A Review of the Report:

High Efficiency Particulate Arrestors (HEPA Filters) in the Nuclear Industry

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Reference

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General Comments

This paper reviews certain aspects of the history of HEPA filters and selected issues on filter testing and performance. The vast majority of issues raised by Goldfield are either common sense operating procedures for testing HEPA filters or are questions that have been addressed in the literature. Goldfield is either not aware or chooses to ignore the large body of information on HEPA filter testing and performance that has been developed over the past four decades. A good resource for this information is the Nuclear Air Cleaning Conference Proceedings. In this paper Mr. Goldfield describes certain obvious weaknesses of HEPA filter testing and performance, but he fails to document steps taken over the history of the nuclear industry to mitigate the weaknesses. This approach leaves the uninformed reader with unwarranted concern over issues that have been addressed.

Comments on "Testing of HEPA filters"

Hot DOP Tests

The "small hot DOP test" described by Mr. Goldfield is used to test respirator cartridges not HEPA filters as they are defined in the paper. Test aerosols produced by this and other "hot DOP test" systems are not believed to have "quite narrow" size distributions.[1] The effects of the broad size distribution produced by these systems on test results have been evaluated[2] and modern filter test systems have been developed[3,4], evaluated[5], and are now being implemented in DOE and US Army filter test programs.

The hot DOP test systems were designed to operate with a monodisperse 0.3 um test aerosol which was the size of maximum penetration for the first generation of HEPA filters. In the past decade it was found that the test systems produced a polydisperse aerosol with a count median diameter in the range of 0.15 um to 0.2 um and that with this aerosol the test systems gave a penetration measurement approximately equal to the penetration at 0.3 um diameter. The current generation of HEPA filters has a size of maximum penetration of approximately 0.15 um diameter. The new test systems are capable of measuring penetration at this size in compliance with DOE filter test standards.

"Why does a HEPA only require an efficiency of 99.97%?"

Nuclear facilities are designed to provide protection from release of airborne hazardous materials. The design requires decontamination of airborne releases to specified safe levels under normal and upset conditions. To accomplish the required level of decontamination ventilation systems are designed with the number of stages of HEPA filters that corresponds to that decontamination level. For example if a facility in a worst case scenario requires that process exhaust concentrations be reduced by a factor of 10^6 then two stages of HEPA filtration would be used. The first stage would reduce the concentration by a factor of at least 2000 and the next by a factor of at least 2000 for an overall decontamination of 4×10^6. These decontamination factors account for the fact that the second stage is challenged with an aerosol that is more

difficult to collect than was the first stage. Almost always another one or two stages of HEPA filtration is used in these facilities to give added measures of protection.

Designers of nuclear facilities prefer to use several stages of the HEPA filters with nuclear grade media certified at 99.97% efficiency rather that fewer stages of non-nuclear grade filters with higher efficiency. One reason is that the several stages provide a greater number of barriers between inside the nuclear containment and the environment. In the event that upstream stages are breached, stages downstream provide the required protection. Of course, the price of higher efficiency is increased energy costs for pushing a given flow through the filtration system. For a given number of stages an order of magnitude increase in operating costs is expected from an order of magnitude decrease in penetration.

The major reason not to change to higher efficiency media is that the 99.97% efficient media is the only media that is nuclear grade. Nuclear grade media meets specifications developed by government and professional organizations. These specifications assure the performance of the media in a variety of upset conditions. Tests are performed to assure flame resistance, strength, performance under high humidity conditions as well as other conditions. A higher efficiency media meeting these specifications has not been developed. So besides costing more to operate, their is no assurance that the higher efficiency media would meet performance criteria other than efficiency.

Comments on "Errors of Testing"

DOE operates three filter test facilities (FTFs) which determine compliance with HEPA filter quality assurance standards and policies. Every HEPA filter purchased for use in DOE nuclear air cleaning systems is tested for penetration and resistance at one of these FTFs prior to installation. In addition the FTF at Rocky Flats plant tests filter models for compliance to DOE qualified filter products standards.

Los Alamos coordinates and reviews data from a round-robin test (RRT) program for the DOE FTFs. This program evaluates measurement consistency within individual FTFs as well as among the FTFs. This program is mandated by DOE standards on filter testing.

"Hot DOP"

Evaluation of particle size control has been performed by Los Alamos and the DOE FTFs.[6] This study showed that the FTFs maintain very good control of particle size during tests of HEPA filters. This same study and another study [7] evaluated the use of a laser aerosol spectrometer for monitoring aerosol size at the FTFs. Use of the spectrometer at the FTFs was supported by the results of these studies.

Test flows at FTFs are calibrated using flow calibration plates traceable to the National Bureau of Standards.[8] Effects of temperature, and atmospheric pressure are accounted for using the ideal gas law.[9] Relative humidity effects were determined to be not significant relative to the accuracy and precision requirements for FTF measurements. Airflow

accuracy and precision for aerosol generation is not a meaningful issue. Airflow measurement is used for coarse adjustment of the aerosol generators and fine adjustment is based on aerosol measurement.

Temperature measurements are used at the FTFs to support test flow measurements and for coarse adjustment of thermal test aerosol generators. Effects on test flow accuracy are related to percent changes in absolute temperature so temperature changes of a couple degrees Celsius result in less than a percent change in flow. Temperature control of oils for generating aerosol is critical to maintain the liquids well below their flash point. A temperature measurement accuracy of approximately $\pm 1^{o}C$ is sufficient for FTF requirements. This accuracy is easily achieved by the modern laboratory equipment used in the FTFs.

All FTF filter penetration measurements are made by first checking the 100% level of the photometer and then quickly making the penetration measurement. The stability of the thermal aerosol generators is such that no significant change in the challenge occurs in the brief period between the 100% level check and the penetration measurement.

There is no evidence that electrostatic charge is affecting FTF measurements. Evaluation of filters tested by the FTFs for the range of of flows and aerosol size at which the tests are carried out indicate that collection is dominated by a diffusion collection mechanism.[5] Mr. Goldfield gives no mechanism by which filters could be inadvertently charged. Elaborate means are required to charge special filters specifically manufactured to take advantage of electrostatic collection. Davies[10] points out that organic oil aerosols are extremely efficient for destroying electrostatic charging capacities of fibrous filters. Nuclear grade HEPA filters are tested with such aerosols by the manufacturer prior to the FTF test. With the evidence that HEPA filter collection is dominated by a non-electrostatic mechanism, that no inadvertent charging mechanism is known, and that filters are dosed with organic oil prior to FTF testing the possibility of electrostatic charges affecting FTF measurements is highly remote.

Comments on "Filter and Installation Leakage"

"General"

Mr. Goldfield inaccurately quotes Burchsted(page 13, second complete paragraph).[11] Failure to pass in-place testing is not as prevalent as Goldfield indicates.[12] Filter installations not passing initial tests are repaired and re-tested until the installation meets test standards.

"Alpha Recoil Effect"

Contamination surveys of the downstream surface of in-service HEPA filters do not find levels above above background.[13] These results indicate that alpha recoil is not a mechanism for significant HEPA filter penetration. Studies should be conducted to determine the maximum possible impact that this mechanism could have on HEPA penetration.

Comments on "Multiple HEPA Filters Against Plutonium Aerosols"

The objective of the Gonzales[14] study was to evaluate performance of HEPA filters in the second and third stages of a filtration system not the performance of the combination of filter and filter mounting frames. Aerosol concentration in these stages is so low that all other sources of contamination had to be eliminated so that penetration through filters could be determined independent of these other potential contamination sources. Decisions to use laboratory aerosols were based on obtaining the most accurate and meaningful results. The laboratory situation provided better control over sample collection and measurement than would a field study. Consequently, results from the laboratory study could more accurately be applied to a variety of field situations than could results of a field study.

"Concentration Problems"

As mentioned above the purpose of the study was to measure the performance of the second and third stage of HEPA filters. Loading of the first stage filters was not relevant. First stage filters were operated within design criteria and were not allowed to plug. Loading on the second and third stages were well below limits where loading affects penetration.

There is no evidence from HEPA filter performance or fibrous filtration media theory that indicates penetration fraction is affected by challenge concentration.

"Leakage Effects"

In terms of operating parameters important to filter performance the 25 CFM filters were operated under the same conditions as are the larger filters in the field.

"Particle Size Effects"

Penetration measurements were made at specific aerosol size bands so that the measurements can be used to predict overall penetration over a wide range of challenge aerosol size distributions. These size bands extended to sizes below that of HEPA minimum efficiency. Consequently, measurements at smaller aerosol sizes would result in higher efficiency measurements.

Particle shape differences between the field aerosols and the laboratory aerosols would not be significant in terms of HEPA filter performance.

"Radon and Thoron Daughters"

Because plutonium activity levels were so low on the second and third stage samples, radon and thoron activity was allowed to decay away before making the plutonium activity measurements. The radon and thoron activity is associated with a naturally occurring gas and is not associated with plutonium processing.

"Filters in Series"

The conclusion of the Gonzales study that "ERDA" guidelines were not violated appears to be substantiated by the results. Addition of the maximum allowable leakage to the maximum penetration measured by Gonzales still results in an overall leakage less that the "ERDA" guide.

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12. J. P. Ortiz, E. D. Garcia, and J. M. Ortega, "In-place Filter Testing Summary," LA-UR-88-2694, 1988.

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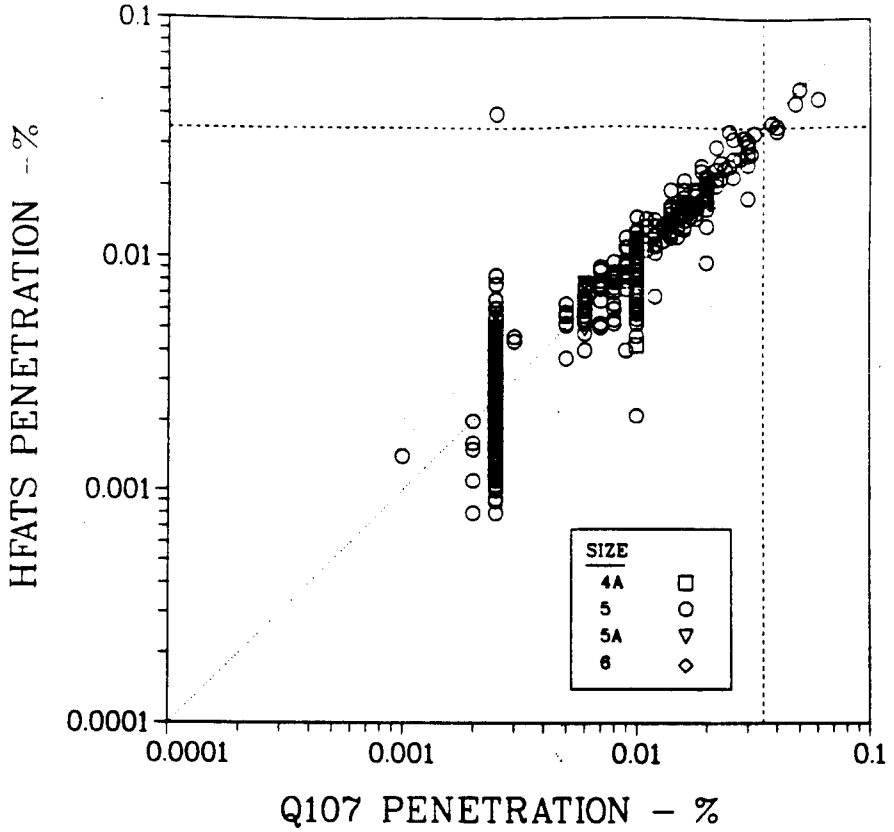

Figure 5. Comparison of the 20% flow test penetration measurements using the 0.31 µm HFATS data.

TABLE II

PENETRATION DIFFERENCES - 0.31 µm TESTS (HFATS - Q107)

FILTER SIZE	AVERAGE DIFFERENCE 100% FLOW	AVERAGE DIFFERENCE 20% FLOW
4A	-0.002*	-0.0004
5	0.001	-0.0004
5A	0.002	0.0002
6	0.002	0.0008

* Underline indicates significant difference (P <0.05).

Rejection rates for the 0.31 µm-HFATS comparisons are also listed in Table III. The combined HFATS rejection rates (HFATS only plus both) for all filters tested were ≤0.8% which is at the lower end of the range of rejection rates observed under routine conditions at the FTFs. The corresponding combined Q107 rates were lower than the HFATS rates.

TABLE III

PENETRATION REJECTIONS FOR THE 0.31 µm-HFATS COMPARISON

		FAILING 100% TESTS						FAILING 20% TESTS					
		HFATS ONLY		Q107 ONLY		BOTH		HFATS ONLY		Q107 ONLY		BOTH	
FILTER SIZE	NUMBER TESTED	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
4A	21	0	0	0	0	0	0	0	0	0	0	0	0
5	737	0	0	0	0	0	0	1	0.1	1	0.1	5	0.7
5A	39	0	0	0	0	0	0	0	0	0	0	0	0
6	52	1	1.9	0	0	2	3.9	1	1.9	0	0	0	0
TOTAL	849	1	0.1	0	0	2	0.2	2	0.2	1	0.1	5	0.6

Penetration Comparison with the 0.15 µm HFATS Data

Another important comparison that demonstrates the capability of the HFATS, is a comparison of HFATS measurements at the maximum penetration bin with the Q107 measurements. To determine if the bin in which the maximum penetration occurs is dependent upon the magnitude of maximum penetration, the maximum penetration bin was plotted against maximum penetration for the 100% and the 20% tests (Figures 6 and 7, respectively). Figure 6 shows that the maximum penetration occurs in the bin diameter range from approximately 0.1 µm to approximately 0.2 µm over the entire range of maximum penetration. No maximum penetration measurement occurred in a bin larger than the 0.21 µm bin. This relation between bin diameter and maximum penetration was independent of penetration. These conclusions are consistent with the shape of the 100% flow penetration curve found in Figure 3 which shows a distinct particle size of maximum penetration.

The 20% flow test results presented in Figure 7 show no such grouping of maximum penetration into a narrow bin diameter range. The data in Figure 7 appear to be evenly distributed over the entire range of bin diameters. This finding is also consistent with the shape of the 20% flow penetration curve found in Figure 3 which showed penetration to be independent of aerosol size.

The 100% flow data were used to plot the distribution of maximum penetration aerosol size (see Figure 8). For each of the filter