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PNNL-25703-3

Final Status of HEPA Filter 10-Year Lifetime Evaluation

September 2020

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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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 decade, the study has now been completed, and all forty-nine HEPA filters have been replaced, due to either technical issues listed in this report, or the previously recommended filter “age limit” of 10 years.

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.

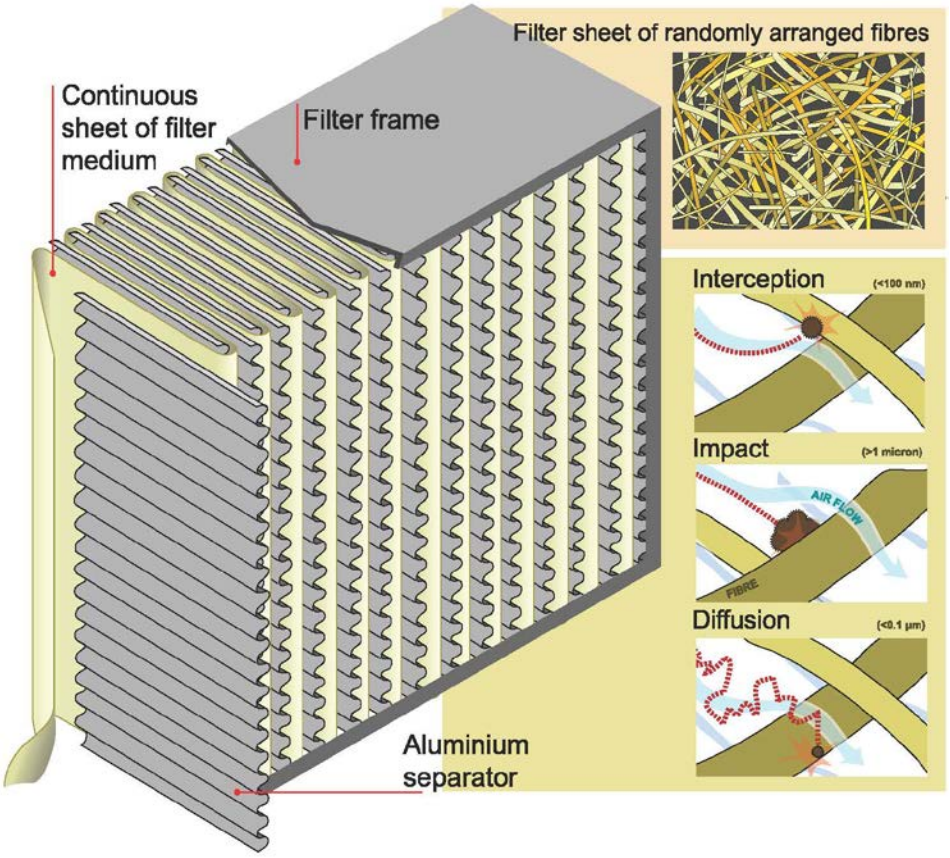

Figure 1. Visual representation of how a HEPA filter is built and catches particulates

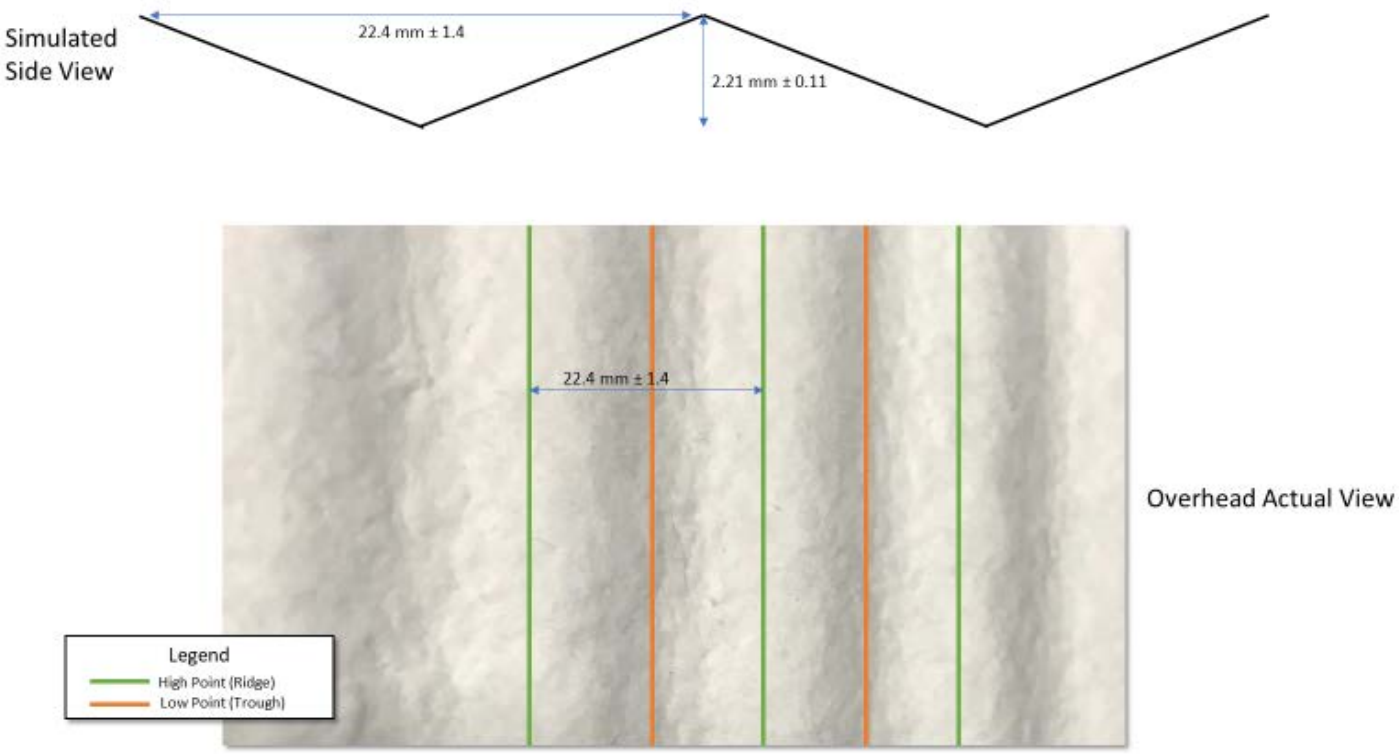

Figure 2. Calculated dimensions of the surface of a HEPA filter with error values. The top figure displays a simulated side view of the filter, showing corrugation. The bottom displays an actual closeup overhead photograph of a HEPA filters' surface.

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 below 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), 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
  - At PNNL, the efficiency result between 99.90% and 99.95% may remain in operation, but a service request for replacement within the next year is required
- 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 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. Each HEPA filter has an average cubic foot per meter (cfm) of 1500 cfm.

Factory recalls and other special conditions are managed on a case-by-case basis.

This 10-year effort is projected to minimize lab expenditures on HEPA filter replacements. By extending the lifetime requirements, described in TPD-012, by 5 years, to a 15-year lifetime, PNNL is projected to save roughly $18,500 USD per filter. The breakdown of this number can be found below:

$2,100	- HEPA filter purchase
$6,200	- Installation
$10,200	- Waste disposal
$18,500	- Total cost excluding annual maintenance

These cost numbers are derived from work packages and service request costs, as well as confirmed by 4 PNNL personnel. The costs were also conservative, with increased costs in 2019 confirming that a per-filter savings was closer to $23,100 USD.

PNNL has approximately 800 HEPA filters in service to comply with WDOH license requirements. Based on the 10-year HEPA filter lifetime study that is now complete, approximately 8% of filters in use will need to be replaced before the end of their 10-year lifetime. This results in about 64 filters having early replacement and 736 filters lasting for 10 years. Assuming 1/10th of these filters are then exchanged yearly, at PNNL there would be 74 filters per year that would need to be replaced.

Therefore, an estimated savings based on 74 HEPA filters per year remaining in service, results in a low-end total of $1.4 million USD savings using $18,500 USD, and a high-end savings of $1.7 million USD using $23,100 USD.

If we assume now the filters will last 15 years and retains the same 8.163% early replacement rate, PNNL will be replacing roughly 51 filters per year due to age and 5 filters per year due to early replacement technical issues. This results in a net filter exchange savings of 23 filters per year. Over 30 years, of the 736 HEPA filters reaching 10 years lifetime, if they are changed twice instead of three times, the resulting cost savings is approximately $15.3 million USD, according to 2019 costs.

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). ASHRAE Standard 52.2 (2017) 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 N511-2017, *In-Service Testing of Nuclear Air Treatment, Heating, Ventilation, and Air-Conditioning Systems* (2018). 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* (2012), and ASHRAE Standard 110, *Method of Testing Performance of Laboratory Fume Hoods* (2016). 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.

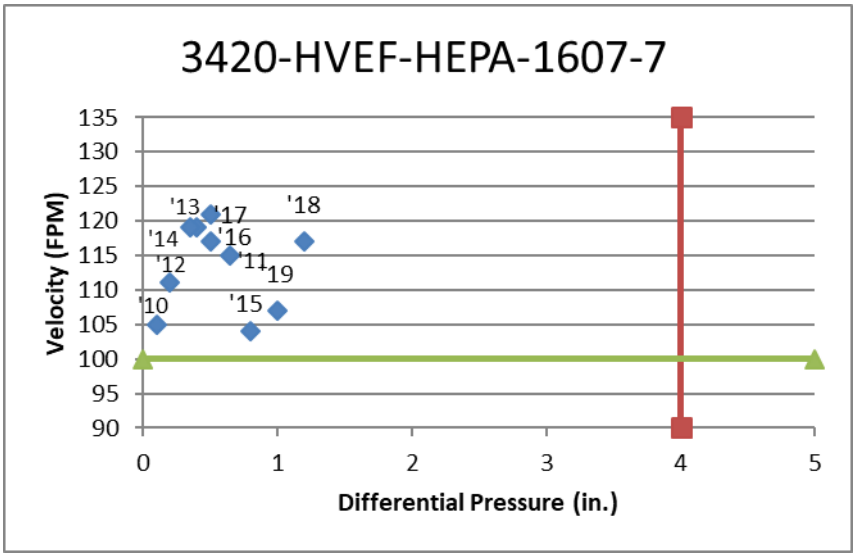

Figure 5. PM data for HEPA filter 1607-7 in the 3420 Building

Fume hoods in the 331 and 325 Buildings are meticulously observed 4 times a year and adjusted if fume hood face velocity is out of its recommended range. Because the fume hoods can be adjusted when they are out of range, they are not recorded as failures. Below, Table 1 shows the number of fume hoods that were operational during the study period at PNNL’s 3410, 3420, 3430, 331 and 325 Buildings.

Table 1. Number of Fume Hoods Operational During the Study

NUMBER OF FUME HOODS:								
YEAR	3410	3420	3430	**PSF**	331	325	**300 Area**	**Yearly Total**
2012	14	-	79	**93**	89	163	**252**	*345*
2013	18	61	77	**156**	92	167	**259**	*415*
2014	15	60	75	**150**	88	165	**253**	*403*
2015	17	42	74	**133**	88	171	**259**	*392*
2016	19	41	71	**131**	78	170	**248**	*379*
2017	19	58	78	**155**	76	162	**238**	*393*
2018	18	58	75	**151**	76	161	**237**	*388*
2019	18	58	78	**154**	75	161	**236**	*390*
TOTAL FOR PNNL CAMPUS:					**390**			

4.0 Discussion

The HEPA filter study is a 10-year study, beginning in 2010 and continuing through 2019. Over the last ten years (2010–2019), only 4 of the 49 HEPA filters were changed during the study due to issues labelled below (Table 2). The first filter changed was in 2010 because it failed the filter efficiency test at commissioning, with an efficiency of 99.90%. Because the filter failed before being used, we believe there was a manufacturing error. The failure was still recorded as such in this study even though it was never used. 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. During 2013 when filter 1404-3 failed, the 3410 Building in which the filter is located, had building exhaust imbalances, and the staff then opened doors to the outside, allowing unfiltered dusty air into the building, which is believed to have caused the HEPA failure during 2013. The third filter failed 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%. By 2019, all 49 filters identified for the original study were decommissioned as they had reached their previously recommended age limit or met the criteria for early replacement (Table 2).

Table 2. HEPA Filters Changed During Study (2010-2019)

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; Failed at commission
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

Because of these recorded failures, we can conclude that our measuring processes for technical failures works. The 1507 filter in the 3430 Building was previously mentioned as a failure at commissioning, as well as the 1404-3 filter failing due to building staff allowing unfiltered air in, we can assume that these HEPA filters failed for outstanding reasons, not from lab use over time. Because the filters still failed during the study, they were recorded as such.

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 2010 dataset in Figure 6(b) is shown because the filter failed its efficiency test with a value of 99.90%, which requires the filter to be replaced. Efficiency is not a parameter on the graphs below; only fume hood face velocity and differential pressure data are represented. The 2013 data point in Figure 6(c) is not visible in the first quadrant because the filter needed to be replaced. Note that in Figure 6(a) there was no recorded Fume Hood Velocity, so there is no 2019 data point.

Lifetime considerations had no effect on the decision to replace the filters during the study period. Only the performance criteria were considered.

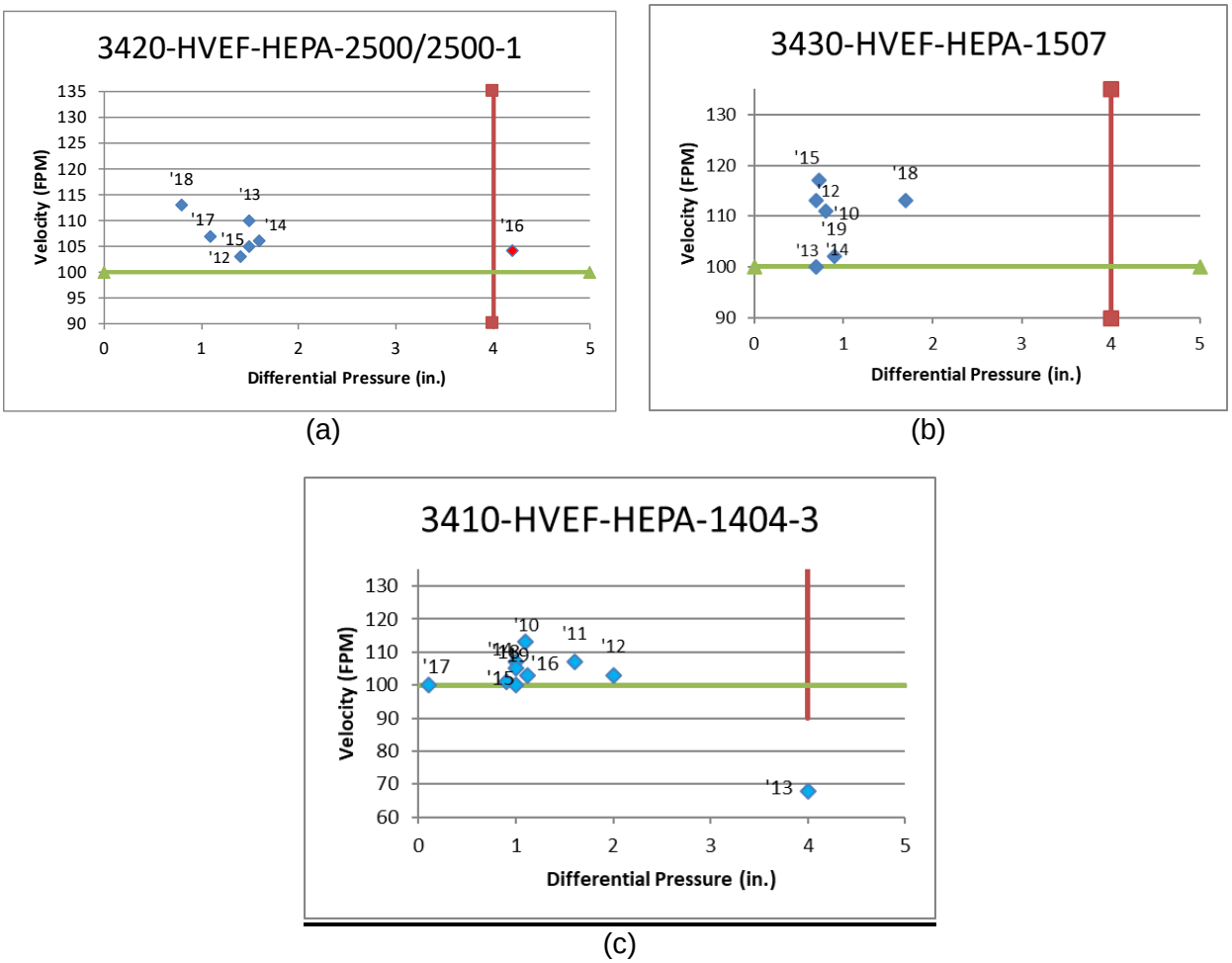

Figure 6. PM data for HEPA filters in the 3420, 3430, and 3410 Buildings. (a) Filter 2500/2500-1 in the 3420 Building; (b) Filter 1507 in the 3430 Building. (c) Filter 1404-3 in the 3410 Building.

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.

Since the Physical Science Facilities (3410, 3420 and 3430 Buildings) became operational in 2010, regulatory agencies required PNNL to change their filters out at a mandatory 10 year “age limit”. Later, in 2014 these same requirements were applied to the 331 and 325 Buildings.

However, a graded approached would maximize the lifetime of the filters. Below, in Tables 3 and 4, the total number of filters per year, in each building are shown to provide background information on the quantity of HEPA filters used a PNNL.

Table 3. Number of HEPA Filters Across PNNL Campus

	NUMBER OF FILTERS							
YEAR	3410	3420	3430	**PSF**	325	331	**300 Area**	**Yearly Total**
2010	19	50	35	**104**	N/A	N/A	**N/A**	*104*
2011	19	50	35	**104**	N/A	N/A	**N/A**	*104*
2012	19	50	35	**104**	431	88	**519**	*623*
2013	26	50	35	**111**	458	88	**546**	*657*
2014	26	50	35	**111**	442	88	**530**	*641*
2015	26	50	37	**113**	450	87	**537**	*650*
2016	27	42	37	**106**	447	86	**533**	*639*
2017	27	46	30	**103**	448	86	**534**	*637*
2018	27	48	34	**109**	477	87	**564**	*673*
2019	27	51	32	**110**	454	87	**541**	*651*
TOTAL FOR PNNL CAMPUS:					**651**			

Table 4. Number of Failed HEPA Filters

	NUMBER OF FAILURES							
DATE	3410	3420	3430	**PSF**	325	331	**300 Area**	**Yearly Total**
2010	0	0	1	**1**	N/A	N/A	**N/A**	*1*
2011	0	0	0	**0**	N/A	N/A	**N/A**	*0*
2012	1	0	0	**1**	6	0	**6**	*7*
2013	7	0	0	**7**	5	1	**6**	*13*
2014	1	0	0	**1**	2	0	**2**	*3*
2015	0	0	0	**0**	1	0	**1**	*1*
2016	0	1	0	**1**	1	0	**1**	*2*
2017	0	0	0	**0**	0	0	**0**	*0*
2018	0	0	0	**0**	0	0	**0**	*0*
2019	0	1	0	**1**	0	0	**0**	*1*
TOTAL FOR PNNL CAMPUS:					**28**			

Over the past ten years, the data we have collected has shown interesting results. As shown in Table 5 below, this study has a consistent trend indicating that filters last longer than the 10 year “age limit” set previously and recommended by the U.S. Department of Energy (DOE-HDBK-1169-2003). Our study has observed an 8.163% failure rate among the 49 HEPA filters. Yet, when we extrapolate our search and include all 651 HEPA filters on the PNNL campus, we observe a much lower failure or replacement rate; approximately 4%, as shown in Table 5 below. The larger sample size supports the study’s claim that HEPA filter change outs should be based on an individual performance-based graded approach. This performance-based approach maximizes the lifetime of the filters and it will decrease the cost required to operate nuclear facilities.

Table 5. Percentage rates of total HEPA filter failures per building

PERCENTAGE OF FAILURE								
YEAR	3410	3420	3430	**PSF**	325	331	**300 Area**	**Annual Site Average**
2010	0.0%	0.0%	2.9%	**1.0%**	N/A	N/A	**N/A**	*1.0%*
2011	0.0%	0.0%	0.0%	**0.0%**	N/A	N/A	**N/A**	*0.0%*
2012	5.3%	0.0%	0.0%	**1.0%**	1.4%	0.0%	**1.2%**	*1.1%*
2013	26.9%	0.0%	0.0%	**6.3%**	1.2%	1.1%	**1.1%**	*2.0%*
2014	3.8%	0.0%	0.0%	**0.9%**	0.5%	0.0%	**0.4%**	*0.5%*
2015	0.0%	0.0%	0.0%	**0.0%**	0.2%	0.0%	**0.2%**	*0.2%*
2016	0.0%	2.4%	0.0%	**0.9%**	0.2%	0.0%	**0.2%**	*0.3%*
2017	0.0%	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	*0.0%*
2018	0.0%	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	*0.0%*
2019	0.0%	2.0%	0.0%	**0.9%**	0.0%	0.0%	**0.0%**	*0.2%*
AVERAGE	4.5%	0.5%	0.0%	**1.3%**	0.4%	0.1%	**0.4%**	*0.5%*
3410, 3420, AND 3430 MAKE UP THE PHYSICAL SCIENCE FACILITIES (PSF). 325 AND 331 MAKE UP THE 300 AREA							**Lifetime Average**	*4.3%*

Table 5, as stated previously, depicts the percentages (out of 651 HEPA filters) of HEPA filters that failed, per building. Easily noticeable, the rates are incredibly low. Overall, the yearly failure rate for filters within the study, combined with data from all other available HEPA filters onsite PNNL, is approximately 0.5152%. This percentage is dramatically lower than what we observed in our study. The 3410 Building had the highest failure percentage, which is clearly the dataset outlier. As mentioned after Table 2, the facility doors were left open, allowing dust and unfiltered air into the facility, compromising the air the HEPA filters were designed for. The high value of 26.923% failure rate accounted for 7 total HEPA filter replacements for 2013 in the facility, with only one of the filters in the original 49 HEPA filter study.

The “N/A” values for the 300 Area facilities during 2010 and 2011 are displayed as such because the Vault database (searched in 2020), where the records of the HEPA filters are kept, did not have the required information available for this table, nor did the building operators. This data would have been sent off to long term storage and was not readily retrievable nor would it have been cost effective to retrieve.

This study is concluded by the prediction supported by this evidence that HEPA filters can and will last longer than 10 years in a laboratory setting. The data pertaining to the low failure percentage rates would be even lower if not for the 3410 Building having technical issues which caused personnel to allow unfiltered ambient outdoor air into the facility, causing HEPA failures. We can predict that the performance failure rate is lower, and that HEPA filters would last longer than 10 years.

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 (8.163% of the original 49 filters over the interim 10-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 (DOE-HDBK-1169-2003). This claim is further supported by the 300-area HEPA filter data and additional PSF HEPA filter data that was not originally part of this 10-year study. This conclusion is supported when compared to HEPA filter replacement of all HEPA filters utilized for PNNL operations, both in this study (49 filters in the PSF buildings) and those more recently included (300 Area and additional PSF filters). Studies to observe the tensile strength of the HEPA filter media are underway in a collaboration with the University of Washington. Because there is so little data from other sources suggesting the age limit should be increased or decreased, and the high cost to replace each filter, HEPA filters should instead be evaluated against the aforementioned criteria, and evaluated on a case-by-case graded approach before being replaced, or allowed to maintain normal operation.

6.0 References

American Industrial Hygiene Association (AIHA). 2012. *American National Standard for Laboratory Ventilation*. American Society of Safety Engineers, ANSI/AIHA/ASSE Z9.5-2012, Park Ridge, Illinois.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2017. *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*. ANSI/ASHRAE 52.2-2017, Atlanta, Georgia.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2016. *Method of Testing Performance of Laboratory Fume Hoods*. ANSI/ASHRAE 110-2016, Atlanta, Georgia.

American Society of Mechanical Engineers (ASME). 1994. *Code on Nuclear Air and Gas Treatment*. ASME AG-1-1994 (reaffirmed 2012), Columbus, Ohio.

American Society of Mechanical Engineers (ASME). 2018. *In-Service Testing of Nuclear Air Treatment, Heating, Ventilating, and Air-Conditioning Systems*. ASME N511-2017, New York, New York.

Barnett, J.M. 2018. PNNL Technical Position Document TPD-012: Regulated HEPA Filters. pp. 1–14, PNNL Technical Position Document TPD-012: Regulated HEPA Filters.

Bergman W. 1999. *Maximum HEPA-Filter Life*. Lawrence Livermore National Laboratory, UCLR-AR-134141, Livermore, California.

Colby S. 2013. *In-Place Aerosol Testing of HEPA Filters*. Pacific Northwest National Laboratory, SOP-AIR-BALANCE-03, Richland, Washington.

Robinson K.S., C. Hamblin, R.C. Hodierne, and M.J.S. Smith. 1986. *In-service Aging Effects on HEPA Filters*. Gaseous Effluent Treatment in Nuclear Installations, pp 60-72, Graham and Trotman, London, United Kingdom.

Rohrig D. 2016. *Local Exhaust Ventilation Inspection*. Pacific Northwest National Laboratory, SOP-GEN-OPR-1, Richland, Washington.

U.S. Department of Energy. 2003. *DOE Handbook: Nuclear Air Cleaning Handbook*. DOE-HDBK-1169-2003, Washington, District of Columbia.

U.S. Environmental Protection Agency. 1989. *Methods for Estimating Radionuclide Emissions*. 40 CFR 61, Appendix D, U.S. Government Printing Office, Washington, District of Columbia.

U.S. Environmental Protection Agency. 2009. *Residential Air Cleaners: A Summary of Available Information*. EPA 402-F-09-002, Washington, District of Columbia.

Appendix A – Preventive Maintenance (PM) Numbers

Table 6. Active PM numbers currently in use per building

Building	HEPA Exhaust Filter Testing	Fume Hood
3410	PM1598	PM12827
3420	PM13493	PM12825
3430	PM13949	PM12824
331	PM13471	PM11255
325	PM11715	PM11267
	PM11753	
	PM11754	
	PM11755	
	PM11756	
	PM11762	
	PM11763	
	PM11770	
	PM11771	
	PM11778	
	PM11779	

Table 7. Outdated PM numbers no longer active per building

Building	HEPA Exhaust Filter Testing	Fume Hood
3410	PSF5501	PSF1368
3420	PSF1083	PSF1339
3430	PSF5503	PSF1214/PSF51214
331	PM55020	PM51120
325	PM55440A	PM51900
	PM55481	
	PM55482	
	PM55483	
	PM55484	
	PM55490	
	PM55491	
	PM55500	
	PM55501	
	PM55510	
	PM55511	

Appendix B – Raw Data Original 49 HEPA Filters

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
		3/1/2019	0.30	99.98			12/13/2019	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	
		3/1/2019	0.60	99.98			12/13/2019	100	
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	
		3/1/2019	1.00	99.98			12/13/2019	100	

3410-HVEF-HEPA-1407-1	6/16/2010	0.70	99.98	Listed as 1407	3410-HVE-FH-1407	10/31/2010	125	
	6/30/2011	0.20	99.98			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	
	3/1/2019	0.40	99.98			12/13/2019	105	
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	
	3/1/2019	0.30	99.98			12/13/2019	104	

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	99.98	Listed as 1403	3410-HVE-FH-1403-1			
		0.40	99.98	Listed as 1403A		10/31/2010	125	
	6/30/2011	0.50	99.98					
		0.20	99.98			11/28/2011	121	
	6/27/2012	0.60	99.98					
		0.60	99.98			10/29/2012	118	
	6/19/2013	1.50	99.98					
		1.60	99.98			12/17/2013	118	
	6/27/2014	0.80	99.98					
		0.85	99.98			12/19/2014	119	
	7/1/2015	0.30	99.98					
		0.30	99.98			12/7/2015	120	
	6/1/2016	0.50	99.98					
		0.52	99.98			12/1/2016	99	
	6/29/2017	0.60	99.98					
		0.70	99.98			12/28/2017	119	
	12/18/2018	0.60	99.98					
		0.80	99.98			12/18/2019	117	
	3/1/2019	0.80	99.98			12/13/2019		
		0.80	99.98				114	
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	
	3/1/2019	1.00	99.98	listed 1602-1 and 1602-2		12/13/2019	106	
		1.00	99.98					

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)	<	<

B.2 PSF 3420

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	
	11/22/2019	1.00	99.98			11/22/2019	107	
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	
	11/22/2019	0.50	99.98			11/22/2019	116	
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	
	11/22/2018	0.70	99.98			11/22/2019	118	
3420-HVEF-HEPA-1705-4	7/26/2010	0.20	99.98		3420-HVEF-FH-1705-6	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	
	11/12/2014	0.60	99.98			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	
	11/22/2019	0.70	99.98			11/22/2019	115	
3420-HVEF-HEPA-1707-4	7/26/2010	0.20	99.98		3420-HVEF-FH-1707-5	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	
	11/12/2014	0.70	99.98			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 B.E.		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	
	11/22/2019	0.70	99.98			11/22/2019	102	
3420-HVEF-HEPA-1707-5	7/26/2010	0.20	99.98		3420-HVEF-FH-1707-4	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	
	11/12/2014	0.70	99.98			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 B.E.		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	
	11/22/2019	0.70	99.98			11/22/2019	108	
3420-HVEF-HEPA-1707E	7/26/2010	N/A	N/A		3420-HVEF-FH-1707-6	10/31/2010	115	
	10/18/2011	N/A	N/A			9/9/2011	121	
	11/15/2012	N/A	N/A			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
	11/22/2019	N/A	N/A	not listed		11/22/2019	122	

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	
	11/22/2019	3.80 3.20	99.98 99.98			11/22/2019	N/A	Under construction
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	
	11/22/2019	0.90 0.80	99.98 99.98			11/22/2019	100	
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	99.98			10/1/2011	103	

		0.85	99.98					
	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
	11/22/2019	1.80 1.90	99.98 99.98			11/22/2019	116	
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	
	11/22/2019	0.50 0.50	99.98 99.98			11/22/2019	100	
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	99.98			11/12/2012		Both sides open,

		0.60	99.98				104 / 125	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
	11/22/2019	0.50 0.50	99.98 99.98			11/22/2019	113	

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
	11/22/2019	0.80 1.00	99.98 99.98			11/22/2019	111 105	
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
	11/22/2019	1.10 1.30	99.98 99.98			11/22/2019	111 120	
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 1.32	99.98 99.98			11/1/2016	110 117 107	
	11/28/2017	1.40 1.40	99.98 99.98			11/28/2017	105 110 111	constant volume
	11/30/2018	1.40 1.60	99.98 99.98			11/30/2018	106 103 111	

	11/22/2019	1.40 1.60	99.98 99.98			11/22/2019	103 117 109	
3420-HVEF-HEPA-1700-2/1700-3	7/29/2010	0.30 0.30	99.98 99.98		3420-HVEF-FH-1700-4/1700-6	10/31/2010	120 115	
	10/18/2011	0.30 0.30	99.98 99.98			11/30/2011	125 116	
	11/19/2012	0.20 0.20	99.98 99.98			11/12/2012	125 117	
	11/19/2013	0.80 0.80	99.98 99.98			11/19/2013	122 113	
	11/21/2014	1.00 1.00	99.98 99.98			11/17/2014	119 124	
	11/30/2015	1.10 0.90	99.98 99.98			11/30/2015	111 110	
	11/1/2016	0.74 0.60	99.98 99.98			11/1/2016	119 105	
	11/28/2017	0.90 0.80	99.98 99.98			11/28/2017	105 109	
	11/30/2018	0.80 0.70	99.98 99.98			11/30/2018	112 114	
	11/22/2019	0.80 0.70	99.98 99.98			11/22/2019	106 120	
3420-HVEF-HEPA-1702-2/1702-3	7/29/2010	0.30 0.30	99.98 99.98		3420-HVEF-FH-1702-1/1702-2/1702-3	10/31/2010	120 115 124	
	10/18/2011	0.30 0.30	99.98 99.98			11/30/2011	119 106 115	
	11/19/2012	0.30 0.35	99.98 99.98			11/12/2012	120 110 122	
	11/19/2013	0.40 0.65	99.98 99.98			11/19/2013	121 111 123	
	11/21/2014	0.40 0.45	99.98 99.98			11/17/2014	119 114 123	
	11/30/2015	0.40 0.40	99.98 99.98			11/30/2015	114 105 107	
	11/1/2016	1.08	99.98			11/1/2016	100 108	all are constant volume

		1.27	99.98				111	
	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
	11/22/2019	1.40 1.30	99.98 99.98			11/22/2019	105 102 105	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
	11/22/2019	0.90 1.00	99.98 99.98			11/22/2019	106 108	
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	0.65 0.60	99.98 99.98			11/19/2013	120 125 115	
	11/21/2014					11/17/2014	113	

		0.70	99.98				108	
		0.80	99.98				125	
	11/30/2015					11/30/2015	117	
		0.20	99.98				106	
		0.20	99.98				105	
	11/1/2016					11/1/2016	103	
		1.94	99.98	Δp across damper			124	
		1.98	99.98	Δp across damper			116	
	11/28/2017					11/28/2017	125	
		0.80	99.98				104	
		0.90	99.98				120	
	11/30/2018					11/30/2018	112	
		0.50	99.98				124	All are constant volume
		0.60	99.98				108	
	11/22/2019					11/22/2019	107	
		1.00	99.98				103	
		1.00	99.98				112	
3420-HVEF-HEPA-1705/1705-1	7/29/2010				3420-HVEF-FH-1703C-1/1705-3/1705-4	10/31/2010	115	
		0.40	99.98				110	
		0.40	99.98				115	
	10/18/2011					11/30/2011	115	
		0.70	99.98				120	
		0.80	99.98				125	
	11/19/2012					11/12/2012	101	
		1.00	99.98				125	
		1.00	99.98				125	
	11/19/2013					11/19/2013	116	
		1.00	99.98				117	
		1.10	99.98				123	
	11/21/2014					11/17/2014	107	
		1.60	99.98				125	
		1.60	99.98				111	
	11/30/2015					11/1/2015	111	
		1.02	99.98				120	
		1.50	99.98				120	
	11/1/2016					11/1/2016	116	
		0.86	99.98				N/A	unlisted
		2.22	99.98				N/A	unlisted
	11/28/2017					11/28/2017	124	
		1.20	99.98				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
	11/22/2019	1.20 1.40	99.98 99.98			11/22/2019	109 111 115	All are 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
	11/22/2019	1.00 0.80	99.98 99.98			11/22/2019	106 101	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					11/17/2014	109	

		2.00	99.98				121	
		2.00	99.98				115	
	11/30/2015					11/30/2015	112	
		1.20	99.98				112	
		1.10	99.98				113	
	11/1/2016					11/1/2016	N/A	removed
		1.52	99.98				N/A	removed
		1.08	99.98				N/A	removed
	11/28/2017					11/28/2017	113	
		1.70	99.98				112	
		1.20	99.98				N/A	removed
	11/30/2018					11/30/2018	112	
		1.80	99.98				115	
		1.40	99.98				N/A	removed
	11/22/2019					11/22/2019	114	
		1.80	99.98				109	
		1.50	99.98				N/A	
3420-HVEF-HEPA-1704/1704-1	7/29/2010	0.30	99.98		3420-HVEF-FH-1704-4/1704-5	10/31/2010	123	
		0.20	99.98				125	
	10/18/2011	0.30	99.98			11/30/2011	116	
		0.25	99.98				121	
	11/19/2012	0.30	99.98			11/12/2012	113	
		0.30	99.98				125	
	11/19/2013	0.35	99.98			11/19/2013	121	
		0.40	99.98				124	
	11/21/2014	0.50	99.98			11/17/2014	115	
		0.50	99.98				118	
	11/30/2015	0.60	99.98			11/30/2015	112	
		0.60	99.98				122	
	11/1/2016	1.02	99.98			11/1/2016	100	renamed 1704-6
		1.04	99.98				112	renamed 1704-7
	11/28/2017	1.30	99.98			11/28/2017	N/A	removed
		1.20	99.97				N/A	removed
	11/30/2018	1.20	99.98			11/30/2018	N/A	removed
		1.20	99.98				N/A	removed
	11/22/2019	1.30	99.98			11/22/2019		
		1.20	99.98				N/A	removed
3420-HVEF-HEPA-1705-2/1705-3	7/29/2010	0.25	99.98		3420-HVEF-FH-1705-1/1705-2/1705-7/1705-8	10/31/2010	125	
		0.25	99.98				118	
							121	
							115	
	10/18/2011					11/30/2011	111	
		0.40	99.98				115	

		0.50	99.98				120 112	
	11/19/2012	0.40 0.40	99.98 99.98			11/12/2012	116 121 119 120	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
	11/22/2019	1.60 1.20	99.98 99.98			11/22/2019	105 111 119 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	99.98			11/12/2012	114 113	

		1.20	99.98				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
	11/22/2019	1.00 1.40	99.98 99.98			11/22/2019	103 119 107	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	99.98			11/1/2016	107 120	

		1.47	99.98				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
	11/22/2019	1.10 1.20	99.98 99.92			11/22/2019	123 119 125	constant volume
3420-HVEF-HEPA-1707/1707-1	7/29/2010	0.40 0.35	99.98 99.98		3420-HVEF-FH-1707-1/1709	10/31/2010	108 115	
	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 BE
	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
	11/22/2019	0.20 0.40	99.98 99.98			11/22/2019	109 116	constant volume

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)	<	<		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)	<	<	1/17/2019	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	
	5/15/2019	0.60	99.98			10/31/2019	120	
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	
	5/15/2019	0.3	99.98	New Damper		10/31/2019	100	
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	
	5/15/2019	0.90	99.98			10/31/2019	102	
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	
	5/15/2019	0.80	99.98			10/31/2019	108	
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	
	5/15/2019	0.10	99.98			10/31/2019	104	
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	
	5/15/2019	1.20 1.40	99.98 99.98			10/31/2019	104	
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			10/19/2017		

		N/A	N/A				106	found 87, adjusted
	5/21/2018	N/A N/A	N/A N/A			10/26/2018	102	
	5/15/2019	N/A N/A	N/A N/A			10/31/2019	100	
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-1300-2/1300-3	10/31/2010	108 105	
	5/26/2011	0.70	99.98			11/28/2011	105 101	
	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
	5/15/2019	1.60	99.98			10/31/2019	115 102	
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
	5/15/2019	0.90	99.98			10/31/2019	104 115	
3430-HVEF-HEPA-1308	6/11/2010	0.40	99.98		3430-HVEF-FH-1308-1/1308-3	10/31/2010	104 109	
	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
	5/15/2019	1.30	99.98			10/31/2019	110 113	

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					11/28/2011	103	

		0.40 0.50	99.98 99.98				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
	5/15/2019	0.90 0.80	99.98 99.98			10/31/2019	119 102 100 102	
	6/11/2010	0.70	99.98	Listed as 3501	3430-HVEF-FH-1305/1406	10/31/2010		

3430-HVEF-HEPA-1305-1/1305-2/1406-1/1406-2		0.60 0.60 0.70	99.98 99.98 99.98	Listed as 3502 Listed as 3503 Listed as 3504			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 0.75 0.80 0.90	99.98 99.98 99.98 99.98			10/28/2013	101 122	
	5/28/2014	0.85 0.90 0.90 1.00	99.98 99.98 99.98 99.98			10/27/2014	102 108	
	5/1/2015	0.66 0.69 0.71 0.71	99.98 99.98 99.98 99.98			10/1/2015	104 109	
	5/1/2016	0.60 0.60 0.65 0.70	99.98 99.98 99.98 99.98			10/4/2016	108 104	
	5/22/2017	0.75 0.80 1.40 0.90	99.98 99.98 99.98 99.98			10/19/2017	103 120	
	5/21/2018	0.02 1.10 1.20 1.20	99.98 99.98 99.98 99.98			10/26/2018	109 114	
	5/15/2019	0.90 0.90 1.00 1.10	99.98 99.98 99.98 99.98			10/31/2019	100 118	
3430-HVEF-HEPA-1310/1310A	6/11/2010	0.20	99.98		3430-HVEF-FH-1310-3/1310-4/1310-5	10/31/2010	105 102	

		0.25	99.98				105	
	5/26/2011	0.50 0.50	99.98 99.98			11/28/2011	114 107 105	
	5/31/2012	0.70 0.65	99.97 99.98			11/9/2012	115 100 102	
	5/28/2013	0.70 0.70	99.98 99.98			10/28/2013	105 106 107	
	5/28/2014	0.70 0.70	99.98 99.98			10/27/2014	112 103 123	
	5/1/2015	0.79 0.82	99.98 99.98			10/1/2015	105 102 114	found 94, adjusted
	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	
	5/15/2019	0.90 0.90	99.98 99.98			10/31/2019	100 105 100	
3430-HVEF-HEPA-1500/1500A	6/11/2010	0.70 0.15	99.98 99.98		3430-HVEF-FH-1501-1/1501-2/1503-1	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	
	5/15/2019	0.70 1.10	99.98 99.98			10/31/2019	108 111 107	
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	

	5/15/2019	0.30 0.60	99.98 99.98			10/31/2019	108 110	

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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