TESTING CLEANABLE/REUSABLE HEPA PREFILTERS FOR MIXED WASTE INCINERATOR AIR POLLUTION CONTROL SYSTEMS

D. B. Burns, A. Wong, B. W. Walker, and J. D. Paul
Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, SC 29808

Abstract

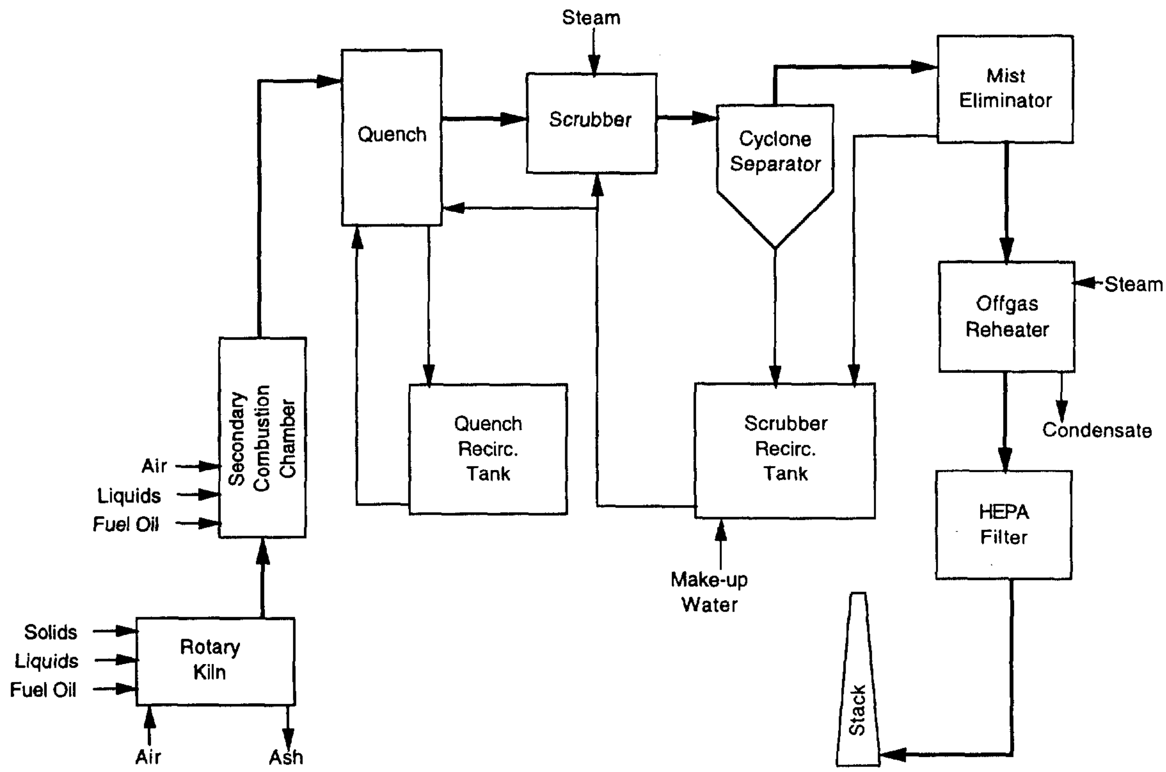
The Consolidated Incineration Facility (CIF) at the US Department of Energy (DOE) Savannah River Site is currently undergoing preoperational testing. The CIF is designed to treat solid and liquid RCRA hazardous and mixed wastes generated by site operations and clean-up activities. The technologies selected for use in the CIF air pollution control system (APCS) were based on reviews of existing commercial and DOE incinerators, on-site air pollution control experience, and recommendations from contracted consultants. This approach resulted in a unique facility design utilizing experience gained from other operating hazardous/radioactive incinerators. In order to study the CIF APCS prior to operation, a 1/10 scale pilot facility, known as the Offgas Components Test Facility (OCTF) was constructed by the Savannah River Technology Center and has been in operation since late 1994. Its current mission is to demonstrate the design integrity of the CIF APCS and optimize equipment/instrument performance of the full scale production facility. Operation of this on-site pilot facility has provided long-term performance data of integrated systems and critical facility components. This effort has reduced facility start-up problems and helped to insure compliance with all facility performance requirements. In today's environment of increased public participation and awareness, technical support programs of this type assist in assuring all stakeholders the CIF can properly treat combustible hazardous, mixed, and low-level radioactive wastes.

Due to the nature of the wastes to be incinerated at the CIF, High Efficiency Particulate Air (HEPA) filters are used to remove hazardous and radioactive particulates from the exhaust gas stream before being released into the atmosphere. The HEPA filter change-out frequency has been a potential issue and was the first technical issue to be studied at the OCTF. Tests were conducted to evaluate the performance of HEPA filters under different operating conditions. These tests included evaluating the impact on HEPA life of scrubber operating parameters and the type of HEPA prefilter used. This pilot-scale testing demonstrated satisfactory HEPA filter life when using cleanable metal prefilters and high flows of steam and water in the offgas scrubber.

I. Introduction

The Consolidated Incineration Facility (CIF), located at the Savannah River Site, is currently undergoing preoperational testing to treat solid and liquid RCRA hazardous and mixed wastes generated by site operations and clean-up activities. In this facility, waste thermal treatment is performed in a 13 million Btu rotary kiln incinerator and 5 million Btu secondary combustion chamber. The facility air pollution control system (APCS) consists of a recirculating liquid quench and steam-atomized scrubber for offgas cooling and cleaning, a cyclone separator and mist eliminator for liquid/gas separation, and final HEPA filtration prior to atmospheric discharge through the facility stack. A process flow diagram for the CIF is shown in Figure 1.

Figure 1
CIF Process Flow Diagram

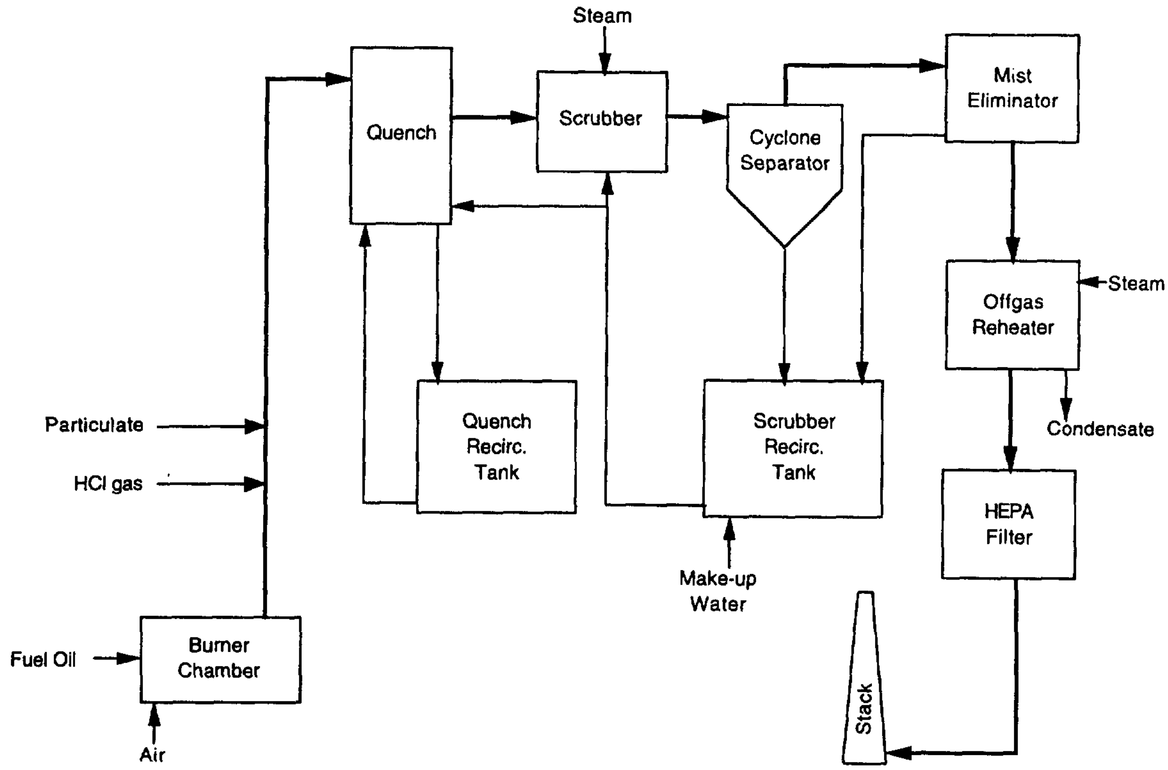


The technologies selected for use in the CIF were based on reviews of existing commercial and DOE incinerators, on-site air pollution control experience, and recommendations from contracted consultants. This approach resulted in a unique facility design utilizing experience gained from other operating hazardous/radioactive incinerators. The Savannah River Technology Center (SRTC) designed, installed, and operated a 1/10 scale pilot facility, known as the Offgas Components Test Facility (OCTF), to demonstrate the design integrity of the CIF APCS and optimize the equipment/instrument performance in the full scale waste treatment facility. Operation of this on-site pilot facility has provided long-term performance data of integrated systems and critical facility components. This effort has reduced facility start-up problems and helped to insure compliance with all facility performance requirements.

II. OCTF Design and Capabilities

The OCTF is a pilot-scale air pollution control system, currently configured to test the design of the CIF APCS. A schematic of the OCTF is shown in Figure 2. Hot offgas is produced in a three million Btu burner chamber. Particulate and HCl gas are metered into the gas stream to simulate particulate carry-over and acid gas produced during incineration of typical hazardous wastes. The offgas is cooled in a co-current recirculating water quench before entering a high efficiency steam-atomized scrubber. The scrubber removes particulates and neutralizes acid gases. The scrubbed offgas enters a cyclone separator where liquid and solid particulates are removed from the gas stream. After exiting the cyclone, the offgas enters a mist eliminator to remove any residual liquid droplets. A reheater upstream of the HEPA filters prevents condensation in the filter housing. The filtered offgas is discharged to the atmosphere through the facility stack.

Figure 2
OCTF Process Flow Diagram



The OCTF is designed to evaluate operational parameters of air pollution control system designs. The OCTF utilizes a modular design which allows replacement/addition of existing unit operations with other technologies that could be tested in the future. The current configuration of the OCTF is a 1/10 scale mock-up of the CIF APCS. Individual equipment components and instruments currently installed were designed and fabricated by the same vendors selected for the CIF. The performance of all CIF APCS components were evaluated as a function of system operating parameters at the OCTF. In addition to obtaining valuable performance data, the OCTF is a useful tool for training operators and maintenance personnel.

III. OCTF Filter Testing

The first test series at the OCTF investigated process parameters that impact system HEPA filter and prefilter life. The APCS must be operated in such a manner to provide acceptable HEPA filter and prefilter life (> 30 days). Short filter life significantly increases facility operating costs associated with procuring, replacing (or cleaning), and disposing system filters. The filter housings used both at the CIF and the OCTF contain 24" x 24" x 11.5" disposable fiber HEPA filters. Upstream of the HEPA filters are 24" x 24" x 6" prefilters. The primary objective of these tests was to determine the APCS operating parameters that are required to meet the goal of 30-day HEPA filter and prefilter life.

Test Plan

This test consisted of six runs. The test facility was operated in a mode that simulated the average design operating conditions of the CIF. The gas temperature exiting the burner chamber was held at approximately 1026°C. The gas flow through the HEPA housing was maintained at approximately 2100 ACFM (700 ACFM/HEPA filter). The offgas temperature passing through the HEPA housing was maintained above 115°C to prevent water condensation. The concentration of salt (NaCl) in the quench recirculating stream was held constant during each run. Salt concentrations in the scrubber solution were maintained below 0.1 wt% due to inflow of makeup water. The operating parameters that were investigated in this test included:

- Type of HEPA prefilter
- Mass ratio of scrubber steam to offgas (α)
- Mass ratio of scrubber water to offgas (β)
- Salt concentration in the quench liquid

Two types of HEPA prefilters were tested. The first was a Flanders paper prefilter (model # T-00K-C-04-00-NL-12-00-E0281, 60-65% @ 1000 cfm). The second prefilter was an Otto York 304 stainless steel prefilter sized to remove 99% of all particles greater than 5 μm in diameter. The Flanders prefilter is a disposable filter, while the Otto York prefilter was cleaned with water after each test and reused.

The test matrix for this program is shown in Table 1.

Table 1 Test Matrix

Run #	Steam/Offgas (α)	Water/Offgas (β)	Quench Salt (wt %)	Prefilter Type
1	0.22	0.5	10	Paper
2	0.22	0.5	5	Paper
3	0.43	1.0	10	304 SS
6	0.26	1.0	10	304 SS
7	0.26	1.0	10	Paper
8	0.26	0.5	10	304 SS

Discussion

The results of all HEPA life test runs are summarized in Table 2. New (or cleaned) prefilters and HEPA filters were installed in the test facility prior to beginning each run. The scrubber operating conditions were maintained at the settings given in the Table 2. Each run ended after sufficient filter pressure drop vs. time data was collected. The actual prefilter and HEPA filter pressure drop observations at the conclusion of each run is listed in Table 2.

Table 2 HEPA LIFE TESTS RESULTS SUMMARY

	Run #					
	1	2	3	6	7	8
Steam Alpha	0.22	0.22	0.43	0.26	0.26	0.26
Water Beta	0.5##	0.5	1.0	1.0	1.0	0.5
Prefilter Type	Paper	Paper	304 SS	304 SS	Paper	304 SS
Quench Salt Concentration	10 wt%	5 wt%	10 wt%	10 wt%	10 wt%	10 wt%
Observed Prefilter dP	3.50" after 40 hrs	2.20" after 110 hrs	1.20" after 415 hrs	1.15" after 375 hrs	3.25" after 215 hrs	0.85" after 475 hrs
Observed HEPA dP	0.40" after 40 hrs	0.35" after 110 hrs	0.85" after 415 hrs	3.00" after 375 hrs	0.40" after 215 hrs	2.80" after 475 hrs
Projected Prefilter Life*	2 days	10 days	42 days	30 days	10 days	68 days
Projected HEPA Life**	#	#	37 days	18 days	#	27 days

* Projected Prefilter Life estimates are derived by extrapolating a third order polynomial function fit to observed data. For paper prefilters, the maximum dP permitted is 4". For cleanable metal prefilters, the maximum dP is 10"

** Projected HEPA life estimates are derived by extrapolating a third order polynomial function fit to observed data. The maximum dP for HEPA filters is 4".

\# Insufficient data to fit a valid a third order polynomial model.

\## Partial plugging of scrubber water nozzles during this run is expected to have contributed to poor scrubber performance.

A mathematical model was fitted to the prefilter and HEPA filter pressure drop (dP) vs. time data. The model that consistently showed the best data fit (in particular for the data sets showing a filter at the maximum useful dP) was a third order polynomial relating the dependent variable (dP) to the independent variable (time). Using this model, filter life expectancies were extrapolated for runs ending prior to reaching the maximum allowable dP. For the disposable Flanders prefilters and HEPA filters, this value was assumed to be 4" water. If filter dP was allowed to exceed this value, filter breakthrough was often observed. For the cleanable metal prefilters, the maximum dP was assumed to be 10" water. These filter life predictions are included in the last two lines of Table 2.

Acceptable filter performance was obtained only when using the cleanable metal prefilters. The maximum observed disposable prefilter life was 10 days under all conditions tested. Under similar conditions, prefilter life was extended approximately 3X when using the metal prefilters. It should be noted that use of the disposable paper prefilters always resulted in plugging and changing of the prefilter before any significant dP increase occurred on the HEPA filter. This explains the inability to predict HEPA life for these runs (1, 2, 7). Insufficient data was available for the HEPA dP profile because the prefilter would plug too rapidly. Yet, use of the metal cleanable prefilter often resulted in plugging of the HEPA filter before the dP limit for the prefilter was obtained. Thus, the data tends to indicate the cleanable prefilter allows a greater fraction of particulate through to the HEPA filter. Yet, this more even distribution of particulate between the prefilter and HEPA filter permits a significantly longer time interval between filter (either prefilter or HEPA filter) changeout or cleaning.

The runs which utilized cleanable HEPA filters were #3, 6, and 8. During these runs, the steam/offgas flow ratio was varied between 0.43 and 0.26. Also, the scrubber water/offgas flow ratio was varied between 1.0 and 0.5. The theoretical best conditions are at higher steam and water flowrates (Run 3). Figures 3 and 4 contain the graphs of prefilter (Fig 3) and HEPA filter (Fig 4) dP vs. time. Also on the plots are the projected performance curves predicted by the third order polynomial model. For this run, it can be seen that the actual data does not cover a significant fraction of the model, particularly were the slope begins increasing. It is likely that the model being used for these conditions is a "worst case" projection. Thus, there is a relatively high probability that actual filter life would be at least what is predicted for this case (and possibly greater).

Figure 3 Run 3 Prefilter Performance

Model: V6=K+A*V1+B*V1**2+C*V1**3

y=(0.1817287)+(0.003141479)*x+(-8.596414e-006)*x**2+(1.379748e-008)*x**3

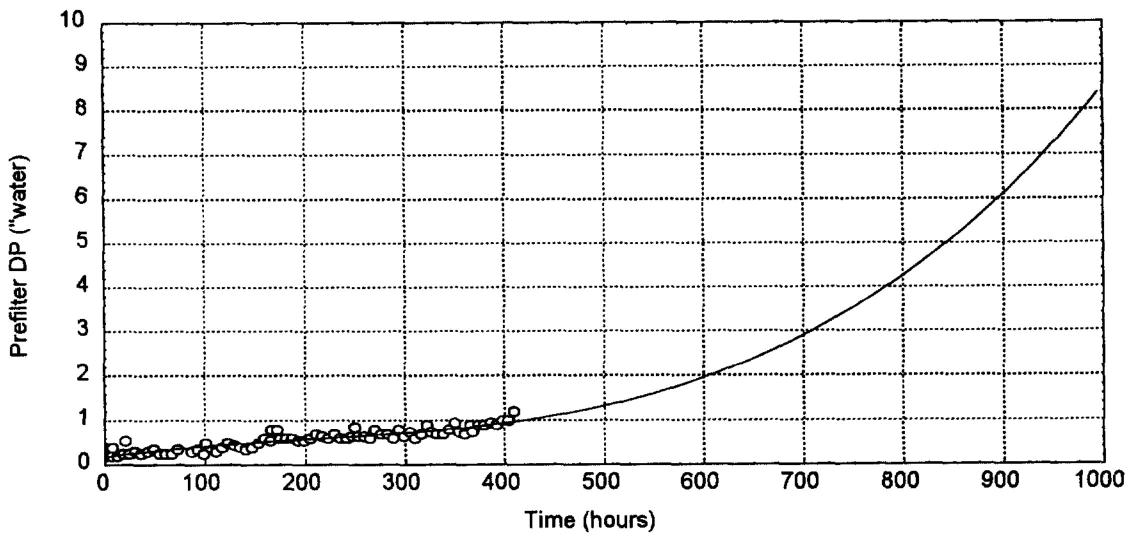
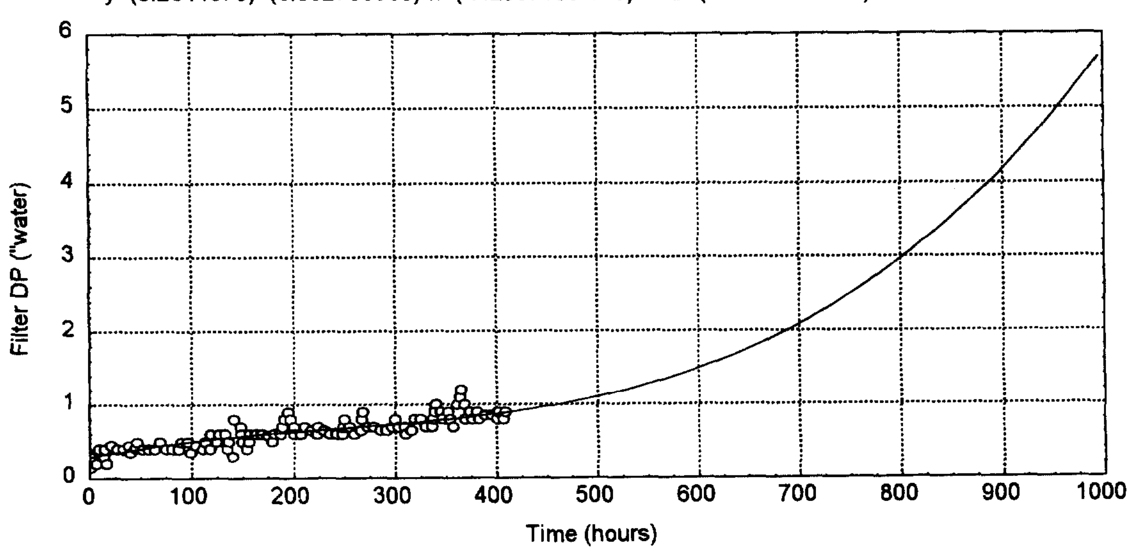


Figure 4 Run 3 HEPA Filter Performance

Model: V7=K+A*V1+B*V1**2+C*V1**3

y=(0.2844875)+(0.002788966)*x+(-7.295733e-006)*x**2+(9.993183e-009)*x**3



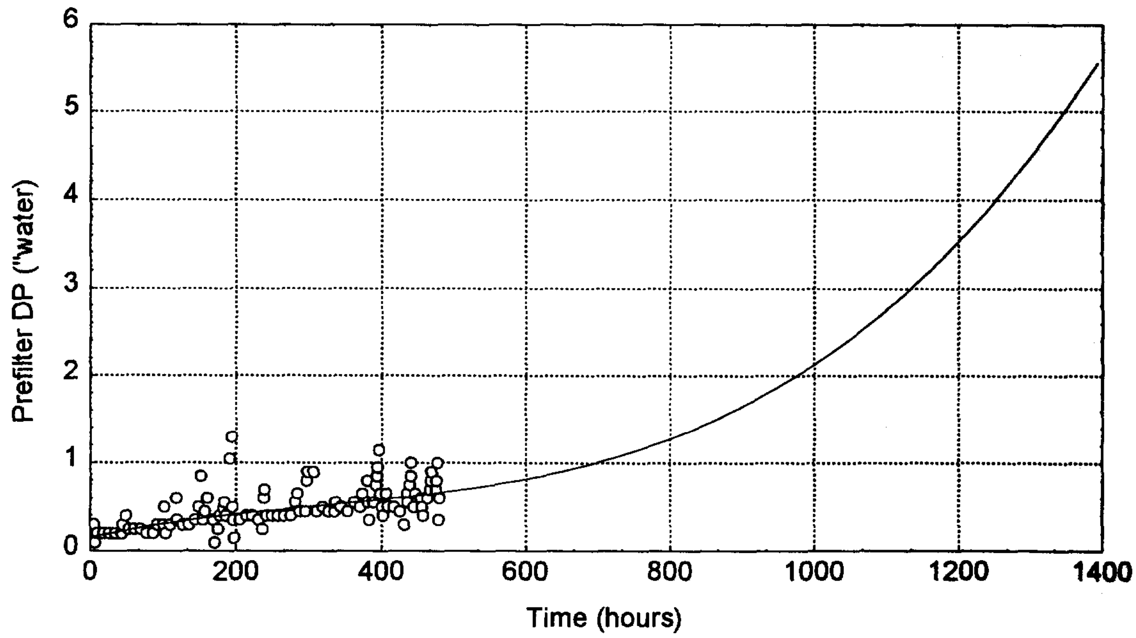
The second best performance was observed in Run 8, when the steam and water flows were both low. This is due to the fact that proper scrubber performance requires the ratio between the scrubber water flow to scrubber steam flow equal two (# water / # steam = 2). If the ratio is too high, the majority of the steam is used to atomize the water and there is insufficient steam for turbulence and pulling offgas through the scrubber. While a low ratio results in insufficient water to properly scrub the offgas. This explains the relatively poor performance in Run 6 (water / steam ratio = 3.8).

Figures 5 and 6 contain the graphs of prefilter (Fig 5) and HEPA filter (Fig 6) dP vs. time for the second best run, Run 8. For this run, it can be seen that the actual data covers enough of the model (especially for the HEPA filter), to consider the projected HEPA filter life a likely estimate. Thus, it is probable that the projected HEPA life of 27 days is an accurate estimate, not a "worst-case" estimate as in Run 3

Figure 5 Run 8 Prefilter Performance

Model: V13=K+A*V1+B*V1**2+C*V1**3

y=(0.1525723)+(0.001824109)*x+(-3.208998e-006)*x**2+(3.36416e-009)*x**3



The particulate size distribution data obtained during these tests indicated that increasing the flow of steam to the scrubber decreased the fraction of large particulates (> 10 µm). This can be seen by comparing the size distribution plot for runs 6 and 3 (Figures 7 and 8). The only difference between these runs is the mass flow of steam. The steam flow was low (0.26 alpha) in Run 6 (Fig 7), and high (0.43 alpha) in Run 3 (Fig 8). This change in the particulate size distribution resulted in increased filter life at the higher steam flow (and a water/steam ratio closer to 2).

Figure 6 Run 8 HEPA Filter Performance

Model: V12=K+A*V1+B*V1**2+C*V1**3

y=(0.5212461)+(0.0009766396)*x+(9.477834e-006)*x**2+(-4.058634e-009)*x**3

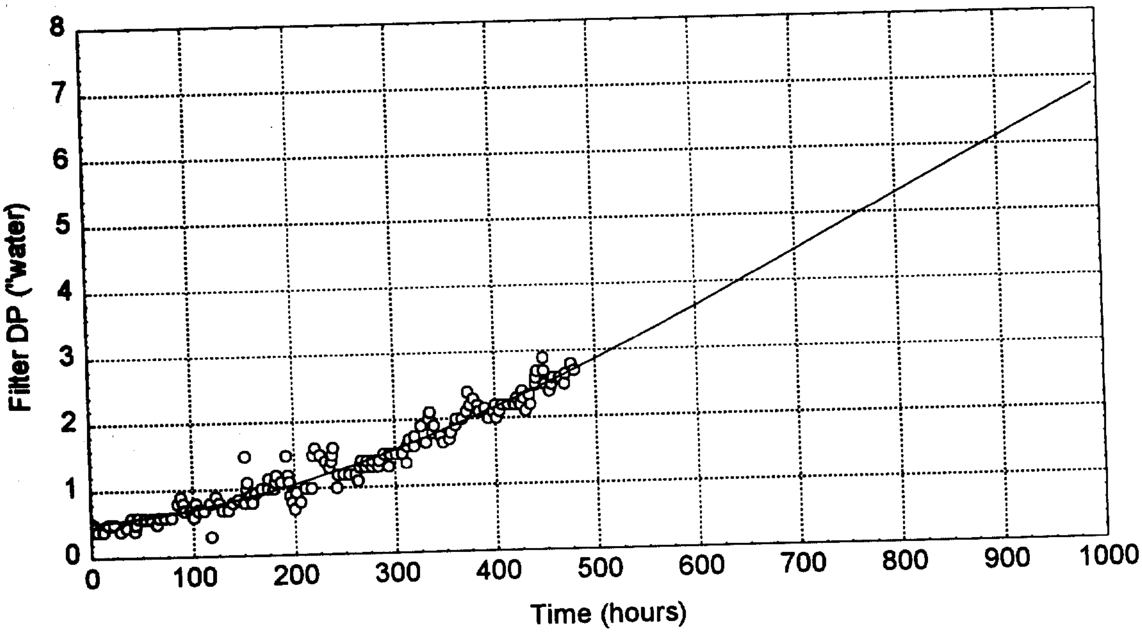


Figure 7 Run 6 Offgas Particulate Size Distribution

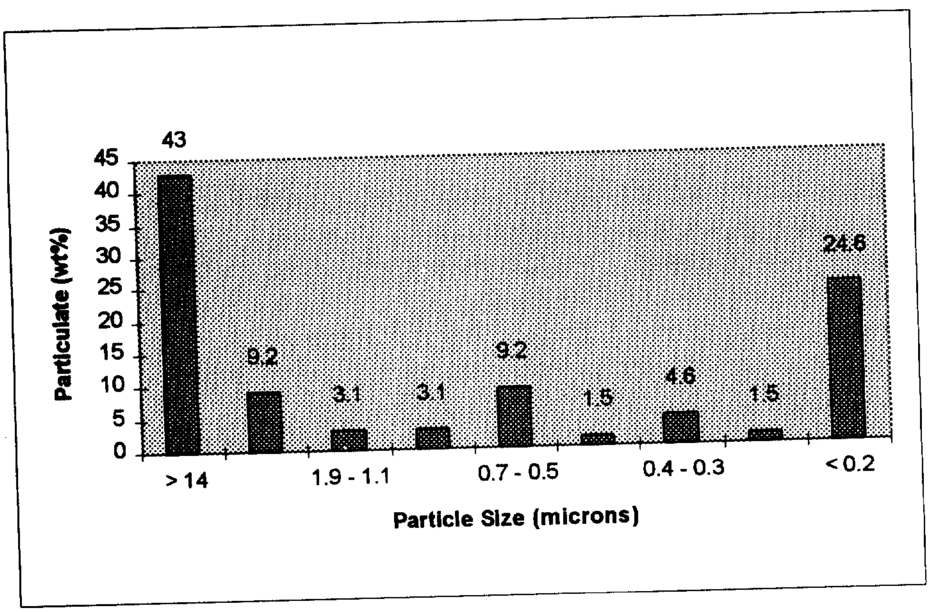
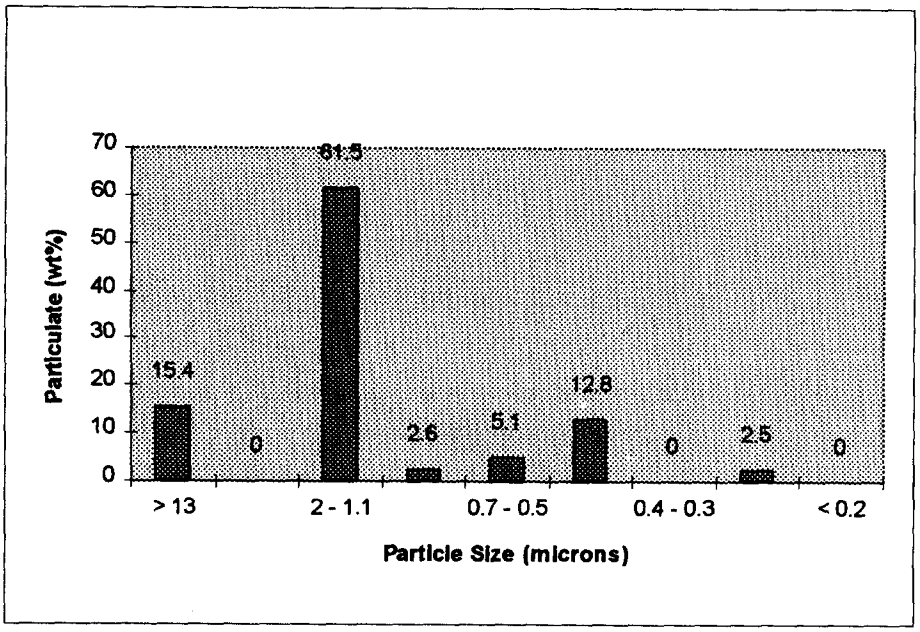


Figure 8 Run 3 Offgas Particulate Size Distribution



Conclusions

The primary conclusion of this test program is that satisfactory prefilter and HEPA filter life is obtainable with the existing CIF APCS. Test results indicate that the life of HEPA prefilters/filters can exceed the operational goal of thirty days under the following conditions: steam ratio, $\alpha = 0.43$, scrubber water ratio, $\beta = 1$, and using 304 SS cleanable prefilters.

IV. Summary

The Consolidated Incineration Facility (CIF) at the US Department of Energy (DOE) Savannah River Site has a unique facility design utilizing experience gained from other operating hazardous/radioactive incinerators. In order to study the CIF APCS prior to operation, a 1/10 scale pilot facility, known as the Off-gas Components Test Facility (OCTF) was constructed by the Savannah River Technology Center and has been in operation since late 1994. This test facility demonstrated the design integrity of the APCS and is currently being used to optimize the equipment/instrument performance of the full scale production facility. Operation of this on-site pilot facility has provided long-term performance data of integrated systems and critical facility components. This effort has reduced facility start-up problems and helped to insure compliance with all facility performance requirements.

Tests were conducted to evaluate the performance of the HEPA filters under different operating conditions. These tests included evaluating the impact on HEPA life of scrubber operating parameters and the type of HEPA prefilter used. This pilot-scale testing demonstrated satisfactory HEPA filter life when using cleanable metal prefilters and high flows of steam and water in the offgas scrubber.

DISCUSSION

BELLAMY: I have two questions I would like to ask. The first is on the slide that showed useful life versus number of runs. For the three runs that were done for the cleanable filters, two of the runs did not get to your acceptable thirty day life. I assume that each run was under different operating conditions?

BURNS: Correct.

BELLAMY: So run three, that was over thirty days, basically defined for you your future operating conditions, rather than the average of those three to be over thirty days?

BURNS: Each run was for a separate operating condition.

BELLAMY: The second question I have is concerned with service life and useful life. For a cleanable pre-filter, how many washable cycles are possible? If I buy one filter am I done forever? If I wash it every thirty days, do I have to replace it every year, two years, three years?

BURNS: That is something we haven't an update on. We are still using the original filter in the test facility. We have at least twenty-five cycles on it. Typically, we just load it up until we have to shut down; usually the HEPA filter is plugged and has to be replaced. The most resistance we have ever gotten on the prefilter has been about 3 in. w.g. When it starts clean, it is less than an inch.

BELLAMY: Not being intimately familiar with manufacturers' names and products, the final conclusion on your final slide used the term Otto-York prefilter. What is the significance of an Otto-York prefilter versus anybody else's prefilter?

BURNS: That just happens to be the one we tested. We consulted our site experts and they had some experience with that particular type of filter, so that was what was recommended. I have no doubt that a similar filter, manufactured by another company, would most likely behave the same.

PORCO: The question I have is, did you check the initial resistance after you cleaned your moisture separator? Did you do a pressure drop test on your moisture separator after you cleaned it?

BURNS: Yes.

PORCO:: How close did it get to the original pressure drop?

BURNS: The same.

PORCO: That answers the question about being reusable. As long as you keep coming down to the initial resistance it means you are getting most of the particles off.

BURNS: The particles we have are salt and iron oxide. When we analyze it we typically see a lot of iron chloride, stuff that washes out fairly easily. It is not sticky or anything like that. It tends to return to the silver clean apperance every time after we have washed it.

PIERCE: You noted on your slide that the glass prefilter you used was rated at 60 - 65% ASHRAE efficiency. What was the ASHRAE efficiency rating of the stainless prefilter?

BURNS: It is a mist eliminator, it has no ASHRAE efficiency rating because it is not really an air filter. The closest figure I have is what the manufacturer says, 95 % removal for water droplets greater than five microns.

PIERCE: The suggestion I am making is that you might not be looking at apples-to- apples if they do not have the same efficiency.

BURNS: It is a totally different item, it is a mist eliminator. It is not an air filter and it is not sold as an air filter.

WEBER: This was an extremely interesting paper. It is not critical to your presentation, but would you say that there was anything done to the knit-mesh of glass and stainless steel to create a fixed pore size?

BURNS: For that filter, to my knowledge, they do not advertise any kind of fixed pore size, it is just a spun fiber. This is really just a totally new application. The gases we are dealing with here contain a lot of water vapor. It is a totally different application than a typical HVAC HEPA filter application. In this case, we found that this particular unit happened to help us out quite a bit.

PORCO:: If you want to find the ASHRAE efficiencies for moisture separators, there is a Mine Safety Appliances Co. report, MSAR-71-45 where you will find efficiencies for a moisture separator. Also in Air Cleaning Conference Proceedings, 14th Conf. p. 694.

FLEMING: Did you say that you were adding HCL to the airstream at some point?

BURNS: Yes, we burn PVC waste, so there is an acid gas. That is the source of the sodium chloride.

FLEMING: That is what I was going to ask, is the sodium coming from a neutralization of the HCL?

BURNS: Exactly.

FLEMING: Do you put it in after the quench or before the quench?

BURNS: It is before. Here is how the system works: from burning PVC or chlorinated waste, HCL or chlorine gas comes out of the incinerator. The scrubber takes it out and the pH in the scrubber solution quickly goes very low, so you have to neutralize it with a caustic. That creates the sodium chloride. The sodium chloride is usually what gets entrained into a fine salt mist that plugs the HEPA filters. Therefore, the concentration of sodium chloride you allow to build up in your loops is a very critical parameter.

FLEMING: What I am really getting to is, what effect does the corrosion have on the filters themselves? Up to this point, have you noticed any corrosive effects, any eating away of the filter as you rinse it off, anything like that?

BURNS: We have seen some. We have not seen any corrosion on that particular unit, but we have seen some signs of corrosion in our HEPA filter housings. Corrosion would be what is going to limit the life of the prefilter. I am surprised we have not seen any corrosion yet.

FLEMING: I am too.

BURNS: It stays pretty dry in there, so that is probably what limits corrosion.

FRANKLIN: From looking at your data, I concluded that you are really using the Otto-York pad as a mist eliminator. The pressure drop does not seem to be rising very much, and I assume all the particles are going through into your HEPA filter. Are you really collecting anything on the pad?

BURNS: Absolutely, yes. The unit is a very dark red when pulled out. The ideal situation for us would be to get a more efficient mist eliminator that would allow more loading. We are not loading the prefilter up as much as we would like to, because our HEPA filter is plugging. To even further optimize the system, we would like to find a more efficient mist eliminator to increase HEPA life.

FRANKLIN: Have you measured the amount of particles on the prefilter?

BURNS: Yes, we did weights before and after. The most we have seen is about three pounds.

DYMENT: I am a little puzzled as to why you decided to use a mist eliminator as a dry filter. Would it not have preformed better as a mist eliminator by using it earlier in the system, before you had heated the solution?

BURNS: We have a mist eliminator earlier in the system. We have a mist eliminator already in the process line.

DYMENT: Is it perhaps not a very good mist eliminator?

BURNS: I would not argue with that.