PERFORMANCE CHARACTERISTICS OF THE MODEL K ELECTRO-POLAR FILTER

Preliminary Report

by

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In this paper the results of preliminary performance tests are presented for the "Electro-polar Filter", an experimental dust collector developed by the Western Precipitation Corporation. The objectives of the field and laboratory testing program on commercial dust collectors have been covered in a previous report by our laboratory (1). These studies are intended to determine collector performance in accordance with applications suggested by the manufacturer and also to investigate new applications by means of minor operating or design changes. The proper evaluation of these data serve as a guide to the Atomic Energy Commission and its contractors in the selection and application of commercially available dust collection apparatus.

The Electro-polar Filter now under test was developed by the manufacturer's research department and would probably be subject to design changes prior to marketing. AEC representatives, contacted by the Western Precipitation Corporation considered it advisable to have the unit tested by the Air Cleaning Laboratory so that its practicability as an air cleaner for low dust load systems could be determined. Since the Electro-polar Filter is an experimental model there is little background data with which to compare its performance. However, the unit employs PF 105 or PF 316 Fiberglas media as the primary filtration elements. These pads have a basic weight collection efficiency of approximately 70 to 80 per cent against atmospheric dust and are suitable only for low dust concentrations.

By placing the floor pads within a strong electric field, electrostatic forces are expected to supplement the usual filtration mechanisms (impaction, interception and diffusion) thus improving the performance of the unit.

Description of Electro-polar Filter - Model K

The Electro-polar Filter consists essentially of a dielectric filter medium of fine glass fibers placed in an electric field. Filter media employed are PF 316 mats or one to two layers of PF 105. The fiber code designation is that of the Fiberglas Corporation. PF 316 is a three micron diameter resin coated glass fiber supplied in 1 inch thick bats at a packing density of 1 lb./ft.^{3}. PF 105 is a one micron diameter resin coated fiber supplied in 1/2 inch bats at a packing density of 0.6 lbs./ft^3. The electric field is furnished by placing the fiberglas mat between two vertically aligned metal screens. The upstream screen is insulated and maintained at a positive potential of 15 kilovolts; the downstream screen, 1 inch removed, is grounded to the unit. Screen construction consists of a stamped diamond shaped grating with a free area of approximately 80 percent. Total filtration area comprises five identical screen sections (20 inch x 60 inch) arranged in a row and all insulated from each other. The entire screen section (total area = 41.5 square feet) is aligned diagonally in a rectangular housing having overall dimensions of 2.5 x 8 x 5.5 feet. This permits a gradual reduction in cross section of the entry plenum so that better air flow distribution may be obtained.

The high voltage supply is furnished by a power pack with a rated output ranging from 11 to 17 kilovolts. Three hundred microamperes are available at 17 Kv. and at currents exceeding 750 μa (resulting from shorting or arcing) a safety control relay turns off the power.

The power pack is enclosed in a 16 x 16 x 9 inch box which occupies one corner of the collector housing. To reduce excessive dust loadings and prevent screen shorting by gross contaminants "Dustop" roughing filters (in a bank of 3) are located at the inlet to the collector.

Rated Operating Conditions

The Electro-polar Filter is designed to operate at 3500 cfm with a 1 inch layer of PF 316, 2900 cfm with a 1/2 inch layer of PF 105 and 1700 cfm with two, 1/2 inch layers of PF 105. The manufacturer recommends that filters be replaced when pressure losses reach 2 inches of water although fan capacity or exhaust requirements may modify this figure. Recommended screen potential is 15 Kv. Arcing between grounded and high voltage screens may occur as a result of high points or sharp edges on the screen surfaces. The high current accompanying arcing will automatically activate the overload control switch and turn off the power supply. In some instances of arcing a sizable hole may be burnt in the filter which will require patching.

Theory of Operation

It is evident that the glass fiber media employed in the Electro-polar Filter are reasonably good filters for atmospheric dust without superimposed electrostatic effects. Preliminary tests indicate weight collection efficiencies ranging from 70 to 90 percent against atmospheric dust at a filtration velocity of 85 fpm (PF 316 media). Previous tests (1) have also shown that similar fiberglas media (PF 105 and PF 314) operate in the same general efficiency range.

Electrostatic charge measurements upon PF 105 media have indicated potentials of 700 volts resulting from handling alone. High static charges may be produced through carding as illustrated by the resin-wool filter (2). This information indicates that electrostatic separating forces come into play in fiber collectors regardless of externally applied electrical fields and in addition to usual collecting mechanisms (impaction, interception and diffusion).

By intensifying the electrostatic effects through placing the fiberglas media within an electrical field the manufacturer has sought to improve the overall dust removal characteristics.

The presence of dielectric fibers within an electrical field produces divergencies in field intensity such that the regions of highest field strength are concentrated about the fibers. Dust particles, which become polarized by passing through the electrical field, migrate toward the regions of highest field intensity. It should be noted that the particle motion is always toward the zone of higher field strength regardless of field direction. Higher dust concentrations in the immediate vicinity of the fibers cause increased agglomeration and enhance the probability of capture by inertial mechanisms.

Although mathematical formulas have been presented by Pohl (3) to quantitate the precipitation of solids from liquids in a highly divergent field, no simple relationships can be advanced at the present time to deal with particulate deposition in fiber beds. Pohl describes a system consisting of a single, positively charged central electrode and a concentric cylindrical negative electrode, used to precipitate a graphite-toluene sol. In this case, it is possible to evaluate the field strength at any point as a function of the potential gradient and the electrode dimensions. Equating viscous forces to electrostatic forces permits estimation of particle migration velocities.

In a general equation migration velocity (v) may be expressed as a function of the difference between the dielectric constant of the fluid and particulate components $(k_1 - k_2)$, particle radius (a), fluid viscosity (η), absolute value of the field strength (E) and its divergence ($\partial E/\partial r$).

$$v = (k_1 - k_2)\, a^2 \frac{\partial}{\partial r}(E)^2 \Big/ 36\pi\eta \qquad (I)$$

Since no data are available to define field divergencies in randomly oriented fiber beds, varying in surface characteristics and having non-uniform resinous coatings, the above equation has only a qualitative significance as far as the Electro-polar Filter is concerned. It should be noted also that in dealing with a dynamic system it would be necessary to combine vectorially the inertial and electrostatic forces. In practical application, Equation I suggests that increased particle size and field potential should improve the collection efficiency of the Electro-polar Filter. For particle diameters >5 microns, however, electrostatic forces are insignificant in comparison with the inertial effects. Similarly, it appears that variation in filtration velocity would effect collection efficiency only through inertial or diffusional mechanisms.

Test Procedure

Inlet and outlet atmospheric dust loadings were determined gravimetrically with high volume samplers and pleated filters (4). Stain efficiency measurements were made with a film badge densitometer on Whatman No. 41 filter discs and count efficiencies were determined with a Bausch and Lomb dust counter.

Copper sulfate loadings were sampled with AC electrostatic precipitators and the concentrations determined by chemical analysis. The method of generating copper sulfate microspheres and complete details on all sampling methods have been described in previous NYO reports (1, 5).

Test Results

Preliminary tests on the Electro-polar Filter were designed to determine if the use of an electrical field significantly improved the basic performance of the PF 316 fiber media. As shown in Table 1, tests 1 and 3 with atmospheric dust and tests 5, 6, 8 and 9 with copper sulfate indicate average efficiency increases of 15 and 11 percent, respectively, when rated screen voltage (15 Kv) was applied. Filter plugging, however, illustrated by slightly higher pressure losses in tests 2 and 7, indicates a gradual improvement in basic fiber efficiency. Table III compares overall collection efficiency as obtained by simultaneous weight, stain and count methods for operations at no voltage and 15 Kv.

A breakdown of weight collection efficiency appears in Table I since the "Dustop" performance is not governed by the electrical field. Overall unit efficiency, therefore, shows a smaller increase (approximately 8 percent) with application of screen voltage. At lower screen voltages (11 Kv) a very slight decrease in efficiency was observed for copper sulfate (test 10).

Filtration velocities ranging from 36 to 85 fpm and screen voltages varying from 11 to 18 Kv showed no significant efficiency changes with atmospheric dust (Table II) according to stain measurements. However, it is expected that additional tests with a copper sulfate aerosol will permit better correlation of these variables. Changes in concentration and particle size distribution of atmospheric dust were partly responsible for inconsistencies in the data.

Humid air also was observed to reduce collection efficiency although the measurements were qualitative.

In order to eliminate the effect of changing bed characteristics due to retention of copper sulfate, tests 5, 6, 8, 9 and 10 were run with alternate screen sections blocked off. Air flow was reduced proportionately to maintain constant velocity (85 fpm) through the PF 316 media. Since the Dustop filter area was not changed, the velocity through this section of the unit varied with total air flow (Table I). Weight collection efficiencies for Dustop filters were a direct function of velocity indicating that inertial separation was the primary collecting mechanism.

Discussion of Tests

Test data indicate that the use of an electrical field increases the overall weight collection efficiency of the Electro-polar Filter by about 8 percent with atmospheric dust and copper sulfate microspheres. It appears that the overall advantage of the electrical field will decrease with filter usage since the efficiency of fiber beds increases with plugging. Preliminary tests indicate this trend even though pressure losses are still below the rated value of 2 inches of water.

No data has yet been obtained for PF 105 media which, because of its small diameter (1 micron), should be a more effective filter.

Final comment regarding the utility of the Electro-polar Filter as a high efficiency cleaner for low dust concentrations is withheld pending completion of tests.

TABLE I

Effect of Screen Voltage on Collection Efficiency of Electro-Polar Filter with Rated Velocity (85 fpm) through PF 316 Media

Test	Inlet Loading Grains/1000 ft.^{3}	Screen Voltage Kv	Pressure Loss PF 316 Media Inches water	Filtration Velocity through Dustop fpm	Weight Collection Efficiency %		
					Dustop	PF 316	Overall
a.	Atmospheric Dust*						
1	0.118	0	1.07	420	52	32.5	91.6
2	0.036	0	1.16	420	52	87.6	94.0
3	0.179	15	1.07	420	52	97.0	98.6
4	0.097	15	1.13	420	--	—	98.2
b.	Copper Sulfate Microspheres**						
5	0.306	0	1.24	168	30.7	85.5	90.2
6	0.281	0	1.24	168	17.0	87.3	89.5
7	0.206	0	1.27	420	46.0	90.1	94.6
8	0.216	15	1.22	252	34.8	97.5	98.3
9	0.185	15	1.26	252	34.8	97.6	98.4
10	0.187	11	1.30	252	34.8	95.7	97.2

* Mass Median = 1.0 microns, Geometric Standard Deviation 1.6.

** Mass Median = 1.2 microns, Geometric Standard Deviation 1.7.

TABLE II

Effect of Voltage and Velocity Variations on Stain Efficiency Tests with Atmospheric Dust

Test	Inlet Loading Grains/1000 ft.^{3}	Screen Voltage Kv	Filtration Velocity fpm	Overall Stain Efficiency %
11	0.087	11	85	98
4	0.098	15	85	95
12	0.125	18	85	98
11	0.087	11	85	98
13	0.123	11	61	98
14	0.208	11	36	98

TABLE III

Effect of Screen Voltage on Simultaneous Weight, Stain and Count Efficiencies for Atmospheric Dust at Rated Capacity (3500 cfm)

Test	Screen Voltage Kv	Overall Collection Efficiency %		
		Weight	Stain	Count
1	0	92	80	54
3	15	98	95	80

SUMMARY

Results of preliminary performance tests are presented for the Electropolar Filter, a dust collector developed by the Western Precipitation Corporation for high efficiency removal of particulates. Separation is achieved through a combination of the mechanical filtration properties of PF 316 or PF 105 fiberglas and electrostatic effects produced by locating

the fibers within an electrical field (created by two metal screens, one maintained at 15 Kv potential and the other grounded). Theory of operation is based upon migration of polarized dust particles to the regions of high field intensity surrounding the glass fibers.

Test results on clean fibers indicate that application of rated screen voltage (15 Kv) increases overall collection efficiency of atmospheric dust and copper sulfate microspheres by about 8 percent. Filter plugging, however, results in higher base efficiency for the fiber which tends to lessen the advantage of the electrical field.

Current tests include a study of the effect of voltage and velocity variations on collection efficiency. Final evaluation of collector utility is withheld pending analysis of all test data.

LITERATURE CITED

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