PROPERTIES OF VARIOUS FILTERING MEDIA
FOR ATMOSPHERIC DUST SAMPLING

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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 prupose 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, an 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 by 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

[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 CWS #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

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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

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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

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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 on 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.

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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	% Penetration—	0.022	0.015	5.0	0.47	0.001	73.	84.	3.7	32.	89.	93.	5.	6.5	30.	93.	0.002	0.002	0.029	0.008	45.
	Pressure Drop—	0.7	0.57	1.1	1.2	1.05	1.9	0.5	7.2	2.5	0.35	0.45	8.7	7.7	9.5	0.35	5.4	4.3	0.7	0.75	0.3
10		0.036	0.023	5.0	0.53	0.001	68.	81.	3.0	26.	84.	89.	2.	4.5	13.	90.	0.002	0.002	0.052	0.020	50.
		1.45	1.45	2.2	2.45	2.2	3.75	0.95	14.6	5.1	0.58	0.9	17.	15.3	17.7	0.7	10.9	8.5	1.45	1.45	0.6
20		0.045	0.04	3.5	0.65	0.003	43.	77.	0.45	16.	77.	81.	0.75	1.4	3.0	85.	0.01	0.01	0.071	0.038	52.
		2.9	2.9	4.6	4.9	4.4	7.7	1.95	27.3	10.7	1.35	1.9	33.	28.6	35.2	1.45	21.6	11.8	3.0	3.05	1.05
28		0.055	0.057	2.0	0.59	0.005	27.	73.	0.35	8.	75.	76.	0.22	0.5	0.9	79.	0.015	0.015	0.073	0.05	52.
		4.2	4.05	6.3	5.9	6.1	10.6	2.8	38.	15.	2.0	2.7	45.5	40.	48.5	2.1	31.	24.5	4.25	4.25	1.6
50		0.045	0.045	1.7	0.45	0.005	11.	62.	0.3	2.8	67.	65.	0.02	0.2	0.15	67.	0.015	0.02	0.08	0.051	51.
		6.7	7.5	9.4	13.	10.8	19.6	5.5	69.4	25.3	3.8	5.5	81.	71.	86.0	3.9	59.6	39.	7.8	7.7	3.0
100		0.031	0.037	0.2	0.1	0.005	1.2	25.	-	0.23	44.	34.	-	-	-	39.	-	-	0.04	0.025	45.
		13.3	17.0	21.8	27.	19.8	40.5	11.5	-	54.	8.1	11.5	-	-	-	8.5	-	-	16.0	15.2	6.5
150		0.021	0.018	0.1	0.025	0.003	0.3	12.	-	-	29.	21.	-	-	-	18.	-	-	0.018	0.013	34.
		22.5	25.5	34.5	38.2	32.5	60.	18.1	-	-	12.5	17.0	-	-	-	15.	-	-	26.7	25.	10.8
200		0.011	0.01	-	-	-	-	-	-	-	15.	13.	-	-	-	7.	-	-	-	-	28.
		29.5	35.	-	-	-	-	-	-	-	17.8	24.0	-	-	-	22.7	-	-	-	-	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 #604	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"	(No particles found after 6 hours running.)	99.9+
Millipore Type "AA"		99.9+
S & S Ultra Filter		-
Hurlbut Glass Paper		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.

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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.

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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.	32.	28.	97.	47.
0.6 - 0.8	69.	38.	64.	98.	77.
0.8 - 1.0	92.	79.	74.	99.3	92.
1.0 - 2.0	95.	74.	70.	99.8	94.
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.

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TABLE V

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

Flow Rate Linear Feet Per Minute	Running Time-Hours	AEC #1	CW3 #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"	Approx. Dust Load
5 FPM	0	0.72	0.72	0.95	1.05	0.95	1.9	0.48	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	63 micrograms per cubic meter
	24	0.75	0.75	1.15	1.2	1.0	5.2	0.80	9.45	5.7	1.2	0.85	28.	16.5	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	1.65	-	-	-	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	6.8	-	-	-	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	5.7	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	
		Test Continued at 28 FPM															Cont'd at 5 FPM		Continued at 28 FPM			
28 FPM 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.

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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.
	4		.008	.0005		
	32		.010	.00022		
	40		.010	.00009		
	41		.010	.00009		
	41H		.007	.00004	Nos. 41H, 50, & 540 are hardened papers.	Analysis of particulate by destruction of medium.
	42		.010	.000064		
	44		.008	.000051		
	50		.005	.00016		
	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	Reported Results (Table I) % Penet.	Range ΔP In. of Water	Range % 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.

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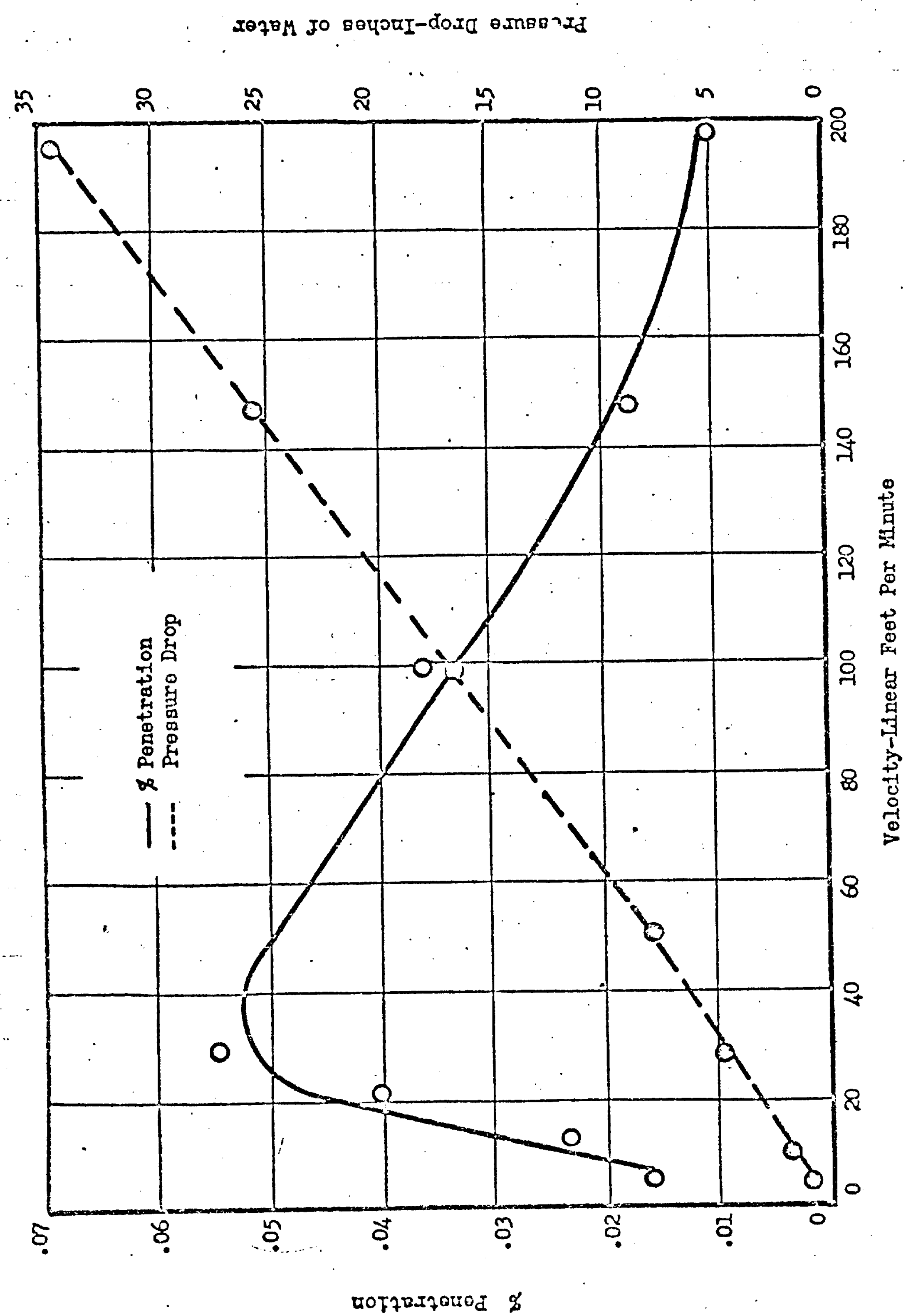
FIGURE 1



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

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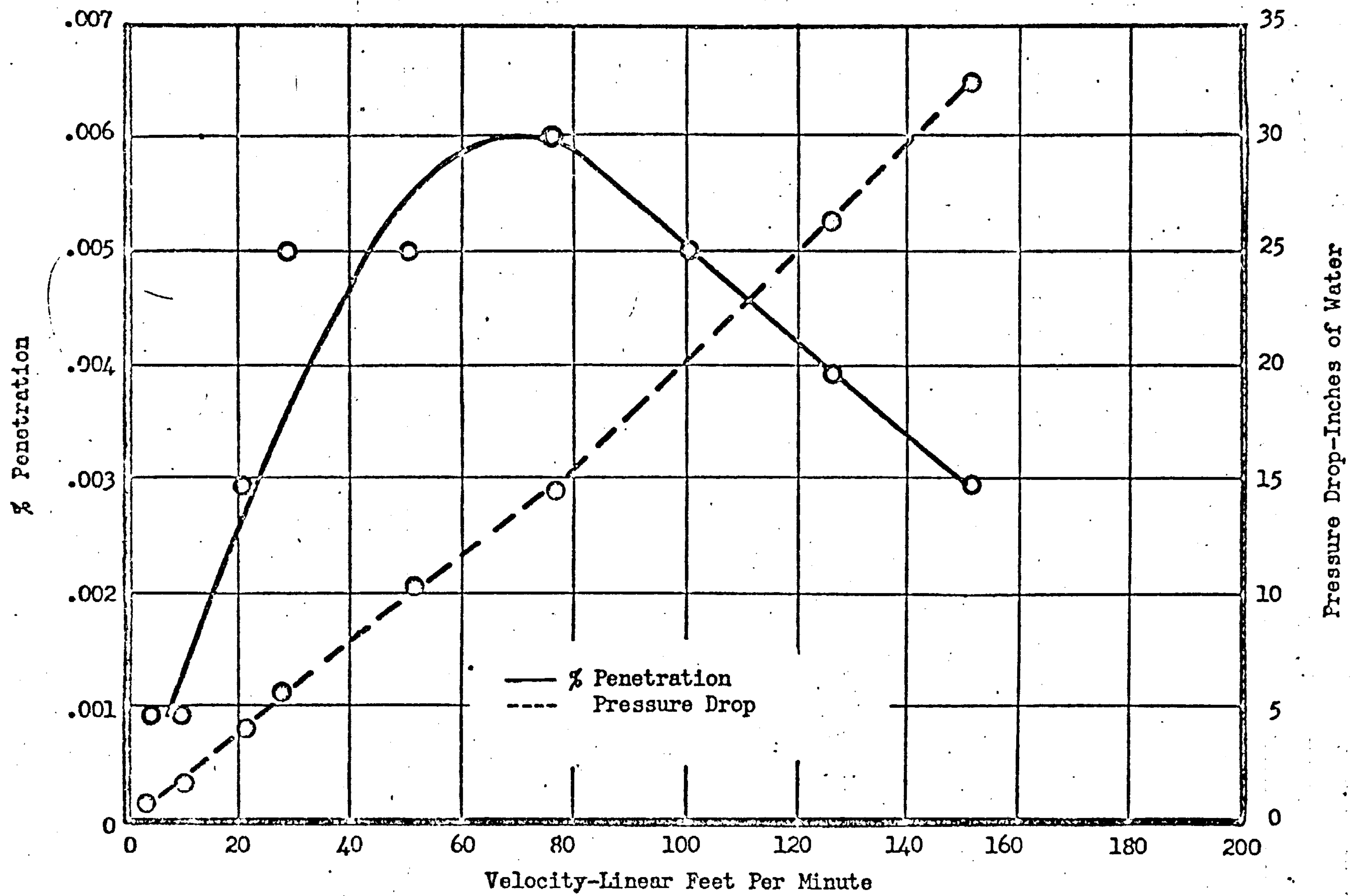
FIGURE 2



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

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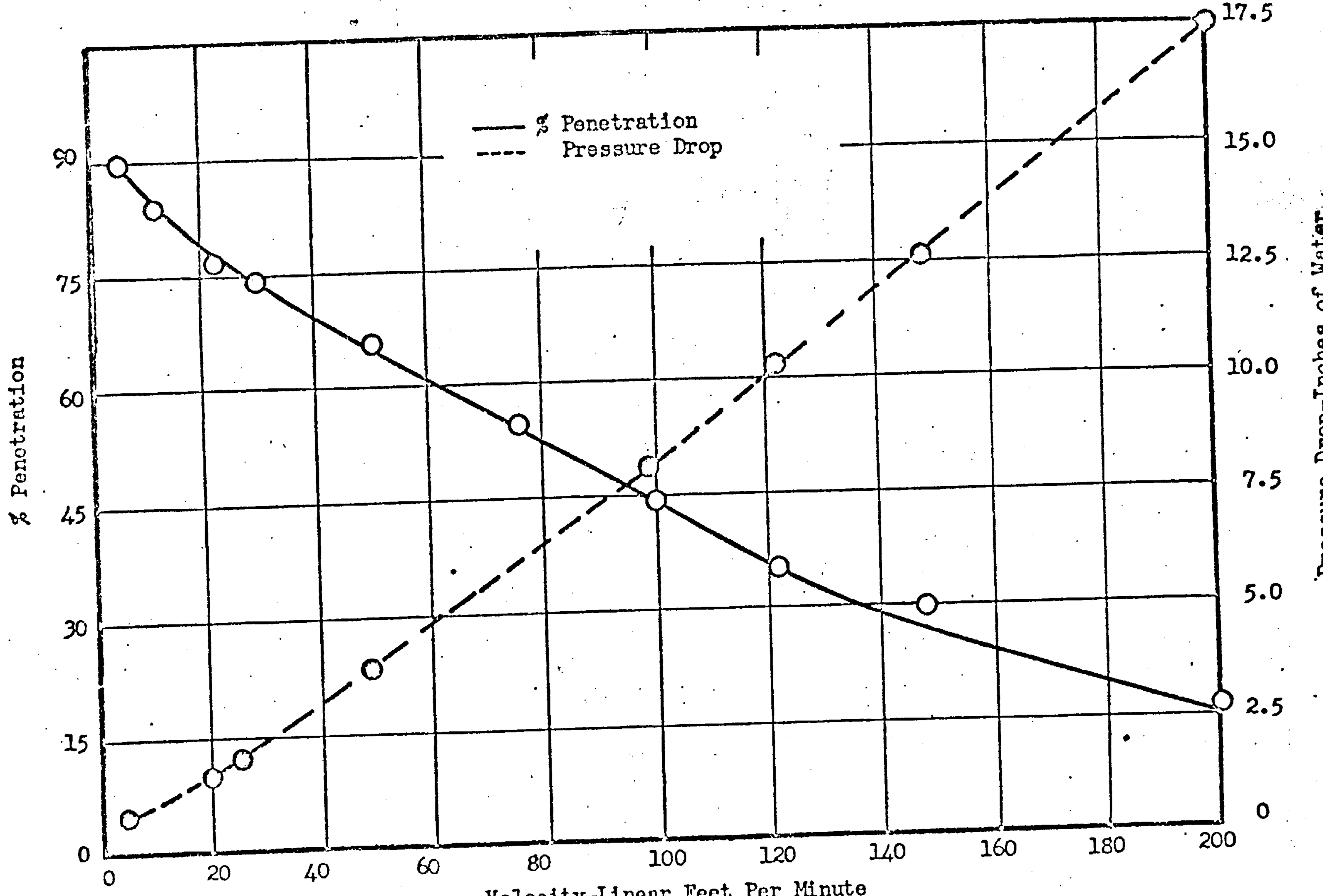
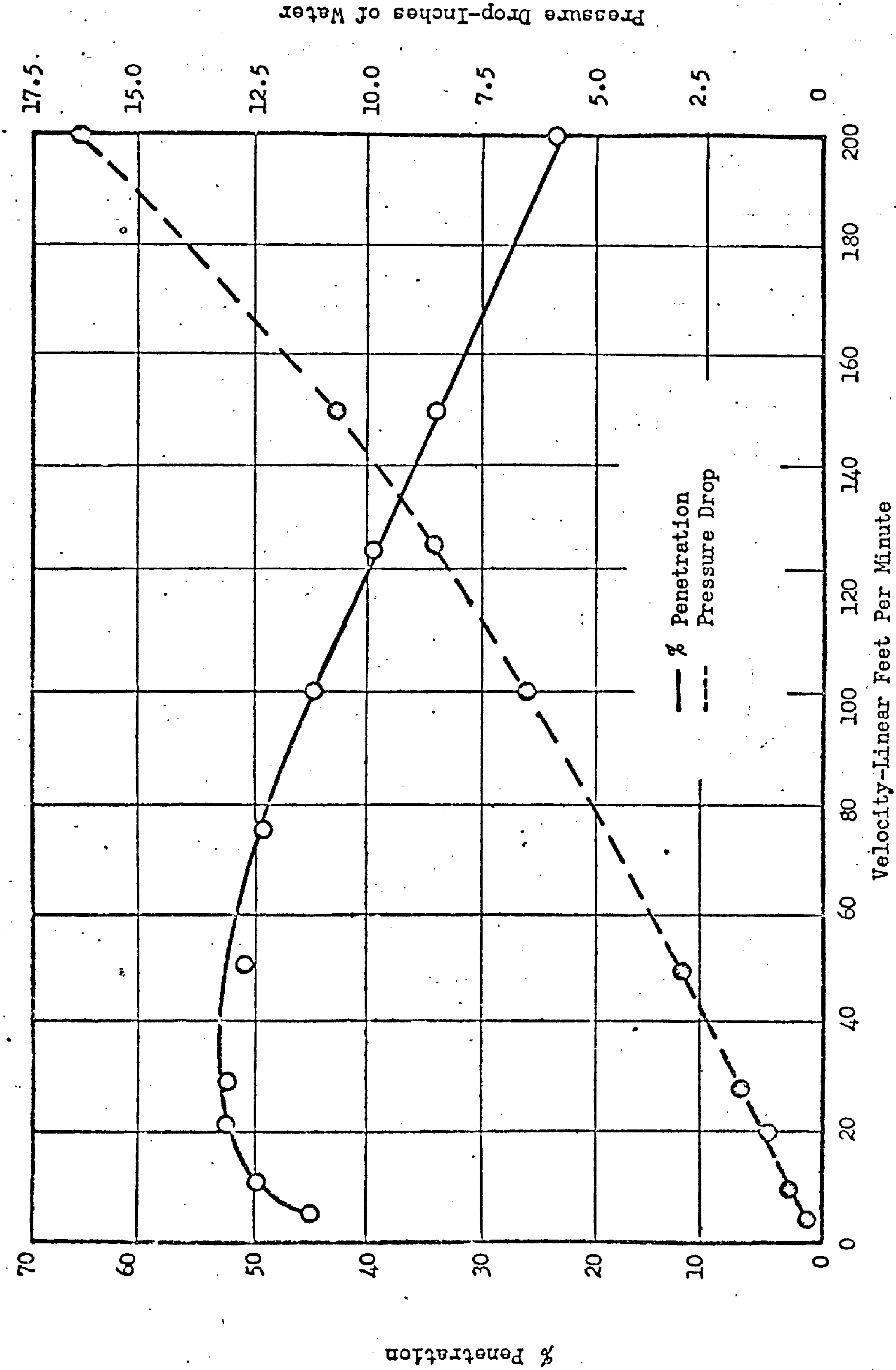
FIGURE 3



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

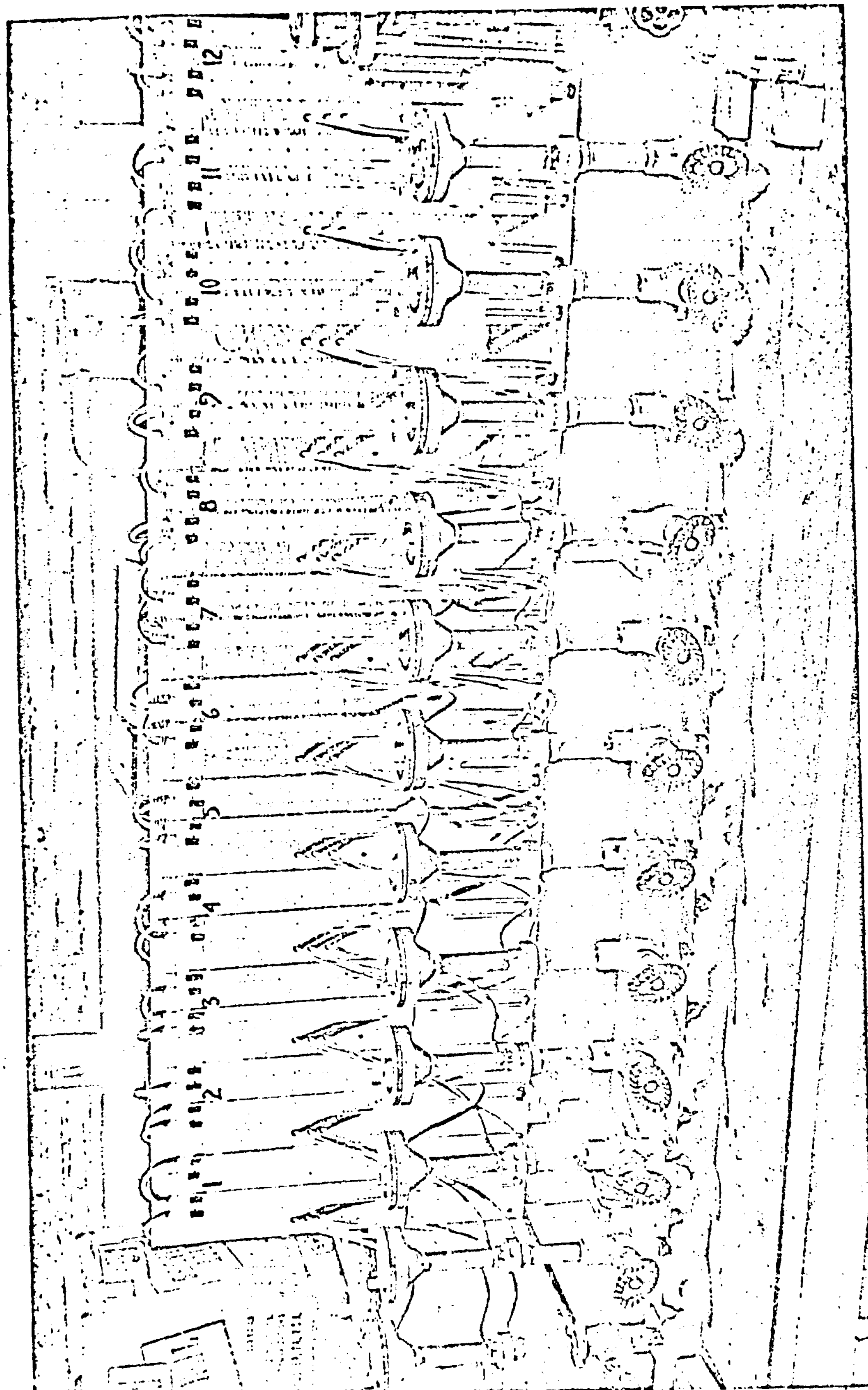


FIGURE 5. LIFE TESTERS FOR AIR FILTER MEDIA