Errata Sheet for Summary Report to:

DIVISION OF ENGINEERING
U.S. ATOMIC ENERGY COMMISSION

Entitled

MEDIA FOR

AIR CLEANING AND AIR-ASSAY PURPOSES

Issued October 3, 1955
Contract No. AT-(30-1)-1013
Arthur D. Little, Inc.

Page 7 - Add word water in Item No. 4, so that it will read:
"Not over 21 mm water at a flow rate of 5 linear feet per minute. 118 mm water at 28 linear ft per minute)"

Page 18 - Change mm to mil in Item No. 4, as follows:
"HV 70 Paper 18 mil thickness"

Page 21 - Add Items No. 7 and 8 following Item No. 6 "Cotton":
"7. Temperate Coniferous Woods"
"8. Temperate Broadleaved Woods"

Page 26 - Add - in equation, as follows:

Where: $E = -\frac{\text{Log}\ \frac{P}{100}}{P}$.

Page 43 - Omit last paragraph:
"Attached is a small sample....."

MEDIA FOR AIR CLEANING AND AIR-ASSAY PURPOSES

Summary Report to
DIVISION OF ENGINEERING
U.S. ATOMIC ENERGY COMMISSION
Under Contract AT-(30-1)-1013

October 3, 1955
C-58197

ARTHUR D. LITTLE, INC.

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I. ABSTRACT

Work was completed on the high-temperature, high-efficiency air filter. Technical assistance was given at a large-scale, privately financed run of an all-glass medium. Full-size filters have been produced in quantity and are offered by manufacturers; it is considered that commercial manufacture has been established.

A survey was made of air-sampling practices at 37 laboratories. Analysis of the survey results indicated that 22 different kinds of air-sampling filter media were in use among the laboratories questioned. We have recommended that air-assay practice be simplified by use of fewer media. A group of five media has been proposed as adequate for meeting all requirements.

Laboratory work was done on the development of a high-efficiency, low-ash, all-purpose, air-assay paper. Two methods of approach were tried. In one an effort was made to produce cellulose fibrils in sufficient quantity and quality to act as the fine-fiber component of a filter. Only moderate success was attained. Better promise was shown by combining synthetic organic microfibers with cellulose fibers in a wet-formed sheet. No plant work was undertaken on this item.

II. INTRODUCTION

This is a final report on work done by Arthur D. Little, Inc., for the Atomic Energy Commission under Contract No. AT-(30-1)-1013 for the period ending December 31, 1954.

During the time covered by this report various items were included in the program. These were:

1. Completion of work on the development of suitable high-temperature, high-efficiency filters and media.
2. Survey of air-sampling media and sampling methods used at AEC areas and others.
3. Development of a low-ash, high-efficiency air-sampling paper.
4. General consulting service and technical assistance to the Atomic Energy Commission and its working groups on the subject of air cleaning.

Much of the material included in this report has been presented already upon one occasion or another. It is now brought together as a summary along with material presented for the first time. Several complete units of this older material have been inserted as appendices. This was done both for the purpose of presenting them in report form, and so that they might serve as items of reference.

III. HIGH-EFFICIENCY, HIGH-TEMPERATURE MEDIA AND FILTER

In our report of August 18, 1953, NYO 4527, entitled "Development of a High-Temperature, High-Efficiency Air Filter," procedures were given for commercial production of all-mineral, fiber-filter media and directions for the construction of filter units. Mineral fiber filters are intended for use where high temperature (500°F) must be withstood, where there is danger of fire, or where corrosive fumes or humid conditions may prohibit the use of cellulose paper filters.

Since the issuance of that report, we have assisted in establishing production of mineral-fiber media in commercial quantity. Manufacture of the filter units also has been established. Figure 1 is a photograph of a 1000 cfm unit manufactured by Cambridge Filter Corporation using an all-glass medium, steel frame, and a ceramic cement seal. This is the design developed by us for AEC.

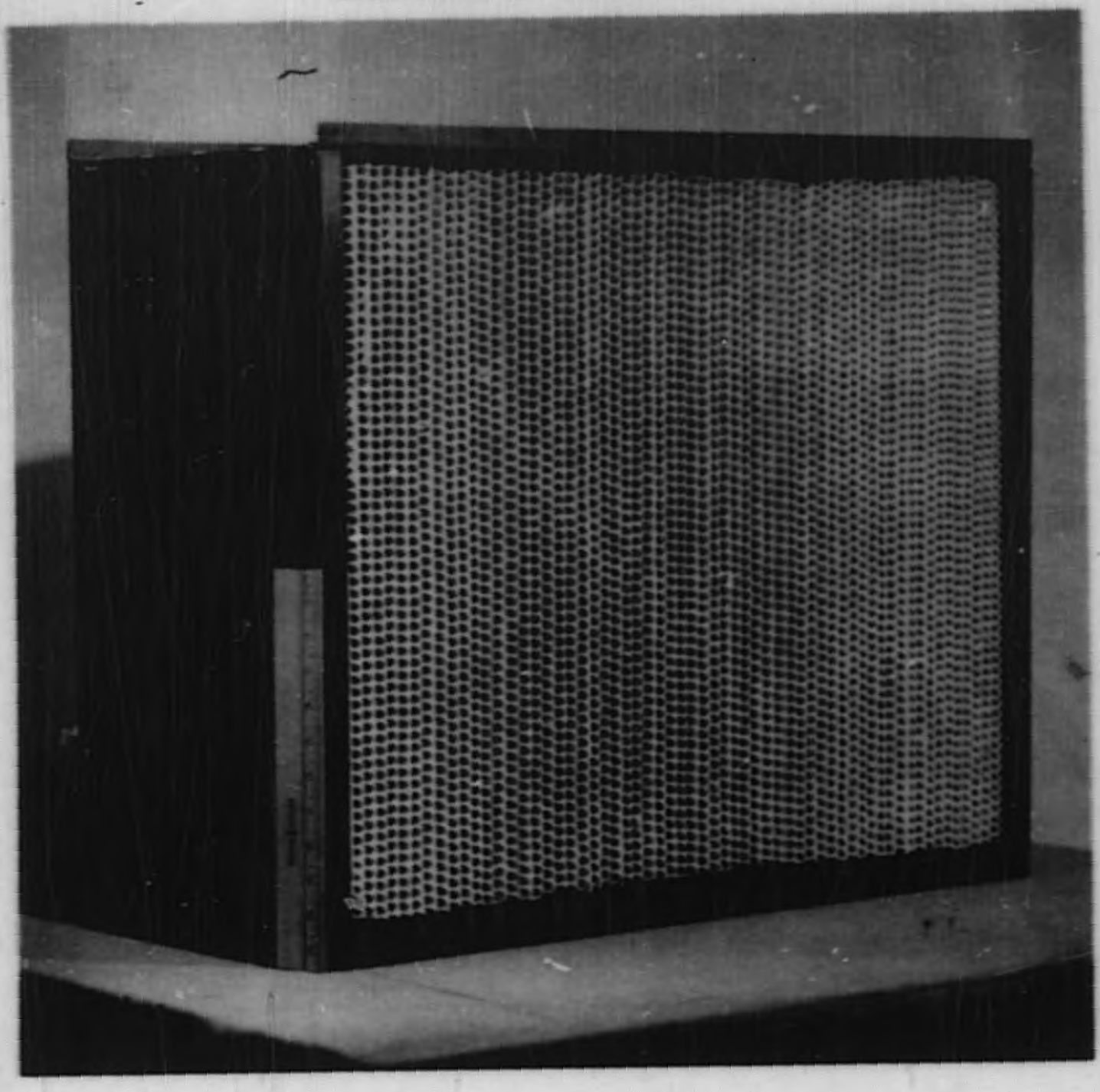
Two paper manufacturers have demonstrated ability to produce mineral-fiber media commercially: Riegel Paper Corporation, Milford, New Jersey; and Hollingsworth and Vose Company, West Groton, Massachusetts. Two manufacturers have indicated to us that they are prepared to supply the Government with high-temperature, high-efficiency filters: Cambridge Filter Corporation, Syracuse, New York; and Flanders Mill, Riverhead, Long Island, New York. We understand that Mine Safety Appliances Company, Pittsburgh, Pennsylvania, also offers this filter.

Mineral fiber paper or media of three kinds have been proposed for air filter use:

1. AEC all-glass fiber with resin binder.
2. AEC glass-and-asbestos with resin binder.
3. H&V glass-and-asbestos with hemp binder.

FIGURE 1

HIGH-TEMPERATURE, HIGH-EFFICIENCY AIR FILTER
1000 CFM COMMERCIAL UNIT
(CAMBRIDGE FILTER CORPORATION)



All of these media can be used to make good-quality filters for high-temperature use. We have recommended the all-glass type for several reasons. All of the materials are domestic, and supplies would not be shut off in the event of war or other international complication. The glass sheet has better mechanical properties. In manufacture, the all-glass medium is easier to make, and control of its performance characteristics is more certain.

The asbestos-containing media have been cheaper solely because asbestos is less costly than fine grades of glass fiber. However, only blue Bolivian asbestos or blue African asbestos is suitable for this application. No domestic asbestos has been found that is usable. Because of this limitation, reliance should not be placed on asbestos-bearing papers by the Atomic Energy Commission or any other Government agency.

In our experience, fine glass fibers have been easier to handle than asbestos. The fact that papers made with glass are more readily controlled in manufacture has helped to offset partly the higher cost of glass fiber.

We urge strongly that encouragement be given to manufacturers of glass fibers who have been cooperative and patient in developing and supplying fine fibers. We believe that glass fibers must be favored in the manufacture of high-efficiency, air-filter media if the national interest is to be best served.

We believe that the situation is now excellent with respect to availability of high-efficiency, air-cleaning filters. This applies to low-temperature filters as well as those that are noncombustible, and resistant to moderate heat. This fortunate procurement situation must be preserved.

If the binder in mineral paper filter units must be burned out after the filters are installed, the question of added heat generation may need to be considered.

This effect is discussed more fully in Appendix A. The problem can be eliminated entirely if the manufacturer were to burn out the binder before shipment of the filter. Where possible, this step should be avoided since glass-fiber medium is weakened by heat cleaning and becomes more susceptible to damage in shipment.

If filters are required to operate at temperatures above the limit set by glass fibers, it is recommended that they be made of Fiberfrax (The Carborundum Company) in combination with asbestos. Fiberfrax alone may be used if fibers of sub-micron size can be procured. They can be wet processed in the same way that glass fibers are handled.

A. Specifications

In the past some confusion has existed regarding performance characteristics of high-efficiency, air-cleaning papers. Part of the trouble is explainable by the variation of paper efficiency with air-flow rate. This effect is illustrated in Appendix D, Figures 1 and 2.

Most of the papers for space filters are used at a low air-flow rate--about five linear feet per minute. At this low-flow rate, efficiency is high. However, it has been the practice to test papers at 28 linear feet per minute. Efficiency is then much lower, and a higher DOP penetration is acceptable. This practice can be followed if the relationship between flow rate and efficiency is well understood. We believe that it is more satisfactory to specify efficiency of the filter medium at the flow rate of use. If a paper is to be used in a standard space filter, its efficiency at five linear feet per minute should be stated.

All of the high-efficiency media, whether for low-temperature use like the cellulose-asbestos types or all-mineral types as 1, 2, and 3, described earlier in this section, can be made to meet a single set of requirements. We offer the

following general tentative specifications to be applied to all high-efficiency filter media.

1.	Composition: (As required by filter manufacturer.)	a. Cellulose and asbestos (CWS No. 6 or AEC No. 1). b. Cellulose and fine-glass fiber. c. Glass fiber - asbestos. d. All-glass fiber.
2.	Thickness:	.038" ± .005".
3.	Tensile Strength:	1-1/2 lbs minimum per inch of width tested in machine direction.
4.	Resistance to Air Flow:	Not over 21 mm at a flow rate of 5 linear feet per minute. (118 mm at 28 linear ft per minute.)
5.	DOP Penetration: (Using 0.3 micron diameter particles.)	Not more than 0.04 per cent at a flow rate of 5 linear feet per minute.
6.	Fold Resistance:	Paper should be foldable back on itself 180° without development of cracks that will impair its performance.
7.	Water Repellency:[1] (Treatment as required by filter manufacturer.)	Treated paper should support a water column 20 inches high without immediate penetration.
8.	Mold Inhibitor:	Commercial products such as Zealate or equivalent.

[1] Water repellency treatment cannot be applied to glass-fiber papers.

IV. SURVEY OF AIR-ASSAY PRACTICES AND EVALUATION OF AIR-ASSAY MEDIA

During 1953 we conducted a survey to determine the requirements of various laboratories with respect to air-assay media. Questionnaires were sent to about 40 laboratories, both within AEC operations and outside. Returns from this survey provided information on sampling practices in general and specific data on the kinds and amounts of media then in use for air-sampling purposes throughout the country. Nearly all of the laboratories contacted provided the information that was requested.

Appendix C is a review of the survey, including a list of the laboratories and individuals contributing data. Details of the survey are given in the single chart of Appendix C. This chart was presented at the Air Cleaning Conference in Los Alamos, September 21, 22, and 23, 1953. A study of this chart will give a complete review of air-assay practices throughout the laboratories included in the study.

Replies were received from 37 laboratories, but many of them reported upon two or more applications of air-sampling media. As a result of this, there were reports on 85 applications of media.

While it is impossible to generalize on the practices of so many laboratories with their varying needs and conditions, we can make a few summarizing observations on the over-all practices in the use of air-sampling media with respect to AEC applications. As would be expected, much of the interest is in radioactive, airborne particulate matter. The chart shows that out of 85 applications, 65 were reported as dealing with radioactive dusts, while only 16 were concerned with non-radioactive dusts. Several tables have been compiled from data of the main chart. These tables are presented for the purpose of bringing out important points that may need to be considered in establishing standards for air-sampling media.

Table I of this section shows the character of aerosols under consideration. The greatest interest by far is in solid particulates, which are mostly atmospheric dust or metallic dusts, oxides, or fumes.

Table II shows the popularity of various assay-sampling media. The most frequently mentioned media are the various Whatman chemical filter papers, with No. 41 the prominent favorite. HV 70 paper was listed more often than any other single paper and, while only 24 users are shown compared with 23 users of Whatman No. 41, 11 times as much HV 70 was used. Other high-efficiency papers are shown as being used in lesser amounts than HV 70.

Molecular membrane filters are shown to be used in large numbers. They are especially well adapted to making counts under the microscope, and it is expected that this medium will be used in increasing amounts.

Yearly requirements as given by the laboratories make possible some estimation of the amount of business involved in supplying air-assay media. Taking a round figure of 15 cents per square foot for high-quality filter papers of all kinds, the value of assay paper used yearly by all of the laboratories participating in the survey would be about $10,700. The value of membrane-type assay filters at 18 cents each would add another $850 to make the total approximately $11,550. It is possible that the purchased cost of paper and media used for air-assay purposes in all laboratories throughout the country does not exceed $100,000 per year.

Table III shows the properties desired in air-assay media, as expressed in the survey returns. Again the emphasis is on properties useful in making radioactivity measurements. The great majority of users require a low-radioactivity background and ability of the medium to collect particles at the surface. Thickness of the filter is of minor importance.

TABLE I

AEROSOLS UNDER STUDY, IN ORDER OF FREQUENCY

Aerosol Composition	Number of Replies
Atmospheric Dust	33
Metal Dusts, Oxides, and Fumes	21
Chemical Dust	2
DOP Smoke	2
Metal Compounds	1
Fused Silicate	1
Fly Ash	1
Road Dust	1
Carbon Solids	1
Soot	1
Acid Mists	1
Organic	1
Bacteria	1

Particle Form:
Solid in 82 cases.
Liquid in 17 cases.

TABLE II

POPULARITY OF FILTER MEDIA IN USE

		Number of Users	Yearly Requirement
Whatman Papers:	No. 41	23	5,000 sq ft
	No. 40	5	950
	No. 4	2	460
	No. 1	2	1,175
	No. 32	1	50
	No. 42	1	1,300
	No. 44	1	25
	No. 50	1	175
	Total	36	9,135 sq ft
HV 70 (both thicknesses)		24	55,000 sq ft
Molecular Membranes:			
Millipore		4	3,600 sheets
Goetz		2	600 sheets
S & S		1	500 sheets
CMS:	No. 6	4	3,200 sq ft
	No. 5	2	150 sq ft
Type "S"		4	1,600 sheets 4 inch dia.
AEC No. 1		1	2,000 sq ft
MSA Comfo		1	3,000 4 inch sheets
MSA HM 2133		1	-
Special Cellulose & Synthetic Fiber		1	-
Glass Wool		1	-
S & S No. 60		1	700 sq ft
Miscellaneous		1	-

TABLE III

PROPERTIES DESIRED IN SAMPLING MEDIA

	Yes	No
Need to be destroyed by ignition.	22	27
Need to be destroyed by chemical digestion.	38	37
Need to be ash-free.	21	26
Importance of thickness.	12	59
Need for low radioactivity background.	62	18
Need to withstand chemical treatment.	10	63
Need to withstand heating treatment.	4	68
Need for surface collection.	55	26

Chemical composition of the filter material becomes a matter of consideration if the arrested particulate matter is to be isolated by destroying the filter. About 45 per cent of the replies indicated that the filter was to be ignited and so must be ash-free. Half of the replies to the question regarding chemical digestion showed that method to be in use. Out of the full 85 replies, 35 stated that the filter was not to be destroyed for analysis of the collected material.

Table IV summarizes the analytical methods reported in the survey. If we add the cases where radioactivity measurements are made by count, metering, photographic, or radioautographic methods, we have a total of 151. Chemical methods appear to be next in importance with 38 cases; followed by optical methods with 32; spectrographic, 27; light and electron microscope, 12 each; gravimetric, 8; and biological, 6.

A. Study of Air-sampling Media

The survey showed that 22 different media were in use among the various laboratories. One object of the study was to help simplify sampling practice, where possible, and to reduce the number of sampling media. As a preliminary to making any firm recommendations, it was necessary to compare the various media for performance under a uniform set of conditions.

Samples of the media reported in the survey were obtained, and properties were studied. This work was done at a time when the subject was also of interest to the American Society For Testing Materials. By permission of the Atomic Energy Commission, the data relative to air-assay-media performance was given in a paper presented before the ASTM July 1, 1953, in Atlantic City. For reference, this paper is included as Appendix D.

Because the survey indicated a generally prevailing interest in collection of particle sizes down to a tenth micron or less in diameter, the filtering properties

TABLE IV

SUMMARY OF ANALYTICAL METHODS EMPLOYED IN LABORATORIES REPLYING TO QUESTIONNAIRE

Method	Number of Users
Gravimetric	8
Optical Methods:	
Light Transmission	20
Light Reflection	4
Turbidometer	8
Direct Microscope Examination:	
Particle Count	10
Estimation	2
Photomicrograph:	
Particle Count	5
Estimation	2
Electron Microscope	12
Spectrographic	27
Radioautograph	44
Radioactivity Measurement:	
Count	62
Metering	22
Photographic	23
Chemical Methods	38
Biological	6

of media were tested. Comparisons were made using the DOP (dioctyl-phthalate) smoke penetration test (employing 0.3 μ diameter aerosol particles), and atmospheric dust particle counts. Also, an effort was made to show efficiency by particle size. In addition, filtering efficiency as a function of flow velocity was measured for the various media. Life tests or rate-of-plugging were determined for all media using identical conditions of atmospheric dust loading. General properties of the various media were listed as a guide to use of the media. Finally, an effort was made to determine the uniformity to be expected in available assay media.

B. Selection of Assay Media

As a result of the survey and subsequent comparison of air-assay media reported to be in current use, it was evident that a small number of media could be selected that would meet all requirements.

A very wide range of chemical filter papers are offered by several manufacturers. Ten different chemical filter papers were reported in use throughout the survey areas. We might begin the simplification by examining the performance range of these chemical papers and their reported applications. Table I of Appendix D compares the papers for DOP smoke penetration and air-flow resistance at various flow rates.

It is seen that the favorite, No. 41 Whatman paper, has low efficiency on DOP particles of 0.3 micron diameter, but also low resistance to air flow. For larger particles, the efficiency of No. 41 paper is better--63 per cent retention of 1.0 to 2.0 micron diameter particles, and complete retention of particles above 2.0 microns. At high-flow velocities, efficiency improves greatly, even for 0.3 micron diameter particles (Figure 3, Appendix D). Thus, No. 41 Whatman paper and papers of equivalent grade would appear to be very useful for high-volume sampling work. At 200 linear feet per minute, pressure drop across the paper would be only about 18 inches of water, collection efficiency would be 85 per cent for 0.3 μ particles, and

larger particles would be collected with even greater efficiency. All of the benefits of high-purity, low-ash, low-radioactivity background, and ready availability go with this paper. Already it has an established acceptance in a large number of laboratories. However, better uniformity in air-filtering properties would be desirable (Table IV, Appendix D).

There are applications where it is necessary to collect very small particles at high efficiency. The special papers designed for this purpose are satisfactory until it is required to work with low-ash media. Again we are back to chemical filter papers. Of these, Nos. 32, 42, and 44 have low penetration on DOP smoke at low-flow rates, and No. 50 is effective above 28 linear feet per minute. If a choice were to be made, it might be No. 44. Again the question of uniformity of air-filtering properties applies.

It has been stated elsewhere that the membrane-type filter possesses most of the properties desired in an air-assay medium. They are especially useful when it is desirable to examine the arrested particles under the microscope. Particles are collected gently and are held at the filter surface. They then may be viewed to excellent advantage under oil immersion, whereby the filter material is rendered invisible. Although pressure drop is somewhat higher for membrane filters than for other high-efficiency media, collection is nearly complete for particles down to 0.3 micron diameter. This type filter plugs but slowly on solid particles. Membrane filters plug rapidly on liquid aerosols.

In Table VI of Appendix D the ash content of two membrane filters is shown as 1.5 per cent. Recent samples have shown almost no ash content. We have been assured by Millipore Filter Corporation that the normal ash content of their filters is less than 0.1 milligram per 47 mm disc. Accordingly, the membrane filter can be used for air-assay work where it is necessary to ignite or otherwise destroy the filter

in order to analyze material collected upon it.

Continuous monitoring instruments are in service that require the use of filter media in rolls. HV70 paper is commonly used for this application. This is a high-efficiency, asbestos-containing paper, carefully manufactured for the express purpose of filtering air and other gases.

For the relatively few cases where filtration must be done at high temperature or where the use of cellulose is not desirable, fine glass-fiber media are suitable.

7. RECOMMENDED AIR-SAMPLING MEDIA

It is our considered opinion that nearly all of the needs of the Atomic Energy Commission for air-assay work can be met by the following group of five available filtering materials:

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

These media would be used as follows:

1. Whatmann No. 41

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

2. Whatmann 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 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)

VI. DEVELOPMENT OF AN ALL-PURPOSE AIR-ASSAY 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:

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; success has been attained on a laboratory scale.

A. Cellulose Fibers

A low-resistance, high-efficiency paper based wholly on cellulose requires the use of very fine fibers with low degree of hydration. These fibers could be

used alone or in combination with larger-diameter fibers. Ideally, the fine fibers would be in the size range of one-micron diameter, or less. Unfortunately, there is no ready natural source of fibers of such fineness. Following[1] are some dimensions of typical natural cellulose fibers:

Source	Fiber Diameter in Microns
1. Straws and Grasses	9 - 13
Rice Straw	8.5
2. Stalks and Reeds	8 - 20
Sugar Cane Bagasse	20
3. Woody Stalks with Bast Fibers:	
Woody Stems	10 - 11
Bast Fibers	16 - 20
4. Leaf Fibers	16 - 18
5. Bamboos	14
6. Cotton:	12 - 20
Temperate Coniferous Woods	32 - 43
Temperate Broadleaved Woods	20 - 40

Among the important fibers of the grass group are wheat, rye, rice, esparto, and sabia. Of those in the group of canes and reeds, sugar cane bagasse and corn stalks may be mentioned.

B. Cellulose Fibrils

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. This fibrillation can be seen in the

[1] Most of this information was taken from Raw Materials for More Paper, Food and Agriculture Organization of the United Nations, FAO Forest and Forest Products Study No. 6.

photographs of Figure 2 by comparing photograph a with b, c with d, and e with f. The fineness of these fibrils can be seen by comparison with Figure 2-h showing a fine, grass fiber--esparto.

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 have occurred to us:

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.

FIGURE 2

CELLULOSE FIBERS AND FIBRILS

a. UNBEATEN COTTON LINTERS

b. COTTON LINTERS BEATEN 4 HOURS IN 18% NaOH

c. UNBEATEN LINEN

d. LINEN BEATEN 8 HOURS IN 18% KOH

e. UNBEATEN COTTON

f. COTTON BEATEN 8 HOURS IN WATER AND SCREEN WASHED (200 MESH)

g. WHATMAN #42 FIBER

h. ESPARTO FIBER

Of the above methods, a, b, and g,---use of hot water, a brine solution, or alcohol--are ways of inhibiting hydration during the beating operation. This approach also discourages fibril production. It is necessary to swell and soften the primary fibers and so reduce the binding forces which hold fibril bundles together.

Methods c, d, e, and f assume that newly exposed cellulose surfaces will react with the reagent and become less-water sensitive. Thus, a fibril as stripped away from its parent fiber should become unreactive with water, and so remain as a fibril. Although experiments were not conducted exhaustively, use of the surface-reactive agents did not give the results for which we had hoped.

Acetylation of partially beaten cotton fibers (method i) gave some indication of being helpful. However, the process was lengthy and served mainly to preserve those fibrils that were present at the time of acetylation. Beating cellulose-acetate fibers, as such, only chops them into a sand-like condition.

If the fibrils are not beaten or worked, they remain in the presence of water for some time without apparent gelatinizing. For this reason, we thought they might be removed as formed and allowed to accumulate without further working (method h). In the laboratory this was done by beating cotton fibers, removing them from the beater periodically, and washing vigorously on a screen fine enough to let through fibrils while retaining fibers. This was a Tyler size No. 30 screen. It was then necessary to wash the fines on a still finer screen (200 mesh) to remove gelatinized stock. Intermediate material thus isolated showed a high concentration of fine fibrils in the size range of 1 or 2 microns diameter. In some cases beaten fibers were washed only once on the finer screen to remove gelatinous matter so as to retain a mixture of fibers and fibrils for the filter stock. However, even these carefully washed stocks did not produce the filter sheets for which we were working.

Figure 2-f is a photomicrograph of fibers prepared in this way.

Attempts were made to pretreat cellulose fibers so that they would be more susceptible to fibrillation when beaten later. Processes are known in which wood fibers are exploded by allowing them to discharge from a condition of high temperature and pressure while moist with water. We were unable to get any effective improvement of fibrillation in cotton by exploding from pressures up to 50 psi in an experimental bomb.

We sought to employ the forces of expansion as water freezes. Cotton soaked in water was frozen in a refrigerator freezing compartment to -15°C, then thawed and beaten in the usual manner. This simple treatment alone did not help noticeably. Greater swelling of fiber was sought by treating the cotton in sodium hydroxide, followed by freezing. No definite indication of improved fibrillation was obtained.

Use of sodium hydroxide in the beater seemed to be helpful in promoting production of fibrils, and many experiments were run in which we tried to take advantage of this tendency. (Figure 2-b and d.)

In the simple beating of cotton in plain water, the progressive changes in the fiber mass lead to papers of increasing effectiveness as filters, but with increased resistance to air flow. To study the relation of these two properties, cotton linters were beaten in water at a pulp consistency of 3 per cent in a Valley beater using a weight load of 2250 grams on the bed plate lever arm. The pulp was sampled at intervals, handsheets were cast from the samples, and DOP smoke penetration tests made. Following are the changes which occurred as beating was continued for four hours:

Sheet No.	Beating Time, Hrs.	Sheet Thickness, Inches	Δ P Pressure Drop, mm Water	Δ P Pressure Drop, Inches Water	DOP Smoke Penetration, %	E
355	0.5	.044	1.5	.059	89.0	2.7
356	0.5	.031	1.0	.039	93.0	3.0
357	1.0	.050	12.0	.47	84.0	0.75
358	1.5	.043	19.0	.75	77.0	0.58
359	2.0	.038	58	2.3	54.0	0.47
360	2.5	.039	110	4.3	41.0	0.36
361	3.0	.034	210	8.3	22.0	0.32
362	3.0	.023	110	4.3	46.0	0.30
363	4.0	.016	900	35.4	0.02	0.41
364	4.0	.018	350	13.8	2.2	0.48
365	4.0	.023	1040	41.5	0.011	0.38
366	4.0	.026	560	22.0	2.0	0.30

Pressure-drop measurements and DOP smoke penetration were measured at an air-flow rate of 28 linear feet per minute.

There is a rapid increase of flow resistance as beating is continued. The quantity "E" describes the value of the sheet as an air filter when tested against a dioctyl phthalate smoke of uniform particle size at 0.30 micron diameter.

Where: $$E = \frac{\text{Log } \frac{P}{100}}{\Delta p}$$

P = % Penetration

Δp = Pressure Drop, mm H_2O

Chemical filter papers, such as are used in chemical laboratory filtrations and which are now often used for air-assay work, are sold in various grades. These grades cover approximately the range of performance shown by the various sheets produced in the above experiment. See Table I of Appendix D under Whatman Chemical Filter Papers and across the line indicating a flow rate of 28 linear feet per minute.

Our work on all-cellulose, air-assay papers has not resulted in any noticeable improvement over standard chemical filter papers when used for the same purpose. However, cellulose fibers, in combination with certain fine, synthetic organic fibers

have given experimental papers of outstanding promise. These are discussed under the next subject.

C. Synthetic Organic Fibers

In the past few years, much effort has been expended by various laboratories on the development of synthetic organic microfibers. The Naval Research Laboratory and E. I. duPont de Nemours & Co. have produced the fine fibers of a number of fusible synthetic resins. We have had limited samples of the products. The American Viscose Corporation has been successful in producing very fine fibers of dynel, acrylonitrile, and vinyon. Our association with the work of American Viscose Corporation has made their fibers more easily available to us, and in quantities sufficient to permit handsheet work in the laboratory.

Although all of the laboratories engaged in development of microfibers have produced very fine fibers (less than one micron diameter), we have had practical quantities only of fibers in the size range of 1 - 2 microns.

The synthetic organic microfibers may be air-laid to form uniform webs or mats which are excellent as air filters. However, webs so made do not have the properties of paper. They tend to be sleazy and lack the compactness so desirable in an assay paper. For some purposes such dry-formed sheets could be useful.

With proper control of conditions, the very fine fibers produced from spinnable synthetic resins can be wet-formed into very effective air-filter media. Our most successful experimental air-assay papers were made using these fibers combined with cellulose fibers. Sheets so formed can be acid treated to produce a low-ash paper. Following is a typical procedure that has given good results.

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 hydroflucric acids.

We believe that an air-assay paper based on cellulose fibers and fine synthetic organic fibers offers the best approach 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.

APPENDIX A

COMPARISON OF THREE MINERAL FIBER AIR-FILTER MEDIA

(copy)

January 5, 1954

U. S. Atomic Energy Commission
Division of Engineering
Washington 25, D. C.

Attn: Mr. Joseph A. Lieberman,
Sanitary Engineer

Gentlemen:

We are sending to you enclosed four copies of a memorandum report describing test work in which three types of mineral fiber papers have been compared for air filter use. This work was prompted by the request to evaluate a sample of hemp-containing glass-asbestos paper submitted by Hollingsworth & Vose Paper Company.

On filtering performance alone (DOP smoke test) the H&V paper showed better properties than either the glass-asbestos or all-glass paper samples with which it was compared. This is not a highly significant point since such properties can be varied. It is sufficient to say that the paper is certainly acceptable on this score. The filtering properties of all three papers remained unimpaired when the binder was burned out.

The H&V paper was definitely weaker in tensile strength than either of the other papers. Again, this property is one over which there is some control, and it may be that improvement could be effected.

We have been well aware that the use of organic materials with mineral fibers is undesirable since it provides a certain amount of combustible material in a filter which otherwise is non-combustible. However, every effort has been made to hold the amount of organic matter to a minimum. Combustion tests showed that the H&V hemp-containing paper would present more of a smoke and fire hazard than either of the resin-bound papers.

There would be no objection at all to organic binders if they were burned out of the filter by the manufacturer. We have considered the advisability of recommending this step. Differences in amount of binder would then be of no consequence.

It is our recommendation that the H&V paper be considered further as a possible medium for use in high-temperature or non-burning filters. We would like to see tensile strength improved and the amount of organic binder reduced. Even in its present form the paper is not inflammable and would certainly be an excellent substitution for the present cellulose-asbestos paper for those applications where fire hazard must be reduced.

We would be pleased to give our further attention to this subject.

Very truly yours,

ARTHUR D. LITTLE, INC.

/s/ Walter J. Smith
Walter J. Smith

Enclosures
WJS:cmc

MEMORANDUM

(copy)

To: Walter J. Smith Case: 58197 Date: Dec. 31, 1953 Page: 1.

Subject: Comparison of Three Mineral Fiber Air Filter Media

We were asked to examine a sample of mineral fiber paper submitted by Hollingsworth & Vose Paper Company and evaluate its utility in relation to mineral fiber papers which have been developed for AEC uses. The H&V paper was described as containing mostly glass and asbestos fibers with a small amount of hemp to serve as the binder.

The following tests were carried out in the course of our examination:

1. Combustion Hazard
2. Performance of Paper Before and After Heating
3. Fire Propagation Through Finished Filters
4. Organic Content of the Media

Comparisons were made among the following media:

a. AEC Glass-Asbestos Medium

b. AEC All-Glass Medium

c. H&V Glass-Asbestos-Hemp Medium

1. Combustion Hazard

Three model filters were built using the usual pleated construction and aluminum separators. One filter each was made with the three kinds of media. Outside dimensions of the filters were uniform, 12" x 12" face area, 12" depth, but the number of pleats varied because of differences in paper thickness:

Medium	Binder	Tensile Strength	Thickness	No. of Pleats
AEC Glass-Asbestos	Resin	2-1/4 lb/in	.037"	40
AEC All-Glass	Resin	3-1/4 lb/in	.045"	36
H&V Glass-Asbestos	Hemp	1-1/2 lb/in	.030"	43

To obtain an indication of the combustibility hazard for each of the filters, they were tested one at a time in the following way:

The filter was placed in an oven having a circulating air system. A thermocouple was run into the oven through the thermometer hole and the junction inserted into the center of the filter body. The oven temperature was brought up gradually using high heat control to 500°F then maintained at approximately that temperature until temperature within the filter returned to 500°F and indications were that all binder was burnt off.

Temperatures were recorded for the air within the oven and for the center of the filter. Figures 1, 2, and 3 show the plotted readings. In each case the filter temperature rose above the oven temperature due to combustion of the binder.

The glass-asbestos filter gave off slight smoke at oven temperature at 500°F and 497°F within the filter. Moderate amount of smoke was noted at 507°F oven temperature and 528° within the filter. Less smoke was noted at 611°F within the filter and stopped smoking at 583°F within the filter on the cooling side of the cycle.

The all-glass filter gave slight smoke at oven temperature of 467.6°F and 404°F within the filter. Moderate amount of smoke was noted at 502°F oven temperature and 550°F within the filter. Less smoke was noted at 553°F within the filter and stopped smoking at 500°F within the filter on cooling down stage.

The Hollingsworth and Vose glass-asbestos-hemp filter gave off slight smoke at 313°F oven temperature and 219°F within the filter. Moderate smoke was noted at 349°F oven temperature and 267°F within the filter. Moderate-to-heavy smoke was noted at 424°F oven temperature and 360°F within the filter. Less smoke was noted at 504°F oven temperature and 761°F within the filter and stopped smoking at 667°F within the filter.

It will be noted that the increase in temperature within the filter was greatest for the H&V hemp-bound medium.

2. Performance of Paper Before and After Heating

For the purpose of observing whether the media might have been impaired by loss of binder in the oven heating, samples were removed from various parts of the filters and tested for DOP penetration at 28 linear feet per minute. Table I shows the results for the three papers compared with the same papers in the new or unheated condition. (See following page)

3. Fire Propagation Through Finished Filters

Small filters were made up of the glass-asbestos, all-glass paper of Arthur D. Little, Inc., and also Hollingsworth & Vose glass-asbestos-hemp paper. These filters had approximately 20 pleats and were approximately 6-1/2" x 6-1/2" x 5-1/2" in size, and all filters contained aluminum separators and were incased in a perforated metal frame. Each filter was connected in turn to the intake of a small blower and air drawn through the filter at low velocity. A lighted bunsen burner was placed against the exposed face of the filter to observe if the filter would ignite and support combustion. At a few places on the face of the filter the bunsen burner was placed close enough to give intense heat. The heat in such places was sufficient to melt the aluminum separators. This was done to see if this more severe heating would induce the filter to burn through to the far side.

The glass-asbestos paper filter gave slight smoke from the exhaust end of blower under moderate flame. Using intense heat it glowed some and gave off slight smoke but did not give any indication of sustained burning. In each case when the flame was taken away any glow and smoke stopped at once. On examining the interior

of filter after above testing, slight discoloration showed on surfaces where moderate heat was used. Where intense heat was used the discoloration extended to approximately a depth of one inch into the filter body.

The all-glass paper filter submitted to the same test as described above gave the same intensity of discoloration on moderate heat. The discoloration where intense heat was used extended to a depth of about one inch into the filter. It was noted again that when the flame was taken away the glow and smoke stopped.

The filter made from Hollingsworth & Vose glass-asbestos-hemp paper was submitted to the same test. Under moderate bunsen burner flame heating the filter gave off slightly more smoke at the exhaust end of the blower. Glow seemed to last slightly longer after the flame was taken away. On intense heat it smoked somewhat badly and seemed more nearly to support combustion. On examining the filter afterwards, depth of discoloration was greater than for either of the AEC papers on moderate heat. In places where intense heat was used, discoloration penetrated the full depth of the filter.

4. Organic Content of the Media

Total carbon was determined by direct combustion in an electric furnace at 1000°C and in the presence of oxygen. The carbon was collected and weighed as CO_2. The apparatus and procedure was that normally used for determining total carbon in steel, described in Technical Methods of Analysis by Griffin.

Carbon in the glass-asbestos paper which contained dispersing agent and binder was found to be 3.37%.

Carbon in the all-glass paper which contained dispersing agent and binder was found to be 3.27%. The percentage of carbon in the glass-asbestos-hemp paper of Hollingsworth & Vose was found to be 5.39%. Assuming there was no other binder used in this paper, the carbon figure represents carbon from the hemp. It would indicate a cellulose content for the paper of 12.1%.

From:

Robert I. Miller

cmc

TABLE I

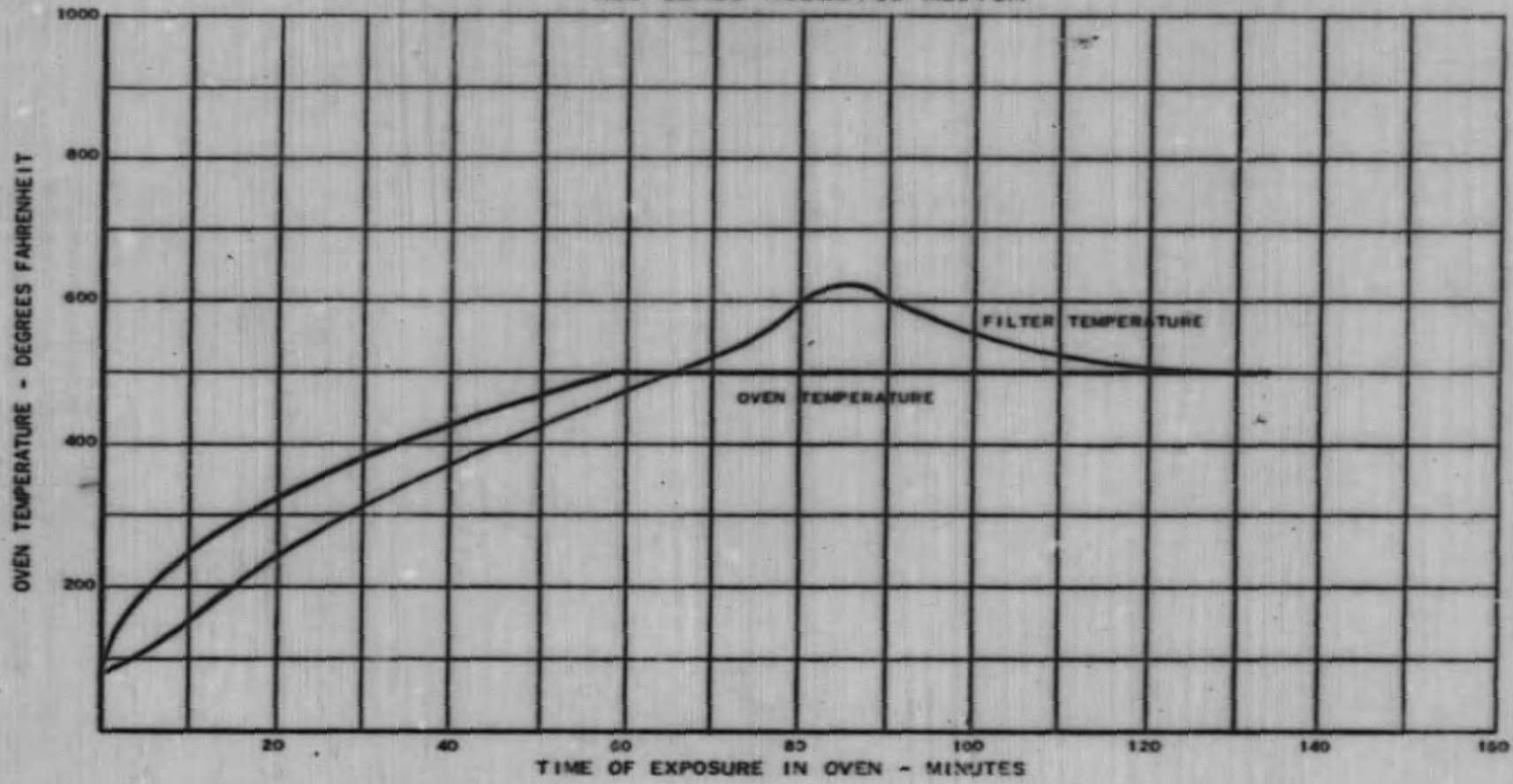
DOP SMOKE PENETRATION TESTS* ON MINERAL FIBER MEDIA BEFORE AND AFTER EXPOSURE TO 500°F OVEN TEMPERATURE

Run No. & Type Paper	Numbers on Samples From Roll	Numbers on Samples From Filter	Before Heating			After Heating			Tests at 5 Linear ft/Min
			Δp	P	E	Δp	P	E	
93061 - Reel 5, Glass-&-Asbestos	1		109	.15	2.60				
	2		108	.14	2.64				
			(18	.06)					1
			(18	.06)					2
		3				109	.11	2.71	
		4				109	.11	2.71	
		5				111	.089	2.74	
		6				109	.11	2.71	
						(18	.043)		3
						(18	.043)		4
						(19	.036)		5
						(18	.04)		6
366 - Experimental All-Glass	5		115	.039	2.97				
	6		112	.046	2.98				
			(20	.0065)					5
			(19	.009)					6
		1				108	.059	2.99	
		2				110	.043	3.06	
		3				109	.021	3.38	
		4				112	.033	3.10	
						(19	.007)		1
						(19	.009)		2
						(19	.009)		3
						(19	.012)		4
Hollingsworth & Vose	1		115	.02	3.20				
	2		114	.02	3.23				
			(20	.012)					1
			(20	.013)					2
Glass Asbestos & Hemp		3				108	.007	3.84	
		4				112	.006	3.76	
		5				107	.007	3.88	
		6				107	.01	3.73	
						(18	.005)		3
						(19	.005)		4
						(19	.004)		5
						(19	.006)		6

*Tests at 28 linear ft per minute except where results are in brackets.

FIGURE 1

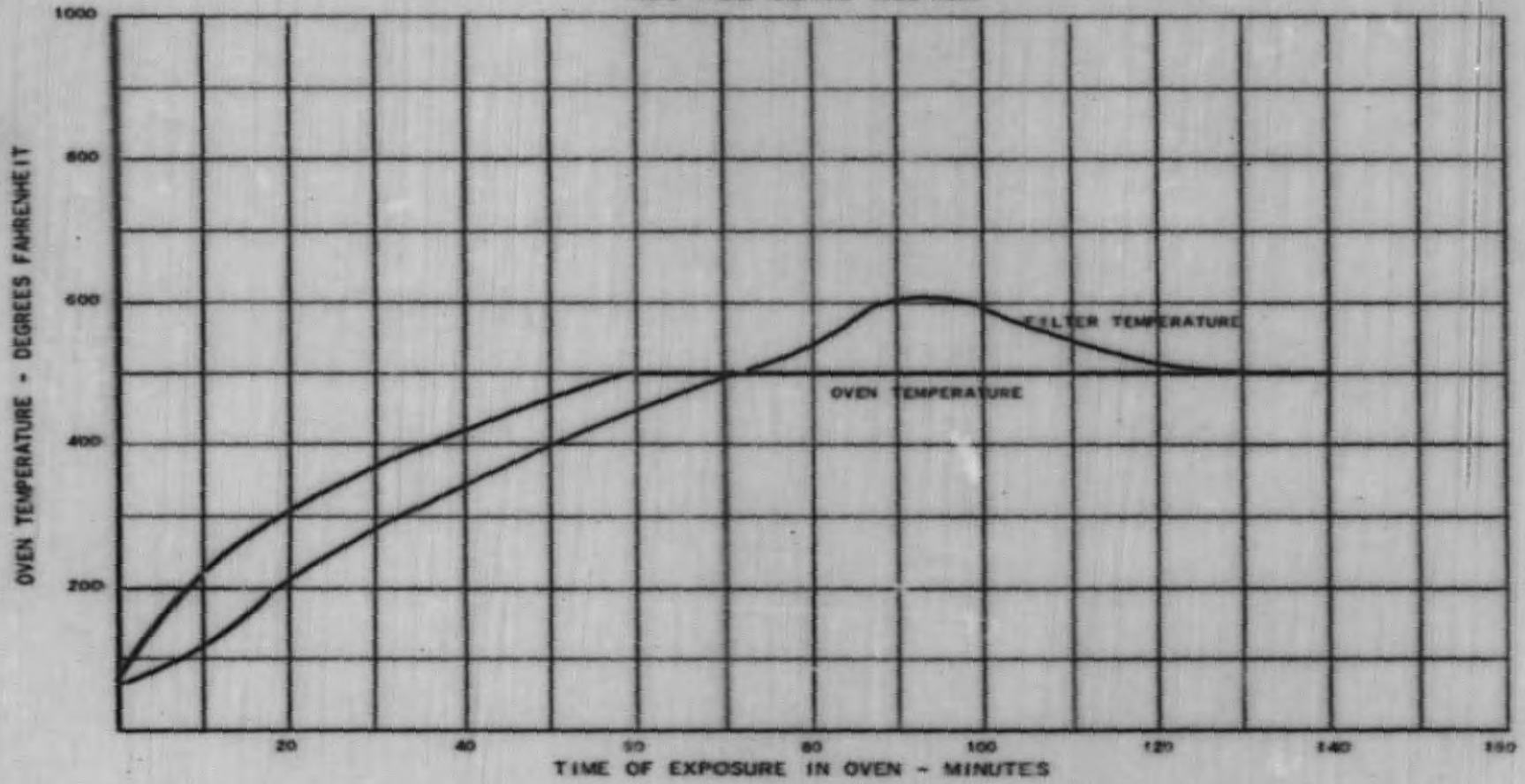
PLOT SHOWING TEMPERATURE RISE IN CENTER OF FILTER MADE WITH AEC GLASS-ASBESTOS MEDIUM



Arthur D. Little, Inc.

FIGURE 2

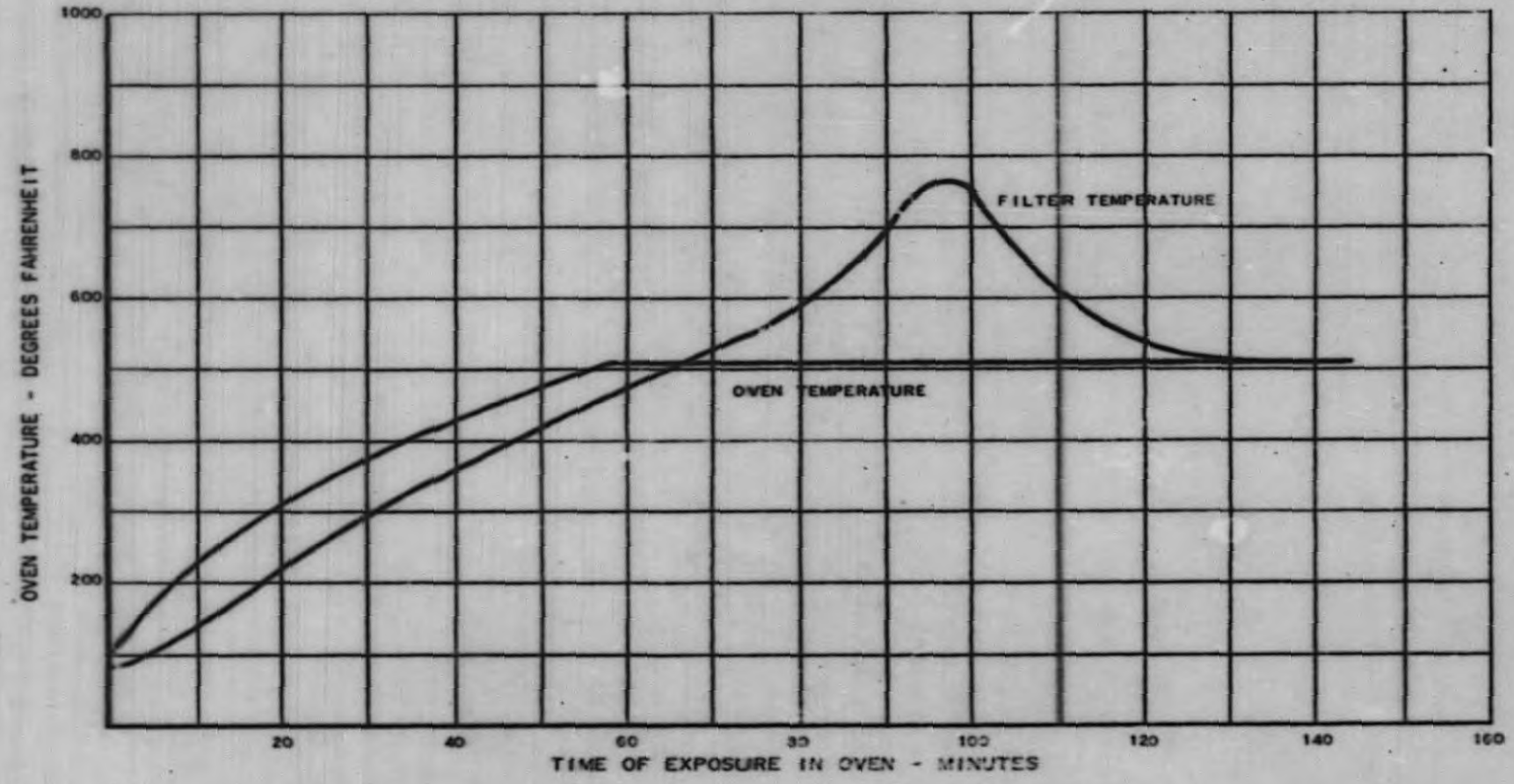
PLOT SHOWING TEMPERATURE RISE IN CENTER OF FILTER MADE WITH AEC ALL-GLASS MEDIUM



Arthur D. Little, Inc.

FIGURE 2

PLOT SHOWING TEMPERATURE RISE IN CENTER OF FILTER MADE WITH HOLLINGSWORTH & VOSE GLASS-ASBESTOS-HEMP MEDIUM



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APPENDIX B

LABORATORY WORK ON DEVELOPMENT OF GENERAL-PURPOSE, AIR-ASSAY PAPER

LABORATORY WORK ON DEVELOPMENT OF GENERAL-PURPOSE, AIR-ASSAY PAPER

A program of experimental work was carried out for the purpose of developing an air-assay paper of the following characteristics:

a. High-collection efficiency on submicron size particles.

b. Low resistance to air flow.

c. Low-ash content.

d. Good strength and fold properties.

e. White.

Equipment employed was that commonly used in a paper laboratory: small beater, sheet molds, steam-heated drum dryer, screens, freeness tester, and Waring Blendor. In addition, we made occasional use of a small Mikro Pulverizer hammermill for dry-shredding pulp.

The laboratory was also provided with a DOP tester, permitting us to make filter efficiency tests on our laboratory handsheets. For all tests, a uniform dioctyl phthalate aerosol of 0.3 micron-particle diameter was used. Concentration was about 50 micrograms DOP per liter of test aerosol. Tests were made, usually at 85 liters per minute through a 5-inch diameter, filter sample disc giving a linear flow rate of 28 feet-per-minute.

All-cellulose Papers:

An effort was made to produce an all-cellulose, high-efficiency paper by favoring the production of fibrils during the beating operation. Studies were made on the fibrillating characteristics of cellulosic materials, including the following:

Wheat straw	Causticized cotton linters
Flax	Cotton
Esparto	Barley
Rice	Alpha cellulose
Bamboo	Soda pulp
Cotton linters	Bleach sulfate

In general, it appeared that cotton or cotton linters gave as good production of fibrils as any of the other fibers tested and was superior to most of them. For this reason, much of the work was done using cotton---either as long-fiber batting, or as linter board.

Various methods of favoring the production of fibrils were tried (discussed in report body). In no case were any sheets of outstanding performance produced. Regardless of the treatment applied, the final filtering efficiency always lay within the range ordinarily found among the chemical filter papers.

Table VI is a collection of data showing some typical results of our attempts to improve performance by favoring fibril formation.

Papers of Synthetic Fiber:

Handsheet samples of paper made with certain finely spun, synthetic organic fibers (always with some cellulose) came close to meeting the characteristics deemed desirable in the ideal paper.

Work was done with fibers of cellulose acetate, vinyon, nylon, dacron, dynel, and acrylonitrile. Our best results were obtained using acrylonitrile. This was partly because we had more of this fiber to work with. It was usually more readily obtained in fine-diameter sizes, and it dispersed more readily in aqueous slurries with the dispersing agents we used.

TABLE VI

PROPERTIES OF HANDSHEETS MADE FROM STOCK TREATED TO FAVOR FIBRIL FORMATION

Sheet No.	Beating Time (Hours)	Kind of Fiber	Preparation of Fiber	Thickness of Sheet	Δp mm (Water)	% Penetration	E	Air Velocity (Liters/min)
7428	1-3/4	Krafelt	Beaten in 0.1% Rhonite 610.	.014	900	0.64	0.24	85
* 228	3.0	Rice	Beaten in 18% NaOH, washed beaten fibers on 200-mesh screen using cold water.	.011	450	2.0	0.38	85
240	3.0	Virgin cotton	Hammermilled fibers before beating; beat in 18% NaOH, washed between fibers on 200-mesh screen using cold water.	.014	860	0.09	0.35	85
257	4.0	Hercules #45 aqua-phobic	Beaten in water, washed beaten fibers on 100-mesh screen using cold water.	.011	770	0.75	0.28	85
368	4.0	Cotton linters	Beaten in cold water 3% consistency.	.017	556	2.6	0.29	85
28	4	Cotton linters	Beaten in 18% NaOH, washed with hot water 140°F.	.030	450	0.25	0.58	85
108	3-1/2	Virgin cotton	Beaten in 6% NaOH, washed with cold water.	.014	700	0.8	0.30	85
53	10	Virgin cotton	Beaten in 18% NaOH, washed with cold water, acidified, rewashed with cold water, hammermilled.	.009	770	0.11	0.38	85
167	1-1/4	Virgin cotton	Beat frozen fibers in water, washed with cold water on 200-mesh screen, boiled washed fibers, and rewashed on 200-mesh screen.	.010	1000	0.19	0.27	67
172	2-1/2	Frozen virgin cotton	Beaten in 6% NaOH, washed, frozen, beat in 0.4% Rhonite 610, washed on 100-mesh screen with cold water.	.013	250	16.0	0.32	85
97	3.0	Virgin cotton	Beaten in water washed on 30-mesh screen using cold water and collected fines on 200-mesh screen, washed with cold water, made pad of fibers, dried, hammermilled.	.010	135	12.0	0.69	85

* Note: Handsheets pressed in letter press before drying.

Following is a procedure which resulted in paper of good performance: Cotton linter board was charged into a one-pound Valley beater. Water was added to give a consistency of one per cent. After 15 minutes with a 7500-gram load on the bed plate arm, the pulp was found to have a freeness of 14 Schopper Riegler at 70°F.

Two grams of acrylonitrile fiber (spun to a diameter of 1-2 microns) were placed in a Waring Blendor with 0.04 g (in 10 ml. water) of Daxad No. 11 and 1200 ml. water. The mixer was operated at highest speed for 4 minutes to shorten and disperse the fiber. One-half gram of cotton linter (dry basic), prepared as described above, was then added to the mixer which was operated for another 15 seconds.

The fiber furnish was diluted to 0.2 per cent consistency and cast in a 6-inch diameter circular mold with a 60x40 mesh screen. Formation was excellent. There was some adhesion to the screen, but this was not serious and could be eliminated by using a finer wire (about 80 or 100 mesh). The sheet was dried on the steam drum while sandwiched between paper blotters.

DOP test on the finished sheet gave a penetration of 0.1 per cent with 270 mm water-pressure drop at an air flow of 28 linear feet per minute. This corresponds to an E value of 1.1.

Ash measurement on the paper gave values of 0.3 per cent and 0.45 per cent on the two samples tested.

Acid extraction to reduce ash content was performed as follows. A 10 per cent acid solution was prepared, containing a mixture of 83.4 parts of hydrochloric to 16.6 parts of hydrofluoric acid. This solution was placed in a paraffin coated dish and the paper sheets put in to soak for 24 hours at room temperature. The sheets were washed free of acid in distilled water and re-dried.

The finished sheets were tested again and found to be unchanged in DOP penetration and air-flow resistance. Ash in the extracted sheets was found to be less than .01 per cent.

While the work with synthetic fibers has given very promising results, we do not consider that the subject has been covered completely by any means. It is recommended and expected that a manufacturer will be found who is willing to do some pilot scale work based on our laboratory results and experience. This should lead to a practical procedure for producing a useful product. We would be pleased to give assistance as needed.

Attached is a small sample of paper made in the manner described except that the acid treatment was not applied. Because of the large number of report copies needed, and because of our limited supply of fiber, we are unable to provide a more generous sample.

APPENDIX C

SURVEY OF AIR-SAMPLING MEDIA AND SAMPLING METHODS USED AT A.E.C. AREAS AND BY OTHERS

SURVEY OF AIR-SAMPLING MEDIA AND SAMPLING METHODS USED AT A.E.C. AREAS AND BY OTHERS

At the A.E.C. Air Cleaning Conference held at Ames, Iowa, September 15-17, 1952, it was agreed that a survey should be made to assemble and summarize information on air-sampling media and sampling methods used by groups doing air-assay work. This survey was to include both A.E.C. areas and others.

The survey was conducted by questionnaire, and an excellent and highly cooperative response was received. A fund of information has resulted which should be of real value to all engaged in air cleaning and in the study of air-borne particulate matter.

An effort has been made to show in a single chart all of the essential information supplied by the survey. A copy of the chart is attached. For the most part, it is self-explanatory.

Across the top of the sheet are given the laboratories and installations, along with the media favored at each site. In some cases several media are used to meet different needs, and this fact is shown.

The side headings represent the various questions that were asked in the survey. Many of these required only a "yes" or "no" reply; others needed more detail. Where an essential piece of information was too lengthy to fit into the chart body, it is shown as a footnote.

Arthur D. Little, Inc.
Cambridge, Massachusetts

September, 1953

QUESTIONNAIRES RECEIVED

Organization or AEC Area	Location	Individual
Air Sampling Equipment Company	Cleveland, Ohio	William L. Wilson
American Cyanamid Company Idaho Reactor Testing Sta. Chemical Processing Plant	Idaho	R. E. Hayden
Ames Area Office, AEC Iowa State College	Ames, Iowa	Allan P. Skoog (Dr.)
Argonne National Laboratory Radiological Physics Div.	Illinois	J. E. Rose
Battelle Memorial Institute	Columbus, Ohio	S. Chapman
Brookhaven National Laboratory Health Physics Division Depts. of Physics, Chemistry, Nuclear Engineering, and Medicine	New York	Lee Gemmell
Brush Beryllium Co. Cleveland Plant	Cleveland, Ohio	F. R. Wolowicz
Luckey Plant	Luckey, Ohio	F. R. Wolowicz
Harshaw Chemical Company	Cleveland, Ohio	A. J. Stefanec
Vitro Manufacturing Co. Health and Safety Div.	-	E. A. McCabe
California, University of AEC Project Contract AT-04-1-GEN-12	Los Angeles, California	Robert J. Buettner
Radiation Laboratory	Los Angeles, California	M. D. Thaxter
California Research & Development Company Livermore Research Lab.	California	R. C. Thorburn
Carbide and Carbon Chemicals Co. Paducah Plant	Paducah	R. C. Baker
Y-12 Area	-	Edward G. Struxness
K-25 Area, C & CCC	-	J. C. Bailey

QUESTIONNAIRES RECEIVED (Cont'd)

Organization or AEC Area	Location	Individual
Chaney, Albert L. Laboratory	Los Angeles, California	Stanley R. Hall (Dr.)
Columbia University Central Aerosol Lab.	New York, New York	Prof. V. K. LaMer
Dept. of Chemical Eng.	New York, New York	Arthur Humphrey
Connecticut State Dept. of Health Bureau of Industrial Hygiene Industrial Hygiene Lab.	Connecticut	Allan L. Coleman
Dow Chemical Company Rocky Flats Plant	-	-
General Electric, ANP, Evendale	Evendale	J. A. Martin
Industrial Hygiene Foundation for America, Inc. Mellon Institute	Pittsburgh, Pennsylvania	W. C. L. Hemeon
Johns-Manville Research Center CWS Contract (not connected with AEC)	Manville, New Jersey	David Sinclair
Knolls Atomic Power Lab. Health and Safety Unit	-	L. J. Cherubin R. Z. Bouton
Los Alamos Scientific Lab. H-1 Radiological Monitoring Section of H Div.	Los Alamos, New Mexico	Dean D. Meyer
Santa Fe Operations Office	Los Alamos, New Mexico	H. F. Schulte Ed Hyatt
Massachusetts, Commonwealth of Dept. of Labor & Industries Division of Occupational Hygiene	Massachusetts	Herwey B. Elkins
Monsanto Chemical Co. Mound Laboratory	Miamisburg, Ohio	J. E. Bradley
National Bureau of Standards U. S. Dept of Commerce Heating and Air Conditioning Section	Washington, D. C.	R. S. Dill
National Lead Company of Ohio Fernald Area	Ohio	R. C. Heatherton

QUESTIONNAIRES RECEIVED (Cont'd)

Organization or AEC Area	Location	Individual
National Reactor Testing Station U.S.A.E.C. Health Physics Division	-	P. Griffiths C. W. Sill
U.S.Weather Bureau Office		Paul A. Humphrey
North American Aviation, Inc. Atomic Energy Research Dept.	-	Alan A. Jarrett
Oak Ridge National Laboratory Health Physics Division	-	D. M. Davis
Phillips Petroleum Co. Materials Testing Reaction	Idaho Falls, Idaho	J. W. McCaslin
National Reactor Testing Station	-	-
Rochester, University of Atomic Energy Project	New York	Robert H. Wilson
Savannah River Plant duPont Health Physics Dept.	-	C. M. Patterson
Stanford Research Institute	Stanford, California	Konrad Semrau
Sylvania Electric Products, Inc.	Bayside & Hicksville, Long Island	Robert P. Gleason
Westinghouse Electric Corp. Atomic Power Division Industrial Hygiene	-	Paul R. Bolton

Arthur D. Little, Inc.
Cambridge, Massachusetts

September, 1953

SURVEY OF AIR SAMPLING MEDIA USED AT A.E.C. AND OTHER AREAS

QUESTIONNAIRE REPLY INFORMATION September, 1953 / AREA AND MEDIA USED	BROOKHAVEN NATIONAL LAB.	MONSANTO CHEMICAL CO MOUND LAB.	JOHNS-MANVILLE RES. CENTER	UNIVERSITY OF CALIFORNIA	LOS ALAMOS UNIVERSITY OF CALIFORNIA	DOW CHEM. ROCKY FLATS	STANFORD RES. INST.	AIR SAMPLING EQUIP.	SYLVANIA ELEC. PROD.	A.L. CHANEY LAB.	COMM. OF MASS.	KNOLLS ATOMIC POWER LABORATORY	BUREAU STANDARDS	COLUMBIA U. CHEM DEPT.	CONN. DEPT. HEALTH	COLUMBIA U. CHEM. DEPT.	UNIVERSITY OF CALIFORNIA RADIATION LAB.	AMES AREA OFFICE	EVENDALE	ARGONNE NAT'L LAB.	WESTINGHOUSE ATOMIC POWER DIVISION	NATIONAL LEAD COMPANY	SAVANNAH RIVER PLANT	IDAHO REACTOR TEST STATION AMERICAN CYANAMID CO.	NATIONAL REACTOR TEST STATION	MATERIALS TESTING REACTOR PHILLIPS PET.	UNIVERSITY OF ROCHESTER	BRUSH BERYLLIUM CO.	HARSHAW CHEMICAL CO.	VITRO MFG. CO.	INDUS. HYGIENE FOUND. OF AM.	N. A. AVIATION INC.	PADUCAH PLANT	CARBIDE & CARBON CHEM. COMPANY Y - 12 AREA	CARBIDE & CARBON CHEM. COMPANY K-25 AREA	OAK RIDGE	BATTELLE MEM. INST.
FILTER MEDIUM																																					
Use Continuous Strips	3" N N N	N N	N N	N N N	N N 1-1/2" N N N N	N	N	3"	N	N	N	N N N N	N	N	N	N	N N N	N	Y	N	N 2-1/4" 5-3/?" N	N Y	N N	N N N	N N N N N N	N N Y	Y Y N N	N N N N N N	N N	N	Y	N N	N	Y N N - -	N	N N N	N
Use Cut Discs	N Various Sizes	[illegible] 3.8cm	5" Squares	47 mm. & 4 in.	1-1/8" N N 4" 4" 47 mm.	2-1/8"	12.5cm	-	4.25 & 9cm	5.5cm	11cm	15cm 13/16" 9"x4" 47 mm 50 mm	2"	3"	13/16"	N	N 3-3/8" 1"	1-1/8"	11cm 1-1/8"	1"	1-1/8" N N 47 mm	1-1/8" & 4"	Several Sizes	1-1/8" N N	1-3/4" 4" 4" 4 x 1-1/8" - 47 mm	1-1/8" N 1-1/8"	N Y Y Y	4" 4" 4" - 4" 4"	1-1/8" -	1-1/8"	1"	7/8" N	1-1/4"	1-1/4" 1-1/4" 1-1/4" 1-1/4"	9 cm	1-1/8" N N	6"
Cut Own Sheets	N N N N	Y Y	N N	N N N	N 4"x9" - N N N N	N	N	N	N	N	N	13/16" N 13/16"	-	Y	Y	Y	9"x4" - -	N	Y	Y	N N N N	N N	Y Y	N Y Y	5"x7" N N N N N	N Y N	Several Sizes	N N N - N N	N N	N	-	N 5"x7"	N	Y Y Y Y Y	N	N Y Y	Y
Thickness	9 mils - - -	9 mils -	- -	- - -	- 18 mils - - - - -	18 mils	-	-	-	5 mils	-	8 mils 6 mils - -	-	1/16-1"	2 layers	+.	9 mils	-	10mils	-	- 9 mils 9 mils -	- -	- -	- - -	- - - - - -	- 9 mils	- - - -	- - - - - -	- -	3 mil	-	9 mil 9 mil	-	9 mil - - - -	-	- - 9 mil	2"
Is Thickness Important	- - -	- -	N N	N N N	Y N N N N N N	Y	N	-	N	Y	N	N N N N	N	Y	1 layer inade.	Y	N N N	N	Y	N	- Y Y N	- -	N N	Y Y N	N N N N N N	N N N	N N N N	N N N N N N	N N	N	-	N N	N	Y N N N N	Y	N - N	Y
Yearly Requirements	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Need to be Ash Free	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ash Content Tolerable	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Need to be Destroyed: By Ignition	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
By Chemical Digestion	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
By Dissolution	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Surface Collection	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Low Radioactivity Background	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Withstand Chemical Treatment	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Withstand Heating	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SAMPLING CONDITIONS																																					
Nature of Gas Stream	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Humidity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Corrosive Gases	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Flow Velocity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Volume Needed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Allowable ΔP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SAMPLING DEVICE																																					
Name of Device	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Continuous	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Automatic	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Portable	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
General Purpose Use	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DESCRIPTION OF AEROSOL																																					
Composition	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Physical Form	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Particle Size & Distribution	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Loading	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Weight to be Caught	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Radioactive	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ANALYTICAL METHOD USED																																					
Gravimetric	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Optical Methods:																																					
Light Transmission	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Light Reflection	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Turbidometer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Direct Microscopic Exam:																																					
Particle Count	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Estimation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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Photomicrograph:																																					
Particle Count	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Estimation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electron Microscope	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Spectrographic	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Radioautograph	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Radioactivity Measurement:																																					
Count	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Metering	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Photographic	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chemical Methods	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Biological	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

N - No
Y - Yes

(1) Continuous Flow Dust Monitor
(2) Modified Research Appliance & Von Brank Sampler
(3) Mats of Cellulose with Nylon, Dacron, or Polystyrene
(4) (a) Hudson Pump; (b) Electrolux Hi-Volume Sampler; (c) Continuous Monitor
(5) (a) NYO Hudson Low Volume; (b) ORNL Constant Air Monitor; (c) ORNL Filtron; (d) MSA Precipitron
(6) (a) Motoair and Continuous Air Sampler; (b) Hi-Volume; (c) Hi-Volume; (d) Hi-Volume and low volume air sampler
(7) (a) Filter Queen; (b) Motoair Unit; (c) Isokinetic Samplers
(8) No longer used

APPENDIX D

PROPERTIES OF VARIOUS FILTERING MEDIA FOR ATMOSPHERIC DUST SAMPLING

PROPERTIES OF VARIOUS FILTERING MEDIA

FOR ATMOSPHERIC DUST SAMPLING

By

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Herman F. Hargreaves

ARTHUR D. LITTLE, INC.
Cambridge 42, Massachusetts

For Presentation to

AMERICAN SOCIETY FOR TESTING MATERIAL
Philadelphia 2, Pennsylvania

July 1, 1953

PROPERTIES OF VARIOUS FILTERING MEDIA FOR ATMOSPHERIC DUST SAMPLING

by Walter J. Smith and Norman F. Surprenant

INTRODUCTION:

In sampling for atmospheric dust and for testing atmospheric dust conditions, a number of methods are in use which depend upon filtration to arrest the dust particles. The effectiveness of any such method or even its success can depend, to an important degree, on the filter medium that is selected. Because they may be so important, the properties of any filter medium should be well understood before its use is recommended for any test method. It is our present purpose to compare and discuss properties of several filter media with respect to various air sampling requirements. All of the media to be considered are now available, and most of them are being used for air assay work.

There are various reasons for collecting a sample of atmospheric dust, and the purpose to be served will influence selection of the filtering medium. To mention some of the reasons or purposes of sampling, we have measurement of mass concentration of dust in the air, particle size distribution, chemical analysis of the particulates, toxicity assay, radioactivity measurements, study of organisms, and evaluation of soiling characteristics.

Conditions under which the sampling must be done may also influence selection of a medium. For example, glass fibers would not be used in an atmosphere known to contain an appreciable amount of hydrofluoric acid vapor.

In some cases a particular filter medium is used in a certain application only because of long standing practice which, for consistency, is kept unchanged. However when the need arises to select a filter for some new or

special purpose, and understanding of the general filtering properties of available media should be useful in making an intelligent choice. It is our purpose to contribute to the fund of such information.

The problems associated with selection and use of air sampling filter media were discussed at the Air Cleaning Seminar, sponsored bu the Atomic Energy Commission and held at Ames, Iowa, Sept. 14-17, 1952. As a result of that meeting a study of filter media and sampling practices was undertaken by Arthur D. Little, Inc. A questionnaire survey of some 40 laboratories, most of them within the Atomic Energy Commission operating areas but including also a number of outside laboratories, provided a list of air sampling media that are in current use at these laboratories.

We assembled a group of samples representing nearly all of the media that were mentioned in the survey. This paper describes and discusses air filtration test results obtained for these media and for a few others[1] that were included because of their special interest. Our test methods have included di-octyl phthalate smoke penetration, atmospheric dust penetration, and plugging rate on atmospheric dust. A range of performance characteristics is provided which may aid one in selecting a filter material for any dust sampling purpose.

Di-Octyl Phthalate Smoke Penetration Test:

The di-octyl phthalate smoke penetration meter or "DOP tester" as it is called more commonly, was developed by the armed services during the war and has become a well known and highly respected device for evaluating high efficiency filters. Instrumental parts of the tester and theories of their

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[1] AEC mineral papers were added to the group.

operation have been presented well in the literature (1,2,3). For our needs here a very brief description will serve. There is a smoke generator for producing a controlled, mono-dispersed liquid aerosol of di-octyl phthalate. This is accomplished by condensation from the vapor state and the droplets so formed are held very close to 0.3 micron diam. Particle loading is about 50 micrograms per cu. decimeter. Also a light scattering chamber is provided with sensitive photoelectric pickup means for accurate measurement of smoke particle concentration. The tester is adjusted against full aerosol concentration (unfiltered smoke) and against absolutely clean air. Penetration through a test specimen of filter medium is then read off directly in per cent.

Since the aerosol particles at 0.3 micron diam. are in the approximate size range for the most numerous microscopically visible atmospheric dust particles, the DOP test gives efficiency values that parallel those obtained by atmospheric dust counts.

Under the somewhat standardized conditions of normal laboratory test procedure, DOP smoke penetration measurements are made at 28 lin. feet per min. through a 4.5 in. diam. circular area of the medium. In the work to be described, this area size was used for flow rates up to 28 feet per min. To reach the higher flow velocities (up to 200 lin. feet per min.) a test area of 1.75 in. diam. was used.

Table I shows DOP smoke penetration efficiencies over a range of air flow velocities for our whole group of air sampling media. It is evident immediately that there is a very great difference in efficiencies as measured by this test. Perhaps this is the point at which we should stress that DOP smoke penetration alone must not be taken as a general measure of usefulness for all filters. It is a very severe test and is now used primarily to rate absolute-type filters.

When we are dealing with media intended to collect bulk dust or to analyze for atmospheric dust on a weight basis, very fine particles contribute to a minor degree and become unimportant; the DOP test then has much less significance. However, if our interest extends to the sub-micron size dust particles of the atmosphere (and these are by far the most numerous) then the DOP tester can tell us a great deal about what we can expect a filtering material to do.

An interesting feature of the data shown in Table I is the relation of DOP filtering efficiency to flow velocity for the different types of filter materials. We have plotted sets of data selected from Table I to show some characteristic curves.

Fig. 1 is for CWS #6 paper. At a low air flow rate, it is very efficient. This is a fortunate circumstance because this type of material is used principally for making large volume high efficiency space filters in which face velocity through the medium is only five lin. feet per minute. With increase of flow rate, smoke penetration increases to a maximum at about 30 feet per min. As the flow rate is further increased, penetration again falls off, and progressively. This behavior has been studied by Ramskill and Anderson of the Naval Research Laboratories (4). They attribute the low velocity positive slope to the influence of diffusional collection while the higher velocity negative slope is explained by influence of inertial effects. In addition to flow velocity, these authors show how the character of the curves is controlled by aerosol particle size, particle density, diameter of the filter fiber, and inter-fiber spacing.

Pressure drop, plotted separately in Fig. 1, is nearly linear with flow rate indicating viscous flow through the medium.

All of the high efficiency papers, AEC #1, AEC mineral fiber papers, and HV 70 (18 mil) show curves similar to that for CWE #6.

Fig. 2 shows the plotted data for a still more highly efficient medium. This is a sample of glass fiber paper made by the Hurlbut Paper Co. and containing a resin binder. The fibers in the sheet have a diameter of about 1/2 micron. The resulting curve also shows the peak typical of high efficiency media.

Chemical filter papers as illustrated by the Whatman papers are made in several types, and they give a variety of curves. Fig. 3 shows a plot for paper No. 41 which is typical of many of the cellulose papers.

Paper No. 42 (Table I) is remarkably efficient for an all-cellulose sheet. This efficiency is attained at low flow velocity, but pressure drop is high.

MSA type "S" filter which is used successfully for high volume air sampling (5) shows an unusually uniform DOP efficiency level over a broad range of flow rates (Fig. 4). While all of the other filter specimens come in flat sheets, type "S" is different. It has a molded shape of concentric convolutions designed to provide a large filtering area. A piece was cut from a reasonably flat area and used as the test specimen.

Membrane filters have been described as molecular sieves. Collection appears to be almost entirely at the surface. It is perhaps for this reason that they fill up rapdily on an oil smoke (like DOP) and so may not show up to best advantage in this test.

All fiber filter materials "fatigue" in the DOP tester. After running on DOP for several minutes, the smoke penetration increases. One explanation

offered is that electrostatic effects in the filter body are lost due to accumulation of liquid. It is known that filters depending on electrostatic effects fail quickly when used on oily smokes, so there is some basis for the suggested explanation. For the present, it is only important to mention that a DOP test should be made over a short period of time.

Efficiency by Atmospheric Dust Counts:

It was stated earlier that DOP test results are comparable with efficiency as measured by counts on atmospheric dust particles. This is shown by the data in Table II. Here the DOP filtering efficiencies of the various media are given, calculated from Table I. Atmospheric dust count efficiencies are shown for comparison.

To measure these efficiencies on atmospheric dust, a high-speed impactor (9) (6) was used for collection. Particle concentrations were measured before and after the filter. In most cases, four tests were made on each filter and 200 counts were made each time. Efficiencies were calculated from counts on the sonic velocity stage of the impactor; particles were one micron and smaller in diameter. No counts were obtained on the clean side of the very efficient media even after running the impactor for six hours. It should be borne in mind that the great numbers of atmospheric dust particles are less than a micron in diameter. Rating of a filter by counts on such dust is the same as rating that filter for performance in those small particles.

Even those who have been aware of the relation of DOP efficiency to particle count efficiency may be surprised by the close correlation of these separate methods. The results strongly indicate that the DOP tester can be relied upon to evaluate all filter media with respect to efficiency against sub-micron

size atmospheric dust particles.

Efficiency by Particle Size:

In the methods just described we dealt only with sub-micron size particles. When we include consideration of larger particles, our attention becomes limited to the cellulose fiber filters on our list. Larger particles do not penetrate the other media of the group.

Table III shows the particle size analysis for unfiltered laboratory air and for the same air after passing through each of several cellulose fiber filters. In every case, the count peak is shifted in the direction of the smaller particles as would be expected. No particles larger than two microns were observed to have passed any of the filters. Time did not permit us to include all of the cellulose fiber filters; we did try to select a representative group.

Efficiency of filtration by particle size is shown in Table IV. Here again efficiency was measured by particle count on high-speed impactor plates. No particles were found above the size of two microns, and all of the filters showed good to excellent efficiency on particles in the one- to two-micron range. When the primary interest is in weight of dust collected, these filters are generally adequate since large dust particles contribute most. The weight contribution of a particle is measured by the cube of its diameter.

All of the results reported have been on fresh samples of media. Allowance should be made for the fact that all filters improve in efficiency as they fill. As a practical matter, all of the media tested here will perform much better in use than our figures indicate.

Life Tests:

In many air sampling applications, plugging rate of a filter medium is not

a problem. But in those cases where it is desired to sample over a long period of time or to accumulate a sizeable quantity of particulate matter, the rate at which plugging occurs may become important. At times flow resistance or the development of flow resistance may even determine the feasibility of taking the sample.

A life test or plugging rate test consists in operating a filter sample at some selected flow rate and observing the increase in pressure drop with time. The kind of equipment we have used for this is shown in Fig. 5. It consists of separate test stations in which samples of filter materials may be mounted and operated over long periods of time. Each station has a sample holder that takes a 3 1/2 in. diam. disc of the medium and exposes a test area 3 in. in diam. A calibrated orifice meter and control valve allows each sample to be run at a selected rate. Our testers are arranged in two banks of twelve units each, all twelve stations in a bank exhaust into a single manifold line which is connected to the intake port of a three-stage Spencer Turbine Blower.

The flow rate tends to fall off, of course, as the filter fills with its accumulated dust load. This necessitates periodic adjustment of the valve to restore the proper rate. Pressure drop across each test sample is measured with a "U" tube water manometer.

It seemed best to life test all of the media at the same time so that any question of varying dust conditions in the air would not enter in. This brought up the matter of flow rate at which to run; for direct comparisons, all should be run at the same rate. The very low rate of five lin. feet per min. was selected as a start with the intention of increasing the rate after the rapidly plugging samples had been removed. When pressure drop became too high for any manometer, that test was stopped. After 480 hours of running, the flow rate

was stepped up to 28 lin. feet per min. for all surviving specimens except the membrane filters. Only seven specimen filters were remaining 120 hours later. Atmospheric dust loading over the time period of the run was measured by weighing the total dust load on a membrane filter.

Table V includes life tests for the entire group of samples. With one exception, the test specimens were flat discs. The exception, MSA type "S", as mentioned before is a molded filter with concentric convolutions. We used a whole filter and adjusted air flow to allow for the greater area which we estimated to be 75 sq. in.

It is interesting that the media which plug most rapidly are not necessarily the most efficient nor those with highest initial pressure drop. As a class the chemical filter papers tend to plug most readily. High efficiency papers show much better life. The membrane filters are very interesting; pressure drop is high initially but increases only a little as dust load accumulates.

In our experience and to the best of our knowledge, the rate at which a filter becomes loaded does not determine its life, regardless of time the pressure drop through a sampling filter is fixed by the amount of accumulated dust. Operating at low flow rate merely extends the time; dust loading in the air (assuming a constant dust composition) and the total amount of air passed are the controlling variables. In our life tests we used very low flow rates. For this reason Table V gives a slow motion picture of plugging rates. Life for any other flow or dust loading can be estimated from the data given.

Discussion of Filter Properties:

For convenience of reference, Table VI contains some general information on the various filter media we have been discussing. We do not consider this Table to be complete in any way. It contains some of the more obvious qualities

along with a few measurements of our own. Values for ash content of the chemical papers were given by the manufacturers. Values for other media, we determined. Very often some special property will determine the suitability of a given material. Such properties are important and must be considered along with filtering performance when a sampling medium is being selected.

Chemical filter papers appear to be used more widely than any other type of air assay medium. This may be because they are nearly always at hand in a laboratory. For those purposes where the filter must be destroyed to isolate or concentrate the dust, the low ash chemical filter papers are particularly useful.

High surface reflectance of light from chemical papers have made them popular for those test methods which are based on discoloration of the collecting surface.

Although chemical filter papers probably were never intended for air sampling work, they have proved to be most popular. Many kinds are available and data in the Tables of this report show the range of performance characteristics that can be expected. There are some properties inherent in paper and other fibrous media which are disadvantageous in some cases. These will be mentioned at the end of this discussion.

Chemical papers in particular often are found to contain pinholes. When this occurs, it is likely that even some very large dust particles will penetrate.

Unless an air filter medium is manufactured especially for the purpose, its performance characteristics are likely to vary from lot to lot. Chemical filter papers are manufactured for chemical laboratory work. They are made and used primarily for wet filtrations. Therefore it is not surprising that wide variation in air filtration is often found for chemical filter paper. Table VII

lists some experimental results that illustrate this point.

The membrane filter is relatively new, but it holds great promise as an all-round assay medium (7,8). It is highly efficient, may be obtained in white or black, particles accumulate only on the surface, refractive index is such that the filter structure itself becomes invisible for oil immersion microscope viewing, and the filter can be dissolved if need be or it may be destroyed in other ways. Because they are very delicate, the membranes must be handled carefully and supported during use. To generalize, there appear to be more useful properties associated with membrane filters than with any other one medium.

The felt-like papers CWS #6, AEC #1, and the AEC mineral fiber papers were designed for efficient air cleaning and serve that purpose effectively. They are not so well suited for most assay work. Dust particles penetrate the structure so that they are buried and lost for some types of radioactivity measurements (α counts). These papers are so high in ash that they are not at all useable where the filter must be destroyed to perform analysis of the dust. If suitable precautions are taken they may be used for gravimetric sampling on even the finest of dusts and fumes.

HV 70 is a closely formed paper and has found use particularly in radioactivity monitoring.

All-glass papers, like those developed by Naval Research Laboratories (10) and made to a limited extent by several paper companies, are to be recommended for high temperatures or in the presence of corrosive fumes or gases. In our series the Hurlbut glass paper is an example. These papers are made of very fine glass fibers and are the most efficient of fibrous filters. Some have resin or other binders, and this should be burned out before using the sheet in most kinds of test work. In gravimetric work care must be taken that loose

fibers are not lost from the sheet.

All fibrous filters, cellulose or glass, have water associated or adsorbed in their structures. The amount depends upon atmospheric humidity and will vary. In weighing the amount of dust load collected by such filters, it is very important to condition the filter at a known humidity level before every weighing and to weigh the filter in a closed container.

Dust collected on a fibrous filter will penetrate the filter body to some extent. For this reason it is very difficult, if not impossible, to make dust studies under the microscope or most paper filters.

SUMMARY:

A group of atmospheric dust sample media has been studied for performance characteristics. The media were selected to represent those in use in a number of laboratories. Test methods used were di-octyl phthalate smoke penetration, atmospheric dust penetration, efficiency by particle size, and plugging rate on atmospheric dust. A wide range of properties were shown.

The filtering properties have been discussed and the suitability of the media for various applications have been indicated.

It has been demonstrated that efficiency measurements by the DOP smoke test follow very closely the results given by atmospheric dust counts. This suggests that the fast DOP method can be used to rate any filter medium on per cent of atmospheric dust penetration by particle count.

ACKNOWLEDGEMENT:

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TABLE I

Effect of Flow Rate on Pressure Drop[a] and DOP Smoke Penetration[b] for Various Air Sampling Media

Flow Rate Linear Feet Per Minute		AEC #1	CWS #6	HV 70 9 mil	HV 70 18 mil	Hurlbut Glass Paper	Whatman Chemical Filter Papers #1	#4	#32	#40	#41	#41H	#42	#44	#50	S&S 604	Membrane Filters HA	Membrane Filters AA	AEC Mineral Filters Glass-Asb.	AEC Mineral Filters All-Glass	MSA Type S
5	% Penet.------ Pressure Drop-	0.022 0.7	0.015 0.67	5.0 1.1	0.47 1.2	0.001 1.08	73. 1.9	84. 0.5	3.7 7.2	32. 2.5	89. 0.25	93. 0.45	1. 8.7	4.5 7.7	30. 9.5	93. 0.35	0.002 5.4	0.002 2.2	0.029 0.7	0.008 0.75	61. 0.3
10		0.036 1.45	0.023 1.45	5.0 2.2	0.53 2.45	0.001 2.2	68. 3.75	81. 0.95	3.0 14.5	24. [illegible]	84. 0.68	89. 0.9	4. 27.	4.5 15.3	13. 27.7	90. 0.7	0.002 10.9	0.002 4.3	0.052 1.45	0.020 1.45	50. 0.6
20		0.065 2.9	0.04 2.9	3.5 4.6	0.85 4.7	0.003 4.4	43. 7.9	77. 1.95	0.45 27.3	10. 10.7	77. 1.35	81. 1.9	0.75 33.	1.6 28.6	3.0 35.2	85. 1.45	0.1 21.6	0.002 6.5	0.071 3.0	0.038 3.05	52. 1.05
28		0.055 4.2	0.037 4.05	2.0 6.3	0.69 6.9	0.005 5.1	27. 10.6	73. 2.6	0.35 30.	8. 15.	75. 2.0	76. 2.7	0.22 45.5	0.5 40.	0.9 48.5	79. 2.1	0.15 31.	0.1 11.6	0.073 4.25	0.05 4.25	52. 1.4
50		0.067 8.7	0.065 7.3	1.7 9.4	0.45 13.	0.005 10.8	11. 19.6	62. 5.5	0.2 69.4	2.8 25.3	67. 3.8	65. 1.5	0.08 81.	0.2 71.	0.15 80.0	67. 3.9	[illegible] 59.6	0.015 24.5	0.08 7.8	0.051 7.7	51. 3.0
100		0.051 13.3	0.037 27.0	0.4 21.6	0.1 27.	0.085 19.8	1.2 40.5	25. 11.5	- -	0.23 54.	44. 8.1	36. 11.5	- -	- -	- -	39. 8.5	- -	0.02 39.	0.04 16.0	0.005 15.2	45. 4.5
150		0.001 22.5	0.018 25.5	0.1 34.5	0.025 30.2	0.003 32.5	0.3 60.	12. 18.1	- -	- -	25. 12.5	21. 17.0	- -	- -	- -	18. 15.	- -	- -	0.018 26.7	0.013 25.	34. 10.8
200		0.011 29.5	0.31 35.	- -	- -	- -	- -	- -	- -	- -	15. 17.8	13. 26.	- -	- -	- -	7. 22.7	- -	- -	- -	- -	28. 16.3

a-Pressure Drop in inches of water.
b-DOP Smoke Penetration in per cent. (Di-Octyl Phthalate particles 0.3 micron diameter, 50 micrograms/liter of air.)

TABLE II

Impactor Count Efficiency on Sub-micron Atmospheric Dust Particles Compared with DOP Efficiency for Various Air Sampling Media

FLOW RATE 20 LINEAR FEET PER MINUTE

Filter Medium		Atmospheric Dust Count Efficiency Per Cent[a.]	DOP Efficiency Per Cent[b.]
Whatman Chemical Filter Paper Nos:	1	50.	57.
	4	15.	23.
	32	99.1	99.5
	40	85.1	84.
	41	26.5	23.
	41H	24.	19.
	42	98.8	99.2
	44	97.	98.6
	50	92.	97.
	540	67.	65.
S & S #640		13.	15.
HV 70 9 mil		96.5	96.5
HV 70 18 mil		99.5	99.3
MSA Type "S"		46.	48.
Millipore Type "HA"		↑	99.9+
Millipore Type "AA"			99.9+
S & S Ultra Filter			-
Hurlbut Glass Paper		(No particles found after 6 hours running.)	99.99+
CWS #6			99.9+
AEC #1			99.9+
AEC Glass-Asbestos		↓	99.9+
AEC All-Glass			99.9+

a. Average of 4 tests.

b. Calculated from Table I.

TABLE III

Particle Size Distribution in Atmospheric Dust
Before and After Filtration Through Different Media

COUNT ANALYSIS OF AIR BORNE PARTICLES - PER CENT OF EACH SIZE

Particle Diameter - Microns -	Unfiltered Air	Filtered Air				
		Whatman #1	Whatman #4	Whatman #41	Whatman #42	MSA "S"
below 0.4	31.8	52.8	45.2	47.4	51.0	50.0
.4 - 0.6	42.6	35.3	38.1	40.3	39.3	41.8
.6 - 0.8	16.2	10.6	14.2	9.1	8.5	7.0
0.8 - 1.0	6.8	1.1	1.9	2.4	1.1	1.0
1.0 - 2.0	1.6	0.2	0.6	0.8	0.1	0.2
over 2.0	1.0	-	-	-	-	-

Notes: Flow Rate: 20 linear feet per minute through the medium.

Each value based on counts for two filters with no fewer than 40 counts each point each filter.

Particles collected sonic velocity impactor. Counts and measurements by oil immersion microscope 1350X.

TABLE IV

Filtering Efficiency[a] by Particle Size
for Each of Several Air Sampling Media

FLOW RATE 20 FEET PER MINUTE

Particle Diameter - Microns -	Whatman #1	Whatman #4	Whatman #41	Whatman #42	MSA Type "S"
below 0.4	57[b]	23[b]	23[b]	99[b]	48[b]
0.4 - 0.6	58.	24.	31.	97.	47.
0.6 - 0.8	67.	25.	59.	98.	77.
0.8 - 1.0	92.	77.	74.	99.3	92.
1.0 - 2.0	94.	63.	63.	99.8	93.
above 2.0	100.	100.	100.	100.	100.

[a]-Efficiency for particle retention in per cent by count. Particles above 0.4 micron diameter collected by high-speed cascade impactor.

[b]-DOP smoke value used for particles below 0.4 micron diameter.

TABLE V

Life Tests - Change of Pressure Drop Across Air Sampling Media with Operating Time

Flow Rate Liters Per Minute	Running Time-Hours	AEC # 1	CWS # 6	HV 70 9 mil	HV 70 18 mil	Hurlbut Glass Paper	Whatman Chemical Filter Papers # 1	# 4	# 30	# 40	# 41	#540	# 42	# 44	# 50	S & S #576	Membrane Filters "AA"	"AS"	AEC Mineral Fibers Glass-ish.	AEC Mineral Fibers Air-Glass	MSA Type "F"	Approx. Dust Load
5 CFM	0	0.72	0.78	0.95	1.05	0.95	1.9	0.68	7.0	2.45	0.35	0.5	8.5	8.0	9.5	0.35	5.4	2.3	0.7	0.7	0.17	4) disregard per cubic meter
	24	0.75	0.75	1.15	1.2	1.0	5.2	0.80	9.65	5.7	1.2	0.85	26.	26.5	27.	0.45	5.45	2.5	0.75	0.7	0.17	
	48	0.75	0.75	1.2	1.25	1.0	6.2	1.15	11.0	6.85	1.5	1.05	-	-	-	0.8	5.5	2.6	0.75	0.7	0.2	
	120	0.85	0.8	1.4	1.4	1.1	7.3	2.3	12.8	8.2	2.15	3.3	-	-	-	1.8	5.7	2.6	0.8	0.7	0.2	
	192	0.85	0.9	1.55	1.7	1.1	8.0	3.2	-	9.0	2.7	4.5	-	-	-	2.6	5.9	2.8	0.9	0.75	0.22	
	288	0.95	1.0	1.8	1.95	1.2	8.5	3.9	-	-	3.35	5.8	-	-	-	3.15	6.4	3.0	1.0	0.85	0.25	
	336	1.00	1.05	1.9	2.0	1.2	-	4.15	-	-	3.9	-	-	-	-	3.45	6.7	3.1	1.2	0.85	0.25	
	384	1.05	1.05	1.9	2.0	1.25	-	4.15	-	-	4.0	-	-	-	-	3.5	7.1	3.15	1.25	0.85	0.25	
	480	1.05	1.1	1.95	2.1	1.25	-	4.25	-	-	4.3	-	-	-	-	3.55	8.1	3.2	1.35	0.85	0.25	
		Dust Continued at 28 CFM															Cont'd at 5 CFM		Continued at 28 CFM			
28 CFM except where otherwise noted.	0	5.6	6.15	11.0	11.7	7.0											8.1	3.2	7.6	4.75	1.2	
	24	5.8	6.35	11.5	12.1	7.15											8.2	3.15	7.8	4.75	1.2	
	48	6.1	6.6	12.6	14.2	7.4											8.5	3.2	8.3	5.0	1.2	
	72	6.6	6.85	-	-	7.6											8.55	3.3	-	5.25	1.25	
	120	7.0	7.4	-	-	8.4											8.6	3.4	-	5.6	1.35	

Figures show pressure drop in inches of water.

TABLE VI

Some General Properties of Air Sampling Media

Material	Type or No.	Manufacturer or Source	Thickness Inches	Ash Content Grams per 9cm Diameter Circle (unless other. stated)	Description	Present Application in Air Sampling
Chemical Filter Papers	Whatman # 1	W. & R. Balston Ltd., England	.008	.00039	White cellulose papers of various grades.	Tests depending on discoloration or change in light transmission.
	Whatman 4		.008	.0005		
	Whatman 32		.010	.00022		
	Whatman 40		.010	.00009		
	Whatman 41		.010	.00009		
	Whatman 41H		.007	.00004	Nos. 41H, 50, & 540 are hardened papers.	Analysis of particulate by destruction of medium.
	Whatman 42		.010	.000064		
	Whatman 44		.008	.000051		
	Whatman 50		.005	.00016		
	Whatman 540		.006	low ash		
	S&S 604	Schleicher & Schuell Co.	.008	.0002	-	-
Membrane Filters	"HA"	Lovell Chemical Co.	.005	1.5%	Porous cellulose ester films.	Particulate counts, identification by microscope. "Final stage" for impactor α counting.
	"AA"		.005	1.5%		
	Ultra Filter membrane type	S & S Co.	.005	-		
HV - 70	9 mil	Hollingsworth & Vose	.009	14%	Asbestos bearing cellulose base paper.	General air assay & radio activity monitoring.
	18 mil		.018	14%		
M S A	"S"	Mine Safety Appliances Co.	.040	1.3%	Molded cellulose - concentric convolutions	High volume air sampling.
Glass Paper	-	Hurlbut Paper Co.	.010	95%	Fine glass paper - resin binder.	High efficiency particulate removal.
C W S	#6	Hollingsworth & Vose	.030	11%	Felt-like paper asbestos & cellulose	High efficiency particulate removal.
A E C	#1		.030	13%		
AEC Mineral Filter	Asbestos	Arthur D. Little, Inc.	.030	95.0%	Glass & asbestos.	High efficiency particulate removal.
	Glass		.030	95.0%	All-Glass Both with resin binders.	

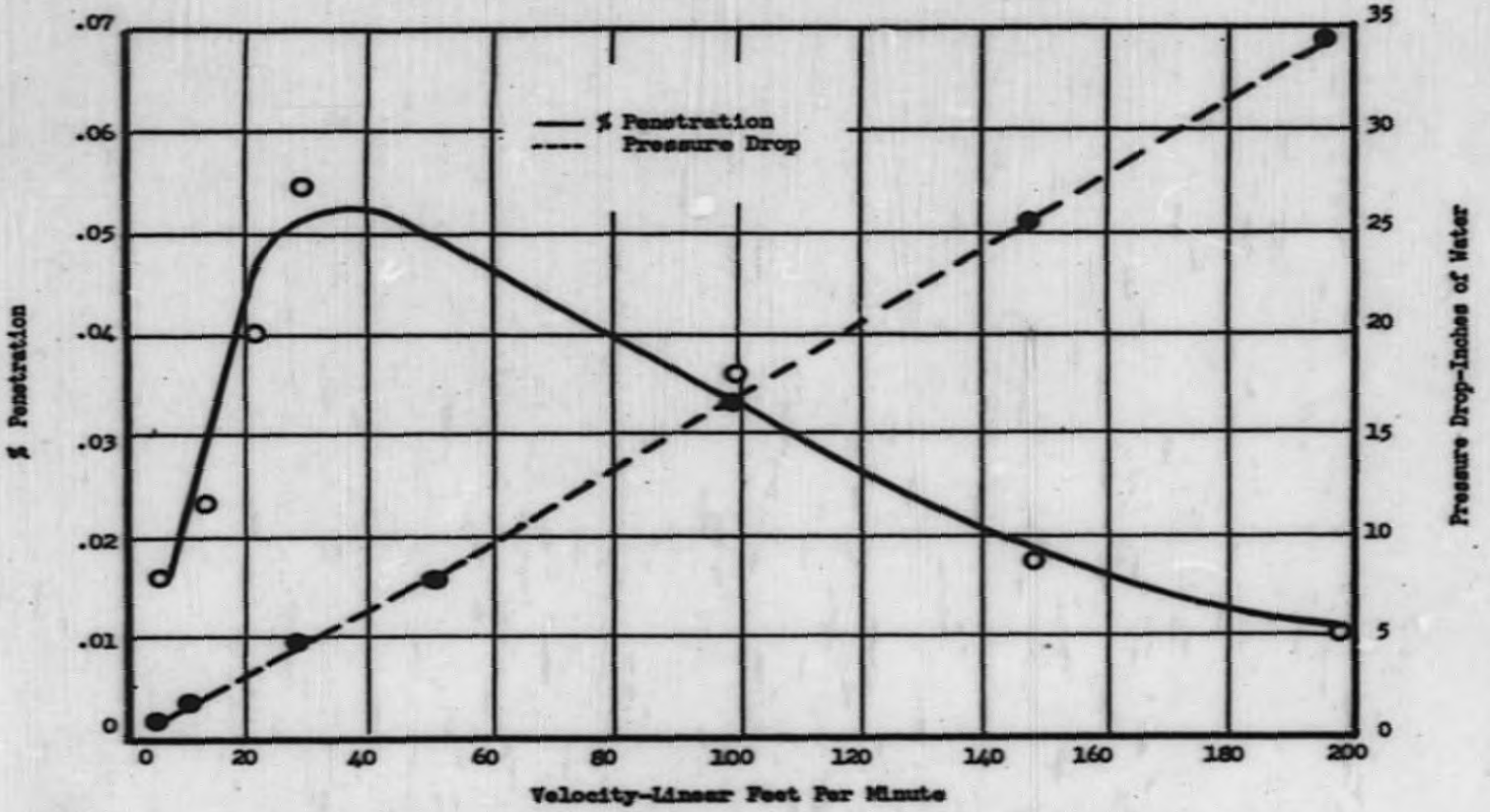
TABLE VII

Variations in DOP Smoke Penetration and Pressure Drop at 28 FPM for Various Samples of Chemical Filter Papers

Whatman Filter Paper No.	Reported Results (Table I) ΔP In. of Water	% Penet.	Range ΔP In. of Water	% Penet.	No. Boxes Tested[1]
1	10.6	27.	9.5 - 12.8	12. - 28.	5
4	2.8	73.	2.2 - 2.8	72. - 75.	2
32	38.	0.35	38. - 45.	.008 - 0.35	1
40	15.	8.	13. - 15.	8. - 13.	2
41	2.0	75.	2.0 - 4.2	49. - 75.	4
41H	2.7	76.	2.7	76. - 82.	1
42	45.5	0.22	44. - 55.	.05 - .9	4
44	40.	0.5	40. - 48.	0.25 - 0.5	1
50	48.5	0.9	48. - 61.	0.3 - 1.2	2

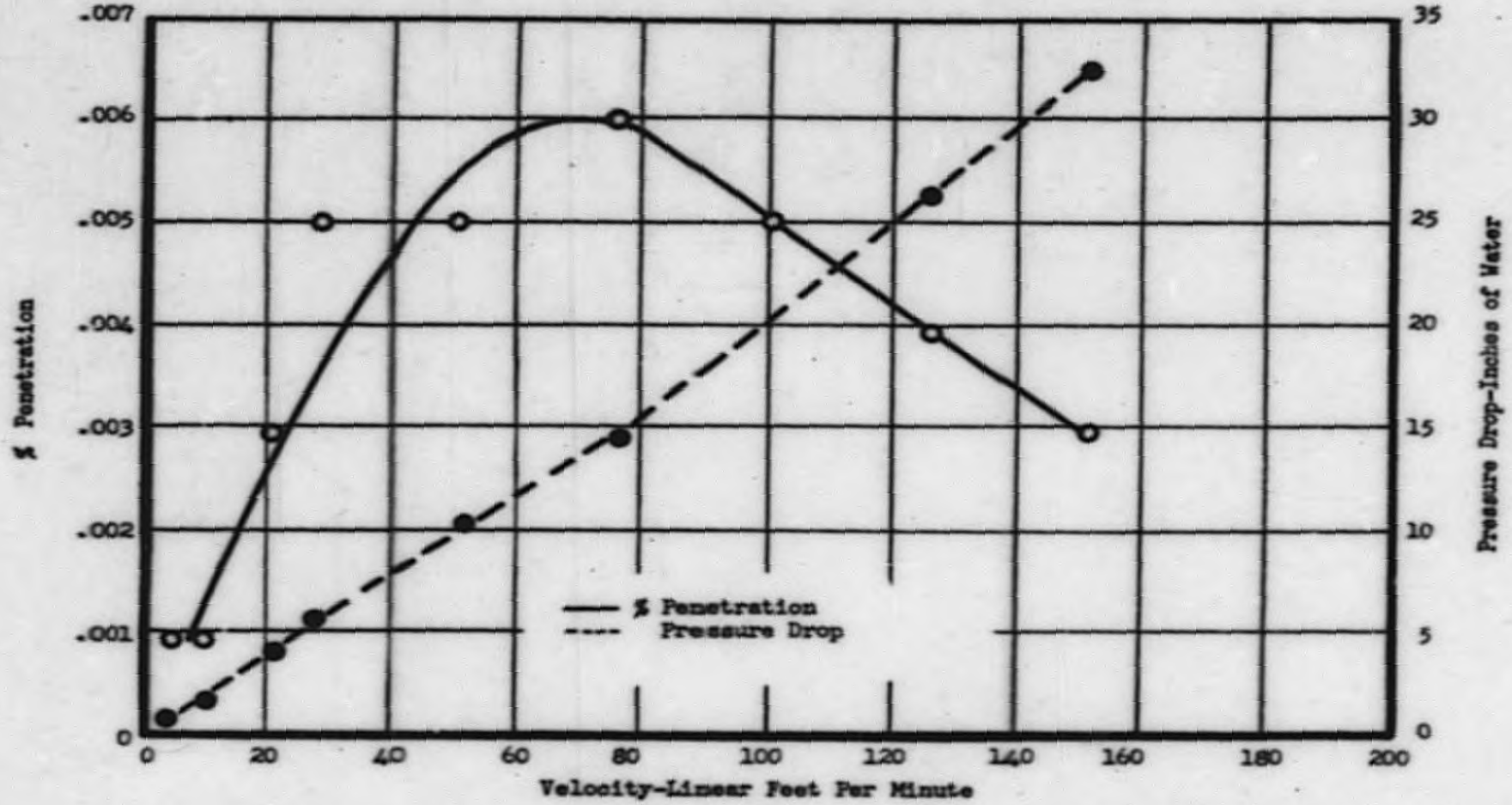
[1] Three samples tested in each box.

FIGURE 1



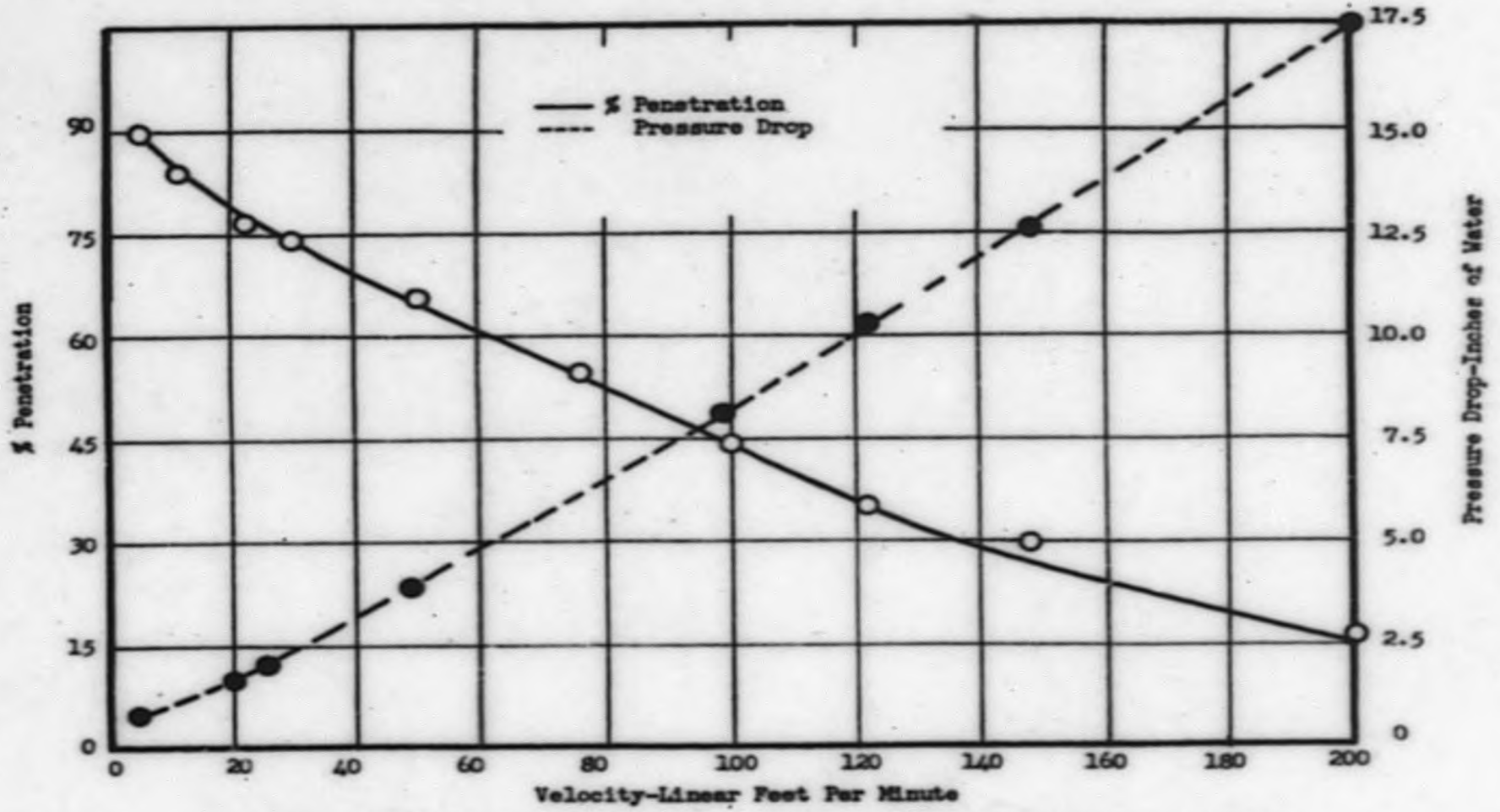
DOP SMOKE PENETRATION AND PRESSURE DROP VERSUS VELOCITY FOR C.W.S. NO. 6 PAPER

FIGURE 2



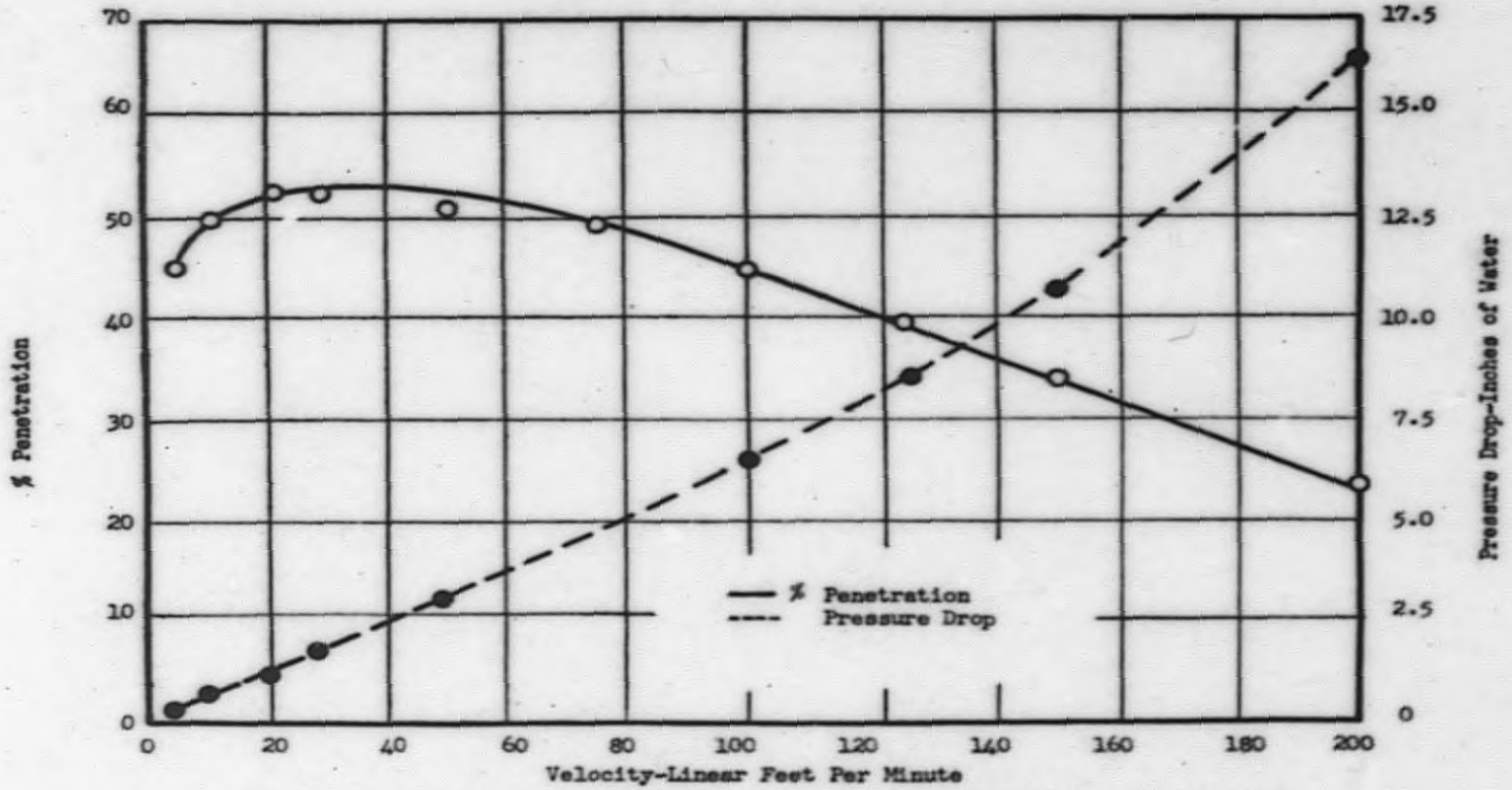
DOP SMOKE PENETRATION AND PRESSURE DROP VERSUS VELOCITY FOR HURLBUT GLASS FIBER PAPER

FIGURE 3



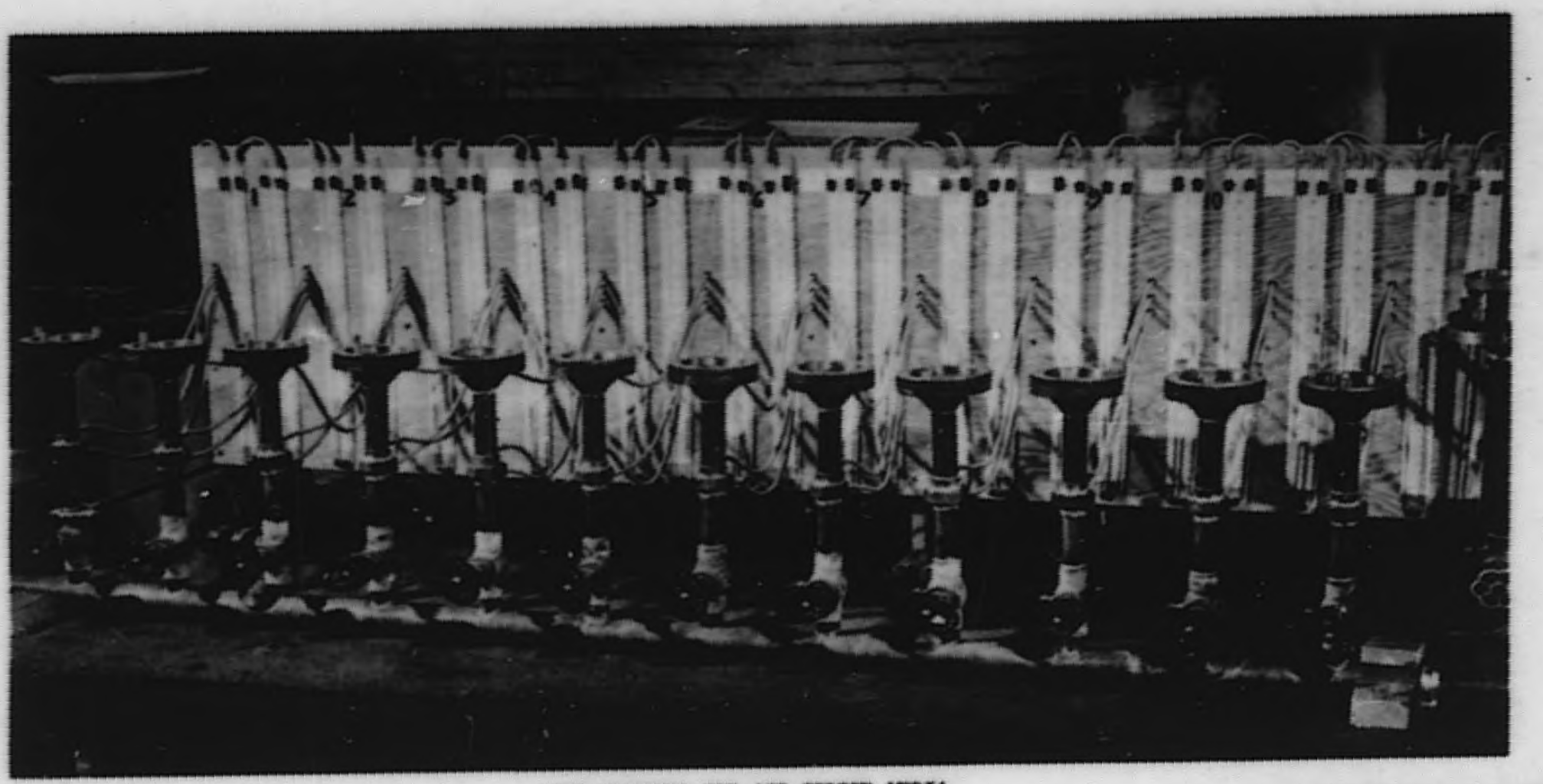
DOP SMOKE PENETRATION AND PRESSURE DROP VERSUS VELOCITY FOR WHATMAN NO. 41 PAPER

FIGURE 4



DOP SMOKE PENETRATION AND PRESSURE DROP VERSUS VELOCITY FOR M.S.A. TYPE "S" FILTER

FIGURE 5



LIFE TESTERS FOR AIR FILTER MEDIA

END