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**FILTER EFFICIENCY TEST
PUREX PLANT VENTILATION EXHAUST FILTERS
SEPTEMBER 1, 1971**

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FILTER EFFICIENCY TEST -- PUREX PLANT VENTILATION EXHAUST FILTERS

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September 1, 1971

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FILTER EFFICIENCY TEST -- PUREX PLANT VENTILATION EXHAUST FILTERS

L. C. Schwendiman

INTRODUCTION

Atlantic Richfield Hanford Company requested Battelle-Northwest to measure the efficiency of the two ventilation filters in use at the Purex Plant.⁽¹⁾ It was desired to use a particle for these tests which could be reasonably well characterized according to size. Measurements conducted in the development of the deep bed glass fiber filters and the design of the current filters indicated that they should have an efficiency of 99.9% or greater for a submicron particle, presumably 0.7 μ m in diameter. A brief study was thus conducted to determine the minimum efficiency of the Purex filters. This report describes the method used, the determinations made of the efficiency, and presents the results.

SUMMARY

Three tests were conducted to measure the efficiency of the two ventilation filters at the Purex Plant (202-A Bldg.). Technical grade fluorescein was used as the indicator particles, which were generated by aspiration from an alcohol-water solution. The mass mean aerodynamic size of these particles was 0.42 μ , 0.3 μ , and 0.3 μ in the three runs, respectively. Size distributions were determined during the three tests with a Scientific Advances 7-stage cascade impactor. Absolute efficiencies greater than 99.5% were measured in all tests for both filters, except in two tests which yielded greater than 99.3%. The "greater than" values were conservatively calculated by assuming that any measurable fluorescence extracted in the samples drawn from downstream of the filters was attributable to fluorescein particles which had penetrated the filters. Samples taken as background blanks prior to two of the tests showed fluorescence approximating that obtained from the test samples.

PUREX FILTER SYSTEM -- BRIEF DESCRIPTION

Air from the ventilation system is collected into a main tunnel running the length of the 202-A Building against the south wall some 40 feet below ground level. This tunnel carries about 150,000 cfm which is moved by the large exhaust fans. The air is drawn in parallel through two deep-bed glass fiber filters, each consisting of a "roughing" glass fiber filter and a polishing filter which consists of compressed fine glass fibers in many filter frames. Filter One, the downstream samples from which are identified in this report as F-2, is the older of the two filters. This filter has been in operation for 15 years. It eventually loaded with ammonium nitrate to a degree that resulted in higher than desirable pressure drop. Efforts to lower the pressure drop were successful and the filter continued in use. Filter Two was installed in 1964 and has operated in parallel with the initial filter since that time. Samples taken downstream of the deep bed of this second unit are identified in this report as F-3. The pertinent engineering drawings describing these installations are listed in the references.

SAMPLING PROVISIONS

The original sampling lines for sampling upstream and downstream of Filter One are shown in Drawing H-2-55018. A second inlet sampler was installed later and was used in this investigation (Drawing H-2-63449). This inlet sampler consists of six inlet probes on the vertical centerline of the duct facing upstream and joined to a common manifold. The 3/8 in. standard pipe withdrawal line runs approximately 30 feet with five elbows from the manifold to Filter Sample House No. 1. Within the sample house an additional 8 feet of pipe plus two elbows make up the line to the point where the collector is inserted.

The downstream sampler for Filter One consists of an inlet probe which is a one-inch standard pipe crossing the duct north to south at the midpoint of the duct. Three curved nozzles on this pipe face into the air stream on the duct centerline. The nozzles are 0.43 in. ID. The one-inch

line is extended to the Sample Building 2 through a distance of about 12 feet including three elbows.

Two downstream samplers for Filter Two are provided. Each has a probe consisting of a one-half inch standard pipe crossing the duct with three curved nozzles attached. The inside diameter of the probe nozzles is 0.62 inch. The first probe, AS-1, samples between the fore-filter and the final filter. For this study AS-1 was used. This sampling point was chosen inadvertently, since it was believed that this sample line was also for sampling downstream of the final filter.

One-half inch tubing with 0.035 inch walls is used from the probe to Sample Building No. 3. The delivery line is about 20 feet in length with three elbows.

Implications of these sampling systems to the tests conducted are considered under Discussion of Results.

TEST AEROSOL

The test aerosol was fluorescein particles generated by atomizing technical grade fluorescein in a solution of 90% ethanol-10% water. The starting concentration was 5% by weight. The generator, devised by A. K. Postma for tests of B-Plant ventilation air filters in 1968,⁽²⁾ consisted of the nozzles and pressure and feed tubes taken from 10 De Vilbiss #15 atomizers.¹ The nozzles were suspended by the pressure tube of the atomizer on an aluminum plate sealed to a large glass desiccator. The desiccator served as the solution reservoir and sight glass. The solution feed tubes were extended to the bottom of the desiccator. The atomizer nozzles were directed outward toward the glass wall of the desiccator which provided an impingement surface. This greatly reduced the droplet size carried away. The fine mist was carried from the generator in a vertical 3-inch aluminum tube or "chimney" 26 inches tall, welded to a 3-inch opening in the aluminum desiccator cover. A 3-inch side arm several

¹De Vilbiss Company, Medical Products Division, P.O. Box 552, Somerset, Pennsylvania 15501.

inches above the desiccator lid was provided for furnishing additional air to carry the particles away. The generator was operated at 40 psig, which resulted in a measured flow rate of 2.5 cfm. Additional air through the side arm of 10 cfm was provided. Two laboratory tests showed the generation rate to be about 0.046 g/minute with the starting solution. The aerodynamic equivalent mass median diameter of the aerosol at the point of entry into the ventilation tunnel was found to be 0.42 microns in Run 1 and 0.30 microns in Run 2 and 3.

Solvent evaporated during generation was replaced by continuous addition of alcohol-water solution. Maintaining the volume constant resulted in a gradual decrease in concentration. This should result in a smaller particle being generated. During the tests the volume of the solution was maintained approximately constant, but no effort was made to precisely control the addition rate of the alcohol-water solution. In one laboratory experiment the evaporation rate plus liquid droplet removal rate was measured at 12.3 cc/minute. The ambient air temperature was over 100°F on the days during the tests and the evaporation rate was between 15 and 20 cc/minute. As indicated by the three particle size measurements, variation in concentration did not materially change the particle size of the aerosol. Since the mass varies as d^3 , a change in mass by a factor of 8 is accompanied by doubling of the diameter; hence, reasonable changes in the solution concentration should not affect the particle size significantly for those tests. The particle size, however, was about half that measured when the generator was previously used in 1968.

DESCRIPTION OF THE FILTER EFFICIENCY MEASUREMENTS

All three experiments were performed in like manner with certain perturbations believed to be minor. At the start of the run the generator was made ready and supported by hanging about three feet below a 16-inch access opening at the top of a surveillance caisson sunk against the south wall of the 202-A Building. The caisson is located 267 feet west of the tunnel running from the 202-A Building over to Filter One and Filter Two.

The 10-foot diameter steel caisson extends 33 feet below grade. Near the bottom a two-foot diameter tube connects the caisson with the main ventilation tunnel. When the cover plate of the connecting tube is removed, air sweeps down through the caisson and into the ventilation tunnel at several thousand ft³ per minute. Since the generator was located just below the 16-inch opening, a good carrying velocity was maintained during the runs. A gasoline driven compressor was available to supply the needed pressure and a Rotron² pump was used for the sweep air through the side arm of the outlet tube of the generator. For these tests a 90° elbow was fitted to the top of the 3-inch "chimney" to direct the aerosol at right angles to the generator.

A Gelman Company³ 47-mm diameter filter holder containing a 3μ pore size membrane filter was inserted in the F-1 sample line which samples the inlet to Filters One and Two. A flow of 2.0 cfm was maintained with a vacuum pump and rotameter.

A Gelman Company 4-inch diameter membrane filter of 2μ pore size was inserted in a special holder which was connected to the sample line from the downstream side of Filter One. Flow was set at 8.0 cfm using a bypass valve and a rotameter and the differential pressure recorded. A nearly identical arrangement was used on the sampling line AS-1 for the newer filter, Filter Two. In Run 3, 0.8μ pore size membrane filters were used. The 0.8μ, 2μ, and 3μ pore size membrane filters are 99+% efficient for particles of the size used and for sampling flowrates in these tests. The filter pore size is only one factor in determining efficiency of membrane filters.

After all three samples, F-1, F-2, and F-3, were started, the aerosol generator was turned on. All times were noted. The generator was operated for around two hours. During Run 2 the compressor ran out of gas, but this was corrected and the compressor restarted. In Run 3 a broken

²Rotron, Inc., 70 Hasbrouck Lane, Woodstock, N.Y. 12498.

³Gelman Instrument Company, P.O. Box 1448, Ann Arbor, Michigan 48106.

ignition wire stopped the compressor, but this was corrected and the compressor restarted. Allowance was made for the downtime, although the run duration of itself was not of great importance to the experiment as long as the generation was long enough to provide an easily-measured concentration in the air stream.

At the end of the run the generator was stopped, the F-1 sample filter holder was removed, and the two 4-inch filters, F-2 and F-3, were removed and placed in individual containers. The filters were taken to a fluorescein-free laboratory for extraction and analysis.

Blank samples were obtained just before fluorescein Runs 1 and 2 using the same flow rates used for the actual test runs. The blank run was omitted in Run 3.

PARTICLE SIZE MEASUREMENTS

During each of the three runs the generated particles were sampled with a Scientific Advances cascade impactor.⁴ The cascade impactor was placed in the caisson on a floor grating some 27 feet below the top of the caisson. A vacuum pump was used that was capable of maintaining critical flow through the orifice provided in the impactor, thus insuring a flow of 0.42 cfm. At the completion of a run the cascade impactor was taken to the laboratory, disassembled and the weight of fluorescein on each stage determined. From these measurements and the calibration curve of the impactor the mass median size was determined.

FLUORESCEIN MEASUREMENT

Each filter or cascade impactor disc was leached with distilled water which was made up to a known volume. Fluorescein is very soluble and several small volume washes were used to dissolve the fluorescein. The volumes were kept as low as practicable for the blanks and the downstream filters. Several washes were collected then evaporated slowly to a low

⁴Scientific Advances, Inc., 1400 Holly Avenue, Columbus, Ohio 43212.

volume and made up to 10.0 ml. The fluorescence of the solutions were read on a Turner Model 110 Fluorometer⁵ which was calibrated with accurate dilutions of the original 5% solution prepared for the aerosol generator. The distilled water blank for this instrument is equivalent to about 2×10^{-9} g/ml. At this sensitivity some fluorescence is measurable in most materials extracted with water.

RESULTS

Results are shown in Tables I, II, and III.

TABLE I
RESULTS FROM RUN I

Sample Designation	Fluorescence Reading (Corrected For Distilled Water Blank)	Sensitivity Scale	Grams Fluorescein Equivalent	Grams Fluorescein Equivalent Per ft ³ Sampled
F-1 (Blank)	8 (10 ml vol.)	X30	4.0×10^{-8}	1.7×10^{-10}
F-2 (Blank)	28 (10 ml vol.)	X30	1.6×10^{-7}	1.7×10^{-10}
F-3 (Blank)	68 (10 ml vol.)	X30	4.3×10^{-7}	4.5×10^{-10}
F-1 (Run)	23 (Equiv. dil. to 500 ml)	X30	7.0×10^{-5}	2.9×10^{-7}
F-2 (Run)	26 (10 ml vol.)	X30	1.5×10^{-7}	1.6×10^{-10}
F-3 (Run)	79 (10 ml vol.)	X30	4.9×10^{-7}	5.1×10^{-10}

Indicated minimum efficiency* = (1 - penetration)

* Minimum efficiency is taken to be the efficiency indicated by a downstream sample having a fluorescence resulting from a penetration of the filter equal to that appearing in the actual sample. In most cases this is essentially the same as saying that as a minimum, 2X blank background could be measured with high probability and would represent fluorescein penetrating the filter. (Further discussed in the next section.)

Filter 1 (Older filter) Eff. > 0.999₄

Filter 2 (Newer filter) Eff. > 0.998₂

Particle Size: Aerodynamic Equivalent Mass Median Diameter = 0.42 μ

(See Figure 1)

⁵G. K. Turner Associates, 2524 Pulgas Avenue, Palo Alto, California 94303

TABLE II
RESULTS FROM RUN 2

<u>Sample Designation</u>	<u>Fluorescence Reading (Corrected For Distilled Water Blank)</u>	<u>Sensitivity Scale</u>	<u>Grams Fluorescein Equivalent</u>	<u>Grams Fluorescein Equivalent Per ft³ Sampled</u>
F-1 (Blank)	8 (10 ml)	X30	4.0×10^{-8}	3.4×10^{-10}
F-2 (Blank)	27 (10 ml)	X30	1.6×10^{-8}	3.3×10^{-10}
F-3 (Blank)	45 (10 ml)	X30	2.7×10^{-8}	5.3×10^{-10}
F-1 (Run)	81 (100 ml)	X10	1.5×10^{-5}	6.12×10^{-8}
F-2 (Run)	37 (10 ml)	X30	2.3×10^{-8}	2.4×10^{-10}
F-3 (Run)	55 (10 ml)	X30	3.4×10^{-8}	3.6×10^{-10}
4" Unused Filter Wash	42 (10 ml)	X30	2.6×10^{-8}	--

Indicated Minimum Efficiency* = 1 - penetration

*See note in Table I

Filter 1 (Older Filter) Eff. > 0.996₁

Filter 2 (Newer Filter) Eff. > 0.994₂

Particle Size: Aerodynamic Equivalent Mass Median Diameter = 0.3 μ

(See Figure 2)

PARTICLE SIZE - MICRONS

TABLE III
RESULTS FROM RUN 3

<u>Sample Designation</u>	<u>Fluorescence Reading (Corrected For Distilled Water Blank)</u>	<u>Sensitivity Scale</u>	<u>Grams Fluorescein Equivalent</u>	<u>Grams Fluorescein Equivalent Per Ft³ Sampled</u>
F-1 (Blank)	Not taken this run.			
F-2 (Blank)				
F-3 (Blank)				
F-1 (Run)	29 (51.0 ml)	X1	2.1×10^{-5}	9.7×10^{-8}
F-2 (Run)	28 (10 ml)	X30	1.7×10^{-7}	1.9×10^{-10}
F-3 (Run)	31 (10 ml)	X10	6.3×10^{-7}	7.09×10^{-10}

Indicated Minimum Efficiency* = (1 - penetration)

*See Note in Table I

Filter 1 (Older Filter) Eff. > 0.998₁

Filter 2 (Newer Filter) Eff. > 0.992₇

Particle Size: Aerodynamic Equivalent Mass Median Diameter = 0.3 μ

(See Figure 3)

DISCUSSION OF RESULTS

The fluorescence extractable from the blank samples taken prior to Run 1 are statistically insignificant from the samples taken during the time fluorescein was being introduced. This would suggest that these two filters were very nearly absolute in efficiency. The minimum filter efficiency calculated assuming that the fluorescence appearing in the downstream samples was actually breakthrough of the test aerosol is quite conservative. Filter F-3, for example, could have been cited to have an efficiency of 0.9998 if the observed blank had been subtracted from the run sample. An efficiency of 0.9990 could have been cited for both filters from results of Run 2 on the same basis. Since blanks were not taken prior to Run 3, these could not be subtracted. It can be seen from these examples that the indicated minimum efficiency as defined in Table I will in all probability underestimate the actual efficiency by a fraction of about 0.002 to 0.004. The indicated minimum efficiency based on the total fluorescence found in the downstream extract is believed to be a reasonable and conservative estimate of efficiency.

As in all experiments in which particles are measured there was some sampling error in the brief study. The sampling lines available were used. Turbulent deposition of particles in sampling lines and errors due to anisokinetic sampling are mitigated when particles are as small as those used for this test; however, the length of lines and the number of elbows present many areas for deposition. An error in estimating the aerosol in the air approaching the filter from line losses would make the concentration appear to be less than the actual, thus a conservative efficiency (lower than actual) would be reported. Errors in measuring flow rates could be positive or negative, but should not be more than a few percent. The rotameter used for the upstream sampler was cross calibrated against a rotameter which had been independently calibrated. The downstream sampler rotameters were checked against each other, and an error here of 10 or even 20% would not materially change the efficiency cited. When a penetration of 0.001 is indicated, for example, a 20% error would give an uncertainty of ± 0.0002 in

the reported efficiency.

The size distribution of the aerosol drawn from the atmosphere of the caisson during the tests was of smaller particle size than anticipated, based on experiments performed several years ago. An aerosol of about 0.8μ MMD was measured at that time. Differences in aspirator pressure, use of a different design cascade impactor and possible differences in capture efficiency on the stage collector plates due to humidity difference or treatment of the plates may account for the indicated smaller particle size. This is not a variable which would materially influence the outcome of these tests, however. An aerosol near 0.3μ in diameter would provide a somewhat more stringent test than for particles 0.8μ in diameter. A few more runs would have allowed a resolution of the apparently smaller sizes of particles than anticipated, but in the interest of time, this was not accomplished.

CONCLUSIONS AND RECOMMENDATIONS

The average indicated minimum efficiency as defined was 0.997_8 for Filter One and 0.995 for Filter Two. Actual filter efficiencies will be higher than these. Because of the inadvertent selection of the AS-1 as the sampling line for downstream of the fine filter in Filter Two, the indicated minimum efficiency does not include the filtering action of the fine filter. The overall actual efficiency of Filter Two is very likely higher by some significant increment than the values in Tables I, II, and III.

Measurement of filter efficiencies could be easily and more realistically accomplished by careful measurement of the inlet and outlet concentration of radioactivity associated with airborne particles in the exhaust air. Size distributions of particles in the ventilation effluent should be measured occasionally to help interpret filter performance, particularly when efficiency deteriorates.

The fluorescein aerosol used could be applied without undue difficulty for obtaining a more definitive filter efficiency than those obtained in this study. Longer generation times, larger samples, particularly downstream, and investigation of the source of fluorescence in the blank samples could

permit an extremely sensitive measurement of filter efficiency. Time available for the study did not permit defining optimum test conditions.

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