PNNL-19563
RPT-STMON-006

U.S. DEPARTMENT OF ENERGY

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

Assessment of the 3420 Building Filtered Exhaust Stack Sampling Probe Location

JA Glissmeyer
JE Flaherty

July 2010

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Pacific Northwest National Laboratory
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) — 7/12/10

John A. Glissmeyer
Stack Monitoring Project Manager

Date

Summary

Pacific Northwest National Laboratory performed several tests in the exhaust air discharge from the new 3420 Building Filtered Exhaust Stack to determine whether location of the air sampling probe for emissions monitoring is acceptable. The method followed involved adopting the results of a previously performed test series from a system with a similar configuration, followed by several tests on the actual system to verify the applicability of the previously performed tests. The qualification criteria for these types of stacks include metrics concerning 1) uniformity of air velocity, 2) sufficiently small flow angle with respect to the axis of the duct, 3) uniformity of tracer gas concentration, and 4) uniformity of tracer particle concentration.

Section 1 of this report provides background information concerning the tests for the 3420 Building, while Section 2 describes the testing strategy, including the criteria for the applicability of the model results and the test matrix. Section 3 describes the flow angle and velocity uniformity tests conducted at the 3420 Building Filtered Exhaust Stack. Sections 4 and 5 present the test results and conclusions, respectively. Test data sheets and applicable qualification results from previously tested stack models are included in Appendices.

The testing conducted from the similarly designed scale model stack was determined to be applicable to the current design of the 3420 Building Filtered Exhaust Stack. As a result, this new system also meets the qualification criteria given in the American National Standards Institute/Health Physics Society N13.1-1999 standard. Changes to the system configuration or operations outside the bounds described in this report (e.g., exhaust stack velocity changes, relocation of sampling probe) will require re-testing or re-evaluation to determine compliance.

Acronyms

acfm	actual cubic feet per minute
AD	aerodynamic diameter
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CFR	Code of Federal Regulations
COV	coefficient of variation
DIA	number of duct diameters, distance divided by duct diameter
DOE	U.S. Department of Energy
DV	hydraulic diameter and mean velocity
EPA	U.S. Environmental Protection Agency
FA	flow angle test run
HDI	“How Do I…?”
HPS	Health Physics Society
M&TE	materials and testing equipment
NQA	National Quality Assurance
PNNL	Pacific Northwest National Laboratory
PSF	Physical Sciences Facility
QA	quality assurance
RAES	Radiological Air Emission Sampling
R&D	research and development
scfm	standard cubic feet per minute
STMON	Stack Monitoring Project
TI	Test Instruction
VT	velocity uniformity test run

Acknowledgments

This work was supported by Project 48043, a Line-Item-funded project to develop, design, and construct the Physical Sciences Facility. Pacific Northwest National Laboratory (PNNL) is operated for the U.S. Department of Energy by Battelle under Contract DE-ACO5-76RL01830.

Preparing and executing these tests involved a number of PNNL staff members. We would like to particularly acknowledge the support of our quality engineer, Kirsten Meier, and administrative support from Mona Champion and Chrissy Charron. Robert Steele, John Hickman, Dan Edwards, and Matthew Barnett, provided technical, logistical, and moral support for these tests. Ernest Antonio and summer students Quintin Quigley and Brian Smith performed these tests. In addition, Carmen Arimescu, Matthew Barnett, and Ernest Antonio provided technical reviews. Wayne Cosby provided editorial support for this report.

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1.0 Introduction

The new construction of the Physical Sciences Facility (PSF) at the Pacific Northwest National Laboratory (PNNL) incorporates three laboratory buildings that will house PNNL radiological capabilities. As a result, PNNL has determined that emissions monitoring must be conducted for radionuclides in the exhaust air discharge of these buildings. The air monitoring system is required to conform to applicable federal regulations (Title 40 of the Code of Federal Regulations Part 61 [40 CFR 61], Subpart H), which in turn requires a sampling probe in the exhaust stream to conform to the criteria of ANSI/HPS[a] N13.1 – 1999, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities*. 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. A facility may choose from one of the three approaches to demonstrate compliance with the federal standards:

1. Perform a full test series on the actual exhaust system
2. Perform the full test series on 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 from previously performed full test series for a system with similar configuration, followed by a partial test of the actual exhaust system to verify the applicability of the previous test results.

The third approach was selected to evaluate the acceptability of the location of the air sampling probes for the three laboratory buildings of the PSF. This report describes the partial test conducted at the 3420 Building, also known as the Radiation Detection Laboratory. Also included in this report are the results from the previously performed full test series that serves as the basis for compliance with the standard. Tests on the actual stack were conducted on June 10 and 11, 2010.

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),[b] 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) The American National Standards Institute delegates the writing, publication and maintenance of this standard to the Health Physics Society, McLean, Virginia.
(b) *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 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.

Glissmeyer and Droppo (2007) conducted tests of a similar stack configuration using a scale model and concluded that the stack was compliant with these criteria. Section 5.2.2.2 of the ANSI/HPS N13.1-1999 standard defines additional criteria for applying the results of the scale model for the actual building stack. A summary of these criteria as applicable for the 3420 building stack follows:

- The scale model and its sampling location must be geometrically similar to the actual 3420 Building Filtered Exhaust Stack.
- The product of the hydraulic diameter and the mean velocity (DV) of the scale model must be within a factor of six of the DV for the actual 3420 Building Filtered Exhaust Stack.
- The Reynolds number for the model and actual stacks must each be >10,000.

The scale-model results are considered valid if the following are shown by testing on the actual stacks:

- The velocity profile in the actual 3420 Building stack meets the uniformity criterion.
- The velocity uniformity (% COV) values for the model and actual stacks agree to within 5%.
- The flow angle criterion is met on the actual 3420 Building stack.

1.2 3420 Building Filtered Exhaust Stack Configuration

Figure 1.1 shows a schematic of the plan view of the 3420 Building Filtered Exhaust Stack. Figure 1.2 shows the scale model stack (designated as HV-C2) tested by Glissmeyer and Droppo (2007). The two designs differ in that the model stack has only two fans, whereas the 3420 Building stack has three fans. However, the 3420 will likely run just two of the three fans operationally. As is the case with the other PSF Building stacks, the model stack is rotated 90° around its long axis (except for the bend at the discharge end) so that the air from the fans enters the duct from the side rather than from the bottom. This should have no effect on the uniformity of tracers and on the flow angles or velocity uniformity. The model stack was tested with one and both fans operating, whereas the 3420 stack was tested with two and three fans operating. Table 1.1 lists key dimensional and flow parameters for both the model stack and the filtered exhaust stack.

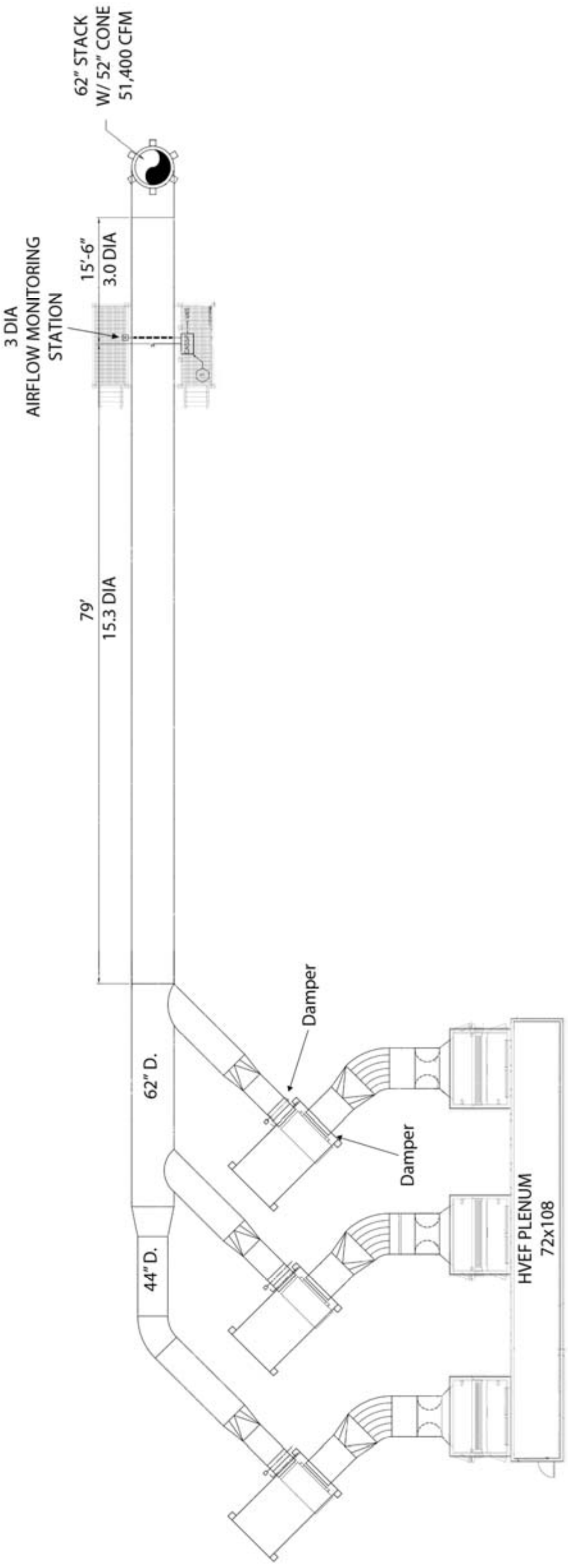

Figure 1.1. Plan View of the 3420 Building Filtered Exhaust Stack

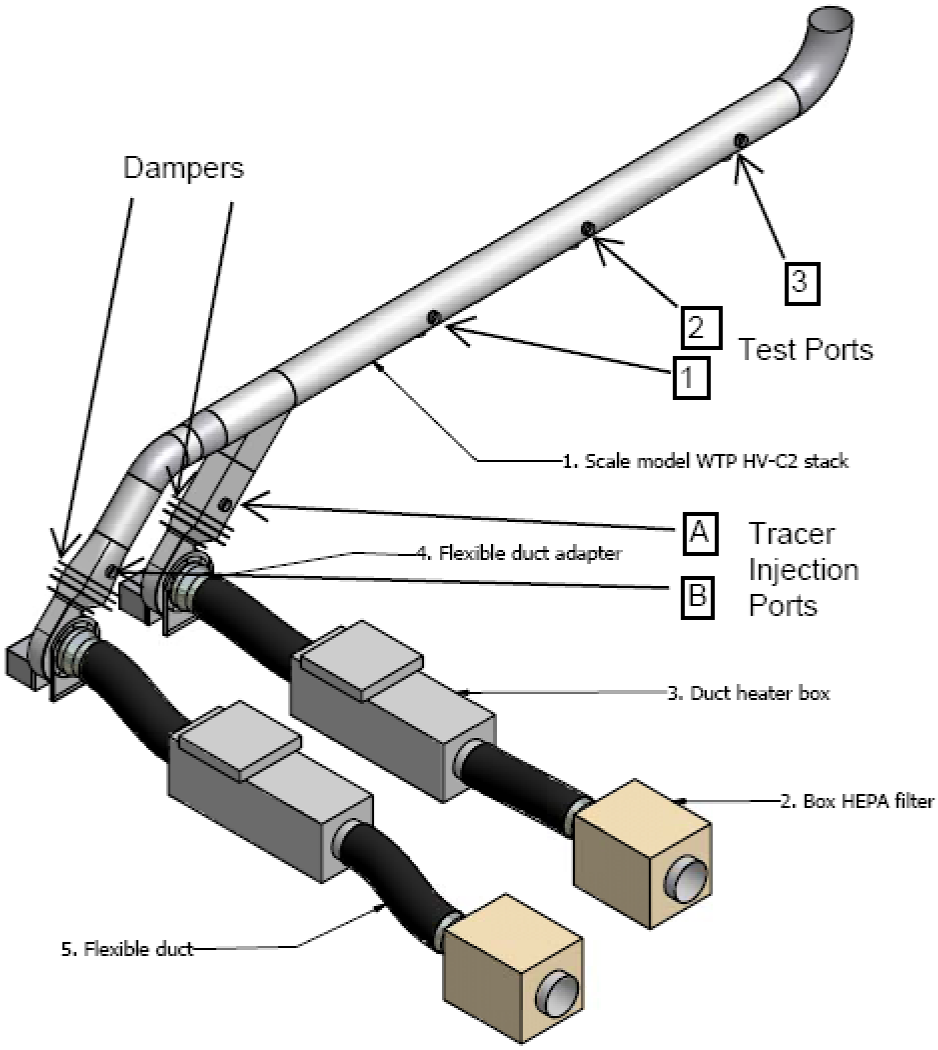

Figure 1.2. Scale Model Tested by Glissmeyer and Droppo (2007)

Table 1.1. Comparison of Model and Actual Stack Dimensions

Operating Parameters	Model	3420 Bldg.
Duct diameter at sampling probe	12 in	62 in
Number of duct diameters from upstream duct junction to sampling probe or test ports	Port 1 – 4.5 Port 2 – 9.5 Port 3 – 14.5	15.3
Number of duct diameters from sampling probe or test ports to downstream bend	Port 3 – 2.25	3
Discharge diameter	12 in	52 in
Number of operating fans	1 and 2	2
Total available fans	2	3

2.0 Testing Strategy

The velocity uniformity test results from the model stack are an important factor in the applicability of the model stack results to any other stack. Table 2.1 lists the results from the velocity uniformity test conducted on the model using Test Ports 2 and 3 with both one and two operating fans. The average velocity uniformity (%COV) results were 4.8% COV and 4.9% COV for one and two operating fans, respectively. The most applicable test for comparison with the 3420 Building exhaust system is the scale model results from Test Port 3 when both fans were running. The average velocity uniformity for these conditions was 4.7% COV. Therefore, the acceptance range for velocity uniformity results for the 3420 Building exhaust is from 0 to 9.7% COV[a] for the results from the HV-C2 scale model to be considered applicable.

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 during the tests with typical flow rates (DV=99,200) was within the acceptable factor of six of the scale model's DV product (32,556 × 6 = 195,336) for two operating fans. Table 2.2 also includes the Reynolds number for the scale tests and the building stack tests. In all cases, the Reynolds numbers are greater than 10,000, which is another criterion for applying the scale-model results to the building stack.

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

[a] 4.7% +/- 5.0% = 0% - 9.7% (considering only positive values).

Table 2.2. Ranges of Acceptable Diameter × Velocity Values and Reynolds Numbers

Stack	Diameter (in.)	Configuration	Mean Velocity (fpm)	D × V (in. × fpm)	Maximum 6 × (D × V)	Reynolds Number
Model	12	One Fan	1245	14,940	89,640	1.3E+05
Model	12	Two Fans	2713	32,556	195,336	2.8E+05
3420	62	Two Fans	1600	99,200		8.6E+05
3420	62	Three Fans	2600	161,200		1.4E+06

Table 2.3 lists the minimum tests needed on the 3420 Building Filtered Exhaust Stack. This table also includes optional tests that may be required if the applicable criteria for velocity uniformity or the diameter × velocity product are not met as presented above.

Table 2.3. Minimum Test Runs for 3420 Building 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 Methods

The testing methods for the confirmatory tests conducted at the 3420 Building stack are outlined in this section. Per the requirement outlined in Section 1, only the flow angle and velocity uniformity tests were conducted on the actual stack. Tracer testing on the actual stack is not currently anticipated. Figure 3.1 shows the portion of the 3420 duct from approximately the location of the air sampling probe and test ports used in this testing to the stack exhaust. The large grey rectangular box affixed to the side of the duct is the Radiological Air Emission Sampling (RAES) system. The individuals in the photograph are standing on the platform on the north side of the duct that allows access to the inspection hatch and test ports. Figure 3.2 is a photo of the stack interior taken with the inspection hatch removed. The photo is looking nominally downstream in the stack and shows the shrouded nozzle and flow sensor that make up the sample probe assembly as well as the Pitot tube used in the testing.

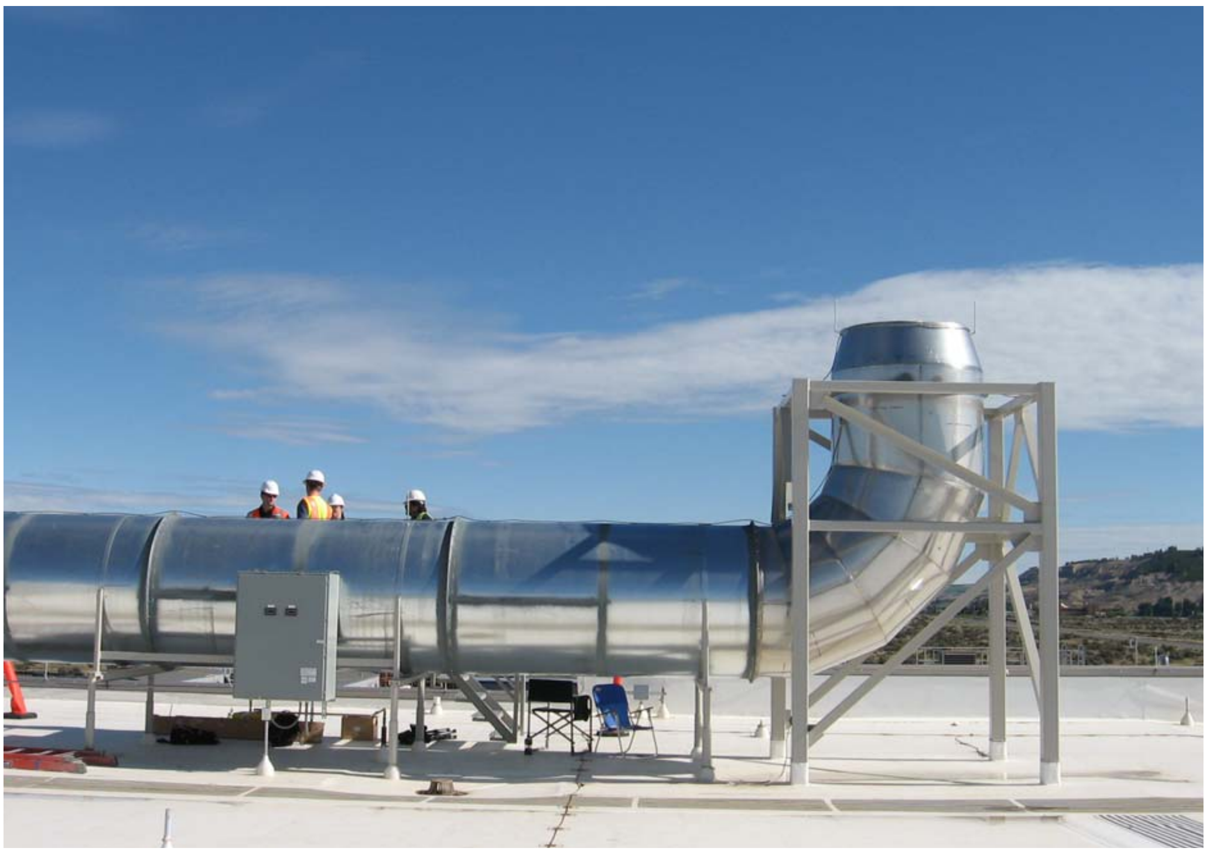

Figure 3.1. The 3420 Stack from the Sampling Probe Location to the Exhaust

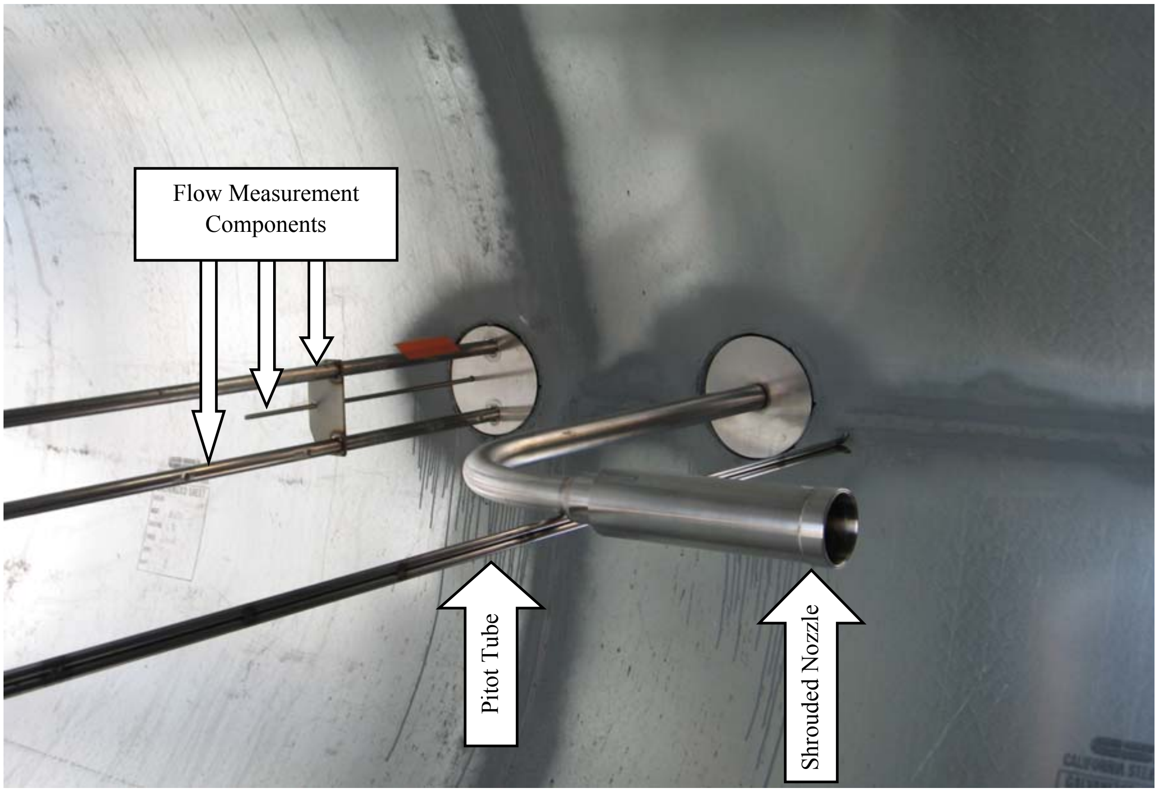

Figure 3.2. Permanent Air Monitoring Probe Assembly with Temporary Pitot Tube Inserted

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 that sample extraction performance is not degraded. The test method to determine the air velocity vector is based on 40 CFR 60, Appendix A, Method 1, Section 11.4, “Verification of the Absence of Cyclonic Flow.” The term “flow angle” refers to the average angle between the air velocity vector and the axis of the exhaust duct (which is parallel to the axis of the sampling nozzle). The flow angle was measured on a grid of points in a cross section of the 3420 Building Filtered Exhaust Stack at the test ports just a few inches downstream 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 (across the north-south diameter of the duct). The other line was perpendicular to the sample probe assembly (across the top-bottom diameter of the duct). 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. The criterion for acceptance from the flow angle test is that the average angle must be <20°.

The flow angle measurements were made with an S-type Pitot tube (Dwyer Instruments, 160S-72, Michigan City, IN) attached by flexible tubing to a slant-tube manometer (Dwyer Instruments, 400-5) and an angle-indicating device attached to the sampling port as shown in Figure 3.3. For this test, the S-type Pitot tube was rotated so that the planes of the two openings at the tip of the tube were parallel to the flow in the duct. The Pitot tube is considered perpendicular to the flow in this position. The large metal plate in Figure 3.3 is the angle-indicating device. It has markings at every degree from -30 degrees to

30 degrees. When the pressures on both tubes of the S-type Pitot tube were equal (as indicated by the manometer), the angle shown on the angle-indicating device is recorded as the reading. Figure 3.3a shows the Pitot tube installed on the 3410 stack, which has a configuration similar to the 3420 Building. Figure 3.3b shows the manometer mounted on the inspection hatch cover at the 3420 Building. The PNNL operating procedure EMS-JAG-05 and the Test Instruction TI-STMON-011 were used to conduct this test.

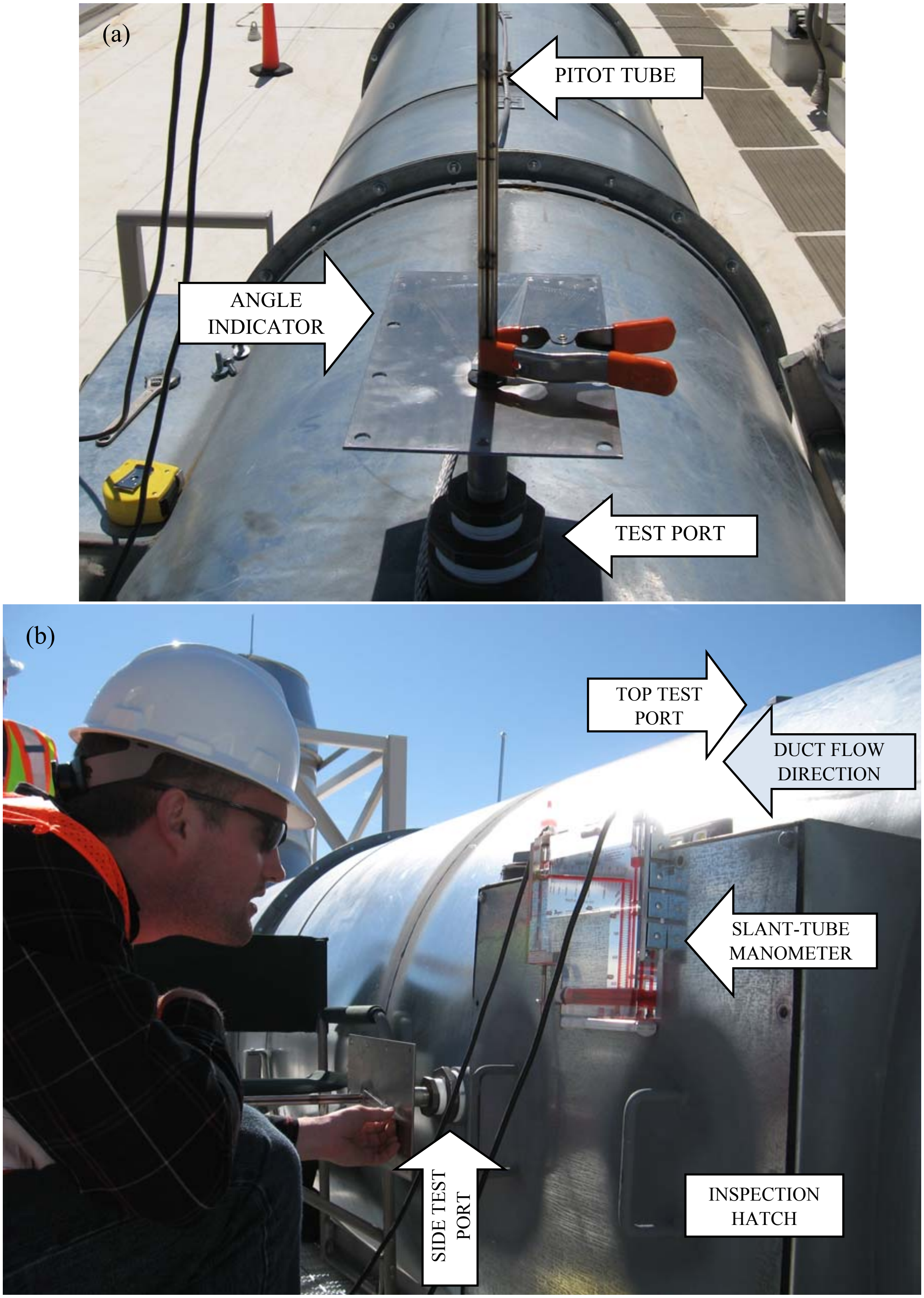

Figure 3.3. Flow Angle Indicator and Pitot Tube Installed on (a) the Top Port of the 3410 Stack as an Example and (b) the Side Port of the 3420 Stack to Show Actual Stack with the Manometer

3.2 Velocity Uniformity Test

The uniformity of air velocity at the stack monitoring location indicates the degree to which the momentum in the stack is well-mixed. The method used to conduct the velocity uniformity tests was based on 40 CFR 60, Appendix A, Method 1. The measurement grid used in the velocity uniformity tests was the same as the grid used for the flow angle test. In general, the criterion for acceptance from the velocity uniformity test is that the COV should be less than 20%.

The air velocity was measured three times at each of the 17 grid points across the cross-section of the duct. The average of the three measurements for the center two thirds of the stack was used to determine the mean and standard deviation of the velocity across the cross-sectional plane. The coefficient of variance (also known as the percent relative standard deviation) was calculated as 100 times the standard deviation divided by the mean. For comparison with the previously conducted tests, the %COV from the actual stack must be between 0 and 9.7% for compliance.

Each air velocity measurement was made using an S-type Pitot tube connected to a calibrated electronic manometer (GrayWolf, Zephyr II+, Shelton, CT) by flexible tubing. Duct air temperature measurements were made with a handheld thermal anemometer (TSI, Model 8360, Shoreview, MN). Figure 3.4 shows the electronic manometer used for this test. In this test, the S-type Pitot tube was positioned so that the normal vector to one of the two openings at the tip was pointing in the same direction as the axis of the duct. The procedure EMS-JAG-04 and the Test Instruction TI-STMON-010 were followed to conduct this test.

Figure 3.4. Electronic Manometer Connected to Pitot Tube (not shown)

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:

- American Society of Mechanical Engineers (ASME) NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part 1, "Requirements for Quality Assurance Programs for Nuclear Facilities (ASME 2000a)."
- ASME NQA-1-2000, Part II, Subpart 2.7, *Quality Assurance Requirements for Computer Software for Nuclear Facility Applications* (ASME 2000b).
- ASME NQA-1-2000, Part IV, Subpart 4.2, *Graded Approach Application of Quality Assurance Requirements for Research and Development* (ASME 2000c).

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

The Stack Monitoring Project (STMON) implements an National Quality Assurance (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—Developmental 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 Developmental Work is to make sure that adequate controls to support movement into commercialization exist.

(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.

- 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,[a] *Document Preparation and Change*. This review verifies that the reported results are traceable, that inferences and conclusions are soundly based, and that 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.

(a) QA-STMON-0601, Rev. 0. January 2, 2010. "Document Preparation and Change," Pacific Northwest National Laboratory, Richland, Washington.

4.0 Stack Testing Results

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

The duct diameters that were field measured at the test ports were found to be 61.5 and 62.0 inches across the vertical and horizontal traverses, respectively, as listed in Table 4.1. The distance from the test ports to the nearest upstream disturbance (the junction of the ducts from the two fans) was 79 ft. The tests were conducted at 15.4 duct diameters (DIA = linear distance divided by duct diameter) downstream of the duct junction. In comparison, the scale model tests were conducted at ports located 4.45 DIA, 9.47 DIA, and 14.5 DIA.

Table 4.1. 3420 Duct Depth Measurements

Direction Across Duct	Measured Duct Diameter, in.
Vertical	61.5
Horizontal	62.0

4.1 Velocity Uniformity

Table 4.2 lists the results for the velocity uniformity tests runs (VTs) performed on the 3420 duct. The maximum flow condition used all three fans with all fume hood sashes opened. The minimum flow condition used two of the fans with all fume hood sashes closed. The typical operating condition is expected to be two fans with a mix of opened and closed fume hoods. In all cases, the results were well within the criterion of COV values less than 20%. The average of the four tests was 3.6% COV, which compares well with the 4.7% COV measured for the most similar (geometric and operational) condition represented by the model tests. COV values were within the acceptance criterion derived in Section 2 (<9.7% COV) for verifying that the 3420 Building Filtered Exhaust Stack configuration is represented by the model tests of Glissmeyer and Droppo (2007). The completed data sheets from these tests are available in Appendix A.

Table 4.2. 3420 Building Filtered Exhaust Stack Velocity Uniformity Test Runs

Fan Operating Configuration	Run Nos.	Measured acfm	% COV
Fans 1, 2, & 3 / Sashes open	VT-1	56,023	3.5
Fans 1, 2, & 3 / Sashes open	VT-2	54,592	3.4
Fans 2 & 3 / Sashes closed	VT-3	33,552	2.3
Fans 2 & 3 / Sashes closed	VT-4	34,284	5.0

4.2 Flow Angle

Table 4.3 lists the results for the flow angle tests (FAs) performed on the 3420 duct. The flow conditions for this test were the same as for the velocity uniformity test. In all cases, the results were well within the criterion of average flow angle values less than 20°. The average flow angle for these tests was 2.0°. The completed data sheets from these two tests are available in Appendix A.

Table 4.3. Summary of Flow Angle Tests

Fan Operating Configuration	Run Nos.	Approx. Air Velocity Near Duct Centerline acfm	Mean Absolute Flow Angle
Fans 1, 2, & 3 / Sashes open	FA-1	3,100	1.9
Fans 1, 2, & 3 / Sashes open	FA-2	3,200	1.8
Fans 2 & 3 / Sashes closed	FA-3	1,750	2.2

5.0 Conclusions

Velocity uniformity tests were performed on the 3420 Building Filtered Exhaust Stack during June 2010 and show an acceptable level of agreement with the results of the scale model tests performed previously (Glissmeyer and Droppo 2007). The previous tests of velocity uniformity had COV values of 4.7%, which allows the results of the actual stack to be up to 9.7% COV. The 3420 velocity tests compared well with the scale model results with an average value of 3.6% COV. Consequently, the location of 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-sized stack. The results from Glissmeyer and Droppo (2007) are included in Appendix B of this report. The results of the flow angle test on the 3420 Building Filtered Exhaust Stack also show compliance with the flow angle criterion.

6.0 References

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

40 CFR 60, Appendix A, Method 1. 2008. "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.

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ASME—American Society of Mechanical Engineers. 2000b. 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.

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Appendix A

Data Sheets

Appendix A: Data Sheets

FLOW ANGLE DATA FORM

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

Site	**EP-3420--01-S**		Run No.	**FA-1**
Date	6/11/2010		Fan Setting	**Fans 1, 2, & 3**
Tester	JEF, BS, EA, QQ		Fan configuration	**Sashes open**
Stack Dia.	61.75	in	Approx. air vel.	3100 fpm at center
Stack X-Area	2994.8	in2	Units	degrees (clockwise > pos. nos.)
Elevation	N.A.	ft	Port	nearest to probe
Distance to disturbance	79	ft	Stack Temp	69.8 deg F
Start/End Time	0850/956			

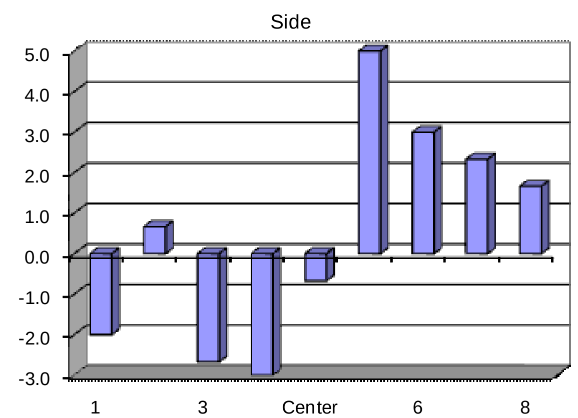
Order -->		1st				2nd			
Traverse-->		Side				Top			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	1.98	-5	-3	2	-2.0	11	11	9	10.3
2	6.51	0	0	2	0.7	2	4	2	2.7
3	12.03	-2	-2	-4	-2.7	-3	1	0	-0.7
4	20.03	-3	-3	-3	-3.0	-1	1	-1	-0.3
Center	31.00	-1	-1	0	-0.7	0	0	1	0.3
5	41.97	4	5	6	5.0	1	1	1	1.0
6	49.97	3	1	5	3.0	2	2	2	2.0
7	55.49	4	0	3	2.3	2	2	2	2.0
8	60.02	2	1	2	1.7	2	2	2	2.0
Mean of absolute values of all data:					2.3				2.4
w/o points by wall:					2.5				1.3
								all	2.4
								w/o wall pts	1.9

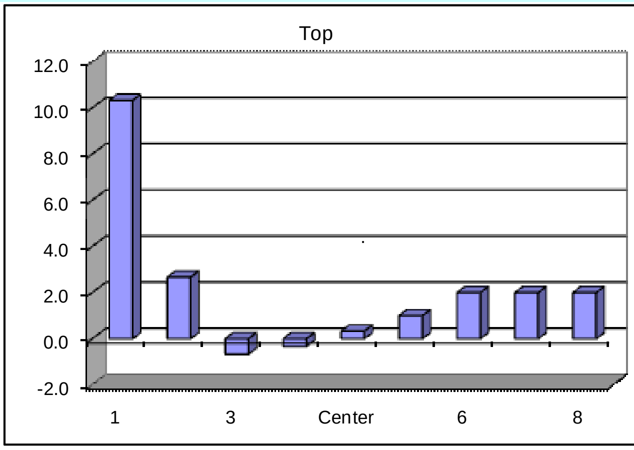
Instuments Used:			**Cal. Due**
S-type pitot	Dwyer 72-inch S-type Pitot#11		Cert. of conformance
Velocity sensor	TSI VelociCalc	SN 305039	6/23/2010
Angle indicator	Shop built	Cat. 3	
Manometer	Dwyer 400-5, S36N	Cat. 3	Man-4

Notes:
start
end
RAES Not functional

Side, position 5 is influenced by probe

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).





Entries made by:	Julia Flaherty		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	Signature on original	6/11/2010	Signature/date	*Signature on original*	6/25/2010

FLOW ANGLE DATA FORM FlowAngleRev0.xls 4-Aug-06 Based on ---- CCP-WTPSP-178

Site	**EP-3420--01-S**	Run No.	**FA-2**
Date	6/11/2010	Fan Setting	**Fans 1, 2, & 3**
Tester	JEF, BS, EA, QQ	Fan configuration	**Sashes Open**
Stack Dia.	61.75 in	Approx. air vel.	3200 fpm at center
Stack X-Area	2994.8 in2	Units	degrees (clockwise > pos. nos.)
Elevation	N.A. ft	Port	nearest to probe
Distance to disturbance	79 ft	Stack Temp	72 deg F
Start/End Time	1000/1045		

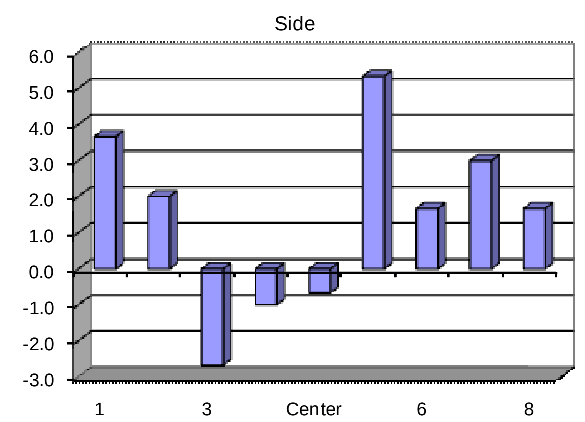
Order -->		2nd				1st			
Traverse-->		Side				Top			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	1.98	6	0	5	3.7	11	11	11	11.0
2	6.51	4	1	1	2.0	0	2	1	1.0
3	12.03	-2	-2	-4	-2.7	-3	-3	-2	-2.7
4	20.03	-1	1	-3	-1.0	-1	-1	-1	-1.0
Center	31.00	-1	0	-1	-0.7	0	-1	0	-0.3
5	41.97	6	5	5	5.3	1	1	1	1.0
6	49.97	-2	5	2	1.7	1	2	1	1.3
7	55.49	2	3	4	3.0	2	2	2	2.0
8	60.02	0	2	3	1.7	2	2	2	2.0
Mean of absolute values of all data:					2.4				2.5
w/o points by wall:					2.3				1.3
								all	2.4
								w/o wall pts	1.8

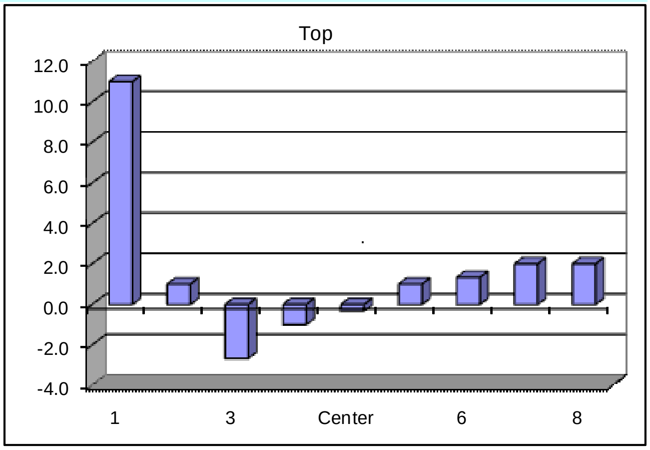
Instuments Used:			**Cal. Due**
S-type pitot	Dwyer 72-inch S-type Pitot#11		Cert. of conformance
Velocity sensor	TSI VelociCalc	SN 305039	6/23/2010
Angle indicator	Shop built	Cat. 3	
Manometer	Dwyer 400-5, S36N	Cat. 3	Man-4

Notes:
start
end
RAES Not functional

Side, position 5 is influenced by probe

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).





Entries made by:	Julia Flaherty		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	Signature on original	6/11/2010	Signature/date	*Signature on original*	6/25/2010

FLOW ANGLE DATA FORM

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

Site	**EP-3420--01-S**	Run No.	**FA-3**
Date	6/11/2010	Fan Setting	**Fans 2, 3**
Tester	JEF, EA, BS, QQ	Fan configuration	**Sashes closed**
Stack Dia.	61.75 in	Approx. air vel.	1750 fpm at center
Stack X-Area	2994.8 in2	Units	degrees (clockwise > pos. nos.)
Elevation	N.A. ft	Port	nearest to probe
Distance to disturbance	79 ft	Stack Temp	74.2 deg F
Start/End Time	11:30/12:10		

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	1.98	1	5	10	5.3	3	0	0	1.0
2	6.51	5	4	4	4.3	-4	0	-4	-2.7
3	12.03	-1	-1	0	-0.7	-6	-3	-4	-4.3
4	20.03	-1	-1	-1	-1.0	-4	-2	-3	-3.0
Center	31.00	-2	-2	-2	-2.0	-2	-2	-3	-2.3
5	41.97	0	0	10	3.3	-2	-1	-3	-2.0
6	49.97	-1	0	5	1.3	-2	0	-2	-1.3
7	55.49	-2	0	4	0.7	-2	0	-2	-1.3
8	60.02	-4	0	3	-0.3	-2	-2	-3	-2.3
Mean of absolute values of all data:					2.1				2.3
w/o points by wall:					1.9				2.4
								all	2.2
								w/o wall pts	2.2

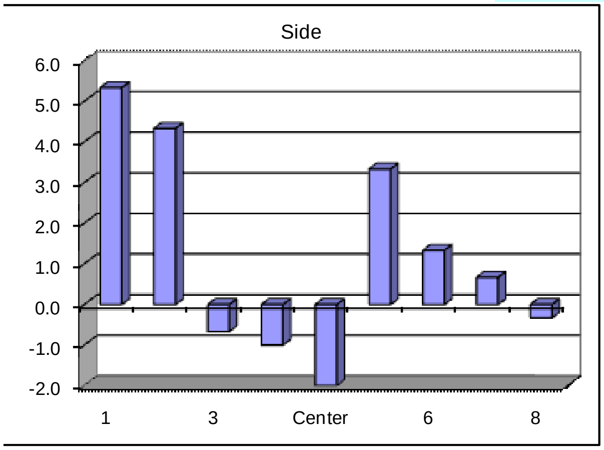
Instuments Used:

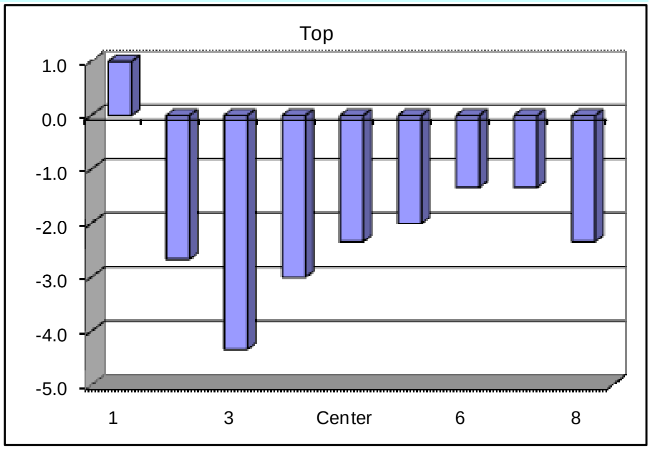
			Cal. Due
S-type pitot	Dwyer 72-inch S-type Pitot#11		Cert. of conformance
Velocity sensor	TSI VelociCalc	SN 305039	6/23/2010
Angle indicator	Shop built	Cat. 3	
Manometer	Dwyer 400-5, S36N	Cat. 3	Man-4

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).

Notes:
start
end RAES Not funcional

Side, position 5 is influenced by probe





Entries made by:	Julia Flaherty		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	*Signature on original*	6/11/2010	Signature/date	*Signature on original*	6/25/2010

VELOCITY TRAVERSE DATA FORM

Site	EP-3420-01-S	Run No.	VT-1
Date	6/10/10	Fan Configuration	Fans 1, 2, & 3
Testers	JAG, QQ, BS, EA	Fan Setting	sashes open
Stack Dia.	61.75 in.	Stack Temp	deg F
Stack X-Area	2994.8 in.2	Start/End Time	1040/1345
Test Port	nearest to probe	Center 2/3 from	5.67 to: 56.08
Distance to disturbance	79 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Pitot correction:	0.84

Order -->		1st				2nd			
Traverse-->		Side				Top			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.98	2107	2213	2142	2154.0	2415	2451	2458	2441.3
2	6.51	2692	2699	2705	2698.6	2747	2754	2731	2744.0
3	12.03	2843	2848	2854	2848.2	2887	2865	2822	2858.0
4	20.03	2915	2912	2907	2911.4	2944	2913	2901	2919.3
Center	31.00	2954	2944	2947	2948.4	2950	2959	2922	2943.6
5	41.97	2833	2876	2890	2866.6	2926	2927	2872	2908.4
6	49.97	2773	2762	2780	2771.7	2859	2853	2794	2835.3
7	55.49	2680	2633	2633	2648.8	2734	2696	2663	2697.8
8	60.02	2407	2396	2388	2396.8	2371	2453	2377	2400.4
Averages ---------->		2689.3	2698.2	2694.1	2693.8	2759.2	2763.7	2726.5	2749.8

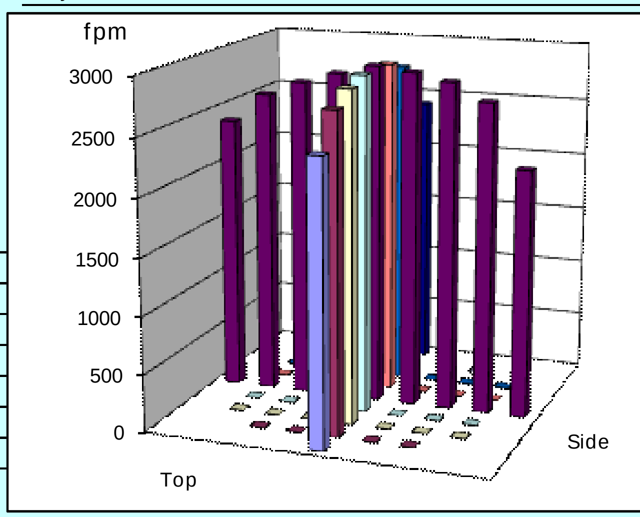
All	ft/min	Dev. from mean	***Center 2/3***	Side	Top	All
Mean	2721.8		Mean	2813.4	2843.8	2828.6
Min Point	2154.0	-20.9%	Std. Dev.	111.0	92.5	99.4
Max Point	2948.4	8.3%	COV as %	3.9	3.3	**3.5**

Flow w/o C-Pt 56023 acfm

Vel Avg w/o C-Pt 2694 fpm

	Start	Finish	
Stack temp	74	75	F
Equipment temp	N.A.	N.A.	F
Ambient temp	67	72	F
Stack static	1.00	0.20	mbars
Ambient pressure	1002	1002	mbars
Total Stack pressure	1003	1002.2	mbars
Ambient humidity	31%	31%	RH

Instuments Used:		Cal Due
Fisher Scientific	SN 90936818	9/29/2010
Zephyr II+	SN 80355	9/18/2010
Dwyer Pitot Tube	PN 1605-72 A304	Cert. of Conf.



Notes: RAES readings, scfm

start not functional

end

16-ft. to the bend from test port

Stack Temp. 74 deg F = 23 deg C

Entries made by:	John Glissmeyer		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	*Signature on original*	6/10/2010	Signature/date	*Signature on original*	6/25/2010

VELOCITY TRAVERSE DATA FORM

Site	**EP-3420-01-S**	Run No.	**VT-2**
Date	**6/10/10**	Fan Configuration	**Fans 1, 2, & 3**
Testers	**JAG, QQ, EA, BS**	Fan Setting	**sashes open**
Stack Dia.	61.75 in.	Stack Temp	deg F
Stack X-Area	2994.8 in.2	Start/End Time	15:15/16:51
Test Port	nearest to probe	Center 2/3 from	5.67 to: 56.08
Distance to disturbance	79 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Pitot correction:	0.84

Order -->		2nd				1st			
Traverse-->		Side				Top			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.98	2010	2090	2108	2069.5	2385	2344	2360	2362.9
2	6.51	2644	2576	2627	2615.8	2675	2738	2621	2677.9
3	12.03	2746	2754	2782	2760.5	2795	2810	2769	2791.0
4	20.03	2816	2863	2832	2836.7	2881	2838	2799	2839.5
Center	31.00	2872	2862	2852	2861.9	2870	2873	2860	2867.8
5	41.97	2790	2817	2821	2809.2	2864	2830	2845	2846.5
6	49.97	2730	2736	2675	2713.8	2785	2776	2759	2773.4
7	55.49	2580	2596	2612	2595.6	2670	2654	2650	2657.8
8	60.02	2310	2266	2310	2295.4	2356	2352	2355	2354.2
Averages ---------->		2610.9	2617.6	2624.3	2617.6	2697.8	2690.5	2668.7	2685.7

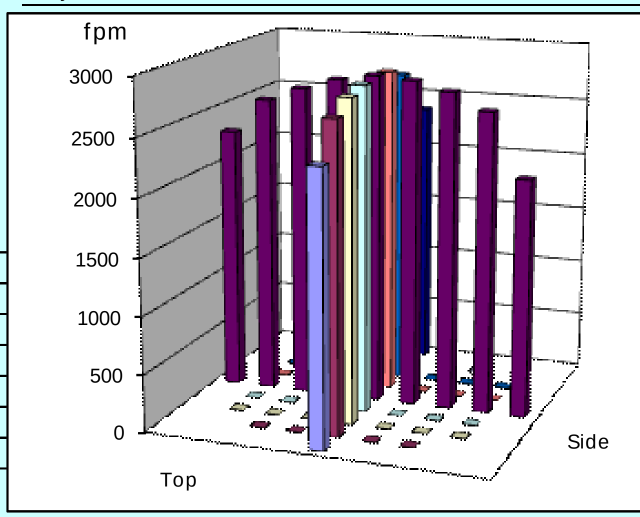
All	ft/min	Dev. from mean	***Center 2/3***	Side	Top	All
Mean	2651.6		Mean	2741.9	2779.1	2760.5
Min Point	2069.5	-22.0%	Std. Dev.	105.2	82.8	93.0
Max Point	2867.8	8.2%	COV as %	3.8	3.0	**3.4**

Flow w/o C-Pt 54592 acfm

Vel Avg w/o C-Pt 2625 fpm

	Start	Finish	
Stack temp	71	67	F
Equipment temp	N.A.	N.A.	F
Ambient temp	74	61	F
Stack static	0.30	0.80	mbars
Ambient pressure	1002	1002	mbars
Total Stack pressure	1002	1002.8	mbars
Ambient humidity	31%	78%	RH

Instuments Used:		Cal Due
Fisher Scientific	SN 90936818	9/29/2010
Zephyr II+	SN 80355	9/18/2010
TSI Velocicalc	SN 305039	6/23/2010
Dwyer Pitot Tube	PN 1605-72 A304	Cert. of Conf.



Notes:

Entries made by:	Brian Smith		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	*Signature on original*	6/10/2010	Signature/date	*Signature on original*	6/25/2010

VELOCITY TRAVERSE DATA FORM

Site	EP-3420-01-S	Run No.	VT-3
Date	6/11/10	Fan Configuration	Fans 2 & 3
Testers	JEF, EA, QQ	Fan Setting	sashes closed
Stack Dia.	61.75 in.	Stack Temp	deg F
Stack X-Area	2994.8 in.2	Start/End Time	13:30/15:05
Test Port	nearest to probe	Center 2/3 from	5.67 to: 56.08
Distance to disturbance	79 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Pitot correction:	0.84

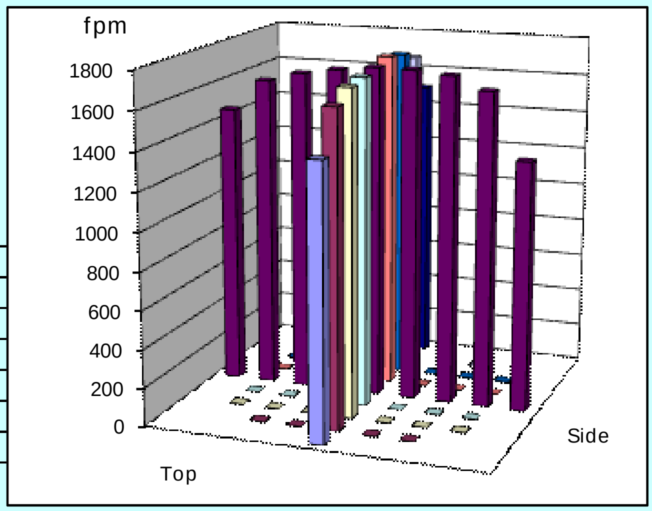
Order -->		2nd				1st			
Traverse-->		Side				Top			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.98	1292	1318	1305	1305.1	1341	1430	1420	1396.6
2	6.51	1635	1647	1654	1645.6	1594	1618	1614	1608.9
3	12.03	1709	1719	1706	1711.4	1631	1686	1687	1668.0
4	20.03	1720	1732	1736	1729.6	1661	1692	1702	1684.8
Center	31.00	1725	1730	1740	1731.5	1671	1709	1730	1703.2
5	41.97	1694	1713	1718	1708.3	1729	1725	1728	1727.3
6	49.97	1671	1697	1672	1679.7	1702	1710	1718	1710.0
7	55.49	1618	1637	1632	1629.0	1672	1667	1660	1666.3
8	60.02	1449	1478	1473	1466.6	1478	1458	1490	1475.6
Averages ---------->		1612.5	1630.3	1626.1	1623.0	1608.8	1632.7	1638.7	1626.7

All	ft/min	Dev. from mean	***Center 2/3***	Side	Top	All
Mean	1624.9		Mean	1690.7	1681.2	1686.0
Min Point	1305.1	-19.7%	Std. Dev.	40.6	38.9	38.5
Max Point	1731.5	6.6%	COV as %	2.4	2.3	**2.3**

Flow w/o C-Pt 33552 acfm
Vel Avg w/o C-Pt 1613 fpm

	Start	Finish	
Stack temp	72.5	74.7	F
Equipment temp	N.A.	N.A.	F
Ambient temp	75.2	77	F
Stack static	0.20	0.20	mbars
Ambient pressure	1010	1011	mbars
Total Stack pressure	1010	1011	mbars
Ambient humidity	32%	31%	RH

Instuments Used:		Cal Due
Fisher Scientific	SN 90936818	9/29/2010
Zephyr II+	SN 80355	9/18/2010
Type K Thermocouple	Tag # 24987	9/11/2010
Dwyer Pitot Tube	PN 1605-72 A304	Cert. of Conf.



Notes:

Entries made by: Julia Flaherty		Technical Data Review performed by: Carmen Arimescu	
Signature/date	*Signature on original* 6/11/2010	Signature/date	*Signature on original* 6/25/2010

VELOCITY TRAVERSE DATA FORM

Site	**EP-3420-01-S**	Run No.	**VT-4**
Date	**6/11/10**	Fan Configuration	**Fans 2 & 3**
Testers	**JEF, EA, QQ**	Fan Setting	**Sashes closed**
Stack Dia.	61.75 in.	Stack Temp	deg F
Stack X-Area	2994.8 in.2	Start/End Time	15:15/16:55
Test Port	nearest to probe	Center 2/3 from	5.67 to: 56.08
Distance to disturbance	79 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Pitot correction:	0.84

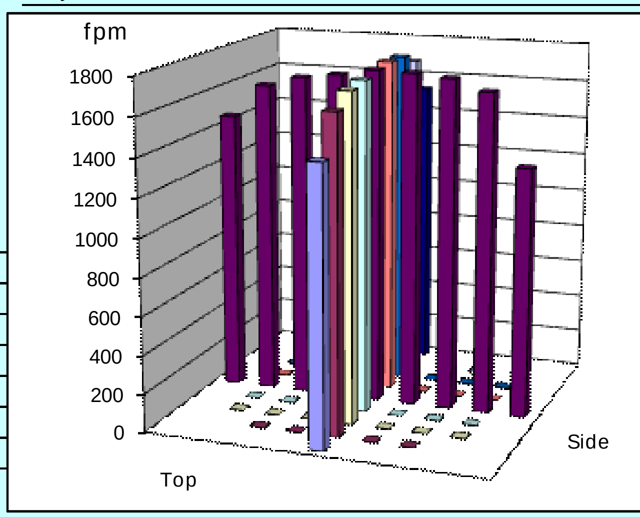
Order -->		1st				2nd			
Traverse-->		Side				Top			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.98	1300	1296	1307	1301.2	1462	1397	1419	1425.8
2	6.51	1668	1667	1678	1671.3	1638	1625	1617	1626.8
3	12.03	1735	1736	1711	1727.6	1688	1685	1707	1693.4
4	20.03	1740	1748	1742	1743.3	1705	1713	1725	1714.2
Center	31.00	1746	1745	1756	1748.9	1737	1743	1723	1734.3
5	41.97	1714	1719	1710	1714.4	1751	1742	1746	1746.4
6	49.97	1692	1691	1683	1688.7	1746	1751	1729	1742.2
7	55.49	1644	1630	1631	1635.2	1704	1667	1704	1691.8
8	60.02	1467	1467	1452	1462.2	1524	1504	1507	1511.7
Averages ---------->		1634.1	1633.3	1630.2	1632.5	1661.7	1647.5	1652.9	1654.1

All	ft/min	Dev. from mean	***Center 2/3***	Side	Top	All
Mean	1643.3		Mean	1704.2	1707.0	1705.6
Min Point	1301.2	-20.8%	Std. Dev.	41.3	41.7	39.9
Max Point	1748.9	6.4%	COV as %	2.4	2.4	**2.3**

Flow w/o C-Pt 33920 acfm
Vel Avg w/o C-Pt 1631 fpm

	Start	Finish	
Stack temp	74.7	73	F
Equipment temp	N.A.	N.A.	F
Ambient temp	77	78	F
Stack static	0.20	0.20	mbars
Ambient pressure	1011	1011	mbars
Total Stack pressure	1011	1011	mbars
Ambient humidity	31%	30%	RH

Instuments Used:		Cal Due
Fisher Scientific	SN 90936818	9/29/2010
Zephyr II+	SN 80355	9/18/2010
Type K Thermocouple	Tag # 24987	9/11/2010
Dwyer Pitot Tube	PN 1605-72 A304	Cert. of Conf.



Notes:

Entries made by:	Julia Flaherty		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	*Signature on original*	6/11/2010	Signature/date	*Signature on original*	6/25/2010

Appendix B

Applicable Qualification Results from the Model Stack

Appendix B: Applicable Qualification Results from the Model Stack

These data are extracted from the report by 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. The model test Port 3 was about 1 duct diameter closer to the nearest upstream disturbance than the test ports on the 3420 Building Filtered Exhaust Stack. Therefore, the tracer uniformity results for the 3420 Building Filtered Exhaust Stack would likely be slightly 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 scale model 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 for test ports 2 and 3 are shown. The model test Port 3 was just 1 duct diameter closer to the nearest upstream disturbance than the test ports on the 3420 Building Filtered Exhaust Stack. 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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