UNITED STATES ATOMIC ENERGY COMMISSION

ALI-23

INVESTIGATION OF STACK GAS FILTERING REQUIREMENTS AND DEVELOPMENT OF SUITABLE FILTERS (Report No. 8)

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Arthur D. Little, Inc.

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INTRODUCTION

This report is written to summarize the present state of the work which has been in progress at this laboratory for the Atomic Energy Commission. Under its contract, Arthur D. Little, Inc. has undertaken to provide a suitable paper filter for the high efficiency removal of air-borne dust particles. A general study of air filtering media was a second part of the program. The application of suitable methods of evaluating the performance of efficient air filters and filter media was necessary to implement the work.

Since many readers of this report may not be familiar with what has gone before, it has been thought desirable to explain some of the parts in detail.

Visits of personnel to and from Arthur D. Little, Inc. and various Atomic Energy Commission Areas have resulted in occasional opportunities to provide a direct service to an area. This is something that has been welcomed and it is hoped that individuals concerned with air filtration problems for A.E.C. will be mindful of this possible source of help.

SUMMARY

At the present time a paper filter design has been developed, and performance characteristics have been determined. Facilities have been set up for producing full size filters in pilot scale production. Samples of these filters have been provided to the various AEC sites for operating tests and for general evaluation. Manufacturing methods are being worked out with the intention that the filters in a variety of sizes will be produced by a commercial manufacturer. It should be understood that this kind of filter comes closer to being an absolute filter than any other type of air cleaning device now produced commercially. It is regularly observed that less than .02% of dust in the size range of 0.2 to 1.0 micron is passed by these filters when new. Filtration very rapidly improves still further with use and the improved efficiency remains up to the point where the dust load becomes so excessive that the units must be replaced.

Much laboratory work has been done to evaluate both the filter medium and finished filter units. The primary dust load in an atomic energy installation is the dirt naturally found in the atmosphere. Therefore the tests have been carried on with particular emphasis on performance against atmospheric air-borne dust. The high speed jet impactor was adopted as the test instrument and has proven itself satisfactory. Special precautions and techniques were found necessary when using the impactor to determine very low dust contents in filtered air. A special discussion of this subject is given.

Filter media other than the especially developed paper have been studied - particularly glass fiber mats, and their performance characteristics have been observed.

A six month test run on several kinds of filter media was conducted at Brookhaven. Increase of pressure drop was moderate, indicating good life expectancy for air filters at that site using such media. No special filtration problems were encountered.

It has been demonstrated that a low efficiency filter medium can be improved greatly for air filtration by priming with a finely divided asbestos fiber. This may be of particular value where special conditions must be met such as exposure to high temperature or contact with corrosive gases.

For the remaining months emphasis will be placed on getting manufacturing procedures on the pleated filter worked out to the point where production of filters can be undertaken by others, if desirable.

EXPERIMENTAL

Filter Development

We have now settled upon a definite filter design so that very little has been done recently on design as such. The effort has been concentrated on improving the technique of construction.

To review briefly, the filter unit now consists of a single sheet of high efficiency paper medium. The paper is pleated and the individual pleats separated by spaces of corrugated paper placed alternately on one side of the medium, then the other. The compact assembly of paper and spacers is cemented tightly into a wooden frame, the face edges of which are provided with gaskets for mounting the unit in its final use position. Fig. 1 is a photograph of the 24" x 24" x 24" x 5 7/8" filter.

A special paper developed for the purpose is the medium. It is of soft open construction and will pass about five linear feet of air per minute at a pressure drop of one inch of water. To improve strength and scuff resistance of the paper, it is coated with a vinyl acetate resin. This resin is applied to the finished sheet as an emulsion and is laid on as a very light porous coating by means of applicator rolls.

Paper spacers are made of an ordinary corrugating stock and are formed as needed on a pair of corrugating rolls. The proper flute depth was determined by a series of flow resistance experiments. By allowing the spacers to protrude beyond the filter medium the latter is protected to some degree from accidental bumps.

Joints between the wood frame and filter body are sealed with "3M" cement, a product of Minnesota Mining and Manufacturing Company. Joints in the frame are fastened with wood screws and sealed against leakage with 3M cement.

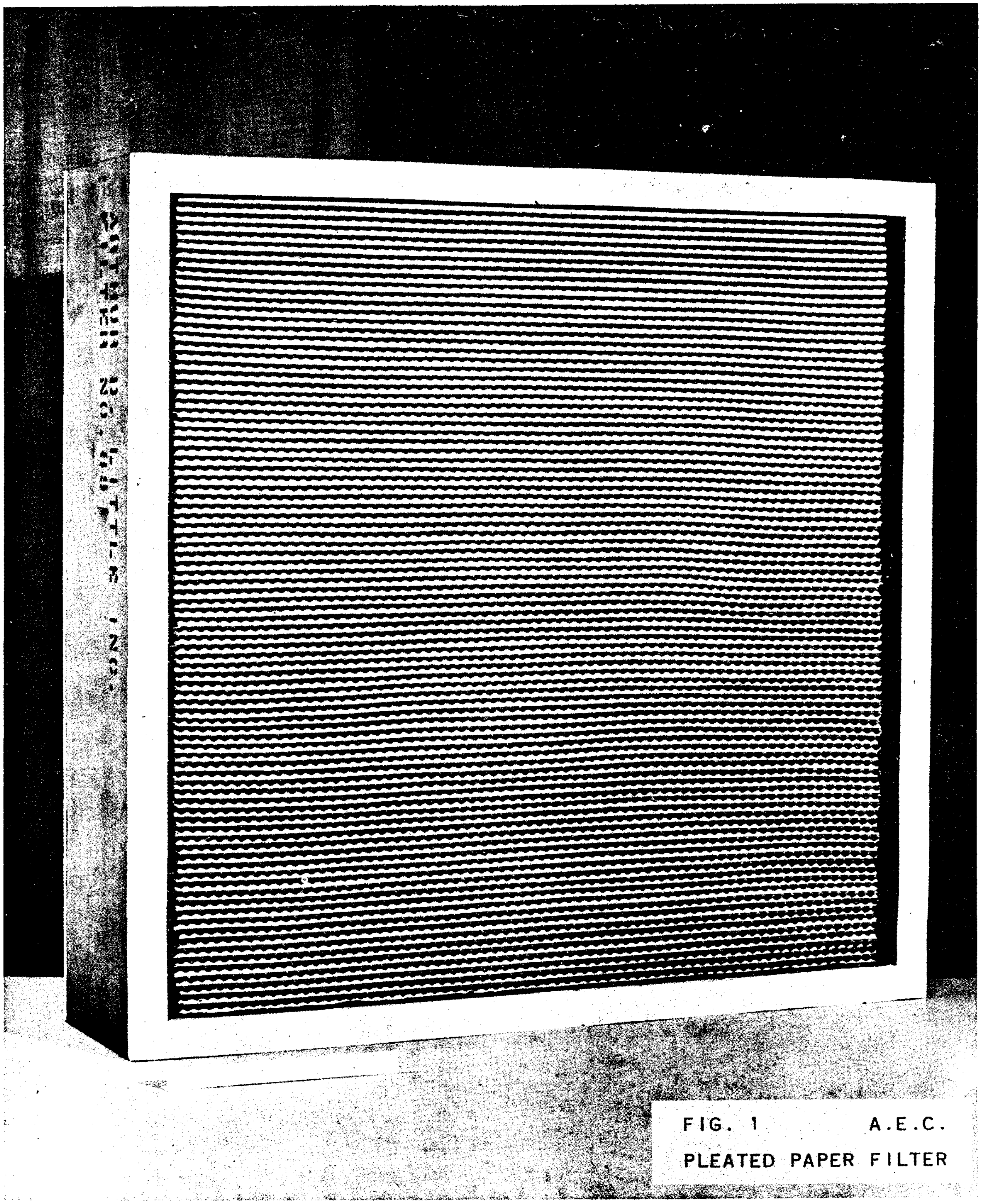


FIG. 1 A.E.C.
PLEATED PAPER FILTER

Strips of 1/4" thick sponge rubber sheet cut to 1" width are cemented to the frame edges on both faces of the filter. Where a strip end abuts the adjacent strip cement is used to prevent the opening of a leak passage.

Each filter is given a performance test against methylene blue smoke. The dye is dissolved in water to a concentration of 0.25%. It is metered at the rate of 45 cc per minute to a Spraco No. F 2070 air nozzle. Air pressure regulated to 60 lbs. per sq. in. is applied to the nozzle. The spray fog is injected into a chamber through which air to the filter is passing. Before entering the chamber the air is heated by electric resistance coils to a temperature rise of about 10 degrees Centigrade.

A high speed impactor is used to collect particles upstream and downstream of the filter. Particle counts made under the microscope are then compared and the efficiency of the filter described in per cent of particles passing. On the upstream side the air sample to the impactor is diluted with 88 times its volume of clean filtered air so that particle concentration in the microscope field will not be too high for counting. Particle sizes are in the range of .2 micron to 1.0 micron and are viewed at 1500 X magnification with an oil immersion lens. Appendix A gives some detail of the counting procedure and some typical results. The measurement appears to be reproducible to within about 5%.

This method of testing filters, though slow and laborious, is quite sensitive. Faults in the cement seal show without question. Two 0.030" pinholes made in the medium of a 120 square foot paper area filter more than tripled the number of particles passing. It is very important in this test that the filter be tightly sealed in its testing position and that there be no leakage of unfiltered atmospheric air into the clean side of the air stream.

Following is a table of the filter capacities and sizes that are favored at this time:

Outside Dimensions Inches	Paper Area Square Feet	Capacity CFM	Pressure Drop Inches of Water
8 x 8 x 5 7/8	12.5	50	1.0
24 x 24 x 5 7/8	120	550	1.0
24 x 24 x 11 3/4	265	800	1.0
20 x 20 x 8	120	450	1.0

When properly installed and gasketed, these units will stop all but 0.02% or less of particles in the size range of 0.2 to 1.0 micron. Efficiency improves with use. If used alone on outdoor country air, the life of these filters, running steadily at full capacity, may be as long as a year. In this time pressure drop may increase two or three fold or greater, depending on the dust load. In city areas or where the dust load is high, prefilters of present commercial manufacture may be used to remove a large percentage of the dust and thus protect and prolong the life of the final filter.

Since these filters expose a large area of combustible material to a fast moving air stream, they will burn rapidly if ignited. For this reason they should not be mounted where exposed to the hazard of fire. In a chemical laboratory hood installation, for example, a glass fiber or, still better, a metal prefilter would be helpful in protecting against flash fires.

At very high humidity the paper expands and there may be some buckling evident in the pleats. Noticeable distortion does not occur until 90% RH is approached. Tests have shown that such distortion does not affect the performance of the filter. However, a filter of this kind should not be used under conditions where the air is frequently saturated with moisture or carrying water fog.

Within the past several months sample filters representing a range of sizes have been sent on request to the various Atomic Energy Commission operating areas. It is expected that these filters will be put to various uses and tests. We are awaiting reports upon them.

Work immediately ahead on filter construction includes applying machine operations to pleating and production of separators. A pleating machine has been built and is being set up for use. A corrugator is already in operation. When the operations have been worked out most efficiently, cost figures will be compiled.

It is expected that ultimately a manufacturer will undertake to produce the filters commercially.

<u>Testing of the Filter Media</u>

Because the paper developed for high efficiency filtration of air comes so close to effecting complete removal of suspended dust, it has been necessary to take special steps in the testing of such media.

Methods commonly used for evaluating commercial air cleaning devices are totally inadequate when they are applied to high efficiency papers. Of the various devices designed for the collection and study of small solid particles we have considered the thermal precipitator and the high speed impactor. The thermal precipitator is very slow - it samples at the rate of only 8 cc of air per minute. For very clean air the time required for a test run becomes impossibly large. For this reason we investigated the high speed impactor as the means for measuring the dust content of clean filtered air. On the other hand, the thermal precipitator is a far more efficient collector than the impactor. An efficiency of 100% has been shown for the thermal precipitator on particles down to 0.1 μ. This instrument therefore can serve as a means for determining the collection efficiency of such devices as the impactor.

Cascade impactors have been described and discussed by May (J. Sci. Inst. Vol. 22, pp. 187-95, 1945) and Sonkin (J. Ind. Hyg. & Tox. Vol. 28, No. 6, pp. 269-272, 1946. The latter showed that particles down to 0.1μ in size could be collected for study.

At first we built a four-stage brass impactor using the jet opening sizes described by Sonkin. It was found that nearly all of the particles of normal atmospheric dust were deposited on the final stage. This model was assembled using especially built nozzle sections with ordinary 1/2" brass pipe fittings. Tests on air effectively filtered by several layers of high efficiency paper gave such a large count of particles that the results could not be accepted. A careful check showed that the piping system had several minute leaks. Some leakage occurred also past the gasket seals enclosing the jet chambers.

The point is brought up to emphasize the very great care that must be used in making up joints and seals on the suction side of all impactors used for accurate determinations of minute dust loads. If the impactor is to be used for evaluation of these highly efficient filters, every possibility for leakage or other sources of stray dust particles must be eliminated.

A new impactor was made having only a single sonic velocity stage passing about one quarter of a cubic foot of air per minute. This was done to reduce the number of gasketed joints to the minimum and to minimize the number of places where stray dust particles might be retained to cause trouble during passage of a low count air sample. The low-speed jets would not be needed for the well filtered air in which we were particularly interested.

In Figure 3, the impactor is shown. It has a single jet which has an opening 0.7 cm x 0.02 cm. The distance between the jet and collector plate is .05 cm. The instrument passes 7.3 liters of air per minute (normal conditions). To introduce or remove the collector plate (microscope slide) there is a removable screw cap at the end of the impactor chamber. A single carefully fitted rubber gasket inside the cap seals it against leakage.

Three plug valves are used to control air flow through the impactor. They are three way, two port, all brass valves and must be of the best quality so that they work easily and remain tight. Connecting lines are 1/2 inch copper tubing with sweat fittings. A globe valve is used between the impactor and vacuum pump. This valve must face in the proper direction to put the valve stem and its packing on the pump side of the seat. A rotary vacuum pump is used (Model 10F F60, Gast Mfg. Co.).

To test the system for tightness and to show the pressure during operation a mercury-in-glass manometer is connected into the impactor chamber.

When left full of atmospheric air, the impactor interior will contain many thousands of particles. Those on the upstream side of the jet will be deposited on the plate if they are not removed before sampling is started. To accomplish this removal of enclosed particles, provision was made for evacuating and flushing the impactor in a way to avoid any deposition of them.

Fig. 2 is a diagram of the impactor and its system of valves. In setting (a) valve V_1 is closed, valves V_2 and V_3 are positioned so that air can flow through the jet in a reverse direction only. When the throttle valve V_4 is opened, the system is evacuated to the pressure of which the vacuum pump is capable (1 in. Hg Abs.).

Valve V_4 is then closed. If the system is tight, no pressure change will show on the manometer at M during a period of several minutes.

Valve V_1 is now turned as in setting (b) so that the air to be sampled is drawn through entrance tube E_1 and fills the system. That part of the air which passes through the jet can only do so in the reverse direction, and there is no dust deposition on the slide S. The evacuation and flushing of the system may be repeated several times to "rinse" it thoroughly. Finally, there will remain only a charge of the air which is to be sampled.

Finally the valves are arranged as in setting (c). With valve V_4 open, the air flows through the impactor jet in a forward direction and dust particles are deposited on the slide S.

Entrance line E_2 is provided so that either of two air sources may be selected by setting of valve V_1, for example, upstream and downstream of a filter. In our work only one entrance line was used and E_2 was closed off.

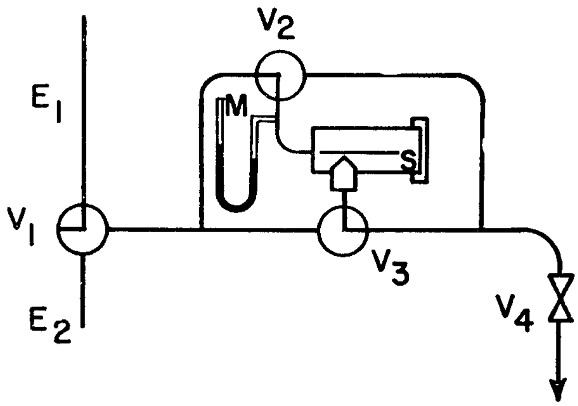
Examination of Impactor Slides

Before insertion in the cell, the pick-up face of the impactor slide is coated with a thin film of adhesive composed of 1 part rosin and 3 parts castor oil blended by heating. A drop of adhesive placed on the slide is doctored down to a very thin layer with the edge of a second slide.

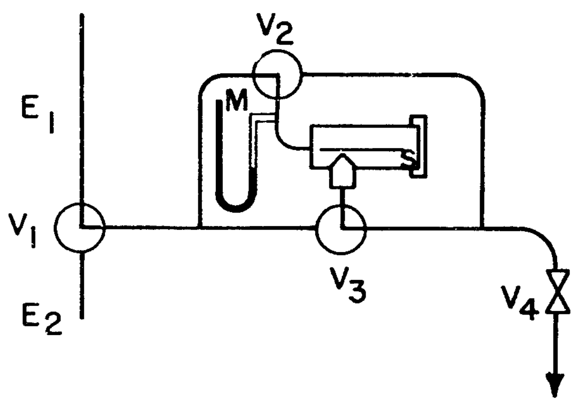
When removed from the cell, the slide can be mounted in the microscope for counting particles. An oil immersion lens will permit use of a 1450 X magnification.

FIG. 2

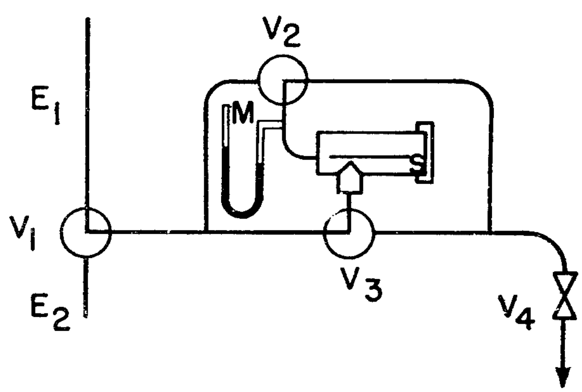
VALVE ARRANGEMENT FOR HIGH SPEED IMPACTOR



SETTING A



SETTING B



SETTING C

In our work an eye piece reticle having 100 squares was used. This was matched against a stage scale and found to measure 5.1 microns on a side or 26 square microns for each small square. The total large field was therefore 2600 square microns. The concentration of particles was ascertained by counting the number per small square and averaging over the whole dust patch. A typical calculation is shown in Appendix A.

Particles in outdoor air were in the size range of 0.2 to 1.0 microns with most particles in the neighborhood of 0.3 to 0.5 micron.

Air Filtration Test Equipment

Experiments are conducted in an enclosed cabinet into which either outdoor or filtered air is led. Provision is also made for injecting and dispersing into the atmosphere of the cabinet any selected dust at a controlled feed rate or batchwise as desired.

Fig. 3 is a photograph of the test chamber. It is constructed of 3/8" plywood sheet, all joints are sealed with putty and the whole is shellac-coated inside and out. The front has a large glass door which swings up to allow access to the interior. When closed the door is gasket sealed and held secure with bolts and wing nuts.

Air from outdoors is led into the top of the chamber through a five inch diameter duct. When filtered air is desired, a pleated paper filter is mounted beneath the duct opening inside the box. Exit air from the box is drawn through the particular filter or media sample which may be under test.

Various sample holders and filter frames in the box can be mounted or removed readily. Fig. 4 shows one device which has been used. It is a circular sample holder designed to test small samples of sheet material or bulk fiber up to 2 1/2 inches in thickness. This holder also makes provision for careful removal of the test media for weighing when this is desired. It is a very versatile unit. The threaded exterior shell allows a cap to be mounted so that special smokes or vapors may be passed through a filter media sample.

In Fig. 5 a rectangular holder is shown which will accommodate a 50 CFM 8" x 8" finished filter. There is also an adapter (not shown) which allows 8" x 8" size sheets of paper or other sheet or pad material to be mounted for test in this same holder. The large threaded nut on the exit tube permits easy and rapid installation and removal of the assembled unit. Air from the test filter passes through a 2-inch copper tube in which are located a flow meter and throttle valves to control the flow rate. The main flow control is an accurately made slide valve. In parallel with this large valve is a 1/4 inch globe valve for fine adjustment.

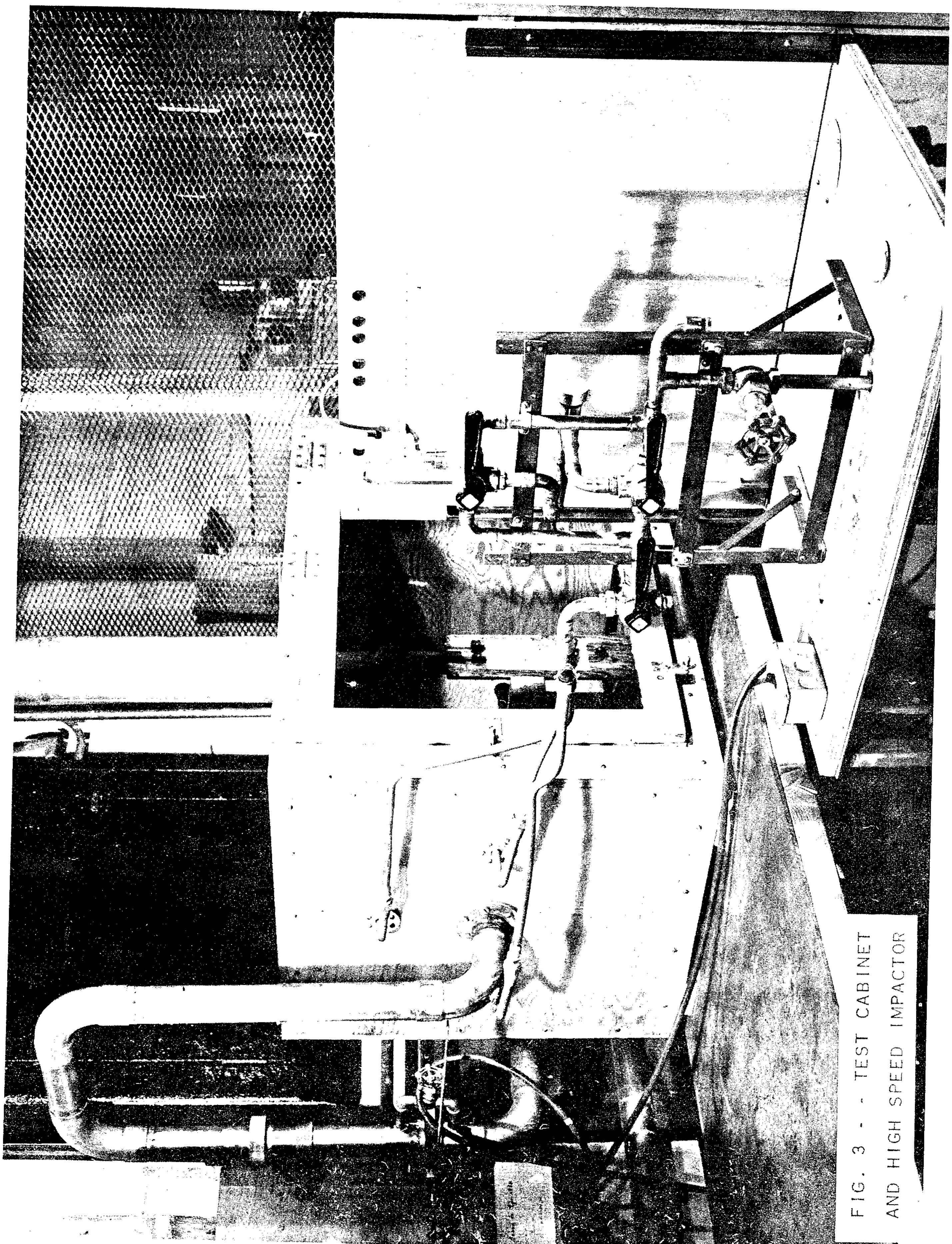


FIG. 3 - - TEST CABINET AND HIGH SPEED IMPACTOR

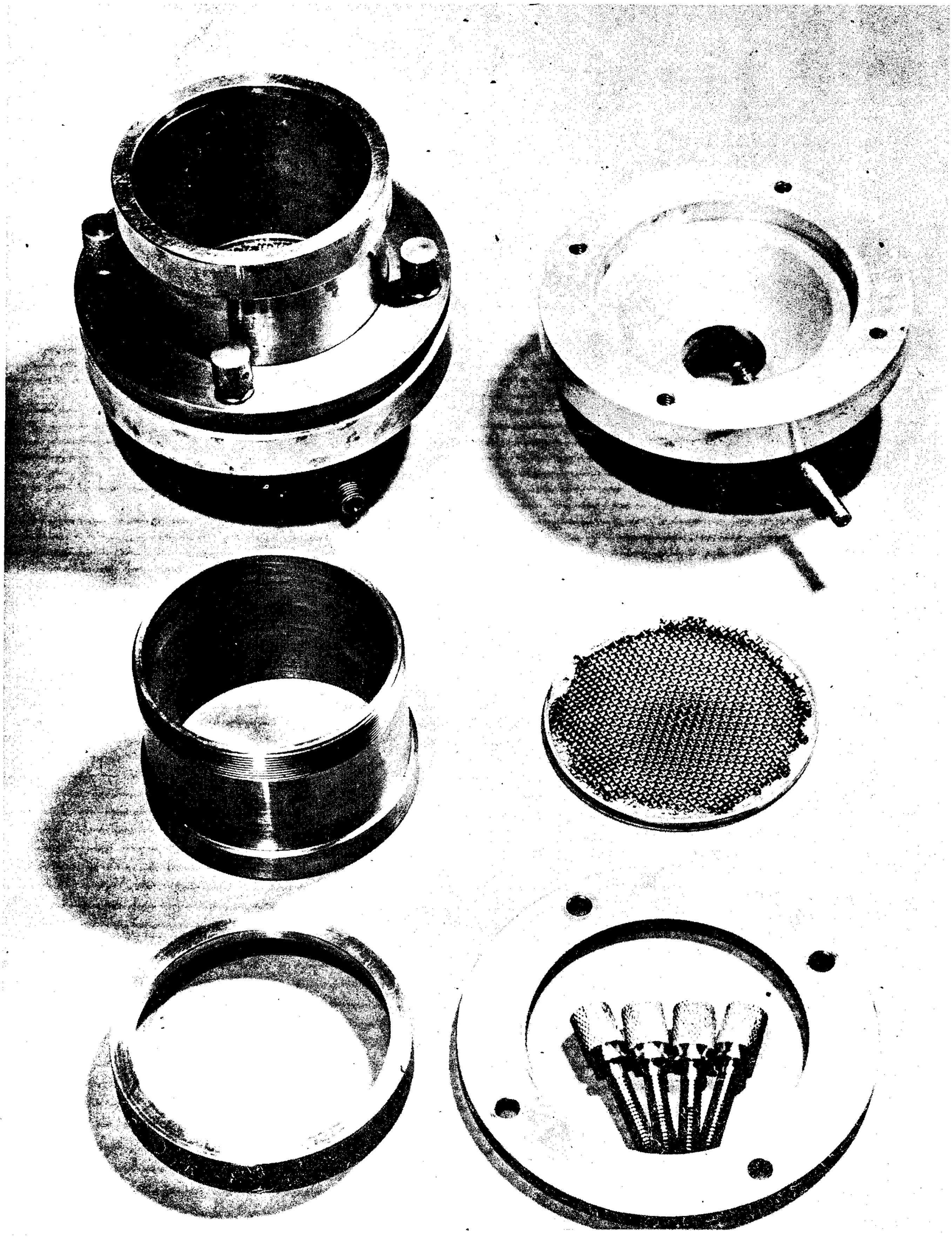


FIG. 4 - - CIRCULAR FILTER MEDIA HOLDER AND ITS PARTS

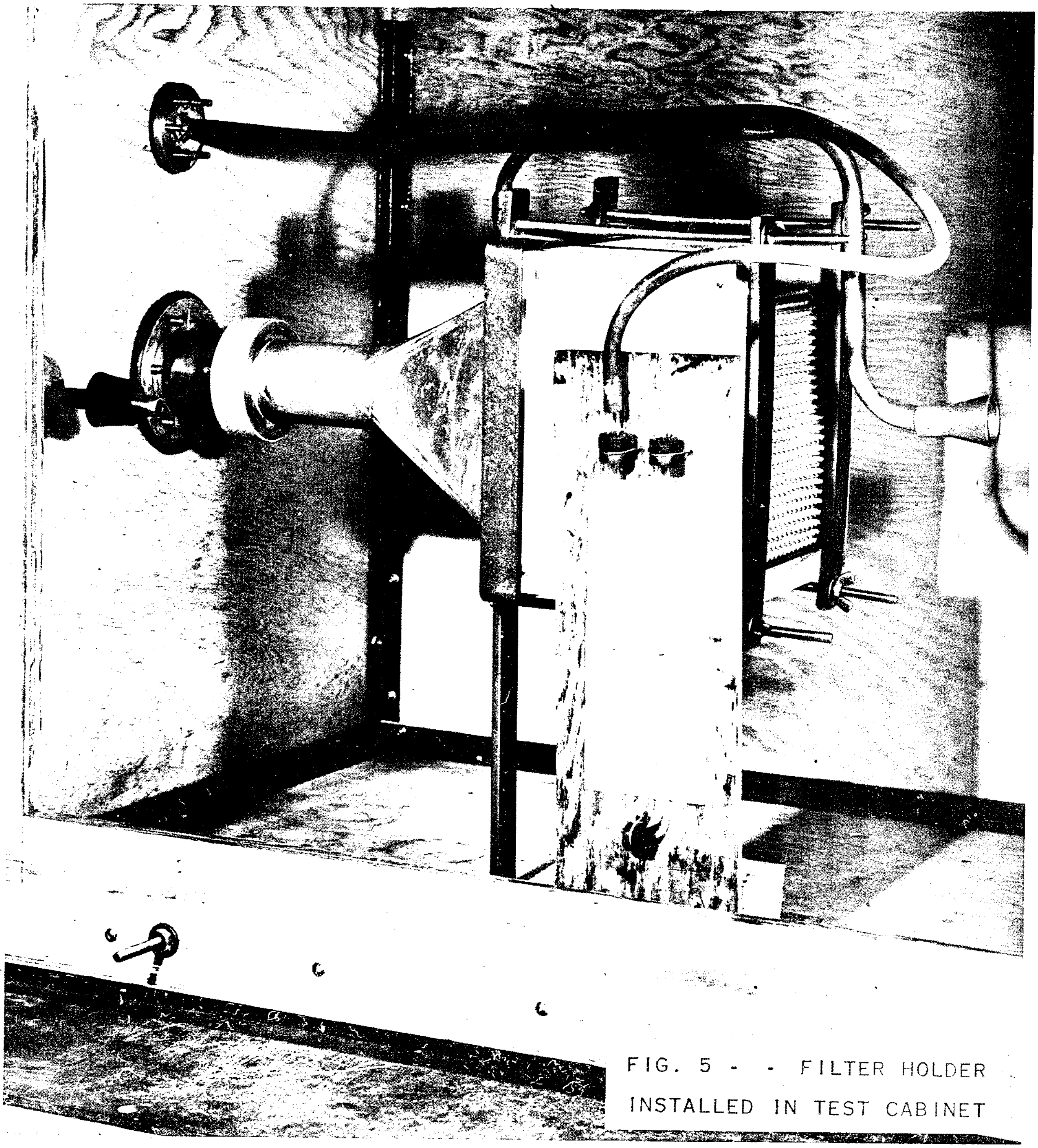


FIG. 5 - - FILTER HOLDER INSTALLED IN TEST CABINET

The flow meter is of the sharp-edge orifice type with removable orifice plates to allow the use of several flow ranges up to 85 cubic feet per minute.

A three stage Spencer turbine blower with a free capacity of 85 cfm and capable of providing a pressure drop of 20 inches of water draws air through the system. This blower will run continuously with very little attention. It is quiet and very effective.

Copper tubes, 1/2 inch in diameter lead from the cabinet interior just before the filter holder and from within the exit line exhausting the filter. These tubes may be coupled to the impactor to obtain dust samples of the air before and after filtration. When sampling tubes are not in use they are closed off with rubber stoppers.

Dust Injector

For the occasion when it is desired to test a filter against a selected dust we have constructed the unit shown in Figure 6. It is somewhat similar to the injector which we used earlier for dust loading tests and which was mentioned in our report No. 3. The present unit is smaller and more precisely made. There are two parts: the feeder and the disintegrator.

For a uniform feed of dust the turntable may be used. The dust is placed in a circular slot on the table, levelled off and the drive motor started. The table rotates at a speed depending upon the gears used. Gears are changeable. The lowest speed is about one revolution in 45 minutes. Feed rates are in the order of 0.005 gram per minute and up and varying, of course, with the sample density.

From the table the dust is drawn up an aspirator tube and injected into the disintegrator which is a type of air micronizer. In this device air at about 20 lbs. per sq. inch pressure is supplied to an annular air space from which air jets lead to a central chamber. These jets, four in number, are arranged tangentially and cause high intensity whirling of the air. The dust-carrying stream also enters tangentially into the inner chamber where shearing forces break up aggregates. Separate particles are then carried in the exit air stream to a central opening, down the hollow supporting shaft and into the filter test chamber. So far as can be observed the shearing forces of the air effectively separate dust aggregates but do not cause breaking up or grinding of individual particles.

Filter Media Efficiencies Against Atmospheric Dust

Using the test cabinet and single stage high speed impactor described in the previous section a number of air filter media were tested for efficiency against normal atmospheric dust. Table I lists the materials, conditions of tests and results.

TABLE I

EFFICIENCIES OF VARIOUS AIR FILTER MEDIA AGAINST ATMOSPHERIC DUST

BASED ON COUNT OF PARTICLES FROM HIGH SPEED IMPACTOR

Material	Flow Rate ft/min.	Pressure Drop Inches of water	Particle per cc in Entering Air	Per cent Particles Passing	Efficiency %	Average Efficiency %
AEC Filter Paper Coated Roll No. 12 Lot 1030	5.25	0.8	2003	.0197	99.980	
Same after 205 min. of running	5.25	.95	1133	.0065	99.993	final time of running 445 min.
AEC Roll No. 12 Lot 1030						
1st 1/2 hour.	5.25	.75	1597	.026	99.974	
After 64 1/2 to 67 1/2 hours	5.25	1.0	1199	.0049	99.995	
One 1/2" Sheet FG 25 Am. Air Filter Co. Med.	33	.05	793	37.2	62.8 *)	
	33		793	36.4	63.6)	62.9
	33		793	39.8	60.2)	
	33		793	34.9	65.1)	
Two 1/2" Sheets FG 25 Am.Air Filter Co. Med.	31	.12	824	50.1	49.9 *)	
	31	.12	824	39.0	61.0)	
	31	.12	824	36.9	63.1)	62.4
	31	.12	824	36.9	63.1)	
One 1/2" Sheet FG 50 Am.Air Filter Co. Med.	28.5	0.61	556	9.34	90.7	
	28.5	0.61	507	8.14	92.0	91.3
	28.5	0.61	556	8.85	91.1	

Two 1/2" Sheets FG 50	26.9	1.48	1990	0.949	99.05	
Am.Air Filter Co. Med.	26.9	1.48	2086	0.920	99.08	99.36
	26.9	1.48	1877	0.235	99.77	
	26.9	1.48	1231	0.462	99.54	
One 1/2" Sheet FG 25)	30	0.91	4248	5.7	94.3	
One 1/2" Sheet FG 50)	30	0.91	4248	6.4	93.6	93.9
Am.Air Filter Co. Med.	30	0.91	4248	6.2	93.8	
Rubber Latex Face Mask Filter	28	0.0	1810	100	0.00	0.00
Vacuum Cleaner bag paper hemp fiber	14	0.32	3099	70.2	29.8	29.8
Dollinger Glastex GB	5.25	.06	793	50.2	49.8	
" "	5.25		713	52.4	47.6	47.5
" "	5.25		537	54.9	45.1	
Dollinger Glastex GB	36.7	.50	891	76.1	23.9	
" "	36.7		658	86.5	13.5	16.2
" "	36.7		525	82.6	17.4	
	36.7		424	90.2	9.8	
Dollinger Glastex GA	5.25	.02	645	85.5	14.5	
" "	5.25			79.7	20.2	
" "	5.25			76.0	24.0	22.4
" "	5.25			80.4	19.6	
" "	5.25			74.1	25.9	
Dollinger Glastex GA	34.2	.25	624	69.9	30.1	
" "	34.2			87.6	12.4	
" "	34.2			88.5	11.5	13.1
" "	34.2			83.8	16.2	
" "	34.2			87.6	12.4	

*Inconsistency may be due to non-uniformity of samples

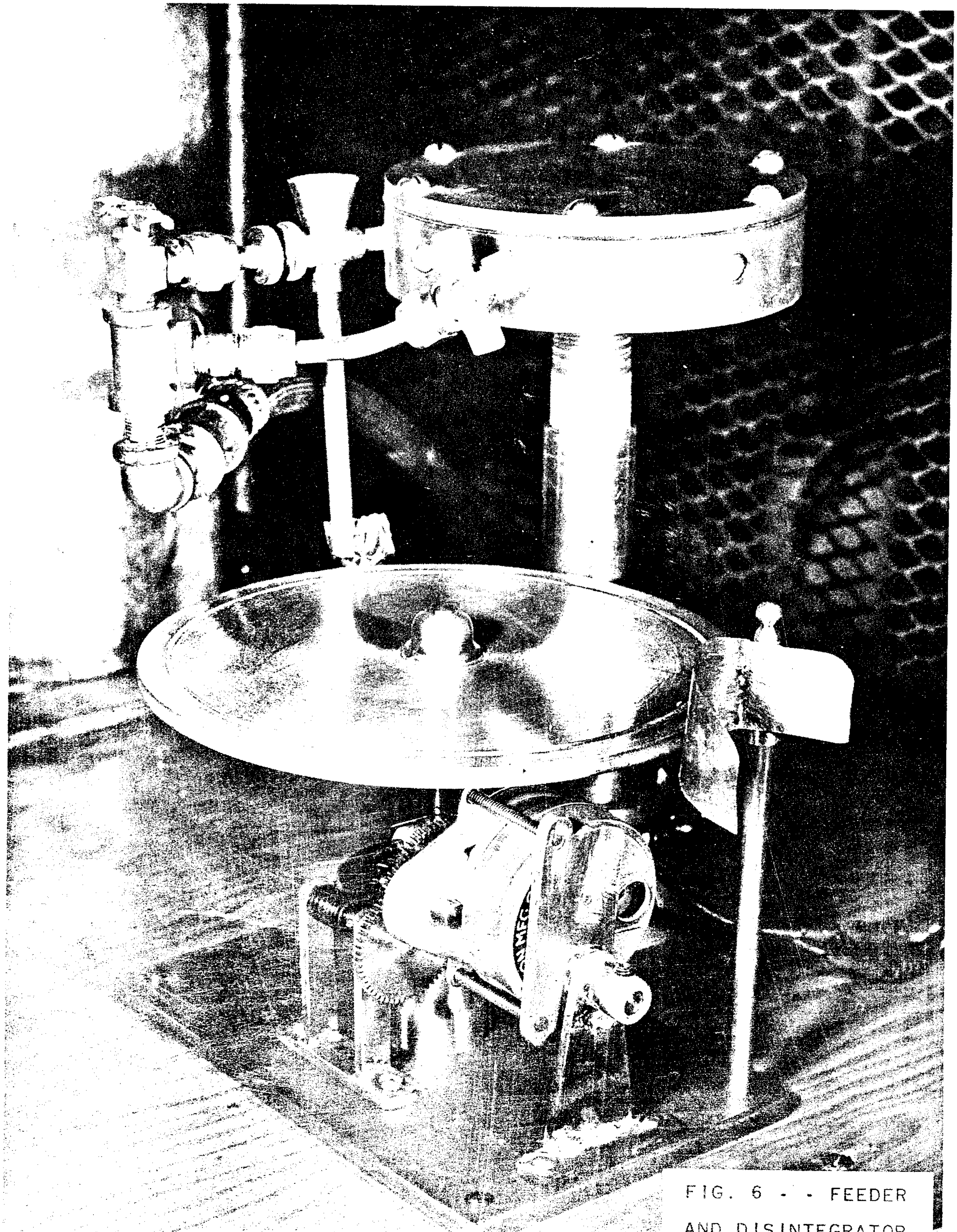


FIG. 6 - - FEEDER AND DISINTEGRATOR FOR DUST INJECTION

Paper medium as represented by the first two items in the table is without question the most effective material for practical high efficiency air filtration. To visualize the cleanliness of air through such a filter: it is often necessary to run the impactor 16 hours to obtain even a line trace with enough particles for a count. On the other hand the entering unfiltered air needs to be sampled no longer than ten seconds to give a dense field of particles on the impactor plate.

Much attention has been given to the use of fine Fiberglas mats as a material for prefilter to protect paper filters against rapid loading and short life. These bulky but compressible glass mats are formed of random fibers of fairly uniform diameter bonded into a stable structure with phenolic resin. One product known as FG-25 is made of glass fiber having a diameter of about 3 microns while FG-50 is composed of 1.3 micron diameter fiber. Both mats are about 1/2 inch thick with a bulk density of 0.5 lbs. per cu. ft. for FG-25 and 0.6 lb. per cu. ft. for FG-50.

Bonded fine glass fiber mats show excellent performance against atmospheric dust. Moreover particle accumulation occurs in depth and this assists in giving long life. The manner of distribution is shown in Fig. 10 for sectioned mats which had been used to filter outdoor air for six months. One objection to their use for absolute filters is the difficulty in making a one hundred per cent seal or bond between the filter mat and its supporting frame.

Earlier work in these laboratories and work by the American Air Filter Co. have demonstrated the desirability of using a graded density filter pack for long-life fiber filters. This and the high efficiency of the FG-25 - FG-50 combination recommends this combination as a fore filter to be used ahead of the final clean-up paper filter.

Two layers of the finer fiber mat FG-50 gives an excellent efficiency, but most of the work is done by the first layer, the life of which determines that of the combination. For a non-hazardous dust it is of course possible when changing filters to move the cleaner second mat into top position and place a fresh mat below.

Rubber sponge filter pads which are sold for use in industrial face mask filters proved to be no barrier whatever to atmospheric dust in these tests. It is quite possible that they would be useful for coarse dusts but this was not determined.

Vacuum cleaner bag paper as used in disposable dust bags gave a low dust retention in our tests. In normal use such a paper would be expected to filter out dust which had been already deposited on the floor, for instance, and therefore agglomerated along with hair, lint, and other large particle material. Under such use the collection efficiency on a mass basis would be large.

Glastex filter media furnished by the Dollinger Corporation are woven glass fiber fabrics. Because of the fabric construction, most of the filtration must occur in the mesh openings. It is not surprising then that this type of media is much less efficient than the fiber mats.

Since fine glass fiber mats are effective in filtration of small air-borne particles, they are of interest as a substitute for combustible paper media and for high temperature work. However, the mats now available commercially are too thick to be pleated into compact units. Upon request the Fiberglas Corporation prepared a number of high density phenolic bonded mats most of which contain mixed AA (1.3 microns) and B (3 microns) fibers. These mats as made were compressed into relatively thin sheets comparable to paper and they show great promise.

Table II contains the experimental results for the fine fiber mats in air filtration tests against atmospheric dust. Except for the last three or four items in the table these mats are easily the equivalent of good papers on solid dust in the size range of 0.2 to 1.0 micron. However, they are not in commercial production and if manufactured probably would be several times more expensive than a paper based mostly on organic fibers.

Improvement of Filter Paper with Use

When efficiencies are measured on the filter papers developed under this contract the particle count downstream of a new filter is so low that the impactor must be run for a period of perhaps an hour to provide enough particles to give a good count. In a series of such tests it was found that check results were not obtained for several successive tests. The indicated efficiency became progressively higher. Table III shows the numerical results for a continued run and the change of efficiency and pressure drop is shown in Fig. 7. One explanation is that minute faults in the paper become filled so that the true filtering ability of the paper is only evident thereafter. The shape of the efficiency curve suggests this mechanism. In any case it has been well demonstrated that even a poor paper improves rapidly so that after a few days of use it is equivalent to a paper which initially was far better.

It is also possible to explain the apparent improvement of the paper in the following manner: Assume that the paper is really highly efficient so that no particles of a size detectable by the impactor technique will penetrate. If then, however, particles on the downstream face of the paper are blown off or particles in the paper but near that surface are blown through, there will then be a maximum count of these particles at first then progressively fewer as their number in the paper becomes less.

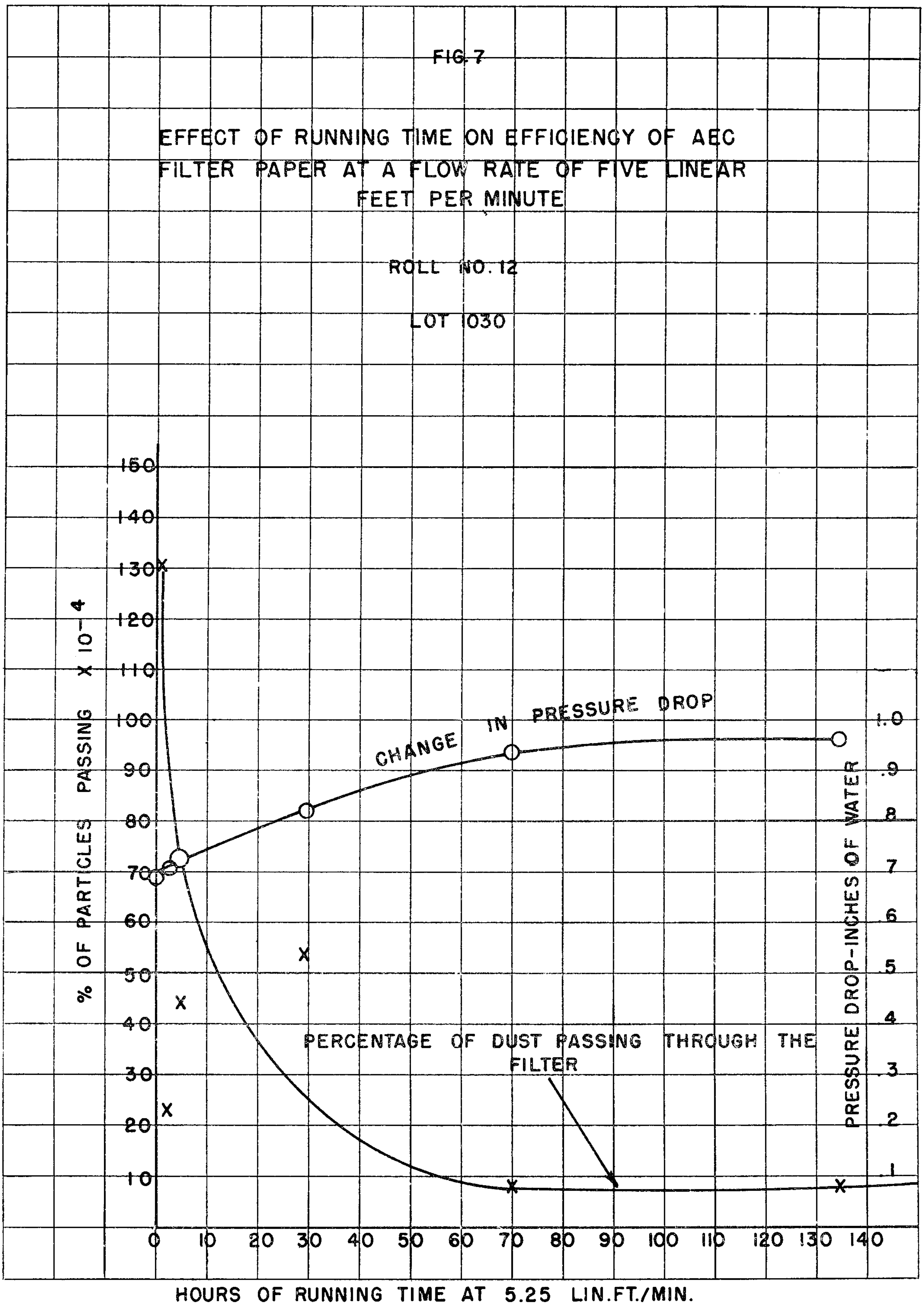


FIG. 7
EFFECT OF RUNNING TIME ON EFFICIENCY OF AEC FILTER PAPER AT A FLOW RATE OF FIVE LINEAR FEET PER MINUTE
ROLL NO. 12
LOT 1030
% OF PARTICLES PASSING X 10⁻⁴
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
CHANGE IN PRESSURE DROP
PERCENTAGE OF DUST PASSING THROUGH THE FILTER
PRESSURE DROP-INCHES OF WATER
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
HOURS OF RUNNING TIME AT 5.25 LIN.FT./MIN.

TABLE

PERFORMANCE OF EXPERIMENTAL
AS AIR FILTERS AGAINST

Sample Identification	Wt % AA Fiber	Wt % B Fiber	Mat thick-ness inches	Mat Density lbs/ cu.ft.	Air Velocity through Media ft/min.
CH-XX-11-1	50	50	0.041	24	5.25
CH-XX-12-1	33	67	0.091	15	5.25
CH-XX-11-6	50	50	0.013	30	5.25
CH-XX-11-5	50	50	0.020	23	5.25
CH-XX-11-4	50	50	0.022	23	5.25
CH-XX-12-3	33	67	0.033	19	5.25
CH-XX-11-3	50	50	0.015	28	5.25
CH-XX-13-1	100(A)		0.048	16	5.25
CH-XX-12-4	33	67	0.055	15	16.5

NO. II

COMPRESSED FINE GLASS FIBER MATS
ATMOSPHERIC DUST* AND D.O.P. SMOKE

Pressure Drop inches water	Dust Count in up-stream particles/cc	Dust Count in downstream particles per cc.	Percent of Particles Passing	D.O.P. Test ΔP mm H_2O	D.O.P. Test p % passing
1.36	3870	0.0106	0.00027	206	0.002
0.89	4930	0.55	0.0112	128	0.017
0.80	1580	0.181	0.0114	117	0.27
0.69	1760	0.0443	0.00255	104	0.36
0.65	2020	0.00738	0.000366	98	0.41
0.38	2200	0.94	0.0428	78	0.60
0.55	1620	1.03	0.0636	113	0.41
0.23	1480	13.9	0.941	41	14.0
1.18	4820	6.8	0.141	66	1.6

*Based on count of particles collected with the high speed impactor

TABLE III

EFFECT OF RUNNING TIME ON EFFICIENCY

OF PAPER AIR FILTER MEDIUM

Filter Medium	Cumulative Running Time Hrs.	Pressure Drop in. H_2O	Lin. Veloc. ft./min.	Upstream particles/cc	Downstream particles/cc	% Particles passing
	0-.075	0.69	5.25	2236	0.293	.0131
AEC paper	.75-2.75	.69-.71	5.25	2027	0.0454	.0022
- coated	2.75-6.75	.71-.74	5.25	1589	0.0688	.0043
	22.75-26.75	.78-.79	5.25	1315	-	-
Roll #12	26.75-32.75	.79-.84	5.25	2854	0.1528	.0054
Lot 1030	57.0 -62.0	.93	5.25	-	-	-
	62.0 -78.0	.93	5.25	2210	0.0175	.00079
	126 - 143	.93 - .96	5.25	2024	0.0154	.00076

To determine if this last mentioned process does in fact take place an experiment was conducted in the following way:

Two sheets of A.E.C. paper (#12 roll) were placed together in the sample holder and air drawn through at the usual velocity (5 linear feet per minute). An initial dust count was made of air after it had passed through both sheets of paper in series. After the papers had been run for 65 hours on unfiltered outdoor air a second set of dust counts was made on the combination of papers. The usual result was found. The second count was only 1/500 part of the first.

The upstream paper was then removed, leaving only the one (previously protected) paper in the tester. At an air flow rate of 5 feet per minute an efficiency determination was made. Again this value was found to be low as for a fresh piece of paper. After 65 hours more of running time the efficiency was found to have improved to the same extent as before.

This experiment demonstrated definitely that the paper efficiency improves with use and that the observed facts can not be attributed to particles from the paper itself.

It should be mentioned here that in the dioctylphthalate smoke test, a very different kind of result is obtained upon continued running. This test uses a finely dispersed oil "smoke" around 0.3 micron in diameter. Here the paper becomes progressively poorer in efficiency as it is run continuously in the tester.

Tests of Filter Media at Brookhaven

In considering the selection of media for air filtration at the Brookhaven National Laboratory at Upton, Long Island, it appeared desirable to make some test runs at the site. By such tests it was hoped to obtain a preview of the performance of the media and to learn of any special problems or difficulties that might be encountered at that location.

Early in 1949 a portable media tester was constructed. The unit is shown in the photograph Fig. 8. It consists of a box housing, an exhaust blower, and four test stations each with its flow meter, control valve and pressure drop manometer. During the run the box was closed so that air was drawn in through the side screened parts to keep out insects and other large objects.

Those in the meteorological group at Brookhaven (particularly Mr. Maynard Smith, group head; and Mr. Daniel Mazarella) were highly cooperative and conducted the tests. All of the data for the run were taken by this group.

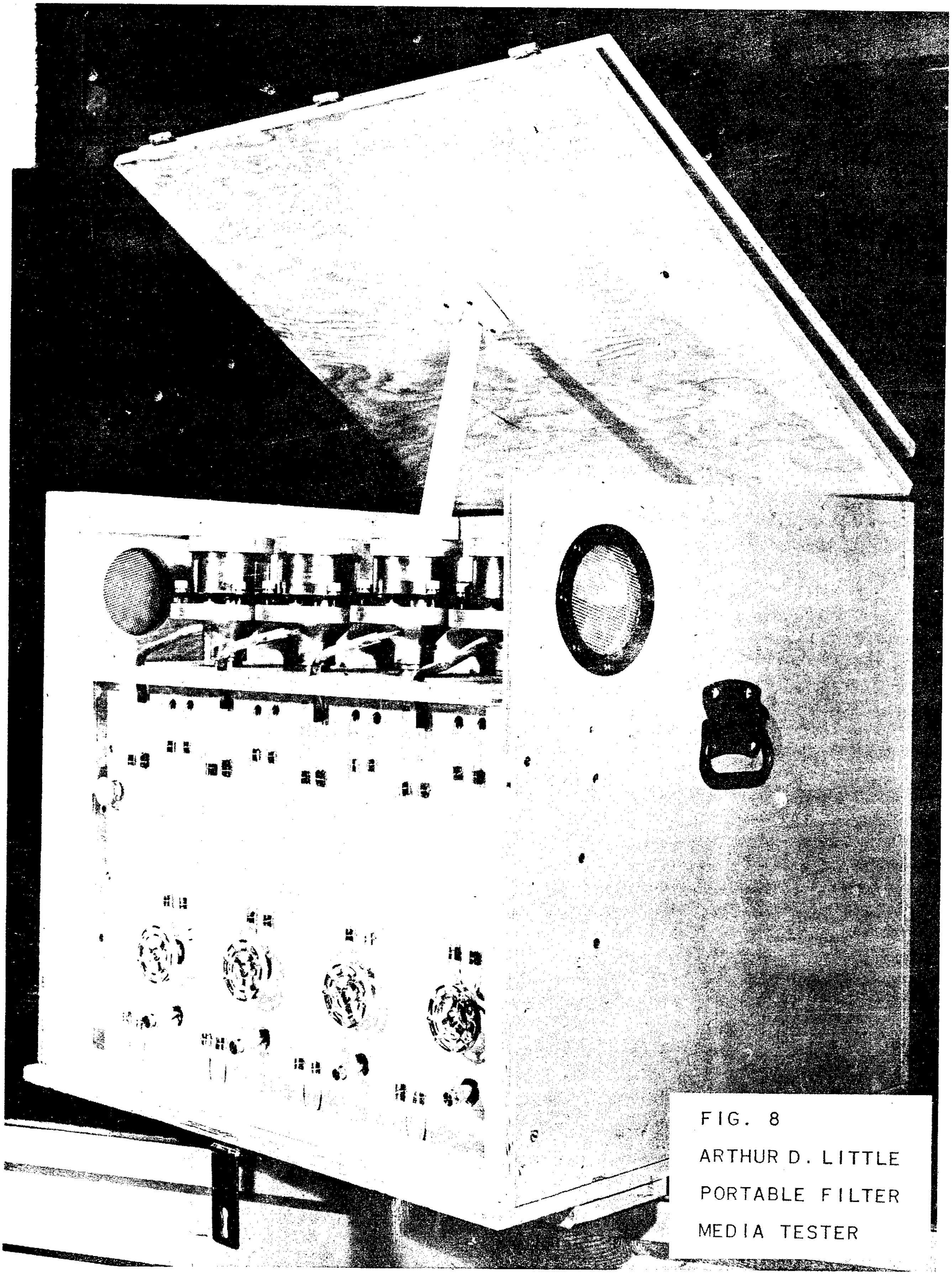


FIG. 8
ARTHUR D. LITTLE
PORTABLE FILTER
MEDIA TESTER

Table IV is a summary of the filter media run showing the materials tested and the results in each case. Originally it was intended to have the air flow rates approximately fifty per cent higher than those actually used. However, 20 ft. per min. is the air flow rate at which the glass fiber media are normally used while the 8 ft. per min. on the paper filter media is a little higher than the 5 ft. per min. normal for the paper.

During the run the flow rates were held constant and a log maintained of pressure drop. A record was also kept of air temperature and humidity. In the final record no correlation was seen between the pressure drop fluctuation and atmospheric conditions, so the latter record is not included here. Fig. 9 is a set of plots showing pressure drops across the filter media samples during the run of about 5 1/3 months. The manometer readings are shown in inches of kerosene. This fluid was used because of the danger of freezing temperatures during the early weeks of the test.

Referring again to Table IV, the pressure drop increase over the entire period is highest for the paper, next highest for the fine fiber in two layers and least for 1/2" B fiber with one layer of fine fiber. These are in the expected order. The per cent pressure drop increases are more nearly alike for all cases.

At the end of the run the weight of dust accumulated was measured. Care was taken to avoid any error due to moisture in the filter mats. All were desiccated to constant weight and weighed in tight metal cans. From the dust weight and the amount of air passed through the media (3" diam. circle) the average dust concentration in the air over the test period was calculated. Good checks were obtained for the glass fiber samples but the difference between them and the paper filter was much higher than could be expected for the known difference in efficiencies of the two types of media.

Figure 10 shows the appearance of the various filter pads after the run. Two layers of FG-50 glass fiber show the accumulation of dust almost entirely in the top layer; where FG-25 and FG-50 were used in series, there was distribution of the dust in depth. This was also true in the case of B fiber followed by FG-50. The dust layer on the filter paper was almost entirely in or near the surface. This is shown clearly in the photomicrograph, Figure 11, which shows the paper in section.

As a result of this experimental run, it is concluded that the dust load in the atmosphere at Brookhaven is very light and performance of the several filter media tested should be entirely normal and satisfactory if used in installations at that site.

Originally it was suspected that a high per cent of sea salt might be accumulated in filters used in this area and that this

TABLE IV

SUMMARY OF FILTER MEDIA TESTS AT BROOKHAVEN (1)

Tester Position No.	Description of Media on Test	Air Flow Rate Linear ft/min	Air Flow Rate Volume CFM	Pressure Drop inches of water Initial	Pressure Drop inches of water Final	Press. Drop increase in. water	Percent Press. drop increase	Wgt. of accumulated Dust in grams	Calc. Dust Conc. in Air mg/cu. meter
1	Two layers FG 50 medium	20	0.95	1.08	1.76	0.68	63	0.2029	.0322
2	Upper layer FG 25 Lower layer FG 50	20	0.95	0.65	1.19	0.54	83	0.2114	.0334
3	Upper layer 1/2" B fiber Lower layer FG 50	20	0.95	0.57	0.98	0.41	72	0.2003	.0318
4	Paper filter medium (uncoated)	8 (2)	0.38	1.68	2.78	1.10	65	0.1660	.0659

Notes: (1) Tests run from March 28, 1949 to September 6, 1949.

(2) Normal flow rate for paper is 5 ft. per min.

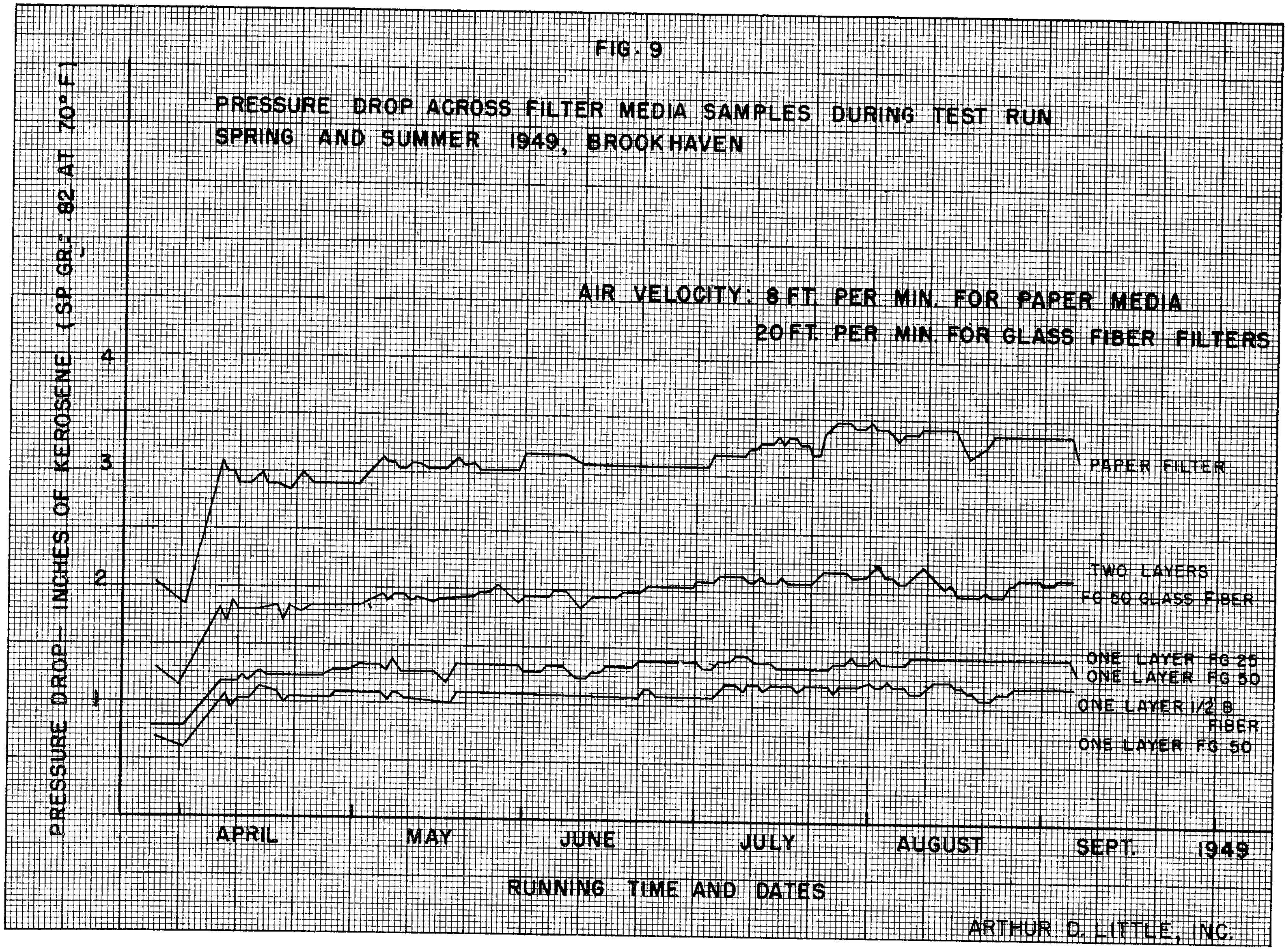
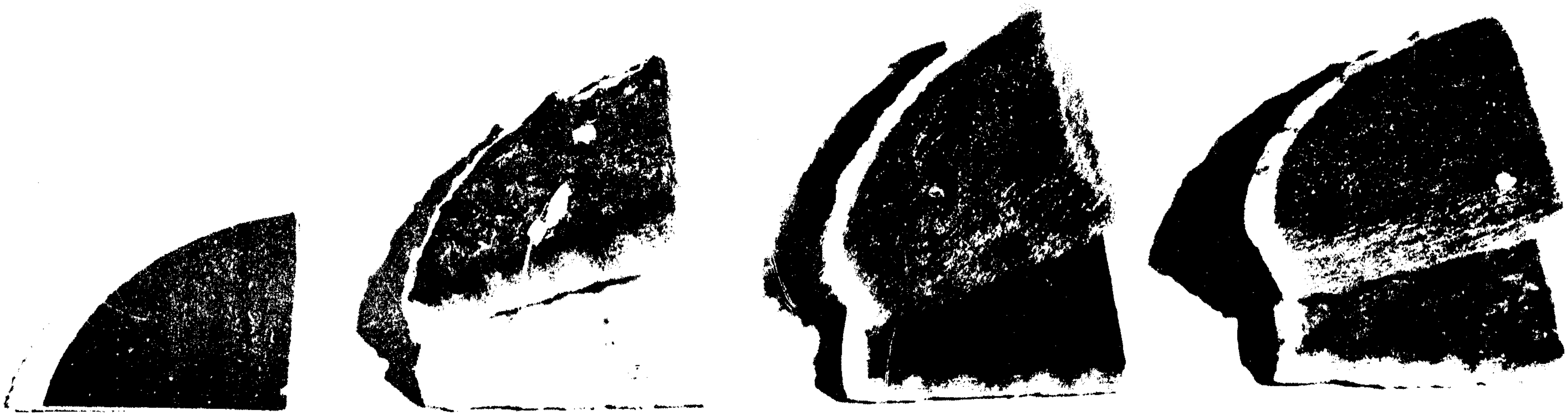


FIG. 9
PRESSURE DROP ACROSS FILTER MEDIA SAMPLES DURING TEST RUN
SPRING AND SUMMER 1949, BROOKHAVEN
AIR VELOCITY: 8 FT. PER MIN. FOR PAPER MEDIA
20 FT. PER MIN. FOR GLASS FIBER FILTERS
PRESSURE DROP– INCHES OF KEROSENE (SP. GR.: .82 AT 70° F)
4
3
2
1
PAPER FILTER
TWO LAYERS
FG 50 GLASS FIBER
ONE LAYER FG 25
ONE LAYER FG 50
ONE LAYER 1/2 B
FIBER
ONE LAYER FG 50
APRIL
MAY
JUNE
JULY
AUGUST
SEPT.
1949
RUNNING TIME AND DATES
ARTHUR D. LITTLE, INC.



UNCOATED PAPER MEDIUM

TWO LAYERS FG 50 FIBER

TOP LAYER FG 25
LOWER LAYER FG 50

TOP LAYER 1/2" B FIBER
LOWER LAYER FG 50

FIG. 10 - DUST PENETRATION IN VARIOUS FILTER MEDIA AFTER SIX MONTHS RUN AT BROOKHAVEN

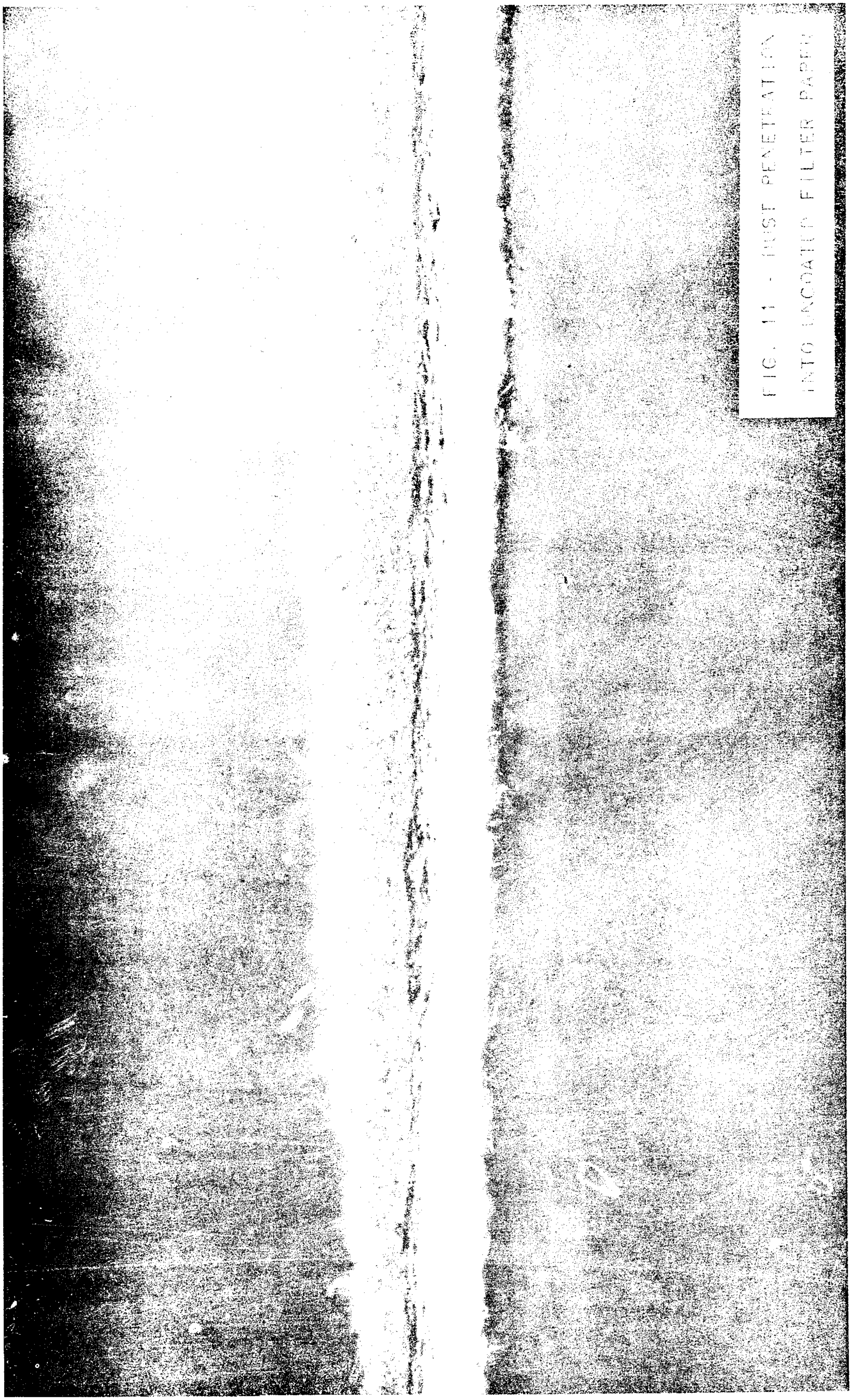


FIG. 11 - DUST PENETRATION INTO UNCOATED FILTER PAPER

would result in early clogging. This difficulty did not arise and an analysis of the dust accumulated in the filter paper showed little or no chloride content.

Improvement of Glass Fabric Filters

For filtration of air at temperatures to 500° F. it has been proposed to use a woven glass fabric filter. Such a filter is made by the Dollinger Corporation and has been planned for atomic plant installation. Because of its woven structure such a filter shows many openings and by test is not an efficient filter on submicron size particles. We felt that an improvement might be made by "priming" the filter with a fine fibrous material.

Some first experiments consisted of mounting one of the 20" x 20" steel frame units so that finely shredded asbestos could be blown into the air stream fed through the filter. The asbestos was fed a small quantity at a time into a Raymond hammermill and the product dropped directly into the air stream ahead of the filter. These attempts failed because the asbestos was too coarse and bridged across the filter fabric pleats closing them off. In this way the pressure drop was greatly increased without appreciable improvement in efficiency.

More recently experiments have been carried on in which "micronized" asbestos was fed into the air stream to a sample of Dollinger GA "Glastex" fabric. In this case the asbestos had been prepared previously by grinding it in a commercial air type micronizer. The individual asbestos fibers were mostly below one micron in diameter and a large percentage were in the small fractional micron range. Fiber lengths varied from very short up to several hundred microns. A small amount of this finely divided material was fed through the dust disperser into the test chamber (Fig. 3) and taken up on a 6" x 6" area of the filter fabric.

At an air rate of 30 linear feet per minute the pressure drop across the filter was 0.20 inch of water at the start. When 0.18 gram asbestos had been fed in the pressure drop had reached 1.0 inch of water. Using the high speed impactor and making particle counts in air samples before and after the filter the efficiency was found to have reached 99%. The value for the fabric initially was 30% measured by the same method.

In another experiment the asbestos primed filter mat was compared with the original fabric in the D.O.P. smoke tester. Again a very great improvement in efficiency was obtained at the cost of a moderate gain in pressure drop. The results of these tests are shown in the following table.

Test Particle	Test Measurement	Filter in Original Condition	Filter when Primed with Micronized Asbestos*
Atmospheric Dust	Pressure drop - in. of H_2O	0.15	1.0
0.2 to 1.0	Filter efficiency by count - % passing	70	1
Dioctylphthalate Smoke	Pressure drop - mm of water		15
0.3	Filter efficiency - % passing	100	9

*Wt. Micronized Asbestos Used 0.15 gm.

The final experiment of priming a full size filter has not been done as yet but it is believe that it will give a successful result. The micronized asbestos is extremely fine - it appears like a smoke as it issues from the nozzle of the disperser and it should present no difficulties of application.

MISCELLANEOUS ITEMS

In carrying out the work described in this report several activities were involved which to this time have not given sufficient results to be reportable. However, for the sake of completeness the items will be mentioned here briefly.

Particle Count Estimator

When using an impactor for determination of filter efficiencies, the greatest task is the microscope counting of small particles. We have given serious consideration to the possibility of estimating the concentration of particles on the impactor target by measuring the reduction in intensity of a light beam passing through the field. This was tried both with light passing through the microscope and with a light beam directly through the dust field. The second method appears to be the more promising and gives an averaged result for the entire dust sample.

A device has been assembled for estimating the density of the impactor dust field but more experimental work must be done with it. It shows promise of being a usable device.

Condensation Chamber

Because the impactor becomes lower in collection efficiency with decrease of particle size, it is certain that many if not most sub-microscopic particles pass along and do not deposit on the collecting plate. To improve the collection efficiency it is possible to condense moisture on the particles which thus increased in mass will be thrown out on the collector plate.

A steel pressure tank of 17 liters capacity was equipped with suitable valves and gages so that air could be compressed into it and the pressure suddenly released. The fog laden air was then put through a high speed impactor, the collector plate of which was coated with a removable film of organic material (formvar, collodion, etc.).

In operation the tank was filled with water. The water was drained out slowly and replaced with a sample of the air to be tested. A pump then forced water back into the tank compressing the air sample to about 60 pounds per square inch. After a period of time in which the air was allowed to cool, a large gate valve at the bottom of the tank was opened to allow the water level to drop rapidly. The air sample with its suspended droplets was then pulled quickly through the impactor with the water level again rising to replace the air.

Even though they were cast on a glass surface, the organic films on the impactor plate in every case were badly battered by the abrasive action of high speed water droplets. No intact films were obtained and we do not know yet how effective the procedure might be for collection of the smallest particles.

Thermal Precipitator

Two thermal precipitator models have been made but, again, they have not had enough experimental use to justify extended discussion here. The device is reported to have 100% efficiency for the particle size range in which we are interested. It is our intention to use the thermal precipitator as a calibrating means for the impactor in those cases where it is necessary to know the actual loading in an air sample. A further possibility is in the use of the thermal precipitator to collect and study submicroscopic particles for electron microscope study. This would permit the counting of particles of sizes normally passing through the impactor.

Electron Microscope Studies

A few samples of dust from the impactor have been examined under the electron microscope. Samples taken directly from the atmosphere have revealed particles down to a few hundredths of a micron in diameter. This indicates that some particles of this size may be caught by the high speed impactor. It is also possible and likely that these small particles are, in part at least, fragments of larger particles or agglomerates shattered by impact with the plate.

APPENDIX A

Procedure Used in Counting Particles on High Speed Impactor Plates

A thin layer of adhesive solution is applied to a microscope slide. The prepared slide is placed in the impactor, and a test is run for a sufficient length of time to obtain an impaction line satisfactory for particle counting.

The slide is prepared for observation under a microscope. The power of magnification used was 1425X. A grid of one hundred squares located in the eyepiece of the microscope divides the field of observation into squares of $26\mu^2$ at 1425 X.

Particle counts are made at eight points along the impaction area on the microscope slide. The usual procedure consists in counting the particles in five consecutive squares at each of the eight points along the impaction area. If the concentration of particles in an impaction line is very light it may be necessary to count the number of particles in ten or even one hundred squares of $26\mu^2$ each at 1425 magnification in order to obtain a reliable value for the particle count.

The average number of particles per $26\mu^2$ of impaction area is calculated and knowing the area of the impaction line, the rate of air passed through the impactor during the test and the length of the test, the number of particles per cubic centimeter of test air can be determined.

Sample Calculation

Impaction line area	$1.4 \times 10^6\mu^2$
Rate of air flow through impactor	$0.258\ ft^3/min.$
Time of run	T minutes
Particle count	N particles/($26\mu^2$ of impaction line area)

Ratio of ft^3 to cc = $ft^3/28,320$ cc

$$\frac{\text{Number of Particles}}{\text{cc}} = \frac{\text{N Particles}}{26\mu^2} \times 1.4 \times 10^6\mu^2 \times \frac{1}{(0.258\ ft^3/\text{min} \times \text{T min.})} \times \frac{ft^3}{28320\ \text{cc}}$$

TABLE V

TYPICAL DATA ON FILTER EFFICIENCY TESTS USING METHYLENE BLUE PARTICLE COUNTS ON HIGH SPEED IMPACTOR PLATES

Filter No.	Sampling Rate cc/min.	Time of Run - Min.	Particles per cc.	Sampling Rate CFM	Time of Run Min.	Particles per cc.	Percent Particles Passing
37	100	1	5410	.312	27	0.183	.0034
47	100	1	9220	.312	37	1.53	.017
45	100	1/2	4891	.312	15	0.90	.018
55	100	1/2	3803	.312	12	0.23	.0061
56	100	1/2	5535	.312	12	0.48	.0087

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