Pacific Northwest
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PNNL-35334

Assessment of the 3430 Building Filtered Exhaust Stack Sampling Probe Location

Stack Verification Following Fan and Air Blender Additions

November 2023

Sarah R Suffield
J Matthew Barnett
Julia E Flaherty

U.S. DEPARTMENT OF ENERGY

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

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Pacific Northwest National Laboratory
Richland, Washington 99354

Summary

The Pacific Northwest National Laboratory 3430 Building, which is part of the Physical Sciences Facility, houses radiological capabilities. Emissions monitoring must be conducted for potential radionuclides in the filtered (EP-3430-01-S stack) exhaust air discharge of the building. The air monitoring system is required to conform to Title 40 of the Code of Federal Regulations Part 61 (40 CFR 61) Subpart H, which requires a sampling probe in the exhaust stream to conform to the criteria of American National Standards Institute/Health Physics Society (ANSI/HPS) N13.1-2011, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities*.

Stack verification tests were previously performed and reported by Glissmeyer and Flaherty (2010). However, a third fan was added in April 2023 to augment the effluent capability as a result of expanded laboratory needs in the 3430 Building. Additionally, an air blender was added to the stack duct to provide the necessary mixing needed to meet the stack qualification criteria.

To support the air emissions permit for the 3430 Building, stack testing that used computational fluid dynamics (CFD) modeling as the surrogate stack and verification tests of velocity uniformity and flow angle on the retrofitted facility stack was performed. The ANSI/HPS N13.1-2011 criteria for the air monitoring probe location are that the coefficient of variation (COV) of velocity uniformity, gaseous tracer uniformity, and particulate tracer uniformity must be less than or equal to 20%. Furthermore, no point in the sampling location may have a gaseous tracer concentration that varies from the mean concentration by more than 30%. Additionally, the flow angle at the sampling location must not be more than 20 degrees. As reported by Suffield et al. (2022), CFD modeling of the stack demonstrated that the stack meets the criteria at the probe location.

The velocity uniformity and flow angle results from the 3430 stack verification tests, performed in April 2023, demonstrated that the CFD model results may be used to support the qualification of the stack sampling location. The measured velocity uniformity verification test result was 2.1 %COV. This value is well within the uniformity criterion, which is that the velocity uniformity be ≤20 %COV. Additionally, this value is well within the criterion that the actual stack measurement must be within 5% of the surrogate stack (i.e., CFD modeled stack); in this case the CFD modeled average result of 2.85 %COV for the nominal operating range of 22,800 cfm to 62,400 cfm. Additionally, the measured average flow angle at the 3430 stack monitor location was 5.6 degrees. The result is ≤20 degrees, so the criterion is met.

Based on these stack verification test results, the reconfigured 3430 Building filtered exhaust stack meets the qualification criteria given in the ANSI/HPS N13.1-2011 standard. Further changes to the system configuration or operating conditions that are outside the bounds described in this and the CFD report (Suffield et al. 2022) may require both additional tests and analysis to determine compliance with the standard.

Acknowledgments

This work was supported by Project S804455, 3430 HVAC Redundant Exhaust Fan Installation and Project 98668 Task 06EMEFRA.4 – Emissions and Compliance Studies.

We would like to acknowledge the support of the team of Pacific Northwest National Laboratory Facilities and Infrastructure Operations staff that helped in preparations and execution of these tests. We appreciate Nick Hollenbeck, Blake Yates, and Brad Gerker, who performed the flow angle and velocity traverse measurements that are reported in this document, as well as Nick Minter, the radiation protection technician who supported these tests. Additionally, specific project staff included Brian Greenaway, Steve Gourley, Will Thomas, and Marina Jewell-Ohran. Data and document review by Michael Klein and Ernest Antonio also are acknowledged.

Acronyms and Abbreviations

ANSI	American National Standards Institute
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
cfm	cubic feet per minute
COV	coefficient of variation
DV	hydraulic diameter × mean velocity
EPRP	Environmental Protection and Regulatory Programs
HDI	“How Do I…?”
HPS	Health Physics Society
NQA	National Quality Assurance
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
RAES	Radiological Air Emission Sampling

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1.0 Introduction

The Pacific Northwest National Laboratory (PNNL) 3430 Building, which is part of the Physical Sciences Facility (PSF), houses radiological capabilities. Filtered emissions monitoring must be conducted for potential radionuclides in the exhaust air discharge of this building. The specific emission unit is the EP-3430-01-S (Washington State Department of Health [WDOH] 2022). The air monitoring system is required to conform to Title 40 of the Code of Federal Regulations Part 61 (40 CFR 61) Subpart H, which requires a sampling probe in the exhaust stream to conform to the criteria of American National Standards Institute/Health Physics Society (ANSI/HPS) N13.1-2011, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities*.

Stack verification tests were previously performed and reported by Glissmeyer and Flaherty (2010). However, a third fan was added in April 2023 to augment the effluent capability as a result of expanded laboratory needs in the 3430 Building. Additionally, an air blender was added to the stack duct to provide the necessary mixing needed to meet the stack qualification criteria. These physical changes necessitated a new stack qualification approach that addressed the new stack flow rates and fan geometry and inclusion of the air blender.

This report summarizes the stack monitoring probe location qualification criteria and describes the approach that was taken for the reconfigured 3430 stack. A surrogate stack was used to demonstrate compliance with the qualification criteria, followed by verification tests per ANSI/HPS N13.1-2011. Verification test results and conclusions regarding stack monitoring system compliance with applicable regulations also are reported.

1.1 Qualification Criteria

The qualification criteria for a stack air monitoring probe location are taken from ANSI/HPS N13.1-2011 and are paraphrased as follows:

1. *Uniform Air Velocity* – It is important that the gas velocity across the stack cross-section where the sample is extracted be fairly uniform. Consequently, the velocity is measured at several points in the stack at the position of the sampling nozzle. The uniformity is expressed as the variability of the measurements about the mean. This is expressed using the coefficient of variation (COV), which is the standard deviation divided by the mean and is expressed as a percentage (X %COV). The lower the COV value, the more uniform the velocity. The acceptance criterion is that the COV of the air velocity must be ≤20% across the sampling plane.
2. *Angular Flow* – Sampling nozzles are typically aligned with the axis of the stack. If the air travels up the stack in cyclonic fashion, the air velocity vector approaching a sampling nozzle could be sufficiently misaligned with the nozzle to impair the extraction of particles. Consequently, the flow angle is measured in the duct at the location of the sampling probe. The average air-velocity angle must not deviate from the axis of the duct by more than 20 degrees.

3. *Uniform Concentration of Tracer Gases* – A uniform contaminant concentration in the sampling plane enables the extraction of samples that represent the true concentration within the duct. The uniformity of the concentration is first tested using a tracer gas to represent gaseous effluents. The fan is a good mixer, so injecting the tracer downstream of the fan provides worst-case results. The acceptance criteria are that 1) the COV of the measured tracer gas concentration is ≤20% across the sampling location and 2) at no point in the sampling location does the concentration vary from the mean by >30%.
4. *Uniform Concentration of Tracer Particles* – The second set of tests addressing contaminant concentration uniformity at the sampling position uses tracer particles large enough to exhibit inertial effects. Tracer particles of 10-μm aerodynamic diameter are used by default unless larger contaminant particles are known to be present in the airstream. The acceptance criterion is that the COV of particle concentration is ≤20% across the sampling location.

Section 5.2.2.2 of the ANSI/HPS N13.1-2011 standard defines additional criteria for applying the results of tests performed on a surrogate stack for the actual building stack. In 2022, the Washington State Department of Health authorized a one-time alternate approval allowing the surrogate stack evaluation to be conducted by computational fluid dynamics (CFD) modeling. A summary of the criteria as applicable for the 3430 Building stack follows:

- The surrogate stack and its sampling location must be geometrically similar to the actual 3430 Building Filtered Exhaust Stack.
- The product of the hydraulic diameter and the mean velocity (DV) of the surrogate stack must be within a factor of six of the DV for the actual 3430 Building Filtered Exhaust Stack. The DV requirement can be expressed as:

1/6 DV of surrogate (CFD) model stack ≤ DV of full-scale stack ≤ 6 DV of surrogate (CFD) model stack.

- The Reynolds number for the surrogate and actual stacks both must be >10,000.

The surrogate stack results are considered valid if the following are shown by testing on the actual stack:

- The velocity uniformity (%COV) in the actual 3430 Building stack meets the uniformity criterion of 20 %COV.
- The velocity uniformity values for the surrogate and actual stacks agree to within 5%.
- The flow angle criterion (≤20 degrees) is met on the actual 3430 Building stack.

2.0 Stack Qualification Strategy

The 3430 Building stack (i.e., emission unit EP-3430-01-S) qualification strategy relies on a full suite of stack qualification tests performed *in silico* to serve as the surrogate stack. Verification tests performed on the actual stack are therefore necessary to determine whether the surrogate stack test results are considered valid. As reported in Suffield et al. (2022), the 3430 Building stack with the additional fan (Fan 3) and static air blender was modeled with the CFD model STAR-CCM+ (Siemens 2021) to evaluate the flow angle, velocity uniformity, gaseous tracer uniformity, and particulate tracer uniformity at the stack sampling location. Several operating conditions (varying flow rates and operating fans) were considered. A schematic of the 3430 Building stack is shown in Figure 1.

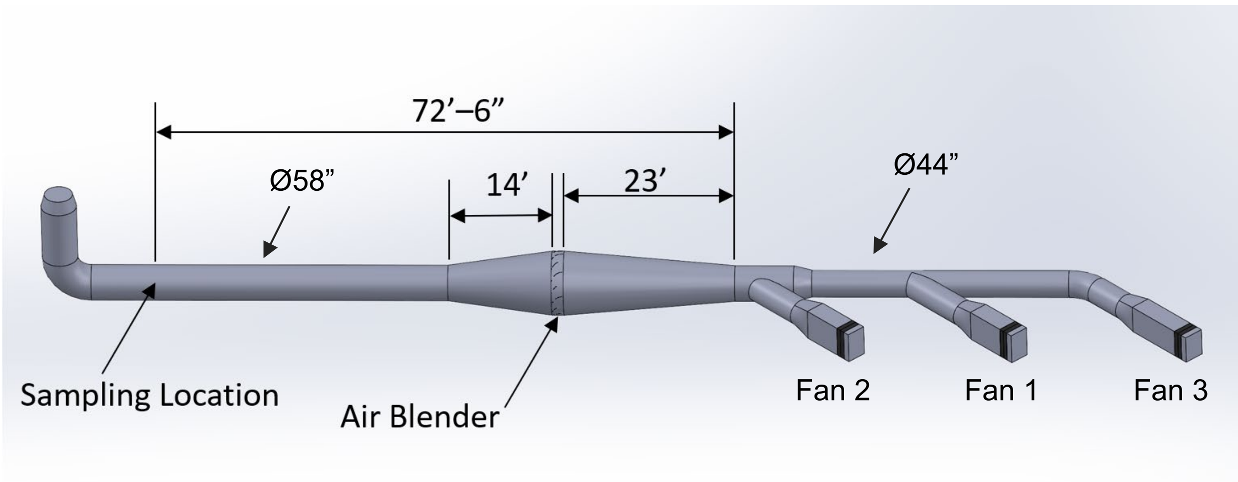


Figure 1. Schematic of the 3430 Building Exhaust System with the Additional Fan (Fan 3) and Static Air Blender

Since the CFD model was a computational model of the stack at full physical scale, the surrogate CFD model and the actual 3430 Building stack are geometrically similar. This first criterion from Section 5.2.2.2 of ANSI/HPS N13.1-2011 for applying the results from a surrogate stack is therefore met. The remaining criteria rely on calculations of DV and Reynolds numbers. Table 1 shows calculations of the acceptable range of the hydraulic diameter (which is equal to the physical diameter for a circular duct) × velocity criterion that determines the applicability of the surrogate stack (CFD model) results to the actual stack. The product of hydraulic diameter and mean velocity from the verification test conditions (38,168 cubic feet per minute [cfm]; DV = 10,053) was within the acceptable factor of six of the surrogate model's DV product. Numerous flow rates and fan combinations were investigated with the CFD model, and Table 1 includes two of the most similar flow conditions to the 38,100 cfm test flow . The CFD cases with Fans 2 and 3 at 22,800 cfm (V=1,243 ft/min) and 62,400 cfm (V=3,401 ft/min) are included in Table 1. The DV range listed for each of these CFD cases encompasses the DV value from the verification test (10,053 ft^2/min); therefore, the verification test meets the DV criterion from the standard. The tested nominal flow rate is expected to increase toward 62,400 cfm over time as building operations grow to the new capacity. Table 1 also includes the Reynolds number for the surrogate (CFD) tests and the building stack verification test. In all cases, the Reynolds numbers are greater than 10,000, which is another criterion for applying the surrogate stack results to the building stack. With this, all three criteria listed in Section 5.2.2.2 of N13.1-2011 for the use of a surrogate stack have been met.

Table 1. Verification Test Comparison with Ranges of Acceptable Diameter × Velocity Values and Reynolds Numbers

Stack	Diameter (in.)	Configuration	Mean Velocity (ft/min)	D × V (ft^2/min)	1/6 - 6 (D×V)	Reynolds Number
3430 Stack	58	Fans 2 & 3	2,080	10,053	-	1.03E+06
CFD Model	58	Fans 2 & 3	1,243	6,006	1,001 – 36,037	6.18E+05
CFD Model	58	Fans 2 & 3	3,401	16,438	2,740 – 98,628	1.69E+06

2.1 Testing Methods

The testing methods for the verification tests conducted at the 3430 Building stack are described in this section. As described in Chapter 1, only the flow angle and velocity uniformity tests are required on the actual stack to demonstrate the validity of the full suite of surrogate stack results. Tracer testing on the actual stack is not required. Figure 2 is a photograph of the new 3430 duct with the reducer, located downstream of the blender, on the far right of the image. The stack verification port is located at the same longitudinal position as the weather-proof enclosure visible in Figure 2.

Figure 2. Photograph of the 3430 Building Exhaust Stack System

Figure 3 shows the portion of the duct where the air blender is installed to provide a perspective for the duct expansion upstream and reduction downstream of the air blender. The air blender is located within the matte grey section of duct.

Figure 3. Photograph of Duct of the 3430 Building Exhaust System with Air Blender Installed (matte grey section with a support stanchion)

PNNL Air Balance staff performed the velocity uniformity measurements following PNNL Environmental Protection and Regulatory Programs (EPRP) procedure EPRP-AIR-016, Rev 8. The procedure follows the guidance provided in 40 CFR 60, Appendix A, Method 1. The PNNL procedure requires the use of standard pitot tube, manometer (or magnehelic gauge), and calibrated temperature gauge to measure the pressure within the stack at 10 discrete measurement points across the stack diameter. Two duct diameter traverses, 90 degrees apart, were measured through a side port and a top port in the duct. The pressure values were converted to velocity values based on equations provided in 40 CFR 60, Appendix A, Method 2, to compute the velocity uniformity across the stack cross section.

PNNL Air Balance staff also performed the flow angle measurements following PNNL procedure EPRP-AIR-017, Rev 7. For this procedure, a Type-S pitot tube is used with an angle meter and a manometer (or magnehelic gauge). The angle of the stack flow was measured at 10 discrete measurement points across one of the two stack diameters (through the side port). Due to instrument limitations, measurements were not possible from the top port. These flow angle values were used directly to compute the average flow angle across the stack diameter.

Figure 4 is a schematic that illustrates the positions of the 10 discrete measurement points used for the velocity uniformity and flow angle measurements. An error was made in the calculation of the traverse point positions, so there was an approximate 3% difference in the traverse point positions compared with the correct positions. As a result, points 1 through 5 are not at the same distances as points 6 through 10 (shown in Figure 4 as two separate sets of concentric circles with differing dash types). This does not impact the test results, as is confirmed by the comparison between the traverse data and MASS-tron II mass flow transmitter (FIT [Air Monitor Corporation, Santa Rosa, CA]) readout which is within 5 to 9% (i.e., the criterion is that the FIT reading must be within 10% of the velocity traverse measurement for the annual traverse to be acceptable [40 CFR 60, Appendix A, Methods 1]).

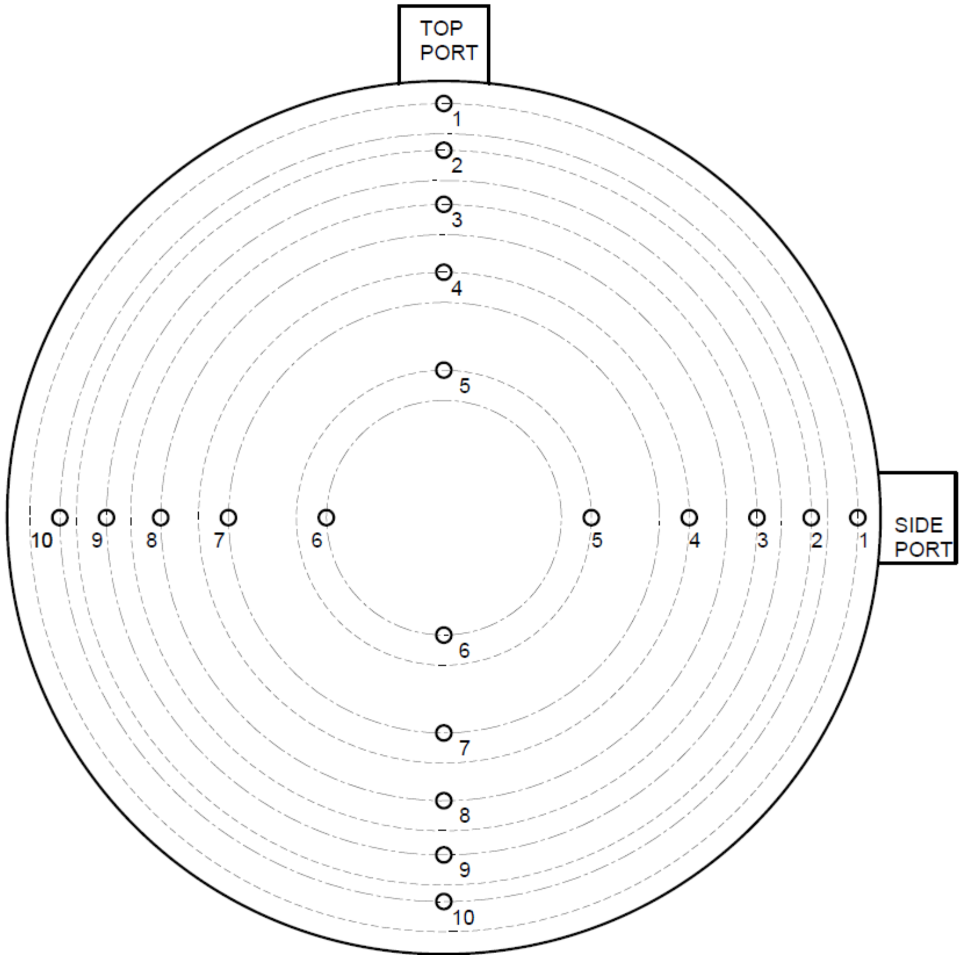


Figure 4. Cross-Section of the Duct at the Test Port with Measurement Points

2.2 Quality Assurance Approach

The PNNL Quality Assurance (QA) Program is based on the requirements as defined in the U.S. Department of Energy Order 414.1C, Quality Assurance, and 10 CFR 830, Energy/Nuclear Safety Management, Subpart A – Quality Assurance Requirements (a.k.a., the Quality Rule). PNNL has chosen to implement the following consensus standards in a graded approach for this work:

- American Society of Mechanical Engineers National Quality Assurance (NQA)-1-2000, Quality Assurance Requirements for Nuclear Facility Applications, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- American Society of Mechanical Engineers NQA-1-2000, Part IV, Subpart 4.2, Graded Approach Application of Quality Assurance Requirements for Research and Development.

The procedures necessary to implement the requirements are documented in PNNL's standards-based management system called "How Do I…" (HDI)..[1]

The PNNL Effluent Management group follows a documented Quality Assurance Plan (Barnett 2022) that outlines more detailed elements of this QA approach. Additionally, the use of spreadsheets to calculate quantities that are reported in this document have followed the *Spreadsheet Utility Calculations* procedure (EPRP-ADMIN-014) developed by the PNNL Effluent Management group.

[1] HDI is a web-based system used at PNNL to manage the delivery of laboratory-level policies, requirements, and procedures.

3.0 Stack Verification Results

Stack verification tests were performed by the PNNL Air Balance staff according to procedures used for collecting velocity uniformity and flow angle measurements as described in Section 2.1. Velocity uniformity tests were conducted with a standard pitot tube, a manometer to measure pressure, and a thermocouple to measure the temperature in the stack. The raw measurements collected by this method were in differential pressure units (inches of water). These measurements were converted to the velocity values needed to compute the velocity uniformity and estimate the mean velocity across the duct cross section.

The air balance procedure specifies 10 measurement points across the diameter of the duct, and two duct traverses, 90 degrees apart, are measured to collect from a total 20 discrete measurement positions. However, the center two-thirds of the stack area, which is used for the velocity uniformity calculation, uses points 3 through 9 of the 10 points total in each traverse. A single test with three replicates of each of the two 90-degree separated traverses was conducted for this stack verification measurement. The result of this test was a velocity uniformity of 2.1 %COV.

The air balance procedure used to collect cyclonic flow, or flow angle measurements, specifies 10 measurement points across the diameter of the duct. Because of equipment limitations, only a horizontal traverse was measured for this test, and only one traverse replicate was performed. In this instance, all 10 traverse points were used in the calculation of the mean flow angle across the duct. The result of this test was a mean flow angle of 5.6 degrees. The flow angle and velocity uniformity test results are summarized in Table 2.

Table 2. Velocity Uniformity and Flow Angle Results from the 3430 Building Stack

Operating Fans	Average Stack Flow Rate (standard ft^3/min)	Flow Angle (degrees)	Velocity Uniformity (%COV)
2, 3	38,200	5.6	2.1

Appendix A contains the data sheets for the cyclonic flow and the velocity traverse measurements data sets. It also shows the data for the velocity uniformity %COV. The data sheets show traverse point distances from the entrance across the duct for a 56-in duct diameter rather than the actual 58-in duct diameter. As noted in the data sheets, this results in an error of less than 3.5% between the 56-in and what should have been the actual traverse points for the 58-in duct diameter. Because of the small error and utilization of the center 2/3rds area for the %COV determination, the traverse points and test results were accepted.

4.0 Conclusions

To support the air emissions permit for the 3430 Building stack, CFD modeling was used for the surrogate stack and verification tests of velocity uniformity and flow angle on the retrofitted facility stack were performed. As was described in Section 1.1, the ANSI/HPS N13.1-2011 criteria for the air monitoring probe location are that velocity uniformity, gaseous tracer uniformity, and particulate tracer uniformity must be less than or equal to 20 %COV. Furthermore, no point in the sampling location may have a gaseous tracer concentration that varies from the mean concentration by more than 30%. Additionally, the flow angle at the sampling location must not be more than 20 degrees. The CFD modeling of the stack, as reported by Suffield et al. (2022) demonstrated that the retrofitted stack meets the criteria at the probe location.

The velocity uniformity and flow angle test results from the surrogate stack are key factors in the applicability of the surrogate stack results to the actual facility stack. Table 3 lists the results of velocity uniformity from the CFD model with two operating fans and with three operating fans (Suffield et al. 2022). Although the current testing condition uses two fans, the results from the conditions with three operating fans are included because it shows that three fan operations are equally sufficient.

Table 3. Velocity Uniformity and Flow Angle Results from the 3430 CFD Model with Both Two and Three Fans in Operation, and Actual Stack Verification Test Results. CFD rows adapted from Suffield et al. 2022.

Stack	Operating Fans	Stack Flow Rate (ft^3/min)	Flow Angle (degrees)	Velocity Uniformity (%COV)
CFD	1, 2, 3	93,600	6.7	2.1
CFD	1, 2, 3	34,200	9.0	2.1
CFD	2, 3	62,400	13.4	3.8
CFD	2, 3	22,800	13.8	3.8
Actual	2, 3	38,200	5.6	2.1

Broadly, the average velocity uniformity (%COV) results from the CFD model were 2.74 %COV for a flow rate range from 11,400 to 114,000 cfm (not all results shown in Table 3). Within a flow rate range from 22,800 to 64,400 cfm, the velocity uniformity was slightly higher at 2.85 %COV. The flow angle results varied from 5.6-17.3 degrees for all CFD cases, with an average flow angle of 11.3 degrees. The CFD results indicate that the velocity uniformity results and the flow angle results are relatively insensitive to stack flow or operating fan configuration, as the numerical results do not demonstrate a trend with flow or fan configuration, and the spread in the results are relatively small, particularly for the velocity uniformity (3 %COV; 12 degrees for flow angle).

The velocity uniformity and flow angle results from the 3430 Building stack verification tests, performed in April 2023 are listed in the last row of Table 3. The measured velocity uniformity verification test result was 2.1 %COV. This value is well within the uniformity criterion of ≤20 %COV. Additionally, this value is well within the criterion that the actual stack measurement must be within 5% of the surrogate stack result of 2.74 %COV for the CFD model.

Additionally, the measured average flow angle at the 3430 Building stack monitor location was 5.6 degrees. The CFD modeling predicted higher flow angles, indicating that the CFD model is conservative. Both the measured and CFD flow angles are ≤20 degrees, so the criterion is met.

Based on these stack verification test results, the reconfigured 3430 Building filtered exhaust stack meets the qualification criteria provided in the ANSI/HPS N13.1-2011 standard. Further changes to the system configuration or operating conditions that are outside the bounds described in this and the CFD report (Suffield et al. 2022) may require additional tests and additional analysis to determine compliance with the standard.

5.0 References

10 CFR 830, Subpart A. 2008. "Quality Assurance Requirements." *U.S. Code of Federal Regulations*, U.S. Department of Energy.

40 CFR 60, Appendix A, Method 1. 2008. "Sample and Velocity Traverses for Stationary Sources." *U.S. Code of Federal Regulations,* U.S. Environmental Protection Agency.

40 CFR 60, Appendix A, Method 2, as amended. "Method 2 – Determination of Stack Gas Velocity and Volumetric Flow Rate." *U.S. Code of Federal Regulations*. U.S. Environmental Protection Agency.

40 CFR 61, Subpart H. 2002. "National Emission Standard for Emissions of Radionuclides other than Radon from Department of Energy Facilities." *U.S. Code of Federal Regulations,* U.S. Environmental Protection Agency.

ASME—American Society of Mechanical Engineers. 2000a. NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part 1, "Requirements for Quality Assurance Programs for Nuclear Facilities." New York, New York.

ASME—American Society of Mechanical Engineers. 2000c. NQA-1-2000, Part IV, Subpart 4.2, "Graded Approach Application of Quality Assurance Requirements for Research and Development." New York, New York.

ANSI/HPS—American National Standards Institute/Health Physical Society. 2011.[2] *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities.* N13.1-2011. Health Physics Society, McLean, Virginia.

Barnett JM. 2022. *Pacific Northwest National Laboratory Effluent Management Quality Assurance Plan*. EM-QA-01, Rev 11, Pacific Northwest National Laboratory, Richland, Washington.

DOE Order 414.1C. *Quality Assurance*. U.S. Department of Energy, Washington, D.C.

Glissmeyer JA and JE Flaherty. 2010. *Assessment of the 3430 Building Filtered Exhaust Stack Sampling Probe Location*. PNNL-19262, RPT-STMON-002, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Pacific Northwest National Laboratory. 2021. *PNNL Stack/Duct Velocity Traverse Method.* EPRP-AIR-016, Rev 8, Richland, Washington.

Pacific Northwest National Laboratory. 2019. *Spreadsheet Utility Calculations*. EPRP-ADMIN-014, Rev 7, Richland, Washington.

Pacific Northwest National Laboratory. 2020. *Verification of Absence of Cyclonic Flow Conditions in Stack and Vents.* EPRP-AIR-017, Rev 7, Richland, Washington.

[2] The standard was reaffirmed in 2011 and is essentially identical to the 1999 version. The standard was revised in 2021 and incorporates CFD modeling as a tool but is not incorporated into regulations.

Siemens PLM Software. 2021. STAR-CCM+16.02.009 *User Guide*. Siemens PLM Software, Plano, Texas.

Suffield SR, Barnett JM, and SE Gourley. 2022. *Qualification of ANSI/HPS N13.1-2011 Mixing Criteria by Computational Fluid Dynamics Modeling for the 3430 Building Fan Addition and Increased Ventilation Capacity*. PNNL-32393, Rev. 1, Pacific Northwest National Laboratory, Richland, Washington.

Washington State Department of Health. 2022. Letter from John Martell, WDOH, to Roger Snyder, Pacific Northwest Site Office, dated October 7, 2022. Approval of Notice of Construction (NOC) 1675 for the Ultra-Trace Laboratory (3430 Building). AIR 22-1002, Richland, Washington.

Appendix A – Data Sheets

This appendix contains the data sheets that resulted from the verification tests performed at the stack sampling probe location of the retrofitted 3430 Building stack. Figure A.1 is the completed cyclonic flow datasheet per the EPRP-AIR-017 Rev 7 procedure. The average yaw angle, 5.60 degrees, is calculated near the bottom of the data table.

Cyclonic Flow Datasheet

Date and Time:	4/4/2023 @ 1024	Traverse Point:	EP-3430-01-1
Pitot Type:	Type-S	Pitot Tube Identification No.:	87 exp 2/2024
Manometer Cal Expiration Date:	11/18/2023	Manometer Type/Code No:	#17

Traverse Point	Distance from Port Entrance (in.)	A Port Traverse (yaw angle)	Traverse Point	Distance from Port Entrance (in.)	B Port Traverse (yaw angle)
1	1.5	5	1	1.5	N/A
2	4.8	5	2	4.8	N/A
3	8.2	3	3	8.2	N/A
4	12.7	2	4	12.7	N/A
5	19.2	1	5	19.2	N/A
6	36.8	6	6	36.8	N/A
7	43.3	7	7	43.3	N/A
8	47.8	8	8	47.8	N/A
9	51.4	9	9	51.4	N/A
10	54.5	10	10	54.5	N/A

# of Traverse Pts	Sum of A	Sum of A & B	Sum of B
10	56	N/A	N/A

Average Yaw Angle	5.60	Acceptable
		Yes

If the Average Yaw Angle is <=20 the traverse location is acceptable

Comments:

Completed by (print and sign): Nick Hollenbeck Date: 4/4/2023

Effluent Management Review: JM Barnett / JM Barnett Date: 4/14/2023

Cyclonic Flow Version 1.2
Microsoft® Excel® for Microsoft 365 MSO (Version 2208 Build 16.0.15601.20540) 64-bit

Figure A.1.The 3420 Stack Cyclonic Flow Datasheet

Figure A.2 is the completed velocity traverse data form that is a result of data collected in the *Stack Velocity Traverse* data sheet completed per the EPR-AIR-016 Rev. 8 procedure. In this case, the procedure collects pressure velocity values, and the data sheet included as these values were converted to velocity values in Figure A.2. The result of this test, 2.1 %COV within the center two-thirds of the stack area, is listed at the bottom right of the table near the center of the sheet.

VELOCITY TRAVERSE DATA FORM

Stack	**3430**	Run No.	**VT-1**	
Date	**4/4/23**	Fan Configuration	**FANS 2/3**	
Testers	Nick Hollenbeck, Blake Yates, Brad Gerk	Fan Setting	**76 %**	
Stack Dia.	58 in.	Stack Temp	62.8 deg F	
Stack X-Area	2642.1 in.2	Start/End Time	08:43/09:52	
Test Port	nearest to probe	Center 2/3 from	5.32	to: 52.68
Distance to disturbance	35.5 ft	Points in Center 2/3	3	to: 9
Velocity units	ft/min			

Order -->		1st				2nd			
Traverse-->		Side (Port A)				Top (Port B)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.5	2023	1984	2099	2035.4	1976	1903	1940	1939.8
2	4.6	2219	2103	2158	2160.0	1976	2027	1964	1989.0
3	8.2	2205	2215	2169	2196.4	2019	2129	2147	2098.4
4	12.7	2107	2136	2065	2102.7	2058	2008	2073	2046.0
5	19.2	2073	2095	2158	2108.8	2035	1992	2069	2031.9
6	36.8	2069	2110	2069	2082.8	2042	2162	2054	2086.0
7	43.3	2069	2095	2088	2084.2	2158	2158	2158	2158.1
8	47.8	2158	2154	2069	2127.2	2061	2154	2118	2111.2
9	51.4	1996	2069	2069	2044.6	2027	2136	2144	2102.2
10	54.5	2069	2054	2039	2053.8	2095	1836	2208	2046.7
Averages ---------->		2098.8	2101.7	2098.3	2099.6	2044.8	2050.5	2087.5	2060.9

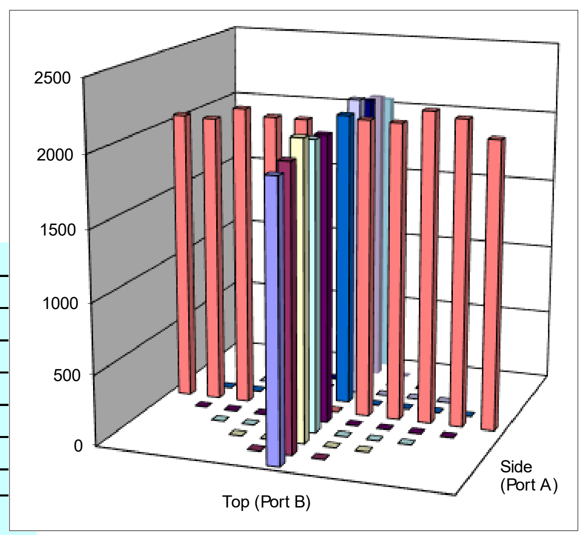
All	ft/min	Dev. from mean	***Center 2/3***	Side	Top	All
Mean	2080.3		Mean	2106.7	2090.6	2098.6
Min Point	1939.8	-6.8%	Std. Dev.	47.3	42.1	43.8
Max Point	2196.4	5.6%	COV as %	2.2	2.0	**2.1**

Flow 38168 cfm

Vel Avg 2080 fpm

Instuments Used:	Cal Due Dat
Standard Pitot Tube #83	02/01/24
ADM Manometer #93	09/01/24
N/A	

	Start	Finish	
Stack temp	62.2	62.8	F
Equipment temp	N/A	N/A	F
Ambient temp	44	44	F
Stack static	0.565	0.598	in H2O
Ambient pressure	29.6	29.6	in Hg
Total Stack pressure	29.64	29.64	in Hg
Ambient humidity	N/A	N/A	RH



Notes:

No center point measurements are collected, as it is not required based on procedure.

CFD Avg all (11.4-114 k) COV: 2.74

CFD Avg Nominal COV (22.8-64.4 k): 2.85

CFD Max (22.8 K) COV (3.90)

System passes if COV is 0 - 7.85 (up to 8.90).

Entries made by:	Matthew Barnett	Technical Data Review performed by:	Michael Klein
Signature/date	4/4/2023	Signature/date	6/22/2023

Figure A.2.The 3430 Velocity Uniformity Datasheet

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