3385

NATIONAL BUREAU OF STANDARDS REPORT

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PERFORMANCE TESTS OF AN AAF CO. ELECTRONIC PRECIPITATOR

by

Henry E. Robinson
Thomas W. Watson

Report to
General Services Administration
Public Buildings Service
Washington 25, D. C.

NBS

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NBS PROJECT		NBS REPORT
1000-30-4837	June 28, 1954	3385

PERFORMANCE TESTS OF AN AAF CO.
ELECTRONIC PRECIPITATOR
ELECTRO-CELL Model A

by

Henry E. Robinson
Thomas W. Watson
Heating and Air Conditioning Section
Building Technology Division

to

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U. S. DEPARTMENT OF COMMERCE
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PERFORMANCE TESTS OF AN AAF CO. MODEL A ELECTRO-CELL ELECTRONIC PRECIPITATOR

1. INTRODUCTION

At the request of the Public Buildings Service, General Services Administration, the performance characteristics of electrostatic air cleaners were determined to provide information to assist in the preparation of new air filter specifications.

The test results presented herein were obtained on a specimen electrostatic filter unit submitted by its manufacturer at the request of the Public Buildings Service and included determinations of dust arresting efficiency with three aerosols (atmospheric air, kerosene lamp smoke, and Cottrell precipitate), pressure drop, specific dirt load and cleanability of the specimen.

2. DESCRIPTION OF THE FILTER SPECIMEN

The cleaner was manufactured by the American Air Filter Company, Inc., Louisville 8, Kentucky, and was of the electrostatic type. It was identified by nameplate as an AAF Electro-Cell Model A3, Size 230, 1200 CFM, Serial 553090. A representative of the manufacturer, present during the tests, stated that the nameplate was incorrectly marked, and that in accordance with AAF Bulletin 252-C it should read: "Model A, Size 230, 1540 CFM (for a rated air velocity of 333 feet per minute) Serial 553090." The power pack had the following nameplate data:

AAF Power Pack

Max. Input 1.5 amps, 115 V - 60 cy 1 PH 100 watts

Max. Output DC 2.2 MA Ionizer 13.0KV Collector 6.5KV

The test unit had a housing with actual outside dimensions of 24¼ inches in width, 36 1/8 inches in height and was 24 inches in length, and was rated as having 4.6 sq. ft. of transverse area, i. e., 1540 CFM air delivery at 333 fpm velocity. Transitions 15 inches in length, with flanges 30 inches square matching those of the duct of the test apparatus, were used to adapt the unit for test. The openings formed by these transitions were 24 inches square both upstream and downstream. The downstream face of the Electro-cell housing was adapted to receive a nominal 24 x 31 x 2 inch after-filter, which for this unit was a 23 3/4 x 31 inch pad of Amer-glas (throwaway type) sandwiched and compressed to a thickness of approximately 1 3/4 inch between two wire grids.

There were seven filter cells in the housing (five full-size and two half-size) as follows: three similar charged plate cells having outside

dimensions of 8 3/8 inches in height, 12 inches in length, and 20 1/8 inches in width, and each containing 28 aluminum plates; two similar grounded plate cells 8 3/8 inches in height, 12 inches in length, and 21 inches in width; and each containing 29 aluminum plates; two half-size grounded plate cells 4 9/16 inches in height, 12 3/8 inches in length and 21 inches in width, and each containing 29 aluminum plates. The charged plate and grounded plate cells were assembled in the housing in position so that the charged plates meshed with the grounded plates. As assembled, adjacent plates were spaced approximately 5/16 inch apart and a total plate surface area of approximately 241 square feet was presented. A stamped hole, about 4½ inches in diameter, at the top of the ionizer assembly frame, and through which the high potential bar passes, was closed by the manufacturer's representative with a circular disc of polystyrene about ¼ inch thick.

The manufacturer furnished an adhesive designated as "Viscosine BA", and an applicator for oiling the collecting plates of the cells by spraying them from the upstream face. The ionizer section and perforated grille were not oiled for the tests. The Amer-glas after-filter had a slight viscid coating on its media as submitted and did not require oiling.

The power pack, connected to a 115-Volt 60-cycle supply, was checked by the manufacturer's representative as being adjusted to recommended settings prior to the tests; the ionizer and plate voltages that resulted were measured by means of a high-resistance voltmeter which was compared with an accurate electrostatic voltmeter.

3. TEST METHOD AND PROCEDURE

Efficiency determinations were made by the NBS "Dust-Spot Method" using the following aerosols: (a) outdoor air drawn through the laboratory without addition of other dust or contaminant; (b) kerosene lamp smoke; and (c) Cottrell precipitate. The test method is described in the paper "A Test Method for Air Filters" by R. S. Dill (ASHVE Transactions, Vol. 44, P. 379, 1938). The test duct and arrangement are shown in Figure 1. A baffle made of two 3-inch wide slats was located in the duct about 3½ ft downstream of the test assembly to intermix the air discharged from it.

For these tests, the unit was installed in the test duct and carefully sealed to prevent inleakage of air. The desired rate of air flow through the air cleaner was established and samples of air were drawn from the center points of the test duct one foot upstream and eight feet downstream of the air cleaner assembly at equal rates and passed through known areas of Whatman No. 41 filter paper. For the atmospheric air and oil lamp smoke tests, the samples were drawn at equal rates through equal areas of filter paper (3/4-inch diameter spots). The downstream sample was drawn continuously during the test; the upstream sample was drawn intermittently in a number of one-minute periods uniformly distributed over the duration of the test, aggregating one-tenth of the downstream sampling period. Under these conditions an efficiency of 90 percent

would be indicated if the upstream and downstream dust-spots on the filter papers had the same opacity, as indicated by the change in the light transmissions of the dust-spot areas before and after the sample was drawn, which were determined by means of a photometer using transmitted light. The filter papers used in the upstream and downstream positions were selected to have the same light transmission readings when clean. If the opacities of the dust-spots differed, the efficiency was calculated by means of the formula

$$\text{Efficiency, percent} = 100 \left[1 - \frac{t_1}{t_2} \cdot \frac{O_2}{O_1} \right] = 100 - 10 \left(\frac{O_2}{O_1} \right)$$

where O_1 and O_2 were the opacities of the dust-spots upstream and downstream, respectively, and t_1 and t_2 were the aggregate times during which the upstream and downstream samples, respectively, were drawn.

For the efficiency tests with Cottrell precipitate as the aerosol, the samples upstream and downstream were drawn at equal rates and for equal times but unequal dust-spot areas were used to obtain opacities that were approximately equal. If the opacities of the dust-spots differed, the value of the efficiency was calculated by means of the formula above, with the ratio A_2/A_1 substituted for the radio t_1/t_2, where A_2 and A_1 were the areas of the dust-spots downstream and upstream respectively.

The following procedure was employed in these tests. After the clean and oiled unit had been installed in the test duct, and all discoverable air leaks into its housing had been sealed, its input and output voltages were adjusted to recommended values by a representative of the manufacturer: (input 115 volts; ionizer 13.4 kv; plates 6.7 kv). Three determinations of the efficiency of the clean unit were made at the rated velocity, using as the aerosol outdoor air drawn into the test duct through a nearby open window. A determination of efficiency with the unit not energized was also made. Following these, single determinations were made, using outdoor air, at velocities 20 percent greater, and 20 percent less than the rated velocity.

Next, three efficiency determinations were made at rated velocity, using as the aerosol outdoor air with the addition of kerosene smoke generated by an open lamp flame near the inlet to the test duct.

Following these, three efficiency determinations were made at rated velocity, using as an aerosol outdoor air in which was dispersed Cottrell precipitate at a concentration of one gram per thousand cubic feet of air. When these had been obtained, the process was begun of loading the unit with a mixture of 4 percent cotton lint and 96 percent Cottrell precipitate, by weight, separately dispersed into the air stream. The lint used for this purpose was No. 7 cotton linters previously ground in a Wiley mill with a 4-millimeter screen; the lint was dispersed into the air stream through an aspirator operating at approximately 35 psi inlet air pressure. At suitable

periods as loading progressed, the efficiency of the unit was determined using 100 percent Cottrell precipitate in outdoor air. In these tests, and during the loading process, the rate of feed of the dispersant was one gram per thousand cubic feet of air. The pressure drop and the ionizer and plate voltages of the unit were recorded at intervals during the tests. The dirt-loading process was continued until about 1060 grams of the lint and Cottrell precipitate mixture had been fed (i.e., 2/3 gram per CFM of unit rating).

At suitable periods as the dirt-loading process progressed, strips of transparent cellulose adhesive tape (3/4 inch wide) were stretched vertically across the test duct near its axis, with the adhesive side facing upstream. Tapes were located at three positions (1) 27 inches upstream, (2) 30 inches downstream, and (3) 9 ft downstream, of the test unit; the tapes at stations (1) and (3) were in the same longitudinal positions in the test duct as the inlets to the upstream and downstream sampling tubes. The adhesive surface of such a tape captured a sample of the particulate matter in the air flowing past it, and after suitable times of exposure to the aerosol, scrutiny of the tapes by eye and with a microscope afforded considerable information as to the vertical distribution, the nature, number, and size of the particles caught at the various stations. Photographic enlargements (10X) by transmitted light were made of sections of the tapes corresponding to a position at mid-height in the test duct.

The filter cells were removed from the test unit and cleaned by means of a stream of cold water from a high pressure hose nozzle, directed at and into the cell plates from both ends of the unit.

4. TEST RESULTS

A summary of the test data, giving efficiencies in percent with the three aerosols, and the pressure drop of the complete unit including the after-filter, in inch W.G., at rates of air flow corresponding to various face velocities, is given in Table 1. Also, a summary of the test data obtained in the dirt-loading test conducted at the rated face velocity of 333 fpm is given in Table 2.

Photographs No. 1, 2 and 3 included in this report are 10X enlargements of the center 3/4x1-inch section of each of the cellophane tapes located at the three similarly-numbered stations described under Test Method and Procedure. The tapes were exposed at their respective stations simultaneously during the dirt-loading test for a period in which 124 grams of mixture were fed to the test unit. This exposure was during the interval in which the dirt-load increased from 45 to 169 grams, as shown in Table 2. After exposure, the tapes were carefully removed from the test duct for photographing and microscopic study.

Throughout the tests with atmospheric air electrical sparking or flashing in the unit audible to the ear occurred intermittently 4 to 6 times per hour. There was no instance of sparking or flashing during the kerosene lamp smoke tests. However, during the Cottrell precipitate and lint loading test electrical sparking occurred intermittently, the frequency increasing from 10 to 12 times per hour at the start to as much as 75 to 90 times per hour at 600 grams of load, and reducing to about 8 to 10 times per hour at the end of the loading test.

5. SUMMARY

A. Performance

The efficiency of the air cleaner in arresting the particulate matter existent in atmospheric air drawn through the unit varied considerably with the face velocity at which it was operated, as shown in Table 1. At the rated velocity (333 fpm), the average efficiency on atmospheric air (90.0 percent), and that on oil lamp smoke (91.3 percent), were very nearly the same. The efficiencies are reported to three significant figures obtained from the test data. In reporting thus, however, it is considered desirable to point out that an uncertainty on the order of one or two percent is possible in determining efficiencies, although in these results the differences between comparable efficiency values were consistently of a lesser magnitude.

The greater part of the pressure drop through the complete unit was due to the resistance of the after-filter. It is noted in Table 2 that in the dirt-loading test, the pressure drop of the complete unit increased by 0.040 inch W.G. for a total dirt-load of 1063 grams. This rise was due chiefly to an increase in the pressure drop of the after-filter, as a result of an accumulation of cotton lint and of comparatively large particles of Cottrell precipitate on its media.

As recorded in Table 2, the ionizer and plate voltages remained substantially constant throughout the dirt-loading test. The efficiency of the unit on Cottrell precipitate as the aerosol remained at a high level, never falling below 96.9 percent and ending with a value of 98.7 percent, approximately equal to that at the start of the loading test. An efficiency determination made with atmospheric air at the end of the dirt-loading test indicated that the unit was as efficient on this aerosol when dirt laden, as it was when clean.

B. Cleanability

The filter cells were subjected to the cleaning process described under Test Method and Procedure. No difficulty was experienced in thoroughly cleaning the ionizer and collector sections of the unit, using moderate care. The after-filter was not cleaned since it was of the throwaway type.

C. General

On completion of the dirt-loading test, the unit was removed from the test duct and examined. Dirt deposits were heaviest on the upstream edges and first 3 or 4 inches of the collector plates, the thickness of the deposits being up to about 1/32 inch. The heaviest deposits were observed on the leading edges of the grounded plates. A continuous, but thinner, layer of dirt was deposited over the remaining area of the collector plates, extending to the after edge. Considerable bridging of lint fibers from one collector plate to another, spanning the gap between them, was observed; such bridging appeared to be most extensive in alternate plate spacings and in the narrowest plate spacings. The perforated upstream grille and ionizer assembly were fairly clean since they were not oiled prior to the tests.

The upstream face of the after-filter revealed considerable deposits of lint, somewhat concentrated in five vertical strips each about 3 inches wide. The after-filter media was approximately uniformly darkened by a dust deposit on its upstream face, and slightly darkened by dust visible on its downstream face. However, there were eight very dark patches located at the vertical edges of the upstream face of the after-filter approximately 1 x 2 inches in size four on each side. On close examination, it was observed that these patches conformed somewhat to air-paths (or leaks) between the outer ground plates and the unit housing. It seemed evident that a portion of the air flow by-passed the collecting plates and that some of the entrained unarrested aerosol was caught by the after-filter. It is difficult to say how much effect these by-pass leaks had on the over-all performance of the unit. However, a reduction of these leaks would result in a higher efficiency.

The dirt (dust) deposits on the electrostatic unit, and on the after-filter, appeared to be well-saturated with oil. Microscopic examination of the cellophane tape exposed at station (2) showed a few droplets of what appeared to be oil, but the number and amount of such droplets were so small that oil entrainment in the effluent air is considered of no practical importance. After the unit had been removed from the test duct, the section downstream of the unit was carefully swept out with a fine brush. The amount of material obtained from the duct by this sweeping was 0.6 gram.

The cellophane tape samples obtained at stations (1), (2) and (3), as shown in Photographs No. 1, 2 and 3, respectively, indicate in a general way the performance of the complete unit. Photograph No. 1 shows many particles under 5 microns in actual size, and a distribution of larger particles up to a few as large as 400 microns, as well as many fibers of lint. (In these photographs, 1/16 inch corresponds to an actual dimension of about 160 microns.) Photograph No. 2, for the tape 30 inches downstream of the unit, shows a few large particles up to about 150 microns in size, but very few fine dust particles considering their number upstream of the unit. Photogrph No. 3, for the tape 9 ft downstream of the unit, shows an absence of the

larger particles of Photograph 2, which apparently settled out of the air stream. No significant amount of lint fibers is visible in either downstream tape photograph, or was observed by microscopic study of the tapes.

Comparison of the numbers of particles on the upstream and downstream tapes indicates, in an obvious way, a high order of efficiency for the unit in arresting Cottrell precipitate, as is also indicated by the discoloration test results presented in Table 2. The latter results show a considerably higher efficiency for the unit when Cottrell precipitate was being received in the air stream than when the aerosol was outdoor air or kerosene lamp smoke. The overall efficiency of the unit on particles of the sizes found in Cottrell precipitate appears therefore to be better than on the finer particles in outdoor air or kerosene smoke. Nevertheless, the downstream tapes, and the deposits on the after-filter, show that a few quite large particles of dust escaped beyond the electrostatic unit. Whether the large particles were passed through the unit because they were not arrested at all, or were caught and later dislodged from the collector plates by electrical sparking, is not known from these tests.

As the photographs show, a few large particles passed unarrested through the after-filter. Assuming that one of the functions of the after-filter is to arrest as much as possible of the material escaping the electrostatic unit, the arrestance characteristics of the after-filter are of major importance in determining the presence or absence, in the air leaving the complete unit, of such particulate matter as is shown in the downstream tape photographs.

Table 1

Face Velocity fpm	Inlet Aerosol*	Ionizer Voltage kv	Plate Voltage kv	Pressure Drop inch WG	Duration of Test minutes	Efficiency percent
333	A	0	0	0.273	18	15.8**
333	A	13.4	6.7	.272	180	90.3
333	A	13.6	6.8	.272	180	89.7
333	A	13.6	6.8	.272	180	90.0
266	A	13.6	6.8	.180	180	93.9
400	A	13.6	6.8	.370	180	87.4
333	S	13.6	6.8	.272	20	91.2
333	S	13.6	6.8	.272	20	91.7
333	S	13.6	6.8	.272	20	91.0
333	C	13.6	6.8	.272	10	98.5
333	C	13.6	6.8	.272	9	98.3
333	C	13.6	6.8	.272	10	98.6

* A = Particulate matter in atmospheric air at NBS.

S = Kerosene lamp smoke in atmospheric air.

C = Cottrell precipitate in atmospheric air (1 gram/1000 CF).

** Since unit was not energized, the efficiency was chiefly that of the after-filter.

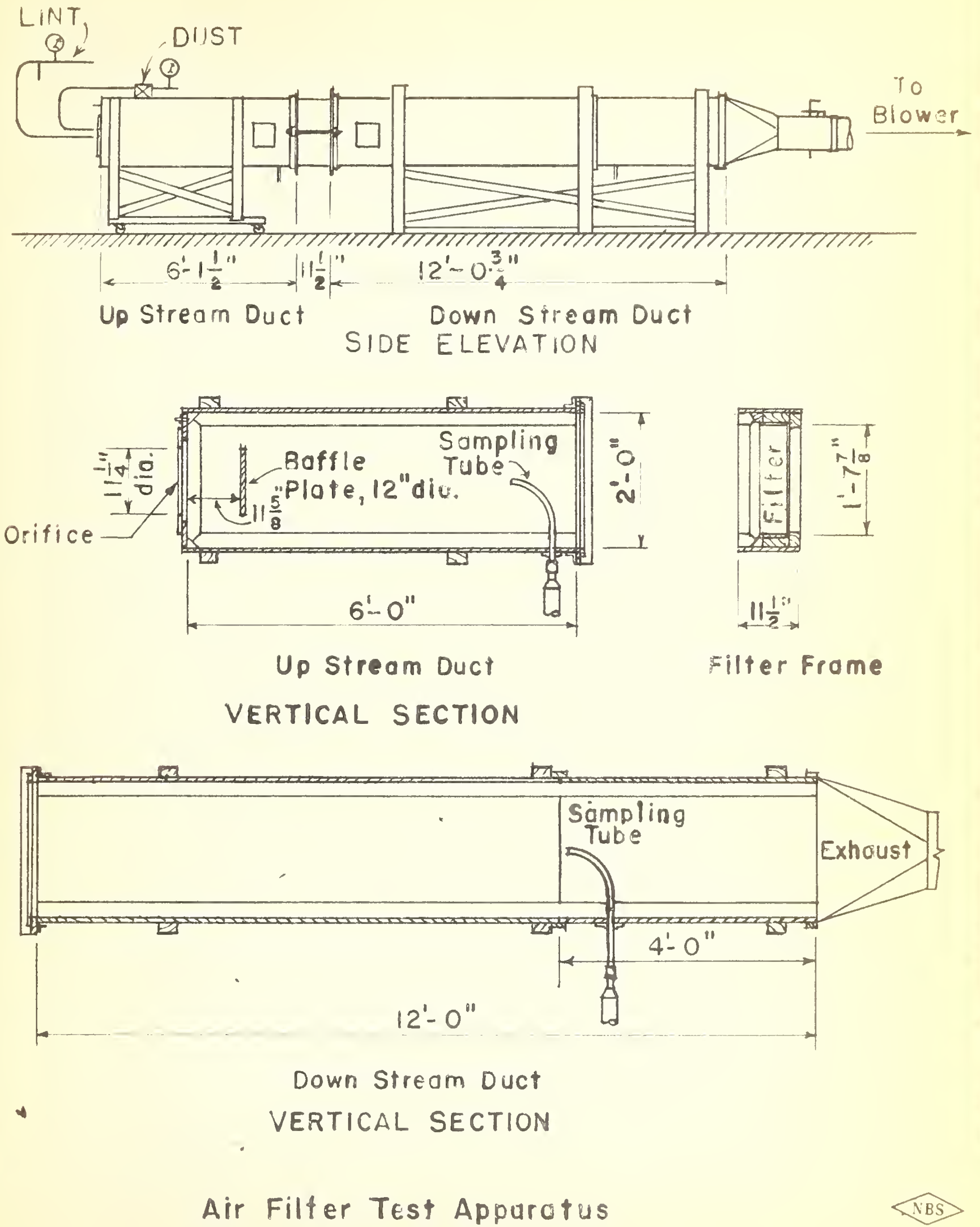
Table 2

Face Velocity fpm	Dirt Load* grams	Ionizer Voltage kv	Plate Voltage kv	Pressure Drop inch W.G.	Efficiency** percent
333	45	13.6	6.8	0.272	98.5 (avg.)
	169	13.6	6.8	.273	--
	183	13.6	6.8	.273	97.9
	327	13.8	6.9	.279	98.0
	487	13.8	6.9	.283	98.1
	615	13.8	6.9	.293	97.9
	742	13.8	6.9	.297	97.8
	870	13.6	6.8	.301	96.9
	998	13.8	6.9	.312	98.2
	1047	13.6	6.8	.312	98.8
	1063	13.8	6.9	.312	98.7
	"	13.8	6.9	.312	90.0***

* Average mixture: 3.9% lint, 96.1% Cottrell precipitate by weight.

** Efficiency determined with 100% Cottrell precipitate.

*** Efficiency determined with aerosol "A", as in Table 1, with the unit dirty.

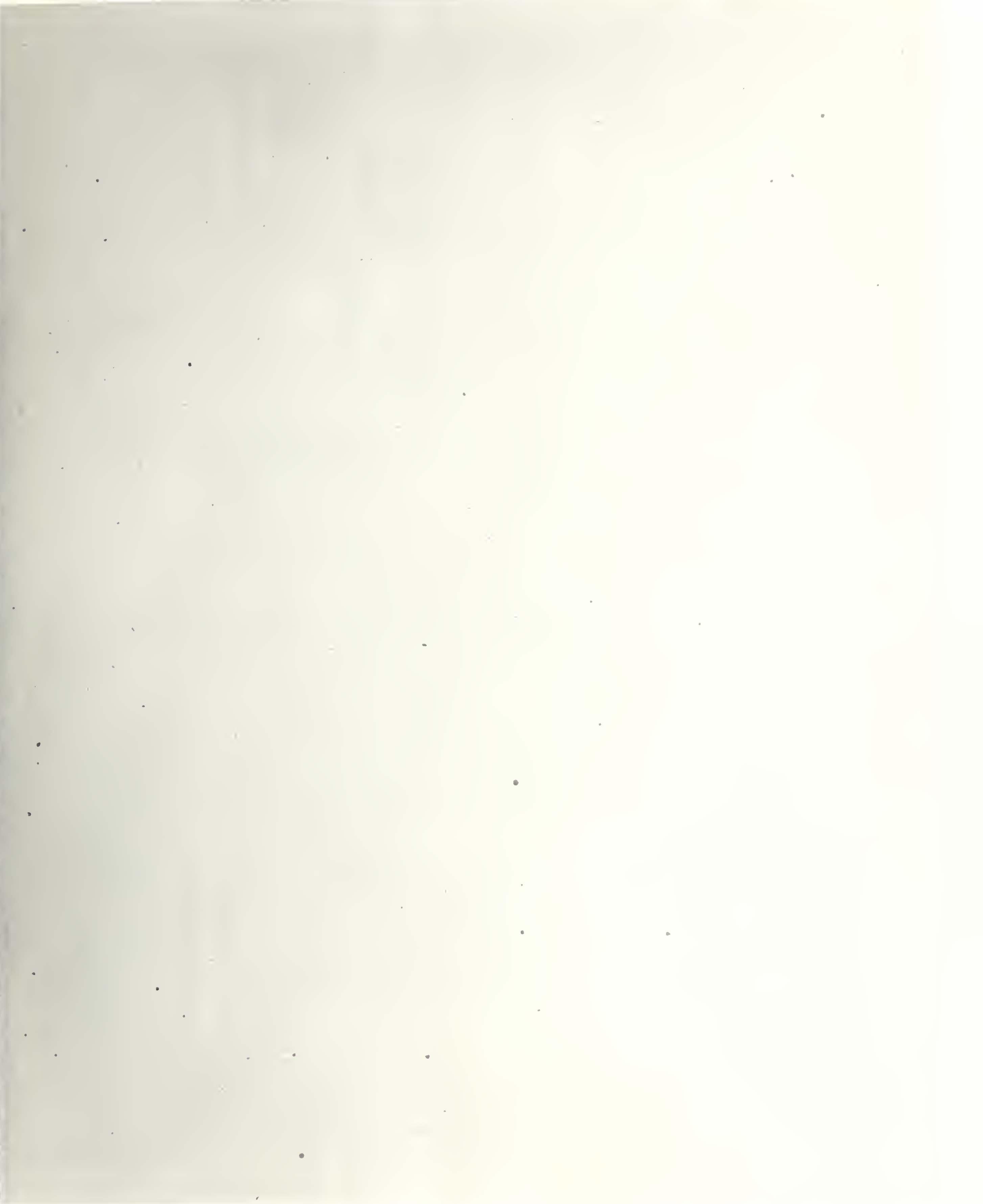


Air Filter Test Apparatus

Figure 1

Photograph No. 1

Photograph No. 2



Photograph No. 3

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