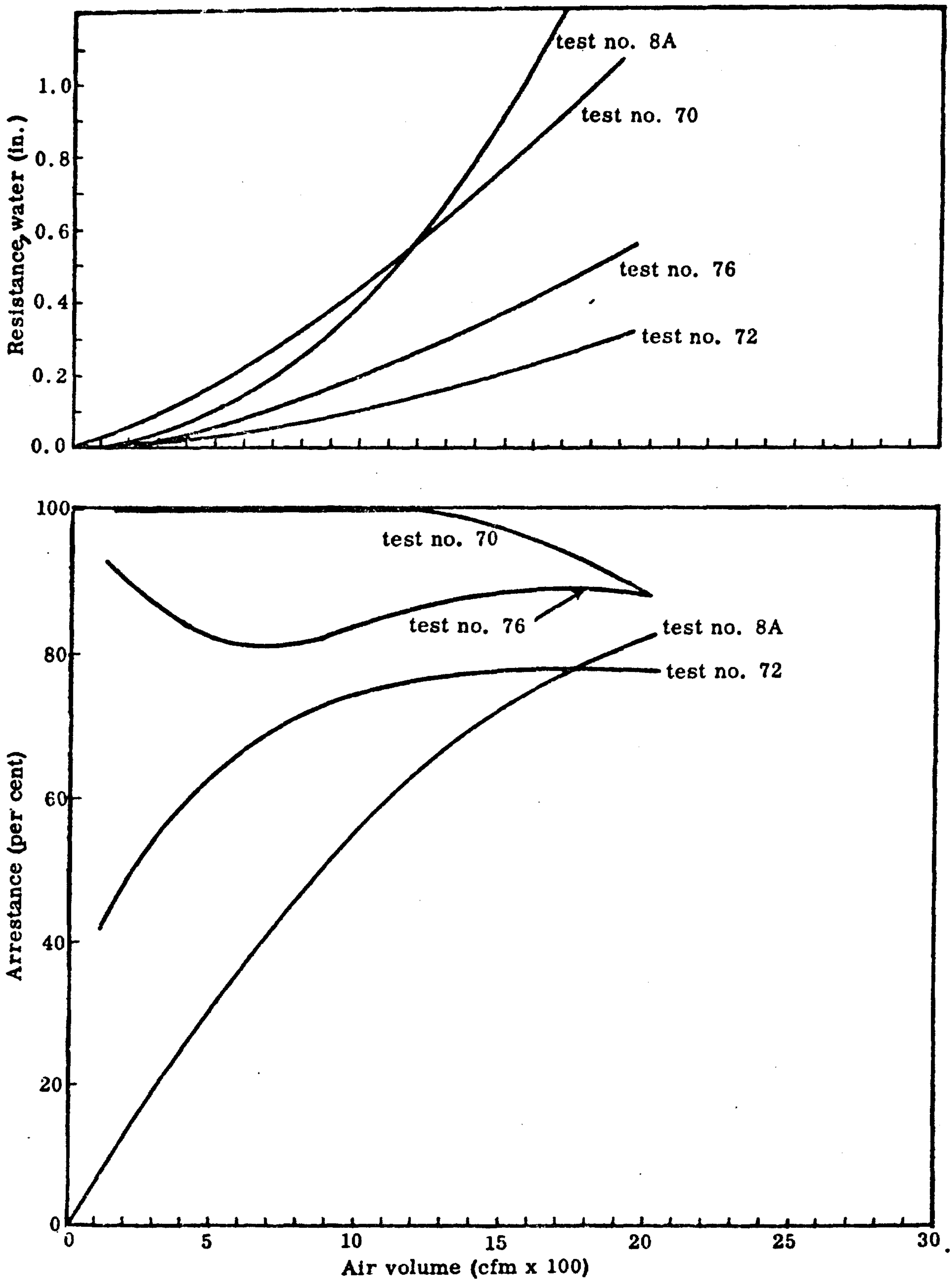

Figure 9. Performance curves for the low velocity dry fibrous filters tested.

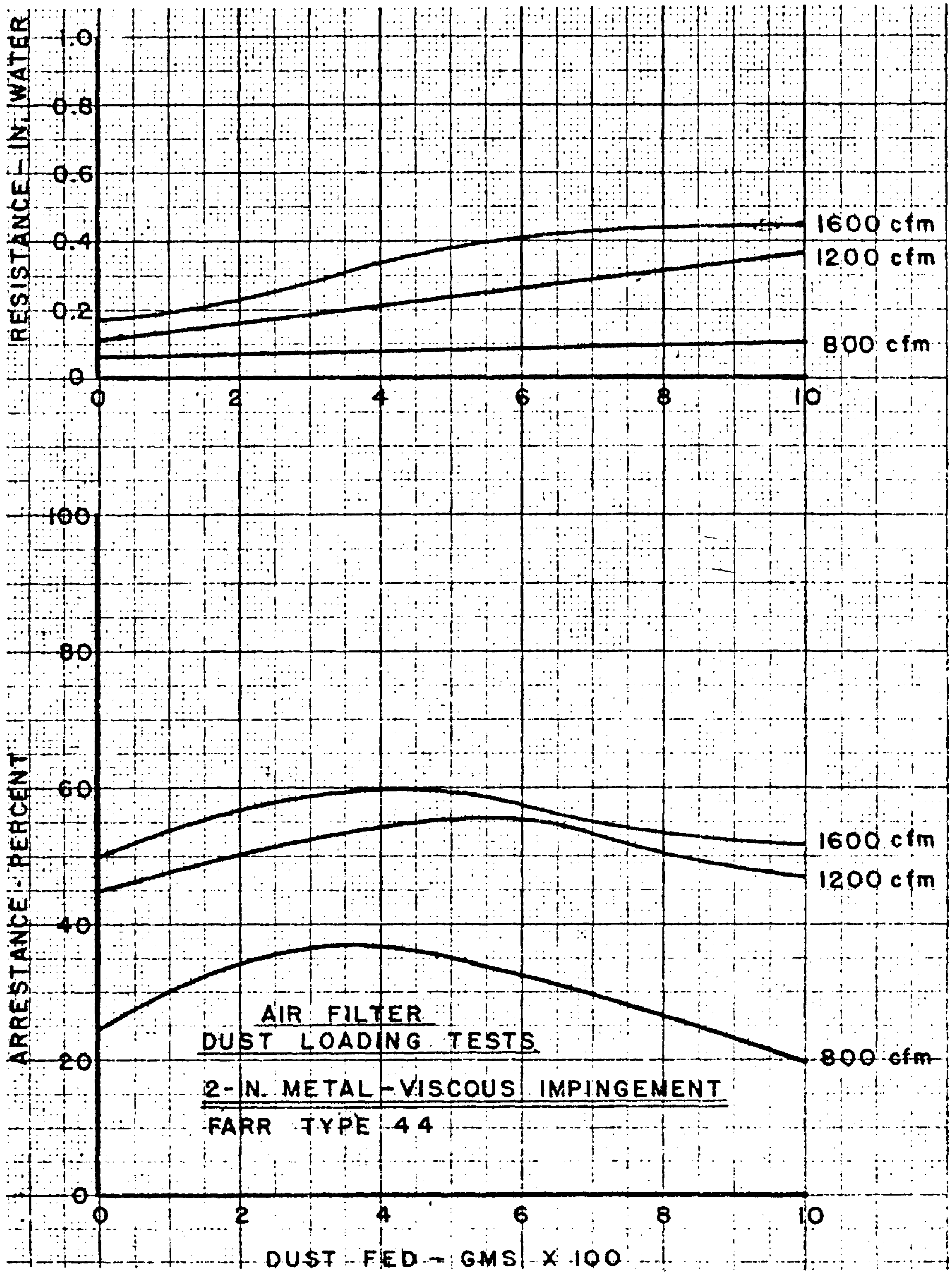
RESISTANCE - IN. WATER
1.0
0.8
0.6
0.4
0.2
0
1600 cfm
1200 cfm
800 cfm
0
2
4
6
8
10
ARRESTANCE - PERCENT
100
80
60
40
20
0
1600 cfm
1200 cfm
800 cfm
AIR FILTER
DUST LOADING TESTS
2-IN. METAL-VISCOUS IMPINGEMENT
FARR TYPE 44
DUST FED - GMS X 100

Fig. 10.

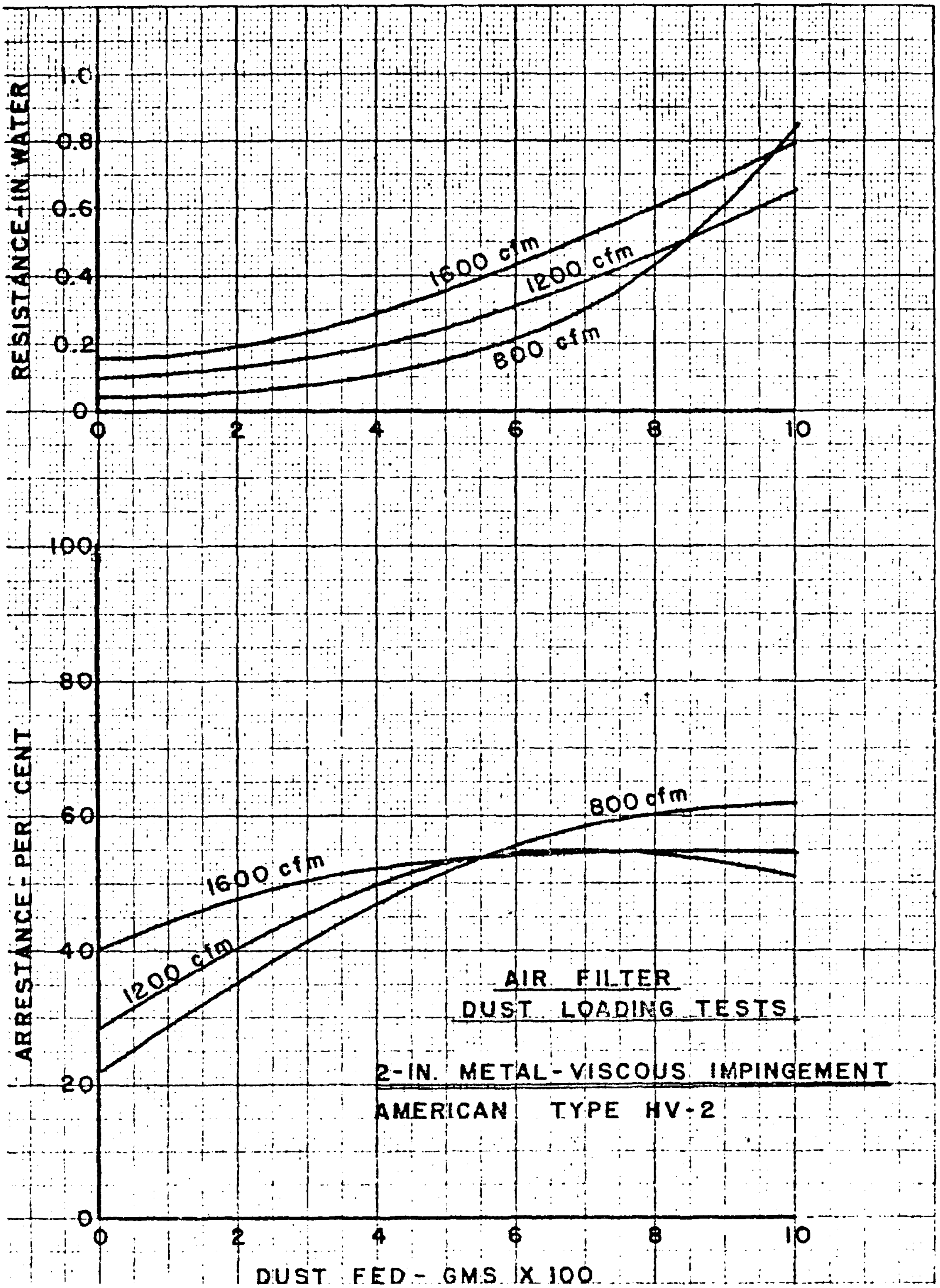
RESISTANCE-IN. WATER
1.0
0.8
0.6
0.4
0.2
0
1600 cfm
1200 cfm
800 cfm
0
2
4
6
8
10
ARRESTANCE - PER CENT
100
80
60
40
20
0
800 cfm
1600 cfm
1200 cfm
AIR FILTER
DUST LOADING TESTS
2-IN. METAL-VISCOUS IMPINGEMENT
AMERICAN TYPE HV-2
0
2
4
6
8
10
DUST FED - GMS X 100

Fig. 11.

EVALUATION OF PARTICULATE FILTERS

By Herbert M. Decker, J. Bruce Harstad, and Frederick T. Lense

INTRODUCTION

There is a continuous and increasing need for highly effective air filtration systems in specific areas of hospitals such as operating rooms, in certain industrial processes, and in research laboratories in which particulate free air is required. Decker et al[1] have reported on the filtration arrestance of spun glass filter pads and mineral filter papers. The latter have been found to be efficient in the removal of a bacterial organism (Serratia indica) from an air stream.

This paper reports the degree of bacterial penetration of 3 types of particulate filter units made from pleated filter papers all having a pressure drop of approximately one inch of water at their rated flow.

DESCRIPTION OF THE FILTERS

The first type filter was a CmlC Ml particulate filter consisting of CmlC Type 6 paper. This paper was 0.035 to 0.045 inches thick and was composed of cellulose, rope and asbestos. Corrugated kraft separators were used between each pleat. The paper was sealed into its frame with rubber cement.

The second type filter evaluated was a high temperature commercially available unit. The paper was 0.03 to 0.04 inch thick and was composed of all glass fibers; 82% of the fibers were approximately 3 microns and 18% were 0.5 microns. Corrugated aluminum separators were used between pleats. The paper was sealed with refractory cement into a 16 gauge perforated cold rolled steel frame.

The third type filter evaluated was a commercially produced glass paper filter fabricated to withstand temperatures up to 1000°F. The paper was 0.010 inch thick and was composed of all glass fibers having an average diameter of 0.5 to 0.75 microns. The one outstanding feature of this unit was compatability of all materials. The frame, gasket and filter media were all made from identical basic materials and will all react the same.

TEST PROCEDURE

A bacterial suspension of B. subtilis var. niger spores (frequently referred to as Bacillus globigii) was used to evaluate the efficiency of the filters. The size of the organism is 0.5 by 1.0-1.5 microns. The organisms were nebulized by means of all glass direct-spray peripheral air jet Chicago Type atomizer into a cloud chamber. Biological material from this nebulizer is not alway unicelluler because agglomeration may occur during or after release of the aerosol. The cloud of bacteria was mixed with air, then passed into a prefilter sampling chamber, through the filter media at a face velocity of approximately 5 feet per minute into a post filter sampling chamber and finally exhausted by means of a blower to the outside air.

DISCUSSION OF RESULTS

The results of the MI filter evaluation tests are shown in Tables 1 and 2.

The first column designates the test number. The average number of test organisms collected per cubic foot of air sampled before the filter during the test period is shown in the second column while the number of hours over which the average composite sample was taken is shown in the third column. Column 4 shows the cumulative hours of nebulization. Column 5 illustrates the cumulative total airflow through the filter, while the last column shows the percent penetration of the test organism through the particulate filter evaluated.

It may be observed that the percent penetration of B. subtilis spores decreased from 8.3×10^{-4} percent during the first hour of nebulization to 1.5×10^{-4} percent after 18 hours nebulization. Evaluation tests on another MI filter are illustrated in Table 2. This filter unit showed penetration of 2.5×10^{-5} percent during the first hours nebulization which decreased 1.9×10^{-5} percent after 19 hours nebulization.

The same test procedures, compilation and reporting of data as outlined above were applied for evaluation of the all glass particulate filter sealed with refractory cement. Tests were conducted at the rated capacity of 25 cfm. The percent penetration of the unit was 4.6×10^{-3} percent during the first hour of the run, and increased to 8.0×10^{-3} percent after 22 hours nebulization as noted in Table 3. This increased penetration may be due to deterioration of the cement seal of the media to the frame. Cracking of the refractory cement was noted upon visual inspection of the filter. It is felt that the cement used in this filter will not hold up over prolonged periods of use.

Results of a series of 11 tests conducted over a 66-hour test period on the all glass paper filter unit comprised of 0.5 to 0.75 micron size glass fibers are recorded in Table 4. The average percent penetration during the first hour of the test period was 6.7×10^{-6} percent which decreased to 7.0×10^{-7} percent after a 66 hour period. It should be noted that there was considerable variation within this penetration range. This is accounted for by the fact that the filtration efficiency was so high that the post filter collection of a few organisms would greatly magnify the allowed penetration in such a low order of leakages. The data collected show this filter to be the most efficient of all the units evaluated.

It should be mentioned that in all filter tests, there was no significant change in pressure drop although there was an increase in efficiency for all filters evaluated, except the glass media filter sealed with refractory cement. This possibly may be accounted for by the fact that the deposited aerosol presents an increased number of targets for the removal of subsequent aerosol particulates. Since there was no significant increase in resistance the phenomena cannot be accounted for by a significant change in void volume.

SUMMARY

Three types of pleated paper air filters were tested at rated capacities for penetration by spores of B. subtilis var niger. The three filters were the Chemical Corps MI particulate filter with CmlC Type 6 paper composed of cellulose, rope and asbestos; an all glass filter paper unit in which the filter paper was sealed to the frame with refractory cement; and an all glass filter paper assembly in which the frame, gasket and filter media were all made from identical basic materials. The three types of pleated paper filters show penetrations of less than one part per million when tested at linear airflows of 5 feet per minute with spores of B. subtilis var. niger. Penetration of the filters decreases with use provided the seal of the filter medium to the frame remains intact; the seal was the weak point in one of the filters.

Table 1—Penetration of Bacillus Subtilis Var. Niger Spores Thru Chemical Corps Particulate Filter (M1)

Test No.	No. organisms collected per cu. ft. air before filter	Duration of Test: No. hrs. per test	Duration of Test: Cumul. hrs.	Total airflow, cu. ft.	Percent penetration during test interval
	$\times 10^5$				$\times 10^{-4}$
1	24.1	1	1	1,800	8.3
2	54.1	5	6	10,800	3.4
3	37.7	6	12	21,600	1.6
4	59.2	6	18	32,400	1.5

Note: Airflow 30 cfm.

Table 2—Penetration of Bacillus Subtilis Var. Niger Spores Thru Chemical Corps Particulate Filter (M1)

Test No.	No. organisms collected per cu. ft. air before filter	Duration of Test: No. hrs. per test	Duration of Test: Cumul. hrs.	Total airflow, cu. ft.	Percent penetration during test interval
	$\times 10^5$				$\times 10^{-4}$
1	71.4	1	1	1,800	2.5
2	55.2	4	5	9,000	1.9
3	48.1	2	7	12,600	1.6
4	164.0	6	13	23,400	2.1
5	130.7	6	19	34,200	1.9

Note: Airflow 30 cfm.

Table 3 — Penetration of Bacillus Subtilis Var. Niger Spores Thru Commercially Produced Glass Paper Particulate Filter

Test No.	No. organisms collected per cu. ft. air before filter	Duration of Test		Total airflow, cu. ft.	Percent penetration during test interval
		No. hrs. per test	Cumul. hrs.		
	$\times 10^{5}$				$\times 10^{-3}$
1	155.0	1	1	1,800	4.6
2	108.0	2	3	5,400	4.1
3	40.7	1	4	7,200	7.5
4	70.8	6	10	18,800	4.9
5	42.0	6	16	28,800	7.5
6	198.0	6	22	39,600	8.0

Note: Airflow 25 cfm.

Table 4 — Penetration of Bacillus Subtilis Var. Niger Spores Thru Commercially Produced High Temperature All Glass Paper Filter

Test No.	No. organisms collected per cu. ft. air before filter	Duration of Test		Total airflow, cu. ft.	Percent penetration during test interval
		No. hrs. per test	Cumul. hrs.		
	$\times 10^{5}$				
1	40.4	3	3	5,400	6.7×10^{-6}
2	67.3	6	9	16,200	2.1×10^{-6}
3	60.0	6	15	27,000	1.6×10^{-5}
4	102.3	6	21	37,800	1.1×10^{-5}
5	114.3	3	24	43,200	5.7×10^{-6}
6	59.9	6	30	54,000	6.2×10^{-6}
7	106.0	6	36	64,800	3.5×10^{-6}
8	58.7	6	42	75,600	1.7×10^{-6}
9	33.9	6	48	86,400	1.9×10^{-6}
10	13.4	6	54	97,200	2.1×10^{-6}
11	51.7	12	66	118,800	7.0×10^{-7}

Note: Airflow 50 cfm.

METEOROLOGY AS RELATED TO AIR CLEANING

By Donald H. Pack
United States Weather Bureau
Washington, D. C.

The science of meteorology is intimately related to air cleaning. After all the oldest and (on a long term basis) one of the most efficient air cleaners is the atmosphere. This is just as well, else the fossil dust of some prehistoric dinosaur might be giving some of us hay fever today. Although enormous amounts of gaseous and particulate matter are constantly transported by the atmosphere, this is only a minute fraction of the amount that has, over geological time, been injected into the air, gradually dispersed, and finally deposited in the oceans and on the land. It is only since the Industrial Revolution that sources of pollution have been so concentrated as to strain and in some instances exceed the natural cleansing capacity of the air, in areas where the resulting concentrations are of biological concern. With the achievement of nuclear fission and the explosive expansion of machines, materials and facilities of a radioactive nature the problem has been made even more acute. For while there seems to be a cause and effect relationship between high concentrations of smog, SO_2, oxidants, etc.) and biological effects (for example witness the Donora, Pennsylvania disaster), the actual chain of events between release of material and evident biological damage is still obscure. On the other hand, the unchecked release of plutonium from a machining facility or all of the fission gases from a fuel processing plant and the subsequent exposure of personnel to internal and external radiological hazard would be an obvious way to cause damage.

Since we know that the atmosphere, unassisted, cannot always reduce local concentrations to levels we feel are acceptable, what place does meteorology play in air cleaning, planning and design? First, an obvious fact; air cleaning devices rarely remove all foreign material, they attempt to reduce the concentration in the released air to tolerable levels. This does not imply that the air has lost any of its diluting capacity, only that we have overloaded a local segment of it. The back-up capacity of the air to reduce initial concentrations by several orders of magnitude in relatively short distances is a comforting safety factor in air cleaning.

Second, unless a valuable and marketable by-product is salvaged, the requirement for air cleaning may impose penalties of time, efficiency, and expense on the processes to which it must be applied.

Thus any assistance that the dilution capacity of the air can provide to increase the safety, or to reduce the costs, of air cleaning devices is useful.

METEOROLOGY AS A DESIGN CRITERION

Engineering design is usually a compromise between what is desired, what is possible, and what there is money to pay for. The use of meteorological data can assist in arriving at the optimum design level by describing the diffusion climate, or in other words the back-up air cleaning capacity of the air. Data such as the variation in wind speed from day to night and month to month, persistancy of wind directions, frequency and persistance of stable atmospheric situations, to mention only a few, all have a bearing on the amount of air cleaning required to obtain allowable concentrations. However these conditions vary widely over a country as large as the United States. The meteorological data now being collected here at Argonne, Brookhaven, NRTS, etc. are often used in the design of air cleaning equipment. Each of these sites measures parameters governing the travel and dilution of material in the atmosphere and has gathered a body of data that gives a fairly complete picture of the expected variation of atmospheric diffusion. Comparison of these data bear out the fact that the diffusion climates vary as much as the general weather. Although the general pattern is similar in that atmospheric dilution is usually greatest during the day and least at night, the records show that poorest diffusion may occur at different times of the year at various sites, that wind persistance differs greatly, and that in general each location will have different problems in the dispersal of contaminants. None of these sites however are in particularly unfavorable dilution climates or locations. At the risk of belaboring the already hard pressed Southern California area, the coincident geographical location and restrictive terrain in that area results in a natural air trap. The West coast inversion "lid" and the mountains to the east confine the air movements to a relatively small area both vertically and horizontally. The result is that "smog" has become a serious threat to the community. Obviously in a situation of this type the back-up dilution capacity of the air is at a minimum and air cleaning devices need to be as efficient and as numerous as possible.

During recent years, as the interest in air pollution and the transport of material by the atmosphere has grown, meteorologists have developed methods for computing the concentration of material as it is diffused by the air. Some of the developments are wholly theoretical, some empirical, and some a combination of the two. A description of the development and assumptions underlying the various equations will not be attempted here. However an outline of a number of the various theories is contained in the recent publication "Meteorology and Atomic Energy [1] The equations of O. G. Sutton, [2] the British meteorologist, are quite flexible and have met with reasonable success when applied to practical problems of determining air and ground concentrations and cloud sizes.

Perhaps a better feeling for the practical aspects of the use of meteorological data in air cleaning design can be shown by an illustration. Figure 1 shows the frequency distribution of various lapse rates at Oak Ridge, Tennessee. It is evident that relatively unstable conditions are most frequent during daylight hours, and that stable conditions are the rule at night. If reasonable "day" and "night" wind speeds are chosen we can obtain concentration curves that can be expected with these conditions. Figure 2 shows such curves, comparing the ground concentrations that would result in the "day" case with "night" conditions. It can be seen that diffusion is much slower with the "night-time" stable conditions. If the maximum permissible level of concentration is known it is immediately evident from computations such as these what requirements are imposed on an air cleaning device.

If the cleaning operation is difficult, or the device can be used only for a limited time of operation, an analysis of the frequency and duration of poor atmospheric diffusion conditions can be made and the time demands on the air cleaning device shown. Figure 3 shows a rough analysis of such data for a single year at the NRTS. The upper curve shows the total hours of stable conditions during each month of the year, with the annual total indicated in the right hand column. The two lower curves show the maximum duration of lapse and stable conditions, during each month of the year. If it is known that air cleaning is required during periods of poor diffusion, then data of this type permits an estimation of the amount time an air cleaning device must operate.

Another direct use of meteorology in air cleaning is in the design of exhaust stacks. As is well known, ground concentrations from an elevated source are less than those from an equivalent source at the ground. Thus tall stacks or high plume rises are beneficial in reducing ground concentrations. On the other hand the achievement of these greater heights usually means greater costs.

Holland [3] has shown that for given stack parameters (height, diameter, gas velocity, heat release, etc.) there exists a critical wind speed that will produce the maximum ground concentrations. If some tolerance concentration level is established it is possible to solve Holland's formula for stack height and compute the minimum stack height necessary to maintain ground concentrations below the established tolerance. The reader is referred to the original publication for the development of this treatment. One difficulty with this approach is that it does not fully account for irregularities in terrain or the influence of buildings. Sherlock and Lesher [4] have described an interesting combination of wind tunnel experiments with actual meteorological data to produce a method for the design of stacks. From both of these treatments a knowledge of the so-called critical wind speeds will permit a statistical determination of the frequency of undesirable concentrations. It is only necessary to examine the meteorological records and tabulate the frequency of occurrence and persistance of the particular speed of interest.

Other obvious uses of weather data in air cleaning design would be for the location of exhausts and intakes, frequency of precipitation and the accompanying wind directions in the evaluation of washout of contaminants, layout of plant buildings in accordance with prevailing winds to prevent mutual interference and contamination.

METEOROLOGY AS AN EVALUATION FACTOR

Whether or not meteorology is considered in the design and installation of air cleaning equipment, an adequate evaluation of the efficacy of the equipment in actual operation may depend on using current meteorological data. Here is a situation where statistically correct random sampling can give an entirely false or misleading picture. This has actually occurred in at least one instance. Mobile samplers at a site were sent out various directions and distances at random and no activity had been observed. Eventually a sampling run detected a significant increase in activity. This measurement was regarded as instrumental error and discarded. Subsequently a meteorologist was discussing the sampling program and this supposed anomaly was mentioned. A quick check of the records showed that on this particular day the sampling run coincided with the wind direction. In fact the records for this single run represented the routine emission, and all the others were almost without meaning. This was verified when, after this discussion, sampling runs were made on the basis of the wind and weather records and values comparable to the single supposedly anomalous record were obtained consistantly. This is an extreme case but it serves to illustrate the necessity for considering all the parameters in the analysis of the control of effluents.

If a network of fixed monitoring stations is being established, the efficiency of the network can be improved by considering the distribution of wind speed and direction frequencies. A good example of this is at the NRTS at Idaho Falls. The mountains surrounding the Snake River Plain channel the majority of the winds into the northeasterly and southwesterly directions, thus it is advantageous to have the densest network of samplers northeast and southwest of the point of release if representative measurements of airborne material are to be obtained. In addition the differing wind velocities will result in a wide variation of possible concentrations, even if the emission rate remained the same. Figure 4 computed from the Sutton equations shows the theoretical ground concentrations resulting from the continuous or from the instantaneous release of material at a height of 50 meters. A computation of this type can be used in two ways. If the winds are persistant in direction as at the NRTS, samplers can be placed in the center line of the average plume, near the point of maximum concentration, if this is feasible. Or, if the wind data shows that the sampling station was not in the center line of the cloud travel, but was off to one side, the wind and stability data can be combined with the values reported from the sampling station to compute the maximum concentration that actually occurred but was not intercepted by a sampler. From these computations it is easily possible to evaluate the air cleaning device. Of course the evaluation is not quite as simple as described here. Wind speed and direction variation over the sampling period must be taken into account. The effluent will probably not behave exactly as predicted by theory, and a large amount of laborious computation is required to come up with the proper numbers for the first few trials. However the technique does work and can be reduced to simple charts, nomagrams and templates if the program is a continuous one. Another useful application of this same technique is the identification of a single source of emission where several possible sources exist. When the effluent is not readily identifiable as originating from a known source, it is possible to work backwards from the point of detection using wind and stability information and reconstruct the probable trajectory of the material. This has been done in numerous cases, and just recently an incident occurred at CRNL where paint damage to automobiles was observed. Examination of the wind records showed that this damage was correlated with wind direction, and that the wind was from the direction of a new steam plant. To make doubly sure of the source, two meteorological blimps were used to carry a high volume sampler into the stack plume. Analysis of the sampler filter and of the fallout near the automobiles were almost identical.

However the design engineer or the plant operator working with air cleaning devices may say, and perhaps rightly so, that the preceding approach assumes that the air cleaning device will not meet its design performance or that it will break down.

It could be contended that if the air cleaning device actually works as well as expected the very small amount of material that escapes the device will always be safely below tolerance. This brings us to a more subtle and more difficult aspect of the uses of meteorology. This is the use of weather data in the evaluation of long term, repeated exposure to contaminants in the atmosphere. Each location has its own preferential weather pattern of winds and stability. We have mentioned this in the location of sampling stations. However in relatively open terrain the dominant features of the pattern may be only a few per cent different from the next most frequent so that relatively uniform dispersal over the whole surrounding area is obtained. Past experience however, shows that the demand for water and the need for isolation very often results in locating industrial plants in general, and nuclear plants in particular, in narrow river valleys where the air flow is restricted to certain directions a very large percentage of the time. Also the terrain may be so irregular as to make application of the diffusion equations open to serious question. We know that in cases of this type, "hot" spots can develop where preferential deposition of material occurs, or perhaps that the side of a hill or bluff is almost always exposed to released effluent. If the effluent should be for example, long lived alpha material, even though the amount released were very small, the operation of the plant for a number of years might result in concentrations in these pockets higher than desirable. In sites of this type it may be necessary to make very careful analyses of the wind and stability patterns using portable meteorological equipment and tracer methods such as smoke pots, or fluorescent particles. From these methods the areas subject to repeated exposure can be defined. Sampling at these points can evaluate any build-up of material and provide information on the long term efficiency of air cleaning.

The evaluation of the long term problem may involve the continuous collection of meteorological records, interspersed with intensive and detailed studies. Since each new site seems to act as a nucleus for subsequent growth and addition of facilities, these changes must be taken into effect in the long term analysis. Addition of new buildings, leveling of hills, removal of trees, and particularly the installation of new sources of contaminants, can change not only the concentration patterns, but may actually influence the small scale air flow.

CURRENT EXAMPLES OF METEOROLOGY APPLIED TO AIR CLEANING

It would be impossible to list all of the current projects under way where the collection and analysis of meteorological data is being used to provide assistance in air cleaning, however a few of the newer projects can be mentioned. Of course there are the continuing programs at the larger AEC sites and in recent months a measuring program was established for the PWR site at Shippingport. This site, about 30 miles northwest of Pittsburgh is a narrow section of the Ohio River valley with high bluffs rising on both sides of the river. In this case the terrain was put to work. The valley is too deep to erect a tower of any practical height so that wind and temperature measuring equipment was placed on the top of a hill overlooking the site, with a second set near the river on the site itself. Comparative measurements from these two locations provide information on the general air flow and the flow in the valley and also the temperature gradients between the floor of the valley and the hilltop.

At the Connecticut Aircraft Nuclear Engine Laboratory south of Hartford, Connecticut the Atomic Energy Commission has requested the Weather Bureau to make a micrometeorological survey of the site. The Weather Bureau together with Pratt and Whitney, the prime contractor, is working to set up a measuring program to describe the air flow and diffusion over the site. This location is again in a river valley, this time the Connecticut River, but the plant location is on a plateau about 150 feet above the river level. In this case it is possible to erect a 200 foot tower from which representative wind and temperature measurements can be obtained.

A third and much more ambitious project is just getting under way at the Taft Sanitary Engineering Center of the Public Health Service in Cincinnati. The last session of Congress authorized a broad scale national investigation of air pollution with the program administered and coordinated by the Department of Health, Education and Welfare. Numerous groups, including agencies such as the Weather Bureau and Bureau of Mines, and various state, local and private organizations are combining to survey every phase of air pollutioh. This will involve, among many other things, extensive urban surveys, sampling networks, chemical analysis of contaminants, tracing the chain of biological effects, determining major sources of pollution, developing a nationwide climatology of air pollution potential, and in general attempting to learn more about how clean air can be assured in the urban United States.

In conclusion it can be fairly stated that when there is an actual or even a potential source of foreign material that can be released into the air the science of meteorology can assist in evaluating the results and minimizing the effects of such events.

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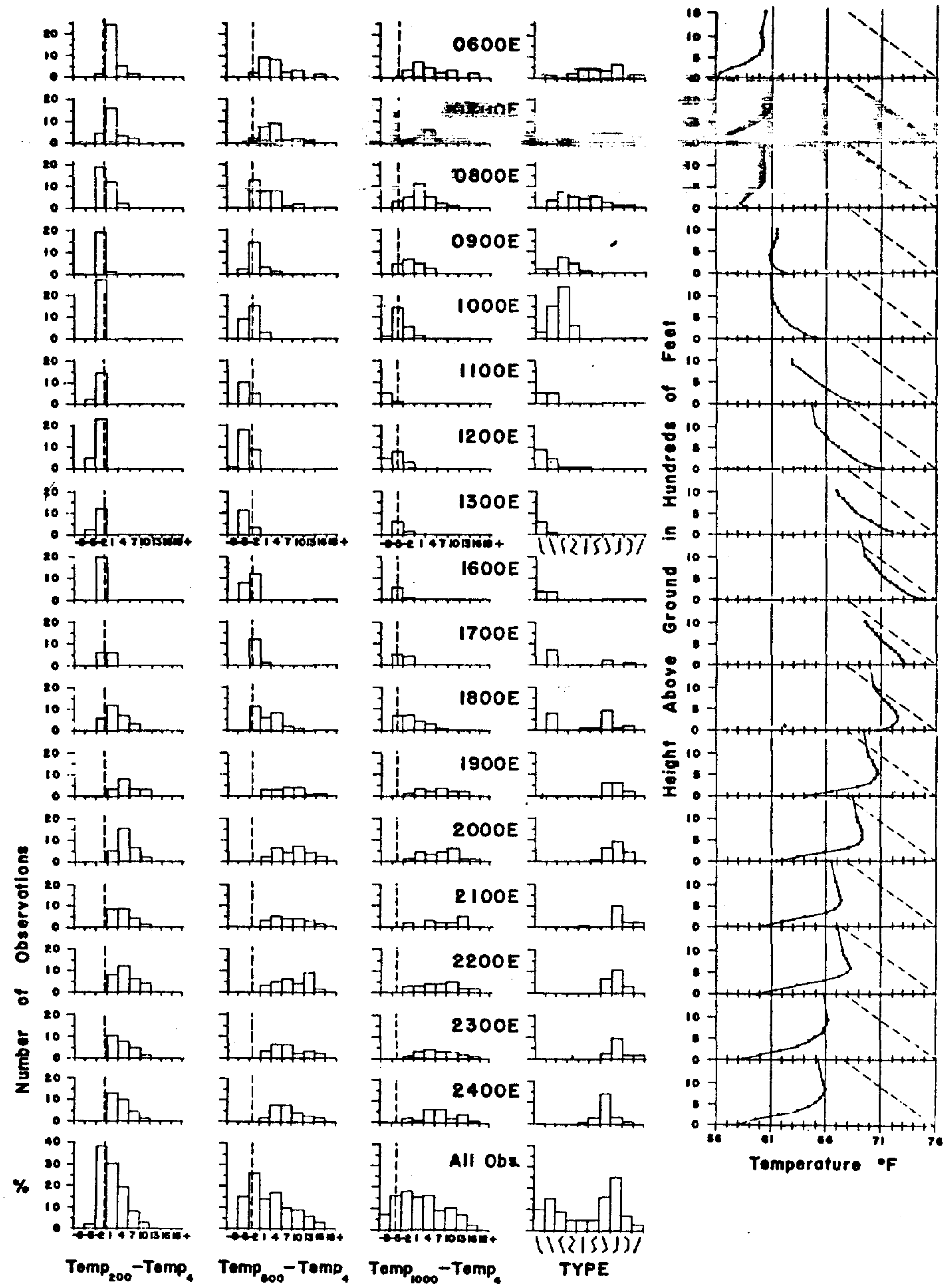


FIG. I

TEMPERATURE GRADIENT FREQUENCIES (OAK RIDGE, TENNESSEE)

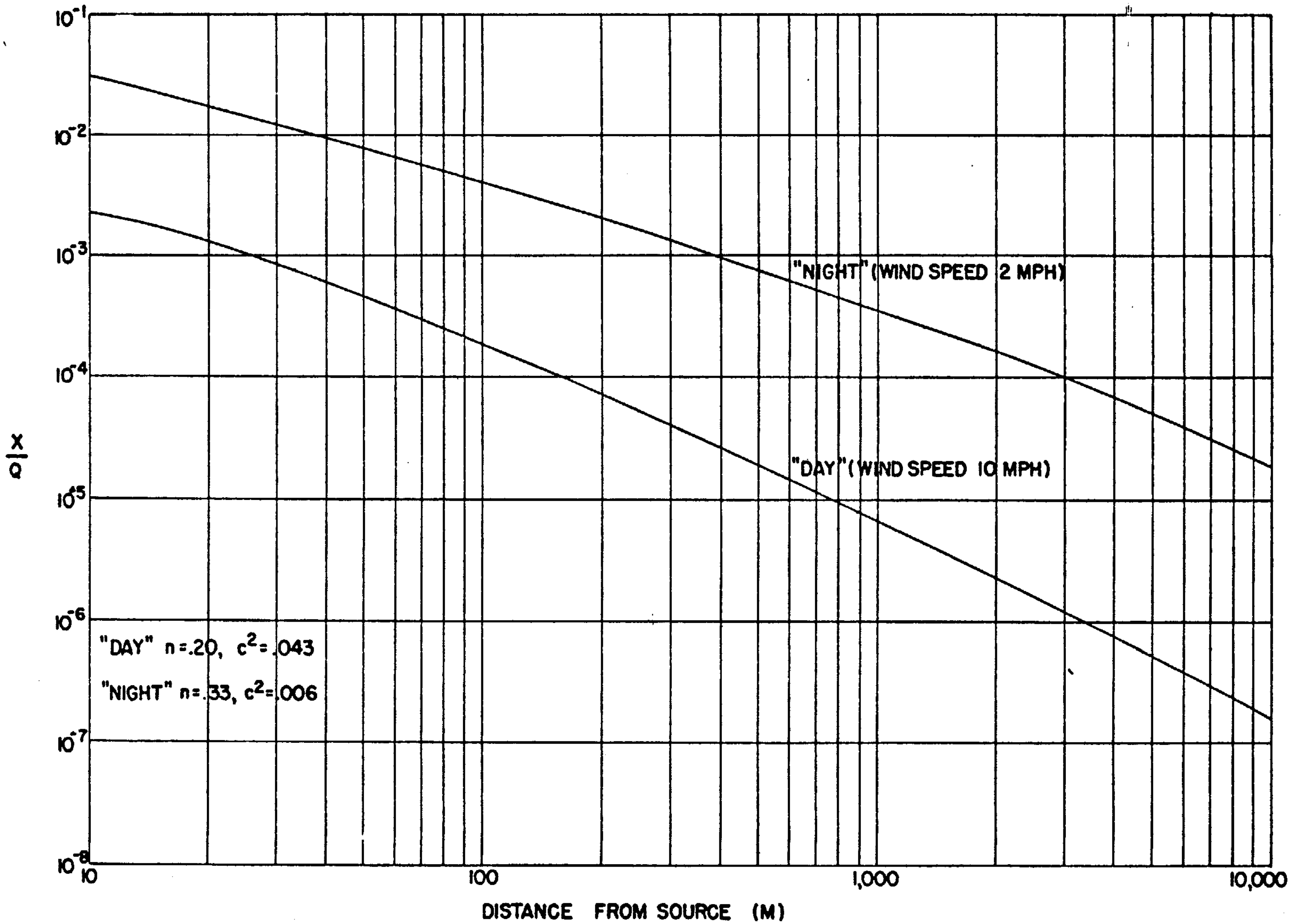


FIG. 2 COMPARISON OF GROUND CONCENTRATIONS

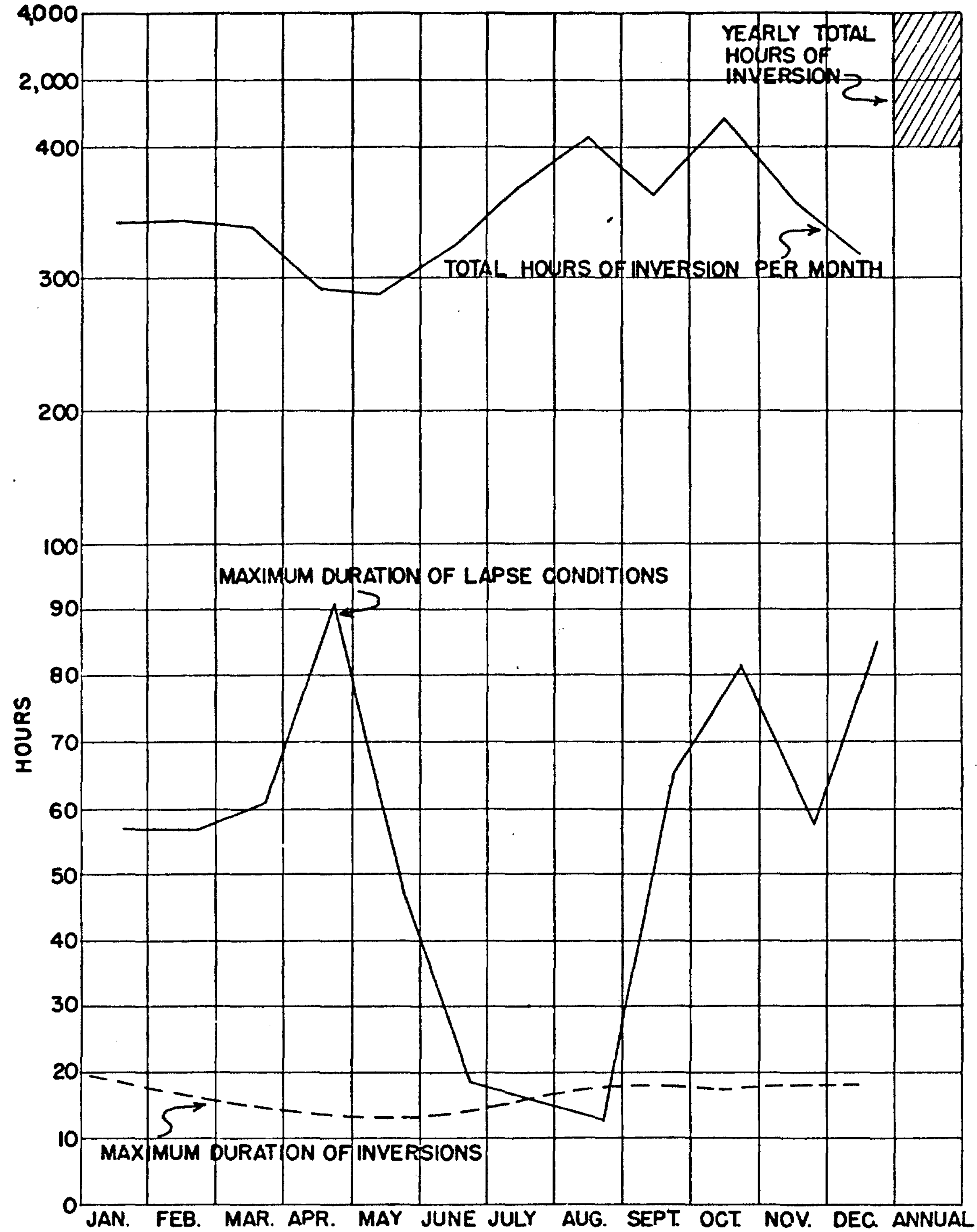
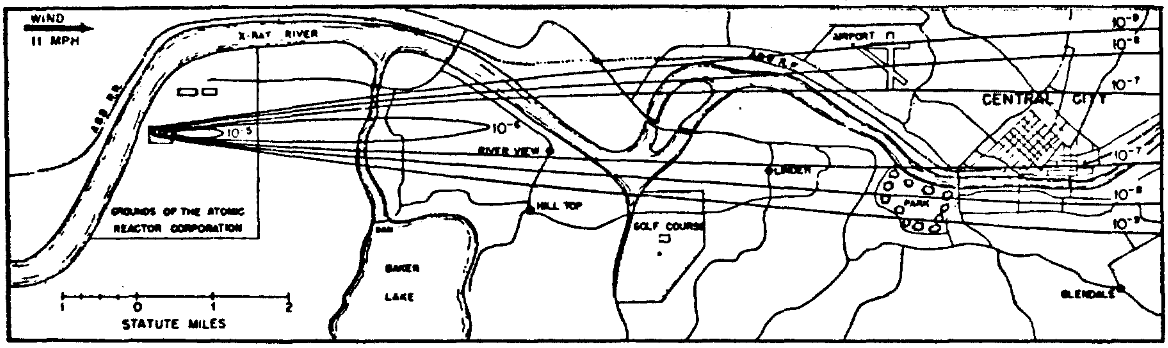
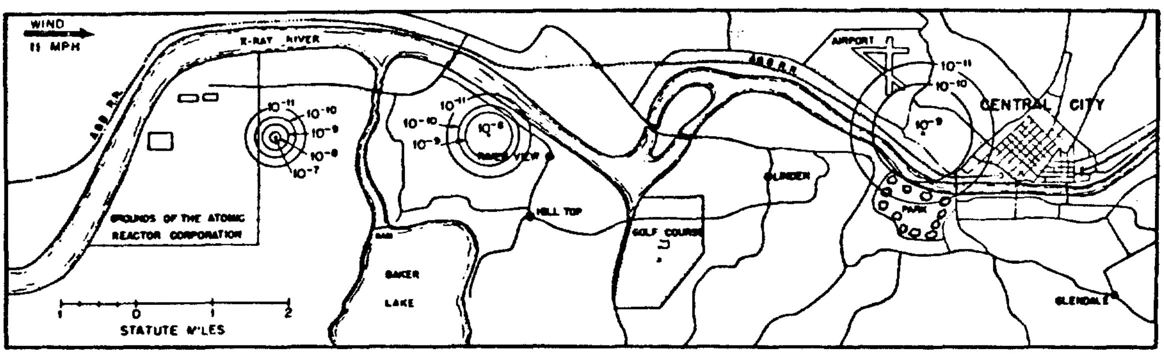


FIG. 3 LAPSE RATE DURATION



(a) Surface concentrations for continuous release from 50 meters



(b) Successive surface concentrations for instantaneous release from 50 meters (8 minutes, 23 minutes, and 53 minutes)

Figure 4. Isopleths of ground concentration (from Sutton formulae).