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PERFORMANCE TESTS OF A PLIOTRON
"ELECTRO-STATIC" AIR FILTER

by

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Report To
Corps of Engineers, U. S. Army
Engineer Research and Development Laboratories
Fort Belvoir, Va.

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Building Technology Division

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1. INTRODUCTION

At the request of the Engineer Research and Development Laboratories, Fort Belvoir, Va. (reference: letters dated October 22, 1953 and October 27, 1954, File TECRD CB 8-88-01-001), tests were made to determine the performance characteristics of a Pliotron "Electro-Static" air filter manufactured by the Goodyear Tire and Rubber Company of Akron, Ohio.

The test results presented herein were obtained on a specimen air filter furnished by its manufacturer and included determinations of dust arresting efficiency with two aerosols (atmospheric air and Cottrell precipitate), pressure drop, dirt load and cleanability of the specimen.

2. DESCRIPTION OF THE FILTER SPECIMENS

The manufacturer supplied five specimen filters, three of the "Screen Vane Type" and two of the "Improved Shredded Design". Each of the filters had the following markings "Pliotron Electro-Static Air Filter" and "Permanent Type Washable Filter Type Bl".

The "Screen Vane Type" filter had actual outside dimensions of 19-5/8 x 19-5/8 x 1-inch and weighed 5.03 pounds when clean. It had media consisting of many layers of 12-mesh white plastic screen piled together and held in place by retaining faces of 1/2-inch wire hardware cloth, enclosed at the edges by a metal frame having a free opening 18-3/16 inches square (2.30 ft.^{2} free area).

The "Improved Shredded Design" filter had overall dimensions of 19-5/8 x 19-5/8 x 1-inch and weighed 3.94 pounds. The filtering media was as follows, starting at the upstream face: one layer of 1/2-inch mesh hardware cloth; one layer of 14 x 17-mesh plastic screen; a pad of shreds of white plastic, strewn in a loose pack about 7/8-inch thick; one layer of very thin glass fiber sheet; one layer of 1/2-inch mesh hardware cloth. The media and screen layers were slightly compressed and surrounded at the edges by a metal frame having a free opening 18-3/16 inches square (2.30 ft.^{2} free area).

3. TEST METHOD AND PROCEDURE

Efficiency determinations were made by the NBS "Dust-Spot Method" using the following aerosols: (a) outdoor atmospheric air drawn through the laboratory without addition of other dust or contaminant; and (b) Cottrell precipitate, dispersed in the outdoor atmospheric air. The test method is described in the paper "A Test Method for Air Filters" by R. S. Dill (ASHVE Transactions, Vol. 44 P. 379, 1948). In conducting the tests air was sampled from the test duct at equal rates, from points one foot upstream and eight feet downstream of the filter, and drawn through known areas of Whatman No. 41 filter paper. The areas of filter paper used upstream and downstream, or the times during which the air was sampled upstream and downstream, were selected experimentally so that the change in transmission of light through the two filter paper spots would be about the same. The filter efficiency was calculated by means of the formula

$$\text{Efficiency, percent} = 100\left[1 - \frac{A_2}{A_1} \cdot \frac{O_2}{O_1} \cdot \frac{T_1}{T_2}\right]$$

where A represents the dust spot area, O the change in light transmittance of the filter paper as measured before and after the deposition of dust, and T the time during which the air sample was drawn. Subscripts 1 and 2 refer to the upstream or downstream positions, respectively.

Three efficiency-measuring techniques, or modifications based on the above formula, were used, depending on the apparent efficiency of the filter with the different aerosols. For the tests made with atmospheric air, techniques L, M and N were used, as indicated in Table 2. For equal changes in light transmission of the upstream and downstream papers, the corresponding efficiencies, as determined from the formula, are 15, zero, and 50 percent, respectively. For the tests made with Cottrell precipitate as the aerosol, the usual procedure, designated as N in Table 2, was followed. The filter efficiency corresponding to equal changes of light transmission of the upstream and downstream papers in this case is 50 percent.

All light transmission measurements were made with the photometer illumination at a constant intensity as determined by measurements on a reference of constant transmission characteristics. The filter papers used upstream and downstream were selected to have equal light transmissions when clean.

In accordance with a request of the Engineer Research and Development Laboratories, the pressure drops at various rates of air flow were measured for both types of filter submitted, with the object of selecting for the performance tests the type of filter having the lower resistance. This was found to be the "Improved Shredded Type", a specimen of which was then tested as indicated below, at an air flow rate of 800 cfm. In all tests, except as noted in Table 2, the frame of the filter was electrically grounded.

The efficiency of the selected filter in arresting the particulate matter in atmospheric air was determined by means of four tests of the L and M types, as described above, with the filter clean. Following these, the efficiency of the filter in arresting Cottrell precipitate was measured by means of three N-type tests, after which was begun the process of loading the filter with a mixture of 4 percent of cotton lint and 96 percent of Cottrell precipitate, by weight, separately dispersed in 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. At suitable periods as loading progressed, the efficiency of the filter was determined using Cottrell precipitate in outdoor air. The pressure drop was recorded at intervals during the test. The dirt-loading was continued until the pressure drop increased to approximately 0.50 inch W.G. The efficiency was again determined with Cottrell precipitate and then with atmospheric air as the aerosols.

The filter was then removed from the test duct and cleaned by immersing it in a bath of luke warm water with detergent added. Following this, a fine spray of cold water from a hose nozzle was used to dislodge lint particles that were not easily removed by the above method.

After being dried over-night, the filter was reinstalled in the test duct and the pressure drop at various air flows was measured. Next, the efficiency of the filter was determined with atmospheric air and with Cottrell precipitate as aerosols. These measurements were made with the filter frame electrically grounded, and electrically ungrounded.

4. TEST RESULTS

Table 1 presents data as to the pressure drops, at several rates of air flow, of a specimen of each of the two types of filter submitted. Values of the dust arrestance or efficiency of each of the types, using atmospheric air as the aerosol, are also given. Because of its lower initial resistance, further tests were conducted on the shredded design filter. Table 1 also gives data on the pressure drop of this filter after it had been loaded with dirt and cleaned.

The performance of the "Improved Shredded Design" filter at 800 cfm is summarized in Table 2. The table gives data on the efficiency of the filter in arresting Cottrell precipitate, and on its pressure drop, as the filter was loaded with a mixture of 4 percent lint and 96 percent Cottrell precipitate by weight. The efficiency of the filter in filtering atmospheric air is given for the clean specimen, and for the specimen when it was loaded with a dirt deposit to a pressure drop greater than 0.50 inch W.G. Efficiency determinations with atmospheric air and with Cottrell precipitate are also recorded for the filter after it had been cleaned following the dirt-loading test. Two measurements were made with the filter frame not grounded as noted in the table; the filter frame was grounded during all other measurements.

Throughout the tests, the relative humidity of the air entering the test duct was within the range from 27 to 56%, at dry bulb temperatures ranging from 73 to 82°F.

Observation of the filter at the end of the dirt-loading test revealed that there was little dust or lint on the plastic fly screen layer of the filter. Some dust and lint was observed to have been arrested in the pad of plastic shreds. The greater part of the arrested dust and lint was found on the upstream face of the glass fiber sheet at the downstream side of the filter. This sheet, white when the filter was clean, was much darkened by dust at the end of the loading test.

Cellophane tapes, stretched across the test duct downstream of the filter with the adhesive side facing upstream, indicated upon visual and microscopic examination after exposure to the air stream that large numbers of particles of sizes from 5 to 200 microns, and considerable lint, had passed through the filter during the Cottrell precipitate tests. Particles much smaller than 5 microns were observed in quantity by microscopic examination of the downstream filter papers obtained in tests with both aerosols; it was not possible to be certain as to the smallest size limit of particles caught upon the cellophane tapes, but particles at least as small as 5 microns were observed with both aerosols.

In cleaning the filter, it was found that immersing and moving the filter in a lukewarm detergent solution readily removed the dust from the media, but did not satisfactorily remove lint fibers from its interior. Most of the lint was removed later by careful flushing with a fine cold water spray from a hose nozzle, but the latter operation required much care, and was not entirely satisfactory, as indicated by the greater pressure drop of the filter after it was cleaned than when it was new and clean.

TABLE 1

Specimen	Air Flow cfm	Face Velocity fpm	Pressure Drop (1) inch W.G.	Pressure Drop (2) inch W.G.	Efficiency Aerosol A percent
Screen Vane Type	400	174	0.123	--	--
	600	261	.250	--	--
	800	348	.417	--	15 (3)
	1000	435	.635	--	--
Shredded Design	400	174	0.071	--	--
	600	261	.130	.143	--
	800	348	.212	.227	15 (4)
	1000	435	.315	.337	--

(1) Initial values for the clean filter.

(2) Values for the test filter after the dirt-loading test and cleaning operation.

(3) Value for one measurement.

(4) Average value for four tests shown in Table 2.

TABLE 2

Performance of "Improved Shredded Design" Filter at 800 CFM

Inlet Aerosol (1)	Total Dirt Load (2) grams	Pressure Drop inch W.G.	Eff. Meas. Technique (3)	Efficiency percent
A	--	0.214	L	13
	--	.216	L	16
	--	.217	L	19
	--	.217	M	12
				15 Avg.
C	7	.217	N	41
	15	.220	N	43
	25	.222	N	43
	109	.340	N	42
	147	.421	N	41
	185	.498	N	40
	193	.533	N	42
				42 Avg.
A	193	.543	L	15.0
		After Cleaning		
A	--	.230	L	9
	--	.232	L	9 (4)
	--	.232	N	16
C	--	.236	N	41
	--	.239	N	40 (4)

(1) Aerosol A: Particulate matter in atmospheric air at NBS.
Aerosol C: Cottrell precipitate in atmospheric air (1 gram per 1000 cf)

(2) Average mixture: 4% lint, 96% Cottrell precipitate, by weight.

(3) Efficiency-measuring technique:
L: Air sampled at equal rates through equal areas; upstream sampling time 85% of that downstream.
M: Air sampled at equal rates through equal areas for equal times.
N: Air sampled at equal rates for equal times; downstream area 50% of that upstream.

(4) Frame of filter electrically ungrounded; in all other tests the frame was electrically grounded.

5. DISCUSSION OF EFFICIENCY RESULTS

The efficiency of the tested specimen in arresting the particulate matter in the atmosphere at the time of the tests is indicated by the results given in Table 2 to be about 15 percent. Agreement of the tests of the L, M and N types is not perfect, but in view of the fact that the efficiencies "shot for" in conducting these tests (15, zero and 50 percent, respectively) differed so widely, the consensus is good that the atmospheric air efficiency is in the neighborhood of 15 percent.

For reasons having to do with the problem of obtaining not-too-dark filter paper spots, tests on the filter with Cottrell precipitate as the aerosol were made only by the method of test (N-type) ordinarily used here in conducting such tests. The results obtained in the Cottrell precipitate tests are therefore directly comparable with those obtained here in tests of other filters with Cottrell precipitate.

THE NATIONAL BUREAU OF STANDARDS

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