Pacific Northwest
NATIONAL LABORATORY

PNNL-25703-2

Interim Status of HEPA Filter 10-Year Lifetime Evaluation

August 2019

HZ Edwards
JM Barnett

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Summary

High-efficiency particulate air (HEPA) filters are widely employed by nuclear facilities to remove radiological particulate matter from their effluent exhaust streams. The purpose of this study is to evaluate the relationships between the 10-year HEPA filter lifespan and its other performance indicators. The 10-year-long endeavor to collect and analyze data regarding the lifetime of HEPA filters at the Pacific Northwest National Laboratory began in 2010. Forty-nine HEPA filters were selected and have been surveyed and analyzed at least annually to verify compliance with permit conditions. The study suggests the frequency of filter replacement should be based on the actual operational requirements, such as fume hood face velocity and/or efficiency test results, instead of on the prescribed filter “age limit” of 10 years from the date of manufacture (e.g., birth date) when operating under dry conditions. Over the past nine years, only four HEPA filters have been replaced for technical issues.

Acronyms and Abbreviations

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
HEPA	high-efficiency particulate air
in. wg	inches water gauge
MDA	minimum detectable activity
PM	preventative maintenance
PNNL	Pacific Northwest National Laboratory
PSF	Physical Science Facility
DP	differential pressure drop

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1.0 Introduction

The Pacific Northwest National Laboratory (PNNL) Effluent Management group performs sampling and monitoring of air emissions from facilities that could potentially emit radiological particles and radioactive gases. These facilities are equipped with nuclear high-efficiency particulate air (HEPA) filters, which are defined by their "… minimum efficiency of 99.97% when tested with an aerosol of essentially monodispersed 0.3-micrometer diameter test aerosol particles" (ASME AG-1). Particles larger or smaller are removed with an even higher efficiency. See Figures 1 and 2 below for an accurate size reference, and representation of HEPA filters' efficiency catching particles. Radioactive gases are not considered because they pass through a HEPA filter.

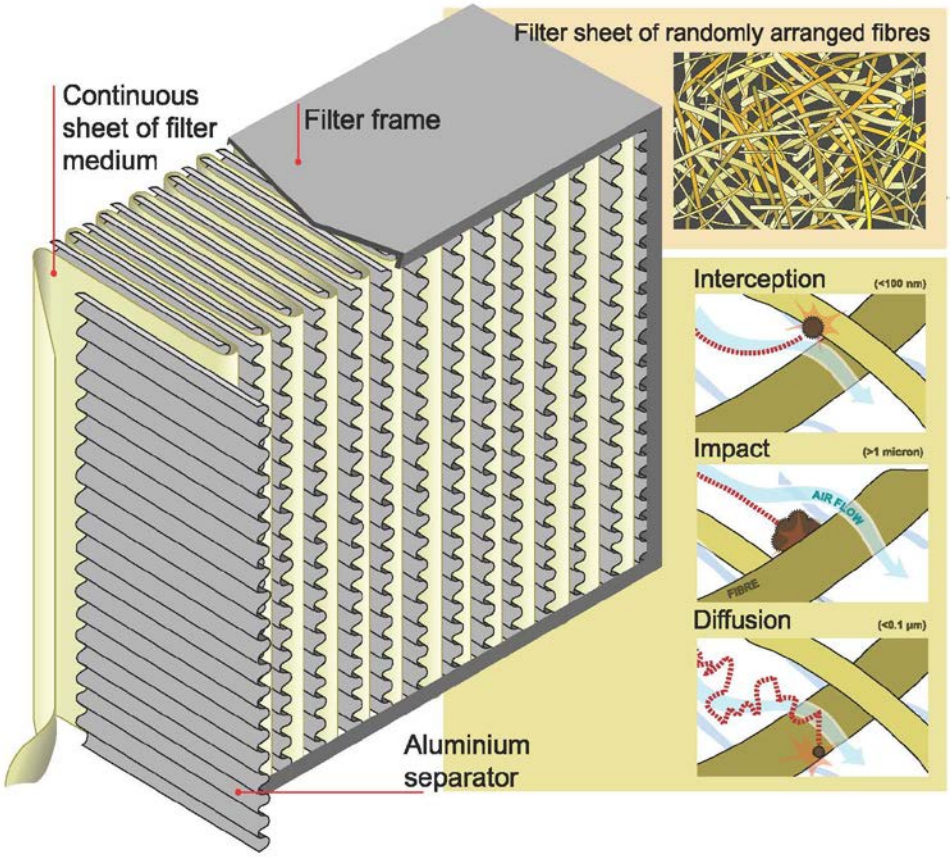

Figure 1. Visual representation of how a HEPA filter is built and catches particulates

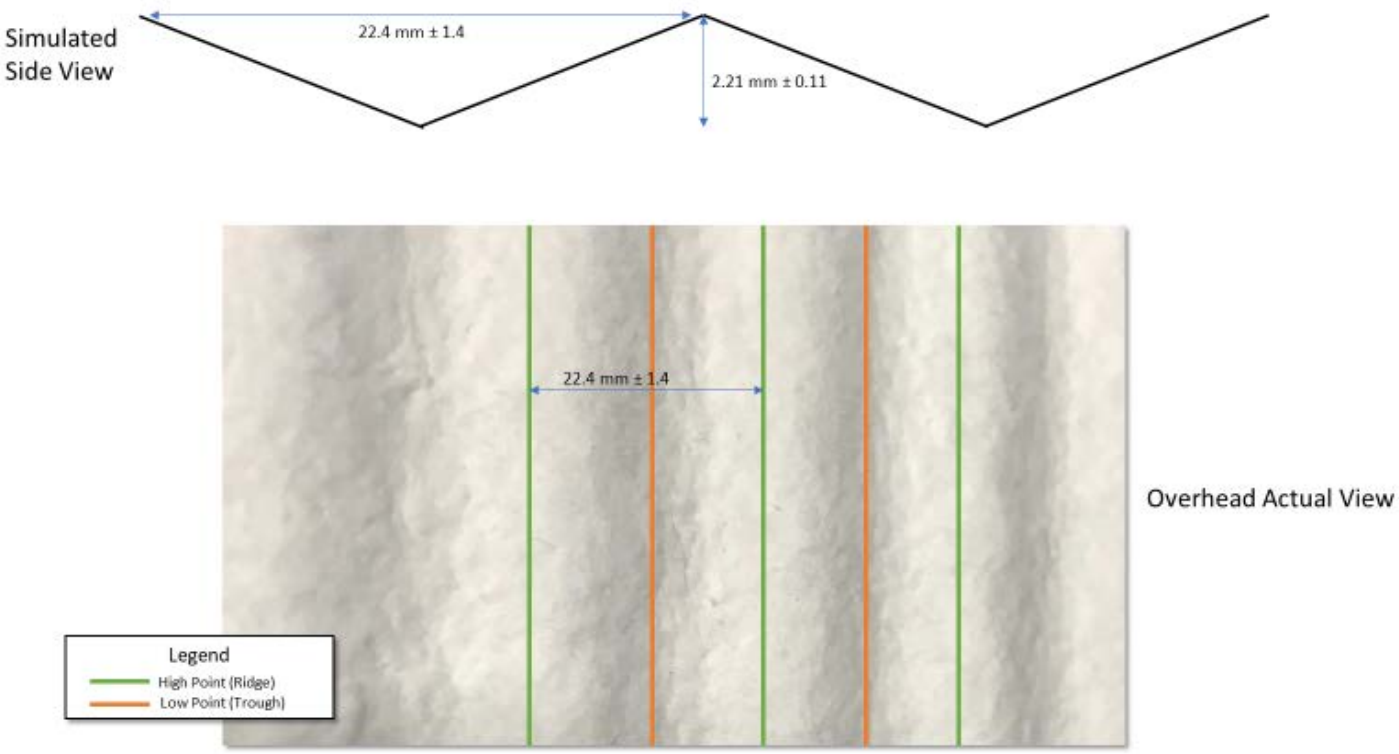

Figure 2. Calculated dimensions of the surface of a HEPA filter with error values. The top figure displays a simulated side view of the filter, showing corrugation. The bottom displays an actual closeup overhead photograph of a HEPA filters' surface.

The U.S. Department of Energy (DOE) uses a conservative interpretation of data to set the age limit of HEPA filters at 10 years (DOE-HDBK-1169-2003). This lifetime was determined by an analysis of multiple HEPA filter research studies. Analysis of data from Robinson et al. (1986) suggests that unfolded media tensile strength fails at 13 years. Folded media are not expected to have the required 2.5-pound/inch tensile strength, even when new, and the tensile strength is reported to be extremely low at 7 years. Therefore, the data displayed failed tensile strength and low burst strengths at an average of 10 years, which the U.S. Environmental Protection Agency (EPA) admits was set conservatively to ensure appropriate tensile strength in the filters because "… extrapolated… data suggests [it] fails at 13 years" (EPA 2009). Figure 3 is a visual representation of failing fibers on folded media. Although filter life was difficult to estimate using the data, based on the relationship between HEPA filter and age, the recommended lifetime was nevertheless set at 10 years under dry conditions (Bergman 1999).

Figure 3. Folded edge of a HEPA filter showing splayed fibers that could possibly decrease efficiency and decrease tensile strength

The 10-year evaluation period from 2010–2020 consists of annual collection of two samples collected during preventative maintenance (PM) for HEPA filters located within the Physical Science Facility (PSF). These PMs are tested for differential pressure drop (DP) and filter efficiency and the fume hood face velocity. These samples are used to determine if the filter has failed and/or needs replacing, depending on if they meet requirements. Radiological dose is measured in mrem/hr and is reported in surveys conducted by PNNL's Radiation Protection Division.

Because HEPA filters are used in nuclear facilities, they are heavily regulated and standardized. The American Society of Mechanical Engineers (ASME) publishes the Code on Nuclear Air and Gas Treatment (ASME AG-1), which provides a robust standard for the performance, design, construction, acceptance, and testing of HEPA filters. Once in use, DOE provides the recommendations and standards for HEPA filters, which are considered "throwaway" and "disposable" (ASME AG-1 p. 391; DOE-HDBK-1169-2003, 3-1). The recommendation for routine HEPA filter replacement is every 10 years. The purpose of this study is to draw a relationship between the HEPA filter lifespan and the following indications of performance.

Criteria to pass inspection are listed in PNNL Technical Position Document TPD-012 (Barnett 2018) and include:

- DP must remain under 4.0 inches water gauge (in. wg)
- Efficiency level must be 99.00% or greater
  - At PNNL, the efficiency standard is 99.95% or greater for the filter lifetime
- Velocity across the inlet face of the fume hood is required to be at least 100 feet/min
- A dose reading that exceeds 20 mrem/hr
- Temperature of environment must not exceed <50° F or >100° F
- Relative humidity must not exceed <10% or >80%, or wetted filter
- Flowrate through HEPA filter exceeds the rated flow of the filter
- Factory recall
- Other special conditions as provided by operating conditions or permit requirements (e.g., perchloric acid hood operations).

If any HEPA filter fails to meet any of the standards listed above, it would be replaced. Temperature and humidity are both performance indicators when levels deviate from an effective range; however, these requirements are met in the building-wide standard operating procedures for the heating, ventilation and heating systems in the PSF buildings, rather than an individual HEPA filter condition. Therefore, additional information on temperature and humidity is not included in this report.

Similarly, flow rate is managed on a facility-wide level, where the sum of the total rate of flow of the installed filters must be less than the emission exhaust rate. Factory recalls and other special conditions are managed on a case-by-case basis.

2.0 Equipment

HEPA filters carry a range of minimum efficiency reporting values from 17–19 (ASHRAE 2012). Minimum efficiency reporting values are set by the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 52.2 is a rating of efficiency on a scale from 1 (lowest) to 20 (highest) (EPA 2009). Each new filter is independently tested at the DOE-sanctioned Filter Test Facility prior to being placed into service. Annual testing of HEPA filters is performed to confirm the filtration has not degraded (Colby 2013).

An in-place aerosol test measures the efficiency of the filters. This test is performed in accordance with ASME/ANSI N511-2007, *In-Service Testing of Nuclear Air Treatment, Heating, Ventilation, and Air-Conditioning Systems.* A compressed gas source is connected to an aerosol generator, which injects aerosol upstream from the filter bank. A photometer then is used to measure the upstream and downstream aerosol DP measurements and concentrations; readings are taken until at least three of the readings are stable (within ±0.01 gauge reading). The final sets of efficiency readings are recorded on the PM worksheet (Colby 2013).

Laboratory fume hoods are tested periodically for adequate airflow. The inspections of laboratory fume hoods are based on ANSI/AIHA Z9.5, *American National Standard for Laboratory Ventilation*, and ASHRAE Standard 110, *Method of Testing Performance of Laboratory Fume Hoods*. Fume hood air flow is tested by verifying that the average face velocity entering the fume hood is within the design parameters. Airflow instruments are calibrated and traceable to the National Institute of Standards and Technology (Rohrig 2016).

Rad dose detection is monitored using alpha and beta detection meters, generally paired with a GM probe (e.g., Ludlum 2360 meter; Figure 4).

Figure 4. General purpose Ludlum 2360 meter generally paired with alpha/beta probe for contamination surveys

3.0 Procedure

Forty-nine nuclear-grade HEPA filters were selected for evaluation in this study from those available at the PNNL PSF buildings: 7 from 3410, 27 from 3420, and 15 from 3430. The “HEPA Exhaust Filter Testing” and “Fume Hood” PMs are performed annually on each filter, and the results are stored electronically in the Facilities and Operations Vault online database. The updated “HEPA Exhaust Filter Testing” PM contains the efficiency and pressure data; its identification numbers are PM1598, PM13493, and PM13949 for 3410, 3420, and 3430, respectively. The updated “Fume Hood” PM contains the velocities; its identification numbers are PM12827, PM12825, and PM12824, also for 3410, 3420, and 3430, respectively.

Radiological data was collected from PNNL’s Radiation Protection Division. The PSF facilities were new in 2011, so surveys were only conducted once that year. Surveys became semiannual beginning in 2012. Surveying the filters did not commence until 2012 for the 3430 Building due to building occupancy, but the semiannual pattern was continued in 2013.

The PM data for the 49 filters were collected and entered into a spreadsheet to graphically evaluate whether filters were replaced and the cause for the replacement. Figure 5 is a sample graph of the PM data for a filter that has not needed to be replaced. The graph is annotated with green and red lines such that any plot points that are placed out of the first quadrant obviously indicate that the filter underperformed. To indicate a radiological dose above minimum detectable activity (MDA) or an efficiency below 99.95% (where limited operations are allowed down to 99.90% with a service request in place for filter replacement within one-year of testing), the descriptor for the plot point is recolored to red.

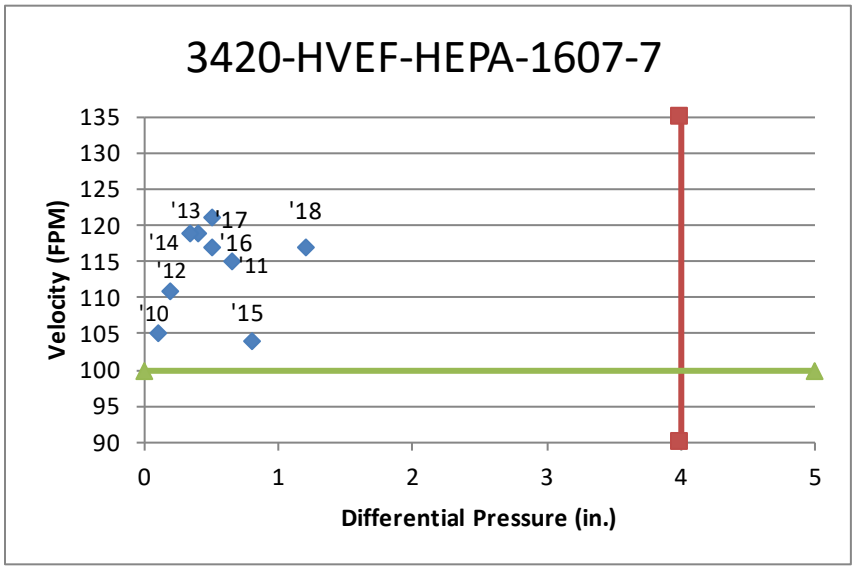

Figure 5. PM data for HEPA filter 1607-7 in the 3420 Building

4.0 Discussion

The HEPA filter study is a 10-year study, beginning in 2010 and continuing through 2020. Over the last nine years (2010–2018), 4 of the 49 HEPA filters have been changed (Table 1). The first filter changed was in 2010 because it failed the filter efficiency test with an efficiency of 99.90%. The second filter replacement was in 2013 for not meeting the DP and fume hood face velocity criteria, with a DP of 4.0 in. wg and face velocity of 68 ft/min. The third filter was in 2016 for not meeting the DP criteria with a high DP of 4.20 in. wg. The fourth filter replaced was in 2017 for failing the efficiency criteria with a measured efficiency of 99.88%.

Table 1. HEPA Filters Changed (2010-2018)

Year	Location	Filter Asset	DP (in. wg)	Efficiency	Fume Hood Asset	Velocity (ft/min)	Standard Failed	Reason
2010	3430	HVEF-HEPA-1507	0.8	99.90	HVEF-FH-1505	111	Efficiency >99.90%	Low Efficiency
2013	3410	HVEF-HEPA-1404-3	4.0	99.98	HVE-FG-1404	68	DP <4.0 in. wg; velocity ≥100 ft/min	DP exceeds 4.0 in. wg; Velocity Low
2016	3420	HVEF-HEPA-2500/ 2500-1	4.20	99.98	HVE-FH-1600	104	DP <4.0 in. wg	DP exceeds 4.0 in. wg
2017	3430	HVEF-HEPA-1310E	0.35	99.88	HVEF-FH-1310-6	124	Efficiency >99.90%	Low Efficiency

Figures 6(a), 6(b), and 6(c) show the results of graphical analyses for the 3430-HVEF-HEPA-1507, 3410-HVEF-HEPA-1404-3, and 3420-HVEF-HEPA-2500/2500-1 filters. The graph for 3430-HVEF-HEPA-1310E is not included because the year the HEPA filter was replaced, 2017, the DP was not recorded, and thus, the graph would not show data for the replacement year. The 2016 data point in Figure 6(a) is not visible in the first quadrant because filter needed to be replaced.

The red data point for 2010 in Figure 6(b) indicates either that the radiological dose was above MDA or that the efficiency was below 99.90%, either of which would require the filter to be replaced. The 2013 data point in Figure 6(c) is not visible in the first quadrant because the filter needed to be replaced.

Laboratory exhaust systems at PNNL are incapable of generating enough pressure or flow that could damage filters, and the tepid temperature and low humidity in the exhaust renders the 10-year filter life cycle conservative (Colby 2013). See Appendix B for the raw data.

Lifetime considerations had no effect on the decision to replace the filters.

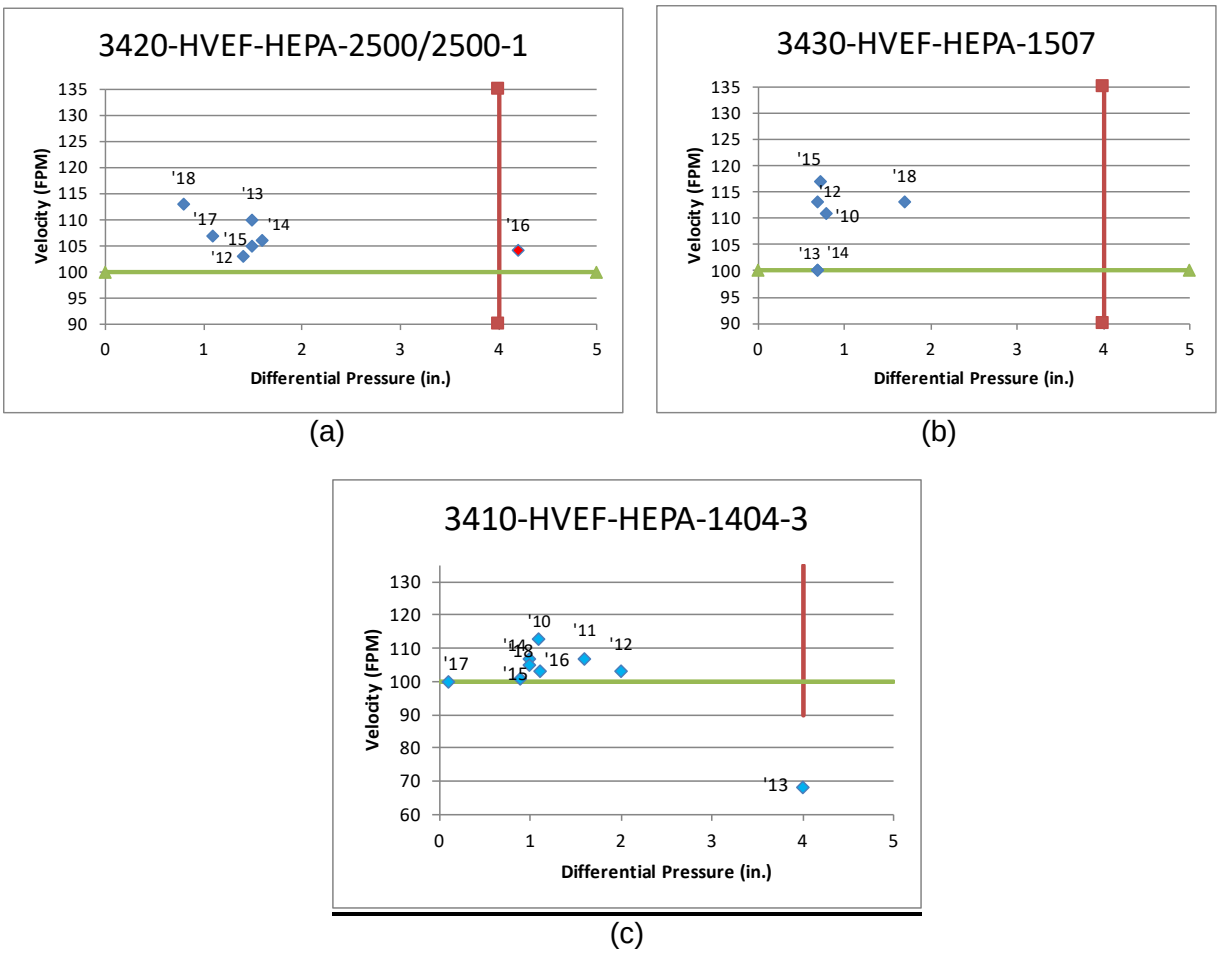

Figure 6. PM data for HEPA filters in the 3420, 3430, and 3410 Buildings. (a) Filter 2500/2500-1 in the 3420 Building; (b) Filter 1507 in the 3430 Building. (c) Filter 1404-3 in the 3410 Building.

5.0 Conclusions

Regular evaluations of the DP, filter efficiency, fume hood face velocity, and radiological dose indicate that the HEPA filter lifetime is longer than the 10 years presently recommended; however, this excludes an evaluation of the tensile strength of the HEPA filter. The low rate of filter changes (8.2% over the interim 9-year period) were due to arbitrary failures of filter performance, not deterioration due to aging. At this point in the study, the filters used in the PSF buildings seem adequate to withstand use beyond the generalized DOE 10-year-recommended age limit. Future studies to observe the tensile strength of the HEPA filter media are planned. Because there is so little data suggesting the age limit should be increased or decreased, filters should instead be evaluated against the aforementioned criteria on a case-by-case basis before being replaced or allowed to maintain normal operation.

6.0 References

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Appendix A – Preventive Maintenance (PM) Numbers

Table A.1. Active PM numbers currently in use

Building	HEPA Exhaust Filter Testing	Fume Hood
3410	PM1598	PM12827
3420	PM13493	PM12825
3430	PM13949	PM12824

Table A.2.Old PM numbers no longer being used

Building	HEPA Exhaust filter testing	Fume Hood
3410	PSF5501	PSF1368
3420	PSF1083	PSF1339
3430	PSF5503	PSF1214/PSF51215

Appendix B – Raw Data

DP = Differential pressure measured in inches water gauge.

Face velocity measured in feet per minute.

MDA = 20 mrem/hr

B.1 PSF 3410

1 HEPA : 1 Fume Hood								
HEPA	**Date**	**DP**	**Efficiency**	**Remarks**	**Fume Hood**	**Date**	**Velocity**	**Remarks**
3410-HVEF-HEPA-1402	6/16/2010	0.70	99.98		3410-HVE-FH-1402	10/31/2010	120	
	6/30/2011	0.60	99.98			11/28/2011	117	
	6/27/2012	1.40	99.98			10/29/2012	122	
	6/19/2013	1.30	99.98			12/17/2013	116	
	6/27/2014	1.30	99.98			12/19/2014	107	
	7/1/2015	0.90	99.98			12/7/2015	107	
	6/1/2016	0.76	99.98			12/1/2016	N/A	unlisted
	6/29/2017	0.90	99.98			12/28/2017	N/A	unlisted
	12/18/2018	0.40	99.98			12/18/2018	N/A	unlisted
3410-HVEF-HEPA-1403-3	6/16/2010	0.70	99.98	Written as 1403B	3410-HVE-FH-1403-2	10/31/2010	119	
	6/30/2011	0.40	99.98			11/28/2011	188	Found as 188 Out of service
	6/27/2012	N/A	99.98	Δp across damper		10/29/2012	144	Found 144 fpm. SR Written for Controller
	6/19/2013	1.00	99.98			12/17/2013	119	
	6/27/2014	N/A	99.98	Δp across damper		12/19/2014	104	
	7/1/2015	N/A	99.98	Δp across damper		12/7/2015	109	
	6/1/2016	N/A	99.98	Δp across damper		12/1/2016	95	
	6/29/2017	0.95	99.98	Δp across damper		12/28/2017	101	found 93, adjusted
	12/18/2018	1.80	99.98	Δp across damper		12/18/2018	102	
3410-HVEF-HEPA-1404-3	6/16/2010	1.10	99.98	Listed as 1404B	3410-HVE-FH-1404	10/31/2010	113	
	6/30/2011	1.60	99.98			11/28/2011	107	
	6/27/2012	2.00	99.98			10/29/2012	103	
	6/16/2013	4.00	99.98	Filter Changed 5707050		12/17/2013	68	Out of service
	6/27/2014	1.00	99.98			12/19/2014	107	
	7/1/2015	1.00	99.98			12/7/2015	105	
	6/1/2016	1.12	99.98			12/1/2016	103	

	6/29/2017	0.10	99.98			12/28/2017	102	found 86, adjusted
	12/18/2018	0.90	99.98			12/18/2018	101	
	6/16/2010	0.70	99.98	Listed as 1407		10/31/2010	125	
3410-HVEF-HEPA-1407-1	6/30/2011	0.20	99.98		3410-HVE-FH-1407	10/1/2011	109	
	6/27/2012	0.60	99.98			10/29/2012	116	
	6/19/2013	0.30	99.98			12/17/2013	116	
	6/27/2014	0.30	99.98			12/19/2014	106	
	7/1/2015	0.20	99.98			12/7/2015	107	
	6/1/2016	0.69	99.98			12/1/2016	103	
	6/29/2017	0.40	99.98			12/28/2017	110	
	12/18/2018	0.30	99.98			12/18/2018	106	
3410-HVEF-HEPA-1607	6/16/2010	1.00	99.98		3410-HVEF-FH-1607	10/31/2010	N/A	Out of service
	6/30/2011	1.00	99.98			10/1/2011	41	Out of service
	6/27/2012	0.90	99.98			10/29/2012	113	
	6/19/2013	1.20	99.98			12/17/2013	105	
	6/27/2014	0.45	99.98			12/19/2014	98	
	7/1/2015	0.30	99.98			12/7/2015	102	
	6/1/2016	0.37	99.98			12/1/2016	100	
	6/29/2017	0.40	99.98			12/28/2017	101	
	12/18/2018	0.35	99.98			12/18/2018	103	

2 HEPA : 1 Fume Hood

HEPA	Date	DP	Efficiency	Remarks	Fume Hood	Date	Velocity	Remarks
3410-HVEF-HEPA-1403-1/ 1403-2	6/16/2010	0.40 0.40	99.98 99.98	Listed as 1403 Listed as 1403A	3410-HVE-FH-1403-1	10/31/2010	125	
	6/30/2011	0.50 0.20	99.98 99.98			11/28/2011	121	
	6/27/2012	0.60 0.60	99.98 99.98			10/29/2012	118	
	6/19/2013	1.50 1.60	99.98 99.98			12/17/2013	118	
	6/27/2014	0.80 0.85	99.98 99.98			12/19/2014	119	
	7/1/2015	0.30 0.30	99.98 99.98			12/7/2015	120	
	6/1/2016	0.50 0.52	99.98 99.98			12/1/2016	99	
	6/29/2017	0.60 0.70	99.98 99.98			12/28/2017	119	
	12/18/2018	0.60 0.80	99.98 99.98			12/18/2019	117	

3410-HVEF-HEPA-1600/1602A	6/16/2010	0.60	99.98	Listed as 1602	3410-HVEF-FH-1602			
		0.60	99.98	Listed as 1602-2		10/31/2010	N/A	
	6/30/2011	0.80	99.98	Listed as 1602-1				
		0.90	99.98	Listed as 1602-2		11/28/2011	110	
	6/27/2012	0.80	99.98	Listed as 1602				
		0.80	99.98	Listed as 1602A		10/29/2012	116	
	6/19/2013	1.25	99.97	Listed as 1602-1				
		1.10	99.97	Listed as 1602-2		12/17/2013	111	
	6/27/2014	0.95	99.98	Listed as 1602				
		1.00	99.98	Listed as 1603		12/19/2014	105	
	7/1/2015	0.80	99.98	Listed as 1602				
		N/A	99.98	Listed as 1603		12/7/2015	117	
	6/1/2016	1.22	99.98	both are listed as 1602				
		1.22	99.98	maols asset corrections		12/1/2016	110	
	6/29/2017	1.30	99.98	listed as 1602-1				
		1.30	99.98	listed as 1602-2		12/28/2017	111	
	12/18/2018	1.10	99.98	listed as 1602-1				
		1.10	99.98	listed as 1602-2		12/18/2018	111	

3410 Contamination Measurements **MDA: minimum detectable activity**

Date	Location	β-γ	α	Date	Location	B-γ	α
12/14/2011	HEPA Units South (1400 hall)	< MDA	<	2/3/2015	HEPA Units South (1400 hall)	<	<
	HEPA Units North (1600 hall)	<	<	2/23/2015	HEPA Units North (1600 hall)	<	<
1/18/2012	HEPA Units North (1600 hall)	<	<	12/15/2016	HEPA Units South (1400 hall)	<	<
1/25/2012	HEPA Units South (1400 hall)	<	<		HEPA Units North (1600 hall)	<	<
11/8/2012	HEPA Units South (1400 hall)	<	<	1/12/2016	HEPA Units South (1400 hall)	<	<
	HEPA Units North (1600 hall)	<	<		HEPA Units North (1600 hall)	<	<
2/5/2013	HEPA Units South (1400 hall)	<	<	7/28/2016	HEPA Units South (1400 hall)	<	<
2/6/2013	HEPA Units North (1600 hall)	<	<		HEPA Units North (1600 hall)	<	<
9/17/2013	HEPA Units South (1400 hall)	<	<	2/28/2017	HEPA Units South (1400 hall)	<	<
	HEPA Units North (1600 hall)	<	<		HEPA Units North (1600 hall)	<	<

1/30/2014	HEPA Units South (1400 hall)	<	<	7/20/2017	HEPA Units South (1400 hall)	<	<
	HEPA Units North (1600 hall)	<	<		HEPA Units North (1600 hall)	<	<
9/26/2014	HEPA Units South (1400 hall)	<	<	2/7/2018	HEPA Unites South (1400 hall)	<	<
	HEPA Units North (1600 hall)	<	<		HEPA Units North (1600 hall)	<	<
				2/21/2019	HEPA Units South (1400 hall)	<	<
					HEPA Units South (1600)	<	<

1 HEPA : 1 Fume Hood								
HEPA	**Date**	**DP**	**Efficiency**	**Remarks**	**Fume Hood**	**Date**	**Velocity**	**Remarks**
3420-HVEF-HEPA-1607-7	7/26/2010	0.10	99.98		3420-HVEF-FH-1607-3	10/31/2010	105	
	10/18/2011	0.65	99.98			10/1/2011	115	
	11/15/2012	0.20	99.98			11/12/2012	111	
	10/8/2013	0.40	99.98			10/8/2013	119	
	11/12/2014	0.35	99.98			10/10/2014	119	
	11/30/2015	0.80	99.98			11/30/2015	104	
	11/1/2016	0.50	99.98			11/1/2016	117	
	11/28/2017	0.50	99.98			11/28/2017	121	
	11/30/2018	1.20	99.98			11/30/2018	117	
3420-HVEF-HEPA-1700-4	7/26/2010	0.60	99.98		3420-HVEF-FH-1700-5	10/31/2010	110	
	10/18/2011	0.65	99.98			10/1/2011	109	P.O. to start
	11/15/2012	N/A	N/A	Perch. Hood		11/12/2012	109	
	10/8/2013	0.70	99.98			10/8/2013	117	
	11/12/2014	0.80	99.98			10/10/2014	113	
	11/30/2015	0.60	99.98			11/30/2015	114	
	11/1/2016	0.53	99.98			11/1/2016	105	
	11/28/2017	0.70	99.98			11/28/2017	103	
	11/30/2018	0.50	99.98			11/30/2018	104	
3420-HVEF-HEPA-1705-5	7/26/2010	0.15	99.98		3420-HVEF-FH-1705-5	10/31/2010	115	
	10/18/2011	0.20	99.98			10/1/2011	116	
	11/15/2012	0.15	99.98			11/12/2012	111	
	10/8/2013	0.20	99.98			10/8/2013	121	
	11/12/2014	0.60	99.98			10/10/2014	119	
	11/30/2015	0.65	99.98			11/30/2015	107	

	11/1/2016	0.64	99.98			11/1/2016	N/A	room 1705 under construction, no access to room
	11/28/2017	0.70	99.98			11/28/2017	109	
	11/30/2018	0.70	99.98			11/30/2018	109	
	7/26/2010	0.20	99.98			10/31/2010	120	
	10/18/2011	0.50	99.98			10/1/2011	121	
	11/15/2012	0.40	99.98			11/12/2012	114	
	10/8/2013	0.55	99.98			10/8/2013	121	
3420-HVEF-HEPA-1705-4	11/12/2014	0.60	99.98		3420-HVEF-FH-1705-6	10/10/2014	116	
	11/30/2015	0.60	99.98			11/30/2015	113	
	11/1/2016	0.57	99.98			11/1/2016	N/A	room 1705 under construction, no access to room
	11/28/2017	0.60	99.98			11/28/2017	110	
	11/30/2018	0.70	99.98			11/30/2018	106	
	7/26/2010	0.20	99.98			10/31/2010	115	
	10/18/2011	0.25	99.98			10/1/2011	122	
	11/15/2012	0.25	99.98			11/12/2012	108	
	10/8/2013	0.85	99.98			10/8/2013	116	
3420-HVEF-HEPA-1707-4	11/12/2014	0.70	99.98		3420-HVEF-FH-1707-5	10/10/2014	104	
	11/30/2015	0.75	99.98			11/30/2015	113	
	11/2/2016	N/A	N/A	under const. not to be tested per Building Engineer		11/1/2016	N/A	room 1707 under construction, no access to room
	11/28/2017	0.70	99.98			11/28/2017	107	
	11/30/2018	0.80	99.98			11/30/2018	108	
	7/26/2010	0.20	99.98			10/31/2010	115	
	10/18/2011	0.30	99.98			10/1/2011	101	
	11/15/2012	0.60	99.98			11/12/2012	108	Found 96 Adjusted
	10/8/2013	0.85	99.98			10/8/2013	124	
3420-HVEF-HEPA-1707-5	11/12/2014	0.70	99.98		3420-HVEF-FH-1707-4	10/10/2014	104	
	11/30/2015	0.80	99.98			11/30/2015	108	
	11/1/2016	N/A	N/A	under const. not to be tested per Building Engineer		11/1/2016	N/A	room 1707 under construction, no access to room
	11/28/2017	0.70	99.98			11/28/2017	106	
	11/30/2018	0.70	99.98			11/30/2018	102	
	7/26/2010	N/A	N/A			10/31/2010	115	
	10/18/2011	N/A	N/A			9/9/2011	121	
3420-HVEF-HEPA-1707E	11/15/2012	N/A	N/A		3420-HVEF-FH-1707-6	11/12/2012	110	
	10/8/2013	N/A	N/A			10/8/2013	113	
	11/12/2014	N/A	N/A			10/10/2014	132	
	11/30/2015	N/A	N/A			11/30/2015	118	

	11/1/2016	N/A	N/A	not listed		11/1/2016	N/A	room 1707 under construction, no access to room
	11/28/2017	N/A	N/A	not listed		11/28/2017	121	
	11/30/2018	N/A	N/A	not listed		11/30/2018	122	constant volume

2 HEPA : 1 Fume Hood

HEPA	Date	DP	Efficiency	Remarks	Fume Hood	Date	Velocity	Remarks
3420-HVEF-HEPA-2500/ 2500-1	7/26/2010	0.90 1.00	99.98 99.98		3420-HVE-FH-1600	10/31/2010	N/A	
	10/18/2011	1.30 1.35	99.98 99.98			10/1/2011	N/A	
	11/15/2012	1.40 1.20	99.98 99.98			11/12/2012	103	
	10/8/2013	1.45 1.50	99.98 99.98			10/8/2013	110	
	11/12/2014	1.50 1.60	99.98 99.98			10/10/2014	106	
	11/30/2015	1.40 1.50	99.98 99.98			11/30/2015	105	
	11/1/2016	4.20 4.20	99.98 99.98	failed DP test, HEPA replaced		11/1/2016	104	
	11/28/2017	1.10 1.10	99.98 99.98			11/28/2017	107	
	11/30/2018	0.80 0.80	99.98 99.98			11/30/2018	113	
3420-HVEF-HEPA-1607/ 1607-1	7/26/2010	1.00 0.90	99.98 99.98		3420-HVEF-FH-1603-1	10/31/2010	110	
	10/18/2011	1.30 1.20	99.98 99.98			10/1/2011	104	
	11/15/2012	1.30 1.20	99.98 99.98			11/12/2012	103	
	10/8/2013	1.40 1.30	99.98 99.98			10/8/2013	110	
	11/12/2014	2.00 1.90	99.98 99.98			10/10/2014	101	
	11/30/2015	1.30 1.20	99.98 99.98			11/30/2015	120	

	11/1/2016	2.23 1.62	99.98 99.98			11/1/2016	106	
	11/28/2017	1.00 0.50	99.98 99.98			11/28/2017	111	
	11/30/2018	1.00 0.90	99.98 99.98			11/30/2018	111	
3420-HVEF-HEPA-1601/ 1601-1	7/26/2010	0.35 0.40	99.98 99.98		3420-HVEF-FH-1603-4	10/31/2010	123	
	10/18/2011	0.75 0.85	99.98 99.98			10/1/2011	103	
	11/15/2012	0.50 0.50	99.98 99.98			11/12/2012	108	
	10/8/2013	0.90 1.00	99.98 99.98			10/8/2013	112	
	11/12/2014	0.90 1.00	99.98 99.98			10/10/2014	115	
	11/30/2015	1.20 1.20	99.98 99.98			11/30/2015	104	
	11/1/2016	1.68 1.75	99.98 99.98			11/1/2016	106	
	11/28/2017	1.70 1.70	99.98 99.98			11/28/2017	103	
	11/30/2018	1.50 1.60	99.98 99.98			11/30/2018	110	Constant Volume
3420-HVEF-HEPA-1607-4/ 1607-5	7/26/2010	0.10 0.10	99.98 99.98		3420-HVEF-FH-1607-1	10/31/2010	123	
	10/18/2011	0.60 0.60	99.98 99.98			10/1/2011	129	
	11/15/2012	0.50 0.50	99.98 99.98			11/12/2012	115	
	10/8/2013	0.40 0.40	99.98 99.98			10/8/2013	122	
	11/12/2014	0.50 0.50	99.98 99.98			10/10/2014	115	
	11/30/2015	0.60 0.50	99.98 99.98			11/30/2015	112	
	11/1/2016	0.67 1.71	99.98 99.98			11/1/2016	121	
	11/28/2017	0.80 0.50	99.98 99.98			11/28/2017	104	

	11/30/2018	0.50 0.60	99.98 99.98			11/30/2018	103	
3420-HVEF-HEPA-1707-2/ 1707-3	7/26/2010	0.10 0.10	99.98 99.98		3420-HVEF-FH-1707-3	10/31/2010	121	
	10/18/2011	0.15 0.20	99.98 99.98			10/1/2011	117/ 120	Both sides open, Read both sides
	11/15/2012	0.60 0.60	99.98 99.98			11/12/2012	104 / 125	Both sides open, read both sides
	10/8/2013	0.20 0.20	99.98 99.98			10/8/2013	123	
	11/12/2014	0.40 0.40	99.98 99.98			10/10/2014	150	
	11/30/2015	0.20 0.20	99.98 99.98			11/30/2015	108 124	Both sides open, Read both sides
	11/1/2016	N/A	N/A	under const. not to be tested per B. E.		11/1/2016	N/A	room 1707 under construction, no access to room
	11/28/2017	0.80 0.50	99.98 99.98			11/28/2017	110	
	11/30/2018	0.50 0.60	99.98 99.98			11/30/2018	113	Constant Volume

2 HEPA : Multiple Fume Hoods

HEPA	Date	DP	Efficiency	Remarks	Fume Hood	Date	Velocity	Remarks
3420-HVEF-HEPA-1603/ 1603-1	7/29/2010	0.20 0.20	99.98 99.98		3420-HVEF-FH-1603-2/ 1603-3	10/31/2010	118 115	
	10/18/2011	0.20 0.20	99.98 99.98			11/30/2011	103 110	
	11/19/2012	0.20 0.20	99.98 99.98			11/12/2012	103 111	
	11/19/2013	0.20 0.20	99.98 99.98			11/19/2013	108 114	
	11/21/2014	0.70 0.70	99.98 99.98			11/17/2014	123 125	
	11/30/2015	0.80 0.80	99.98 99.98			11/30/2015	112 116	
	11/1/2016	0.73 1.02	99.98 99.98			11/1/2016	103 109	
	11/28/2017	0.80 1.20	99.98 99.98			11/28/2017	108 102	both constant volume

	11/30/2018	0.90 1.20	99.98 99.98			11/30/2018	104 101	both Constant Volume
3420-HVEF-HEPA-1607-2/ 1607-3	7/29/2010	0.10 0.10	99.98 99.98		3420-HVEF-FH-1607-2/ 1607A	10/31/2010	114 N/A	
	10/18/2011	0.30 0.30	99.98 99.98			11/30/2011	118 N/A	
	11/19/2012	0.90 1.00	99.98 99.98			11/12/2012	113 106	
	11/19/2013	0.80 0.90	99.98 99.98			11/19/2013	118 N/A	
	11/21/2014	0.90 1.00	99.98 99.98			11/17/2014	118 N/A	
	11/30/2015	1.00 1.10	99.98 99.98			11/30/2015	113 108	
	11/1/2016	0.58 2.89	99.98 99.98			11/1/2016	107 117	
	11/28/2017	0.80 1.30	99.98 99.98			11/28/2017	102 122	unable to raise sash to test alarm
	11/30/2018	1.00 1.30	99.98 99.98			11/30/2018	102 120	1607A Constant Volume
3420-HVEF-HEPA-1700/ 1700-1	7/29/2010	0.30 0.30	99.98 99.98		3420-HVEF-FH-1700-1/ 1700-2/ 1700-3	10/31/2010	125 120 123	
	10/18/2011	0.40 0.40	99.98 99.98			11/30/2011	116 122 113	
	11/19/2012	0.40 0.40	99.98 99.98			11/12/2012	125 122 108	
	11/19/2013	0.40 0.40	99.98 99.98			11/19/2013	112 118 111	
	11/21/2014	0.65 0.65	99.98 99.98			11/17/2014	120 120 117	
	11/30/2015	0.70 0.80	99.98 99.98			11/30/2015	124 120 109	
	11/1/2016	1.18	99.98			11/1/2016	110 117	

		1.32	99.98				107	
	11/28/2017					11/28/2017	105	constant volume
		1.40	99.98				110	
		1.40	99.98				111	
	11/30/2018					11/30/2018	106	
		1.40	99.98				103	
		1.60	99.98				111	
3420-HVEF-HEPA-1700-2/ 1700-3	7/29/2010	0.30	99.98		3420-HVEF-FH-1700-4/ 1700-6	10/31/2010	120	
		0.30	99.98				115	
	10/18/2011	0.30	99.98			11/30/2011	125	
		0.30	99.98				116	
	11/19/2012	0.20	99.98			11/12/2012	125	
		0.20	99.98				117	
	11/19/2013	0.80	99.98			11/19/2013	122	
		0.80	99.98				113	
	11/21/2014	1.00	99.98			11/17/2014	119	
		1.00	99.98				124	
	11/30/2015	1.10	99.98			11/30/2015	111	
		0.90	99.98				110	
	11/1/2016	0.74	99.98			11/1/2016	119	
		0.60	99.98				105	
	11/28/2017	0.90	99.98			11/28/2017	105	
		0.80	99.98				109	
	11/30/2018	0.80	99.98			11/30/2018	112	
		0.70	99.98				114	
3420-HVEF-HEPA-1702-2/ 1702-3	7/29/2010	0.30	99.98		3420-HVEF-FH-1702-1/ 1702-2/ 1702-3	10/31/2010	120	
		0.30	99.98				115	
							124	
	10/18/2011	0.30	99.98			11/30/2011	119	
		0.30	99.98				106	
							115	
	11/19/2012	0.30	99.98			11/12/2012	120	
		0.35	99.98				110	
							122	
	11/19/2013	0.40	99.98			11/19/2013	121	
		0.65	99.98				111	
							123	
	11/21/2014	0.40	99.98			11/17/2014	119	
		0.45	99.98				114	
							123	

	11/30/2015	0.40 0.40	99.98 99.98			11/30/2015	114 105 107	
	11/1/2016	1.08 1.27	99.98 99.98			11/1/2016	100 108 111	all are constant volume
	11/28/2017	1.40 1.20	99.98 99.98			11/28/2017	102 105 110	
	11/30/2018	1.40 N/A	99.98 N/A	not listed		11/30/2018	101 107 111	all are constant volume
3420-HVEF-HEPA-1702/ 1702-1	7/29/2010	0.60 0.60	99.98 99.98		3420-HVEF-FH-1702-4/ 1702-5	10/31/2010	118 110	
	10/18/2011	0.40 0.50	99.98 99.98			11/30/2011	108 121	
	11/19/2012	0.40 0.40	99.98 99.98			11/12/2012	117 116	
	11/19/2013	0.80 0.80	99.98 99.98			11/19/2013	123 106	
	11/21/2014	1.50 1.50	99.98 99.98			11/17/2014	120 119	
	11/30/2015	1.40 1.30	99.98 99.98			11/30/2015	107 113	
	11/1/2016	0.83 0.95	99.98 99.98			11/1/2016	108 107	
	11/28/2017	0.90 1.10	99.98 99.98			11/28/2017	110 112	
	11/30/2018	0.90 1.00	99.98 99.98			11/30/2018	112 111	both are constant volume
3420-HVEF-HEPA-1703/ 1703-1	7/29/2010	0.60 0.60	99.98 99.98		3420-HVEF-FH-1703A-1/ 1703A-2/ 1703A-3	10/31/2010	124 108 105	
	10/18/2011	0.30 0.30	99.98 99.98			11/30/2011	105 108 116	
	11/19/2012	0.60 0.70	99.98 99.98			11/12/2012	123 104 116	found 131, adjusted
	11/19/2013					11/19/2013	120	

		0.65	99.98				125	
		0.60	99.98				115	
	11/21/2014	0.70	99.98			11/17/2014	113	
		0.80	99.98				108	
	11/30/2015	0.20	99.98			11/30/2015	125	
		0.20	99.98				117	
							106	
							105	
	11/1/2016	1.94	99.98	Δp across damper		11/1/2016	103	
							124	
		1.98	99.98	Δp across damper			116	
	11/28/2017	0.80	99.98			11/28/2017	125	
		0.90	99.98				104	
							120	
	11/30/2018	0.50	99.98			11/30/2018	112	
		0.60	99.98				124	All are constant volume
							108	
3420-HVEF-HEPA-1705/ 1705-1	7/29/2010	0.40	99.98		3420-HVEF-FH-1703C-1/ 1705-3/ 1705-4	10/31/2010	115	
		0.40	99.98				110	
							115	
	10/18/2011	0.70	99.98			11/30/2011	115	
		0.80	99.98				120	
							125	
	11/19/2012	1.00	99.98			11/12/2012	101	
		1.00	99.98				125	
							125	
	11/19/2013	1.00	99.98			11/19/2013	116	
		1.10	99.98				117	
							123	
	11/21/2014	1.60	99.98			11/17/2014	107	
		1.60	99.98				125	
							111	
	11/30/2015	1.02	99.98			11/1/2015	111	
		1.50	99.98				120	
							120	
	11/1/2016	0.86	99.98			11/1/2016	116	
		2.22	99.98				N/A	unlisted
							N/A	unlisted
	11/28/2017	1.20	99.98			11/28/2017	124	
							116	

		1.30	99.98				114	
	11/30/2018	1.10 1.20	99.98 99.98			11/30/2018	114 116 111	C-1 is Constant Volume
3420-HVEF-HEPA-1703-2/ 1703-3	7/29/2010	0.60 0.55	99.98 99.98		3420-HVEF-FH-1703C-2/ 1703C-3	10/31/2010	110 115	
	10/18/2011	0.60 0.60	99.98 99.98			11/30/2011	107 114	
	11/19/2012	0.50 0.60	99.98 99.98			11/12/2012	110 125	
	11/19/2013	0.50 0.50	99.98 99.98			11/19/2013	110 124	found 131, adjusted
	11/21/2014	0.90 1.00	99.98 99.98			11/17/2014	110 123	
	11/30/2015	0.60 0.65	99.98 99.98			11/1/2015	106 120	
	11/1/2016	1.87 1.91	99.98 99.98	Δp across damper Δp across damper		11/1/2016	107 107	
	11/28/2017	0.90 0.70	99.98 99.98			11/28/2017	106 111	
	11/30/2018	0.90 0.90	99.98 99.98			11/30/2018	110 114	Both constant volume
3420-HVEF-HEPA-1704-2/ 1704-3	7/29/2010	0.60 0.60	99.98 99.98		3420-HVEF-FH-1704-1/ 1704-2/ 1704-3	10/31/2010	125 120 123	
	10/18/2011	0.75 0.75	99.98 99.98			11/30/2011	118 124 123	
	11/19/2012	0.70 0.70	99.98 99.98			11/12/2012	109 107 106	
	11/19/2013	0.70 0.70	99.98 99.98			11/19/2013	110 110 113	
	11/21/2014	2.00 2.00	99.98 99.98			11/17/2014	109 121 115	
	11/30/2015					11/30/2015	112	

		1.20 1.10	99.98 99.98				112 113	
	11/1/2016	1.52 1.08	99.98 99.98			11/1/2016	N/A N/A N/A	removed removed removed
	11/28/2017	1.70 1.20	99.98 99.98			11/28/2017	113 112 N/A	 removed
	11/30/2018	1.80 1.40	99.98 99.98			11/30/2018	112 115 N/A	 removed
3420-HVEF-HEPA-1704/ 1704-1	7/29/2010	0.30 0.20	99.98 99.98		3420-HVEF-FH-1704-4/ 1704-5	10/31/2010	123 125	
	10/18/2011	0.30 0.25	99.98 99.98			11/30/2011	116 121	
	11/19/2012	0.30 0.30	99.98 99.98			11/12/2012	113 125	
	11/19/2013	0.35 0.40	99.98 99.98			11/19/2013	121 124	
	11/21/2014	0.50 0.50	99.98 99.98			11/17/2014	115 118	
	11/30/2015	0.60 0.60	99.98 99.98			11/30/2015	112 122	
	11/1/2016	1.02 1.04	99.98 99.98			11/1/2016	100 112	renamed 1704-6 renamed 1704-7
	11/28/2017	1.30 1.20	99.98 99.97			11/28/2017	N/A N/A	removed removed
	11/30/2018	1.20 1.20	99.98 99.98			11/30/2018	N/A N/A	removed removed
3420-HVEF-HEPA-1705-2/ 1705-3	7/29/2010	0.25 0.25	99.98 99.98		3420-HVEF-FH-1705-1/ 1705-2/ 1705-7/	10/31/2010	125 118 121 115	
	10/18/2011	0.40 0.50	99.98 99.98			11/30/2011	111 115 120 112	
	11/19/2012	0.40 0.40	99.98 99.98			11/12/2012	116 121 119	

					1705-8		120	Found 127 Adjusted
	11/19/2013	0.30 0.30	99.98 99.98			11/19/2013	129 115 108 133	Adjusted 107 Adjusted to 119
	11/21/2014	1.10 1.10	99.98 99.98			11/17/2014	105 112 114 108	
	11/30/2015	1.35 1.20	99.98 99.98			11/30/2015	108 106 105 117	
	11/1/2016	1.44 1.60	99.98 99.98			11/1/2016	N/A	room 1705 under construction- no access to room
	11/28/2017	1.30 1.20	99.98 99.98			11/28/2017	104 102 114 N/A	removed
	11/30/2018	1.50 1.70	99.98 99.98			11/30/2018	104 111 114 N/A	removed
3420-HVEF-HEPA-1706-2/ 1706-3	7/29/2010	0.30 0.30	99.98 99.98		3420-HVEF-FH-1706-1/ 1706-2/ 1706-3	10/31/2010	120 115 122	
	10/18/2011	1.20 1.20	99.98 99.98			11/30/2011	115 111 125	
	11/19/2012	1.20 1.20	99.98 99.98			11/12/2012	114 113 113	
	11/19/2013	0.90 0.90	99.98 99.98			11/19/2013	118 112 122	
	11/21/2014	0.75 0.75	99.98 99.98			11/17/2014	121 115 116	

	11/30/2015	1.00 1.40	99.98 99.98			11/30/2015	N/A N/A N/A	Under construction
	11/1/2016	1.14 1.21	99.98 99.98			11/1/2016	108 110 111	
	11/28/2017	1.30 1.20	99.98 99.98			11/28/2017	100 110 102	constant volume
	11/30/2018	1.30 1.20	99.98 99.98			11/30/2018	101 112 103	constant volume
3420-HVEF-HEPA-1706/ 1706-1	7/29/2010	0.30 0.30	99.98 99.98		3420-HVEF-FH-1706-4/ 1706-5/ 1706-6	10/31/2010	105 115 109	
	10/18/2011	0.50 0.50	99.98 99.98			11/30/2011	101 112 122	
	11/19/2012	0.80 0.80	99.98 99.98			11/12/2012	111 121 120	
	11/19/2013	0.60 0.60	99.98 99.98			11/19/2013	109 125 124	found 54, adjusted
	11/21/2014	0.70 0.70	99.98 99.98			11/17/2014	108 114 113	
	11/30/2015	1.40 1.40	99.98 99.98			11/30/2015	N/A N/A N/A	Under construction
	11/1/2016	1.43 1.47	99.98 99.98			11/1/2016	107 120 116	
	11/28/2017	1.30 1.20	99.98 99.98			11/28/2017	121 121 110	
	11/30/2018	1.30 1.30	99.98 99.98			11/30/2018	113 118 124	All constant volume
	7/29/2010	0.40	99.98			10/31/2010	108	

3420-HVEF-HEPA-1707/ 1707-1		0.35	99.98		3420-HVEF-FH-1707-1/ 1709		115	
	10/18/2011	0.50 0.50	99.98 99.98			11/30/2011	88 110	Out of Service
	11/19/2012	0.50 0.50	99.98 99.98			11/12/2012	125 115	
	11/19/2013	0.55 0.50	99.98 99.98			11/19/2013	119 74	WR# written by Building Engineer
	11/21/2014	0.60 0.55	99.98 99.98			11/17/2014	119 122	
	11/30/2015	0.65 0.60	99.98 99.98			11/30/2015	111 123	
	11/1/2016	N/A	N/A	under const. not to be tested per B.E.		11/1/2016	N/A	room 1707 under construction; no access to room
	11/28/2017	0.40 1.00	99.98 99.98			11/28/2017	107 113	
	11/30/2018	0.30 0.40	99.98 99.98			11/30/2018	109 116	Constant volume

B.2 PSF 3420

3420 Contamination Measurements MDA: minimum detectable activity

Date	Location	β-γ	α	Date	Location	β-γ	α	Date	Location	β-γ	α
12/7/2011	floors	<	<	12/16/2014	1703 (4)	<	<	3/4/2016	1703 (4)	<	<
2/29/2012	2nd floor open areas floor inside 2500-2508	<	<		1705 (6)	<	<		1705 (6)	<	<
		<	<		1707 (7)	<	<		1707 (7)	<	<
3/13/2013	1703 (4)	<	<		1709	<	<		1709	<	<
	1705 (6)	<	<		1800	<	<		1800	<	<
	1707 (7)	<	<		1706 (4)	<	<		1706 (4)	<	<
	1709	<	<		1704 (4)	<	<		1704 (4)	<	<
	1800	<	<		1702 (4)	<	<		1702 (4)	<	<
	1706 (4)	<	<		1700 (5)	<	<		1700 (5)	<	<
	1704 (4)	<	<		1601 (2)	<	<		1601 (2)	<	<
	1702 (4)	<	<		1603 (2)	<	<		1603 (2)	<	<
	1700 (5)	<	<		1607 (8)	<	<		1607 (8)	<	<

	1601 (2)	<	<		2500 (2)	<	<		2500 (2)	<	<
	1603 (2)	<	<	6/10/2015	1703 (4)	<	<	7/29/2016	1703 (4)	<	<
	1607 (8)	<	<		1705 (6)	<	<		1705 (6)	<	<
	2500 (2)	<	<		1707 (7)	<	<		1707 (7)	<	<
10/21/2013	1703 (4)	<	<		1709	<	<		1709	<	<
	1705 (6)	<	<		1800	<	<		1800	<	<
	1707 (7)	<	<		1706 (4)	<	<		1706 (4)	<	<
	1709	<	<		1704 (4)	<	<		1704 (4)	<	<
	1800	<	<		1702 (4)	<	<		1702 (4)	<	<
	1706 (4)	<	<		1700 (5)	<	<		1700 (5)	<	<
	1704 (4)	<	<		1601 (2)	<	<		1601 (2)	<	<
	1702 (4)	<	<		1603 (2)	<	<		1603 (2)	<	<
	1700 (5)	<	<		1607 (8)	<	<		1607 (8)	<	<
	1601 (2)	<	<		2500 (2)	<	<		2500 (2)	<	<
	1603 (2)	<	<	12/11/2015	1703 (4)	<	<	5/19/2017	1703 (4)	<	<
	1607 (8)	<	<		1705 (6)	<	<		1705 (6)	<	<
	2500 (2)	<	<		1707 (7)	<	<		1707 (7)	<	<
5/8/2014	1703 (4)	<	<		1709	<	<		1709	<	<
	1705 (6)	<	<		1800	<	<		1800	<	<
	1707 (7)	<	<		1706 (4)	<	<		1706 (4)	<	<
	1709	<	<		1704 (4)	<	<		1704 (4)	<	<
	1800	<	<		1702 (4)	<	<		1702 (4)	<	<
	1706 (4)	<	<		1700 (5)	<	<		1700 (5)	<	<
	1704 (4)	<	<		1601 (2)	<	<		1601 (2)	<	<
	1702 (4)	<	<		1603 (2)	<	<		1603 (2)	<	<
	1700 (5)	<	<		1607 (8)	<	<		1607 (8)	<	<
	1601 (2)	<	<		2500 (2)	<	<		2500 (2)	<	<
	1603 (2)	<	<								
	1607 (8)	<	<								
	2500 (2)	<	<								

Date	Location	β-γ	α	Date	Location	β-γ	α	Date	Location	β-γ	α
11/3/2017	1703 (4)	<	<	2/15/2018	1703 (4)	<	<	3/28/2018	2ND Floor equipment room	<	<
	1705 (6)	<	<		1705 (6)	<	<				
	1707 (7)	<	<		1707 (7)	<	<	1/17/2019	1703 (4)	<	<
	1709	<	<		1709	<	<		1705 (6)	<	<
	1800	<	<		1800	<	<		1707 (7)	<	<
	1706 (4)	<	<		1706 (4)	<	<		1709	<	<
	1704 (4)	<	<		1704 (4)	<	<		1800	<	<
	1702 (4)	<	<		1702 (4)	<	<		1706 (4)	<	<

	1700 (5)	<	<		1700 (5)	<	<		1704 (4)	<	<
	1601 (2)	<	<		1601 (2)	<	<		1702 (4)	<	<
	1603 (2)	<	<		1603 (2)	<	<		1700 (5)	<	<
	1607 (8)	<	<		1607 (9)	<	<		1601 (2)	<	<
	2500 (2)	<	<		2500 (2)	<	<		1603 (2)	<	<
									1607 (8)	<	<
									2500 (2)	<	<

B.3 PSF 3430

1 HEPA : 1 Fume Hood								
HEPA	**Date**	**DP**	**Efficiency**	**Remarks**	**Fume Hood**	**Date**	**Velocity**	**Remarks**
3430-HVEF-HEPA-1310D	6/11/2010	0.50	99.98		3430-HVEF-FH-1310-1	10/31/2010	103	
	5/26/2011	N/A	N/A	Not Listed		11/28/2011	112	
	5/31/2012	0.35	99.98			11/9/2012	116	
	5/28/2013	0.41	99.97			10/28/2013	109	
	5/28/2014	0.30	99.98			10/27/2014	101	
	6/2/2015	0.20	99.98			11/9/2015	102	Found 94, Adjusted
	5/1/2016	N/A	99.98	Δp across damper		10/4/2016	105	
	5/22/2017	N/A	99.98	under construction		10/19/2017	117	Constant Volume
	5/21/2018	0.60	99.98			10/26/2018	103	
3430-HVEF-HEPA-1310E	6/11/2010	N/A	N/A	Perc. Hood, Out of Service	3430-HVEF-FH-1310-6	10/31/2010	N/A	Out of Service
	5/26/2011	N/A	N/A	Not Listed		11/28/2011	N/A	Out of Service
	5/31/2012	0.40	99.98	Perc. Hood		11/9/2012	115	Found 126, Adjusted
	5/28/2013	0.40	99.98			10/28/2013	123	
	5/28/2014	0.40	99.98			10/27/2014	125	
	6/2/2015	0.42	99.98			11/9/2015	116	Constant Volume
	5/1/2016	0.45	99.98	perc. Hood		10/4/2016	122	
	5/22/2017	N/A	99.88	Failed initial test, filter was replaced		10/19/2017	118	
	5/21/2018	0.55	99.98	Perchloric Hood		10/26/2018	124	
3430-HVEF-HEPA-1507	6/11/2010	0.80	99.90	Failed DOS Test HEPA Replaced	3430-HVEF-FH-1505	10/31/2010	111	

	5/26/2011	N/A	N/A			11/28/2011	100	Ovens in hood
	5/31/2012	0.70	99.98			11/9/2012	113	
	5/28/2013	0.70	99.98			10/28/2013	100	
	5/28/2014	0.70	99.98			10/27/2014	100	
	6/2/2015	0.73	99.98			11/9/2015	117	
	5/1/2016	N/A	99.98	Δp across damper		10/4/2016	101	sash can't be lowered due to equip
	5/22/2017	N/A	99.98	disconnected		10/19/2017	118	sash can't be closed due to equip
	5/21/2018	1.70	99.98			10/26/2018	113	
3430-HVEF-HEPA-1507A	6/11/2010	0.60	99.98		3430-HVEF-FH-1507	10/31/2010	103	
	5/26/2011	N/A	N/A	Not Listed		11/28/2011	107	
	5/31/2012	0.80	99.98			11/9/2012	110	
	5/28/2013	0.95	99.98			10/28/2013	111	
	5/28/2014	0.90	99.98			10/27/2014	108	
	6/2/2015	0.97	99.98			11/9/2015	112	
	5/1/2016	N/A	99.98	Δp across damper		10/4/2016	125	
	5/22/2017	0.95	99.98			10/19/2017	117	
	5/21/2018	3.70	99.98			10/26/2018	119	
3430-HVEF-HEPA-1601-4	6/11/2010	0.50	99.98	Listed as 1601-C	3430-HVEF-FH-1601-1	10/31/2010	N/A	Not Listed
	5/26/2011	N/A	N/A			11/28/2011	N/A	
	5/31/2012	0.20	99.98			11/9/2012	105	Listed as 1601
	5/28/2013	0.60	99.98			10/28/2013	114	Listed as 1601
	5/28/2014	0.10	99.98			10/1/2014	117	Listed as 1601
	6/2/2015	0.05	99.98			11/9/2015	85	found 90, adjusted value of 85 deemed O.K.
	5/1/2016	N/A	99.98	Δp across damper		10/4/2016	116	
	5/22/2017	0.40	99.98			10/19/2017	105	listed as 1601
	5/21/2018	0.30	99.98			10/26/2018	110	

2 HEPA : 1 Fume Hood								
HEPA	**Date**	**DP**	**Efficiency**	**Remarks**	**Fume Hood**	**Date**	**Velocity**	**Remarks**
3430-HVEF-HEPA-1306/1306A	6/11/2010	0.20 0.10	99.98 99.98		3430-HVEF-FH-1306-3	10/31/2010	104	

	5/26/2011	1.00 0.20	99.98 99.98			11/28/2011	100	
	5/31/2012	0.50 0.50	99.98 99.98			11/9/2012	100	
	5/28/2013	0.50 0.60	99.98 99.98			10/28/2013	103	
	5/28/2014	0.40 0.50	99.98 99.98			10/27/2014	109	
	6/2/2015	0.18 0.20	99.98 99.98			11/9/2015	101	adjusted from 95
	5/1/2016	1.20 1.10	99.98 99.98			10/4/2016	122	
	5/22/2017	1.20 1.40	99.98 99.98			10/19/2017	103	
	5/21/2018	1.30 1.50	99.98 99.98			10/26/2018	105	
3430-HVEF-HEPA-1301B/1301C	6/11/2010	N/A N/A	N/A N/A		3430-HVEF-FH-1310-2	10/31/2010	105	
	5/26/2011	N/A N/A	N/A N/A			11/28/2011	103	
	5/31/2012	N/A N/A	N/A N/A			11/9/2012	104	
	5/28/2013	N/A N/A	N/A N/A			10/28/2013	107	
	5/28/2014	N/A N/A	N/A N/A			10/27/2014	106	
	6/2/2015	N/A N/A	N/A N/A			11/9/2015	109	
	5/1/2016	1.40 1.50	99.98 99.98			10/4/2016	112	
	5/22/2017	N/A N/A	N/A N/A			10/19/2017	106	found 87, adjusted
	5/21/2018	N/A N/A	N/A N/A			10/26/2018	102	

1 HEPA : 2 Fume Hoods								
HEPA	**Date**	**DP**	**Efficiency**	**Remarks**	**Fume Hood**	**Date**	**Velocity**	**Remarks**
3430-HVEF-HEPA-1300	6/11/2010	0.20	99.98		3430-HVEF-FH-1300-2/	10/31/2010	108 105	
	5/26/2011	0.70	99.98			11/28/2011	105	

					1300-3		101	
	5/31/2012	1.10	99.98			11/9/2012	106 113	
	5/28/2013	0.70	99.98			10/28/2013	106 102	
	5/28/2014	0.70	99.98			10/27/2014	103 83	Out of Service, 5727927
	6/2/2015	0.93	99.98			11/9/2015	108 102	found 85, adjusted
	5/1/2016	N/A	99.98	Δp across damper		10/4/2016	103 107	
	5/22/2017	3.00	99.98	Δp across 50% open damper		10/19/2017	113 106	
	5/21/2018	3.20	99.98			10/26/2018	111 102	Constant volume Constant volume
3430-HVEF-HEPA-1302	6/11/2010	0.20	99.98		3430-HVEF-FH-1302-1/ 1302-2	10/31/2010	123 116	
	5/26/2011	0.20	99.98			11/28/2011	112 110	
	5/31/2012	0.50	99.98			11/9/2012	110 116	
	5/28/2013	0.30	99.98			10/28/2013	111 112	
	5/28/2014	0.45	99.98			10/27/2014	105 115	
	6/2/2015	0.39	99.98			11/9/2015	111 113	
	5/1/2016	N/A	99.98	Δp across damper		10/4/2016	103 112	
	5/22/2017	0.40	99.98			10/19/2017	114 120	constant volume constant volume
	5/21/2018	3.00	99.98	Δp across damper		10/26/2018	114 111	constant volume constant volume
	6/11/2010	0.40	99.98			10/31/2010	104	

3430-HVEF-HEPA-1308					3430-HVEF-FH-1308-1/ 1308-3		109	
	5/26/2011	0.70	99.98			11/28/2011	115 109	
	5/31/2012	1.15	99.98			11/9/2012	113 109	
	5/28/2013	1.30	99.98			10/28/2013	112 118	
	5/28/2014	1.25	99.98			10/27/2014	115 109	
	6/2/2015	1.08	99.98			11/9/2015	106 102	
	5/1/2016	2.00	99.98	fix test port @100%		10/4/2016	111 118	
	5/22/2017	2.10	99.98	Δp across 100% open damper		10/19/2017	112 113	
	5/21/2018	1.80	99.98			10/26/2018	104 111	Constant volume

Multiple HEPA : Multiple Fume Hoods

HEPA	Date	DP	Efficiency	Remarks	Fume Hood	Date	Velocity	Remarks
3430-HVEF-HEPA-1300A/ 1300B	6/11/2010	0.45 0.45	99.98 99.98		3430-HVEF-FH-1300-1/ 1302-3/ 1306-2/ 1306-4	10/31/2010	107 103 122 100	
	5/26/2011	0.40 0.50	99.98 99.98			11/28/2011	103 108 107 106	
	5/31/2012	0.60 0.60	99.98 99.98			11/9/2012	101 113 104 100	
	5/28/2013	0.70 0.70	99.98 99.98			10/28/2013	111 111 104 108	

	5/28/2014	0.70 0.75	99.98 99.98			10/27/2014	110 113 101 110	
	5/1/2015	0.59 0.70	99.98 99.98			10/1/2015	111 114 107 106	found 96, adjusted found 94, adjusted
	5/1/2016	N/A N/A	99.98 99.98	Δp across damper Δp across damper		10/4/2016	103 103 107 N/A	unlisted
	5/22/2017	0.80 1.80	99.98 99.98			10/19/2017	109 101 107 115	constant volume constant volume constant volume constant volume
	5/21/2018	3.50 3.50	99.98 99.98			10/26/2018	116 101 106 105	constant volume constant volume
3430-HVEF-HEPA-1305-1/ 1305-2/ 1406-1/ 1406-2	6/11/2010	0.70 0.60 0.60 0.70	99.98 99.98 99.98 99.98	Listed as 3501 Listed as 3502 Listed as 3503 Listed as 3504	3430-HVEF-FH-1305/ 1406	10/31/2010	N/A N/A	
	5/26/2011	0.75 0.65 N/A N/A	99.98 99.98 N/A N/A			11/28/2011	N/A N/A	
	5/31/2012	0.70 0.65 0.80 0.90	99.98 99.98 99.98 99.98			11/9/2012	108 120	found 94, adjusted
	5/28/2013	0.70	99.98			10/28/2013		

		0.75	99.98				101	
		0.80	99.98				122	
		0.90	99.98					
	5/28/2014	0.85	99.98			10/27/2014	102	
		0.90	99.98					
		0.90	99.98				108	
		1.00	99.98					
	5/1/2015	0.66	99.98			10/1/2015	104	
		0.69	99.98					
		0.71	99.98				109	
		0.71	99.98					
	5/1/2016	0.60	99.98			10/4/2016	108	
		0.60	99.98					
		0.65	99.98				104	
		0.70	99.98					
	5/22/2017	0.75	99.98			10/19/2017	103	
		0.80	99.98					
		1.40	99.98				120	
		0.90	99.98					
	5/21/2018	0.02	99.98			10/26/2018	109	
		1.10	99.98					
		1.20	99.98				114	
		1.20	99.98					
3430-HVEF-HEPA-1310/ 1310A	6/11/2010	0.20	99.98		3430-HVEF-FH-1310-3/ 1310-4/ 1310-5	10/31/2010	105	
		0.25	99.98				102	
							105	
	5/26/2011	0.50	99.98			11/28/2011	114	
		0.50	99.98				107	
							105	
	5/31/2012	0.70	99.97			11/9/2012	115	
		0.65	99.98				100	
							102	
	5/28/2013	0.70	99.98			10/28/2013	105	
		0.70	99.98				106	
							107	
	5/28/2014	0.70	99.98			10/27/2014	112	
		0.70	99.98				103	
							123	
	5/1/2015	0.79	99.98			10/1/2015	105	found 94, adjusted
							102	

		0.82	99.98				114	
	5/1/2016	1.30 1.30	99.98 99.98			10/4/2016	109 113 122	
	5/22/2017	N/A N/A	N/A N/A	under construction under construction		10/19/2017	105 106 102	
	5/21/2018	1.00 0.85	99.98 99.98			10/26/2018	105 118 111	
3430-HVEF-HEPA-1500/ 1500A	6/11/2010	0.70 0.15	99.98 99.98		3430-HVEF-FH-1501-1/ 1501-2/ 1501-3	10/31/2010	100 102 112	
	5/26/2011	N/A N/A	N/A N/A			11/28/2011	N/A 119 110	out of service
	5/31/2012	0.60 0.60	99.98 99.98			11/9/2012	110 121 111	
	5/28/2013	1.60 0.02	99.98 99.98			10/28/2013	112 105 112	
	5/28/2014	1.50 1.40	99.98 99.98			10/27/2014	105 102 111	
	5/1/2015	1.64 1.48	99.98 99.98			10/1/2015	108 117 113	
	5/1/2016	N/A N/A	99.98 99.98	Δp across damper renamed 1501		10/4/2016	109 109 106	
	5/22/2017	3.75 3.80	99.98 99.98	Δp across 50% open damper Δp across 50% open damper		10/19/2017	110 119 115	sash blocked

	5/21/2018	1.90 2.00	99.98 99.98	renamed 1501 renamed 1501A		10/26/2018	106 116 113	
3430-HVEF-HEPA-1503/ 1503A	6/11/2010	0.65 0.50	99.98 99.98		3430-HVEF-FH-1503-1/ 1503-2	10/31/2010	109 103	
	5/26/2011	N/A N/A	N/A N/A			11/28/2011	N/A 123	out of service
	5/31/2012	0.65 0.60	99.98 99.98			11/9/2012	111 116	
	5/28/2013	0.60 0.55	99.98 99.98			10/28/2013	102 106	
	5/28/2014	0.60 0.50	99.98 99.98			10/27/2014	104 105	
	5/1/2015	0.63 0.55	99.98 99.98			10/1/2015	101 100	
	5/1/2016	N/A N/A	99.98 99.98	Δp across damper		10/4/2016	113 103	
	5/22/2017	1.65 1.60	99.98 99.98			10/19/2017	111 119	found 91, adjusted
	5/21/2018	2.20 2.20	99.98 99.98			10/26/2018	102 116	

3430 Contamination Measurements

Date	Location	β-γ	α	Date	Location	B-γ	α
2/15/2012	1310: A–E	< MDA	<	5/14/2013	HEPA's	<	<
	1308: A–C	<	<	10/13/2013	HEPA units	<	<
	1304: A, B	<	<		HEPA units	<	<
	1300: A, B	<	<	5/30/2014	HEPA units	<	<
	1406: 1, 2	<	<	11/7/2014	HEPA units	<	<
	2506	<	<	2/27/2015	HEPA units	<	<
	1280	<	<	9/4/2015	HEPA units	<	<
	1500 A	<	<	6/22/2016	HEPA units	<	<
	1503 A	<	<	10/28/2016	HEPA units	<	<

	1601: 1 - 6	<	<	6/27/2017	HEPA units	<	<
10/29/2012	HEPA filters	<	<	11/21/2017	HEPA units	<	<
	HEPA filters	<	<	6/21/2018	HEPA Units	<	<
				10/17/2018	HEPA Units	<	<
				4/26/2019	HEPA Units	<	<

Appendix C – Instructions for HEPA Filter Study Updating

1. Get access to Vault, which is an Auto Desk database product. This is where the completed records of the HEPA filter exhaust and the fume hood reports are held.
2. Use the previous years' PM numbers to search for the most recent documents in Vault. The PM numbers can be found in the file PSF-HVEF-HEPA from Maximo (003).xlsx on the fourth sheet.
3. Add current PM numbers to the new documents to the above spreadsheet; they will be at the top of the documents. There will be two PM numbers per building—one for the fume hoods and one for HEPA filters. Both numbers will need to be searched in Vault.
4. There are two documents for each building for each year—one for fume hoods and one for HEPA filters. The buildings are 3410, 3420, and 3430.
5. Print the documents mentioned in the above step. Then highlight all fume hoods and HEPA filters that are being used in this study. This list can be found in EXCEL file "HEPA TO FH WITH DATA.xlsx."
6. The HEPA filter documents will contain three numbers for each filter—only two of the numbers are needed. One of those is the DP and the other is the efficiency. Ignore the third number.
7. New values should be added to the spreadsheet titled "HEPA TO FH WITH DATA.xlsx." Only add the information for the filters listed; these were the ones selected for this study.
8. Record any notes on the forms under the "Remarks" columns.
9. If any information is not found, simply note that and write "N/A."
10. If two velocities are listed, note both but put only the adjusted value in the velocity column in the spreadsheet.
11. If a filter has been replaced (this should be noted on the documents found in Vault), highlight it in yellow.
12. The spreadsheet "HEPA DP 10 year collection 2 0.xlsx" contains graphs. Simply enter the new information there. If there are any "N/A" situations, leave the cell blank as it interferes with the graph. Otherwise formatting is the same as "HEPA TO FH WITH DATA.xlsx."
13. The graph data labels for each point need to be manually adjusted, to replace the data point label to an apostrophe, followed by the last two digits of the corresponding year. Example: a 2018 data point would be typed as " '18".
14. Replace old "Raw Data" building sheets in the Interim Report word document, with the updated sheets from "HEPA TO FH WITH DATA" to include most recent data.
15. Update 3410, 3420, and 3430 contamination measurements found in Appendix B with updated previous years' data. New data should be added to the spreadsheet "PSF Building Contamination Measurements." To get this data, contact Matthew Barnett (email below) for assistance.
16. Replace old graphs and figures (including dates) in Interim Report with new data, from "HEPA DP 10 year collection 2 0" (see steps 12 and 13 first).
17. If any questions or issues arise, contact Matthew Barnett at matthew.barnett@pnnl.gov.

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