Filter Autopsy Procedure for Evaluating the Effects of Particle Size Distribution and Media Velocity on Loading Patterns

Steven L. Alderman, Michael S. Parsons, Charles A. Waggoner

Institute for Clean Energy Technology, Mississippi State University

Abstract

The Institute for Clean Energy Technology (ICET) at Mississippi State Univeristy (MSU) has been involved in evaluating the performance of AG-1 HEPA filters for several years. A number of 12”x12”x11.5” filters have been loaded with a variety of aerosol challenges that include potassium chloride (KCl), iron salts, and soot. Filter testing has involved different media velocities and particle size distributions of the aerosol challenge.

A study is being conducted to evaluate loading patterns associated with testing that has been conducted at ICET by methodically disassembling loaded filters. This paper presents the current methodology that is being followed in the autopsying of individual filters and also presents preliminary data from the evaluation of five filters.

The initial portion of the paper focuses on the autopsy of an AG-1 filter loaded with KCl aerosol from 1” to 6” dp at the rated flow. Aerosol challenge particle size distribution had a count median diameter 180 nm and geometric standard deviation of 2.1, and a mass mean diameter of 3000 nm (without cyclone in place).

Data presented for the initial discussion in the paper is then compared to data obtained from autopsying four additional filters from the same manufacturer that have been loaded at 5 fpm and 7.5 fpm media velocity. Two filters were loaded at these media velocities with an equivalent particle size distribution (mass median diameter of 1000 nm) of KCl while two were loaded with a signficantly larger mass median diameter (3000 nm).

Procedure for Filter Autopsy

The filter chosen for documenting the autopsy procedure was an AG-1 12”x12”x11.5” filter loaded from 1” w.c. to 6” w.c. with potassium chloride. The loading procedure for the filter was performed over the course of 3 days in 2003 (September 17-19). Loading was accomplished by aerosolizing KCl in the ICET large particle generator and injecting into the ICET HEPA test stand operating at 250 cfm (5 fpm media velocity). The KCl aerosol was passed through a cyclone with a 3 µm cut-point before entering the test stand. This produced a particle size distribution with count median diameter of 180 nm, a geometric standard deviation of 2.1, and mass meidan diameter of 1000 nm. The filter was housed in a Flanders housing specifically manufactured to hold 12”x12”x11.5” filters and adapted to the ICET HEPA test stand. The test stand is made of 6” diameter electropolished stainless steel tubing. Figure 1 illustrates the ICET HEPA stand test stand.

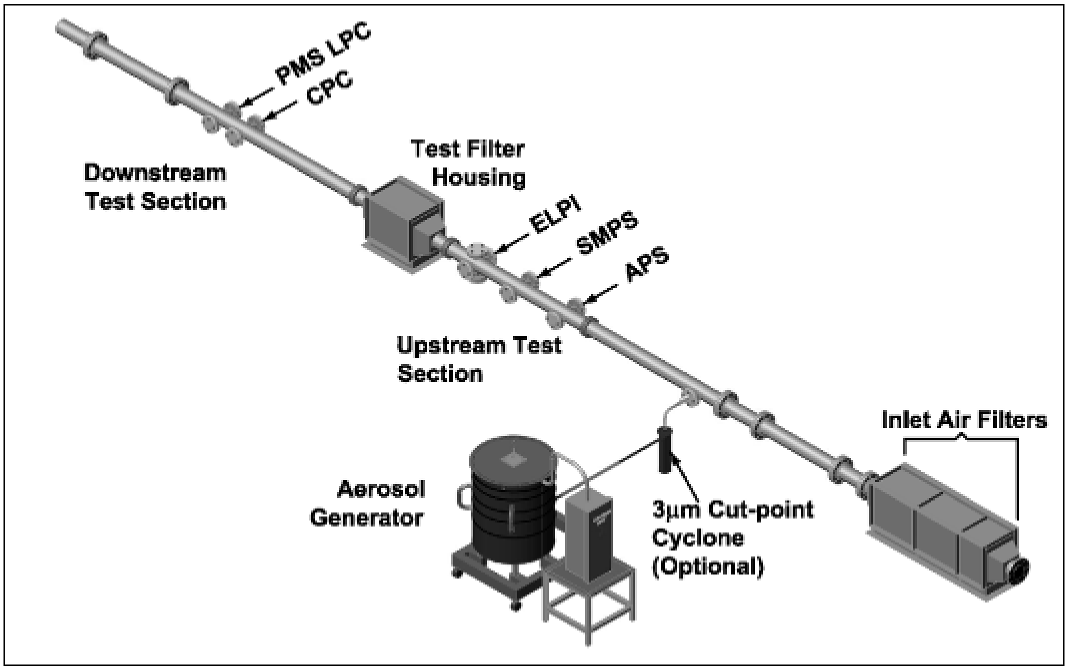

Figure 1. ICET HEPA test stand, high-output aerosol generator, and aerosol instrumentation sampling locations.

Before the autopsy procedure was performed, each filter was dried for 4 hours in an oven at 250^{0}F in order to ensure the particulate matter in the filter was dry and that the measured mass of particulate matter on the filter would be the same as the loaded mass recorded in 2003. The mass of particulate matter was determined to be 434 g in 2003. The mass of the dry filter recorded in 2003 was used in conjunction with the post-drying mass of the loaded filter to verify that significant material had been lost from the filter prior to initiating the autopsy. The pre-autopsy mass of KCl in the loaded filter was determined to be 431 g. These results show the the filter had lost only 3 g since its original loading in 2003.

The filter chosen for this portion of the autopsy study was manufactured with a total of 39 separators and 40 pleats. An exploded diagram representing the construction of the filter is given in Figure 2. As will be illustrated in the discussion of dissasembly of the filter, it will be necessary to remove the the two outer most separators and pleats as they are glued to the sides of the filter housing. Therefore they will not be utilized in this study. For the purposes of this study, the filter will be discussed as having 37 separators and 38 pleats (neglecting the outer most pleats and separators).

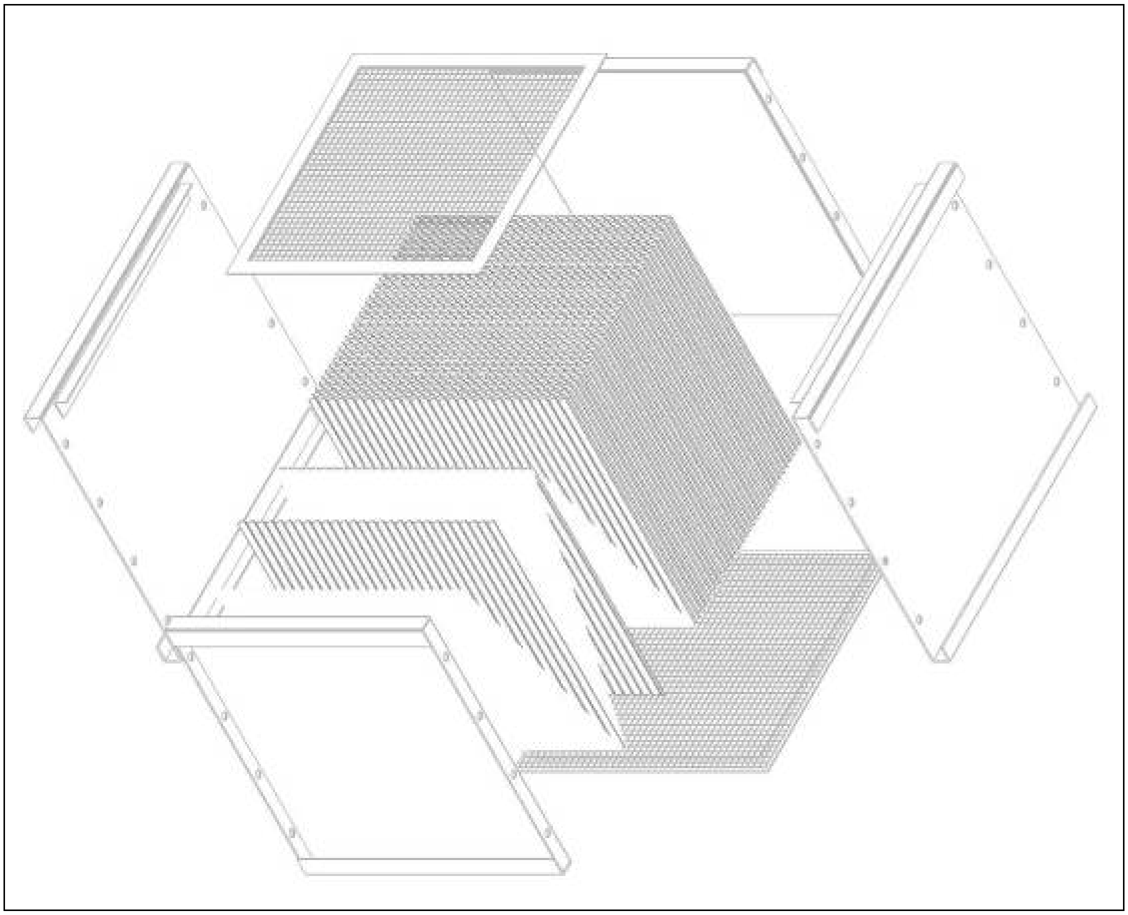

Figure 2. Exploded diagram illustrating filter construction.

The filter pleats chosen for dissecting into 25 sections (5x5 grid pattern) were on either side of separators 3 (left edge), 11 (left center), 19 (center), 27 (right center), and 35 (right edge). These separators and associated pleats were chosen so as to yield mass loading data representative of the total area of filter media. Figure 3 illustrates the location of each separator and pleat in the filter.

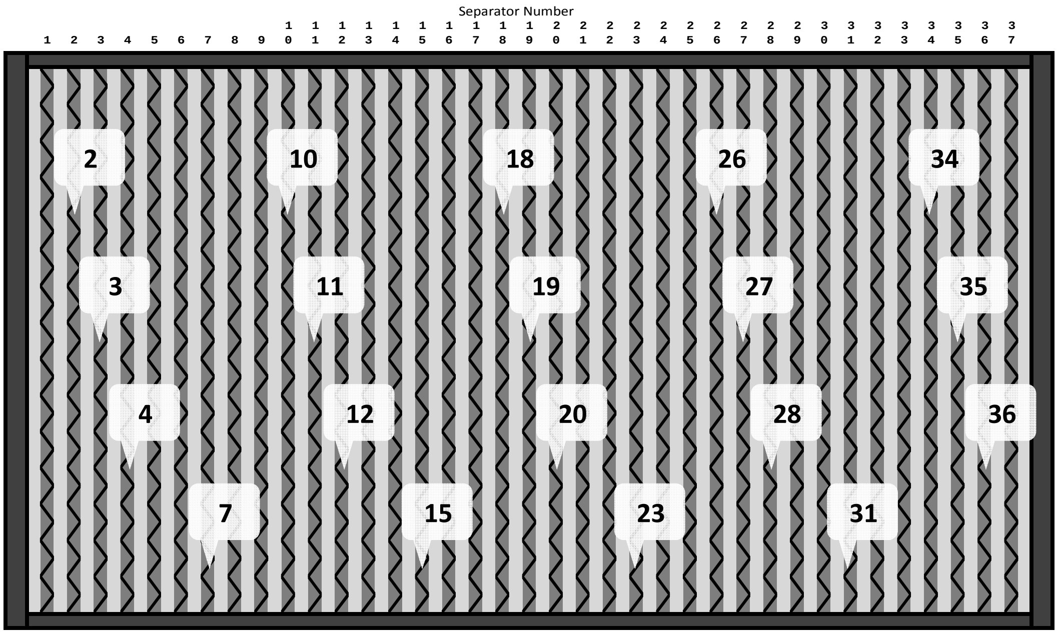

Figure 3. Illustrated view of front of filter with separators numbered from left to right.

The filter pleats chosen for dissecting into 3” strips were those on either side of separators 2, 4, 10, 12, 18, 20, 26, 28, 34, and 36; separators 2 and 4 on either side of separator 3, etc. The pleats chosen for dissecting into 8cm x 8cm squares were those on either side of separators 7, 15, 23, and 31. After removal of the housing, the filter pack was placed on its right side and separators 3, 7, 11, 15, 19, 23, 27, 31, and 35 were marked by placing non-sticking marking flags approximately 1/16” between pleat and separator. This provided a mechanism for keeping the separators/pleats marked while the autopsy was being performed.

The following steps were performed during the autopsy of the filter:

<u>Step 1 – Drying procedure for filter</u>

As stated earlier, before the autopsy procedure was performed, the filter was dried for 4 hours in an oven at 250^0F in order to ensure the particulate matter in the filter was dry and that the measured mass of particulate matter on the filter would be the same as the loaded mass recorded in 2003. The filter was allowed to cool in the oven, a process that required approximately 30 minutes. The filter was weighed as soon it reached ambient temperture.

<u>Step 2 – Determination of mass loading on the filter</u>

After drying and cooling, the mass of particulate matter on the filter was determined to be 431 g. The mass loading on the filter as determined in 2003 was 434 g, showing only a 3 g (0.7%) variance in the masses.

Step 3 – Removal of the gasket

The next step in the autopsy procedure was removal of the gasket on the front of the filter. This was accomplished by gently peeling the gasket away with a metal scraper. Special care was exercised to capture all KCl that may become dislodged from the protective screen during this process. Figure 4A depicts the removal of the gasket and 4B shows the filter with gasket removed.

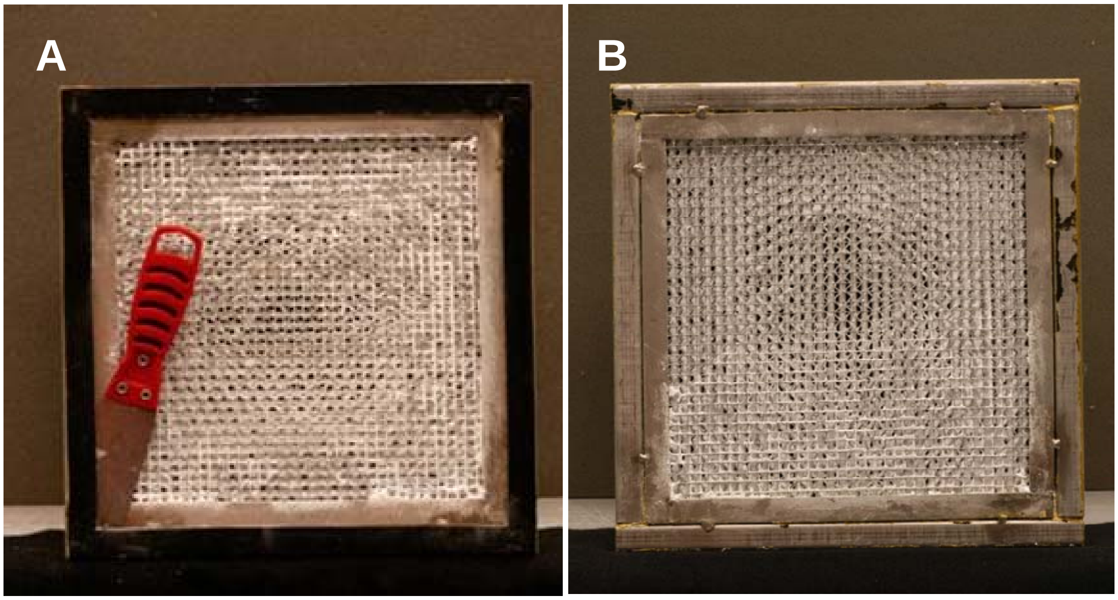

Figure 4. A: Gasket removal. B: Filter after gasket is removed.

Step 4 – Removal of material from the front screen of filter

Once the gasket was removed, the KCl particulate matter caught by the front screen was carefully removed by brushing onto a sheet of aluminum foil. The KCl removed was weighed and mass of KCl on the screen was determined to be 3.3152 g. Following removal of the front screen (see Step 5), the front screen was weighed, washed, dried and reweighed. It was determined that an additional 0.17 g of KCl was washed from the screen. The total mass of particulate matter on the screen was thus determined to be 3.4852 g.

Step 5 – Removal of the screens (front and rear)

After removal of particulate matter from the screen, the front and rear screens of the filter were removed. This was accomplished by utilizing a small grinder with a cut-off wheel to cut the 8 spot welds holding each screen in place. (See Figure 5.) A large piece of paper was placed over the screen prior to grinding away welds attaching the screen to the filter housing so as to cover the filter pack and prevent contamination of the filter pack with metal filings from the grinding process. The rear screen was removed first by placing the filter face down on a sheet of aluminum foil. This provided a mechanism to collect any particulate matter dislodge from the face of the filter due to removing the rear screen. The particulate was saved and added to the particulate matter removed from the leading edge of the pleats in Step 6. Once the rear screen was removed, the filter was inverted and the front screen removed.

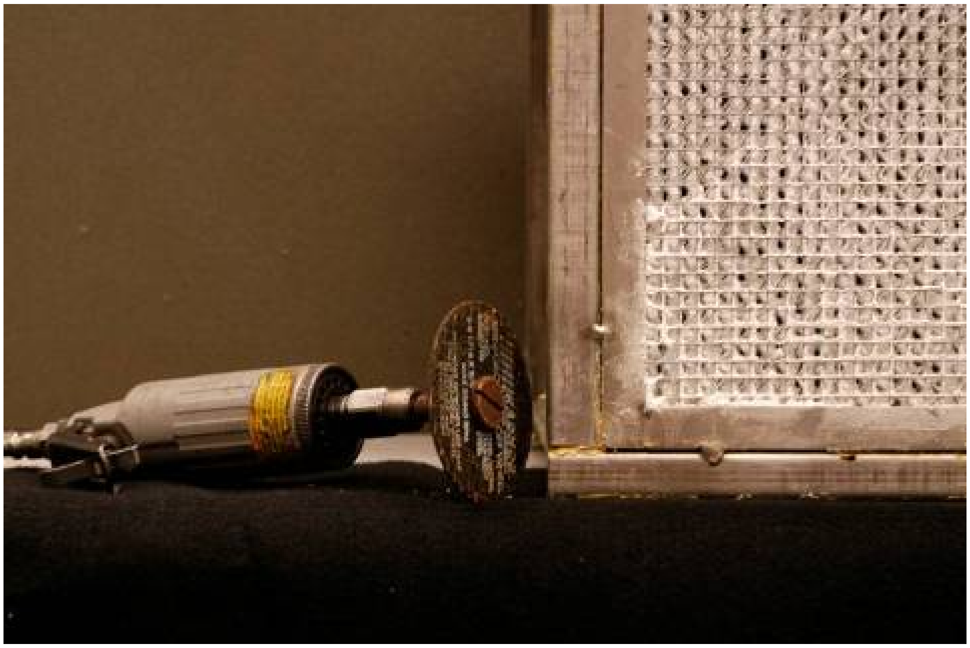

Figure 5. Removal of screens.

Step 6 – Removal of material from front pleats

Following removal of the screens, the particulate matter caked (see Figure 7A) onto the leading edge of the pleats was gently removed by brushing onto a sheet of aluminum foil and weighed. The mass of particulate removed from the leading edge of the pleats was determined to be 59.4671 g. The total mass of particulate on the filter but not down in the filtering media was thus determined to be 62.9523 g. Subtracting from the total mass of particulate on the filter, we determined the mass of particulate down in the filtering media to be 368.0477 g. Figure 7B depicts the filter after removal of particulate from the leading edge of the pleats.

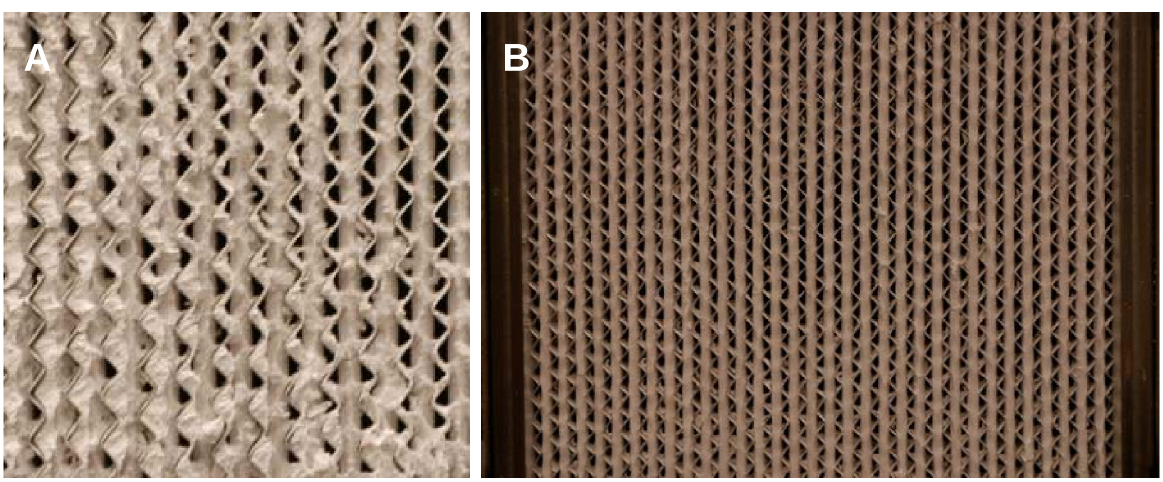

Figure 7. A: Particulate matter caked onto leading edge of pleats. B: Face of filter after removal of particulate matter from leading edge of pleats.

Step 7 – Removal of sides of housing

Once the above procedures were completed, the metal housing was removed. The bolts holding the metal frame of the filter together were removed. The left and right sides were pried off using a screw driver and the first pleat and separator glued to these sides was cut away and discarded as discussed earlier. Figure 8A depicts removal of the left and ride sides of the housing. The top and bottom of the filter is glued to the top and bottom of the pleats and separators requiring that these be removed by cutting off with a band saw. This procedure is illustrated in Figure 8B and C. The remaining filter pack to be utilized in this remainder of the autopsy is depicted in Figure 8D.

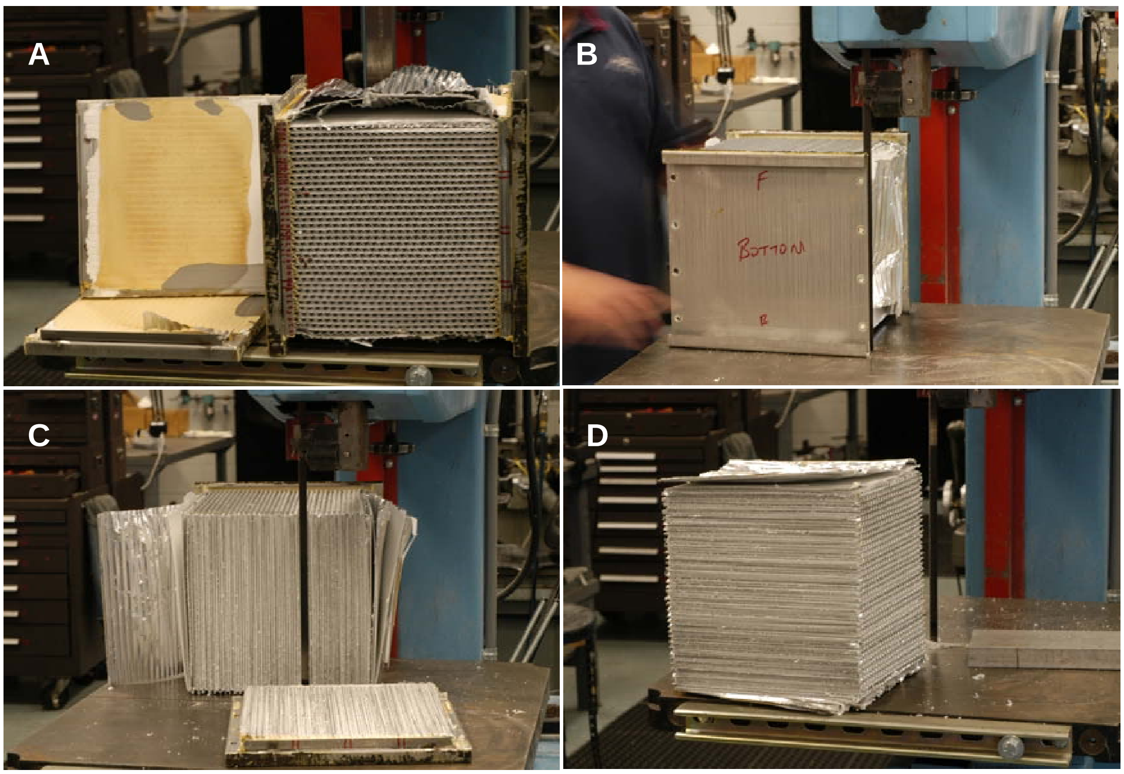

Figure 8. A: Removal of sides of housing. B: Cutting away bottom of housing. C: Filter after bottom of housing is removed. D. Filter pack after housing is removed.

The process of removing the filter from the housing involves processes capable of dislodging significant amounts of KCl from individual sheets of media. Care was exercised to minimize the effects of the removal process and observations of loose KCl within the filter pack as individual were removed indicated that little damage was done during the removal processes.

Step 8 – Dissecting selected pleats into a 25 sections

Pleats surrounding five separators (numbers 7, 11, 19, 27, and 35) were removed for dissecting. Figure 9 provides a pictoral description of the dissection grid pattern for the two sheets surrounding each separator. Each dissected section was approximately 1” x 1” in size.

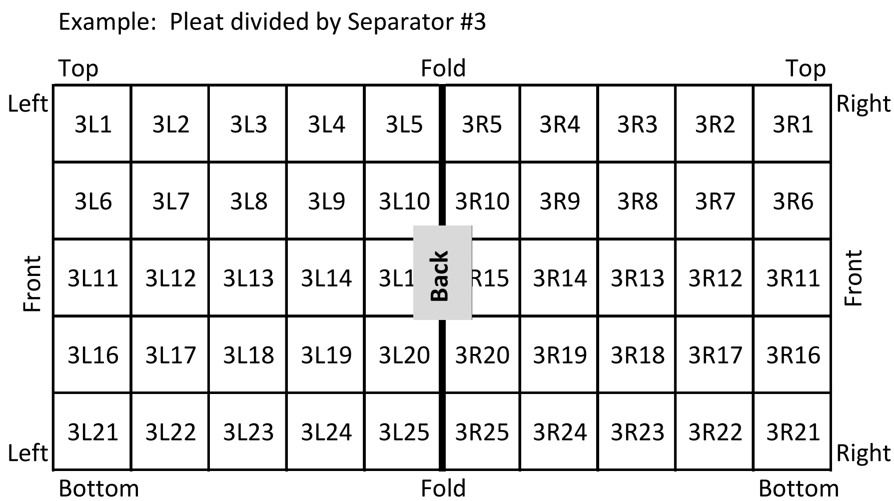

Figure 9. Numbering system for 5x5 grid sections.

Prior to cutting into sections following the 5x5 grid pattern, the left and right edges of each sheet surrounding the separator were trimmed by removing approximately 1/8" of media. This was performed to ensure that contamination from the disassembly process would not affect the results. Trimming the top and bottom of each sheet was not necessary as these edges were not included in the sections cut. Sections L1, L6, L11, L16, L19, L5, L10, L15, L20 and L25 were cut from the trimmed edges inward. The same cutting methodology was employed on the right sheet of the pleat. The remaining sections from both left and right sheets of the pleat were cut using the metal scraper as a guide.

The sectioning process of each sheet began by placing the sheet loaded side up on 20" x 24" sheet of plate glass. Care was taken in the process to excise each 1" x 1" coupon of media. A 1.25" metal scraper was utilized as a cutting guide and cutting was done using a utility knife. All horizontal cuts were made along the midline of a particulate matter 'valley' to, as much as possible, ensure that the section was representative and comparable to other sections cut from the same pleat or other pleats. This procedure is illustrated in Figure 10A. Figure 10B depicts a 'valley' on the surface of the media produced by the separator.

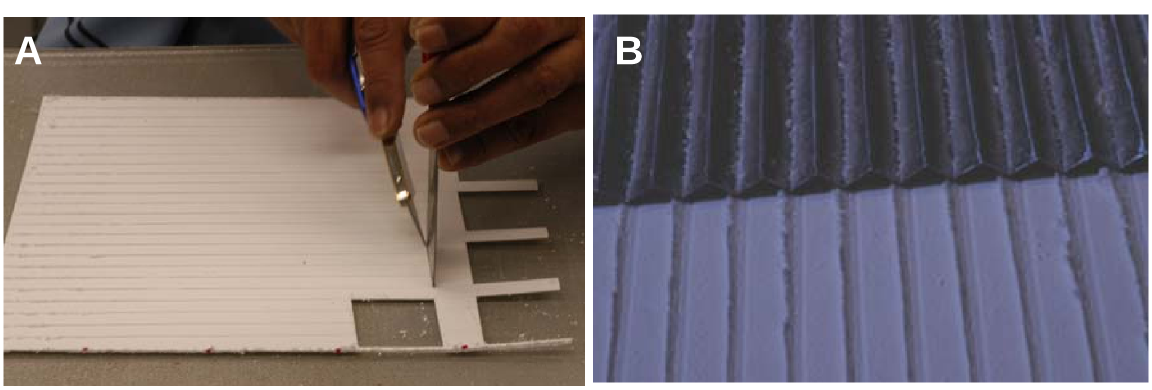

Figure 10. A: Procedure for cutting out 5x5 grid sections. B: Illustration of a "valley" along which horizontal cuts were made.

Each coupon was weighed, washed, dried, and reweighed. A variety of methods were evaluated for removing KCl from the execised coupons of media. The simplest and most repeatable technique evaluated employed washing for approximately 30 seconds under a flowing tap followed by sonicating for approximately 10 seconds. The coupons were then dried for 2 hours at 250^{0}F. This process is illustrated in Figure 11A-D.

Figure 11. A: Weighing 5x5 grid sections. B: Washing 5x5 grid sections under flowing tap. C: Sonicating 5x5 grid sections. D: Drying 5x5 grid sections.

The size (area in cm^2) of each section was calculated by dividing the mass of each section after washing/drying by the average density calculated in Step 10. The mass loading (mg/cm^2) onto each section was calculated by dividing the mass lost by each section by the calculated area of each section.

<u>Step 9 – Dissecting pleats into large coupons</u>

Additional mass loading data were collected by sectioning the pleats on either side of the separator chosen for the 25 sections (Step 8) into 3 strips (top, middle, and bottom). For example, the first pleat chosen for cutting into small sections in a 5x5 grid pattern in Step 8 surrounded separator #3. The pleats surrounding separators #2 and #4 were sectioned into 3 large horizontal strips (approximately 3" wide,) as shown in Figure 12. As in Step 8, each horizontal cut was made along the midline of a 'valley'. Each strip was weighed, washed, dried and reweighed utilizing the same procedures in Step 8. The size (area in cm^2) of each section was calculated by dividing the mass of each section after washing/drying by the average density calculated in Step 10. The mass loading (mg/cm^2) onto each section was calculated by dividing the mass lost by each section by the calculated area of each section.

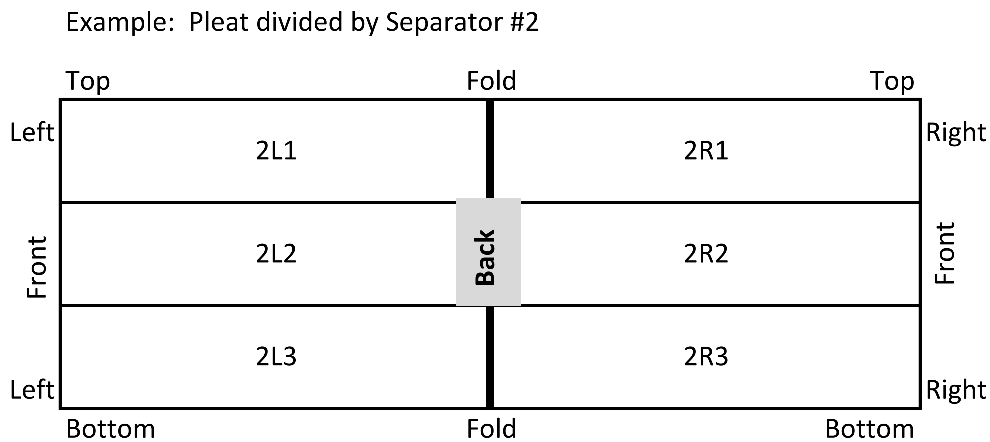

Figure 12. Numbering system and cutting pattern for large sections.

Step 10 – Dissecting 4 pleats into 12 8cm x 8cm squares (3 each) to be used in determing the density (g/cm^2) of the filter media.

The final step involved dissecting 4 pleats into 12 (3 each) 8cm x 8cm squares to be used in determing the density (g/cm^2) of the filter media. The pleats chosen for dissecting into 8cm x 8cm squares were those surrounding separators 7, 15, 23, and 31. These squares were cut utilizing an 8cm x 8cm template made of 1/8" stainless steel. The 12 8cm x 8cm squares were cut from random locations on the pleats. The 8cm x 8cm sections were washed, dried, and weighed in the same manner described in Step 8. The density of each section was calculated by the dividing the mass of the section by the area (64 cm^2). The densities of these 12 sections were averaged to yield an average density for the filter media. This average density was used to calculate the mass of particulate matter (mg/cm^2) loaded onto each section dissected in Steps 8 and 9.

Results

The mass loading data for the small (1" x 1") coupons are provided in Tables 1 -5 and depicted graphically in Figure 14. These results show an increased mass loading of the sheet of filter media closer to the center of the filter. It is important to remind the reader that the pleat description used this paper is composed of media surrounding a separator that protrudes from the filter pack toward the upstream side of the filter. This is in contrast to describing a pleat in which the two sheets cover the upstream end of a separator. The consistent pattern of media on the mid-line side of a separator having a larger loading is consistent with observations of build-up on the protective wire screen. Figure 13 provides a close-up view of KCl captured on the wire screen. This pattern appears indicative of an angular component to the air flow and is radially symmetrical around the center of the filter face. It is also significant to note that maximum loading rate is observed to occur on the mid-line pleat.

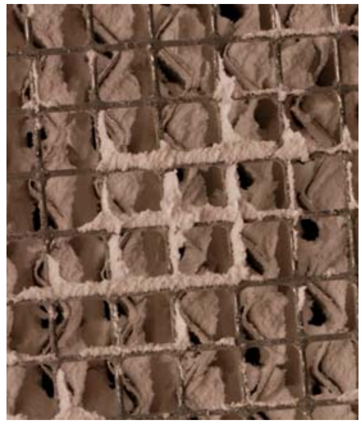

Figure 13. Close-up view of KCl captured on protective wire screen.

The other consistent trend observed in these data is the greater loading rate toward the back (downstream) portion of the media sheets surrounding the separator. This trend is seen in all of the sheets that were sampled with the greatest effect in the center of the filter.

The mass loading data for large coupons (3”x 11”) are shown in Tables 6 – 10 and depicted graphically in Figure 15. These results indicate the same trend observed above. For the center pleats (separators #18 and 20) the mass loading was essentially the same on the left and right sides of the pleat.

An unexpected pattern of loading is observed in the data of Tables 6 – 10. The particle size distributions and volumetric flow rates within the test stand should not cause significant stratification of mass vertically within the air flow. However, the trend demonstrated from data surrounding the midline pleat of the filter shows a distinct difference in mass loading from the top to the bottom of the pleat. This pattern is seen on all four sheets sampled from the pleats on either side of the midline pleat of the filter (pleats surrounding separators 18 and 20). Additionally, this trend is also observed for media sheets surrounding the surface of separators toward the midline of the filter. Media sheets on the side of separators away from the midline did not demonstrate this top to bottom differential mass loading rate.

The data collected for determination of the filter media density are given in Table 11. The density of each section was calculated by dividing the mass in mg by the area in cm^2. These 12 densities were average to yield an average density of 9.41 mg/cm^2 for the filter media.

Table 1: Mass loading on pleat (left and right sheets) surrounding separator #3.

Separator #3 (Extreme Left)

5.71	4.90	4.65	4.94	6.37	13.06	8.14	7.09	6.94	8.74
5.43	4.41	4.33	4.59	6.24	10.81	7.60	6.36	6.19	7.82
5.33	4.59	4.57	4.55	6.36	8.33	7.47	6.24	5.91	8.22
5.35	4.51	4.60	4.70	6.70	8.45	7.73	6.47	6.18	7.54
5.77	4.95	4.86	5.13	6.88	9.34	8.11	6.80	6.52	7.09

Mass loading across media in mg/cm^2

Table 2: Mass loading on pleat (left and right sheets) surrounding separator #11.

Separator #11 (Middle Left)

6.28	5.30	5.13	5.32	6.66	10.50	7.29	6.52	6.85	8.35
6.07	5.43	5.51	5.82	7.06	12.94	8.27	7.39	7.95	9.33
6.62	5.67	5.58	6.08	8.34	14.54	8.92	7.85	7.63	7.69
6.70	5.80	5.85	6.73	8.75	12.83	8.26	7.79	7.44	12.60
6.89	5.46	5.45	6.11	8.24	11.59	8.67	7.91	7.65	12.01

Mass loading across media in mg/cm^2

Table 3: Mass loading on pleat (left and right sheets) surrounding separator #19.

Separator #19 (Center)

7.88	6.21	6.15	6.57	8.29	8.19	6.67	6.33	6.68	9.46
7.42	7.14	7.37	8.11	11.59	10.22	8.45	7.50	7.23	7.71
6.14	7.72	8.72	9.98	15.05	14.54	10.32	9.00	8.36	6.54
7.75	8.02	8.36	10.91	22.25	21.92	12.29	9.53	9.40	7.92
10.21	6.80	7.12	7.92	21.96	24.11	13.80	8.94	8.61	13.14

Mass loading across media in mg/cm^2

Table 4: Mass loading on pleat (left and right sheets) surrounding separator #27.

Separator #27 (Middle Right

9.67	6.53	6.64	7.32	9.93	8.66	5.71	5.21	5.28	6.17
8.63	7.41	7.80	9.35	13.18	7.16	5.75	5.24	5.08	6.32
8.73	7.92	8.54	9.68	14.40	8.82	6.26	5.65	5.82	6.75
10.81	7.79	8.16	9.03	16.24	8.73	6.14	5.86	5.88	7.15
13.38	7.75	8.21	9.00	13.44	9.66	6.30	5.77	5.79	8.29

Mass loading across media in mg/cm^2

Table 5: Mass loading on pleat (left and right sheets) surrounding separator #35.

Separator #35 (Extreme Righ

7.96	6.44	6.66	7.30	10.09	7.35	5.43	4.90	5.19	5.91
8.67	7.14	7.19	7.81	10.22	5.93	4.59	4.31	4.52	5.58
8.79	6.77	6.80	7.64	9.33	6.53	5.06	4.76	4.89	6.15
8.09	6.63	6.89	7.75	9.70	6.45	5.37	5.01	5.72	6.02
7.37	6.50	7.12	7.90	10.18	6.02	5.26	5.03	5.12	5.96

Mass loading across media in mg/cm^2

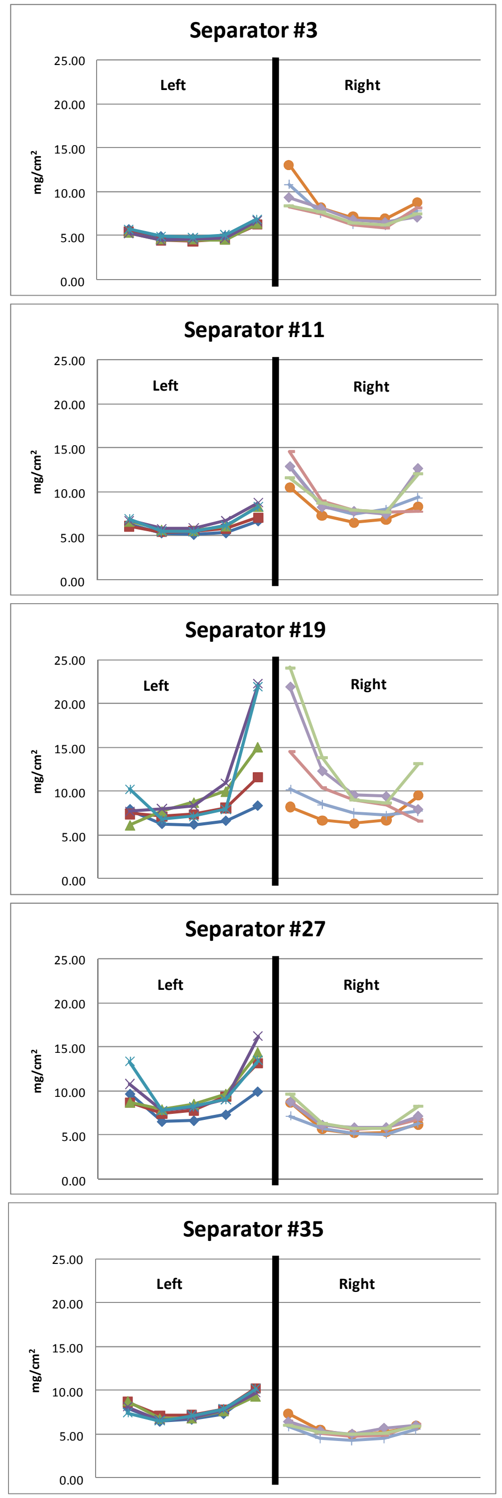

Figure 14: Mass loading curves for pleats surrounding separators 3, 11, 19, 27, and 35 (left and right sheets).

Table 6. Mass loading results (mg/cm^2) on pleats surrounding separators 2 and 4.

[redacted]

Table 7. Mass loading results (mg/cm^2) on pleats surrounding separators 10 and 12.

	Left 10	Right 10	
L1	5.65	8.31	R1
L2	6.10	9.63	R2
L3	5.67	9.75	R3
	Left 12	Right 12	
L1	6.39	8.66	R1
L2	7.45	10.10	R2
L3	7.59	10.81	R3

Table 8. Mass loading results (mg/cm^2) on pleats surrounding separators 18 and 20.

	Left 18	Right 18	
L1	7.10	8.06	R1
L2	9.12	10.33	R2
L3	8.66	11.29	R3
	Left 20	Right 20	
L1	8.00	7.92	R1
L2	10.38	9.57	R2
L3	10.88	10.84	R3

Table 9. Mass loading results (mg/cm^2) on pleats surrounding separators 26 and 28.

	Left 26	Right 26	
L1	8.06	6.65	R1
L2	8.93	7.07	R2
L3	10.09	7.24	R3
	Left 28	Right 28	
L1	8.34	6.67	R1
L2	9.50	6.68	R2
L3	9.56	6.97	R3

Table 10. Mass loading results (mg/cm^2) on pleats surrounding separators 34 and 36.

	Left 34	Right 34	
L1	7.32	5.69	R1
L2	8.49	5.15	R2
L3	7.73	5.82	R3
	Left 36	Right 36	
L1	9.20	4.46	R1
L2	9.55	4.45	R2
L3	9.09	5.89	R3

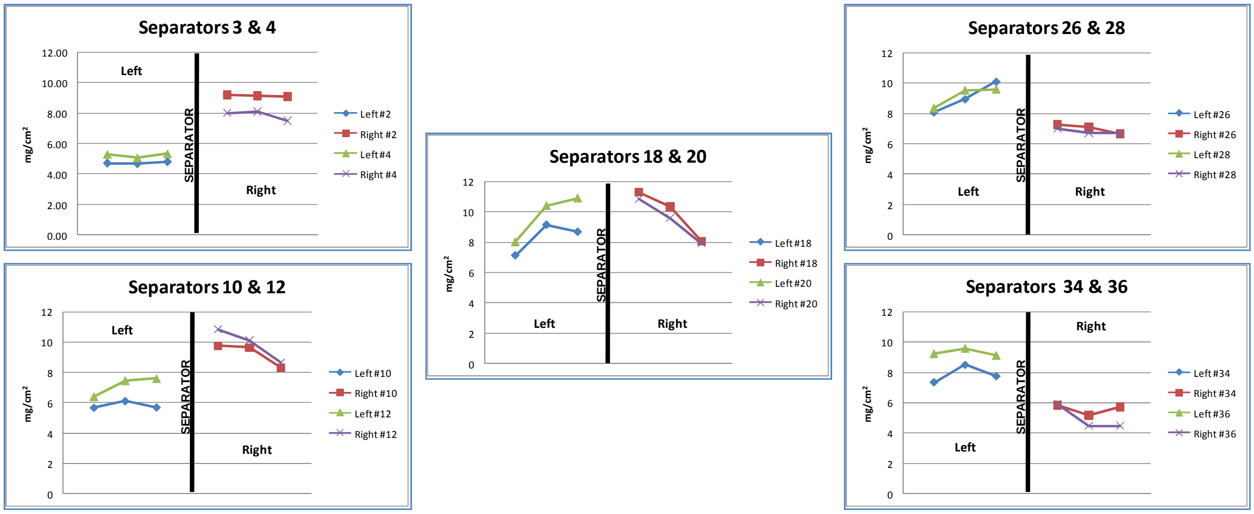

Figure 15. Mass loading curves for pleat pairs 2-4, 10-12, 19-20, 26-28, and 34-36.

Table 11. Results of determination of density of filter media.

Section Size: 8 cm x 8 cm = 64 cm^2

Separator No.	Section No.	Post-wash Mass (mg)	Density (mg/cm^2)
7	1	611.3	9.55
7	2	610.4	9.54
7	3	606.0	9.47
15	1	599.7	9.37
15	2	602.6	9.42
15	3	595.0	9.30
23	1	605.6	9.46
23	2	598.4	9.35
23	3	611.4	9.55
31	1	595.4	9.30
31	2	601.5	9.40
31	3	587.7	9.18
		Average	9.41

Media Velocity and Particle Size Distribution Effects

This portion of the study involved autopsying four filters from the same manufacturer as the filter discussed above. Two filters were loaded at each media velocity, either 5 fpm or 7.5 fpm. The filters at each media velocity were loaded under different challenge conditions, KCl aerosols with either a 1000 nm or 3000 nm mass median diameter.

The autopsy of this set of four filters followed the general procedure outlined above above and involved a different grid pattern for the pleats selected for sampling. Pleats 5, 15, 22, and 29 were selected for sampling and Figure 16 illustrates the grid pattern. The following labeling system acronyms designate the area of the pleat from which the section was taken:

- MF – Middle Front
- MB – Middle Back
- TC – Top Center
- MC – Top Center
- BC – Bottom Center

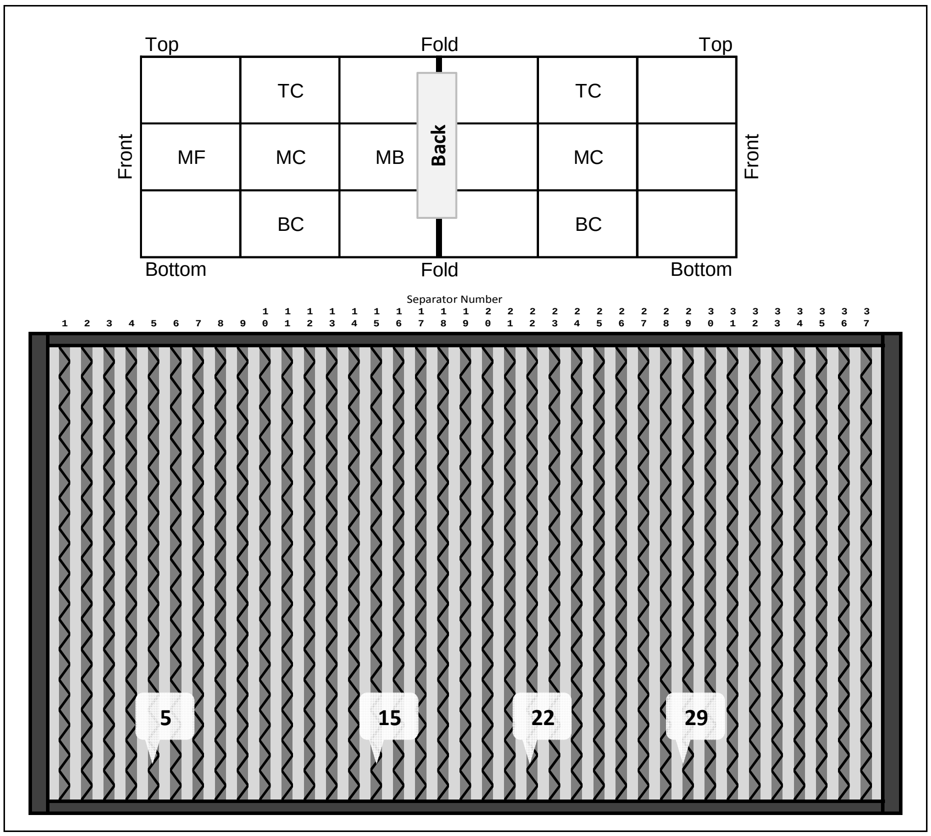

Figure 16. Top: Labeling system of sections. Bottom: Illustration of pleats chosen for study.

The mass loading (mg/cm^2) determined for the sections from the selected pleats from these four filters are given in Tables 12, 13, 14, and 15. These data are depicted graphically in Figures 17, 18, 19, and 20. For pleat #5 and filter #3 (7.5 fpm with no cyclone), no data were obtained for the right pleat side, top center (TC) section nor for the right pleat side, bottom center (BC).

Table 12. Mass loading on the designated sections from pleat 5.

Pleat #5

	Loading (mg/cm^2)			
Section ID	5 fpm No Cy	5 fpm w/ Cy	7.5 fpm No Cy	7.5 fpm w/ Cy
L-MF	9.81	3.60	9.92	2.99
L-MB	7.16	3.21	2.49	2.70
L-TC	8.22	3.17	3.99	2.83
L-MC	7.62	3.16	3.36	2.73
L-BC	9.53	3.59	4.69	3.12
R-TC	14.81	4.33		3.80
R-MC	16.15	4.42	12.67	4.12
R-BC	15.30	4.12		3.72

Table 13. Mass loading on the designated sections from pleat 15.

Pleat #15

	Loading (mg/cm^2)			
Section ID	5 fpm No Cy	5 fpm w/ Cy	7.5 fpm No Cy	7.5 fpm w/ Cy
L-MF	13.91	4.22	9.88	3.98
L-MB	16.72	3.92	10.82	3.92
L-TC	14.17	3.88	9.47	3.52
L-MC	14.86	4.10	10.77	3.75
L-BC	7.11	4.15	8.80	3.69
R-TC	15.43	4.19	10.52	3.85
R-MC	17.23	4.64	11.41	4.10
R-BC	14.40	4.33	11.09	4.08

Table 14. Mass loading on the designated sections from pleat 22.

Pleat #22

	Loading (mg/cm^2)			
Section ID	5 fpm No Cy	5 fpm w/ Cy	7.5 fpm No Cy	7.5 fpm w/ Cy
L-MF	14.20	4.48	11.21	3.91
L-MB	12.07	4.84	13.71	4.26
L-TC	11.69	4.25	13.03	3.87
L-MC	12.60	4.48	12.27	4.02
L-BC	11.14	4.29	12.52	3.85
R-TC	14.89	4.03	7.58	3.72
R-MC	16.16	4.22	8.48	3.82
R-BC	15.92	4.07	6.57	3.60

Table 15. Mass loading on the designated sections from pleat 29.

Pleat #29

	Loading (mg/cm^2)			
Section ID	5 fpm No Cy	5 fpm w/ Cy	7.5 fpm No Cy	7.5 fpm w/ Cy
L-MF	18.18	4.82	14.49	4.35
L-MB	20.15	4.65	14.11	4.50
L-TC	15.46	4.49	13.14	3.87
L-MC	16.36	4.81	14.67	4.28
L-BC	16.64	4.39	12.26	3.97
R-TC	8.12	3.56	3.90	3.31
R-MC	9.47	3.56	3.61	3.25
R-BC	8.49	3.73	4.09	3.07

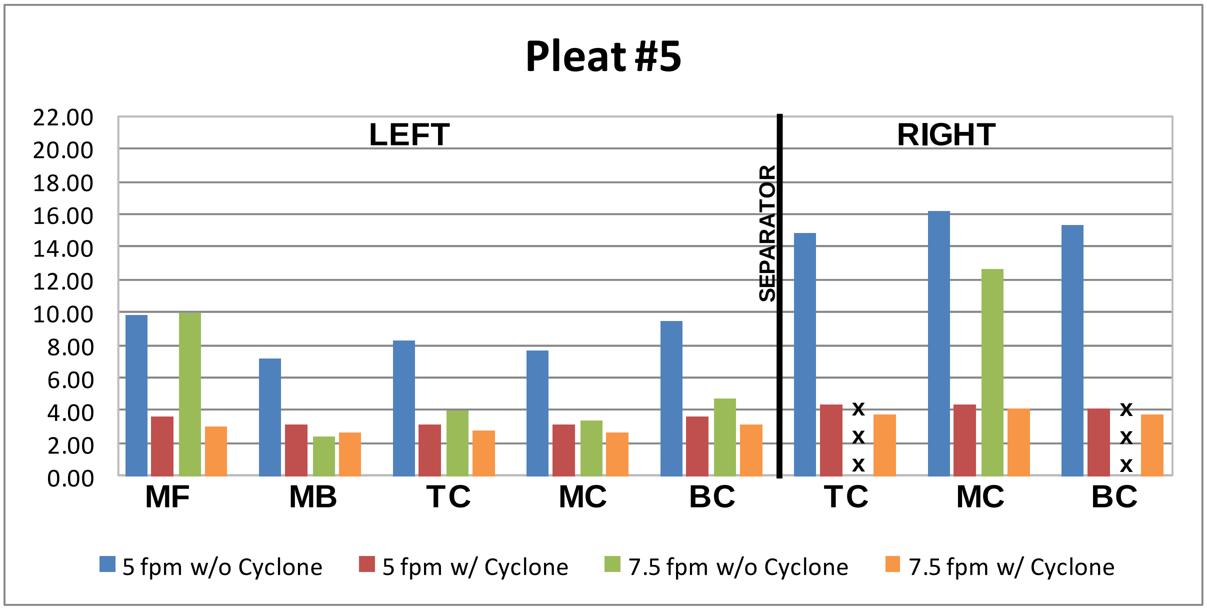

Figure 17. Mass loading on pleat #5 for the four filters autopsied.

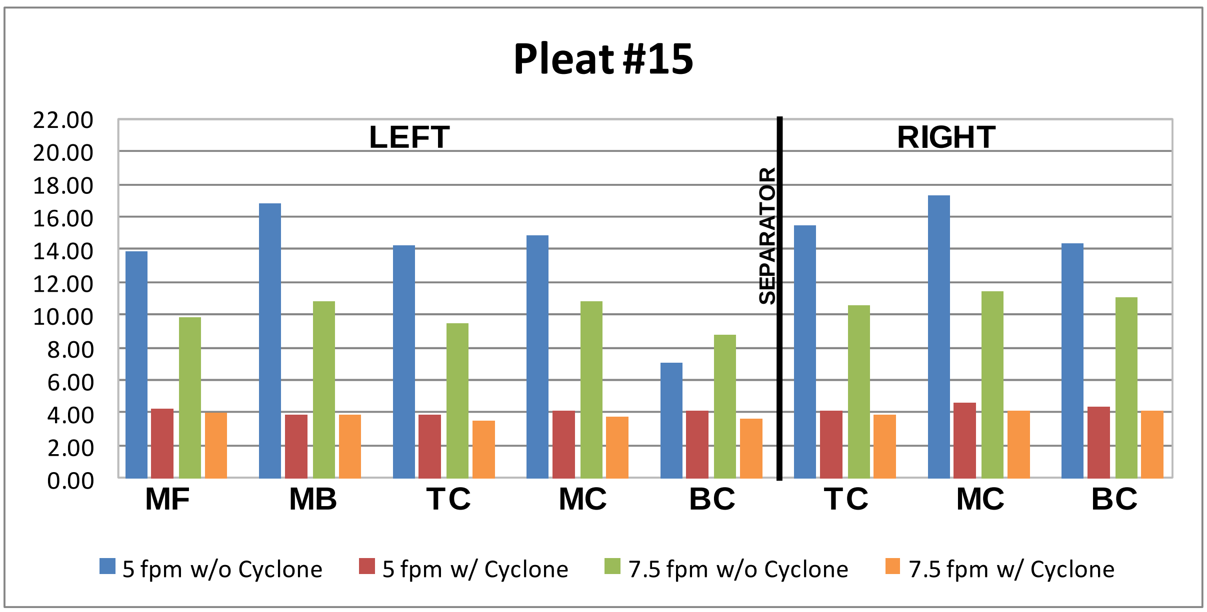

Figure 18. Mass loading on pleat #15 for the four filters autopsied.

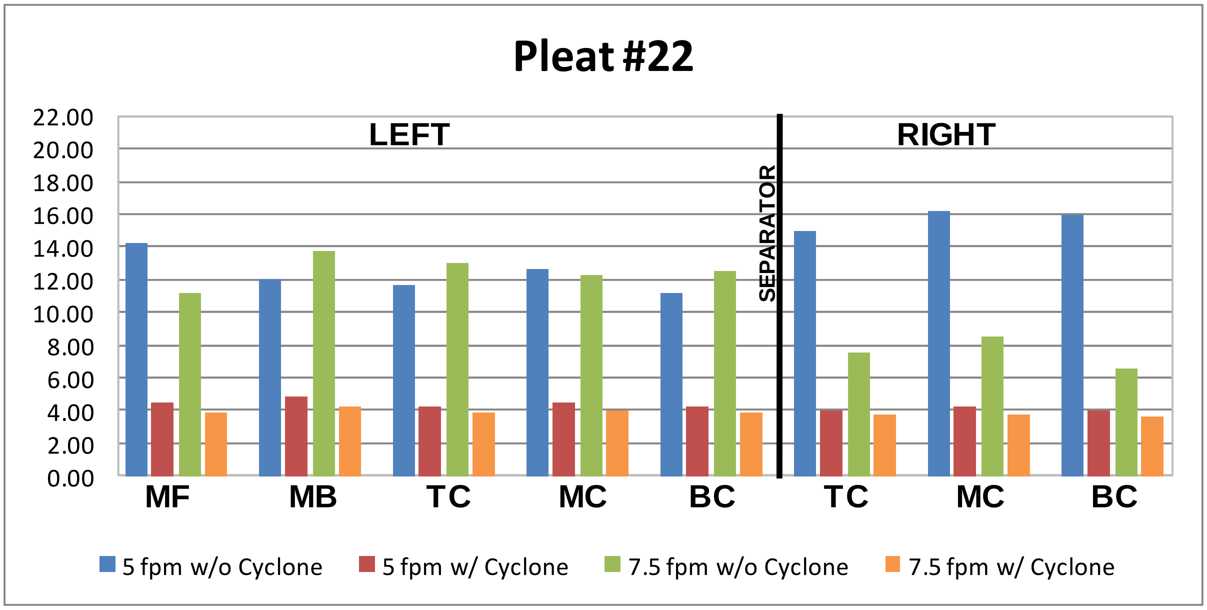

Figure 19. Mass loading on pleat #22 for the four filters autopsied.

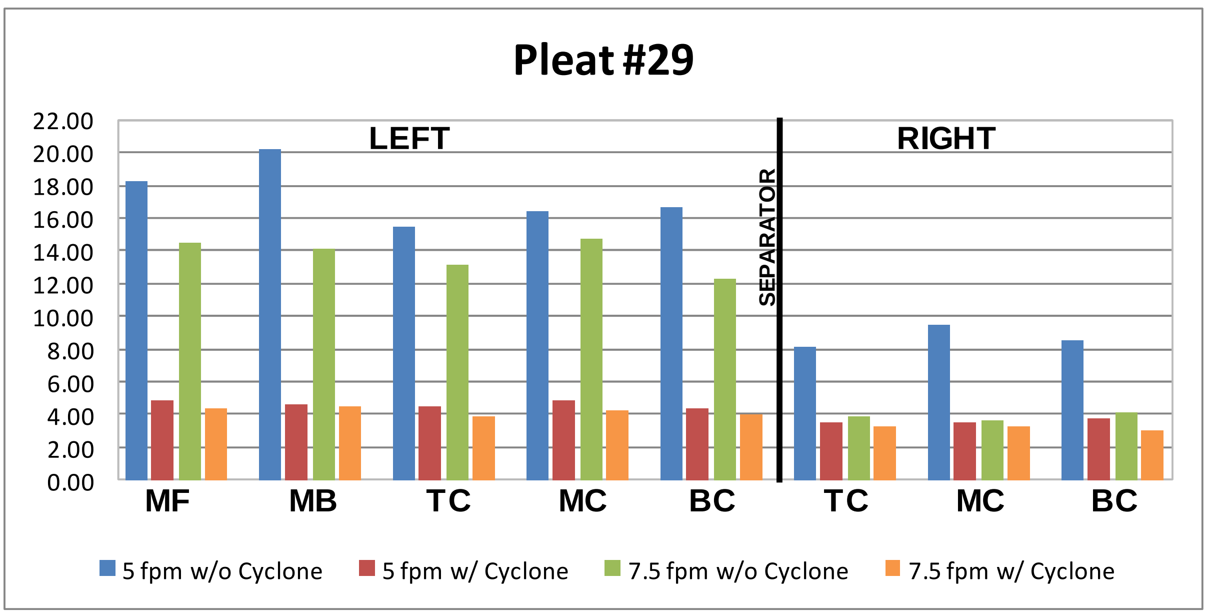

Figure 20. Mass loading on pleat #29 for the four filters autopsied.

The autopsies performed on the four filters of this portion of the study were conducted first and lessons learned incorporated in later efforts. Differences between data collected in the autopsy described previously in this paper and the sampling strategy employed for this set of four filters include the absence of the midline pleat and a random sampling scheme for each sheet of the four pleats removed from each filter pack.

Trends indicating a higher loading rate on the midline side of individual separators identified in the autopsy portion of this paper are also seen clearly in data from pleats 5 and 29 when filters are challenged with the 3000 nm mass median diameter aerosols. Specifically, this trend appears to be independent of media velocity. There does not seem to be an equivalent trend when filters are challenged with smaller aerosol particles (1000 nm mass median diameter challenge). Additionally, the trend is not as obvious for pleats 15 and 22 closer to the midline of the filter. This observation of more uniform loading around the separator near the midline of the filter is also consistent with trends identified in the autopsy section.

In general it is observed that higher media velocities result in lower loading rates virtually regardless of particle size distribution or media velocity. Additionally, elevated media velocities (7.5 fpm) appear to produce relatively equivalent mass loading rates for media on the outside of separators near a housing wall (pleats 5 and 29).

ACKNOWLEDGEMENT

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