U.S. DEPARTMENT OF ENERGY

PNNL-19262
RPT-STMON-002, Rev. 0

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

Assessment of the Building 3430 Filtered Exhaust Stack Sampling Probe Location

JA Glissmeyer

April 2010

Pacific Northwest NATIONAL LABORATORY

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Richland, Washington 99352

Completeness of Testing

This report describes the results of work and testing specified by test plan TP-STMON-001. The work and any associated testing followed the quality assurance requirements outlined in the test specification/plan. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Test plan results are reported. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.

Approved:

John A. Glissmeyer (signature) — Feb. 17, 2010

John A. Glissmeyer
Stack Monitoring Project Manager

Date

Summary

Pacific Northwest National Laboratory performed a demonstration to determine the acceptable location in which to place an air sampling probe for emissions monitoring for radionuclides in the exhaust air discharge from the new 3430 Building Filtered Exhaust Stack. The method was to adopt the results of a previously performed test series for a system of similar configuration, followed by a partial test on the actual system to verify the applicability of previously performed tests. The qualification criteria included 1) a uniform air velocity, 2) an average flow angle that does not deviate from the axis of the duct by more than 20°, 3) a uniform concentration of tracer gases, and 4) a uniform concentration of tracer particles.

Section 1 provides background information for the demonstration, and Section 2 describes the test strategy, including the criteria for the applicability of model results and the test matrix. Section 3 describes the flow angle test and the velocity uniformity test, Section 4 provides the test results, and Section 5 provides the conclusions. Appendix A includes the test data sheets, and Appendix B gives applicable qualification results from the previously tested model stack.

The data from the previously tested and similarly designed stack was demonstrated to be applicable to the current design for the 3430 Building Filtered Exhaust stack. Therefore, this new system also meets the qualification criteria given in the ANSI/HPS N13.1 standard. Changes to the system configuration or operations outside of the bounds of this report (e.g., exhaust velocity increases, relocation of sample probe) will require retesting/reevaluation to determine compliance to the requirements.

Acronyms

acfm	actual cubic feet per minute
AD	aerodynamic diameter
ANSI	American National Standards Institute
CFR	Code of Federal Regulations
COV	coefficient of variance
D	duct diameter
DOE	U.S. Department of Energy
DV	product of duct diameter times mean air velocity
EPA	U.S. Environmental Protection Agency
HDI	“How Do I…?”
HPS	Health Physics Society
NQA	Nuclear Quality Assurance
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
R&D	Research and Development
scfm	standard cubic feet per minute
STMON	Stack Monitoring Project

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1.0 Introduction

Pacific Northwest National Laboratory (PNNL) determined that emissions monitoring must be conducted for radionuclides in the exhaust air discharge from the new 3430 Building. The performance of the air monitoring system must conform to the applicable federal regulations (40 CFR 61, Subpart H). This regulation requires that a sampling probe be located in the Building 3430 Filtered Exhaust stack according to the criteria of the American National Standards Institute/Health Physical Society (ANSI/HPS 1999). This standard requires that a series of tests be performed to demonstrate the acceptability of the location of the air sampling probe in the system. The test series includes flow angle, velocity uniformity, gas tracer uniformity, and particle tracer uniformity as measured in the stack cross section at the sampling probe nozzle location.

A facility may choose to perform the demonstration using one of the following three approaches:

1. Perform the full test series on the actual exhaust system.
2. Perform the full test series of a scale model of the exhaust system, followed by a partial test of the actual exhaust system to verify the validity of the model results.
3. Adopt the results of a previously performed test series for a system of similar configuration, followed by a partial test on the actual system to verify the applicability of the previously performed tests.

It was the last approach that was selected to be used for this facility. Consequently, a limited series of tests were performed on the actual exhaust system, and the results were compared to those of the previously tested system. This report describes the tests performed on the actual system and also presents the results from the previously tested system that serves as the basis for compliance with the standard as concerns the location of the sampling probe.

The tests conducted by PNNL during January 2010 on the 3430 Building filtered air exhaust system are described within this report. The test results indicate that the proposed air sampling location meets the criteria of the standard.

1.1 Qualification Criteria

The qualification criteria for a stack air monitoring probe location are taken from ANSI/HPS N13.1-1999 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),[(a)] which is the standard deviation divided by the mean and expressed as a percentage. 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.

(a) *Coefficient of variation* is considered "dated" terminology. The modern terminology is *percent relative standard deviation*. However, because the standard uses the older terminology, it will likewise be used here.

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 proposed location of the sampling probe. The average air-velocity angle must not deviate from the axis of the duct by more than 20°.

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 (AD) are used by default unless it is known that larger contaminant particles will be present in the airstream. The acceptance criterion is that the COV of particle concentration is ≤ 20% across the sampling location.

It was determined that compliance with these criteria was already demonstrated for a similar stack configuration by testing a scale model as reported by Glissmeyer and Droppo (2007).

To be able to apply the results of the scale model tests, Section 5.2.2.2 of the ANSI/HPS N13.1-1999 standard sets additional criteria for applying the results as a substitute for the actual Building 3430 Filtered Exhaust stack.

- The scale model and its sampling location must be geometrically similar to the actual Building 3430 Filtered Exhaust stack.
- The product (mean velocity) × (hydraulic diameter) for the scale model must be within a factor of six of the product for the actual Building 3430 Filtered Exhaust stack.
- The Reynolds number for the actual and model stacks must be > 10,000.

The scale-model results are considered valid if it is shown by testing, on the actual stacks, that:

- The velocity profile in the actual Building 3430 Filtered Exhaust stack meets the uniformity criterion.
- The velocity uniformity COV values for the actual and model stacks agree within 5% COV.
- The flow angle criterion (with a mean value less than or equal to 20°) is met.

1.2 Building 3430 Filtered Exhaust Stack Configuration

Figure 1.1 shows a crude plan view of the Building 3430 Filtered Exhaust stack on the roof of the 3430 Building. Figure 1.2 shows the scale model stack (designated HV-C2) tested by Glissmeyer and Droppo (2007).

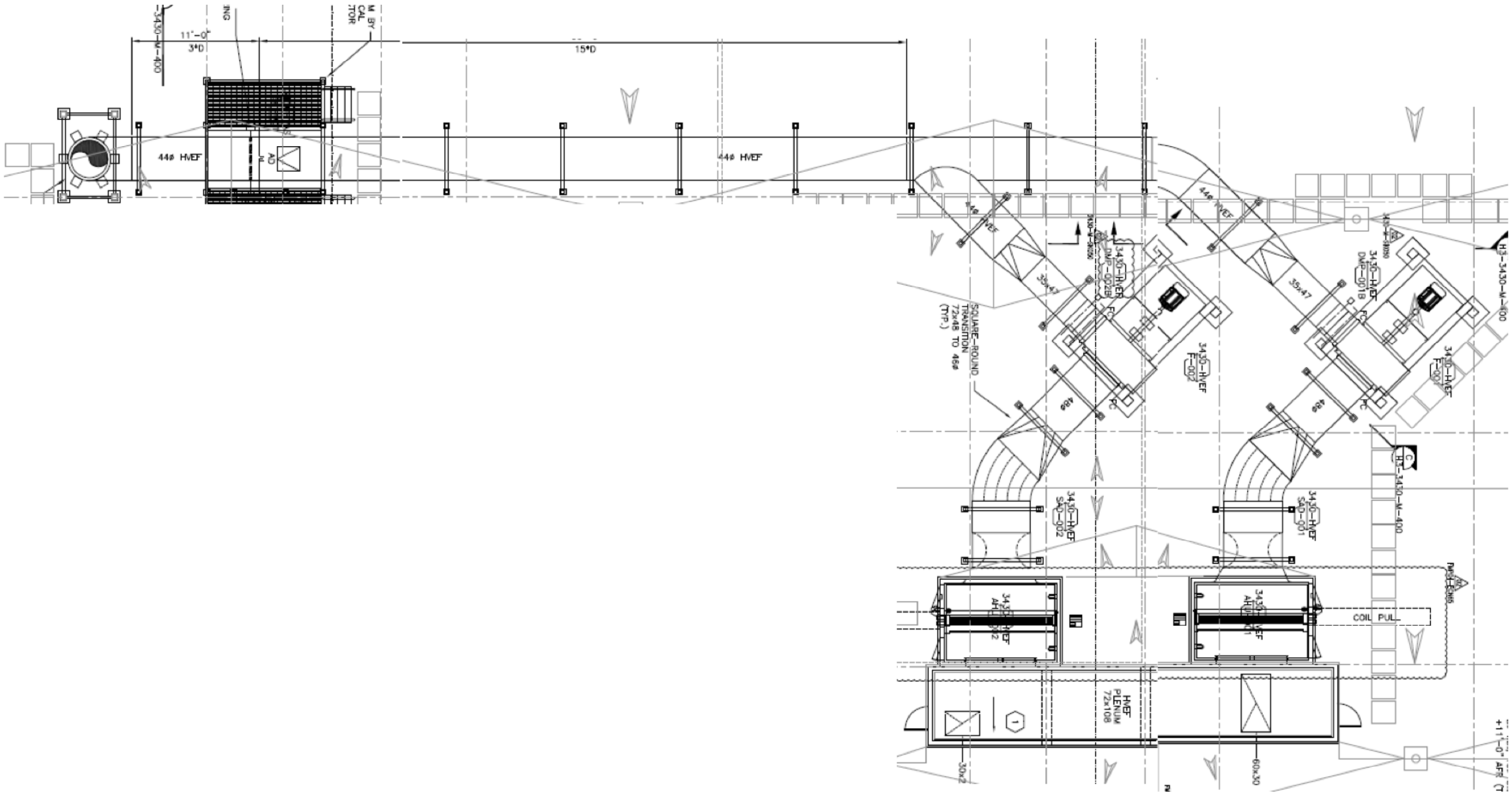

Figure 1.1. Plan View of 3430 Building Filtered Exhaust Stack

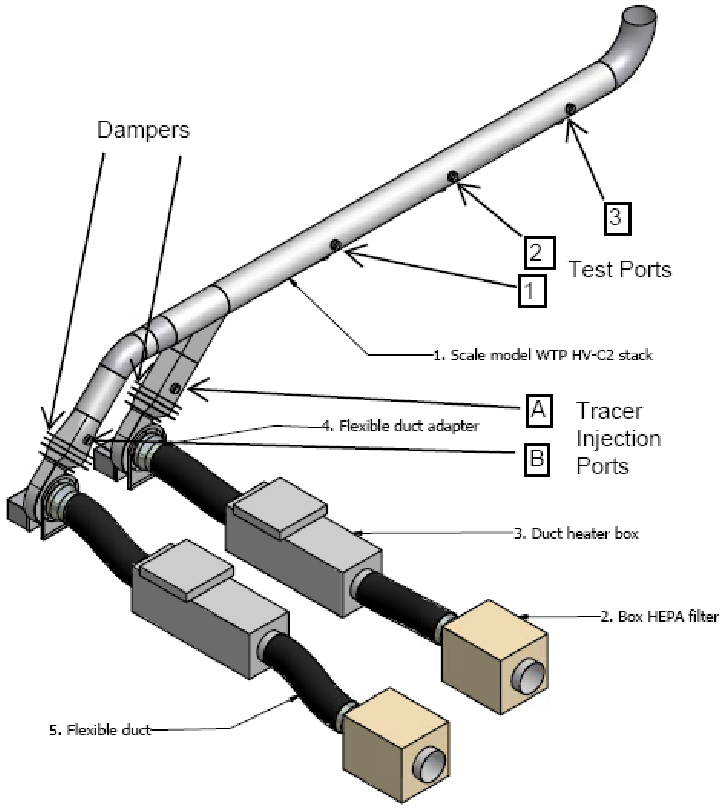

Figure 1.2. Scale Model Tested by Glissmeyer and Droppo (2007)

The difference between the two designs is that the model stack (except for the bend upwards at the discharge end) is rotated 90° around its long axis so that the air from the fans enters the straight section from the side rather than from the bottom. This should have no effect on the uniformity of tracers and the air velocity uniformity and flow angles. The model stack was tested with one and both fans operating, which covers the possible operating modes.

Figure 1.3 is a diagram of the discharge end of the 3430 Building Filtered Exhaust system. Both fans draw air from the same plenum; therefore, the air flow from both fans is from the same stream.

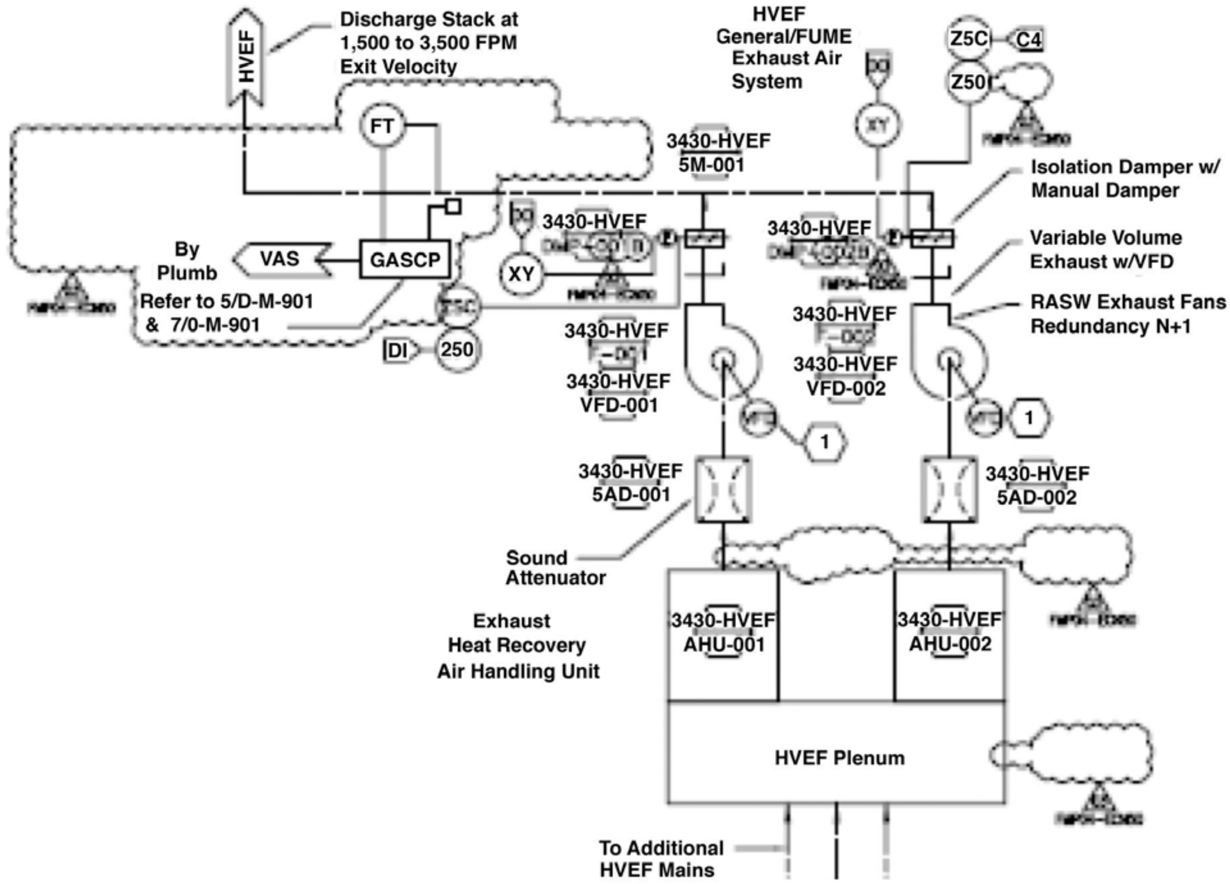

Figure 1.3. 3430 Building Filtered Exhaust Diagram

Table 1.1 lists key dimensional and flow parameters for both the model stack and the 3430 Building Filtered Exhaust stack.

Table 1.1. Comparative Stack Dimensions

Operating Parameters	Model	Bldg. 3430
Duct diameter at sampling probe	12 in.	43.75 in.
Number of duct diameters from upstream duct junction to sampling probe or test ports	Port 2—9.4 Port 3—14.5	20.4
Number of duct diameters from sampling probe or test ports to downstream bend	Port 3—2.25	3
Discharge diameter	12 in.	38 in.
Number of operating fans	1 and 2	2
Total available fans	2	2

2.0 Test Strategy

2.1 Criteria for Applicability of Model Results

The velocity uniformity test results from the model stack are a factor in the formulation of one of the criteria for the applicability of the model results to any other stack. Table 2.1 lists the results from the velocity uniformity tests performed on the model using Test Ports 2 and 3 for both one and two operating fans. The average velocity uniformity (% COV) results were 4.8 and 4.9 for one and two operating fans, respectively. Therefore, the acceptance range for velocity uniformity results for the 3430 Building Filtered Exhaust stack is 0 to 9.9 %COV [a] for the results from the HV-C2 scale model to be considered applicable.

Table 2.1. List of HV-C2 Velocity Uniformity Test Results with Dampers Installed (from Glissmeyer and Droppo 2007)

Test Port	Operating Fans	Run No.	Control Damper Setting (degrees)	Back Flow Damper Setting (degrees)	Flowrate cfm	Velocity fpm	% COV
2	A	VT-16	90	70	973	1239	3.6
2	B	VT-19	90	70	977	1244	6
3	A	VT-17	90	70	1002	1276	3.4
3	B	VT-18	90	70	959	1221	6
				Average	977.8	1245.0	4.8
2	A & B	VT-13	90	70	2094	2666	6.1
2	A & B	VT-23	90	70	2132	2715	5.1
2	A & B	VT-24	90	70	2126	2706	4.4
3	A & B	VT-14	90	70	2117	2696	4.4
3	A & B	VT-21	90	70	2136	2720	5.1
3	A & B	VT-22	90	70	2180	2775	4.5
				Average	2130.8	2713.0	4.9

Table 2.2 shows calculations of the acceptable range of the diameter × velocity criterion that also determines the applicability of the scale-model results to the actual stacks. The product of duct diameter times air velocity (DV=113,750) is within the acceptable 6× factor of six of the scale model's DV product (195,336) for two operating fans.

[a] 4.9 ±5.0 = 0 – 9.9

Table 2.2. Calculation of Acceptable Ranges of Diameter × Velocity Products

Stack	Diameter in.		Mean. velocity, fpm	Product DV, in × fpm	6 × limit
Model	12	One fan	1245	14940	89640
Model	12	Two fans	2713	32556	195336
3430	43.75	Two Fans	2600	113750	

2.2 Test Matrix

Table 2.3 lists the minimum matrix of tests needed for the 3430 Building Filtered Exhaust stack. Also included in the list are the optional tests that may be required if the applicable criteria for velocity uniformity and diameter/velocity product are not met as presented above.

Table 2.3. Minimum Test Runs to be Performed for 3430 Qualification

Test Configuration				Estimated Number of Test Runs			
Fans	#	Injection Port	Test Port	Flow Angle	Velocity	Gas Tracer (optional)[(a)]	Particle Tracer (optional)
Maximum flowrate	1	Junction	At Probe	2	2	7	2
Minimum flowrate	2	Junction	At Probe	1	1	1	1
Total				3	3	8	3
Grand Total				17			

(a) Five of the seven runs involve injecting the tracer gas in the four corners and center of the cross section at the injection location. The two additional runs are replicates of the test with the worst-case result.

3.0 Testing

The test methods for the flow angle and velocity uniformity are outlined below. Tracer tests are not currently planned. Figure 3.1 shows the layout of the duct in the location of the air sampling probe and the test ports used in the testing.

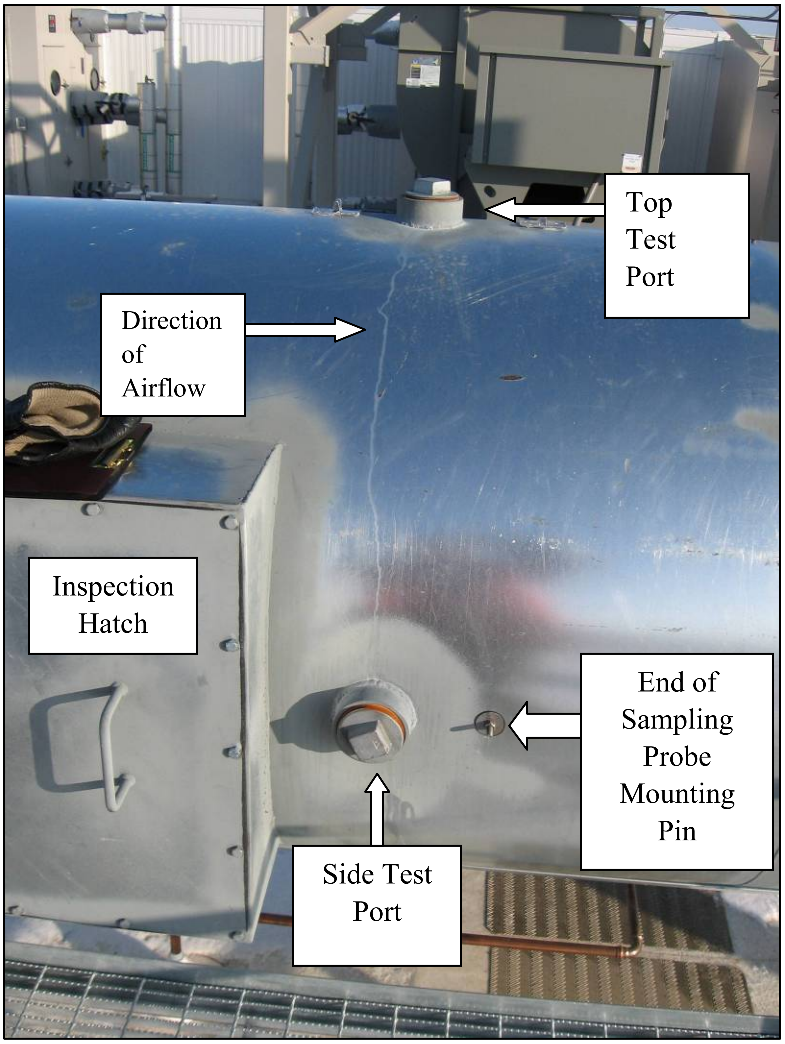

Figure 3.1. Layout of Test Ports and Other Duct Features

Figure 3.2 shows the inside of the duct looking downstream (inspection hatch removed). A shrouded nozzle and flow sensor are part of the sample probe assembly.

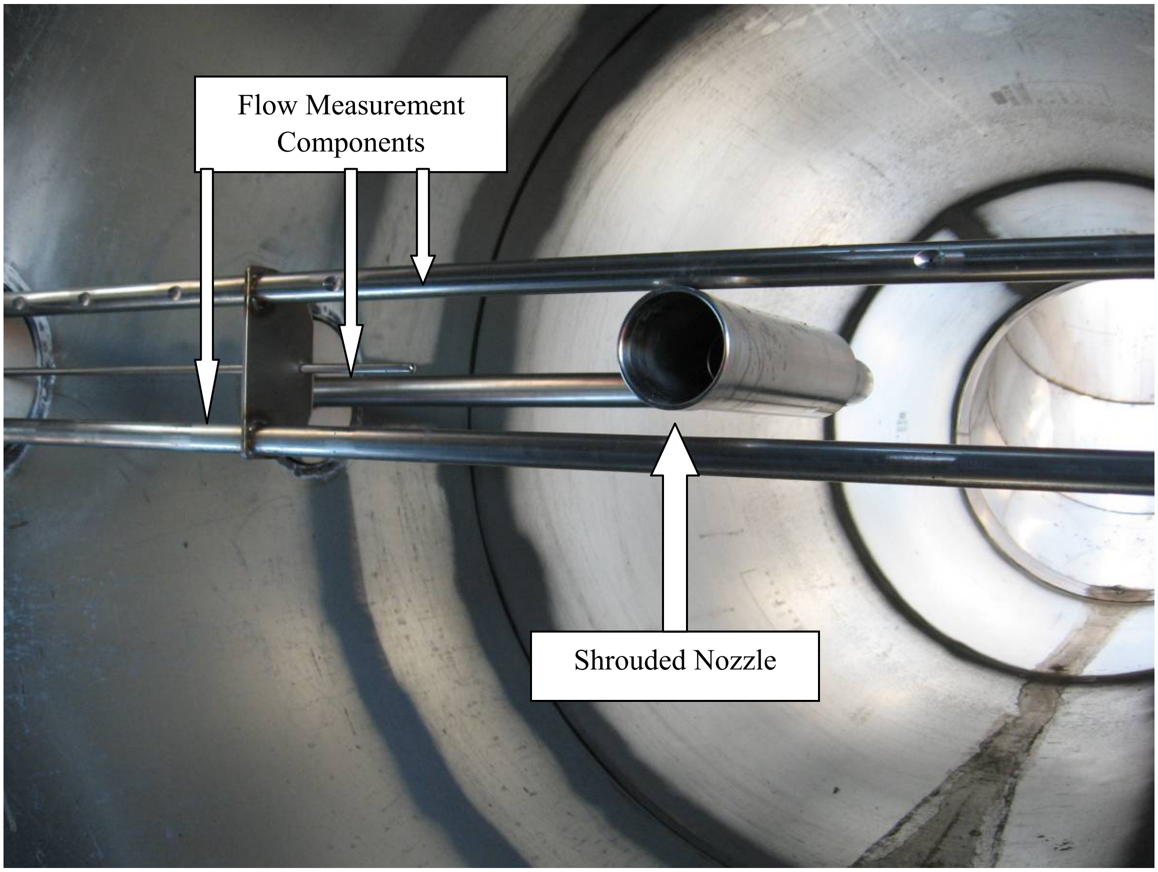

Figure 3.2. Sampling Probe Assembly

3.1 Flow Angle Test

The air-velocity vector approaching the sample nozzle should be aligned with the axis of the nozzle, within an acceptable angle, so sample extraction performance is not degraded (see Section 2). The test method is based on 40 CFR 60, Appendix A, Method 1, Section 2.4, American National Standards Institute/Health Physical Society

The term “flow angle” is the angle between the air velocity vector and the axis of the sampling nozzle. The flow angle was measured at a grid of points in a cross section of the Building 3430 Filtered Exhaust stack at the test ports just a few inches upstream of the actual sampling probe. The grid is an array of points in an x-pattern in the cross section of the duct. One line of points is aligned in the same direction as the sampling probe assembly. The other line was perpendicular to the sample probe assembly. The number and distance between measurement points is based on the U.S. Environmental Protection Agency’s (EPA’s) method in 40 CFR 60, Appendix A, Method 1.

Measurements were made using a type-S Pitot tube, a slant tube manometer, and an angle-indicating device. PNNL operating procedure EMS-JAG-05,[a] "Test to Determine Flow Angle at the Elevation of a Sampler Probe," was used for determining the mean flow angle.

Figure 3.3 is a view looking upstream from the test ports toward the exhaust fans. The S-type Pitot tube is installed in the duct attached to an angle-indicating device threaded to the top test port. Figure 3.4 shows the slant-tube manometer.

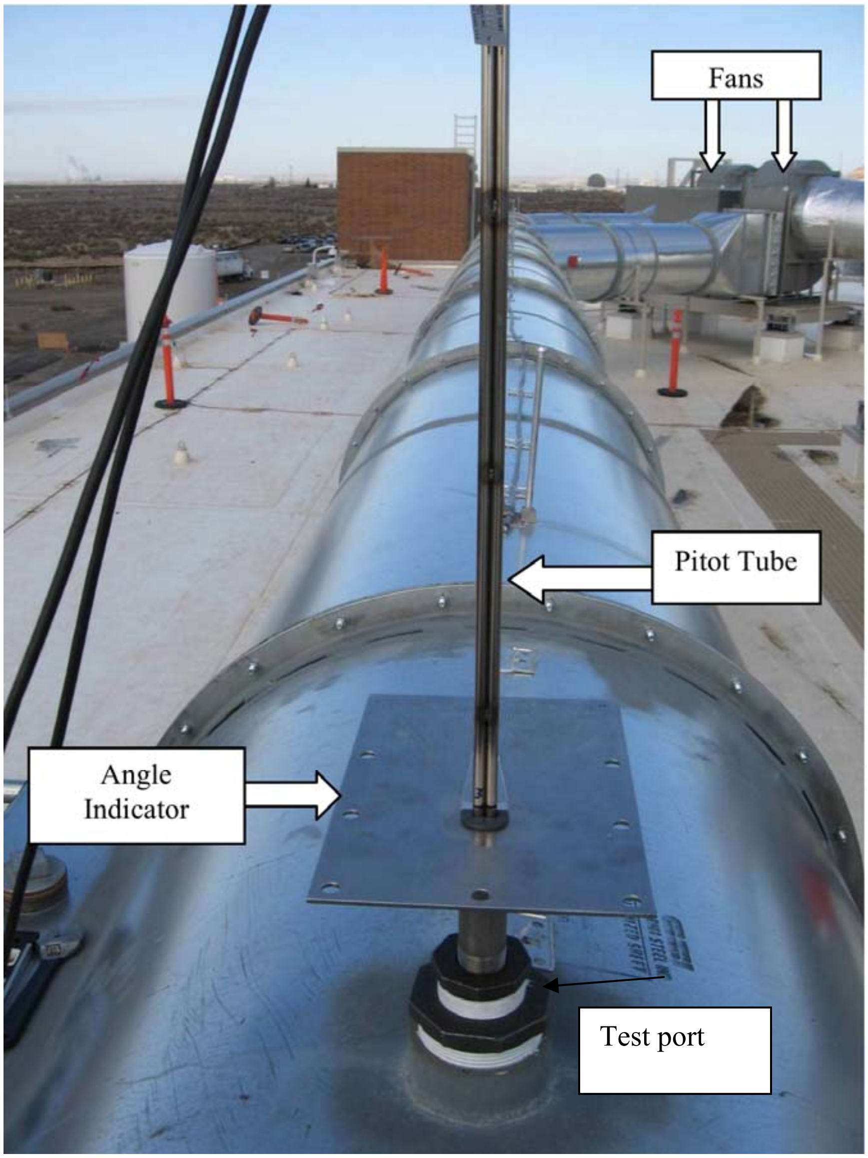

Figure 3.3. Flow Angle Indicator and Pitot Tube Installed

(a) EMS-JAG-05, Rev. 2, March 27, 2009. "Test to Determine Flow Angle," internal operating procedure, Pacific Northwest National Laboratory, Richland, Washington.

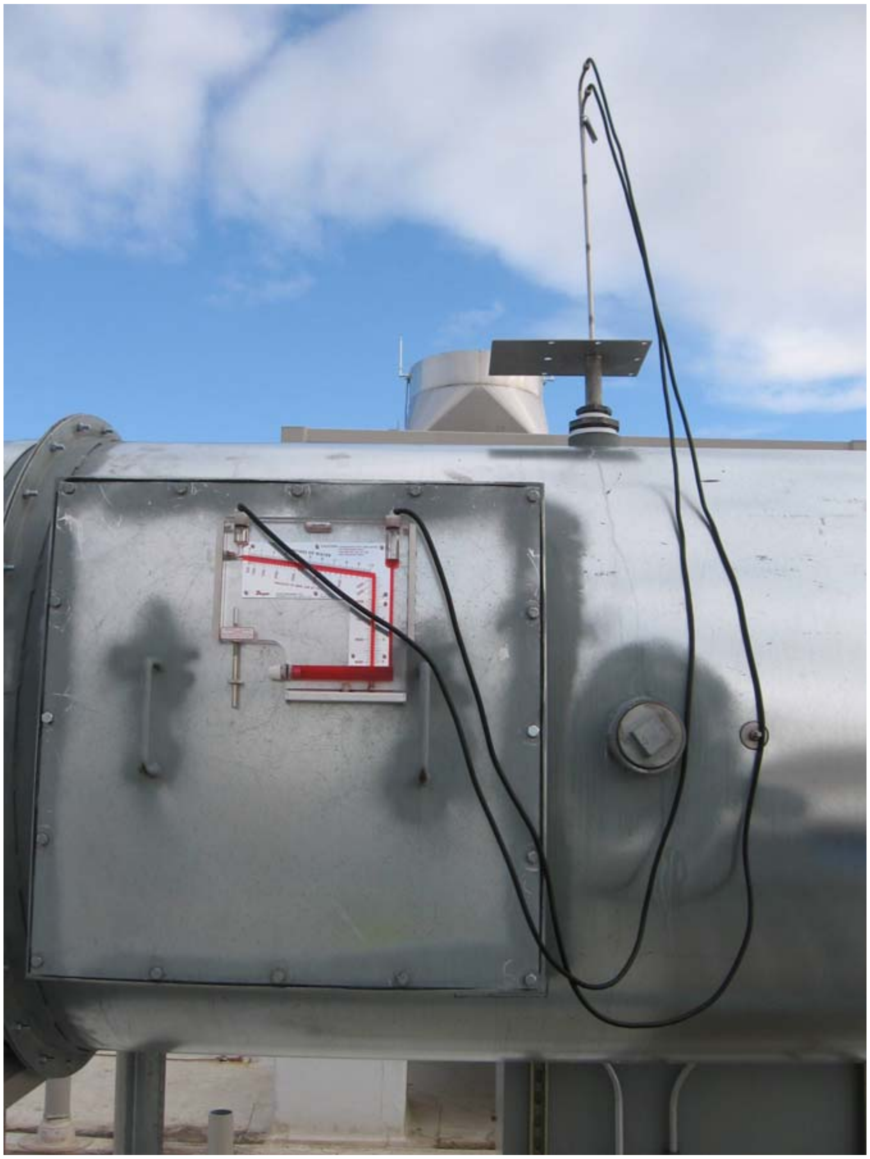

Figure 3.4. Slant Tube Manometer on Inspection Hatch Cover

3.2 Velocity Uniformity Test

To determine uniformity, air velocity is measured at the same grid of points used for the flow angle test. The method used is based on 40 CFR 60, Appendix A, Method 1.

The air velocity is measured three times at each grid point, and each measurement is recorded. The measurements at each grid point are averaged to determine the mean velocity at each grid point. The average values for each grid point in the center $^2/_3$ of the stack are used to calculate the mean and standard deviation of velocity for the sampling location. The % COV is calculated as 100 times the standard deviation divided by the mean. This value should be less than or equal to (9.9% for the scale model tests to apply to this stack.

The test equipment used included an S-type Pitot tube and a calibrated electronic manometer as shown in Figure 3.5. The Pitot tube is inserted in the duct as shown in Figure 3.4, except an electronic manometer is used in place of the slant-tube manometer. The electronic manometer indicates actual air velocity, assuming a Pitot tube correction factor of 1. Because the S-type Pitot tube has a correction factor is 0.84, the recorded values were corrected after the test. PNNL operating procedure EMS-JAG-04,[(a)] "Test to Determine Uniformity of Gas Velocity at the Elevation of a Sampler Probe," was used for this test.

Figure 3.5. Electronic Manometer Connected to Pitot Tube

3.3 Quality Assurance

The PNNL Quality Assurance (QA) Program is based upon the requirements as defined in the U.S. Department of Energy (DOE) 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:

- ASME NQA-1-2000, Quality Assurance Requirements for Nuclear Facility Applications, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- ASME NQA-1-2000, Part II, Subpart 2.7, Quality Assurance Requirements for Computer Software for Nuclear Facility Applications.

(a) EMS-JAG-04, Rev. 2, March 27, 2009. "Test to Determine Uniformity of Air Velocity at a Sampler Probe." internal operating procedure, Pacific Northwest National Laboratory, Richland, Washington.

- ASME 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 through PNNL's "How Do I…?" (HDI).[(a)]

The Stack Monitoring Project (STMON) implements an NQA-1-2000 Quality Assurance Program, graded on the approach presented in NQA-1-2000, Part IV, Subpart 4.2. The STMON Quality Assurance Manual (QA-STMON-0002[(b)]) describes the technology life cycle stages under the STMON Quality Assurance Plan (QA-STMON-0001[(c)]). The technology life cycle includes the progression of technology development, commercialization, and retirement in process phases of basic and applied research and development (R&D), engineering, and production and operation until process completion. The life cycle is characterized by flexible and informal QA activities in basic research, which becomes more structured and formalized through the applied R&D stages.

- BASIC RESEARCH—Basic research consists of research tasks that are conducted to acquire and disseminate new scientific knowledge. During basic research, maximum flexibility is desired to allow the researcher the necessary latitude to conduct the research.
- APPLIED RESEARCH—Applied research consists of research tasks that acquire data and documentation necessary to make sure that results can be satisfactorily reproduced. The emphasis during this stage of a research task is on achieving adequate documentation and controls necessary to be able to reproduce results.
- DEVELOPMENTAL WORK—Development Work consists of research tasks moving toward technology commercialization. These tasks still require a degree of flexibility, and there is still a degree of uncertainty that exists in many cases. The role of quality on Development Work is to make sure that adequate controls to support movement into commercialization exist.
- RESEARCH AND DEVELOPMENT SUPPORT ACTIVITIES—Support activities are those that are conventional and secondary in nature to the advancement of knowledge or development of technology, but allow the primary purpose of the work to be accomplished in a credible manner. An example of a support activity is controlling and maintaining documents and records. The level of quality for these activities is the same as for developmental work.

The work described in this report has been completed under the QA Technology level of Development Work. STMON addresses internal verification and validation activities by conducting an independent technical review of the final data report in accordance with STMON's procedure QA-STMON-601,[(d)] *Document Preparation and Change*. This review verifies that the reported results are

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(a) A system for managing the delivery of laboratory-level policies, requirements, and procedures.
(b) QA-STMON-0002, Rev. 0. January 2, 2010. "Pacific Northwest National Laboratory Stack Monitoring Project Quality Assurance Manual." Pacific Northwest National Laboratory, Richland, Washington.
(c) QA-STMON-0001, Rev. 0. January 2, 2010. "Pacific Northwest National Laboratory Stack Monitoring Project Quality Assurance Plan." Pacific Northwest National Laboratory, Richland, Washington.
(d) QA-STMON-0601, Rev. 0. January 2, 2010. "Document Preparation and Change." Pacific Northwest National Laboratory, Richland, Washington.

traceable, that inferences and conclusions are soundly based, and the reported work satisfies the Test Plan objectives.

The tests were conducted according to an approved test plan and test instructions. Data transcription and calculations were independently reviewed.

4.0 Test Results

Independent reviews were performed to verify the data transcription and calculations. The final data sheets are attached in Appendix A.

The duct diameters were field measured at the test ports and found to be 43.75 inches as listed in Table 4.1. The distance from the test ports to the nearest upstream disturbance (the junction of the ducts from the fans) was 74.5 ft. Therefore, in terms of duct diameters (distance divided by the duct diameter), the tests were performed 20.4 duct diameters (D) downstream of duct junction. In comparison, the test ports in the model tested by Glissmeyer and Droppo (2007) were 4.45 D, 9.47 D, and 14.5 D for test ports 1, 2, and 3, respectively, downstream of the junction.

Table 4.1. Test Port Depth Measurements

Side of duct	Measurement Port	Measured Duct Depth, in.
Top	1	43.75
West Side	2	43.75

4.1 Velocity Uniformity Results

The measured air velocity % COV values are summarized in Table 4.2. For the high and low flow conditions, the average result was 3.5% COV. This was well within the acceptance criterion derived in Section 2.1 (<9.8 % COV) for verifying that the Building 3430 Filtered Exhaust stack configuration is represented by the model tests of Glissmeyer and Droppo (2007).

Table 4.2. Building 3430 Filtered Exhaust Stack Velocity Uniformity Test Runs

Fan operating configuration	Run Nos.	Measured acfm	% COV
Maximum	VT-1	27147	3.2
Maximum	VT-2	26961	3.5
Minimum	VT-3	17712	3.7

4.2 Flow Angle Results

The results for the flow angle tests are listed in Table 4.3. For the high and low flow conditions, the average flow angle of 2.6° was acceptable and much less than the acceptance criterion of 20°.

Table 4.3. Building 3430 Filtered Exhaust Stack Flow Angle Test Runs

Fan Operating Configuration	Run Nos.	Airflow Displayed in Sampling Cabinet scfm	Mean Absolute Flow Angle
Maximum	FA-1	27400	2.8
Maximum	FA-2	27300	2.2
Minimum	FA-3	17000	2.9

5.0 Conclusions

Velocity uniformity tests were performed on the 3430 Building Filtered Exhaust stack and show acceptable agreement with the scale model tests performed previously (Glissmeyer and Droppo 2007). Consequently, the location for the air sampling probe meets the qualification criteria given in ANSI/HPS-1999. The gas and particle tracer qualification results of the scale model apply equally to the full size stack. Those results from Glissmeyer and Droppo (2007) are appended to this report. The results for the flow angle test on the Building 3430 Filtered Exhaust stack also show compliance with the flow-angle criterion.

6.0 References

10 CFR 830, Energy/Nuclear Safety Management, Subpart A – "Quality Assurance Requirements." *Code of Federal Regulations*, U.S. Department of Energy.

40 CFR 60, Appendix A, Method 1, Section 2.4. 1971. "Sample and Velocity Traverses for Stationary Sources." *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." *Code of Federal Regulations,* U.S. Environmental Protection Agency.

ASME 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*, New York, New York.

ASME NQA-1-2000, Part II, Subpart 2.7, "Quality Assurance Requirements for Computer Software for Nuclear Facility Applications." *American Society of Mechanical Engineers*, New York, New York.

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

ANSI/HPS—American National Standards Institute/Health Physical Society. 1999. *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities.* N13.1-1999. *Health Physics Society*, McLean, Virginia.

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

Glissmeyer JA and JG Droppo. 2007. *Assessment of the HV-C2 Stack Sampling Probe Location*. PNNL-16611, Pacific Northwest National Laboratory, Richland, Washington.

Appendix A

Data Sheets

Appendix A: Data Sheets

FLOW ANGLE DATA FORM

FlowAngleRev0.xls

4-Aug-06 Based on ---- CCP-WTPSP-178

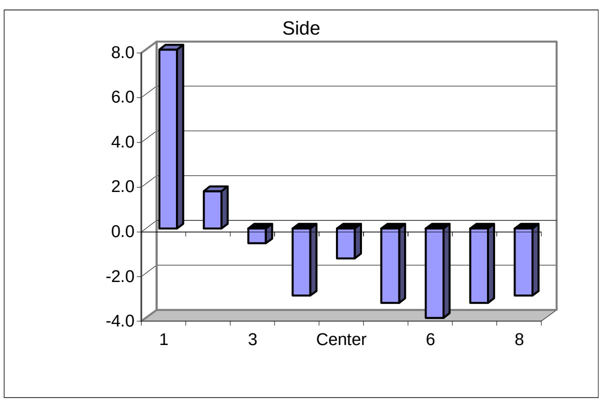
Site	**3430 Stack**	Run No.	**FA-1**
Date	1/6/2010	Fan Setting	**Maximum**
Tester	JAG/JEF	Fan configuration	**2 fans**
Stack Dia.	43.75 in	Approx. air vel.	2670 sfpm at side center
Stack X-Area	1503.3 in2	Units	degrees (clockwise > pos. nos.)
Elevation	N.A. ft	Port	1&2
Distance to disturbance	74.5 ft	Stack Temp	55 F
Start/End Time	1055/1140		

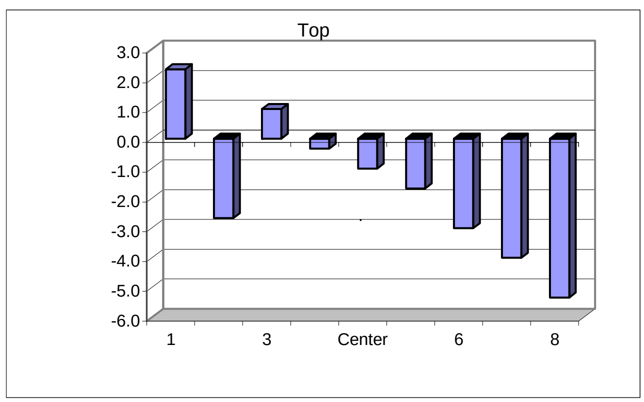
Order -->		1st				2nd			
Traverse-->		Side				Top			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	1.40	8	8	8	8.0	2	3	2	2.3
2	4.58	0	0	5	1.7	-5	-2	-1	-2.7
3	8.46	-2	0	0	-0.7	1	1	1	1.0
4	14.09	-5	-4	0	-3.0	0	0	-1	-0.3
Center	21.81	-4	0	0	-1.3	-1	-1	-1	-1.0
5	29.53	-4	-1	-5	-3.3	-2	-1	-2	-1.7
6	35.16	-5	-3	-4	-4.0	-3	-3	-3	-3.0
7	39.04	-4	-3	-3	-3.3	-4	-4	-4	-4.0
8	42.23	-3	-4	-2	-3.0	-6	-5	-5	-5.3
Mean of absolute values of all data:					3.1				2.4
w/o points by wall:					2.5				2.0
								all	2.8
								w/o wall pts	2.2

Instuments Used:		**Cal. Due**
S-type pitot	Dwyer 72-inch S-type Pitot#11 160S-72-A30U	Cert. of conformance
Velocity sensor	TSI VELOCICALC 209060	7/14/2010
Angle indicator	Shop built	Cat. 3
Manometer	Dwyer 400-5, S36N	Cat. 3

Notes: Air sampler Masstron shows 27,400 scfm stack flow.
All hood sashes open

Note:
To assure similar hose connections between the manometer and pitot tube, rotating the pitot tube assembly clockwise drives the meniscus to the right (to higher pos. numbers).





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FLOW ANGLE DATA FORM

FlowAngleRev0.xls — 4-Aug-06 Based on ---- CCP-WTPSP-178

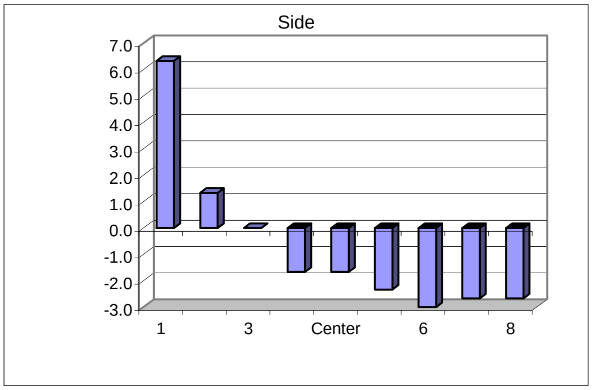
Site	**3430 Stack**		Run No.	**FA-2**
Date	1/6/2010		Fan Setting	**Maximum**
Tester	JAG/JEF		Fan configuration	**2 fans**
Stack Dia.	43.75	in	Approx. air vel.	2820 sfpm at side center
Stack X-Area	1503.3	in2	Units	degrees (clockwise > pos. nos.)
Elevation	N.A.	ft	Port	1&2
Distance to disturbance	74.5	ft	Stack Temp	57 F
Start/End Time	1250/1318			

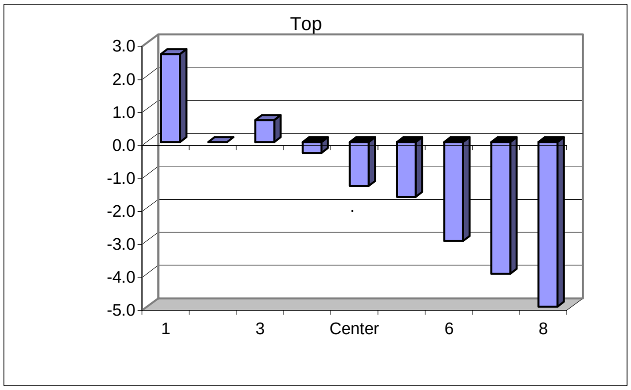
Order -->		2nd				1st			
Traverse-->		**Side**				**Top**			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	1.40	8	5	6	6.3	2	4	2	2.7
2	4.58	4	0	0	1.3	0	0	0	0.0
3	8.46	1	0	-1	0.0	0	1	1	0.7
4	14.09	-1	-1	-3	-1.7	-1	0	0	-0.3
Center	21.81	-1	-2	-2	-1.7	-2	-1	-1	-1.3
5	29.53	-2	-2	-3	-2.3	-2	-2	-1	-1.7
6	35.16	-3	-3	-3	-3.0	-3	-3	-3	-3.0
7	39.04	-2	-3	-3	-2.7	-4	-4	-4	-4.0
8	42.23	-2	-3	-3	-2.7	-5	-5	-5	-5.0
Mean of absolute values of all data:					2.4				2.1
w/o points by wall:					1.8				1.6
								all	2.2
								w/o wall pts	1.7

Instuments Used:		**Cal. Due**
S-type pitot	Dwyer 72-inch S-type Pitot#11 160S-72-A30U	Cert. of conformance
Velocity sensor	TSI VELOCICALC 209060	7/14/2010
Angle indicator	Shop built	Cat. 3
Manometer	Dwyer 400-5, S36N	Cat. 3

Notes: Air sampler Masstron rads 27,300 scfm
All sashes open

Note:
To assure similar hose connections between the manometer and pitot tube, rotating the pitot tube assembly clockwise drives the meniscus to the right (to higher pos. numbers).





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FLOW ANGLE DATA FORM

FlowAngleRev0.xls — 4-Aug-06 Based on ---- CCP-WTPSP-178

Site	**3430 Stack**	Run No.	**FA-3**
Date	1/7/2010	Fan Setting	**Minimum, night setback**
Tester	JAG/DMT	Fan configuration	**1 & 2**
Stack Dia.	43.75 in	Approx. air vel.	1740 sfpm at side center
Stack X-Area	1503.3 in2	Units	degrees (clockwise > pos. nos.)
Elevation	N.A. ft	Port	1&2
Distance to disturbance	74.5 ft	Stack Temp	58 F
Start/End Time	1230/1325		

Order -->		1st				2nd			
Traverse-->		Side				Top			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	1.40	8	7	6	7.0	2	0	-6	-1.3
2	4.58	4	5	6	5.0	-4	-4	-3	-3.7
3	8.46	-1	2	-1	0.0	-2	-3	1	-1.3
4	14.09	-2	-2	-3	-2.3	-3	-1	-1	-1.7
Center	21.81	-4	-3	-3	-3.3	-2	-2	-2	-2.0
5	29.53	-3	-3	-4	-3.3	0	-2	-2	-1.3
6	35.16	-2	-3	-3	-2.7	-3	-3	-3	-3.0
7	39.04	-3	-4	-3	-3.3	-2	-3	-3	-2.7
8	42.23	-4	-5	-4	-4.3	-5	-5	-3	-4.3
Mean of absolute values of all data:					3.5				2.4
w/o points by wall:					2.9				2.2

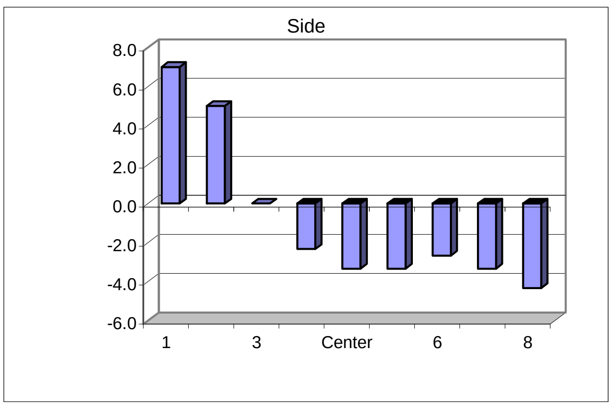
all	2.9
w/o wall pts	2.5

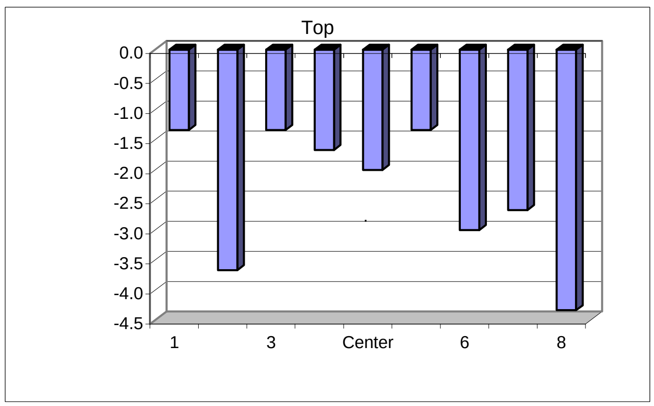
Instuments Used: — **Cal. Due**

S-type pitot	Dwyer 72-inch S-type Pitot#11 160S-72-A30U	Cert. of conformance
Velocity sensor	TSI VELOCICALC 209060	7/14/2010
Angle indicator	Shop built	Cat. 3
Manometer	Dwyer 400-5, S36N	Cat. 3

Notes: RAES Masstron reads 17,000 scfm and 1615 afpm

Note:
To assure similar hose connections between the manometer and pitot tube, rotating the pitot tube assembly clockwise drives the meniscus to the right (to higher pos. numbers).





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VELOCITY TRAVERSE DATA FORM

Site	**3430 Bldg**	Run No.	**VT-1**
Date	**1/6/10**	Fan Configuration	**Fans 1&2**
Testers	JAG/JEF	Fan Setting	**Maximum**
Stack Dia.	43.75 in.	Stack Temp	57.8 deg F
Stack X-Area	1503.3 in.2	Start/End Time	1324/1509
Test Port	1&2	Center 2/3 from	4.01 to: 39.74
Distance to disturbance	74.5 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Pitot corr. Factor	0.84

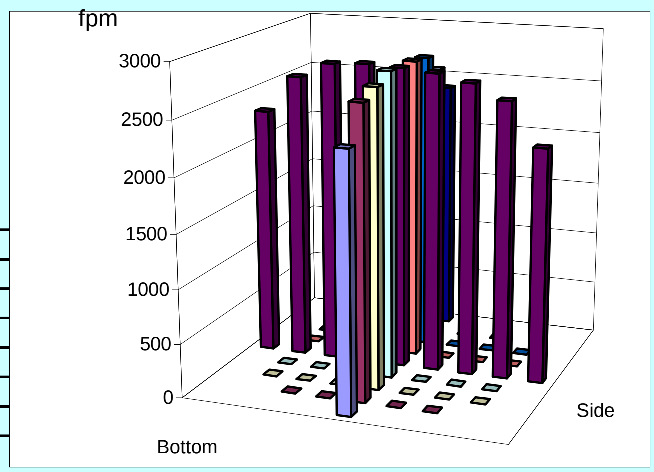
Order -->		1st				2nd			
Traverse-->		Side				Top			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.40	2196	2024	2176	2131.9	2396	2342	2327	2354.8
2	4.58	2545	2511	2512	2522.8	2675	2672	2680	2675.7
3	8.46	2629	2633	2706	2655.8	2693	2794	2757	2747.9
4	14.09	2696	2733	2735	2721.3	2827	2839	2814	2826.9
Center	21.81	2733	2751	2761	2748.2	2809	2797	2790	2798.6
5	29.53	2770	2774	2748	2763.9	2810	2806	2796	2803.6
6	35.16	2754	2763	2724	2746.8	2778	2785	2780	2781.0
7	39.04	2604	2619	2600	2607.6	2667	2630	2551	2616.0
8	42.23	2285	2234	2291	2270.0	2386	2390	2367	2380.8
Averages ---------->		2579.0	2560.2	2583.6	2574.3	2671.1	2672.8	2651.2	2665.0

All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2619.6		Mean	2680.9	2750.0	2715.4
Min Point	2131.9	-18.6%	Std. Dev.	89.8	77.0	88.0
Max Point	2826.9	7.9%	COV as %	3.3	2.8	**3.2**

Flow w/o C-Pt 27147 acfm
Vel Avg w/o C-Pt 2600 fpm

	Start	Finish	
Stack temp	58.5	57	F
Equipment temp	N.A.	N.A.	F
Ambient temp	45	42	F
Stack static	0.10	0.10	mbars
Ambient pressure	1021	1022	mbars
Total Stack pressure	1021	1022	mbars
Ambient humidity	37%	42%	RH

Instuments Used:		Cal Due
Fisher Scientific	SN 90936818	9/29/2010
Zephyr II+	SN 80355	9/18/2010
TSI Velocicalc	SN 209060	7/14/2010
Dwyer Pitot Tube	160S-72-A30U	Cert. of Conf.



Notes:

Entries made by: John Glissmeyer	Technical Data Review performed by: J. Matthew Barnett
Signature/date 1/6/2010	Signature/date 1/18/2010
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VELOCITY TRAVERSE DATA FORM

Site	**3430 Bldg**	Run No.	**VT-2**
Date	**1/6/10**	Fan Configuration	**Fans 1&2**
Testers	JAG/JEF	Fan Setting	**Maximum**
Stack Dia.	43.75 in.	Stack Temp	56.5 deg F
Stack X-Area	1503.3 in.2	Start/End Time	1525/1630
Test Port	1&2	Center 2/3 from	4.01 to: 39.74
Distance to disturbance	74.5 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Pitot corr. Factor	0.84

Order -->		2nd				1st			
Traverse-->		Side				Top			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.40	2119	2187	2147	2151.0	2347	2410	2345	2367.4
2	4.58	2411	2507	2477	2465.1	2676	2659	2696	2677.1
3	8.46	2553	2600	2607	2586.4	2755	2751	2710	2738.7
4	14.09	2717	2691	2689	2698.9	2822	2755	2734	2770.3
Center	21.81	2752	2737	2725	2737.8	2793	2789	2713	2765.0
5	29.53	2773	2706	2747	2741.8	2763	2790	2737	2763.0
6	35.16	2748	2726	2745	2739.8	2774	2766	2744	2761.4
7	39.04	2527	2596	2583	2568.7	2638	2629	2611	2625.8
8	42.23	2276	2298	2278	2284.2	2434	2373	2336	2381.1
Averages ---------->		2541.7	2560.9	2555.3	2552.6	2666.8	2657.9	2625.2	2650.0

All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2601.3		Mean	2648.4	2728.8	2688.6
Min Point	2151.0	-17.3%	Std. Dev.	109.1	55.7	93.1
Max Point	2770.3	6.5%	COV as %	4.1	2.0	**3.5**

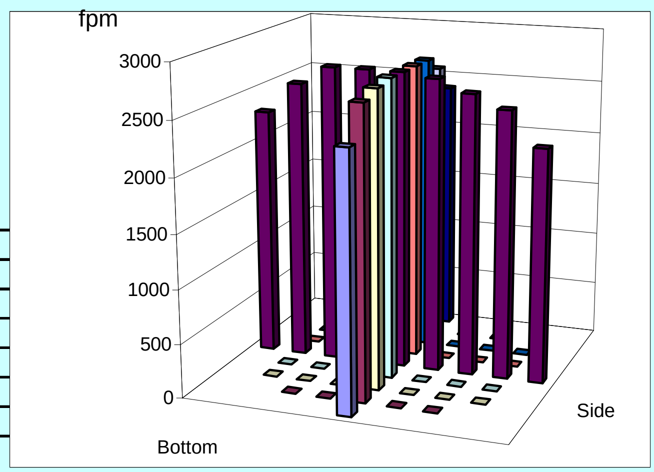
Flow w/o C-Pt 26961 acfm

Vel Avg w/o C-Pt 2583 fpm

Instuments Used:

		Cal Due
Fisher Scientific	SN 90936818	9/29/2010
Zephyr II+	SN 80355	9/18/2010
TSI Velocicalc	SN 209060	7/14/2010
Dwyer Pitot Tube	160S-72-A30U	Cert. of Conf.

	Start	Finish	
Stack temp	57	56	F
Equipment temp	N.A.	N.A.	F
Ambient temp	42	35	F
Stack static	0.10	0.10	mbars
Ambient pressure	1022	1021	mbars
Total Stack pressure	1022	1021	mbars
Ambient humidity	42%	54%	RH



Notes:

Entries made by: John Glissmeyer	Technical Data Review performed by: J. Matthew Barnett
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VELOCITY TRAVERSE DATA FORM

Site	**3430 Bldg**	Run No.	**VT-3**
Date	**1/7/10**	Fan Configuration	**Fans 1&2**
Testers	JAG/DMT	Fan Setting	**Minimum**
Stack Dia.	43.75 in.	Stack Temp	60.0 deg F
Stack X-Area	1503.3 in.2	Start/End Time	1355/1550
Test Port	1&2	Center 2/3 from	4.01 to: 39.74
Distance to disturbance	74.5 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Pitot corr. Factor	0.84

Order -->		2nd				1st			
Traverse-->		Side				Top			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.40	1429	1389	1394	1403.9	1482	1564	1547	1531.0
2	4.58	1694	1685	1667	1682.2	1744	1774	1768	1762.0
3	8.46	1744	1754	1756	1751.4	1852	1850	1861	1854.4
4	14.09	1781	1758	1779	1772.7	1871	1891	1851	1871.0
Center	21.81	1802	1798	1798	1799.3	1837	1794	1797	1809.4
5	29.53	1812	1817	1803	1810.8	1809	1781	1793	1794.2
6	35.16	1798	1788	1804	1796.8	1713	1763	1740	1738.8
7	39.04	1636	1686	1643	1655.1	1659	1665	1672	1665.4
8	42.23	1525	1483	1523	1510.0	1538	1561	1538	1545.6
Averages ---------->		1691.1	1684.2	1685.4	1686.9	1722.7	1738.1	1729.8	1730.2

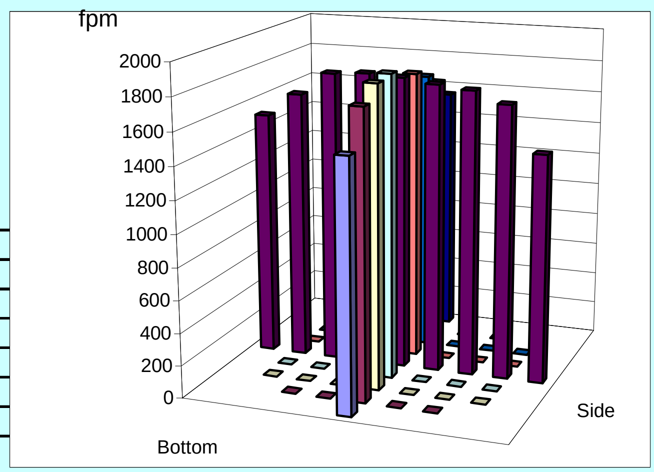
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	1708.6		Mean	1752.6	1785.0	1768.8
Min Point	1403.9	-17.8%	Std. Dev.	61.1	70.5	65.6
Max Point	1871.0	9.5%	COV as %	3.5	4.0	**3.7**

Flow w/o C-Pt 17712 acfm

Vel Avg w/o C-Pt 1697 fpm

	Start	Finish	
Stack temp	66	54	F
Equipment temp	N.A.	N.A.	F
Ambient temp	36	33	F
Stack static	0.10	0.10	mbars
Ambient pressure	1021	1020	mbars
Total Stack pressure	1021	1020	mbars
Ambient humidity	47%	52%	RH

Instuments Used:		Cal Due
Fisher Scientific	SN 90936818	9/29/2010
Zephyr II+	SN 80355	9/18/2010
TSI Velocicalc	SN 209060	7/14/2010
Dwyer Pitot Tube	160S-72-A30U	Cert. of Conf.



Notes:

RAES MASStron reads 17,300 scfm

Entries made by:	John Glissmeyer	Technical Data Review performed by:	J. Matthew Barnett
Signature/date	1/7/2010	Signature/date	1/18/2010
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Appendix B

Applicable Qualification Results from Model Stack

Appendix B: Applicable Qualification Results from Model Stack

These data are extracted from Glissmeyer and Droppo (2007).

Table B.1 lists the gas-tracer uniformity tests conducted on the scale model with the dampers installed at the fan outlets. Only the data for test ports 2 and 3 are shown, but even the model test port 3 was about 5 D closer to the nearest upstream disturbance than the test ports on the Building 3430 Filtered Exhaust stack. Therefore, the tracer uniformity results for the Building 3430 Filtered Exhaust stack would probably be even more favorable relative to the acceptance criteria.

The % COV was calculated for the measured gas concentration at the points in the center two-thirds area of the Building 3430 Filtered Exhaust stack. The percent deviation from the mean concentration was also calculated for any point in the measurement grid.

Table B.1. Summarized Results of Gas-Tracer Uniformity Tests with Dampers

Injection Port		Operating Fans	Test Port	Run No.	Control Damper Setting (degrees)	Back Flow Damper Setting (degrees)	Center $^2/_3$% COV	% Deviation from Mean
B	Center	A & B	2	GT-49	45.0	45.0	1.7	4.4
B	Center	A & B	3	GT-48	45.0	45.0	1.3	2.6
A	Center	A	2	GT-38	90.0	70.0	1.3	2.6
A	Center	A	3	GT-37	90.0	70.0	2.3	5.3
A	Center	A & B	2	GT-27	90.0	70.0	7.2	13.8
A	Center	A & B	3	GT-34	90.0	70.0	3.2	7.9
B	Center	B	2	GT-46	90.0	70.0	1.1	1.9
B	Center	B	3	GT-47	90.0	70.0	1.7	2.9
B	Center	A & B	2	GT-52	90.0	70.0	6.3	12.3
B	Center	A & B	3	GT-54	90.0	70.0	3.9	9.1
A	Far Left	A & B	2	GT-28	90.0	70.0	5.2	9.8
A	Far Left	A & B	2	GT-31	90.0	70.0	4.5	13.1
A	Far Left	A & B	3	GT-32	90.0	70.0	3.2	6.6
A	Far Right	A & B	2	GT-29	90.0	70.0	10.0	28.3
A	Far Right	A & B	3	GT-33	90.0	70.0	2.8	5.8
A	Near Left	A & B	2	GT-51	90.0	70.0	2.0	4.5
A	Near Left	A & B	3	GT-36	90.0	70.0	2.9	5.5
A	Near Right	A & B	2	GT-30	90.0	70.0	5.7	9.6
A	Near Right	A & B	3	GT-35	90.0	70.0	3.5	7.9

Table B.2 lists the particle tracer uniformity results for the model stack. Only the data are shown for test ports 2 and 3, although the test ports on the Building 3430 Filtered Exhaust stack were about 5 duct diameters farther downstream of the duct junction thane even test port 3 on the model. The last column shows the uniformity results for the combination of operating parameters tested.

Table B.2. Particle-Tracer Uniformity Tests with Dampers

Injection Port	Operating Fans	Test Port	Run No.	Control Damper Setting (degrees)	Back Flow Damper Setting (degrees)	Normalized % COV
A	A & B	2	PT-12	90	70	13.75
A	A & B	2	PT-21	90	70	7.41
A	A & B	3	PT-13	90	70	9.72
A	A & B	3	PT-20	90	70	8.12
A	A	2	PT-15	90	70	2.46
A	A	3	PT-14	90	70	3.73
B	B	2	PT-18	90	70	3.02
B	B	3	PT-19	90	70	3.61

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