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

Sampling Point Compliance Tests for 325 Building at Set-Back Flow Conditions

MY Ballinger
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May 2011

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Richland, Washington 99352

Summary

The stack sampling system at the 325 Building (Radiochemical Processing Laboratory [RPL]) was constructed to comply with the American National Standards Institute's (ANSI's) *Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities* (ANSI N13.1–1969). This standard provided prescriptive criteria for the location of radionuclide air-sampling systems. In 1999, the standard was revised (*Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stacks and Ducts of Nuclear Facilities* [ANSI/Health Physics Society [HPS] 13.1–1999]) to provide performance-based criteria for the location of sampling systems.

Testing was conducted for the 325 Building stack to determine whether the sampling system would meet the updated criteria for uniform air velocity and contaminant concentration in the revised ANSI/HPS 13.1–1999 standard under normal operating conditions (Smith et al. 2010). Measurement results were within criteria for all tests. Additional testing and modeling was performed to determine whether the sampling system would meet criteria under set-back flow conditions. This included measurements taken from a scale model with one-third of the exhaust flow and computer modeling of the system with two-thirds of the exhaust flow.

This report documents the results of the set-back flow condition measurements and modeling. Tests performed included flow angularity, uniformity of velocity, gas concentration, and particle concentration across the duct at the sampling location. Results are within ANSI/HPS 13.1–1999 criteria for all tests. These tests are applicable for the 325 Building stack under set-back exhaust flow operating conditions (980–45,400 cubic feet per minute [cfm]) with one fan running. The modeling results show that criteria are met for all tests using a two-fan configuration exhaust (flow modeled at 104,000 cfm). Combined with the results from the earlier normal operating conditions, the ANSI/HPS 13.1–1999 criteria for all tests are met for all configurations: one, two, or three fans (normal).

Acronyms and Abbreviations

AD	aerodynamic diameter
ANSI	American National Standards Institute
CFD	computational fluid dynamics
CFR	Code of Federal Regulations
cfm	cubic feet per minute
COV	coefficient of variation
EPA	Environmental Protection Agency
ft	foot/feet
HPS	Health Physics Society
Hz	hertz
in	inch(es)
kg	kilogram(s)
L	liter(s)
mm	millimeter(s)
OPC	optical particle counter
PNNL	Pacific Northwest National Laboratory
RPL	Radiochemical Processing Laboratory (325 Building)

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1.0 Introduction

The stack sampling system at the 325 Building (Radiochemical Processing Laboratory [RPL]) was constructed to comply with the American National Standards Institute's (ANSI's) *Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities* (ANSI N13.1–1969). This standard provided prescriptive criteria for the location of radionuclide air-sampling systems. In 1999, the standard was revised (*Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stacks and Ducts of Nuclear Facilities* [ANSI/Health Physics Society {HPS} 13.1–1999]) to provide performance-based criteria for the location of sampling systems. Testing was conducted for the 325 Building stack to determine whether the sampling system would meet the updated criteria for uniform air velocity and contaminant concentration in the revised ANSI/HPS 13.1–1999 standard.

The 325 Facility emission point exhausts air from all areas of the building where radioactive materials are handled. The exhaust stream passes through high-efficiency particulate air filters located just upstream of the exhaust fans. The stack (Figure 1.1) is 88 feet (ft) tall and 8 ft in diameter, with flows at approximately 140,000 cfm. The sampling system is located approximately 80 ft above the ground (see the platform in Figure 1.1).

Figure 1.1. The 325 Building Stack

Because of the difficulty in taking measurements at the elevated sampling location and to avoid possible disruptions to facility operations, a scale model was used for the tests. The scale model was fabricated on an outside concrete pad. Scaffolding was used as support for the stack section and to gain access to the sample ports. Four variable speed fans were connected to the scale model in a configuration geometrically similar to the actual stack. The 325 facility normally operates only three of the four fans and alternates the standby fan. Therefore, a similar arrangement was used in the first set of testing (Smith et al. 2010). Testing results from measurements taken in 2002 demonstrated that the sampling location on the 325 Building met the criteria in the 1999 standard for a well mixed location under normal operating conditions.

Subsequent testing was conducted in 2004 to determine whether the stack sampling system at the 325 Building would meet the 1999 standard criteria for uniform air velocity and contaminant concentration if the exhaust air flow was reduced to one-third to reduce energy use. The same scale model was used for these reduced flow tests. Tests performed included flow angularity, uniformity of velocity, gas concentration, and particle concentration across the duct at the sampling location. Tests were conducted with the fan nearest to the stack operating and the fan farthest from the stack operating in order to test the two extremes of fan configuration. Results are within ANSI/HPS 13.1–1999 criteria for all tests. These tests are applicable for the 325 Building stack under reduced flow operating conditions (below 45,400 cfm) with any single fan running.

In addition to the scale model testing, a computational fluid dynamics (CFD) model was used to predict results for a two-fan configuration. Results from the fluid dynamics model were also within ANSI/HPS 13.1–1999 criteria for all tests and bridged the data between the one- and three-fan configurations tested using the scale model.

2.0 Test Information and Results

This section discusses testing of a scale model of the RPL final exhaust system to determine whether the sampling system location met the criteria in ANSI/HPS N13.1–1999 for a well mixed location. The approach, test methods, and results are provided.

2.1 Test Plan

The objective of these tests was to demonstrate whether the EP-325-01-S exhaust stack meets the applicable regulatory criteria regarding the placement of the air-sampling probe under reduced exhaust flow. This has already been demonstrated for the normal flow-rate with three operating fans (Ballinger et al. 2004, Smith et al. 2010). This retest demonstrates whether the criteria are still met if the system flow-rate is reduced from the normal value by a factor of three when only one fan is used. The tests were conducted by Pacific Northwest National Laboratory (PNNL) staff. The standard governing the performance of the tests, test methods, and acceptance criteria is ANSI/HPS N13.1–1999, *Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stack and Ducts of Nuclear Facilities* (ANSI 1999). The test plan for this series is included in Appendix A.

2.2 Scale-Model Testing Criteria

The ANSI/HPS N13.1–1999 standard contains acceptance criteria for the use of a similarly designed stack, including a scale-model, as a substitute for the actual stack (Section 5.2.2.2 of ANSI/HPS N13.1–1999). The acceptance criteria are summarized as follows:

1. The scale model and its sampling location must be geometrically similar to the actual stack, with components influencing contaminant mixing and velocity profile proportional in the scale model proportional to those in the actual stack.
2. The scale model's mean velocity times hydraulic diameter must be within a factor of six of the actual stack. The stack diameter of the scale model must be at least 250 millimeters (mm) at the sampling location. The Reynolds number for the prototype and scale model stacks must be greater than 10,000.

The scale model results are considered valid if:

1. The velocity profile in the actual stack meets the uniformity criteria, and
2. The difference between velocity coefficients of variation (COVs) of the two systems is not more than 5% COV units.
3. The sampling location is placed at a geometrically similar location in the actual and scale model stacks.

A scale model was used for these tests because of the difficulty in taking measurements at the elevated sampling location and to avoid possible disruptions to operations in this nuclear facility. The scale model of the RPL final exhaust system was designed with consideration for the above criteria. The portion of the RPL exhaust system containing the final exhaust fans, downstream ducting, and stack was considered a sufficient segment to model velocity and contaminant mixing adequately. Several scales were considered that fit the criteria above, with a 1:5.33 scale selected based on convenient stack and duct size (the scale model was 18 ft high and 18 inches [in; 46 cm] in diameter), and similarity of stack velocity. See the test plan in Appendix A for more detail on considerations for the scale model. Figure 2.1 shows a side view of the scale model after it was completed.

Figure 2.1. Side View of Scale Model of RPL Final Exhaust System

2.3 Uniformity of Air Velocity

The uniformity of air velocity in the stack cross section where the air sample is being extracted ensures that the air momentum in the stack is well mixed. The method used to demonstrate air velocity uniformity and the results obtained are detailed in the following sections.

2.3.1 Method

To facilitate the performance of this and subsequent tests, it was first necessary to correlate the fan speed controller (a variable frequency drive) with the stack flowrate. Following the procedure in Appendix B, a velocity uniformity measurement (Run VT-LOW1) was made at the midrange fan speed setting (30 hertz [Hz]) to identify a single measurement point that best represented the average velocity. The air velocity was then measured at that point as a function of fan speed setting. The results are plotted in Figure 2.2. The set point for the balance of the tests reported here (37.1 Hz) was estimated from the plot. The Run VT-LOW1 also provided a data point for velocity uniformity.

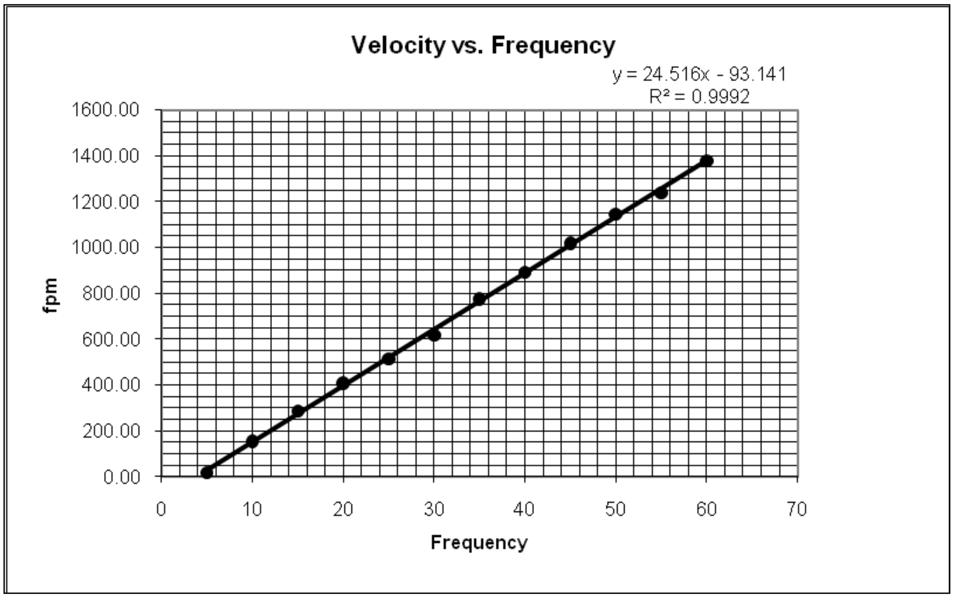


Figure 2.2. Air Velocity as a Function of Fan Speed

For this and most other tests, either the fan nearest to or farthest from the stack (Figure 2.3) was running. These configurations were used because they are expected to bracket the cases for stack mixing. Disturbances closer to the sampling port are expected to be more disruptive to uniform mixing than those further away; thus, the near fan configuration should provide the worst case for velocity uniformity.

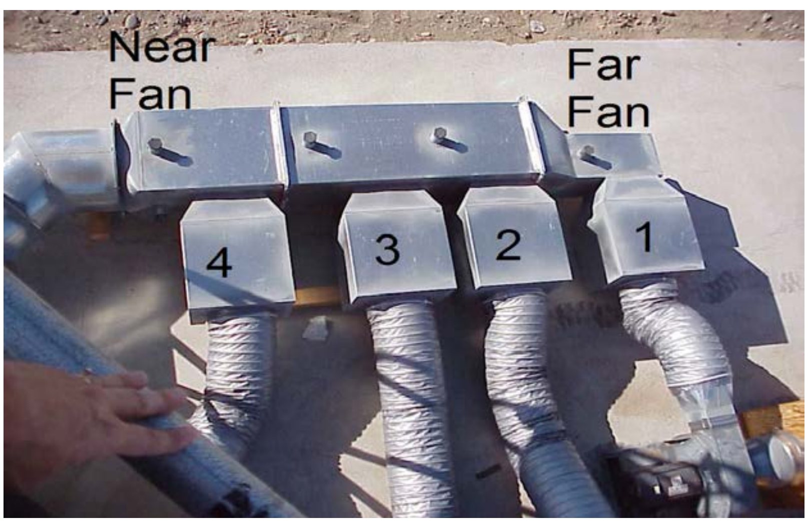


Figure 2.3. Fan Configuration

The method to determine velocity uniformity is an adaptation of 40 Code of Federal Regulations (CFR) 60, Appendix A, Method 1. The equipment included a standard Prandtl-type pitot tube and a calibrated electronic manometer as shown in Figure 2.4. The procedure is detailed in Appendix C. The grid of measurement points was laid out in accordance with the U.S. Environmental Protection Agency (EPA) procedure for eight points on each of two linear traverses, arranged perpendicular to each other.

The center point was added for additional information over what is otherwise a long distance between points 4 and 5. Thus, there were 9 points along the northeast/southwest direction and also along the southeast/northwest direction.

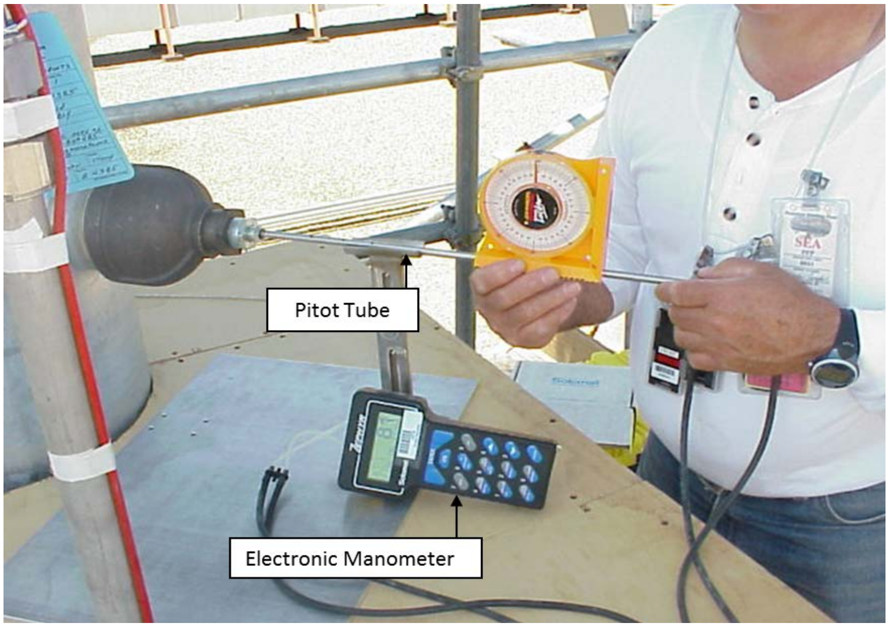


Figure 2.4. Velocity Uniformity Measuring Equipment

2.3.2 Results

The acceptance criterion for uniformity of air velocity is that the COV of the air velocity must be ≤20% across the center two-thirds of the area of the stack. The measured COVs for air velocity in the center two-thirds of the area of the scale model stack are listed in Table 2.1 and range from 1.6 to 9.4. The data sheets are included in Appendix C. All of the scale model test results for velocity uniformity meet the criterion that the air velocity COVs be ≤20%. On the actual stack with one fan operating, the full-scale velocity uniformity COVs range from 3.9 to 10.7 (Recknagle et al. 2008). The scale model and the full scale results show good agreement. This agreement meets the acceptance criterion (±5% COV units) for validating the scale model results. Figure 2.5 shows a bar graph of the mean velocity measured at each point for Run VT-1, one of the scale model results.

Table 2.1. Scale Model Velocity Uniformity Results

Runs	Fan Frequency Setting (Hz)	Stack Flow Rate (cfm)	% COV
Near Fan			
VT-LOW1	30	1100	9.4
VT-1	37.1	1389	4.0
VT-3	37.1	1421	3.4
Far Fan			
VT-2	37.1	1334	1.6
VT-4	37.1	1335	1.9

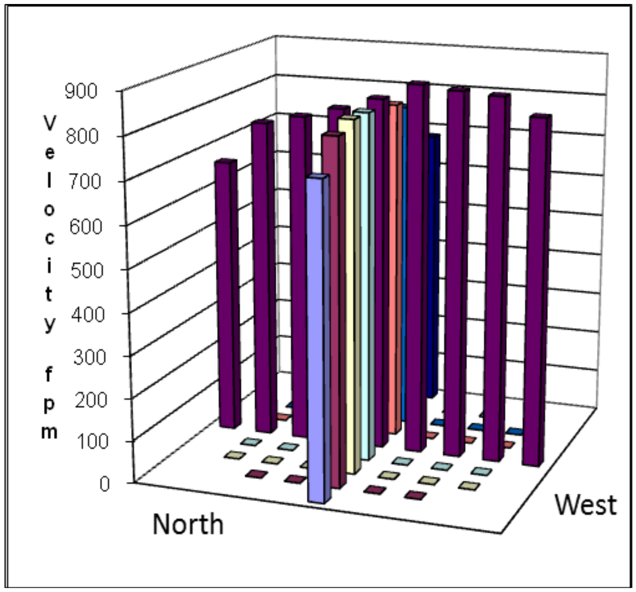


Figure 2.5. Velocity Measurements over the Measurement Grid for Run VT-1

2.4 Angular Flow

The angular flow measurement in the stack cross section where the air sample is being extracted ensures that the flow angle is not more than 20° across the sampling plane. The method used to demonstrate the angular flow and the results obtained are presented below.

2.4.1 Method

The test method used was based on 40 CFR 60, Appendix A, Method 1, Section 2.4, “Verification of the Absence of Cyclonic Flow.” This test was conducted at the scaled set-back flowrate in the model stack. Measurements were made using a type-S pitot tube, a slant tube or electronic manometer, and a protractor level attached to the pitot tube (Figure 2.6). The flow angle was measured at the elevation of the sampling nozzle and at the same points as those used for the velocity uniformity test. The pitot tube was rotated until a null differential pressure reading was obtained, and the angle of rotation was then recorded. Appendix D provides the detailed procedure.

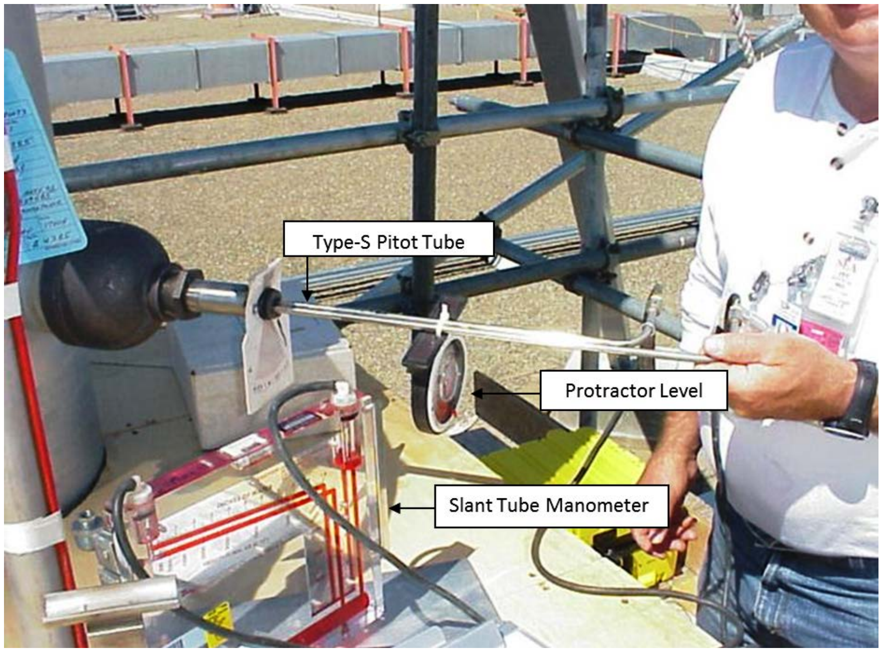


Figure 2.6. Type-S Pitot Tube and Protractor Level used to Measure Angular Flow

2.4.2 Results

The acceptance criterion for angular flow is an average flow-angle of < 20° across the sampling plane. Measurements were made at the same grid points as for the velocity uniformity. The acceptance criterion (≤ 20°) was met in all cases. The results range from 8.0 to 14.3°. Table 2.2 shows a summary of the angular flow testing results. The data sheets for the angular flow test are presented in Appendix D.

Table 2.2. Flow Angle Results

Runs	Fan Frequency Setting, Hz	Mean Flow Angle
Far Fan		
FA-1	37.1	9.5
Near Fan		
FA-2	37.1	14.3
FA-3	37.1	8.0

2.5 Uniformity of Tracer Gases

A uniform gas contaminant concentration at the sampling plane enables the extraction of samples that represent the true gas concentration within the stack. Testing for uniformity of tracer gases at the sampling plane was conducted on the scale model stack at the scaled set-back flowrate.

2.5.1 Method

The concentration uniformity is demonstrated with a tracer gas (sulfur hexafluoride) injected into the exhaust duct, in the same area as the discharge from the model heat recovery boxes for the near- and far-fans. The concentration of the tracer gas is then measured at the sampling location using the same grid of points as used in the other tests. From the measurements, the COV and maximum deviation from the mean are calculated as measures of uniformity.

The gas samples are withdrawn from the stack through a simple probe and a gas analyzer (Figure 2.7). A Bruel and Kjaer (Naerum, Denmark) Model 1302 calibrated for the tracer gas, is used for the measurements. The procedure and data sheets are detailed in Appendix E.

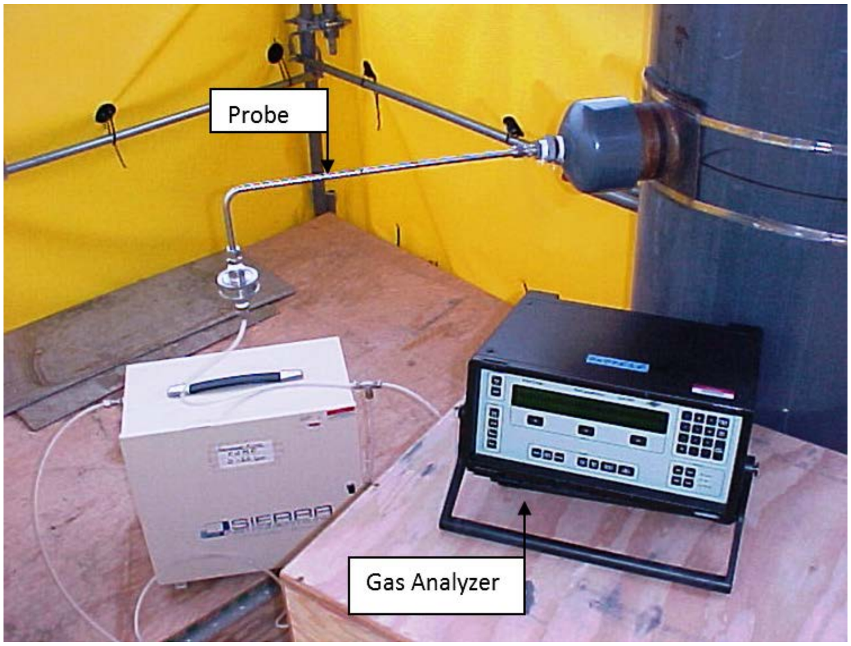


Figure 2.7. Tracer Gas Probe and Analyzer

2.5.2 Results

The acceptance criteria for uniformity of tracer gases are:

1) the COV of the tracer gas concentration be ≤ 20% across the center two-thirds of the sampling plane
2) the average concentration, for each measurement point, differ from the mean concentration by < 30%.

Table 2.3 lists the tests performed and their results. Five injection points were used at each injection location. Corner injections were made within 1 in (25% of a hydraulic diameter) of the walls at the corners of the duct (Figure 2.3). The worst case result was repeated as Run GT-11, where the uniformity results ranged from 1.6 to 5.5% COV. The absolute value of the maximum deviations from the means ranged from 2.6 to 12.6%. In all cases, the acceptance criteria were met. Figure 2.8 is a bar graph of the results of Run GT-1.

Table 2.3. Summary of Gas Tracer Uniformity Results During Simulated Setback Condition

Run	Injection Point	% COV	Max % Dev
Near Fan			
GT-1	Top-south	4.75	12.6
GT-11	Top-south	5.48	–10.2
GT-2	Top-north	2.49	–4.2
GT-3	Center	3.54	6.3
GT-4	Bottom south	3.75	–6.9
GT-5	Bottom-north	3.88	8.1
Far Fan			
GT-6	Top-south	1.63	–2.6
GT-7	Top-north	1.82	3.4
GT-8	Center	2.28	4.8
GT-10	Bottom south	2.22	4.1
GT-9	Bottom-north	2.50	–4.4

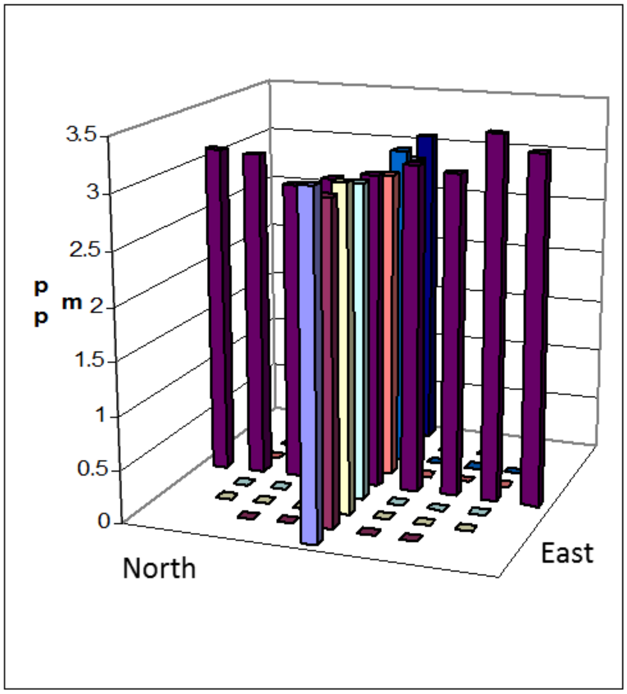


Figure 2.8. Plot of GT-1 Results

2.6 Uniformity of Tracer Particles

A uniform particulate contaminant concentration at the sampling plane enables the extraction of samples that represent the true particulate concentration within the stack. Testing for uniformity of tracer particles at the sampling plane was conducted on the scale model stack. The method for determining uniformity of tracer particles and the results of the tests are detailed in the following sections.

2.6.1 Method

The test method for uniformity of tracer particles is similar to that of tracer gases, with the tracer gas replaced by tracer particles. However, only the centerline injection position is required. The concentration of the tracer particles, in the size range of interest, was measured at the same test points used in the other tests. Spraying vacuum-pump oil through a nozzle mounted inside a chamber produced the particles measured by the testing. These particles were then injected into the duct entrained in a stream of compressed air as shown in Figure 2.9.

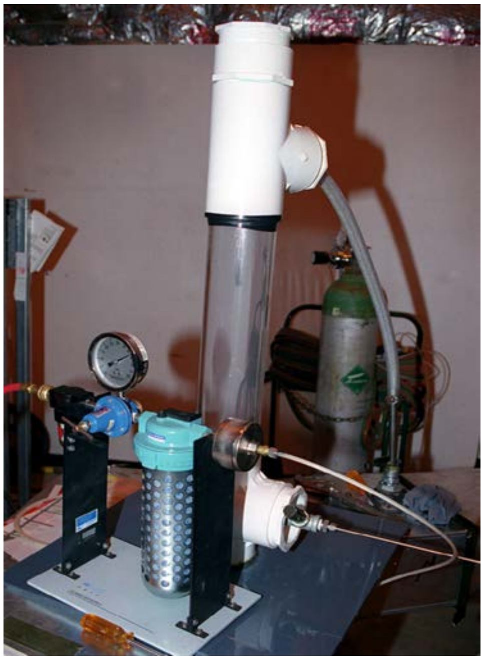


Figure 2.9. Typical Particle Generator Setup

A simple probe was used to extract the sample from the stack and transport it to the optical particle counter[1] (OPC) arranged as shown in Figure 2.10. The OPC sorts the number of particles into six size channels. Only the readings from the size channel that measures particles in the 9 to 11 µm size range are used for statistical calculations. Each data point consists of the number of particles counted during a one-minute sampling period. Three readings were taken at each point and averaged. The COV of the average concentration readings at each point is calculated and the result compared to the acceptance criterion for uniformity. The detailed procedure and data sheets are included in Appendix F.

[1] Met-One Model A2408, Hach Analytics, Grants Pass, OR.

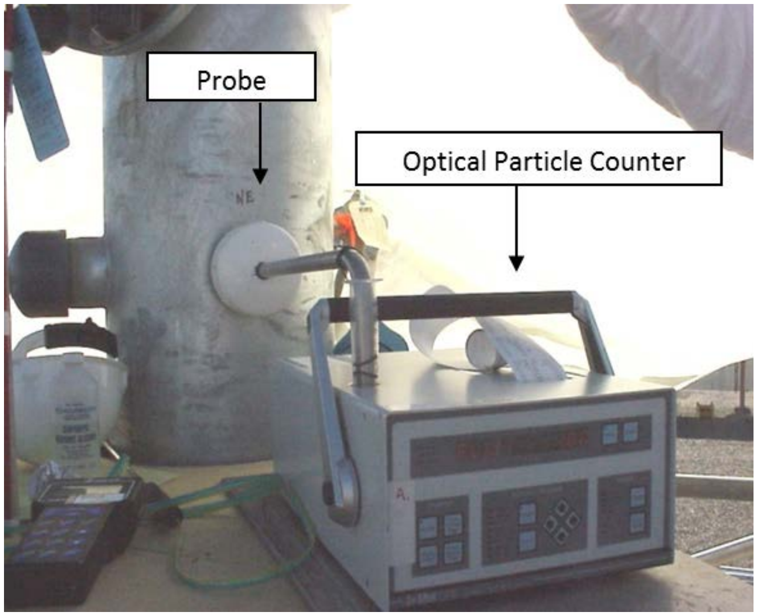


Figure 2.10. Optical Particle Counter and Probe Arrangement for a Particle Uniformity Test

2.6.2 Results

The acceptance criterion for uniformity of tracer particle is a COV less than 20% for tracer particles of the 10-μm range across the center two-thirds of the sampling plane.

The particle concentration uniformity is demonstrated with tracer particles injected into the exhaust duct, in the same area as the discharge from the model heat recovery boxes for the near- and far-fans. Tests were conducted at the simulated set-back flowrate. The results are summarized in Table 2.4 and the data sheets are included in Appendix F. The results show slightly more uniformity for the near fan configuration than for the far fan configuration. However, in all cases, the performance criterion was met. Figure 2.11 is a bar chart showing the normalized concentration data for the worst case test, PT-1.

Table 2.4. Particle Tracer Uniformity Results for the Center Two-Thirds of the Stack

	Injection Point	Un-normalized % COV	Normalized % COV
	Far Fan		
PT-1	Center	10.5	11.6
PT-3	Center	10.5	7.4
	Near Fan		
PT-2	Center	8.5	8.3

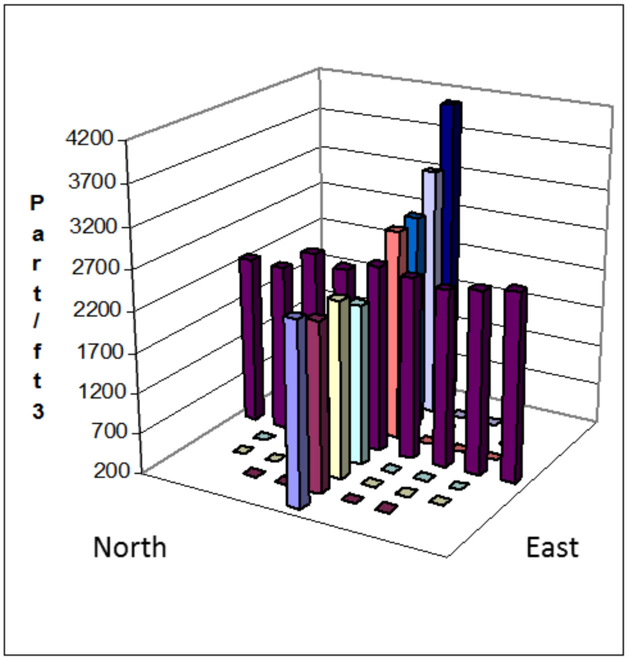


Figure 2.11. Bar Chart of PT-1 Results

The COV results are shown in Table 2.4 with and without any normalization with time. The results after normalization also are shown. The normalization method adjusts all of the concentration readings by the same amount so that the center point readings taken from the two traverse directions were equalized. The effect of normalization would be more pronounced in cases where there was a shift in concentration with time. All of the normalized data met compliance criteria.

3.0 Computational Fluid Dynamics Model

In previous modeling work, a three-dimensional CFD model was created and validated for flow simulations of the RPL effluent stack (Recknagle et al. 2008). The CFD model from this previous work included the ability to simulate the operation of both the scale-model and the full-scale final exhaust system with any number or combination of the four fans. For the present work, this model was exercised to simulate operation in each of the six permutations of two-fan operation, each fan operating at 52,000 cfm for a total of 104,000 cfm air flow. Results of these simulations were then analyzed to determine the effectiveness of each fan combination to meet the ANSI/HPS N13.1–1999 criteria for well-mixed flow at the stack sampling location.

3.1 Method

The STAR-CD[2] code was used to simulate the stack flow and analyze the simulation data to determine if the conditions at the sampling point would meet the criteria in ANSI/HPS N13.1–1999 for uniformity of air velocity, flow angularity, and uniformity of tracer gas and particles. In the calculations for the tests, STAR-CD solved the finite-volume Navier-Stokes (conservation of mass and momentum) and transport equations to obtain the steady-state flow field and species concentrations at each location within the system. For the sulfur hexafluoride tracer gas simulations, a Eulerian two-phase flow model was used in the calculations. A Lagrangian dispersed two-phase flow model was used for the aerosol (oil droplet) release simulations. The Lagrangian methodology includes models for droplet collision, breakup, drag, and turbulent dispersion of the dispersed phase (oil droplets). In all simulation cases, the generation and dissipation of turbulence was modeled using the κ-ε turbulence model for large Reynolds number flow (as implemented in the STAR-CD code). The κ-ε model is a widely tested and validated two-equation (partial differential equation) closure model for the turbulent transport terms in the time-averaged Navier-Stokes system of equations for fluid momentum transport. In the model equations, κ is the turbulence kinetic energy, and ε is the rate of dissipation of that energy. This turbulence model is considered suitable for the flow conditions present in such a duct. Additional details on the modeling approach can be obtained from Recknagle et al. (2008).

A three-dimensional model of the RPL final ventilation system was created to replicate the actual system geometry from the final exhaust fans to the stack exit (Figure 3.1). The view angle in the figure is slightly off vertical showing the horizontal orientation of the fan ducts and their perpendicular entry into the main duct (also horizontal), the 90° horizontal turn of the main duct, and the turn from horizontal to the vertically oriented exhaust stack. Fan 1 is located furthest from the stack and fan number increases with proximity of the stack.

A simulation was run for each of the 2-fan configurations: fans 1 & 2, 1 & 3, 1 & 4, 2 & 3, 2 & 4, and 3 & 4. Data from each of simulations was extracted to obtain flow velocity, flow angle, concentration of tracer gas, and concentration of particles at each traverse point at the elevation of the sampling system. The data was entered into spreadsheets to determine whether the ANSI/HPS N13.1–1999 criteria would be met. Data sheets and plots are included in Appendix H.

[2] The CFD program STAR-CD, Version 3.15, Methodology Volume, is copyrighted by the CD-adapco Group (CD-adapco, Seattle Office, 3150 Richards, Suite 204, Bellevue, WA 98005).

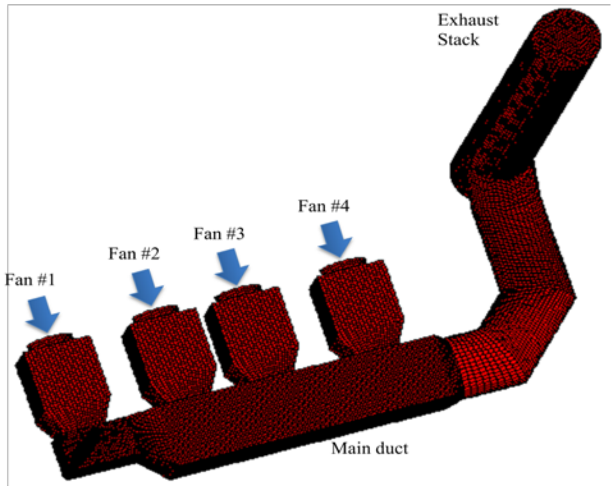


Figure 3.1. Three-Dimensional Model Geometry of the RPL Final Effluent Stack

3.2 Results

Detailed flow field results from the two-fan configuration case simulating operation with fans 1 and 2 are shown in Figure 3.2 and in Appendix H. The figure shows flow velocity vectors in which high velocity is red and low velocity is blue. Figure 3.2 shows the flow in a horizontal plane entering the duct through fans 1 and 2, passing the non-operating fans 3 and 4, turning the 90° bend in the horizontal duct, and entering the vertical stack. Air from fan 1 was directed toward the main duct via turning vanes and joined by air from fan 2 in the main duct.

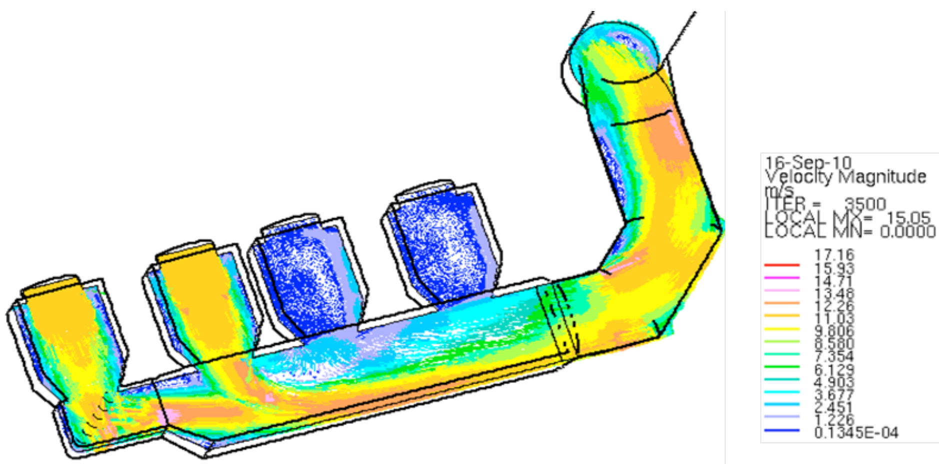


Figure 3.2. Flow Velocity Vectors in a Horizontal Plane (2-Fan Configuration, 104,000 cfm)

The transition from the horizontal duct to the vertical stack set up a swirl in the stack flow that can be seen in Figure 3.2 by the low velocity (blue) zone within the stack. A closer view of the horizontal section through the stack in Figure 3.3 shows the circulation zone at upper right with relatively higher speed flow surrounding the zone. This swirl was present in each flow case and contributed to the mixing within the stack.

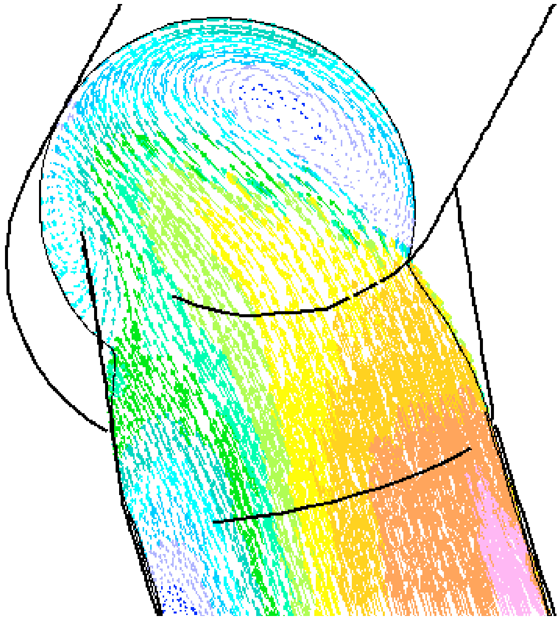


Figure 3.3. Detail of Flow Vectors in a Horizontal Plane

Results of each of the two-fan configuration simulations are shown in Table 3.1, along with criteria from ANSI/HPS N13.1–1999. As shown in the table, all criteria are met in each of the simulations.

Table 3.1. Results from CFD Modeling of RPL Final Exhaust System

Two-Fan Configuration	Velocity Uniformity (COV %)	Cyclonic Flow (Angle °)	Gas Tracer Uniformity (COV %)	Gas Tracer Uniformity (max deviation from and % of mean)	Aerosol Uniformity (COV % , normalized)
1, 2	5.75	11.4	6.83	13.8	6.72
1, 3	5.83	11.2	6.18	13.3	7.60
1, 4	5.84	12.4	9.29	23.2	10.4
2, 3	5.61	10.8	6.22	14.3	7.12
2, 4	6.00	11.5	8.80	20.3	10.8
3, 4	6.02	11.4	8.74	20.4	10.9
ANSI/HPS N13.1–1999 criteria	≤ 20	≤ 20	≤ 20	≤ 30	≤ 20

4.0 Conclusions

A scale model was designed following criteria in ANSI/HPS N13.1–1999 of the 325 Building RPL final exhaust system. The scale model was used to determine whether the stack sampling system would meet criteria in ANSI/HPS 13.1–1999 for sampling system location under reduced exhaust flow conditions. A summary of the tests, measurement results, and criteria are provided in Table 4.1 and demonstrate that the sampling location on the 325 Building main stack meets the criteria in ANSI/HPS N13.1–1999 for a well mixed location during the set-back flow condition when only one fan is in operation.

Table 4.1. Summary of Test Results for Low Flow RPL Exhaust

Test	Scale-Model Measurement (1-fan)	Full-Scale Measurement (1-fan)	CFD Simulation Results (2-fan)	ANSI/HPS N13.1–1999 Criteria
Velocity uniformity (COV %)	1.6 – 9.4	3.9 – 10.7	5.6 – 6.0	≤ 20
Cyclonic flow (angle °)	8.0 – 14.3		10.8 – 12.4	≤ 20
Gas tracer uniformity (COV %)	1.6 – 5.5		6.2 – 9.3	≤ 20
Gas tracer uniformity (maximum deviation from and % of the mean)	2.6 – 12.6		13.3 – 23.2	≤ 30
Aerosol uniformity (COV %, normalized)	8.3 – 11.6		6.7 – 10.9	≤ 20

With regard to acceptance of the scale model as a substitute for the actual stack, the model used was designed to be geometrically similar to the actual stack. Components influencing contaminant mixing and velocity profile in the scale model were proportional to those in the actual stack, and the sampling location in the scale model placed in a geometrically similar location as in the actual stack. The velocity profile in the actual stack meets the uniformity criteria, and the difference between velocity COVs of the two systems is not more than 5% COV units (Table 4.1). The scale model stack diameter of 18 inches is greater than the minimum of 250 mm (10 in).

The lowest flow used in the scale model testing was 1,100 cfm (Table 1.1) resulting in a Reynolds number of 91,000 which is well above the required minimum of 10,000. Reynolds number calculations are shown in Appendix G for the ranges of flows in the actual and scale model stacks under normal and reduced flow conditions. All Reynolds numbers are substantially above 10,000.

Finally, the scale model's mean velocity times hydraulic diameter must be within a factor of six of the actual stack. For the one fan configuration, the scale model's mean velocity times hydraulic diameter at the 37.1 Hz setting ranged from 930–1200 ft^2/min. Using a factor of six, this corresponds to stack flows of 980–45,400 cfm (calculations in Appendix G).

All combinations of two-fan configurations were evaluated using a three-dimensional CFD model. The CFD simulation results are shown in Table 4.1 and indicate that the stack sampling system also meets ANSI/HPS N13.1–1999 criteria for a well mixed location with any two fans operating.

The scale-model measurement tests cover the reduced operating range of flows less than 45,400 cfm using a one fan configuration. Earlier tests were conducted on normal flow conditions covering three fan configurations ranging from 129,000 to 186,300 cfm (Smith et al. 2010). The three-dimensional CFD simulations were performed to evaluate all two-fan configurations. All measurements and simulations results showed that the sampling system location in the RPL stack meets the ANSI/HPS N13.1–1999 criteria for flow angularity and uniformity of flow, tracer gas, and aerosol under one-, two-, or three-fan configurations and flow conditions.

5.0 References

ANSI—American National Standards Institute. 1969. *Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities*. ANSI N13.1–1969, American National Standards Institute, NY. February 19.

ANSI/HPS—American National Standards Institute/Health Physics Society. 1999. *Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stacks and Ducts of Nuclear Facilities*. ANSI/HPS N13.1–1999, American National Standards Institute, NY.

Ballinger MY, JM Barnett, JA Glissmeyer, and DL Edwards. 2004. "Evaluation of Sampling Locations for Two Radionuclide Air-Sampling Systems Based on the Requirements of ANSI/HPS N13.1-1999." *Health Physics* 86(4):406-415.

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

Recknagle KP, ST Yokuda, MY Ballinger, and JM Barnett. 2008. "Scaled Tests and Modeling of Effluent Stack Sampling Location Mixing." *Health Physics* 96(2):164-174.

Smith BM, MY Ballinger, JA Glissmeyer, and JM Barnett. 2010. *Sampling Point Compliance Tests for the 325 Building Stack at Full Flow Condition*. PNNL-19998, Pacific Northwest National Laboratory, Richland, WA.

Appendix A

Test Plan for Qualifying the EP-325-01-S Stack Air Sampling Position for Set-Back Flow Condition

Test Plan for Qualifying the EP-325-01-S Stack Air Sampling Position for Set-Back Flow Condition August 10, 2004

This series of tests will demonstrate whether the EP-325-01-S exhaust stack meets the applicable regulatory criteria regarding the placement of the air-sampling probe. This has already been demonstrated for the normal flowrate with three operating fans. This re-test will demonstrate whether the criteria are still met if the system flowrate is reduced from the normal value by a factor of three when only one fan is used. This stack exhausts the filtered ventilation air from all areas of the 325 Building Radiochemical Processing Laboratory where radionuclides are handled, including hot cell, waste treatment and radiochemistry. The tests will be conducted by Pacific Northwest National Laboratory staff. The standard governing the performance of the tests, test methods, and acceptance criteria is ANSI/HPS N13.1-1999, Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stack and Ducts of Nuclear Facilities.

Performance Criteria

The qualification criteria for the location of the air sampling probe are as follows (Table 4, ANSI/HPS N13.1-1999):

1. Flow Angle - Sampling nozzles are usually aligned with the axis of the stack. If the air travels up the stack in cyclonic fashion, the air velocity vector approaching the nozzle could be misaligned with the sampling nozzles enough to impair the extraction of particles. Consequently, the flow angle is measured in the stack at the elevation of the sampling nozzle. The average air-velocity angle must not deviate from the axis of the sampling nozzle by more than 20°.

2. Air Velocity Uniformity - It is important that the gas momentum across the stack cross section where the sample is extracted be well mixed or uniform. Consequently, the velocity is measured at several points in the stack at the elevation of the sampling nozzle. The uniformity is expressed as the variability of the measurements about the mean. This is expressed using the relative coefficient of variance (COV), 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 criteria is that the COV of the air velocity must be ≤20% across the center two-thirds of the area of the stack.

3. Gas Tracer Uniformity - A uniform contaminant concentration in the sampling plane enables the extraction of samples that represent the true concentration. This 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 center two-thirds of the sampling plane and 2) at no point in the sampling plane does the concentration vary from the mean by >30%.

4. Particle Tracer Uniformity - Uniformity in contaminant concentration at the sampling elevation is further demonstrated using tracer particles large enough to exhibit inertial effects. Particles of 10-µm aerodynamic diameter (AD) are used by default unless it is known that larger particles are present in the airstream. The acceptance criteria is that the COV of particle concentration is ≤20% across the center two-thirds of the sampling plane.

Scale Model Testing Criteria

Testing to satisfy Criteria 1 – 4 will be conducted on a scale model of the exhaust ductwork and stack, from the heat recovery coils to the elevation of the sampling probe. The ANSI/HPS N13.1-1999 standard sets acceptance criteria for the use of a scale model as a substitute for the actual stack.

- The scale model and its sampling location must be geometrically similar to the actual stack.
- The model's mean velocity x hydraulic diameter product will be within a factor of six of the actual stack.
- The Reynold's number for the prototype and model stacks must > 10,000.

The scale model results are considered valid if:

- The velocity profile in the actual stack meets the uniformity criteria, and
- The uniformity COV for the actual and model stacks agree within 5% COV.

Conduct of Tests

Compliance with each performance criteria is demonstrated through performing a specific test procedure. The four procedures to be used are briefly described below and in the order in which they are usually conducted. Specific Test Instructions will be issued prior to the conduct of a test.

The tracer tests result in the emission of tracer gas (sulfur hexafluoride) and tracer particles (vacuum pump oil mist) from the scale model. The estimate of emissions from these tests is given below.

The Job Hazard Analysis (if any) and MSDS's for the tracer compounds are to be reviewed by testing staff prior to the conduct of any test. These documents are also to be kept available at the test site.

1.0 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. The test method is based on 40 CFR 60, Appendix A, Method 1, Section 2.4, "Verification of the Absence of Cyclonic Flow."

This test is conducted on the scale model stack. The flow angle is measured at a grid of points in a cross section of the stack at the scaled elevation of the actual sampling probe. The grid is an array of points in an x-pattern. One line of points is aligned in the same direction as the existing sampling probe on the actual stack. The other line will be perpendicular to that. The number and distance between measurement points is based on the EPA procedure 40 CFR 60, Appendix A, Method 1.

Measurements are made using a type-S pitot tube, a slant tube or electronic manometer, and a protractor level or angle indicating device attached to the pitot tube. The procedure EMS-JAG-05 Test to Determine Flow Angle at the Elevation of a Sampler Probe provides the general procedure for the determination of mean flow angle. Instructions specific for this stack will be given in a test instruction.

2.0 Air Velocity Uniformity Test

The uniformity of air velocity where the air sample is being extracted ensures that the air momentum in the stack is well mixed. To determine uniformity, air velocity is measured at the same grid of points used for the angular flow test. The method used is based on 40 CFR 60, Appendix A, Method 1. The equipment includes a standard Prandtl-type or S-type pitot tube and a calibrated electronic manometer. Procedure EMS-JAG-04, Test to Determine Uniformity of Gas Velocity at the Elevation of a Sampler Probe, is used for this test. This test takes about 90 minutes. A test instruction will be issued specifically for this test.

3.0 Gas Tracer Uniformity Test

A uniform contaminant concentration in the sampling plane enables the extraction of samples that represent the true concentration. Procedure EMS-JAG-01, Test to Determine Uniformity of a Tracer Gas at a Sampler Probe, is used for this test. The gaseous contaminant concentration uniformity is demonstrated using a tracer gas (sulfur hexafluoride) injected into the ductwork at various positions. For each injection position, the tracer concentration is measured at the sampling plane at the same grid of measurement points as used for the above tests. The uniformity is expressed as the COV of the measured tracer concentrations.

Tracer gas concentration is measured with a Bruel and Kjaer (Naerum, Denmark) Model 1302 gas analyzer calibrated for the tracer gas. The absolute calibration of the analyzer is unimportant to the test results; however, the analyzer response is checked using calibration standards prior to the conduct of the test. If the indicated concentration is within 20% of the standard, the response is acceptable.

For the proposed reduced flow condition, any one of the available four fans would be used to maintain the reduced airflow. There is a heat recovery box between each fan and the final exhaust duct. The planned tracer gas injection locations are just downstream of the heat recovery boxes nearest and farthest from the stack. These should represent the best and worst case conditions. An optional location would be in the duct just upstream of the breach to the stack. The tracer is injected along the centerline of the duct and at four locations near the corners of the duct.

For the single operating fan configuration, the five tracer injection points will be used for each injection location. The test will be repeated for the injection point found to have the least favorable result. Other repeat runs may be made at the discretion of the test director after a review of the preliminary results. Therefore, there will be a minimum of 11 test runs. Each run takes about 90 minutes. A test instruction will be issued specifically for this test.

The usage and emission of the tracer gas, sulfur hexafluoride, is based on a stack flow of 1442 cfm, a desired concentration of 1 ppm, and 13 tests. The total emission would be about 0.30 kg for 13 tests, or about 0.022 kg/test.

4.0 Particle Tracer Uniformity Test

The test for uniformity of tracer particles is similar to the test for uniformity of tracer gases. The general approach is to inject particles of a range of sizes, including the size of interest, into the center of the airstream. The concentration of the particles of the size range of interest is then measured at several points in the cross section of the sampling plane using an optical particle counter (OPC, Met-One Model A2408, Grants Pass, Oregon). A simple probe is used to extract the sample and deliver it to the OPC. The measurement points are the same as used for the above tests. The OPC should be within calibration.

The particles are made by spraying vacuum-pump oil through a nozzle housed in a chamber. The chamber provides a controlled means for injecting the particles into the airflow through a probe. Compressed air and an injection probe are required for the operation of the chamber.

The tracer injection port is the same as for the gaseous tracer; however, only the centerline injection point is used. The layout of measurement points is the same as for all of the other tests, except where the size of the probe does not permit sampling as close to the inside of the stack wall.

The OPC's sort the number of particles into six size channels. Each concentration reading is the count of particles collected in the 9- to 11-µm channel. The readings are recorded on a data sheet. Three readings are taken at each point and averaged. The coefficient of variance of the average concentration readings at all points is calculated and the result compared to the acceptance criteria for uniformity. The particle mixing is acceptable if the COV of the tracer particles of 10-µm aerodynamic diameter (AD) is less than or equal to 20% across the center two-thirds of the sampling plane.

There will be a minimum of 5 test runs, one for each injection position (used for the gas tracer uniformity tests) and flowrate, and one repeat test. Each test run can require up to four hours. Procedure EMS-JAG-02, Test to Determine Uniformity of a Tracer Aerosol at a Sampler Probe, is used for this test. A test instruction will be issued specifically for this test.

The usage and emission of the tracer aerosol oil (Fisherbrand 19 vacuum pump oil) may be as about high as 50 g per test run. (The use rate has never actually been measured. In any demonstrations that we have done, it has always been less than 0.5 L total.) Three tests can be completed in an 8-hour period.

Fan Configuration

In the actual fan house, there are four electric fans, three of which are normally used at a time. The capacity of the electric fans are about 46,000 cfm each. With three fans operating, the exhaust airflow is about 138,000 cfm. With one fan running in the reduced flow condition, the exhaust airflow would be about 46,000 cfm. The fans are housed in a small building. Each fan discharge's upward and into a heat recovery box, where coils and heat transfer fluid recover heat from the exhaust airflow. Each heat recovery box discharges into the main plenum which connects to the stack. Figure 1 is a diagram of the scale model for this part of the ventilation system. The parameters for the scale model are given in Table 1. The 5.33:1 scale results in a convenient stack and duct size of 18 inches to represent the actual 8 feet. It also results in a velocity close to that of the actual system. (With three fans operating, the actual and model velocities would be 2755 and 2449 fpm respectively.) To remain within the scaling parameters (velocity times hydraulic diameter within a factor of six) the model flowrate of 1442 cfm corresponds to 46,157 cfm, or one-third the stack flowrate of 138,473 (the average of eleven separate stack flow measurements).

There are plans to upgrade the fan capacities to about 50,000 or 60,000 cfm each. That would be a flowrate around 50,000 – 240,000 cfm depending on the fan usage. The overall flowrate range is then 45,666 (based on the lowest 3-fan stack flowrate measured) – 240,000 cfm. The corresponding minimum scale model flowrates would then be 1427 – 7500 cfm.

Table 1. Possible Scale Model Parameters

Flow parameters in scale models

(colored values are inputs)
John Glissmeyer 4/13/01

Sheet protected for data entry, no password
Want to keep velocity < Mach 0.3, or <19700 fpm

Fluid characteristics:

Mol. Wt.	28.95	
Temperature	70	F
Pressure	1	atm
Gas Density	0.0748	lb/ft3
Viscosity	0.000176	g/cm-s

Prototype Stack characteristics:

Diam	8.00	ft
Flow	138473	cfm
X-area	50.265	sq. ft
Mean U	**2755**	ft/min
Reynolds	**2.33E+06**	

Range of Reynolds number for scale model:

Min	3.88E+05	1/6 prototype
Max	1.40E+07	6 X prototype

Range of Q/D for scale model:

Min	2.88E+03	1/6 prototype
Max	1.04E+05	6 X prototype
Prototype	1.73E+04	

Range of DV for scale model:

Min	3.67E+03	1/6 prototype
Max	1.32E+05	6 X prototype
Prototype	2.20E+04	

		Scaled ft at 1:X					
Section	**Prototype ft**	3.20	4.00	5.33	7.00	1.00	1.00
Round Duct Section	Stack						
Diam, ft	8.00	2.500	2.000	1.500	1.143	8.000	8.000
Area, ft2	50.3	4.91	3.1	1.8	1.0	50.3	50.3
Flow at min Q/D, cfm	138473	7212	5770	4327	3297	23079	23079
Vel fpm	2755	1469	1837	2449	3214	459	459
Re	2.3E+06	3.9E+05	3.9E+05	3.9E+05	3.9E+05	3.9E+05	3.9E+05
Ratio Re		6.00	6.00	6.00	6.00	6.00	6.00
Round Duct Section	Stack						
Diam, ft	8.00	2.50	2.00	1.50	1.14	8.00	8.00
Area, ft2	50.3	4.91	3.1	1.8	1.0	50.3	50.3
Flow at min Q/D, cfm	45666	2378	1903	1427	1087	7611	7611
Vel fpm	908	485	606	808	1060	151	151
Re	2.3E+06	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05	1.3E+05
Ratio Re		18.19	18.19	18.19	18.19	18.19	18.19
Round Duct Section	Stack						
Diam, ft	8.00	2.500	2.000	1.500	1.143	8.000	8.000
Area, ft2	50.3	4.91	3.1	1.8	1.0	50.3	50.3
Flow at min Q/D, cfm	240000	12500	10000	7500	5714	40000	40000
Vel fpm	4775	2546	3183	4244	5570	796	796
Re	2.3E+06	6.7E+05	6.7E+05	6.7E+05	6.7E+05	6.7E+05	6.7E+05
Ratio Re		3.46	3.46	3.46	3.46	3.46	3.46
Round Duct Section	Stack						
Diam, ft	8.00	2.500	2.000	1.500	1.143	8.000	8.000
Area, ft2	50.3	4.91	3.1	1.8	1.0	50.3	50.3
Flow at min Q/D, cfm	60000	3125	2500	1875	1429	10000	10000
Vel fpm	1194	637	796	1061	1393	199	199
Re	2.3E+06	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05	1.7E+05
Ratio Re		13.85	13.85	13.85	13.85	13.85	13.85

Test Runs

Table 2 lists the estimated number of runs of the individual tests that will be performed for the reduced flow configuration.

Table 2. Minimum Test Runs to be Performed for the Reduced Flow Configuration

		Estimated number of test runs			
Configuration	Scaled Stack Flowrate	Flow Angle	Air Velocity	Gas Tracer	Particle Tracer
Current Fans	1427	1	2	11	3

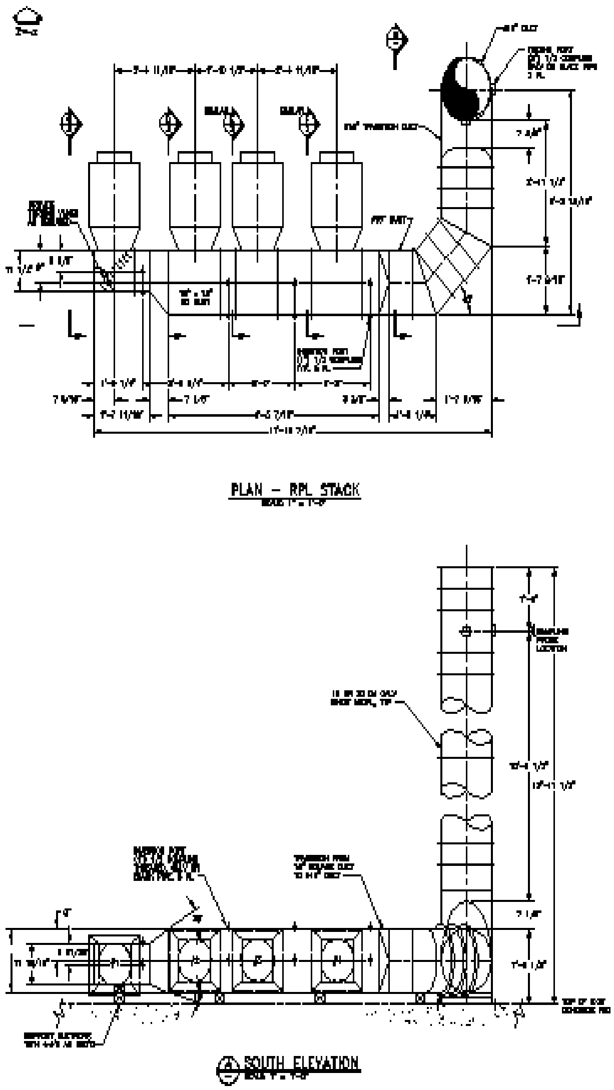
All measurements are planned to be conducted at the simulated sampling probe elevation of the stack. The probe centerline is about 55.94-ft (?) above the top stack breach. That should be 10.5 ft on the scale model.

The test strategy underlying Table 2 is outlined in Table 3.

Table 3. Proposed Test Sequence

Test	**Run**	**Injection Points**	**Comments**
One Fan Configuration			
Flow Control Cal.	VT-1, VF-1	N.A.	VT-1 at 30 Hz on controller, VF-1 at 5-Hz increments
Velocity Uniformity	VT-2, VT-3, VT-4 and VT-5	N.A.	First two where fan closest to the stack is used. Second two where the farthest fan is used
Flow Angle	FA-1, FA-2, FA-3	N.A.	One run per condition plus one repeat
Gas Tracer	GT-1 to GT-5	With injection downstream of Fan 4	1427 cfm
	GT-6 to GT-10	With injection downstream of Fan 1	1427 cfm
	GT-11	Repeat of worst case from above	1427 cfm
Particle Tracer	PT-1 to PT-3	Centerline after Fan 1 and 4 and repeat of worst case	1427 cfm

Figure 1. Scale Model Drawing for 325 Stack



Appendix B

Flow Calibration Procedure and Data

INDEPENDENT TECHNICAL REVIEW RECORD

PACIFIC NORTHWEST NATIONAL LABORATORIES INDEPENDENT TECHNICAL REVIEW RECORD	DOCUMENT NO.: Plot of Velocity Versus Fan Frequency for 291-Z-1 Model, Spreadsheet 04-325-FlowCal.XLS	Page 1 of 1

The referenced document is submitted for your review. Instructions for completing this form are attached. Please return the completed form to: John Glissmeyer. If you have any questions, please call John Glissmeyer, 376-8552, cell 531-8006. Comments Due: 9/28/04

Additional Information: (Scope of Review, etc) Please verify the following:

1. Transfer of field data to spreadsheet
2. Calculation of intermediate mean velocity values per frequency setting
3. Calculation of parameters for fitted line, do not force intercept to zero

Organization/Department	Designated Reviewer:	Signature/Date
Environmental Health Sciences Group	Rosanne Aaberg	Rosanne L. Aaberg 9/30/04

CONCUR [ ]	CONCUR, WITH COMMENTS [x]	DO NOT CONCUR [ ]	NOT REVIEWED [ ]

Comt. No	Comment and/ or Recommendation:	Resolution:
1.	O – There should be consistency in identifying the instrument by serial number or calibration barcode, noted on VT-1	1. Changed to serial number.
2	O – Stack temp (top of page VT-1) is starting temperature, rather than average based on table.	2. Changed to calculate the average of starting and ending temperatures.
3	E – Set number format for stack static pressure (0.04 shows as 0.0)	3. Done
4	M – The units given on the temperature/ pressure table must correspond to the values listed; ambient pressure given in inches of Hg on original datasheet, noted as mbars VT1. Barometric pressure units listed on sheet 'Cal Data' are inches of H_20, but value is in inches of Hg.	4. Changed ambient pressure entries to in. Hg on both data sheets.
5	E – Sheet "Cal Data": remove unnecessary text from cells, far right column of velocity table, "Estimated Hz" and "45+" below.	5. Done
6	O - "Velocity vs. Frequency Data Form" original lists E1, elevation above disturbance as 121.5; all other sheets list 120 5/8.	6. Changed to 120 5/8

Concur with Resolution	Date	Comments Resolved By	Date
Rosanne L. Aaberg	9/30/04	John Glissmeyer	9/30/04

VELOCITY TRAVERSE DATA FORM

Site	325 Model	Run No.	VT-LOW1
Date	8/19/2004	Fan Configuration	FAN 4 (near stack)
Testers	JMB/GSH/MYB/DDD	Fan Setting	30 HZ
Stack Dia.	18 in.	Stack Temp	95.6 deg F
Stack X-Area	254.5 in.2	Start/End Time	12:19PM - 2:20PM
Elevation	139.75	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 5/8 inches	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Data Files:	NA

Traverse-->		East				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.58	633	709	665	669.0	595	620	561	592.0
2	1.89	693	688	681	687.3	668	679	647	664.7
3	3.49	690	708	718	705.3	708	704	673	695.0
4	5.81	713	689	692	698.0	724	701	708	711.0
Center	9.00	647	675	647	656.3	670	660	642	657.3
5	12.19	610	589	541	580.0	647	616	624	629.0
6	14.51	591	586	521	566.0	543	602	570	571.7
7	16.11	546	542	555	547.7	536	610	552	566.0
8	17.42	535	572	539	548.7	507	542	525	524.7
Averages --------->		628.7	639.8	617.7	628.7	622.0	637.1	611.3	623.5

All	ft/min	Dev. from mean	*Center 2/3*	West	North	All
Mean	626.1		Mean	634.4	642.1	638.2
Min Point	524.7	-16.2%	Std. Dev.	67.7	56.6	60.1
Max Point	711.0	13.6%	COV as %	10.7	8.8	**9.4**

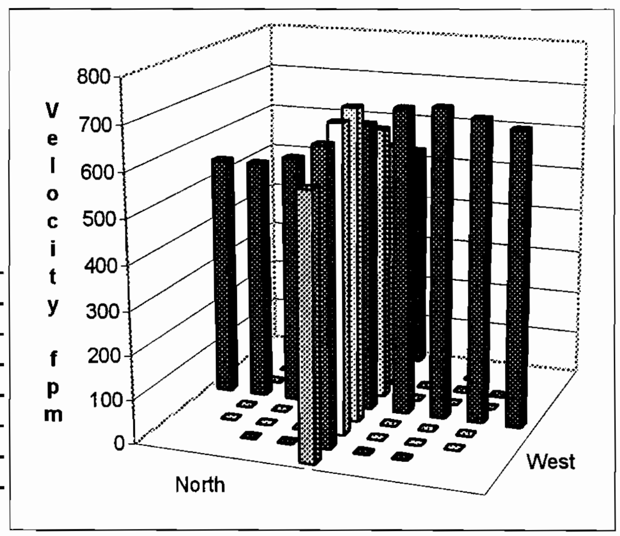
Flow w/o C-Pt 1100 acfm

Vel Avg w/o C-Pt 622 fpm

Instuments Used:

Solomat Zephyr SN 1295-1472 Cal 8/12/04

	Start	Finish	
Stack temp	98	93.2	F
Equipment temp	87	88.7	F
Ambient temp	87	92	F
Stack static	0.04	0.03	mbars
Ambient pressure	29.4	29.4	in Hg
Total Stack pressure	1013.1	1012.2	mbars
Ambient humidity	37%	31%	RH



Notes: Wind ENE 6 mph

Signature signifies compliance with Procedure EMS-JAG-4
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

VELOCITY vs. FREQUENCY DATA FORM

Site **325 Model**
Date 8/19/2004
Tester JMB/GSH/MYB
Stack Dia. 18 in.
Stack X-Area 254.5 in2
Elevation N.A.
El. above disturbance 120 5/8 inches
Velocity Readings, units = fpm

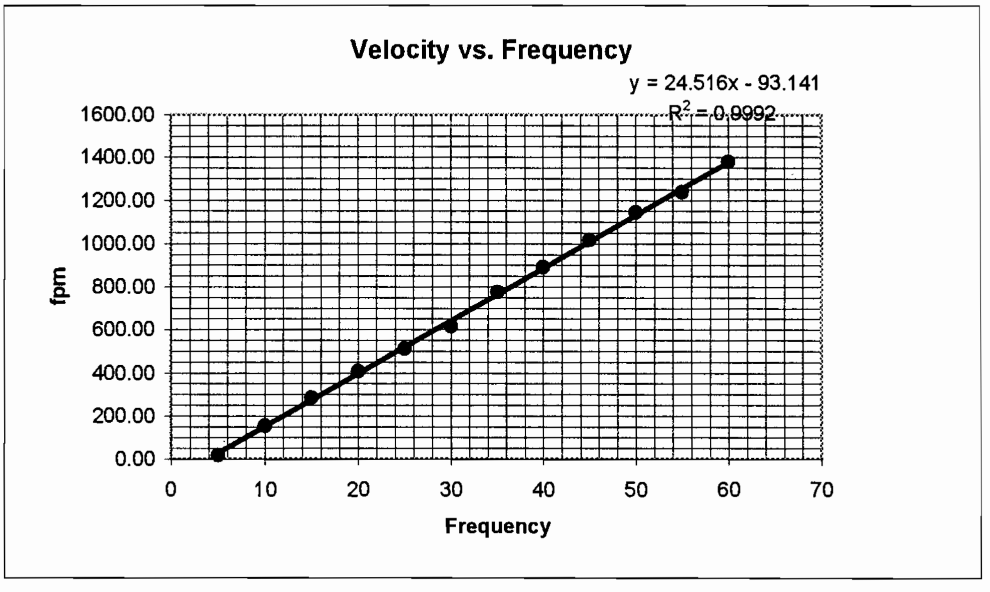
Run No. **Cal 1**
Stack Temp 87.9 deg F
Stack RH% 31%
Baro Press 29.4 in Hg
Fan Configuration 1 fan (near fan)
Start/End Time 14:50 - 15:30
Reference point from velocity test VT North 5

Target cfm	Target fpm
1350	764
1450	821

Hz	fpm 1	fpm 2	fpm 3	Mean	StDev	2 StDev	cfm
5	32	0	22	18.00	16.37	32.74	31.81
10	150	138	177	155.00	19.97	39.95	273.91
15	320	266	272	286.00	29.60	59.19	505.40
20	420	406	400	408.67	10.26	20.53	722.17
25	536	490	513	513.00	23.00	46.00	906.55
30	669	576	604	616.33	47.71	95.42	1089.15
35	797	736	795	776.00	34.66	69.31	1371.31
40	923	852	903	892.67	36.61	73.22	1577.47
45	1004	1042	1009	1018.33	20.65	41.30	1799.54
50	1117	1150	1165	1144.00	24.56	49.11	2021.61
55	1207	1233	1271	1237.00	32.19	64.37	2185.96
60	1414	1361	1361	1378.67	30.60	61.20	2436.31

Instuments Used:
Zephyr-Selomat 12951472, S/N 14714

Cal Exp. Date:
8/12/2005



Signature signifies compliance with Procedure EMS-JAG-3
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roxanne L Haber 9/30/04

Test Instruction		
Project: **325 Stack Sampler Qualification**	Date: **August 16, 2004**	Work Package: **F59676**

Tests: **Calibration of Ventilation Flow Controller for 325 Model Stack, 1 Electric Fan Configuration**

Staff: John Glissmeyer, Dave Douglas, Marcel Ballinger, Matthew Barnett

Reference Procedures:

1. Operating Manual for Solomat Zephyr, or other micromanometer used
2. Procedure EMS-JAG-03 Test to Calibrate Ventilation Flow Controller, Rev. 0, Nov. 18, 1998

Equipment:

1. Model Stack, Fans and Fan Speed Controller. Fans will be in positions EF1, EF4.
2. Solomat Zephyr, or other micromanometer, and pitot tube

Safety Considerations:

Review and observe the applicable Job Hazard Analysis for the project

Instructions:

1. ✓ Assemble the equipment for the flow controller calibration test at the ports 12.5 feet elevation above the ground.
2. ✓ Measure the stack inside diameter and layout the measurement points for an 8 point traverse
3. ✓ With one fan operating, set the flow controller set at midrange (30 Hz) and measure the velocity at each point. Repeat each measurement thrice.
4. ✓ Record data on velocity data sheets
5. ✓ Identify point of average velocity
6. ✓ Mount pitot tube at that point and measure velocity at 5 Hz increments from 5 to 60 Hz.
7. ✓ Record and plot the data
8. ✓ Determine approximate setpoints for subsequent target test flowrate (1350 – 1450 cfm, 764 - 821 fpm) for one operating fan. (35-37 Hz)

6. ✓ Diagram mounting fixtures and retain assembly for subsequent tests (duct tape port)

Desired Completion Date: 8/27/04

Approvals: John Glissmeyer (signature)
John Glissmeyer, project manager — Date 8/19/04

Test completed by: (signature) — Date: 8/20/04

Appendix C

Velocity Uniformity Procedure and Data

INDEPENDENT TECHNICAL REVIEW RECORD

PACIFIC NORTHWEST NATIONAL LABORATORIES INDEPENDENT TECHNICAL REVIEW RECORD	DOCUMENT NO.: Calculation of Velocity Uniformity for 325 Model Stack, Spreadsheet 04-325velocity.xls	Page 1 of 1

The referenced document is submitted for your review. Instructions for completing this form are attached. Please return the completed form to: John Glissmeyer. If you have any questions, please call John Glissmeyer, 376-8552, cell 531-8006. Comments Due: 9/28/04

Additional Information: (Scope of Review, etc) Please verify the following:

1. Transfer of field data to spreadsheet
2. Calculation of intermediate mean velocity values per traverse (one per port) and measurement point (1st and last points per port)
3. Calculation of port and overall mean velocity, standard deviation, and %COV for the center 2/3 of stack area
4. Calculation of grand mean and maximum deviation of mean for all measurement point.
5. Calculation of normalized velocity data (2 points) for plotting
6. Verify orientation of plotted bars

Organization/Department	Designated Reviewer:	Signature/Date
Environmental Health Sciences Group	Roseanne Aaberg	Roseanne L Aaberg 9/30/04

CONCUR [ ]	CONCUR, WITH COMMENTS [x]	DO NOT CONCUR [ ]	NOT REVIEWED [ ]

Comt. No.	Comment and/ or Recommendation:	Resolution:
1	Ambient pressure units should be listed in inches of Hg rather than in mbars, all four sheets	See Comment 4 below.
2	E - Label on Velocity Traverse Data Form Table: Change "Correct Label" to "Point", all forms	OK
3	E – Change number format of stack static pressure to show two decimal paces, VT-1, VT-3, VT-4. Should have one decimal place for stack temp,	OK, but the temperature indicator actually shows tenths, but is accurate to about a half of a degree.
4	M – Change units on ambient pressure to inches of Hg, VT-1 and VT-2. (Note that ambient pressure is in mbars on VT-3 and VT-4.)	OK
5	O – The labels of points (corresponding to depth) in the West series is represented in reverse order from the labels of the graphs. In the future, the confusion could be reduced by reversing the points charted in the graph (source M32:U32 of spreadsheet).	OK
Concur with Resolution: Roseanne L Aaberg, Date 9/30/04		Comments Resolved By: John Glissmeyer, Date 9/30/04

VELOCITY TRAVERSE DATA FORM

Site	325 Model	Run No.	VT-1		
Date	8/20/2004	Fan Configuration	Fan 4 (near stack)		
Testers	MYB/DDD/GSH/JMB	Fan Setting	37.1 Hz		
Stack Dia.	18 in.	Stack Temp	82.5 deg F		
Stack X-Area	254.5 in.2	Start/End Time	9:07AM - 10:15AM		
Elevation	139 3/4	Center 2/3 from	1.65	to:	16.35
Distance to disturbance	120 5/8 inches	Points in Center 2/3	2	to:	7
Velocity units	ft/min	Data Files:	NA		

Traverse-->		West				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	0.58	797	810	803	803.3	713	781	709	734.3
2	1.89	842	874	817	844.3	822	803	798	807.7
3	3.49	861	855	836	850.7	836	835	810	827.0
4	5.81	860	857	861	859.3	847	810	818	825.0
Center	9.00	814	812	838	821.3	827	854	837	839.3
5	12.19	830	780	769	793.0	816	809	803	809.3
6	14.51	750	764	793	769.0	797	754	808	786.3
7	16.11	770	732	741	747.7	808	772	781	787.0
8	17.42	688	630	628	648.7	733	696	610	679.7
Averages --------->		801.3	790.4	787.3	793.0	799.9	790.4	774.9	788.4

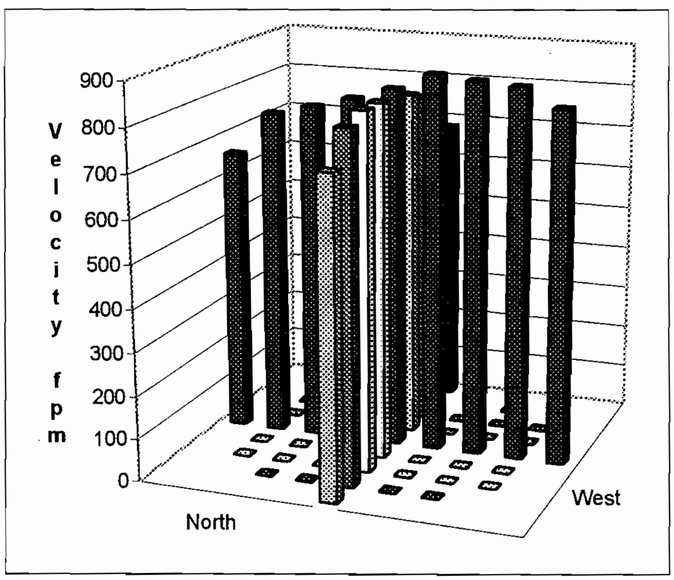
All	ft/min	Dev. from mean	*Center 2/3*	West	North	All
Mean	790.7		Mean	812.2	811.7	811.9
Min Point	648.7	-18.0%	Std. Dev.	43.2	20.2	32.4
Max Point	859.3	8.7%	COV as %	5.3	2.5	**4.0**

Flow w/o C-Pt 1389 acfm

Vel Avg w/o C-Pt 786 fpm

Instuments Used:

	Start	Finish	
Stack temp	83	86	F
Equipment temp	81	83	F
Ambient temp	77	85	F
Stack static	0.02	0.02	mbars
Ambient pressure	29.5	29.5	in. Hg
Total Stack pressure	1014.0	1014.0	mbars
Ambient humidity	51%	41%	RH



Notes: Wind SE 140; 7-9 mph, 1013.7 mbar

Signature signifies compliance with Procedure EMS-JAG-4 Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roxanne L Aikens 9/30/04

VELOCITY TRAVERSE DATA FORM

Site	325 Model	Run No.	VT-2
Date	8/20/2004	Fan Configuration	Fan 1 (far from stack)
Testers	MYB/DDD/GSH/JMB	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	85.6 deg F
Stack X-Area	254.5 in.2	Start/End Time	10:25 - 11:32
Elevation	139 3/4	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 5/8 inches	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Data Files:	NA

Traverse-->		West				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	0.58	742	745	694	727.0	750	660	696	702.0
2	1.89	791	786	762	779.7	753	760	726	746.3
3	3.49	767	775	780	774.0	769	769	736	758.0
4	5.81	772	788	760	773.3	734	786	797	772.3
Center	9.00	760	778	760	766.0	734	771	757	754.0
5	12.19	781	792	801	791.3	757	761	768	762.0
6	14.51	778	787	785	783.3	801	769	757	775.7
7	16.11	766	767	801	778.0	747	782	742	757.0
8	17.42	611	699	679	663.0	769	716	712	732.3
Averages --------->		752.0	768.6	758.0	759.5	757.1	752.7	743.4	751.1

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	755.3		Mean	778.0	760.8	769.4
Min Point	663.0	-12.2%	Std. Dev.	8.1	10.3	12.6
Max Point	791.3	4.8%	COV as %	1.0	1.4	**1.6**

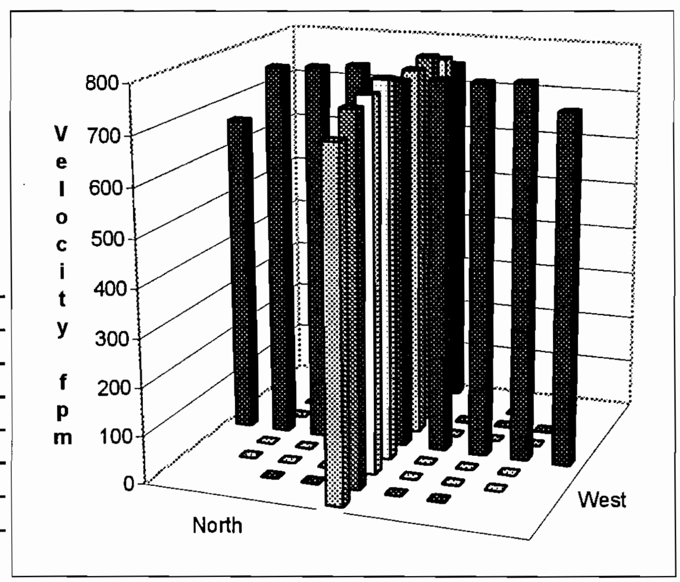
Flow w/o C-Pt 1334 acfm

Vel Avg w/o C-Pt 755 fpm

Instuments Used:

Solomat Zephyr #14714

	Start	Finish	
Stack temp	86	91	F
Equipment temp	83	84	F
Ambient temp	85	90	F
Stack static	0.02	0.02	mbars
Ambient pressure	29.5	29.5	in. Hg
Total Stack pressure	1014.0	1013.0	mbars
Ambient humidity	41%	31%	RH



Notes: wind from SW 6-9 mph

Signature signifies compliance with Procedure EMS-JAG-4
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L. Aaberg 9/30/04

VELOCITY TRAVERSE DATA FORM

Site	325 Model	Run No.	VT-3
Date	8/26/2004	Fan Configuration	Near Fan (#4)
Testers	JAG/GSH/JMB	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	82.4 deg F
Stack X-Area	254.5 in.2	Start/End Time	11:22
Elevation		Center 2/3 from	1.65 to: 16.35
Distance to disturbance	inches	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Data Files:	NA

Traverse-->		West				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	0.58	827	831	771	809.7	772	700	742	738.0
2	1.89	830	888	819	845.7	829	784	784	799.0
3	3.49	858	896	844	866.0	836	817	843	832.0
4	5.81	918	894	835	882.3	855	832	856	847.7
Center	9.00	851	821	827	833.0	841	856	828	841.7
5	12.19	800	837	781	806.0	821	839	801	820.3
6	14.51	859	798	740	799.0	821	851	804	825.3
7	16.11	803	793	766	787.3	785	811	803	799.7
8	17.42	751	633	671	685.0	694	784	697	725.0
Averages ---------->		833.0	821.2	783.8	812.7	806.0	808.2	795.3	803.2

All	ft/min	Dev. from mean	*Center 2/3*	West	North	All
Mean	807.9		Mean	831.3	823.7	827.5
Min Point	685.0	-15.2%	Std. Dev.	35.7	19.0	27.7
Max Point	882.3	9.2%	COV as %	4.3	2.3	**3.4**

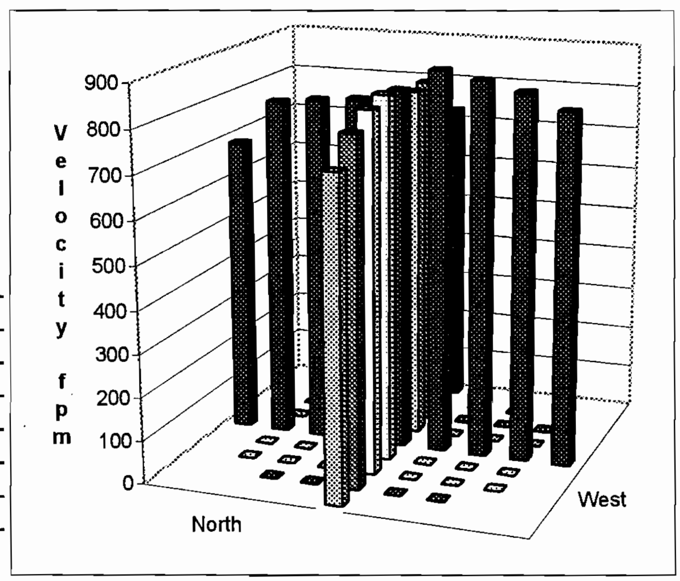
Flow w/o C-Pt 1421 acfm

Vel Avg w/o C-Pt 804 fpm

Instuments Used:

Solomat Zephyr SN 1295-1472

	Start	Finish	
Stack temp	81	84	F
Equipment temp	74	79	F
Ambient temp	74	76	F
Stack static	0.02	0.00	mbars
Ambient pressure	1016.5	1016.5	mbars
Total Stack pressure	1017.0	1017.0	mbars
Ambient humidity	43%	38%	RH



Notes:

Signature signifies compliance with Procedure EMS-JAG-4

Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

VELOCITY TRAVERSE DATA FORM

Site	325 Model	Run No.	VT-4
Date	8/26/2004	Fan Configuration	Far Fan (#1)
Testers	JAG/GSH	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	86.9 deg F
Stack X-Area	254.5 in.2	Start/End Time	13:21
Elevation		Center 2/3 from	1.65 to: 16.35
Distance to disturbance	inches	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Data Files:	NA

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	0.58	739	719	743	733.7	682	604	717	667.7
2	1.89	751	782	782	771.7	767	763	789	773.0
3	3.49	768	779	813	786.7	810	788	772	790.0
4	5.81	716	789	782	762.3	807	764	791	787.3
Center	9.00	755	741	774	756.7	771	760	767	766.0
5	12.19	762	790	779	777.0	760	782	797	779.7
6	14.51	786	797	780	787.7	796	796	742	778.0
7	16.11	769	745	693	735.7	789	760	784	777.7
8	17.42	637	677	623	645.7	738	726	750	738.0
Averages --------->		742.6	757.7	752.1	750.8	768.9	749.2	767.7	761.9

All	ft/min	Dev. from mean	*Center 2/3*	West	North	All
Mean	756.4		Mean	768.2	778.8	773.5
Min Point	645.7	-14.6%	Std. Dev.	18.4	8.1	14.7
Max Point	790.0	4.4%	COV as %	2.4	1.0	**1.9**

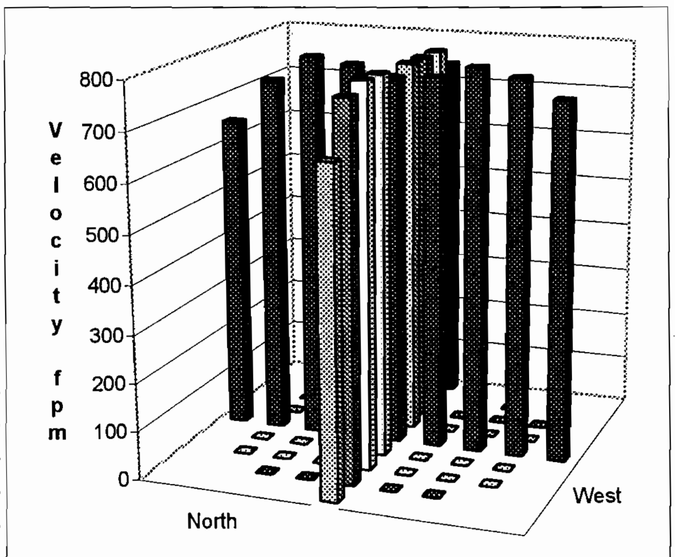
Flow w/o C-Pt 1335 acfm

Vel Avg w/o C-Pt 756 fpm

Instuments Used:

Solomat Zephyr SN 1295-1472

	Start	Finish	
Stack temp	85	89	F
Equipment temp	79	80	F
Ambient temp	80	80	F
Stack static	0.01	-0.04	mbars
Ambient pressure	1016.4	1016.8	mbars
Total Stack pressure	1016.4	1016.8	mbars
Ambient humidity	28%	28%	RH



Notes:

Signature signifies compliance with Procedure EMS-JAG-4

Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

Test Instruction		
Project: **325 Stack Sampler Qualification**	Date: **August 16, 2004**	Work Package: **F59676**
Tests: **Velocity Uniformity in 325 Model Stack, 1 Electric Fan Configuration**		
Staff: John Glissmeyer, Dave Douglas, Marcel Ballinger, Matthew Barnett		

Reference Procedures:

1. Operating Manual for air velocity instrument used
2. Procedure EMS-JAG-04, Test to Determine Uniformity of Gas Velocity at the Elevation of a Sampler Probe
3. Model Stack, Fans and Fan Speed Controller. Fans will be in positions EF1, EF4.

Equipment:

1. TSI VelociCalc , Solomat Zephyr and 36" standard pitot tube, or other calibrated velocity measurement instrumentation

Safety Considerations:

Observe the applicable Job Hazard Analysis for the project

Instructions:

1. Verify training on the procedure and that instrumentation is within calibration.
2. Assemble the equipment at the ports at the 12.5 foot elevation above the ground. Use the same measurement points as for flow calibration test.
3. Mark the completion of each step on the field copy of the procedure. Mark-out those steps not applicable to this stack.
4. With one operating fan, set the fan controller to achieve the desired approximate flowrate (1350 - 1450 cfm)
5. Record data on velocity data sheet
6. If target flowrate is not achieved, adjust fan controller and rerun test.
7. Repeat this test with the other fan operating.
8. Repeat this test again with either fan operating or with the configuration yielding the highest % COV from the first two tests.
9. Diagram mounting fixtures and retain assembly for subsequent tests

Desired Completion Date: 08/27/04

Approvals: John Glissmeyer (signature) — John Glissmeyer, test director — 8/19/04 Date

Test completed by: John Glissmeyer (signature) — Date: 8/26/04

PNNL Operating Procedure	
Title: Test to Determine Uniformity of Gas Velocity at the Elevation of a Sampler Probe	**Org. Code:** D9T99 **Procedure No.:** EMS-JAG-04 **Rev. No.:** 0
Work Location: General	**Effective Date:** November 24, 1998
Author: John A. Glissmeyer	**Supersedes Date:**
Identified Hazards: ▩ Radiological ▩ Hazardous Materials Physical Hazards ▩ Hazardous Environment ▩ Other:	**Identified Use Category:** ▩ Mandatory Use ▩ Continuous Use Reference Use ▩ Information Use

Are One-Time Modifications Allowed? Yes ▩ No

Person Signing	Signature	Date
Technical review: James L. Huckaby		
Project Manager: John Glissmeyer		
Line Manager: James Droppo		
Quality Engineer: Thomas G. Walker		

1.0 Purpose

The performance of new stack sampling systems must be shown to satisfy the requirements of 40 CFR 61, Subpart H, "National Emission standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." This regulation governs portions of the design and implementation of effluent air sampling. The stack sampler performance is adequately characterized when potential contaminants in the effluent are of a uniform concentration at the sampling plane and line losses are within acceptable limits. (The sampling plane is the cross section of the stack or duct where the sampling nozzle inlet is located.) Uniformity of contaminant concentration is unlikely where the gas velocity throughout the sampling plane is significantly non-uniform. This procedure provides the means to determine the uniformity of gas velocity, and is performed prior to measurements of contaminant uniformity. This procedure is performed after the range of gas flow conditions are established. Other procedures that usually follow address flow angle, and uniformity of gas and aerosol contaminants.

2.0 Applicability

This procedure can be used in the field or on modeled stacks and ducts to determine the uniformity of air velocity throughout the sampling plane. The results also provide a detailed determination of the flowrate at the ventilation control settings used for the procedure. The tests are applicable within the following constraints:

- The operating limits of the air velocity measurement device used are observed.
- The air velocity sensor element does not occupy more than a few percent of the cross sectional area in the sampling plane.

This procedure may need to be repeated if there are changes made in the configuration of the ventilation system. If the system under test operates within a limited range of airflow that does not change more than ± 25%, then this procedure is usually conducted once at the middle of the range. If the flow may vary more, then the procedure is performed at least at the extremes of flow.

3.0 Prerequisites and Conditions

Conditions and concerns that must be satisfied prior to performing this procedure are listed below:

- The job-hazards analysis for the work area must be prepared and followed.
- Safety glasses, hard toed or substantial shoes may be required in the work areas.
- Scaffold user training may be required to access the sampling ports of the stack.
- The flow ventilation control device must be installed and means available for its adjustment.
- Air velocity measurement equipment must be within calibration.
- The test instruction must be read and understood.

4.0 Precautions and Limitations

Access to the test ports may require the use of ladders, scaffolding or manlifts, which may necessitate special training for sampling personnel and any observers. The training requirements will be indicated in the job hazard analysis.

5.0 Equipment Used for Measurements

The following are essential items of equipment:

- Air velocity measurement apparatus, which may consist of a calibrated slant tube or electronic manometer, pitot tube, or some other type of sensor;
- Platform, ladders, or manlifts as needed to access the test ports;
- Fittings to limit leakage around the velocity sensor and to stabilize the sensor so it can be repositioned repeatably.

Further details on specific equipment for the job are provided in the Test Instruction. The air velocity instrumentation may be either the types used in 40 CFR 60, Appendix A, Method 2, or other measurement device for discrete points, such as a rotating vane or thermal anemometer. The user must be aware that different devices may give readings in terms of different gas conditions.

6.0 Work Instructions for Setup, Measurements, and Data Reduction

Job specific instructions given in the Test Instruction, illustrated in Exhibit B, will provide details and operating parameters necessary to perform this procedure.

6.1 Preliminary Steps:

6.1.1 Verify that the interior dimensions of the stack or duct at the sampling plane agree with those used in calculating the grid of measurement points given in the test instruction or data sheet.

6.1.2 Provide essential supplies at the sampling location (velocity measuring instrumentation, fittings to adapt the sensor to the test ports, marking pens, data sheets, writing and sensor supporting platforms).

6.1.3 Verify that the ventilation flow control device is capable of the flow control settings given in the Test Instruction.

6.1.4 Prepare a data sheet for the detailed velocity traverse. See illustration in Exhibit A. Label the columns of traverse data by the direction of the traverse.

> **Note.** For example, if the first reading is closest to the east port, and the last reading is closest to the west port, then label the traverse east-west. Also the first point is the one closest to the port.

> **Note.** The grid of velocity measurement points is calculated in accordance with 40 CFR 60, Appendix A, Method 1. A centerpoint is included as a common reference and for graphical purposes. The layout design divides the area of the sampling plane so that each point represents approximately an equal-sized area

6.1.5 Mark the velocity sensor body to indicate the insertion depth for each point in the measurement grid.

6.1.6 Obtain barometric pressure, relative humidity, and stack or duct temperature and static pressure if needed to convert the velocity sensor readings to velocity units.

6.1.7 Insert the velocity sensor in the stack or duct and seal the opening around it.

6.2 Velocity Uniformity Measurement

6.2.1 Set the flow controller per the test instruction.

6.2.2 Verify that the directional orientations and the numbered measurement positions are consistent with the data sheet.

6.2.3 Measure and record, on the data sheet, the velocity or pressure reading at each measurement point in succession. If the readout device has an averaging feature, record the average of a series of several readings.

6.2.4 Repeat Step 6.2.3.

6.2.5 Compare the results in Step 6.2.3 with those of 6.2.4. If the measurements are not highly reproducible, repeat Step 6.2.3 again.

6.2.6 Calculate the average air velocity for each measurement point.

6.2.7 Calculate the overall average velocity and flowrate for the stack or duct, omitting the center point.

6.2.8 Calculate the coefficient of variance (COV, 100 times the standard deviation divided by the mean) using the average velocity for all points in the inner two-thirds of the cross section area (including the centerpoint).

6.2.9 Compare the observed COV for each run to the acceptance criterion. The acceptance criterion for the COV is #20% for the inner two-thirds of the stack diameter.

6.2.10 Review the datasheets for completeness.

6.2.11 Sign and date the datasheets attesting to their validity.

7.0 Exhibits/Attachments

Exhibit A - Illustration of Detailed Velocity Traverse Data Sheet

VELOCITY TRAVERSE DATA FORM

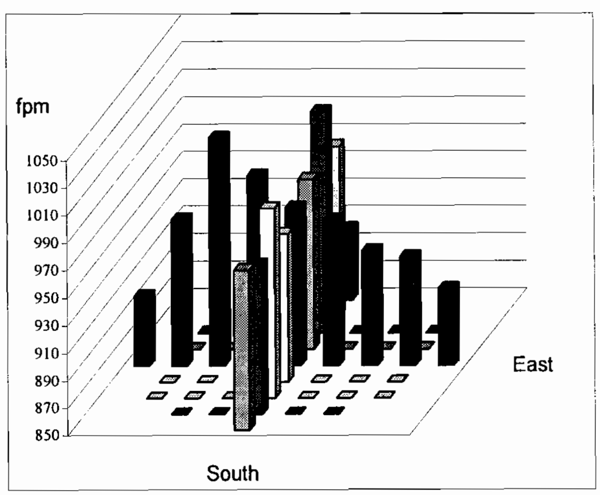
Site	W420 6" Model in 305 Building	Run No.	VT6May5_1
Date	May 5, 1998	Stack Temp	74 deg F
Tester	Maughan	Stack RH	39 %
Stack Dia.	6.328 in.	BP (sta. + static)	992 + 0.94 =~ 993 mbars
Stack X-Area	31.5 in.	Fan Setting	20 Hz
Elevation		Center 2/3 from	0.58 to: 5.75
El. above disturbance	49.25 in.	Points in Center 2/3	2 to: 7
Units	fpm		

Traverse-->		East				South			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	0.50	892	884	932	902.7	970	980	950	966.7
2	0.66	909	935	933	925.7	955	961	960	958.7
3	1.23	948	912	930	930.0	979	1005	979	987.7
4	2.04	946	961	951	952.7	963	951	957	957.0
Center	3.16	955	970	960	961.7	978	955	961	964.7
5	4.28	970	990	994	984.7	975	967	978	973.3
6	5.10	1022	991	1024	1012.3	1055	1010	968	1011.0
7	5.66	971	944	944	953.0	969	960	992	973.7
8	5.83	917	890	886	897.7	920	873	911	901.3
		West				North			
Traverse Averages ---------->					946.70				966.00

Average of all data	956.35		
Upper Limit 1.3 x mean	1243.26	Max Point	1012.33
Lower Limit 0.7 x mean	669.45	Min Point	897.67

Center 2/3	E/W	S/N	All
Mean	960.00	975.14	967.57
Std. Dev.	30.363	18.967	25.559
COV %	3.2	1.9	2.6

Flow 209 cfm
Flow 355 m3/hr



Notes:

Instuments Used:
Solomat Zephyr #12951472
Cal # 521-28-09-001, Expires 5/1/99

Signature signifying compliance with Procedure EMS-JAG-04

Signature/Date

Exhibit B – Illustrative Test Instruction

Test Instruction		
Project: W420 6" Stack Calibration 28361	Date: August 19, 1998	Work Package: **K83017**
Tests: Velocity Uniformity High Flow in W420 6" Full-Scale Model Stack		
Staff: David Maughan		
Reference Procedures: 1. Operating Manual for Solomat Zephyr 2. Test to Determine Uniformity of Gas Velocity at the Elevation of a Sampler Probe, Procedure EMS-JAG-04		
Equipment: 1. W420 6" Full-Scale Model Stack, Fan and Fan Speed Controller located in 305 Bldg. 2. Solomat Zephyr and pitot tube		
Safety Considerations: Review and observe the applicable Numatec Job Hazard Analysis for the project		
Instructions: 1. Assemble the equipment for the velocity uniformity test at the ports at the elevation of the sampling probe 2. Layout the measurement points with the following distances from the inside of the stack wall: 0.5, 0.66, 1.23, 2.04, 3.16, 4.28, 5.10, 5.66, 5.83 inches.3. Measure the velocity at each point at the high (400 cfm) extreme of stack flow. Repeat each measurement twice. 4. Record data on velocity data sheets 5. Diagram mounting fixtures and retain assembly for subsequent tests		
Desired Completion Date: 12/5/98		
Approvals: ______________________ John Glissmeyer, project manager	Date	
Test completed by:	Date:	

Appendix D

Flow Angle Procedure and Data

INDEPENDENT TECHNICAL REVIEW RECORD

PACIFIC NORTHWEST NATIONAL LABORATORIES INDEPENDENT TECHNICAL REVIEW RECORD	DOCUMENT NO.: Calculation of Flow Angle for 325 Model Stack, Spreadsheet 04-325-8ptfloang.xls	Page 1 of 1

The referenced document is submitted for your review. Instructions for completing this form are attached. Please return the completed form to: John Glissmeyer. If you have any questions, please call John Glissmeyer, 376-8552, cell 531- 8006. Comments Due: 9/28/04

Additional Information: (Scope of Review, etc) Please verify the following:

1. Transfer of field data to spreadsheet
2. Calculation of intermediate mean values of flow angle per traverse (one per port) and measurement point (1st and last points per port)
3. Calculation of overall mean absolute angle

Organization/Department Environmental Health Sciences Group	Designated Reviewer: Rosanne Aaberg	Signature/Date Rosanne L Aaberg 9/30/04

CONCUR [ ]	CONCUR, WITH COMMENTS [x]	DO NOT CONCUR [ ]	NOT REVIEWED [ ]

Comt. No.	Comment and/ or Recommendation:	Resolution:
1	O- Instruments are not identified specifically. Manometer has calibration due date; barcode would identify instrument.	Barcode inserted.
	Concur with Resolution Rosanne L Aaberg Date 9/30/04	Comments Resolved By John Glissmeyer Date 9/30/04

FLOW ANGLE DATA FORM

Site **325 Model**
Date 8/20/2004
Tester MYB/GSH/JMB
Stack Dia. 18 in
Stack X-Area 254.5 in2
Elevation 121.5 in
Distance to disturbance 75 in

Run No. **FA-1**
Fan Setting **37.1 Hz**
Fan configuration **Fan 1 (Far from stack)**
Approx. stack flow 1442 cfm
Units degrees (clockwise > pos. nos.)

Traverse-->		East				North			
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	0.58	-15	-8	-15	-12.7	-13	-14	-17	-14.7
2	1.89	-14	-7	-20	-13.7	-12	-13	-16	-13.7
3	3.49	-4	-8	-15	-9.0	-10	-10	-12	-10.7
4	5.81	-7	-7	-9	-7.7	-4	-8	-6	-6.0
Center	9.00	3	-1	-1	0.3	3	-5	4	0.7
5	12.19	6	5	1	4.0	7	5	7	6.3
6	14.51	7	9	12	9.3	11	10	11	10.7
7	16.11	9	12	10	10.3	12	12	12	12.0
8	17.42	10	12	9	10.3	14	16	15	15.0
Mean of absolute values		8.3	7.7	10.2		9.6	10.3	11.1	
w/o points by wall:		7.1	7.0	9.7		8.4	9.0	9.7	

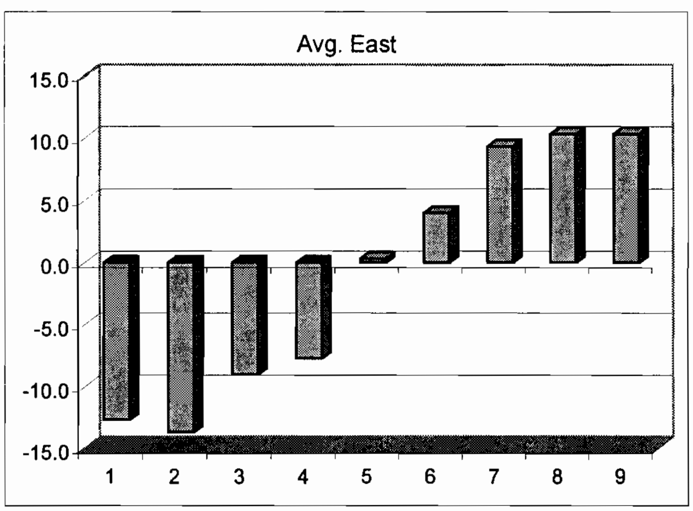
all	9.5
w/o wall pts	8.5

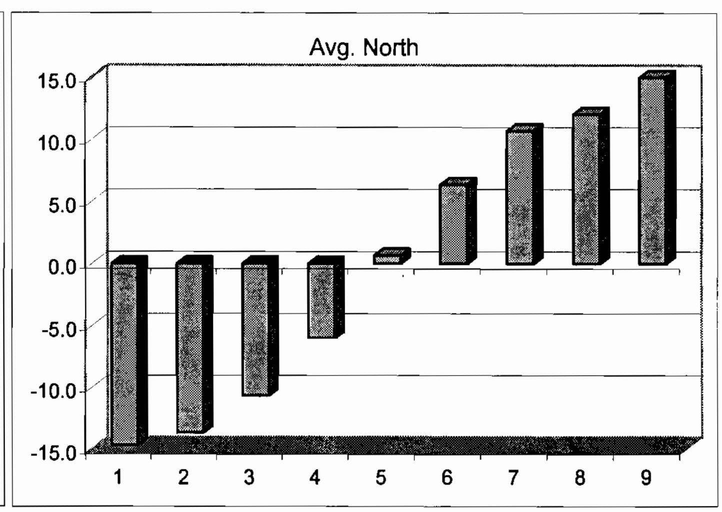
Instuments Used:

S-type pitot	Pitot 2
Stanley protractor level	Prot 2
Manometer	Man-3 Barcode 18120

Notes:
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).

Manometer Cal. Due 8/6/2005





Signature signifies compliance with Procedure EMS-JAG-05

Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

FLOW ANGLE DATA FORM

Site **325 Model**
Date 8/20/2004
Tester MYB/GSH/JMB
Stack Dia. 18 in
Stack X-Area 254.5 in2
Elevation 121.5 in
Distance to disturbance 75 in

Run No. **FA-2**
Fan Setting **37.1 Hz**
Fan configuration **Fan 4 (near stack)**
Approx. stack flow 1442 cfm
Units degrees (clockwise > pos. nos.)

Traverse-->		East				North			
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	0.58	-12	-10	-20	-14.0	-19	-21	-20	-20.0
2	1.89	-12	-10	-22	-14.7	-15	-15	-15	-15.0
3	3.49	-21	-22	-25	-22.7	-20	-16	-13	-16.3
4	5.81	-15	-19	-18	-17.3	-9	-15	-8	-10.7
Center	9.00	-5	0	-8	-4.3	-8	-6	-4	-6.0
5	12.19	7	5	1	4.3	7	8	12	9.0
6	14.51	18	13	7	12.7	13	15	16	14.7
7	16.11	20	17	15	17.3	19	15	18	17.3
8	17.42	21	22	23	22.0	21	19	19	19.7
Mean of absolute values		14.6	13.1	15.4		14.6	14.4	13.9	
w/o points by wall:		14.0	12.3	13.7		13.0	12.9	12.3	

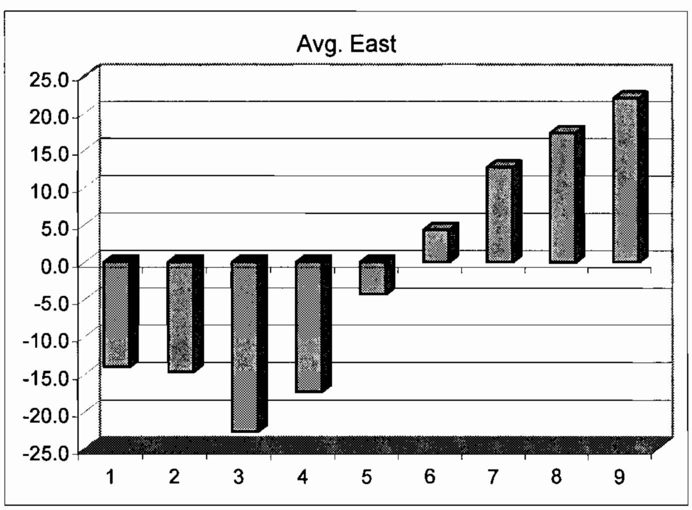
all	14.3
w/o wall pts	13.0

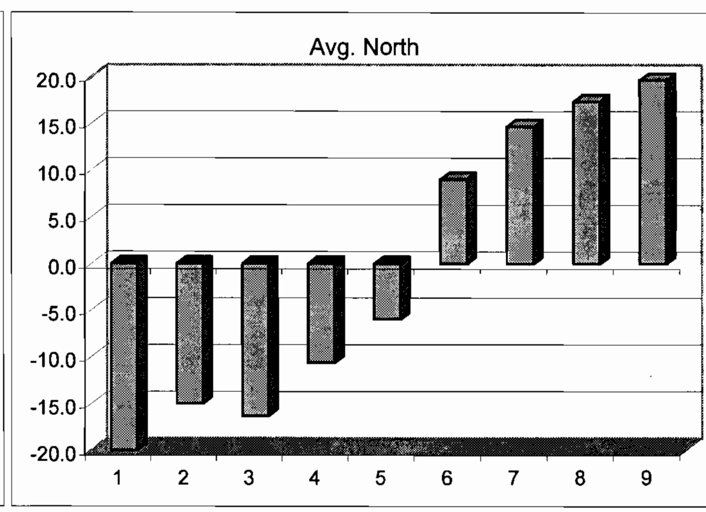
Instuments Used:

S-type pitot	Pitot 2
Stanley protractor level	Prot 2
Manometer	Man-3 Barcode 18120

Notes:
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).

Manometer Cal. Due 8/6/2005





Signature signifies compliance with Procedure EMS-JAG-05

Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roxanne L Faber 9/30/04

FLOW ANGLE DATA FORM

Site **325 Model**
Date 8/26/2004
Tester GSH/JAG
Stack Dia. 18 in
Stack X-Area 254.5 in2
Elevation 121.5 in
Distance to disturbance 75 in

Run No. **FA-3**
Fan Setting **37.1 Hz**
Fan configuration **Near**
Approx. stack flow ______ cfm
Units degrees (clockwise = NEG. nos.)

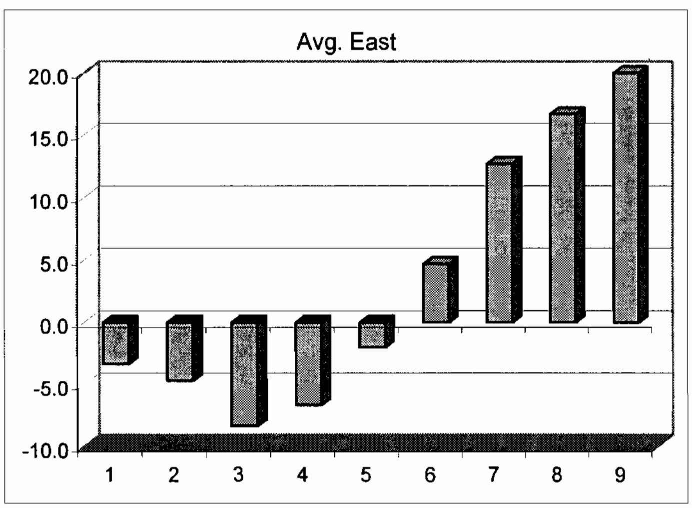
Traverse-->		East				North			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	0.58	-2	-4	-4	-3.3	-1	-2	-2	-1.7
2	1.89	-3	-4	-7	-4.7	-3	-4	-4	-3.7
3	3.49	-4	-7	-14	-8.3	-4	-5	-7	-5.3
4	5.81	-3	-6	-11	-6.7	-3	-4	-4	-3.7
Center	9.00	0	-3	-3	-2.0	0	1	0	0.3
5	12.19	4	4	6	4.7	7	8	6	7.0
6	14.51	13	13	12	12.7	13	15	13	13.7
7	16.11	18	14	18	16.7	12	16	15	14.3
8	17.42	22	20	18	20.0	15	16	15	15.3
Mean of absolute values		7.7	8.3	10.3		6.4	7.9	7.3	
w/o points by wall:		6.4	7.3	10.1		6.0	7.6	7.0	
								all	8.0
								w/o wall pts	7.4

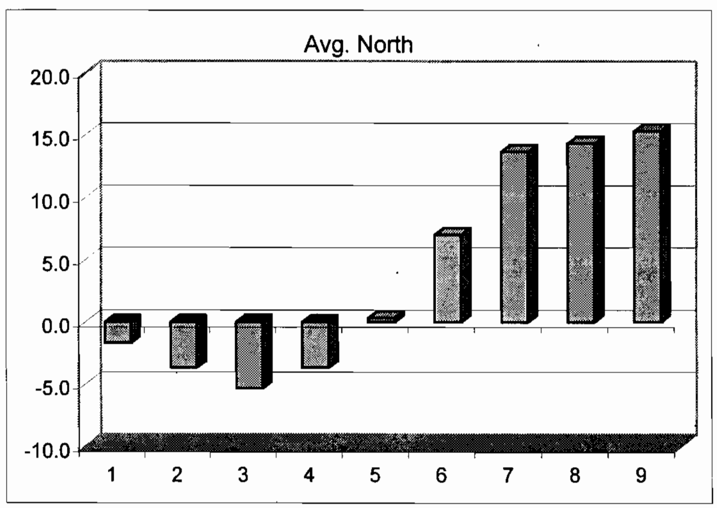
Instuments Used:

S-type pitot	Pitot 2
Stanley protractor level	Prot 2
Manometer	Man-3 Barcode 18120

Notes:
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).

Manometer Cal. Due 8/6/2005





Signature signifies compliance with Procedure EMS-JAG-05

Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: R Barney Hables 9/30/04

Test Instruction		
Project: **325 Stack Sampler Qualification**	Date: **August 16, 2004**	Work Package: **F59676**

Tests: Flow Angle at Nominal Flow in 325 Model Stack, 1 Electric Fan Configuration

Staff: John Glissmeyer, Marcel Ballinger, Matthew Barnett, Dave Douglas

Reference Procedures:

1. *Test to Determine Flow Angle at the Elevation of a Sampler Probe*, Procedure EMS-JAG-05

Equipment:

1. S-type Pitot Tube, slant tube or electronic manometer, connecting surgical or silicone tubing, clamp-on pointer and protractor, and protractor level, tape measure, Sharpie Pen, or pre-marked template
2. Adapter swivel fittings to interface pitot tube to test port
3. Model Stack, Fans and Fan Speed Controller. Fans will be in positions EF1, EF4.

Safety Considerations:

Observe the applicable Job Hazard Analysis for the project

Instructions:

1. Verify training on the procedure and that instrumentation is within calibration.
2. Mark the completion of each step on the field copy of the procedure. Mark-out those steps not applicable to this stack.
3. Assemble the equipment for the flow angle test at the test ports ~12.5 feet above the ground. The protractor level can be attached to the pitot tube for flow in the vertical direction.
4. Use the same measurement points as for flow calibration test.
5. Repeat flow angle measurement for both fans, which will be operated one at a time.
6. Verify that stack flow is about the target flowrate (1350 – 1450 cfm). This can be determined from manual velocity readings, the predetermined flow control setpoint, or the output of the installed stack flowmeter.
7. Measure the flow angle at each point. Repeat each measurement three times.
8. Record the data on flow angle data sheets.
9. Diagram mounting fixtures and retain assembly for subsequent tests.

Desired Completion Date: 8/27/04

Approvals: MBarnett for JAG — John Glissmeyer   Date: 8/24/04

Test completed by: MBarnett   Date: 8/20/04

PNNL Operating Procedure	
Title: Test to Determine Flow Angle	**Org. Code:** D9T99 **Procedure No.:** EMS-JAG-05 **Rev. No.:** 0
Work Location: General	**Effective Date:** November 24, 1998
Author: John A. Glissmeyer	**Supersedes Date:**
Identified Hazards: ▒ Radiological ▒ Hazardous Materials Physical Hazards ▒ Hazardous Environment ▒ Other:	**Identified Use Category:** ▒ Mandatory Use ▒ Continuous Use Reference Use ▒ Information Use

Are One-Time Modifications Allowed? Yes ▒ No

Person Signing	Signature	Date
Technical review: James L. Huckaby		
Project Manager: John Glissmeyer		
Line Manager: James Droppo		
Quality Engineer: Thomas G. Walker		

1.0 Purpose

The performance of new stack sampling systems must be shown to satisfy the requirements of 40 CFR 61, Subpart H, "National Emission standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." This regulation governs portions of the design and implementation of effluent air sampling. The stack sampler performance is adequately characterized when potential contaminants in the effluent are of a uniform concentration at the sampling plane and line losses are within acceptable limits. (The sampling plane is the cross section of the stack or duct where the sampling nozzle inlet is located.) Uniformity of contaminant concentration is highly unlikely where the mean angle of the gas velocity throughout the cross section of the stack or duct is significantly non-zero. This condition would also mean that the air velocity approaches the sampling nozzle at an unacceptable angle, degrading the performance of the nozzle. This procedure provides the means to determine the mean flow angle, and is performed prior to measurements of contaminant uniformity. This procedure is performed after the range of gas flow conditions is established. Other associated procedures generally follow and address uniformity of flow and of gas and aerosol contaminants.

2.0 Applicability

This procedure can be used in the field or on modeled stacks and ducts to determine the angle of the air velocity relative to the axis of the duct or stack. The angle measured is the roll angle. This should be determined at the sampling plane. The tests are applicable within the following constraints:

- The operating limits of the air velocity measurement device used are observed.
- The air velocity sensor element does not occupy more than a few percent of the cross-sectional area in the plane of the element.

This procedure may need to be repeated if there are changes made in the configuration of the ventilation system. If the system under test operates within a limited range of airflow that does not change more than ± 25%, this procedure is usually conducted once at the middle of the range. If the flow varies more, the procedure is performed at least at the extremes of flow.

3.0 Prerequisites and Conditions

Conditions and concerns that must be satisfied prior to performing this procedure are listed below:

- The job-hazards analysis for the work area must be prepared and followed.
- Safety glasses, hard toed or substantial shoes may be required in the work areas.
- Scaffold user training may be required to access the sampling ports of the stack.
- A ventilation flow control device must be installed and means available for its adjustment.
- Air velocity measurement equipment must be within calibration.
- The test instruction must be read and understood.

4.0 Precautions and Limitations

Access to the test ports may require the use of ladders, scaffolding or manlifts, which may necessitate special training for sampling personnel and any observers. The training requirements will be indicated in the job hazard analysis.

5.0 Equipment Used for Measurements

The following are essential items of equipment:

- A Type-S pitot tube with sufficient length to reach across the diameter of the test stack,
- Slant tube or calibrated electronic manometer to indicate when the differential pressure reading of the pitot tube is about zero,
- Device for measuring the pitot tube angle at traverse points (e.g., a protractor level with good angle resolution). (Note: A three dimensional velocity probe capable of measuring both pitch and yaw angles of gas flow is also acceptable provided that modifications in the method outlined below are made),
- Tape or template to mark insertion depths on the pitot tube,
- Velocity sensor to check the stack airflow,
- Means to obtain temperature and barometric pressure for any corrections needed for the current test conditions,
- Platform, ladders, or manlifts as needed to support equipment and to access the test ports,
- Fittings to limit leakage around the pitot tube and to stabilize the tube so that it can be positioned repeatedly in the test stack at the same location.

Further details on specific equipment for the job are provided in the Test Instruction. The test method is based on 40 CFR 60, Appendix A, Method 1, Section 2.4, "Verification of the Absence of Cyclonic Flow." The measurement instrumentation may be either the type used in Method 1, or another measurement device designed for measuring the angle of the velocity vector at discrete points. The user should be aware that different devices may give different readings.

6.0 Work Instructions for Setup, Measurements, and Data Reduction

Job specific instructions given in the Test Instruction, illustrated in Exhibit A, will provide details and operating parameters necessary to perform this procedure. Prior to determination of flow angles, measurements should be made to assess whether the stack velocity flow is within normal limits.

6.1 Preliminary Steps:

6.1.1 Verify that the interior dimensions of the stack or duct at the measurement locations agree with those used in calculating the grid of measurement points given in the test instruction or data sheet.

> **Note.** The grid of measurement points is calculated in accordance with 40 CFR 60, Appendix A, Method 1. A centerpoint is included as a common reference and for graphical purposes. The layout design divides the area of the sampling plane so that each point represents approximately an equal-sized area

6.1.2 Provide essential supplies at the sampling location. (S-Type pitot tube, manometer, tubing, fittings to adapt the sensor to the test ports, marking pens, data sheets, writing and sensor supporting platforms).

6.1.3 Verify that the ventilation flow control device is capable of the flow control settings given in the Test Instruction.

MTS 8/29/04

6.1.4 Prepare a data sheet for the measurement traverse. See illustration in Exhibit B. Label the columns of traverse data by the direction of the traverse. For example, if the first reading is closest to the east port, and the last reading is closest to the west port, then label the traverse "east-west".

6.1.5 Mark the Type-S pitot tube to indicate the insertion depth for each point in the measurement grid.

6.1.6 Set the stack flow control per the test instruction. (Use a velocity or flow sensor to verify that correct flow has been achieved.)

> **Note.** Flow verification can be based on a single point velocity reading. The single point can be the same one determined in the stack flow controller calibration in Procedure EMS-JAG-03. The barometric pressure, relative humidity, stack temperature and static pressure values may be needed to convert the velocity sensor readings to velocity units.

6.1.7 Insert the Type-S pitot tube in the stack or duct, seal the opening around it, and check for smooth operation of the pitot tube.

> **Note.** Good measurements are dependent upon making small repeatable rotations of the pitot tube in the available fittings.

6.1.8 Establish a convention for representing the angular direction of flow.

> **Note.** If an inclined manometer is used, connect the flexible tubes between the connectors on the pitot tube and the manometer so that rotating the pitot tube assembly clockwise drives the meniscus to the right, i.e., to higher positive numbers.
>
> Attach a circular protractor to the pitot tube near the tubing connectors. Generally the protractor hangs below the pitot tubes. When the parallel tubes are in horizontal position, the protractor should indicate zero degrees. If the tubing assembly is rotated clockwise, the resulting counter-clockwise movement of the angle indicator produces an angle that is read as a positive number. This is consistent with the convention for reading circular angles.

6.1.9 Position the inclined manometer on a stable platform and level the device using the spirit level.

> **Note**: Movement on the test platform may affect the manometer level. It should be checked frequently. Adjustments can be made at any time when the pitot tube is moved to the next position, but not during readings at any single point.

6.1.10 Connect the flexible tubes to the inclined manometer but disconnect them from the pitot tube.

6.1.11 Increase or decrease the red oil level in the inclined portion of the manometer to zero the meniscus. (This is done using a finger-adjustable screw at the base of the manometer.)

6.1.12 Reconnect the flexible tubes to the pitot tube.

6.2 Angular Flow Measurements

6.2.1 Verify that the directional orientations and the numbered measurement positions are consistent with the data sheet.

6.2.2 Measure and record, on the data sheet, the angular reading at each measurement point in succession. If the readout device has an averaging feature, record the average of a series of several readings.

> **Note:** Each test relies on one repetition for each measurement point in each traverse direction, repeated three times. The repeats are made as three separate runs and not as three consecutive measurements at each point.
>
> The readings may be erratic for some flow conditions and at some traverse positions. Care should be taken to approach these variable readings from both higher and lower angles to obtain the most accurate equilibrium reading.

jmB 8-20-04 **6.2.3** Repeat Step 6.3.3.

jmB 8-20-04 **6.2.4** Compare the results in Step 6.3.4 with those of 6.3.3. If the measurements are not highly reproducible, repeat Step 6.3.3 again.

jmB 8-20-04 **6.2.5** Calculate the absolute average air-flow angle for each measurement point.

jmB 8-20-04 **6.2.6** Calculate the average absolute flow angle for all measurement points.

> Note: The acceptance criterion is that the average flow angle not exceed 20 degrees.

jmB 8-23-04 **6.2.7** Review the datasheets for completeness.

jmB 8-23-04 **6.2.8** Sign and date the datasheets attesting to their validity.

7.0 Exhibits/Attachments

Exhibit A – Illustrative Test Instruction

Test Instruction		
Project: W420 6" Stack Calibration 28361	Date: August 19, 1998	Work Package: **K83017**
Tests: Flow Angle at High Flow in W420 6" Full-Scale Model Stack		
Staff: David Maughan		
Reference Procedures: 1. Operating Manual for Solomat Zephyr 2. Test to Determine Flow Angle at the Elevation of a Sampler Probe, Procedure EMS-JAG-05		
Equipment: 1. W420 6" Full-Scale Model Stack, Fan and Fan Speed Controller located in 305 Bldg. 2. S-type Pitot Tube, slant tube or electronic manometer, and Protractor Level		
Safety Considerations: Review and observe the applicable Numatec Job Hazard Analysis for the project		
Instructions: 5. Assemble the equipment for the flow angle test at the ports at the elevation of the sampling probe. 2. Layout the measurement points with the following distances from the inside of the stack wall: 0.5, 0.66, 1.23, 2.04, 3.16, 4.28, 5.10, 5.66, 5.83 inches.3. Measure the flow angle at each point at the high (400 cfm) extreme of stack flow. Repeat each measurement twice. 4. Record the data on flow angle data sheets. 5. Diagram mounting fixtures and retain assembly for subsequent tests		
Desired Completion Date: 12/5/98		
Approvals: ______________________ John Glissmeyer, project manager		____________ Date
Test completed by:		Date:

Exhibit B – Illus tration of Flow Angle Data Sheet

W420 296-C-5 FLOW ANGLE at High and Low Average Flow Rates

Site Bldg. 305 — Run No. ______
Date 12/ /1998 — Stack Temp ______ deg. F
Tester ______ — Stack RH ______ percent
Stack Dia. 12 in — Baro Press ______ mbar
Stack X-Area 113.1 in2 — Fan Setting ______ Hz
Elevation ______ ft — Fan input port ______
El. above disturbance ______ in — Flowrate (pre- & post-) ______ and ______
Input air filtered? ______ Y or N — Approx. avg. Flowrate ______ cfm at centerline
Units degrees (clockwise > pos. nos.)

Traverse-->		East			South		
Trial ---->		1	2	3	1	2	3
Point	Depth, in.	deg. cw	deg. cw	deg. cw	deg. cw	deg. cw	deg. cw
1	0.50						
2	0.80						
3	1.42						
4	2.12						
5	3.00						
6	4.27						
CenterPt.	6.00						
7	7.77						
8	9.00						
9	9.88						
10	10.58						
11	11.20						
12	11.50						
		West			North		All
Absolute Average of all data:		0.0	0.0	0.0	0.0	0.0	0.0

All: 0.0

Instuments Used:
Parallel-tube pitot with 90-deg. bends at sample ends, 24-inches in length.
Dwyer Instruments 0-5 inch inclined manometer with red guage oil
zero'd and leveled (with connecting tubes open to room atmosphere).
Angles made using Empire #36 circular protractor.

Cal Exp. Date:
NA

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

______

______

Signature signifies compliance with Procedure EMS-JAG-05
Signature/date

Appendix E

Tracer Gas Uniformity Procedure and Data

INDEPENDENT TECHNICAL REVIEW RECORD

PACIFIC NORTHWEST NATIONAL LABORATORIES INDEPENDENT TECHNICAL REVIEW RECORD	DOCUMENT NO.: Calculation of Gas Tracer Uniformity Characteristics for 325 Model Stack, Spreadsheets 04-325 Scalegasunif.xls	Page 1 of 1

The referenced document is submitted for your review. Instructions for completing this form are attached. Please return the completed form to: John Glissmeyer. If you have any questions, please call John Glissmeyer, 376-8552, cell 531-8006. Comments Due: 9/28/04

Additional Information: (Scope of Review, etc) Please verify the following:

1. Transfer of field data to spreadsheet (all runs)
2. Calculation of intermediate mean concentration values per traverse (one per port) and measurement point (1st and last points per port) for the first and last runs.
3. Calculation of port and overall mean concentration, standard deviation, and %COV for the center 2/3 of stack area in first and last runs.
4. Calculation of grand mean and maximum deviation of mean for all measurement points in first and last runs.
5. Calculation of normalized concentration data (2 points) for plotting in the first and last runs.
6. Verify orientation of plotted bars in the first and last runs.
7. Verify consistency of equations in intermediate runs by inspection of spreadsheet in software form. (May print spreadsheet formulas and inspect and mark them.)

Organization/Department	Designated Reviewer:	Signature/Date
Environnemental Health Sciences	Rosanne Aaberg	Rosanne L Aaberg 9/30/04

CONCUR [ ]	CONCUR, WITH COMMENTS [x]	DO NOT CONCUR [ ]	NOT REVIEWED [ ]

Comt. No.	Comment and/ or Recommendation:	Resolution:
1	O- Injection flowmeter row in temperature/pressure table needs a footnote explaining what "ball**" indicates (black, plastic ball or steel ball), and the units associated with the value given in the table.	Done, however the reading is just a percent of scale. We adjust the flow to get in the concentration range that we want..
2	M - Ambient pressure with units of mbar, listed at the bottom of temperature/ pressure table of sheets GT-1 though GT-4 should be listed as Ambient **temperature**, with units °F, as on the original sheets. Sheets GT-5 through GT-11 originals list Ambient Pressure in this location; Ambient Temperature is listed under Notes. These sheets should be corrected to list the Ambient temperature, same as for GT-1 through GT-4.	Added the ambient temperature data where it existed.
3	O – The labels of points (corresponding to depth) in each of the East series plots (GT-1 through GT11) are represented in reverse order from the labels on the graphs. In the future, the confusion could be reduced by reversing the points charted in the graph (source M32:U32 of spreadsheets).	OK

Concur with Resolution	Date	Comments Resolved By	Date
Rosanne L Aaberg	9/30/04	John Glissmeyer	9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-1		
Date	9/1/2004	Fan Configuration	Near fan		
Tester	JAG/GSH/JMB	Fan Setting	37.1 Hz		
Stack Dia.	18 in.	Stack Temp	85 deg F		
Stack X-Area	254.5 in.2	Start/End Time	1500/1630		
Elevation	N.A.	Center 2/3 from	1.65	to:	16.35
Distance to disturbance	120 inches	Points in Center 2/3	2	to:	7
Measurement units	ppm SF6	Injection Point	Top South		

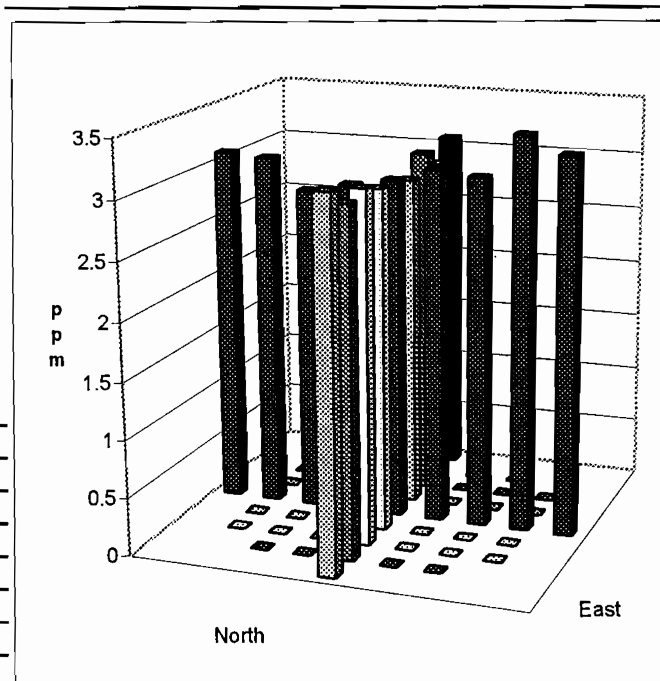
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.55	3.03	3.24	3.27	3.25	3.27	2.94	3.15
2	1.89	3.91	3.26	3.09	3.42	3.10	2.80	3.05	2.98
3	3.49	3.12	2.89	3.12	3.04	3.00	2.86	3.24	3.03
4	5.81	3.28	3.01	2.97	3.09	3.02	3.01	2.84	2.96
Center	9.00	2.84	2.93	3.14	2.97	3.00	3.01	2.85	2.95
5	12.19	2.94	2.88	2.90	2.91	2.79	2.90	2.96	2.88
6	14.51	2.76	2.87	2.86	2.83	2.94	3.24	2.95	3.04
7	16.11	3.08	3.38	2.80	3.09	2.81	2.86	2.99	2.89
8	17.42	3.33	2.98	3.02	3.11	2.97	3.09	3.10	3.05
Averages --------->		3.20	3.03	3.02	3.08	2.99	3.00	2.99	2.99

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.04		Mean	3.05	2.96	3.01
Min Point	2.83	-6.8%	Std. Dev.	0.19	0.06	0.14
Max Point	3.42	12.6%	COV as %	6.21	2.14	**4.75**

Avg. Conc. 3.047 ppm

Gas analyzer checked:
9/1/2004
Wind WSW 18 mph, gusts to 25 mph

	Start	Finish	
Tracer tank pressure	350	375	psig
Sample Port Temp	85	85	F
Centerline vel.	833	826.0	fpm
Injection flowmeter	3	3	% bl. ball**
Stack flow			cfm
Sampling flowmeter	10	9.5	lpm Sierra
Ambient pressure	748.3	748.5	mm Hg
Ambient humidity	28.0	24.0	RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	41/33/35/28/ 29	35/34/25/28	ppb
No. Bk-Gd samples	5	4	n
Ambient temp.	81.0	83.0	deg. F



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 18 x 18 inches
The injection probe reaches 8-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 8-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roxanne Haber 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-2
Date	9/2/2004	Fan Configuration	Near fan
Tester	JAG/GSH/JMB	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	82 deg F
Stack X-Area	254.5 in.2	Start/End Time	1347/1445
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Top North - 1-in from walls at corner

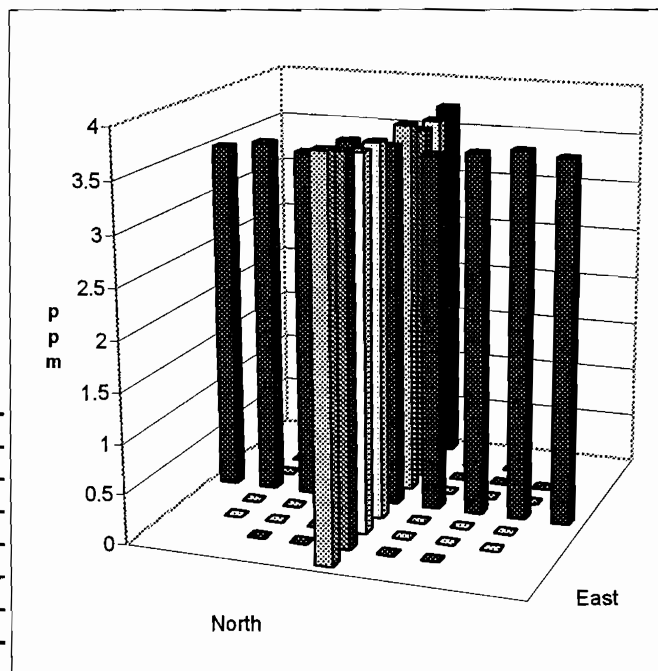
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.42	3.70	3.71	3.61	3.68	3.64	3.60	3.64
2	1.89	3.55	3.86	3.56	3.66	3.68	3.57	3.43	3.56
3	3.49	3.65	3.71	3.44	3.60	3.64	3.37	3.43	3.48
4	5.81	3.50	3.70	3.46	3.55	3.62	3.43	3.43	3.49
Center	9.00	3.56	3.63	3.66	3.62	3.64	3.33	3.19	3.39
5	12.19	3.65	3.79	3.48	3.64	3.63	3.55	3.34	3.51
6	14.51	3.61	3.49	3.38	3.49	3.54	3.32	3.33	3.40
7	16.11	3.66	3.63	3.42	3.57	3.54	3.35	3.36	3.42
8	17.42	3.63	3.57	3.30	3.50	3.64	3.51	3.30	3.48
Averages --------->		3.58	3.68	3.49	3.58	3.62	3.45	3.38	3.48

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.53		Mean	3.59	3.46	3.53
Min Point	3.39	-4.2%	Std. Dev.	0.06	0.06	0.09
Max Point	3.66	3.5%	COV as %	1.56	1.86	**2.49**

Avg. Conc. 3.538 ppm

Gas analyzer checked:
9/1/2004
Wind WSW 18 mph, gusts to 25 mph

	Start	Finish	
Tracer tank pressure	315	375	psig
Sample Port Temp	79	85	F
Centerline vel.	813	826.0	fpm
Injection flowmeter	3	3	% bl. ball**
Stack flow			cfm
Sampling flowmeter	10	9.5	lpm Sierra
Ambient pressure	29.56	748.5	mm Hg
Ambient humidity	28	27	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	25/22/26/26/ 26	29/21/23/21/ 21	ppb
No. Bk-Gd samples	5	4	n
Ambient temp.			deg. F



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 18 x 18 inches
The injection probe reaches 8-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 8-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Joanne L Haber 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	**325 Model**	Run No.	**GT-3**		
Date	9/2/2004	Fan Configuration	**Near fan**		
Tester	JAG/GSH/JMB	Fan Setting	**37.1 Hz**		
Stack Dia.	18 in.	Stack Temp	87 deg F		
Stack X-Area	254.5 in.2	Start/End Time	1445/1525		
Elevation	N.A.	Center 2/3 from	1.65	to:	16.35
Distance to disturbance	120 inches	Points in Center 2/3	2	to:	7
Measurement units	ppm SF6	Injection Point	Center		

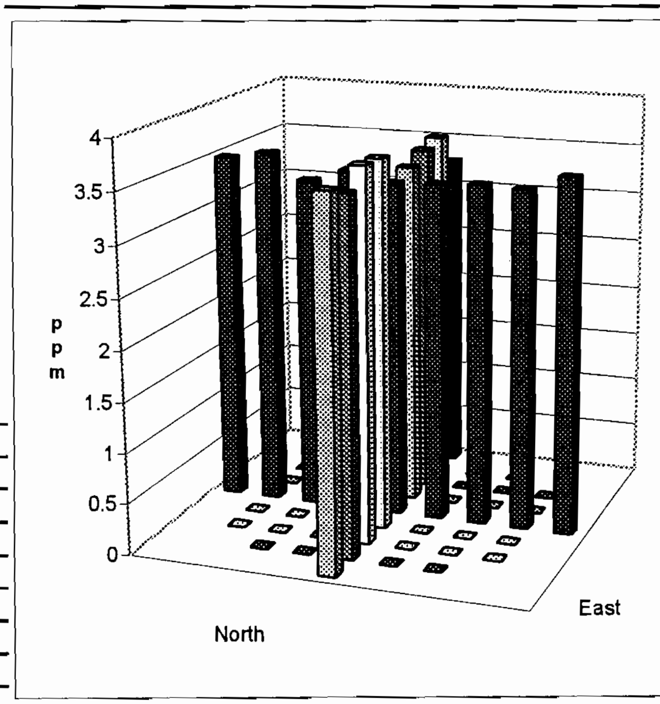
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.54	3.36	3.67	3.52	3.66	3.70	3.52	3.63
2	1.89	3.49	3.26	3.39	3.38	3.50	3.70	3.35	3.52
3	3.49	3.36	3.72	3.10	3.39	3.70	3.97	3.41	3.69
4	5.81	3.28	3.30	3.53	3.37	3.67	3.38	3.99	3.68
Center	9.00	3.46	3.15	3.44	3.35	3.58	3.48	3.01	3.36
5	12.19	3.45	3.48	3.42	3.45	4.08	3.21	3.01	3.43
6	14.51	3.37	3.14	3.45	3.32	3.61	3.38	3.59	3.53
7	16.11	3.79	3.45	3.46	3.57	3.55	3.27	3.92	3.58
8	17.42	3.50	3.29	3.70	3.50	3.16	3.42	3.20	3.26
Averages -------->		3.47	3.35	3.46	3.43	3.61	3.50	3.44	3.52

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.47		Mean	3.40	3.54	3.47
Min Point	3.26	-6.1%	Std. Dev.	0.08	0.12	0.12
Max Point	3.69	6.3%	COV as %	2.41	3.47	**3.54**

Avg. Conc. 3.489 ppm

Gas analyzer checked:
9/1/2004

	Start	Finish	
Tracer tank pressure	315	315	psig
Sample Port Temp	86	88	F
Centerline vel.	830	779.0	fpm
Injection flowmeter	3	3	% bl. ball**
Stack flow			cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	29.54	29.5	mm Hg
Ambient humidity	27	24	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	29/21/23/21/ 21	25/20/24/22/ 23	ppb
No. Bk-Gd samples	5	5	n
Ambient temp.	75.0	76.0	deg. F



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 18 x 18 inches
The injection probe reaches 8-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 8-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Haber 9/30/04

04-325 Scale gasunif.xls GT3 9/30/2004

TRACER GAS TRAVERSE DATA FORM

Site	**325 Model**	Run No.	**GT-4**
Date	9/2/2004	Fan Configuration	**Near fan**
Tester	JAG/GSH/JMB	Fan Setting	**37.1 Hz**
Stack Dia.	18 in.	Stack Temp	84.5 deg F
Stack X-Area	254.5 in.2	Start/End Time	1525/1606
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Bottom South - 1-in from corner walls

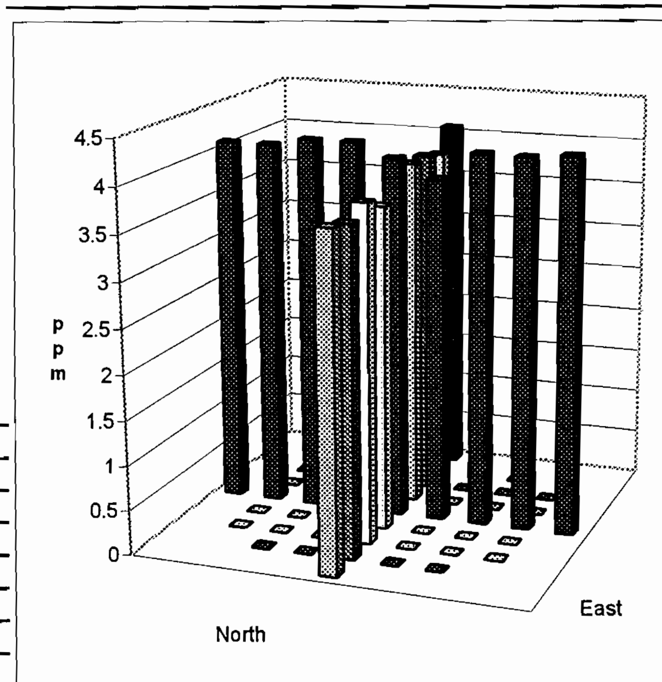
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	4.23	3.64	4.27	4.05	3.73	3.69	3.72	3.71
2	1.89	4.00	4.41	3.61	4.01	3.54	3.73	3.70	3.66
3	3.49	3.76	4.14	4.14	4.01	3.49	3.94	3.89	3.77
4	5.81	3.92	3.51	3.73	3.72	3.73	3.64	3.53	3.63
Center	9.00	3.97	4.15	3.60	3.91	3.89	4.05	4.23	4.06
5	12.19	3.63	4.10	4.41	4.05	3.81	3.95	3.96	3.91
6	14.51	4.22	3.93	3.98	4.04	3.77	4.17	3.78	3.91
7	16.11	3.91	3.97	4.01	3.96	3.56	3.96	4.00	3.84
8	17.42	4.09	3.58	4.22	3.96	3.67	4.08	4.48	4.08
Averages --------->		3.97	3.94	4.00	3.97	3.69	3.91	3.92	3.84

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.90		Mean	3.96	3.82	3.89
Min Point	3.63	-6.9%	Std. Dev.	0.12	0.15	0.15
Max Point	4.08	4.4%	COV as %	2.92	3.92	**3.75**

Avg. Conc. 3.894 ppm

Gas analyzer checked:
9/1/2004

	Start	Finish	
Tracer tank pressure	315	315	psig
Sample Port Temp	88	81	F
Centerline vel.	779	771.0	fpm
Injection flowmeter	3	5	% bl. ball**
Stack flow			cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	29.54	29.5	mm Hg
Ambient humidity	24	25	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	25/20/24/22/ 23	20/25/20/17/ 22	ppb
No. Bk-Gd samples	5	5	n
Ambient temp.	76.0	77.0	deg. F



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 18 x 18 inches
The injection probe reaches 8-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 8-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01	Signature verifying data and calculations:
Signature/date John Glissmeyer 9/30/04	Roxanne L Haber 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-5
Date	9/3/2004	Fan Configuration	Near fan
Tester	JAG/JMB	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	84.8 deg F
Stack X-Area	254.5 in.2	Start/End Time	1404/1504
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Bottom North - 1-in from corner walls

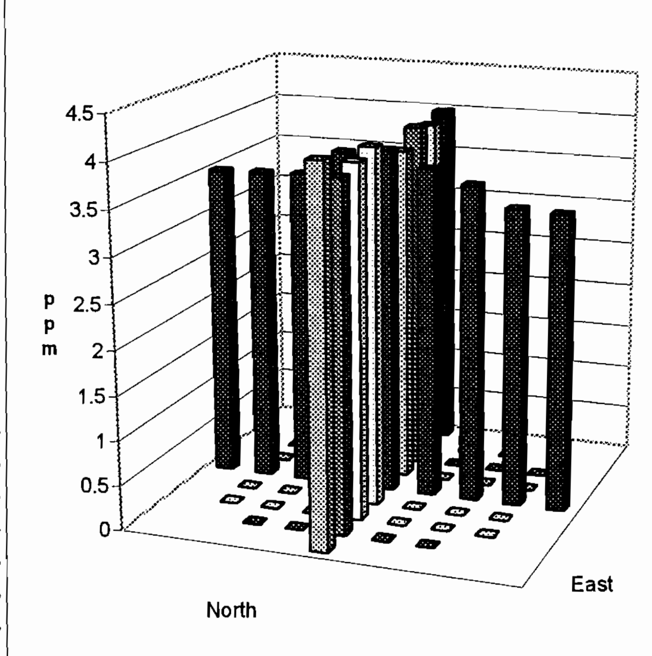
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.10	3.67	3.19	3.32	3.68	3.73	3.94	3.78
2	1.89	3.14	3.51	3.37	3.34	3.54	3.39	3.68	3.54
3	3.49	3.31	3.30	4.08	3.56	3.44	3.85	3.50	3.60
4	5.81	3.32	4.17	3.63	3.71	3.50	3.79	3.69	3.66
Center	9.00	3.66	4.02	3.96	3.88	3.73	3.52	3.38	3.54
5	12.19	4.17	3.69	3.62	3.83	3.58	3.23	3.54	3.45
6	14.51	3.42	3.43	3.78	3.54	3.26	3.78	3.81	3.62
7	16.11	3.65	3.47	3.48	3.53	3.43	3.83	3.43	3.56
8	17.42	3.92	3.02	3.62	3.52	3.45	3.59	3.86	3.63
Averages --------->		3.52	3.59	3.64	3.58	3.51	3.63	3.65	3.60

All	ppm	Dev. from mean	*Center 2/3*	East	North	All
Mean	3.59		Mean	3.63	3.57	3.60
Min Point	3.32	-7.5%	Std. Dev.	0.19	0.07	0.14
Max Point	3.88	8.1%	COV as %	5.19	1.89	**3.88**

Avg. Conc. 3.575 ppm

Gas analyzer checked: 9/1/2004

	Start	Finish	
Tracer tank pressure	310	330	psig
Sample Port Temp	84.9	84.7	F
Centerline vel.	782	801.0	fpm
Injection flowmeter	4	4	% bl. ball**
Ambient temp.	78	80	deg. F
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	751.20	750.5	mm Hg
Ambient humidity	30	27	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	29/23/31/29/26/31	29/28/22/21/25	ppb
No. Bk-Gd samples	6	5	n
Ambient pressure	1016.5	1015.6	mbar



Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solomat Zephyr SN 1295-1472

**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 18 x 18 inches The injection probe reaches 8-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 8-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01 Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roxanne L Hadley 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	**325 Model**	Run No.	**GT-6**
Date	9/3/2004	Fan Configuration	**Far fan**
Tester	JAG/JMB	Fan Setting	**37.1 Hz**
Stack Dia.	18 in.	Stack Temp	88.25 deg F
Stack X-Area	254.5 in.2	Start/End Time	1504/1630
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Top South, 1-inch from corner walls

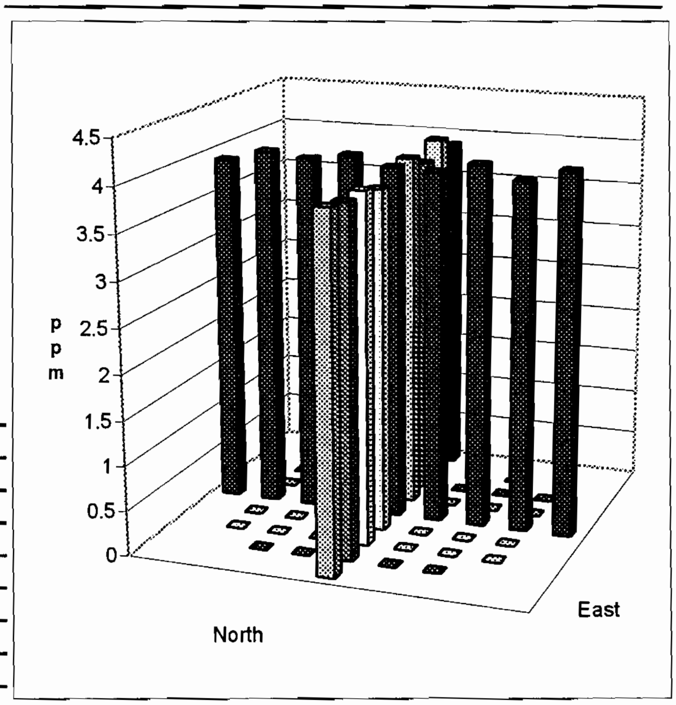
Traverse-->		East				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	4.01	3.89	4.03	3.98	3.98	3.84	3.94	3.92
2	1.89	3.79	3.91	3.83	3.84	3.80	3.76	4.06	3.87
3	3.49	3.97	3.96	4.02	3.98	3.83	4.04	3.82	3.90
4	5.81	3.83	3.92	3.87	3.87	3.87	3.72	3.85	3.81
Center	9.00	3.93	3.73	4.01	3.89	3.85	4.13	3.91	3.96
5	12.19	3.74	4.06	4.16	3.99	3.77	4.05	4.09	3.97
6	14.51	3.99	3.88	3.89	3.92	3.82	3.79	3.90	3.84
7	16.11	3.95	3.99	3.97	3.97	3.89	4.00	4.14	4.01
8	17.42	3.75	3.80	3.99	3.85	3.92	3.95	3.75	3.87
Averages --------->		3.88	3.90	3.97	3.92	3.86	3.92	3.94	3.91

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.91		Mean	3.92	3.91	3.92
Min Point	3.81	-2.6%	Std. Dev.	0.06	0.07	0.06
Max Point	4.01	2.5%	COV as %	1.46	1.89	**1.63**

Avg. Conc. 3.912 ppm

Gas analyzer checked:
9/1/2004

	Start	Finish	
Tracer tank pressure	330	350	psig
Sample Port Temp	88.7	87.8	F
Centerline vel.	764	759.0	fpm
Injection flowmeter	4	4	% bl. ball**
Ambient temp.	80	80	deg. F
Sampling flowmeter	10	9.5	lpm Sierra
Ambient pressure	750.50	741.0	mm Hg
Ambient humidity	27	24	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	23/23/27/29/ 28	31/25/28/31/ 32	ppb
No. Bk-Gd samples	5	5	n
Ambient pressure	1015.6	1002.8	mbar



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 11 x 12 inches
The injection probe reaches 5-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 5-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Brian L. Hadley 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-7
Date	9/8/2004	Fan Configuration	Far fan
Tester	JAG/JMB	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	84 deg F
Stack X-Area	254.5 in.2	Start/End Time	1130/1222
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Top North, 1-inch from corner walls

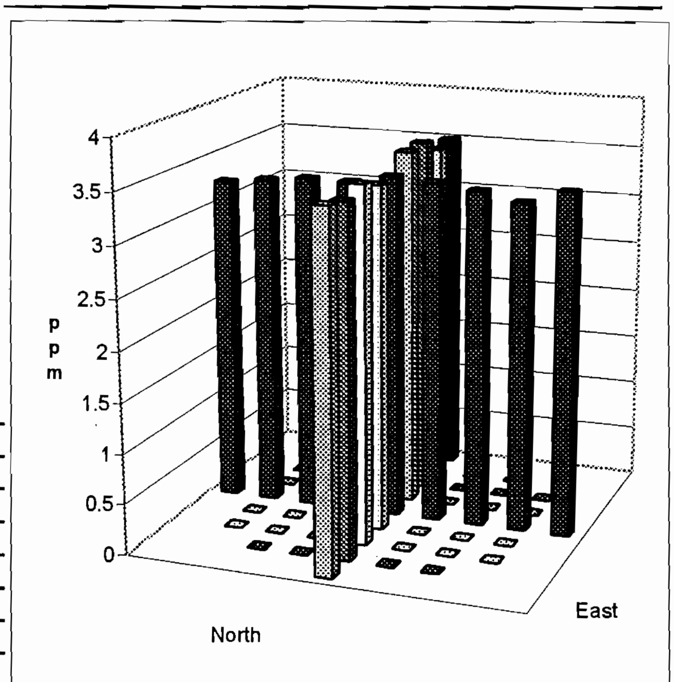
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.33	3.32	3.58	3.41	3.36	3.35	3.40	3.37
2	1.89	3.27	3.32	3.24	3.28	3.38	3.25	3.33	3.32
3	3.49	3.23	3.43	3.41	3.36	3.48	3.39	3.31	3.39
4	5.81	3.26	3.36	3.59	3.40	3.51	3.19	3.21	3.30
Center	9.00	3.42	3.42	3.46	3.43	3.19	3.24	3.48	3.30
5	12.19	3.22	3.41	3.42	3.35	3.44	3.36	3.58	3.46
6	14.51	3.49	3.35	3.23	3.36	3.44	3.53	3.45	3.47
7	16.11	3.39	3.18	3.37	3.31	3.39	3.26	3.36	3.34
8	17.42	3.30	3.15	3.35	3.27	3.55	3.28	3.26	3.36
Averages --------->		3.32	3.33	3.41	3.35	3.42	3.32	3.38	3.37

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.36		Mean	3.36	3.37	3.36
Min Point	3.27	-2.8%	Std. Dev.	0.05	0.07	0.06
Max Point	3.47	3.4%	COV as %	1.56	2.16	**1.82**

Avg. Conc. 3.360 ppm

Gas analyzer checked:
9/1/2004

	Start	Finish	
Tracer tank pressure	315	315	psig
Sample Port Temp	83	85	F
Centerline vel.	765	765.0	fpm
Injection flowmeter	3.5	3.5	% bl. ball**
Ambient temp.	77	79	deg. F
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	748.30	748.3	mm Hg
Ambient humidity	38	35	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	38/40/41/37/ 40	38/37/36/35/ 35	ppb
No. Bk-Gd samples	5	5	n
Ambient pressure	1012.9	1012.9	mbar



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 11 x 12 inches
The injection probe reaches 5-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 5-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Joanne L Haber 9/30/04

04-325 Scale gasunif.xls GT7 9/30/2004

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-8
Date	9/8/2004	Fan Configuration	Far fan
Tester	JAG/JMB	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	87 deg F
Stack X-Area	254.5 in.2	Start/End Time	1222/1302
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Center

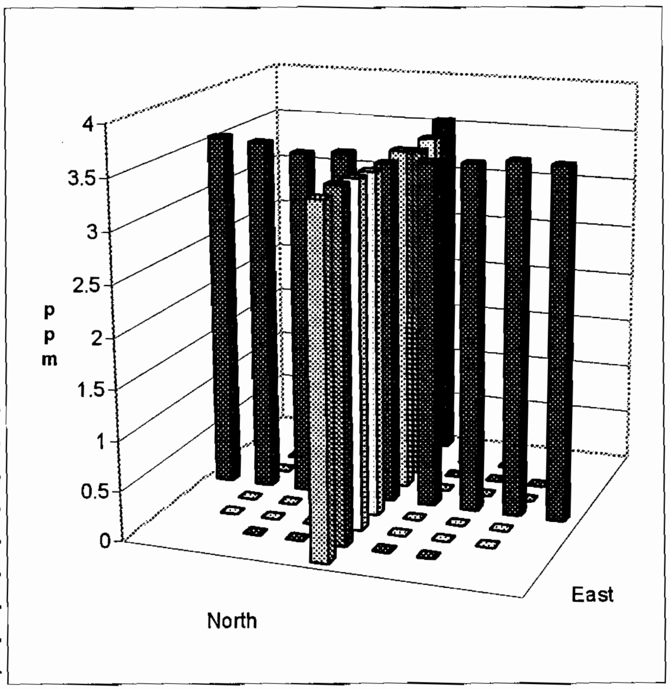
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.34	3.15	3.50	3.33	3.47	3.39	3.42	3.43
2	1.89	3.24	3.35	3.43	3.34	3.48	3.54	3.38	3.47
3	3.49	3.25	3.33	3.29	3.29	3.54	3.43	3.36	3.44
4	5.81	3.29	3.22	3.33	3.28	3.48	3.44	3.34	3.42
Center	9.00	3.25	3.25	3.21	3.24	3.45	3.44	3.36	3.42
5	12.19	3.30	3.22	3.41	3.31	3.60	3.42	3.36	3.46
6	14.51	3.27	3.25	3.30	3.27	3.54	3.33	3.26	3.38
7	16.11	3.33	3.41	3.31	3.35	3.55	3.25	3.48	3.43
8	17.42	3.34	3.47	3.32	3.38	3.59	3.50	3.52	3.54
Averages -------->		3.29	3.29	3.34	3.31	3.52	3.42	3.39	3.44

All	ppm	Dev. from mean	*Center 2/3*	East	North	All
Mean	3.38		Mean	3.30	3.43	3.36
Min Point	3.24	-4.1%	Std. Dev.	0.04	0.03	0.08
Max Point	3.54	4.8%	COV as %	1.20	0.89	**2.28**

Avg. Conc. 3.382 ppm

Gas analyzer checked:
9/1/2004

	Start	Finish	
Tracer tank pressure	315	370	psig
Sample Port Temp	85	89	F
Centerline vel.	765	739.0	fpm
Injection flowmeter	3.5	3.5	% bl. ball**
Ambient temp.	79	80	deg. F
Sampling flowmeter	10	9.5	lpm Sierra
Ambient pressure	748.30	747.8	mm Hg
Ambient humidity	35	32	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	38/37/36/35/35	32/32/35/31/31	ppb
No. Bk-Gd samples	5	5	n
Ambient pressure	1012.9	1012.2	mbar



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 11 x 12 inches
The injection probe reaches 5-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 5-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-9		
Date	9/8/2004	Fan Configuration	Far fan		
Tester	JMB	Fan Setting	37.1 Hz		
Stack Dia.	18 in.	Stack Temp	89.5 deg F		
Stack X-Area	254.5 in.2	Start/End Time	1302/1354		
Elevation	N.A.	Center 2/3 from	1.65	to:	16.35
Distance to disturbance	120 inches	Points in Center 2/3	2	to:	7
Measurement units	ppm SF6	Injection Point	Bottom North		

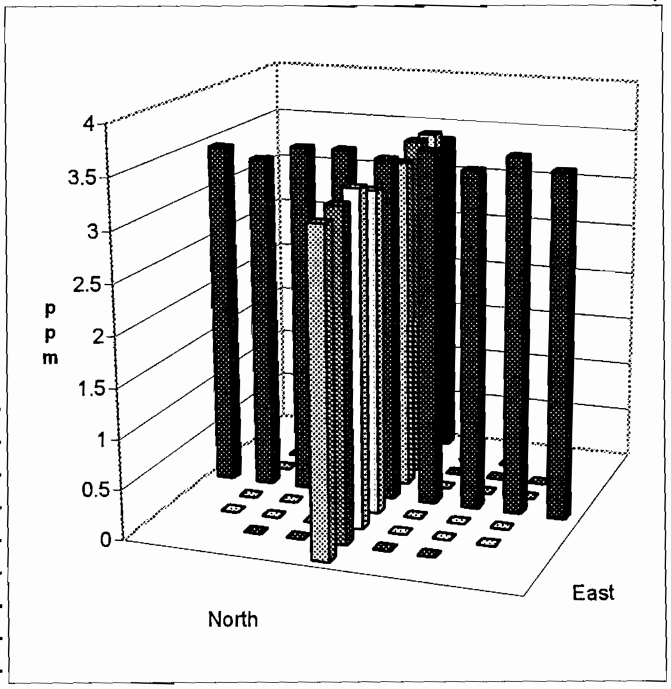
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.24	3.54	3.21	3.33	3.37	3.26	2.98	3.20
2	1.89	3.49	3.33	3.50	3.44	3.25	3.36	3.20	3.27
3	3.49	3.27	3.23	3.35	3.28	3.47	3.33	3.23	3.34
4	5.81	3.58	3.35	3.40	3.44	3.42	3.09	3.18	3.23
Center	9.00	3.28	3.26	3.46	3.33	3.61	3.41	3.33	3.45
5	12.19	3.70	3.36	3.13	3.40	3.72	3.12	3.17	3.34
6	14.51	3.46	3.38	3.34	3.39	3.76	3.34	3.32	3.47
7	16.11	3.27	3.27	3.22	3.25	3.64	3.36	3.41	3.47
8	17.42	3.36	3.27	3.42	3.35	3.43	3.23	3.35	3.34
Averages -------->		3.41	3.33	3.34	3.36	3.52	3.28	3.24	3.35

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.35		Mean	3.36	3.37	3.37
Min Point	3.20	-4.4%	Std. Dev.	0.07	0.10	0.08
Max Point	3.47	3.6%	COV as %	2.23	2.93	**2.50**

Avg. Conc. 3.347 ppm

Gas analyzer checked:
9/1/2004

	Start	Finish	
Tracer tank pressure	370	390	psig
Sample Port Temp	87	92	F
Centerline vel.	739	764.0	fpm
Injection flowmeter	3.5	3.5	% bl. ball**
Ambient temp.	80	83	deg. F
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	747.80	747.4	mm Hg
Ambient humidity	32	29	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	32/32/35/31/31	38/33/31/32/30	ppb
No. Bk-Gd samples	5	5	n
Ambient pressure	1012.2	1012	mbar



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 11 x 12 inches
The injection probe reaches 5-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 5-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-10
Date	9/8/2004	Fan Configuration	Far fan
Tester	JMB/JAG	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	92 deg F
Stack X-Area	254.5 in.2	Start/End Time	1354/1434
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Bottom South

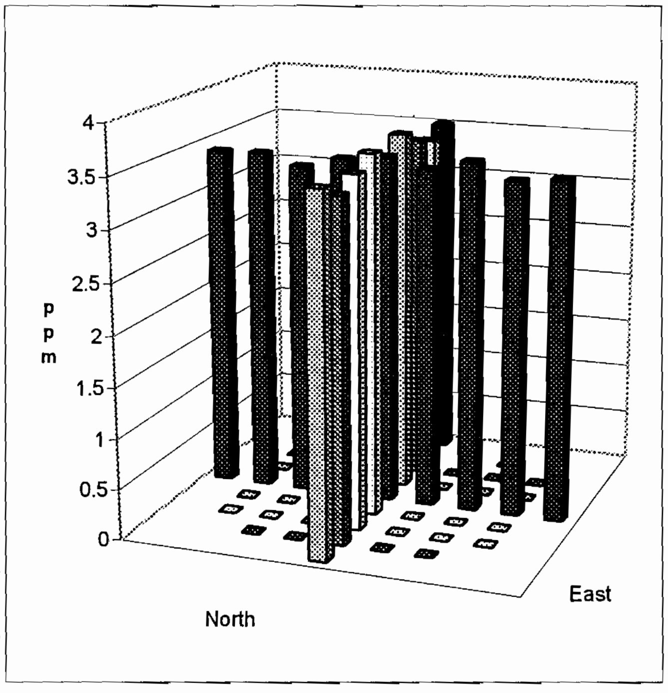
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.42	3.29	3.44	3.38	3.36	3.58	3.43	3.46
2	1.89	3.30	3.33	3.38	3.34	3.17	3.29	3.47	3.31
3	3.49	3.51	3.46	3.51	3.49	3.55	3.43	3.28	3.42
4	5.81	3.30	3.54	3.32	3.39	3.51	3.75	3.33	3.53
Center	9.00	3.28	3.53	3.62	3.48	3.45	3.40	3.40	3.42
5	12.19	3.31	3.45	3.52	3.43	3.41	3.64	3.63	3.56
6	14.51	3.27	3.47	3.23	3.32	3.55	3.43	3.29	3.42
7	16.11	3.33	3.60	3.35	3.43	3.28	3.50	3.27	3.35
8	17.42	3.45	3.43	3.38	3.42	3.52	3.47	3.33	3.44
Averages --------->		3.35	3.46	3.42	3.41	3.42	3.50	3.38	3.43

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.42		Mean	3.41	3.43	3.42
Min Point	3.31	-3.2%	Std. Dev.	0.07	0.09	0.08
Max Point	3.56	4.1%	COV as %	1.91	2.61	**2.22**

Avg. Conc. 3.418 ppm

Gas analyzer checked: 9/1/2004

	Start	Finish	
Tracer tank pressure	390	390	psig
Sample Port Temp	92	92	F
Centerline vel.	764.0	763.0	fpm
Injection flowmeter	3.5	3.5	% bl. ball**
Ambient temp.	83	85	deg. F
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	747.4	747.1	mm Hg
Ambient humidity	29	27	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	38/33/31/32/ 30	46/31/36/38/ 30	ppb
No. Bk-Gd samples	5	5	n
Ambient pressure	1012	1012	mbar



Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solomat Zephyr SN 1295-1472

**Reading on black plastic ball float in flowmeter

Notes: At this point, the duct is 11 x 12 inches The injection probe reaches 5-in off center, so with the elevation adjusted accordingly, the injection is one-inch from both sides of a corner. Also, the center injection point is 5-in closer to the stack than the injection port.

Signature signifies compliance with Procedure EMS-JAG-01 Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Joanne L. Haber 9/30/04

TRACER GAS TRAVERSE DATA FORM

Site	325 Model	Run No.	GT-11
Date	9/8/2004	Fan Configuration	Near fan
Tester	JMB/JAG	Fan Setting	37.1 Hz
Stack Dia.	18 in.	Stack Temp	90 deg F
Stack X-Area	254.5 in.2	Start/End Time	1505-1545
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	Top South

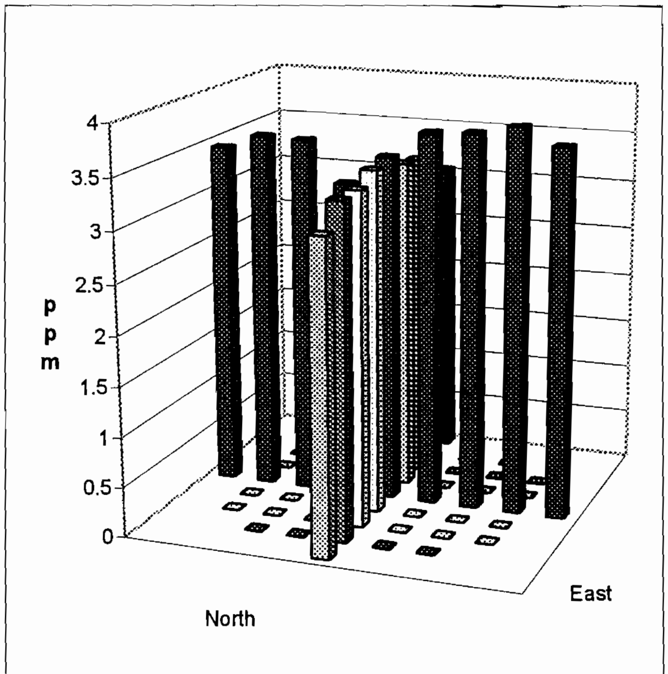
Traverse-->		East				North			
Trial --->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.58	3.32	3.80	3.32	3.48	3.02	2.65	3.62	3.10
2	1.89	4.00	3.45	3.44	3.63	3.03	3.37	3.58	3.33
3	3.49	3.76	3.42	3.47	3.55	3.21	3.31	3.49	3.34
4	5.81	3.62	3.18	3.78	3.53	3.47	3.50	3.35	3.44
Center	9.00	3.28	3.45	3.11	3.28	3.38	3.42	3.65	3.48
5	12.19	3.03	2.99	2.99	3.00	3.07	3.48	3.46	3.34
6	14.51	3.45	3.08	3.61	3.38	3.31	3.50	3.08	3.30
7	16.11	3.26	3.46	3.46	3.39	2.86	3.14	2.96	2.99
8	17.42	3.14	3.42	3.22	3.26	2.77	3.04	3.30	3.04
Averages --------->		3.43	3.36	3.38	3.39	3.12	3.27	3.39	3.26

All	ppm	Dev. from mean	***Center 2/3***	East	North	All
Mean	3.32		Mean	3.39	3.32	3.36
Min Point	2.99	-10.2%	Std. Dev.	0.21	0.16	0.18
Max Point	3.63	9.2%	COV as %	6.17	4.82	**5.48**

Avg. Conc. 3.318 ppm

Gas analyzer checked:
9/1/2004

	Start	Finish	
Tracer tank pressure	350	390	psig
Sample Port Temp	89	91	F
Centerline vel.	769.0	768.0	fpm
Injection flowmeter	3.5	3.5	% bl. ball**
Ambient temp.	85	89	deg. F
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	747.1	746.4	mm Hg
Ambient humidity	27	27	%RH
B&K vapor correction	N	N	Y/N
Back-Gd gas level	46/31/36/38/ 30	36/34/36/30/ 30	ppb
No. Bk-Gd samples	5	5	n
Ambient pressure	1012	1011	mbar



Instuments Used:

B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solomat Zephyr SN 1295-1472
**Reading on black plastic ball float in flowmeter

Notes:

Signature signifies compliance with Procedure EMS-JAG-01
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roxanne L Haley 9/30/04

Test Instruction

Project: **325 Stack Sampler Qualification**	Date: **August 16, 2004**	Work Package: **F59676**

Tests: **Tracer Gas Uniformity in 325 Model Stack, 1 Electric Fan Configuration**

Staff: John Glissmeyer, Dave Douglas, Marcel Ballinger, Matthew Barnett

Reference Procedures:

1. Procedure EMS-JAG-01, Rev. 1, *Test to Determine Uniformity of a Tracer Gas at a Sampler Probe*, May 26, 2000
2. Operating Manual for Bruel and Kjaer Model 1302 Gas Analyzer

Equipment:

1. 325 Model Stack and inspected work platforms. Fans will be in positions EF1, EF4.
2. Sulfur hexafluoride gas (pure and calibration gas), regulator, control valve, rotameter, injection probe, and tubing. Injection occurs in ports along horizontal duct. The near wall injection points are within 3 in. (25% of hydraulic diameter) for smaller duct section and 4in. for 18" x 18" duct. Size injection probe accordingly.
3. Bruel and Kjaer Model 1302 Gas Analyzer, probe, vacuum pump, fittings

Safety Considerations:

Observe the applicable Job Hazard Analysis for the project

Instructions:

1. Verify training on the procedure and verify that instrumentation is within calibration
2. Weigh the tracer cylinder before shipment to jobsite N/A. no scale available. JAG 9/1/04
3. Obtain climatic information from the Hanford Weather Service, phone 373-2716 or http://etd.pnl.gov:2080/HMS/lastob.htm
4. Mark the completion of each step on the field copy of the procedure. Mark-out those steps not applicable to this stack.
5. Install equipment as directed in the procedures
6. Mark sampling probe for the measurement points shown on the data sheet
7. With one fan operating, verify that stack flow is about 1350 – 1450 cfm.
8. Set the injection flowrate at about 0.07 lpm for a tracer concentration of ~ 1 ppm (reads about 0.14 lpm on an air rotameter when corrected for gas density, about 7 on the rotameter scale with the glass ball).
9. Set the sampler flowrate at approximately 10 lpm.
10. Record each run's data on copies of the attached data sheet
11. Diagram mounting fixtures and retain assembly for any subsequent re-tests
12. Conduct one or more tracer mixing tests at the following sets of conditions:

Downstream of Fan	Injection Positions	Possible Runs
EF4 ON	Center, 1 inch from each corner	GT1 - 5
EF1 ON	Center, 1 inch from each corner	GT 6 – 10
Worst case	Repeat of worst case	GT 11

Desired Completion Date: 08/27/04

Approvals: John Glissmeyer (signature), John Glissmeyer, test director — Date: 8/25/04

Test completed by: J Glissmeyer (signature) — Date: 9/8/04

PNNL Operating Procedure	
Title: Test to Determine Uniformity of a Tracer Gas at a Sampler Probe	**Org. Code:** D9T99 **Procedure No.:** EMS-JAG-01 **Rev. No.:** 1
Work Location: General	**Effective Date:** May 26, 2000
Author: John A. Glissmeyer	**Supersedes Date:** November 10, 1998
Identified Hazards: ☐ Radiological ☐ Hazardous Materials Physical Hazards ☐ Hazardous Environment ☐ Other:	**Identified Use Category:** ☐ Mandatory Use ☐ Continuous Use Reference Use ☐ Information Use
Are One-Time Modifications Allowed? Yes ☐ No	

Person Signing	Signature	Date
Technical review: James L. Huckaby		
Project Manager: John Glissmeyer		
Line Manager: James Droppo		
Concurrence:		
Quality Engineer: Thomas G. Walker		

1.0 Purpose

The performance of new stack sampling systems must be shown to satisfy the requirements of 40 CFR 61, Subpart H, "National Emission standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." This regulation governs portions of the design and implementation of effluent air sampling. The stack sampler performance is adequately characterized when potential contaminants in the effluent are of a uniform concentration at the sampling location (plane), and line losses are within acceptable limits. This procedure determines whether the concentration of gaseous contaminants is uniformly distributed in the area of the sampling probe. Other procedures address flow angle, uniformity of gas velocity, and uniformity of particulate contaminants. A contaminant concentration that is uniform at the sampling plane enables the extraction of samples that represent the true emission concentration.

The uniformity is expressed as the variability of the measurements about the mean. This is expressed using the relative coefficient of variance (COV), which is the standard deviation divided by the mean and expressed as a percentage. The lower the COV value, the more uniform the gas concentration. The acceptance criterion is that the COV of the measured gas concentrations be # 20% across the center two-thirds of the area of the stack. Furthermore, the average concentration measured at any point cannot differ from the mean of all points by more than 30%.

2.0 Applicability

This procedure can be used in the field or on modeled stacks to determine whether air-sampling probes can collect representative samples under normal operations. The tests are applicable to effluent stacks or ducts within the following constraints:

- The tracer gas tests are generally limited to stacks with flowrates greater than 50 cubic feet per minute range. The upper bound of flowrate is determined by the sensitivity of the gas analyzer, the background reading for the tracer gas, and the availability of the tracer.
- Environmental constraints – the gas analyzer will require the use of a controlled temperature environment to maintain the equipment above 55 degrees Fahrenheit.

3.0 Prerequisites and Conditions

Conditions and concerns that must be satisfied before sampling are listed below:

- Safety glasses and hard toed or substantial shoes are required in the work areas.
- Properly constructed and inspected work platforms may be needed to access the test ports.
- Scaffold-user or fall protection training may be required in some instances to access the sampling ports of the stack.
- Alcohol may be used for equipment cleanup. A flammable equipment storage cabinet is required to flammable chemicals.

- Familiarity with the use and operation of gas delivery systems and the ability to detect concentration build-ups of the gas is essential to avoid exceeding ACGIH concentration for the tracer gas.

- Knowledge of the setup, use of, and operation of flowmeters, gas analyzers, and computers is essential.

- A job-hazards analysis may be required in certain cases.

4.0 Precautions and Limitations

Caution: The American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour time-weighted average limit for human exposure to sulfur hexafluoride gas is 1000 ppm (6,000 mg/m^3). It is colorless and odorless.

During tests of stacks with high flow rates, sulfur hexafluoride will be injected at a high rate into the base of the stack to overcome the large dilution factor needed to detect the tracer at the sampling ports above. If a leak occurs in the gas delivery system, the potential is present for a buildup of SF_6 to occur that could approach the 1000-ppm level. The gas is five times as heavy as air, so it will accumulate in confined spaces and in low areas. Leak tests of the delivery system will be made at least daily to prevent such an occurrence.

Access to the test ports may require the use of scaffolding or manlifts, either of which will necessitate special training for sampling personnel and any observers. The training requirements will be indicated in the job hazard analysis. This will limit access to the sampling ports to trained personnel.

If the purpose of a given run is to investigate the sensitivity of the COV determination to the tracer-injection location, the test may be invalid if the ending ambient concentration is elevated above that at the start of the test. This would indicate poor dispersion away from the test site and recirculation of the tracer to the inlet of the fan if the stack exhaust point is in view of and is reasonably close to the fan inlet. This may result in a false indication of good mixing.

5.0 Equipment Used for Stack Measurements

Specific calibration check concentration levels, probe dimensions, measurement grids, flow rates, and other special requirements will be provided in the specific Test Instruction. Exhibit A provides a typical layout for the test setup. The following are essential items of equipment:

- Sulfur hexafluoride calibration check gas
- Sulfur hexafluoride bulk gas

- Bruel and Kjaer Model 1302 Gas analyzer
- Gas regulators and flowmeters
- Gas sampling probe
- Gas injection probe
- Vacuum pump (Sierra)
- Air velocity meter

The absolute calibration of the Model 1302 Gas Analyzer is not as important as its general response because the concentration data are used in a relative manner in calculating the COV and in plotting the concentrations at the measurement points. Consequently, the analyzer is Category 2 MTE (user calibrated) and will be checked against a calibrated gas mixture before and after the series of tests, and the instrument's response may be checked on a daily basis. Agreement within 10% of the calibration gas is acceptable.

6.0 Work Instructions for Setup, Measurements, and Data Reduction

The steps taken to setup, configure, and operate the stack fans and test equipment are listed. Based on previous field measurements, the steps are ordered to achieve maximum efficiency in the testing. In addition to these steps, test instructions, which are developed for each test series, provide specific details and operating parameters.

6.1 Preliminary Steps:

JG 7/1/04

6.1.1 Provide essential supplies at the sampling location. (gas cylinders and regulators, fittings and probe-port couplers, marking pens, data sheets, writing, and probe-supporting platforms).

6.1.2 Fill in test information on data form.

6.1.3 Obtain barometric, temperature, and relative-humidity information for the gas analyzer.

6.1.4 Set up the gas analyzer system at the stack sampling port according to the illustrations in Exhibits A and B.

Note: The **sampling equipment** consists of a stainless steel probe with enough length to reach across the inside diameter of the stack, allowing for fittings. The intake end should have a 90° bend so that the open end of the tube faces downward or into the flow within the stack). The outlet end of the probe should terminate in a tee. One leg of the tee connects by flexible tubing to a rotameter and vacuum pump. This leg should draw from 1- to 10-lpm flow of air, depending on the volumetric flow in the stack. The other leg of the tee connects via flexible tubing to a coarse in-line filter (47-mm-diameter glass fiber filter) and then to the Model 1302 gas analyzer inlet. To minimize tubing length to the analyzer, locate the gas analyzer near the test port on the stack.

6.2 System Startup

6.2.1 If not already running, start the stack fan, adjust the flow to the velocity called for in the test instruction, and record on the data sheet.

JG 9/1/04

6.2.2 Verify the stack centerline air velocity in the sampling plane using a velocity flow meter, and record value on data sheet.

6.2.3 Turn-on the gas analyzer.

6.2.4 Program the analyzer for:

- 60-second samples,
- continuous operation,
- the current barometric pressure,
- moisture compensation if needed.

Note: Gas analyzer readings can be made with or without water-vapor correction. If the air is sufficiently dry (< than about 60% relative humidity) where the water vapor contribution is negligible (< than about 14.5E+03 ppm), the balance of the readings can be made with water vapor compensation but without water vapor measurement to reduce sample times.

6.2.5 Set the sample probe to the center position.

Note: Mark the sampling probe with a permanent marker so the inlet can be placed at each successive measurement point. The layout for the sample points is given in the test instruction.

> **Note: Sampling plane traverse points** Use the grid of measurement points provided with the tests instruction and dataform. This is usually the same as used for the velocity uniformity test. A centerpoint, is included as a common reference and for graphical purposes. The layout design divides the area of the sampling plane so that each point represents approximately an equal-sized area.

6.3 Daily Tracer Gas Background Concentration Measurement

JGS 9/1/04

6.3.1 At the beginning of sampling each day and after the analyzer has stabilized (about 10 minutes), obtain at least six consecutive background readings. Do not proceed with the test if the background exceeds 5% of the anticipated average concentration in the stack.

6.3.2 Record these readings in the logbook designated for the tests.

6.4 Gas Injection and Sample Collection

The injection equipment consists of a pressurized cylinder of pure liquid sulfur hexafluoride that converts to gas when released. The setup is shown in the figure in Exhibit B and includes a gas regulator, valve, flowmeter (rotameter), flexible tubing, and a stainless steel injection probe with a 90E bend at the discharge end, which is secured at one of five positions. The connections and fittings should be checked to ensure that they are secure and leak free to prevent the loss of gas.

> **Note: Location of Tracer Gas Injection Points**
> Injection plane – The tests are repeated using five tracer gas injection points (at the centerpoint and at four orthogonally spaced points) within the injection plane. These four points are located near the corners if the duct cross section is rectangular. The distance from these four points to the corner or wall is less than 25% of the duct's hydraulic diameter (HD), which is calculated by
>
> $$HD = \frac{2HW}{H+W}$$
>
> where H and W are the height and width of a rectangular duct (H and W are the same in a round duct). More specific dimensions are given in the Test Instruction.

JAG 9/1/04

6.4.1 Position the injection probe, according to the test instruction found as Attachment A.

6.4.2 Start injection of the tracer gas and adjust for flow rate specified in the test instruction and note the time.

> **Note: Estimation of Sulfur Hexafluoride Injection Rate**
> Estimate the SF_6 injection rate so the average diluted concentration will be within the range of 10 to 100% of the concentration of the calibration check gas according to the following equation:
>
> $$injection\ flowrate = stack\ flowrate \times \frac{target\ ppmv}{10^6}$$
>
> The rotameter reading should be adjusted for the density of the SF_6. The air equivalent reading is
>
> $$rotameter\ reading = k\ x\ actual\ flowrate$$
>
> where *k* is 2.53 (the square-root of the density) for SF_6.

6.4.3 On the data sheet, label the columns of data according to the directions of the traverses.

6.4.4 Verify that the directional orientations and the numbered sample positions are consistent.

6.4.5 Position the sample probe at each measurement point in succession, and record the reading on the dataform.

> **Note:** Each test relies on one repetition for each measurement point in each traverse direction, repeated three times. The repeats are made as three separate runs and not as three consecutive measurements at each point.

6.4.6 Perform two additional repetitions of Step 6.4.5. above

6.4.7 Switch the tests to the other direction and repeat Steps 6.4.5 and 6.4.6.

6.4.8 Check the data sheet for completeness.

6.4.9 Record the final

- Rotameter flow rate
- Time since the start of gas injection
- Pressure in the gas cylinder.

6.4.10 Shut down the delivery of tracer gas.

6.4.11 Continue operation of the gas analyzer for several minutes to purge any remaining gas through the analyzer.

6.4.12 Measure the background tracer gas concentration and record the levels on the data sheet.

6.4.13 Record any climatic conditions that have changed on the data sheet.

6.4.14 Enter the centerline stack velocity flow on the data sheet.

6.4.15 Record any deviations from the above procedure on the data sheet.

6.4.16 Repeat steps 6.4.1 – 6.4.15 for each run as indicated in the Test Instruction.

6.5 Data Recording and Calculations

Prepare the electronic data sheet on which to enter gas concentration readings and other information relevant to the test (see test instruction).

JAG 9/8/04

6.5.1 Review the raw data sheets for completeness.

6.5.2 Enter the data into the electronic data sheet.

6.5.3 Calculate the COV for the run.

> **Note:** The EXCEL datasheet shown in Appendix C is set up to calculate the COV for each tracer gas concentration traverse using the average concentration data from all points in the inner two-thirds of the cross section area of the plane (including the center point).

6.5.4 Compare the observed COV for each run to the acceptance criterion.

> **Note:** The test is acceptable if the COV is within #20% for the inner two-thirds of the stack diameter and if no point differs from the mean by more than 30%. This is determined by inspecting the average concentration at each measurement point. The COV is 100 times the standard deviation divided by the mean.

6.5.5 Sign and date the data sheet attesting to its validity.

> **Note:** A separate datasheet will be provided and signed-off for each test run.

6.6 Gas Analyzer Calibration Check Steps

Check the gas analyzer calibration by subjecting the analyzer to sulfur hexafluoride calibration gas. Refer to the analyzer's manual, parts 2 and 4.

JAY 9/1/04

6.6.1 Set up the system for gas analysis with the regulator, the valve, flexible tubing, and a tee with one leg exhausting excess gas through a flowmeter and the other leg attached to the inlet of the Model 1302. Program the units of measurement as in Part 4.2.3. Enter the barometric pressure in mm Hg pressure, standard temperature (that used by the calibration gas vendor), and the sampling tube length into the environmental setup (Part 4.2.4). Record the information on the data sheet.

6.6.2 Set the Model 1302's clock. Program the analyzer for water compensation, but not water measurement, at 1-minute continuous measurement mode (according to Part 4.4.2 in manual).

6.6.3 Program for a continuous monitoring task (4.2.5), and initiate monitoring (4.2.6).

6.6.4 Monitor room conditions, and record the data for several measurements by sampling zero air or room air for at least 5 minutes.

> **Note:** If the test location has a buildup of the gas, a zero air cylinder or clean air supply will be needed. The SF_6 concentration in the room should be several orders of magnitude below the calibration-gas. These settings optimize the low detection capabilities of the acoustically-based detection system.

6.6.5 Sample calibration gases (from lowest available concentrations to highest) for at least five readings each or until no observable trend is found. Record the identification of the calibration gas used. Record data and results in the Logbook.

> **Note:** Set the calibration gas flow rate high enough to ensure that the glass ball in the rotameter does not drop to zero during any of the observed steps of a sample cycle. As the calibration check continues, gas levels exhausted during the check will be released into the room, and the SF_6 background concentrations will increase as the analyzer is checked. The SF_6 reading should be within 10% of the calibration-gas concentration, and the water content should be much lower than ambient.

JAS 9/1/01 Not noted on sheet. all readings were <50 ppb

6.6.6 Obtain baseline tracer (calibration gas) readings at the end of the calibration check. Record results on the data sheet.

> **Note:** The reading will generally be recorded from the digital concentration display. It may be convenient to record the data on a printer or computer, which can be coupled to the analyzer. See the Manual Part 12 (especially Part 12.2.5) for connecting to a printer in data log mode.

7.0 Exhibits/Attachments

Exhibit A – Overview of Stack and Injection/Sampling Setups

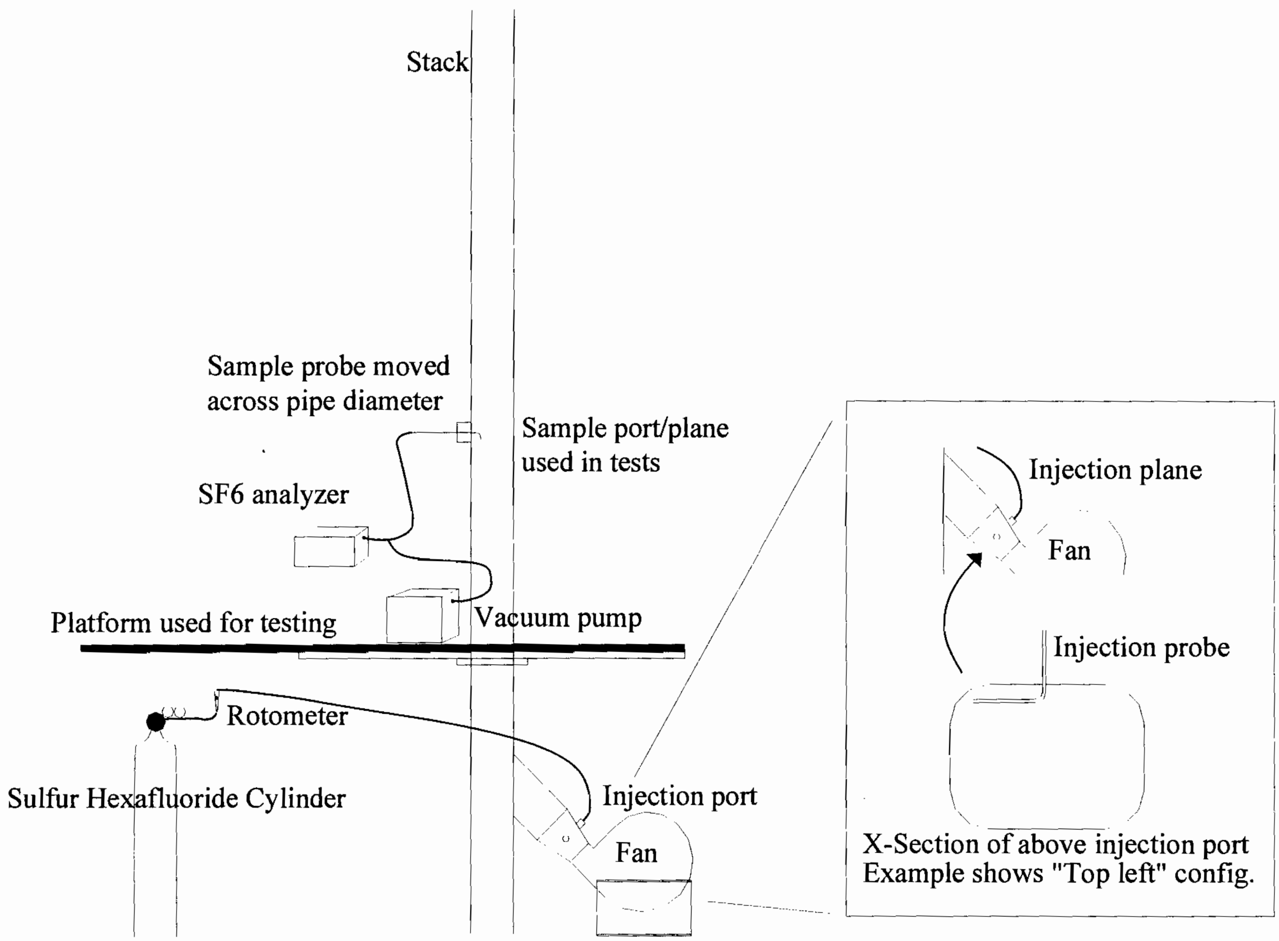


Exhibit B – Details for Stack Sampling Probe and Gas Analyzer Setup

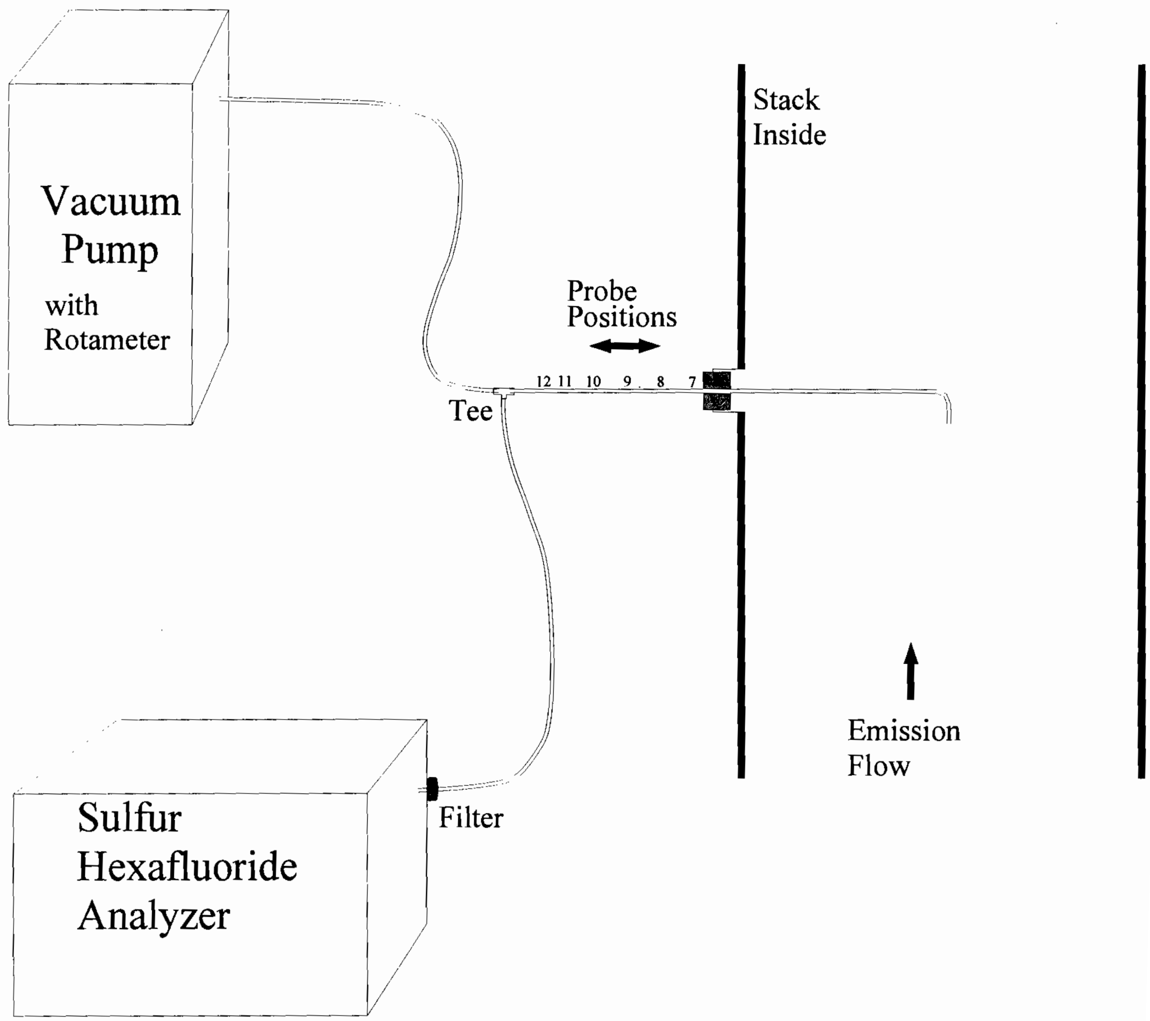


Exhibit C – Example EXCEL Data Sheet

TRACER GAS TRAVERSE DATA FORM

Site		Run No.	
Date		Injection point	
Tester		Fan Setting	Hz
Stack Dia.	27.25 in.	Stack Temp	deg F
Stack X-Area	583.2 in.	Start/End Time	
Elevation		Center 2/3 from	2.50 to: 24.75
El. above disturbance	in.	Points in Center 2/3	3 to: 10
Concentration units	ppm SF_6		

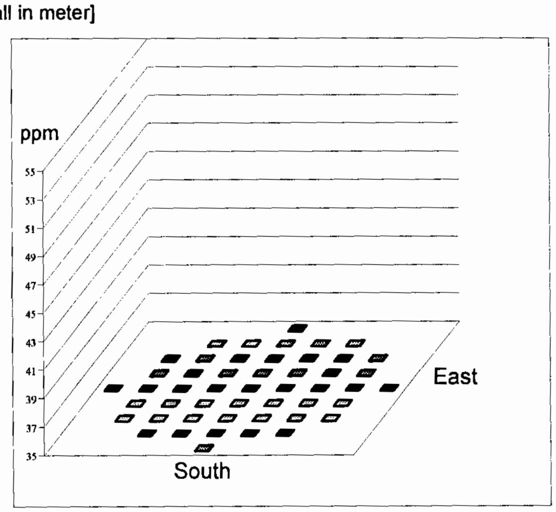
Traverse-->		East				South			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	1.00								
2	1.83								
3	3.22								
4	4.82								
5	6.81								
6	9.70								
Center	13.63								
7	17.55								
8	20.44								
9	22.43								
10	24.03								
11	25.42								
12	26.25								
		West				North			
Traverse Averages ---------->									

				~~Center 2/3~~	~~E/W~~	~~S/N~~	~~All~~
Average of all data				Mean			
Maximum Positive Deviation		Max Point		Std. Dev.			
Maximum Negative Deviation		Min Point		COV %			

	Start	Finish	
Tracer tank pressure			psig
Ambient Temp			F
Centerline vel.			fpm
Record stack flow			fpm
Injection flowmeter			lpm [glass ball in meter]
Sampling flowmeter			lpm Sierra
Ambient pressure			mm Hg
Ambient humidity			RH
B&K vapor correction			Y/N
Back-Gd gas level			ppm
No. Bk-Gd samples			n

Gas analyzer checked ____________

Notes: ____________



Notes: ____________

Instuments Used:

Solomat Zephyr #12951472

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Signing/dating signifies compliance with sections 6.1.1-6.5.5 in the PNNL Procedure No. EMS-JAG-01 (11/10/98).

Signature/Date:

Attachment A – Illustrative Test Instruction.

Test Instruction

Project: Canister Storage Stack Qualification, 29303	Date: November 10, 1998	Work Package: K97052

Tests: Tracer Gas Uniformity of Full-Scale Stack

Staff: David Maughan, John Glissmeyer

Reference Procedures:

1. Procedure EMS-JAG-01, Rev. 0, Test to Determine Uniformity of a Tracer Gas at a Sampler Probe, Nov. 10, 1998
2. Operating Manual for Bruel and Kjaer Model 1302 Gas Analyzer

Equipment:

1. Canister Storage Stack and inspected work platforms
2. Sulfur hexafluoride gas (pure and calibration gas), regulator, control valve, rotameter, injection probe (¼ in. OD × 36 in. long stainless tubing), and tubing
3. Bruel and Kjaer Model 1302 Gas Analyzer, probe, vacuum pump, fittings

Safety Considerations:

Review and observe the applicable Duke Job Hazard Analysis for the project

Instructions:

1. Verify training on the procedure and verify that instrumentation is within calibration
2. Weigh the tracer cylinder before shipment to jobsite
3. Obtain climatic information from the Hanford Weather Service, phone 373-2716 or http://etd.pnl.gov:2080/HMS/lastob.htm
4. Install equipment as directed in the procedures
5. Mark sampling probe for the measurement points shown on the data sheet
6. Verify that stack flow is about the target flowrate of 9000 (2232 fpm)
7. Set the injection flowrate at about 0.76 lpm for a tracer concentration of ~ 3 ppm
8. Set the sampler flowrate at approximately 10 lpm
9. Conduct one or more tracer mixing tests at the following sets of conditions:

Stack Flow	Injection point at duct from fan to stack
Normal	Centerline, top left, top right, bottom left, bottom right

   (The injection plane should be at the fittings provided on the rectangular discharge of the fan. Left and right are from the point of view of the fan looking toward the stack)

10. Record data on copies of the attached data sheet
11. Repeat the test with the worst case result two additional times
12. Diagram mounting fixtures and retain assembly for any subsequent re-tests
13. Weigh the tracer gas cylinder after these tests

Desired Completion Date: 11/20/98

Approvals: ______________________________ __________

John Glissmeyer, Project Manager — Date

Test completed by: — Date:

INDEPENDENT TECHNICAL REVIEW RECORD

PACIFIC NORTHWEST NATIONAL LABORATORIES INDEPENDENT TECHNICAL REVIEW RECORD	DOCUMENT NO.: Calculation of Gas analyzer Calibration Checks Documented in Spreadsheet 04-325-B&Kcalcheck.xls.	Page 1 of 1

The referenced document is submitted for your review. Instructions for completing this form are attached. Please return the completed form to: John Glissmeyer. If you have any questions, please call John Glissmeyer, 376-8552, cell 531-8006. Comments Due: 9/28/04

Additional Information: (Scope of Review, etc) Please verify the following:

1. Transfer of field data to spreadsheet.
2. Calculation of intermediate mean and standard deviation of concentration values per calibration gas mixture.

Organization/Department	Designated Reviewer:	Signature/Date
Environmental Health Sciences Group	Rosanne Aaberg	Rosanne L Aaberg 9/30/04

CONCUR [ ]	CONCUR, WITH COMMENTS [X]	DO NOT CONCUR [ ]	NOT REVIEWED [ ]

Comt. No.	Comment and/ or Recommendation:	Resolution:
1	O – Add standard deviation of concentration values to spreadsheet (line 27), as per review instructions.	Done
2	E – Set number format for calibration readings to the appropriate number of decimal places. Column 1, 20.38 ppm readings should be set to one decimal place to show values of 21.0.	Done

Concur with Resolution	Date	Comments Resolved By	Date
Rosanne L Aaberg	9/30/04	John Glissmeyer	9/30/04

Sulfur hexafluoride Gas Calibration performed on B&K on 9/1/2004 **by** John Glissmeyer
Geoff Hunsaker

Setup details: B&K sample inlet tube = 6 ft
996.7 mbar station pressure, analyzer corrects to 20 deg C
83 deg F ambient temp
32 percent RH

20.38 ppm SF_6 +/- 5% standard

Cylinder:SV16208 w/ starting P of 1900 psi
End press 1850 psi

B&K Calibration readings: (ppm)

20.7 Compensating for water vapor
20.6
20.8
21.1
21.0
21.1 Not compensating for water vapor
21.0
21.0
21.0
21.0

20.9 = avg
0.17 Std Dev

1.04 ppm SF_6 +/- 10% standard

Cylinder: SV14250 w/ starting P of 1700 psi
end P = 1500 psi

B&K Calibration readings: (ppm)

1.06 Compensating for water vapor
1.05
1.05
1.05
1.04
1.07
1.08
1.08 Not compensating for water vapor
1.07
1.07
1.07
1.07

1.06 = avg
0.01 Std Dev

Pre-Test Room background, ppb
Not compensating for water vapor, monitoring task 2
Not recorded. All were <50 ppb.
Compensating for water vapor, monitoring task 1
Not recorded. All were <50 ppb.

Signature signifies compliance with Procedure EMS-JAG-01 Signature/date (on field data form)	John Glissmeyer 9/30/04	Signature verifying data and calculations: Rosanne L Aaberg	9/30/04

Appendix F

Particle Tracer Gas Uniformity Procedure and Data

INDEPENDENT TECHNICAL REVIEW RECORD

PACIFIC NORTHWEST NATIONAL LABORATORIES INDEPENDENT TECHNICAL REVIEW RECORD	DOCUMENT NO.: Calculation of Particle Tracer Uniformity Characteristics for 325 Stack Model, Spreadsheet 04-325 Scale 8ptpart.xls	Page 1 of 2

The referenced document is submitted for your review. Instructions for completing this form are attached. Please return the completed form to: John Glissmeyer. If you have any questions, please call John Glissmeyer, 375-4345, cell 531-8006. Comments Due: 9/28/04

Additional Information: (Scope of Review, etc) Please verify the following:

1. Transfer of field data to spreadsheet (all runs)
2. Calculation of intermediate mean concentration values per traverse (one per port) and measurement point (1st and last points per port) for one of the runs.
3. Calculation of port and overall mean concentration, standard deviation, and %COV for the center 2/3 of stack for one run.
4. Calculation of grand mean and maximum deviation of mean for all measurement points in one run.
5. Calculation of normalized concentration data (2 points) for plotting in one run.
6. Verify orientation of plotted bars in one run.
7. Verify consistency of equations in all runs by inspection of spreadsheet in software form. (May print spreadsheet in equation form and mark calculations checked.)

Organization/Department	Designated Reviewer:	Signature/Date
Environmental Health Sciences	Rosanne Aaberg	Rosanne L. Aaberg 9/30/04

CONCUR [ ]	CONCUR, WITH COMMENTS [x]	DO NOT CONCUR [ ]	NOT REVIEWED [ ]

Comt. No.	Comment and/ or Recommendation:	Resolution:
1	M -Correction to particle concentration table, East, Trial 3, Center, from 4094 to 4084.	Corrected on PT-2a
2	E - Change the Note at the bottom of page PT-1a to a footnote concerning column 1 of the Particle Concentration table. (Column 1 is replaced by a forth data set.) Locating the footnote just below the table would be helpful.	Done
3	M – The units given on the temperature / pressure table must correspond to the values listed; ambient pressure is noted as mbar, when it is given in inches of Hg.	Corrected to in. Hg.
4	O - Stack Temperature at the top of page is given as an average of start and end temperature in PT-2a; it is a number typed in PT-1a and PT-3	Replaced this cell with a formula to calculate the average of the values recorded in the parameter table.
5	O – Ambient pressure on data form for finish of PT-2a is given as 29.258 on original datasheet, but is rounded down to 29.25.	Changed to 29.258 on PT-2 and PT-2a
6	O – Compressor output units listed as psi rather than psig as on original, all three sheets.	They all read psig now.
7	O – The labels of points (corresponding to depth) in the Eest series is represented in reverse order from the labels of the graphs. In the future, the confusion could be reduced by reversing the points charted in the graph (source M32:U32 of spreadsheet).	OK

PACIFIC NORTHWEST NATIONAL LABORATORIES INDEPENDENT TECHNICAL REVIEW RECORD	DOCUMENT NO.: Calculation of Particle Tracer Uniformity Characteristics for 291-Z-1 Model, Spreadsheet 291z18ptpart.xls	Page 2 of 2

Comt. No.	Comment and/ or Recommendation:	Resolution:

Concur with Resolution	Date	Comments Resolved By	Date
Rosanne L Aaberg	9/30/04	John Glissmeyer	9/30/04

PARTICLE TRACER TRAVERSE DATA FORM

Site	**325 Model Stack**	Run No.	**PT-1**
Date	9/16/2004	Fan configuration	**Far Fan**
Tester	JAG/MYB/JMB	Fan Setting	**37.1 Hz**
Stack Dia.	18 in.	Stack Temp	80 deg F
Stack X-Area	254.5 in.2	Start/End Time	2:18 PM/ 4:30 PM
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Dwnstrm of far fan, centerline**

Order ----->		2nd				1st			
Traverse-->		East				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.58	2579	2506	2538	2541.0	2524	2067	2059	2216.7
2	1.89	2694	2438	2278	2470.0	2440	1953	1799	2064.0
3	3.49	2616	2443	2133	2397.3	2402	2109	1931	2147.3
4	5.81	2528	2539	2309	2458.7	2068	1904	1923	1965.0
Center	9.00	2403	2568	2596	2522.3	2855	1928	2014	2265.7
5	12.19	2272	2550	2427	2416.3	3089	2513	2022	2541.3
6	14.51	2473	2421	2692	2528.7	3024	2620	2063	2569.0
7	16.11	2265	2274	2298	2279.0	4035	2782	2126	2981.0
8	17.42	2409	2464	2010	2294.3	4183	3298	3443	3641.3
Averages ---------->		2471.0	2467.0	2364.6	2434.2	2957.8	2352.7	2153.3	2487.9

All	pt/ft3	Dev. from mean	***Center 2/3***	East	North	All	Normlzd
Mean	2461.1		Mean	2438.9	2361.9	2400.40	2534.19
Min Point	1965.0	-20.2%	Std. Dev.	85.8	355.9	251.90	292.62
Max Point	3641.3	48.0%	COV as %	3.5	15.1	**10.49**	**11.55**

Avg Conc 2469 pt/ft3

Instuments Used:

TSI Velocity Calc Plus S/N 209060 Calib 8/25/04

	Start	Finish	
Generator Inlet Press	3-4	~3	psig
Stack Temp	80	80	F
Centerline vel.	770	805.0	fpm
Ambient pressure	29.37	29.34	inHg
Ambient humidity	34%	32%	RH
Ambient temp	74	73	F
Back-Gd aerosol	3,12,3,4,3,4	12,17,17,12, 19,20	pt/ft3
No. Bk-Gd samples	6	6	
Compressor output reg	110	115	psig

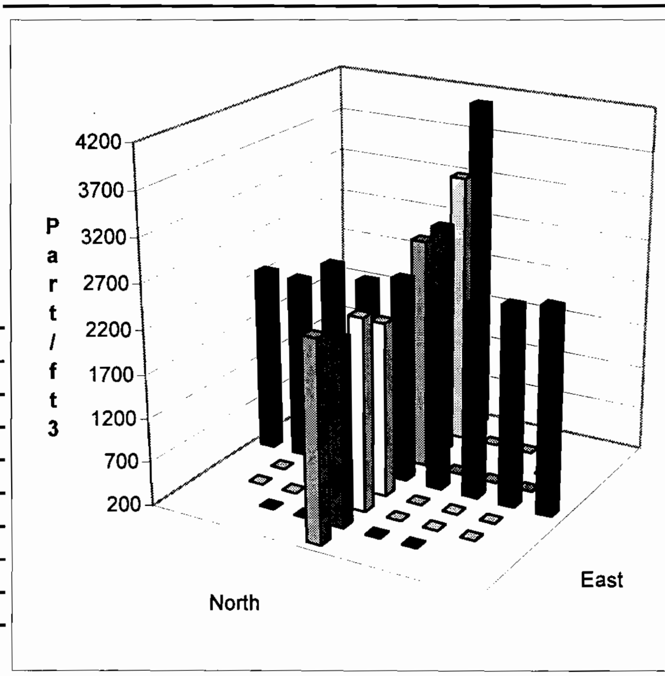
Optical Particle Counters:

Met One A2408 S/N 96258675 Cal 8/5/04

Pre-test stability readings: 2248, 2160, 2200, 2210, 2091, 1980, 1908, 2033, 2005

Oil Used: FisherBrand 19

Probe has a 4.5-in throw so is that much closer to the stack than the port.



Signature signifies compliance with Procedure EMS-JAG-02
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L. Aaberg 9/30/04

PARTICLE TRACER TRAVERSE DATA FORM

Site	**325 Model Stack**	Run No.	**PT-1a**
Date	9/16/2004	Fan configuration	**Far Fan**
Tester	JAG/MYB/JMB	Fan Setting	**37.1 Hz**
Stack Dia.	18 in.	Stack Temp	80 deg F
Stack X-Area	254.5 in.2	Start/End Time	2:18 PM/ 4:30 PM
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Dwnstrm of far fan, centerline**

Order ----->		2nd				1st			
Traverse-->		East				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.58	2579	2506	2538	2541.0	1834	2067	2059	1986.7
2	1.89	2694	2438	2278	2470.0	1877	1953	1799	1876.3
3	3.49	2616	2443	2133	2397.3	2069	2109	1931	2036.3
4	5.81	2528	2539	2309	2458.7	2048	1904	1923	1958.3
Center	9.00	2403	2568	2596	2522.3	2352	1928	2014	2098.0
5	12.19	2272	2550	2427	2416.3	2196	2513	2022	2243.7
6	14.51	2473	2421	2692	2528.7	2184	2620	2063	2289.0
7	16.11	2265	2274	2298	2279.0	3462	2782	2126	2790.0
8	17.42	2409	2464	2010	2294.3	2969	3298	3443	3236.7
Averages ---------->		2471.0	2467.0	2364.6	2434.2	2332.3	2352.7	2153.3	2279.4

NOTE: Column 1 North replaced with fourth data set which was taken after noticing a steady decline in concentrati
with respective measurements starting with North 1, 2, then 3.
Concern that more time was needed to stabilize after starting up particle generator.

All	pt/ft3	Dev. from mean	***Center 2/3***	East	North	All	Normlzd
Mean	2356.8		Mean	2438.9	2184.5	2311.71	2532.63
Min Point	1876.3	-20.4%	Std. Dev.	85.8	304.6	252.26	273.40
Max Point	3236.7	37.3%	COV as %	3.5	13.9	**10.91**	**10.79**

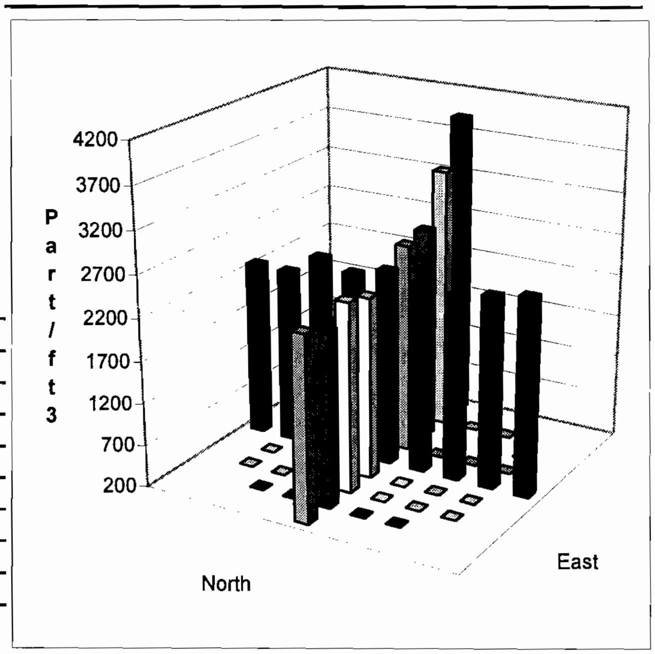
Avg Conc 2363 pt/ft3

Instuments Used:
TSI Velocity Calc Plus S/N 209060 Calib 8/25/04

	Start	Finish	
Generator Inlet Press	3-4	~3	psig
Stack Temp	80	80	F
Centerline vel.	770	805.0	fpm
Ambient pressure	29.37	29.34	inHg
Ambient humidity	34%	32%	RH
Ambient temp	74	73	F
Back-Gd aerosol	3,12,3,4,3,4	12,17,17,12,19,20	pt/ft3
No. Bk-Gd samples	6	6	
Compressor output reg	110	115	psig

Optical Particle Counters:
Met One A2408 S/N 96258675 Cal 8/5/04
Pre-test stability readings: 2248, 2160, 2200, 2210, 2091, 1980, 1908, 2033, 2005

Oil Used: FisherBrand 19
Probe has a 4.5-in throw so is that much closer to the stack than the port.



Signature signifies compliance with Procedure EMS-JAG-02 Signature/date John Glissmeyer 9/30/04	Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

PARTICLE TRACER TRAVERSE DATA FORM

Site	**325 Model Stack**	Run No.	**PT-2**
Date	9/17/2004	Fan configuration	**Near Fan**
Tester	JAG/MYB/JMB	Fan Setting	**37.1 Hz**
Stack Dia.	18 in.	Stack Temp	66 deg F
Stack X-Area	254.5 in.2	Start/End Time	10:50/13:20
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Near Fan, Centerline downstream**

Order ----->		1st				2nd			
Traverse-->		East				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.58	4987	2769	2930	3562.0	2629	2880	3068	2859.0
2	1.89	4980	2677	3068	3575.0	2772	3186	2879	2945.7
3	3.49	3190	3812	2676	3226.0	2758	3355	3548	3220.3
4	5.81	3499	4058	2584	3380.3	2787	3185	4027	3333.0
Center	9.00	4049	4810	2839	3899.3	2560	2986	4222	3256.0
5	12.19	4318	3638	2564	3506.7	2658	2651	3828	3045.7
6	14.51	3785	4313	3182	3760.0	3913	2753	3528	3398.0
7	16.11	3673	4102	3688	3821.0	3755	2513	4860	3709.3
8	17.42	3103	3172	2725	3000.0	2951	2999	5331	3760.3
Averages ---------->		3953.8	3705.7	2917.3	3525.6	2975.9	2945.3	3921.2	3280.8

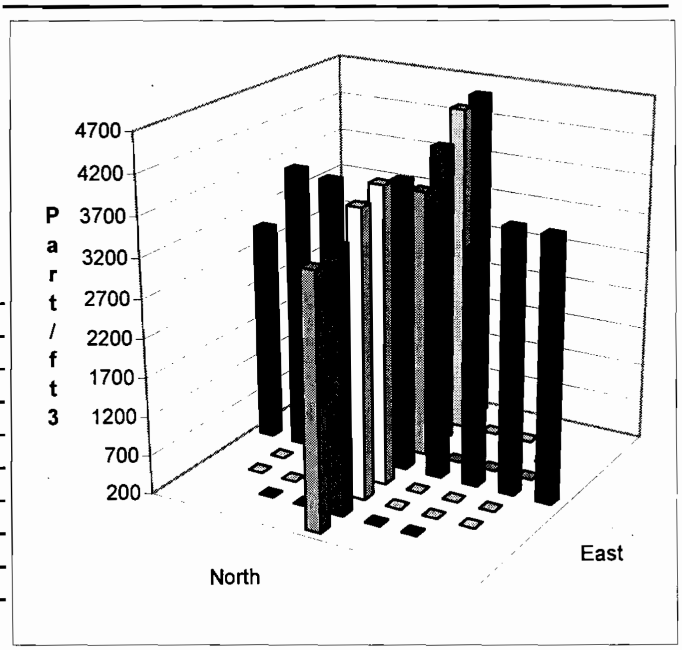
All	pt/ft3	Dev. from mean	*Center 2/3*	East	North	All	Normlzd
Mean	3403.2		Mean	3595.5	3272.6	3434.02	3757.33
Min Point	2859.0	-16.0%	Std. Dev.	245.4	248.8	290.60	311.44
Max Point	3899.3	14.6%	COV as %	6.8	7.6	**8.46**	**8.29**

Avg Conc 3381 pt/ft3

Instuments Used:

TSI Velocity Calc Plus S/N 209060 Calib 8/25/04

	Start	Finish	
Generator Inlet Press	4	4	psig
Stack Temp	61	71	F
Centerline vel.	855	795.0	fpm
Ambient pressure	29.3	29.258	inHg
Ambient humidity	74%	53%	RH
Ambient temp	58	66	F
Back-Gd aerosol	3,3,2,3,4,5	1,3,4,3,0,3	pt/ft3
No. Bk-Gd samples	6	6	
Compressor output reg	110	115	psig



Optical Particle Counters:

Met One A2408 S/N 96258675 Cal 8/5/04

Wind 12 mph steady

Oil Used: FisherBrand 19

Probe has a 4.5-in throw so is that much closer to the stack than the port.

It appears that there was a decline and then a recovery in concentration durring the test. See column averages.

Consistency checks: at East1 after the East measurements:
4430/4487/4661/4399/4338/4602

At North2: 3699/3692/3805/3727/3715/3804/3918/3999

At North7: 5065/4957/5263/5052

Signature signifies compliance with Procedure EMS-JAG-02
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Rosanne L Aaberg 9/30/04

PARTICLE TRACER TRAVERSE DATA FORM

Site	**325 Model Stack**	Run No.	**PT-2a**
Date	9/17/2004	Fan configuration	**Near Fan**
Tester	JAG/MYB/JMB	Fan Setting	**37.1 Hz**
Stack Dia.	18 in.	Stack Temp	66 deg F
Stack X-Area	254.5 in.2	Start/End Time	10:50/13:20
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Near Fan, Centerline downstream**

Order ----->		1st				2nd			
Traverse-->		East				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.58	4987	2769	4527	4094.3	2629	2880	3068	2859.0
2	1.89	4980	2677	3534	3730.3	2772	3186	2879	2945.7
3	3.49	3190	3812	4235	3745.7	2758	3355	3548	3220.3
4	5.81	3499	4058	4313	3956.7	2787	3185	4027	3333.0
Center	9.00	4049	4810	4084	4314.3	2560	2986	4222	3256.0
5	12.19	4318	3638	3973	3976.3	2658	2651	3828	3045.7
6	14.51	3785	4313	3856	3984.7	3913	2753	3528	3398.0
7	16.11	3673	4102	3532	3769.0	3755	2513	4860	3709.3
8	17.42	3103	3172	2589	2954.7	2951	2999	5331	3760.3
Averages ---------->		3953.8	3705.7	3849.2	3836.2	2975.9	2945.3	3921.2	3280.8

All	pt/ft3	Dev. from mean	*Center 2/3*	East	North	All	Normlzd
Mean	3558.5		Mean	3925.3	3272.6	3598.93	4130.79
Min Point	2859.0	-19.7%	Std. Dev.	205.4	248.8	403.43	339.31
Max Point	4314.3	21.2%	COV as %	5.2	7.6	**11.21**	**8.21**

Avg Conc 3530 pt/ft3

Instuments Used:

TSI Velocity Calc Plus S/N 209060 Calib 8/25/04

	Start	Finish	
Generator Inlet Press	4	4	psig
Stack Temp	61	71	F
Centerline vel.	855	795.0	fpm
Ambient pressure	29.3	29.258	inHg
Ambient humidity	74%	53%	RH
Ambient temp	58	66	F
Back-Gd aerosol	3,3,2,3,4,5	1,3,4,3,0,3	pt/ft3
No. Bk-Gd samples	6	6	
Compressor output reg	110	115	psig

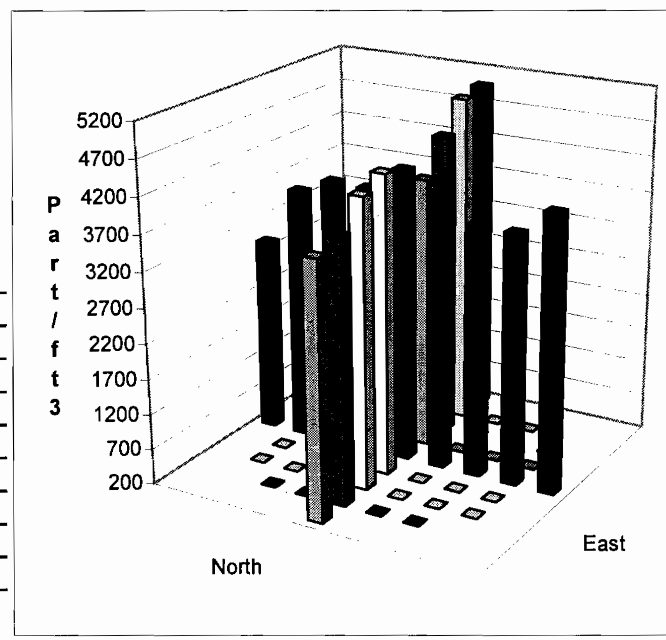
Optical Particle Counters:

Met One A2408 S/N 96258675 Cal 8/5/04

Wind 12 mph steady

Oil Used: FisherBrand 19

Probe has a 4.5-in throw so is that much closer to the stack than the port.



Signature signifies compliance with Procedure EMS-JAG-02

Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roxanne L. Hobey 9/30/04

NOTE: Column 3 East replaced with fourth data set taken after perceiving in increase in concentrations

PARTICLE TRACER TRAVERSE DATA FORM

Site	**325 Model Stack**	Run No.	**PT-3**
Date	9/17/2004	Fan configuration	**Far Fan**
Tester	JAG/MYB/JMB	Fan Setting	**37.1 Hz**
Stack Dia.	18 in.	Stack Temp	70.5 deg F
Stack X-Area	254.5 in.2	Start/End Time	1415/1620
Elevation	N.A.	Center 2/3 from	1.65 to: 16.35
Distance to disturbance	120 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Dwnstrm of far fan, centerline**

Order ----->		2nd				1st			
Traverse-->		East				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.58	765	651	648	688.0	665	519	486	556.7
2	1.89	715	646	688	683.0	625	542	657	608.0
3	3.49	642	572	556	590.0	542	712	844	699.3
4	5.81	533	571	510	538.0	772	477	812	687.0
Center	9.00	472	563	657	564.0	767	521	836	708.0
5	12.19	651	533	548	577.3	757	557	808	707.3
6	14.51	632	600	500	577.3	769	559	778	702.0
7	16.11	549	617	491	552.3	739	556	762	685.7
8	17.42	518	541	375	478.0	818	766	778	787.3
Averages ---------->		608.6	588.2	552.6	583.1	717.1	578.8	751.2	682.4

All	pt/ft3	Dev. from mean	***Center 2/3***	East	North	All	Normlzd
Mean	632.7		Mean	583.1	685.3	634.24	708.68
Min Point	478.0	-24.5%	Std. Dev.	47.3	35.2	66.47	52.82
Max Point	787.3	24.4%	COV as %	8.1	5.1	**10.48**	**7.45**

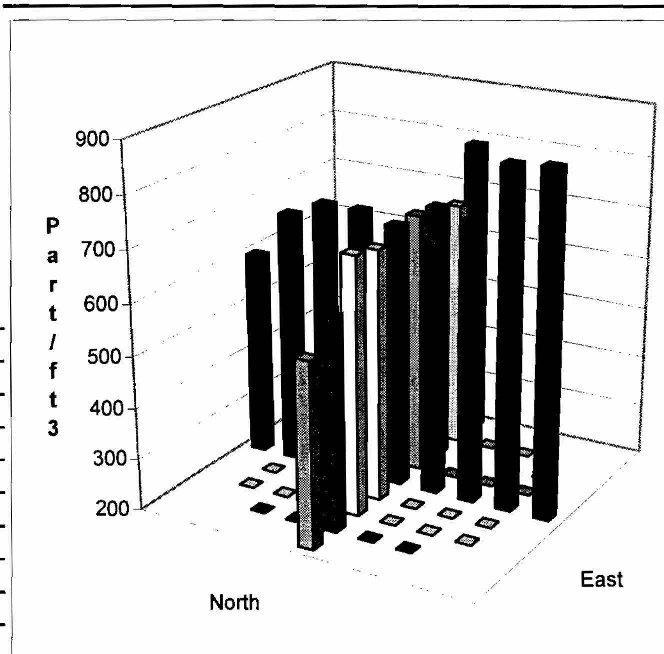
Avg Conc 632 pt/ft3

Instuments Used:
TSI Velocity Calc Plus S/N 209060 Calib 8/25/04

	Start	Finish	
Generator Inlet Press	3	4	psig
Stack Temp	72	69	F
Centerline vel.	800	785.0	fpm
Ambient pressure	29.256	29.04	inHg
Ambient humidity	53%	45%	RH
Ambient temp	67	67	F
Back-Gd aerosol	11,13,12,8,1 4,9	6,12,9,6,9,3	pt/ft3
No. Bk-Gd samples	6	6	
Compressor output reg	110	115	psig

Optical Particle Counters:
Met One A2408 S/N 96258675 Cal 8/5/04
SW wind 10 mph at start
SE wind 12 mph at end

Oil Used: FisherBrand 19
Probe has a 4.5-in throw so is that much closer to the stack than the port.
Pretest consistency checked at N4 point:
718, 672, 642, 672, 739



Signature signifies compliance with Procedure EMS-JAG-02
Signature/date John Glissmeyer 9/30/04

Signature verifying data and calculations: Roanne L Hobbs 9/30/04

Test Instruction

Project: **325 Stack Sampler Qualification**	Date: **August 16, 2004**	Work Package: **F59676**

Tests: **Tracer Particle Uniformity in 325 Model Stack, 1 Electric Fan Configuration**

Staff: John Glissmeyer, Dave Douglas, Marcel Ballinger, Matthew Barnett

Reference Procedures:
1. Procedure EMS-JAG-02, Rev. 1, *Test to Determine Uniformity of a Particulate Aerosol at a Sampler*, May 24, 2000
2. Operating Manual for Met-One Optical Particle Counter (OPC), Model A2408

Equipment:
1. 325 Model Stack and inspected work platforms. Fans will be in positions EF1, EF4.
2. Vacuum pump oil, oil mist generator, air lines, regulator, precision pressure gauge compressed air source
3. Oil mist injection probe, OPC sample probes, probe/stack couplers, tape measure, marking pen
4. OPC with computer (optional) and link
5. Velocity measurement device (optional) for verifying stack flow

Safety Considerations:
Observe the applicable Job Hazard Analysis for the project

Instructions:
1. Verify training on the procedure and that instrumentation is within calibration
2. Obtain climatic information from the Hanford Weather Service, phone 373-2716 or http://etd.pnl.gov:2080/HMS/lastob.htm
3. Mark the completion of each step on the field copy of the procedure. Mark-out those steps not applicable to this stack.
4. Install equipment as directed in the procedures. Only the mobile OPC will be used. The aerosol delivery line should be as vertical as possible to avoid oil accumulation.
5. Use a sliding platform for the OPC and clamp the probe so both the OPC and probe move together.
6. Mark sampling probe for the measurement points shown on the data sheet.
7. Verify that stack flow is about 1350 – 1450 cfm.
8. Initially set the injection system input psi at 5 and vary to obtain particle counts at the sampling ports that are about 10 times background for 10-micron particles.
9. Monitor the flowrate on the OPC. Record data on copies of the attached the data sheet. Diagram mounting fixtures and retain assembly for any subsequent re-tests
10. Conduct one or more tracer mixing tests at the following sets of conditions:

Downstream of Fan	Injection Positions	Possible Runs
EF1	Center	PT 1
EF4	Center	PT 2
Worst case fan position from either this or gas tracer tests	Center	PT 3

Desired Completion Date: 08/27/04

Approvals: John Glissmeyer
John Glissmeyer, test director — 8/19/04 Date

Test Completed by: John Glissmeyer — Date: 9/17/04

PNNL Operating Procedure	
Title: Test to Determine Uniformity of a Tracer Aerosol at a Sampler Probe	**Org. Code:** D9T99 **Procedure No.:** EMS-JAG-02 **Rev. No.:** 1
Work Location: General	**Effective Date:** May 24, 2000
Author: John A. Glissmeyer	**Supersedes Date:** November 10, 1998
Identified Hazards: ☐ Radiological ☐ Hazardous Materials Physical Hazards ☐ Hazardous Environment ☐ Other:	**Identified Use Category:** ☐ Mandatory Use ☐ Continuous Use Reference Use ☐ Information Use
Are One-Time Modifications Allowed? Yes ☐ No	

Person Signing	Signature	Date
Technical review: James L. Huckaby		
Project Manager: John Glissmeyer		
Line Manager: James Droppo		
Concurrence:		
Quality Engineer: Thomas G. Walker		

1.0 Purpose

The performance of new stack sampling systems must be shown to satisfy the requirements of 40 CFR 61, Subpart H, "National Emission standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." This regulation governs portions of the design and implementation of effluent air sampling. The stack sampler performance is adequately characterized when potential contaminants in the effluent are of a uniform concentration at the sampling location (plane), and line losses are within acceptable limits. This procedure determines whether the concentration of aerosol particulate contaminants is uniformly distributed in the area of the sampling probe. Other procedures address flow angle, uniformity of gas velocity, and uniformity of gas contaminants. A contaminant concentration that is uniform at the sampling plane enables the extraction of samples that represent the true emission concentration.

The uniformity is expressed as the variability of the measurements about the mean. This is expressed using the relative coefficient of variance (COV), which is the standard deviation divided by the mean and expressed as a percentage. The lower the COV value, the more uniform the particle concentration. The acceptance criterion is that the COV of the measured particle concentrations be # 20% across the center two-thirds of the area of the stack.

2.0 Applicability

This procedure can be used in the field or on modeled stacks to determine whether air-sampling probes can collect representative samples under normal operations. The tests are applicable to effluent stacks or ducts within the following constraints:

- The aerosol particulate tests are generally limited to stacks with flowrates greater than 50 cubic feet per minute range. The upper bound of flowrate is determined by the output capacity of the aerosol generator, the background reading for particulate aerosols, and the operational detection range of the optical particle counters.
- Environmental constraints – optical particle counters will require the use of a controlled temperature environment to maintain the equipment above 55 degrees Fahrenheit.

3.0 Prerequisites and Conditions

Conditions and concerns that must be satisfied before sampling are listed below:

- Safety glasses and hard toed or substantial shoes are required in work areas.
- Test ports for tracer injection and sampling.
- Properly constructed and inspected work platforms may be needed to access the test ports.
- Scaffold-user or fall protection training may be required to access the sampling ports of the stack.
- Alcohol may be used for equipment cleanup. A flammable equipment storage cabinet is required to hold chemicals. Material Safety Data Sheets must be provided.

- Air pressure (up to about 75 psi) is used to aerosolize oil into fine particles. Knowledge of the use and operation of pressurized air-lines, and the careful observations of any buildup of oil mist outside of the generator is essential to prevent exceeding American Conference of Governmental Industrial Hygienists (ACGIH) levels listed below.
- Knowledge of the setup, use of, and operation of flowmeters, particle counters, and computers is essential.
- A job-hazards analysis may be required in certain cases.

4.0 Precautions and Limitations

Caution: The ACGIH 8-hour time-weighted average limit for human exposure to mineral oil mist is 5 mg/m^3. It is odorless.

During tests of stacks with high flowrates, oil droplets will be injected into the base of the stack to overcome the large dilution factor needed to detect selected particles at the sampling ports above. The potential is present for a buildup of oil mist to occur outside of the aerosol generator that could approach the 5 mg/m^3 caution level. The undiluted mist is heavier than air, so it may accumulate in confined spaces and in low areas if allowed to escape. Visual inspections of the delivery system will be made at least daily to prevent such an occurrence.

Access to the test ports may require the use of scaffolding or manlifts, either of which will necessitate special training for sampling personnel and any observers. The training requirements will be indicated in the job hazard analysis.

The test may be invalid if the ending ambient concentration of mist is elevated above that observed at the start of the test. This would indicate poor dispersion away from the test site caused by recirculation of the tracer to the inlet of the fan and will only occur if the stack exhaust point is in view of and is reasonably close to the fan inlet. This may result in a false indication of good mixing.

5.0 Equipment Used for Stack Measurements

Specific calibration check concentration levels, probe dimensions, measurement grids, flowrates, and other special requirements will be provided in the specific Test Instruction. Exhibit A provides a typical layout for the test setup. The following are essential items of equipment:

- Vacuum pump oil
- Oil mist generator
- Compressed air, compressed air hoses, and precision air regulators
- Oil mist injection probe
- Aerosol sampling probes
- Mechanism for accurate placement of sampling probe

- Optical particle counters
- Computers linked to particle counters
- Velocity flow measurement meter.

Two optical particle counters (OPCs) may be used simultaneously to count particles that are approximately in the10-micron size range. A mobile OPC is designated to make point-by-point measurements in the orthogonal traverses. An optional reference OPC may be used to note trends in aerosol generator output over time and to validate the mobile sampler results. The operation of the reference OPC, at some fixed position in the stack, may be contingent on whether a suitable port is available on the test stack.

The counters, rechecked annually for calibration by the manufacturer, are synchronized for time, sample mode, flow, and count range to monitor their field performance. The absolute calibration of the OPCs is not as important as the general response because the concentration data are used in a relative manner in calculating the COV and in plotting the concentrations at the measurement points.

The aerosol generator siphons oil from a reservoir and forces the air/oil mixture through a spray nozzle to produce polydisperse particles. Non-hazardous oil with a low vapor pressure (such as Fisherbrand 19 vacuum pump oil) should be used in the reservoir. The quantity of aerosol generated is controlled by the amount of compressed air pressure, which should be filtered and controlled by a precision regulator. The nozzle is mounted in a large diameter, clear-plastic pipe (4-inches diameter or larger) so the output level can be observed. The aerosol generator output should connect to an injection tube with an inside diameter of at least 0.5 inches to minimize collisions with the inner wall of the tubing. Optimal operation depends on uniformly “wetting” the inner surfaces of the generator and transfer tubes; thus, a warm up period of up to ½ hour is needed for a constant aerosol output.

6.0 Work instructions for Setup, Measurements, and Data Reduction

The steps taken to set up, configure, and operate the stack fans and test equipment are listed. Based on previous field measurements, the steps are ordered to achieve maximum efficiency in the testing. In addition to these steps, the test instruction illustrated in Attachment A will provide specific details and operating parameters.

6.1 Preliminary Steps:

9/15/04 JG **6.1.1** ✓ Provide essential supplies at the sampling location (particulate generation equipment, supply air and regulators, fittings and probe-port couplers, marking pens, data sheets, writing and probe-supporting platforms).

MYB 9/16/04 **6.1.2** ✓ Fill in test information on dataform.

MYB 9/16/04 **6.1.3** ✓ Observe the current flow setting for the test stack and record on the data sheet.

MYB 9/16/04 **6.1.4** ✓ Obtain barometric, temperature, and relative humidity information for the particle counter location.

MYB 9/16/04 **6.1.5** ✓ Measure the stack centerline air velocity in the sampling plane using a velocity flow meter, and record value on data sheet.

9/15/04 JG **6.1.6** ✓ Mark the sampling probe with a permanent marker so the inlet can be placed at each successive measurement point.

> **Note: Sampling plane traverse points.** Use the grid of measurement points provided with the test's instruction and dataform. This is usually the same as used for the velocity uniformity test. A center point is included as a common reference and for graphical purposes. The layout design divides the area of the sampling plane so that each point represents approximately an equal-sized area

9/15/04 JG **6.1.7** ✓ Couple the OPCs and probes to the stack sampling ports according to the illustration in Exhibit A.

> **Note**: The **sampling equipment** consists of stainless steel probes with ¾ outside diameter and thin-wall tubing with sufficient length to reach across the inside diameter of the stack while allowing for fittings. The sampling probe should have gradual 90° bends to minimize the inertial impact of particles with inner walls at bends, and the open end of the tube should face downward or into the flow in the stack. The outlet end of the probe should terminate at the OPC inlet. Minimize tubing length to minimize particle losses.
>
> The sampling probes for both OPCs should be similar and of a simple design. The elevation of the intake nozzle of the traversing unit should be approximately in the same as the sampling plane. The intake nozzle for the reference unit may be located anywhere within the stack at an elevation near that of the sampling plane; however, the two probes should not interfere with each other, either physically or by causing flow disturbances for each other. The intake nozzles may be of sub-isokinetic or of shrouded design to optimize the collection of 10-micron particles.
>
> The aerodynamic characteristics of the probes for both OPCs should be the same so that they have similar line-loss (penetration) values. For optimal particle collection, the probes should be of a fixed and rigid configuration. The mobile OPC with its attached probe should be mounted together on a sliding platform to move as a unit along the axis of the sampling port.

6.1.8 ✓ Turn-on the mobile ~~and reference~~ MYB optical particle counters.

MYB 9/16/04

> **Note**: Ensure that internal air circulation fans in the OPCs are on and that the sample probes are tightly connected to and are directly above or apart from the OPC sample inlet openings. Also ensure that the sliding platform supporting the mobile sampler is aligned for easy, free movement at the correct height for its stack port.

6.1.9 ✓ Program and synchronize the OPCs for

MYB 9/16/04

- 60-second samples
- 9- to 11-micron particle counting
- the current time
- cumulative counting mode.

6.2 Daily Particulate Background Concentration Measurement

6.2.1 At the beginning of each sampling day before starting the aerosol generator, obtain at least six consecutive background readings for both mobile and reference OPCs.

6.2.2 Record these readings on the data sheet ~~and in the logbook~~ designated for the tests.

6.2.3 Start and run the aerosol generator for approximately 30 minutes to stabilize its output.

6.3 Particle Injection and Sample Collection

The injection equipment includes an air regulator, a precision air pressure gauge, and other components described in Section 5. The ¾-inch (OD) (or larger) injection probe with a 90E bend (with an approximately 3-inch radius of turn) will inject aerosol particles in the direction of emission flow. The connections and fittings should be checked to ensure that they are secure and leak free.

> **Note: Location of the Injection Point**
> Injection plane -- The tests are repeated using the centerpoint as the aerosol release point.

6.3.1 Position the injection probe, according to the test instruction.

6.3.2 Start injection of the aerosol and adjust the flowrate to the input capabilities of the OPCs.

> **Note:** Aerosol injection is not precisely controlled. At air pressure readings above about 10 psi for the specific PNNL generator used, a dense oil mist is created in the generator and is available for injection. However, if the back-pressure, caused by a high rate of airflow past the port in the stack, at the injection port is high, carrier air may be required to inject the aerosol into the base of the stack. Under these conditions, the overall aerosol output will be low (less than perhaps 200 particles measured at the counter).
>
> In contrast, if there is little back-pressure, most of the generated aerosol, minus that lost from interactions with internal generator system and line walls, becomes available for injection. Here the output will be high (hundreds to thousands of particles injected per minute).

> **Note:** The OPC draws air from the stack, via the sample probe, at a fixed rate (one cubic foot per minute). Within the OPC, the air stream with particles passes through a laser beam where the particles are counted and placed in six size categories. In the less than 0.5-micron category, several hundred thousand differential counts are typical; but in the 9- to 11-micron category, oil mists greater than about 3,000 cpm cause a sensor overload condition. Thus, at the OPC, the flow rate is fixed, and a ceiling exists on the measurement of particles. Essentially, there is no adjustment of particle counting capability at the OPC, and the aerosol generator becomes the controlling factor for particulate output.

mYB 9/16/04

6.3.3 Record the initial

- injection system dispersion pressure in psi
- flowrate for the mobile ~~and reference~~ OPC mYB
- centerline flow velocity for the test stack.

mYB 9/16/04

6.3.4 On the data sheet, label the columns of data according to the directions of the traverses.

mYB 9/16/04

6.3.5 Verify that the directional orientations and the numbered sample positions are consistent.

mYB 9/16/04

6.3.6 Position the OPC and sample probe at each measurement point in succession, and record the reading on the data form.

mYB 9/16/04

> **Note:** In each test, the measurement at each point is the average of three readings. The repeats are made as three separate runs and not as three consecutive measurements at each point.

mγB 9/16/04

6.3.7 Perform two additional repetitions of Step 6.3.6.

6.3.8 Switch the tests to the other direction and repeat steps 6.3.6 and 6.3.7.

mγB 9/16/04

6.3.9 Check the data sheet for completeness.

6.3.10 Record the final

mγB 9/16/04

- injection system dispersion pressure in psi
- flowrate for the mobile ~~and reference OPC~~ mγB

mγB 9/16/04

6.3.11 Shut off the air pressure to the aerosol generator.

mγB 9/16/04

6.3.12 Continue operation of the OPCs for several minutes to purge any remaining test aerosol from the stack.

mγB 9/16/04

6.3.13 Measure the centerline background particulate concentrations at the mobile monitor and record the levels on the data sheet.

mγB 9/16/04

6.3.14 Record any climatic conditions that have changed on the data sheet.

mγB 9/16/04

6.3.15 Measure the final centerline stack velocity flow on the data sheet.

mγB 9/16/04

6.3.16 Record any deviations from the above procedure on the data sheet.

mγB 9/16/04

6.3.17 Repeat steps 6.3.1 to 6.3.16 for each run as indicated in the test instruction.

JG 9/17/04

6.4 Data Recording and Calculations

Prepare the electronic data sheet on which to enter particle-count readings and other information relevant to the test (see test instruction).

JAG 9/17/04 **6.4.1** Review the raw data sheets for completeness.

JAG 9/19/04 **6.4.2** Enter the data into the electronic data sheet.

JAG 9/19/04 **6.4.3** Calculate the COV for the run.

> **Note:** The EXCEL datasheet shown as Attachment C is set up to calculate the COV for each particulate concentration traverse using the average concentration data from all points in the inner two-thirds of the cross section area of the plane (including the center point).

JAG 9/19/04 **6.4.4** Compare the observed COV for each run to the acceptance criterion.

> **Note:** The test is acceptable if the COV is #20% for the inner two-thirds of the stack diameter, and if no point differs from the mean by more than 30%. This is determined by inspecting the average concentration at each measurement point. The COV is 100 times the standard deviation divided by the mean.

JAG 9/20/04 **6.4.5** Sign and date the data sheet illustrated in Attachment C attesting to its validity.

> **Note:** A separate datasheet will be provided and signed-off for each test.

Exhibits/Attachments

Exhibit A – Overview of Stack and Injection Setup and Particle Counters

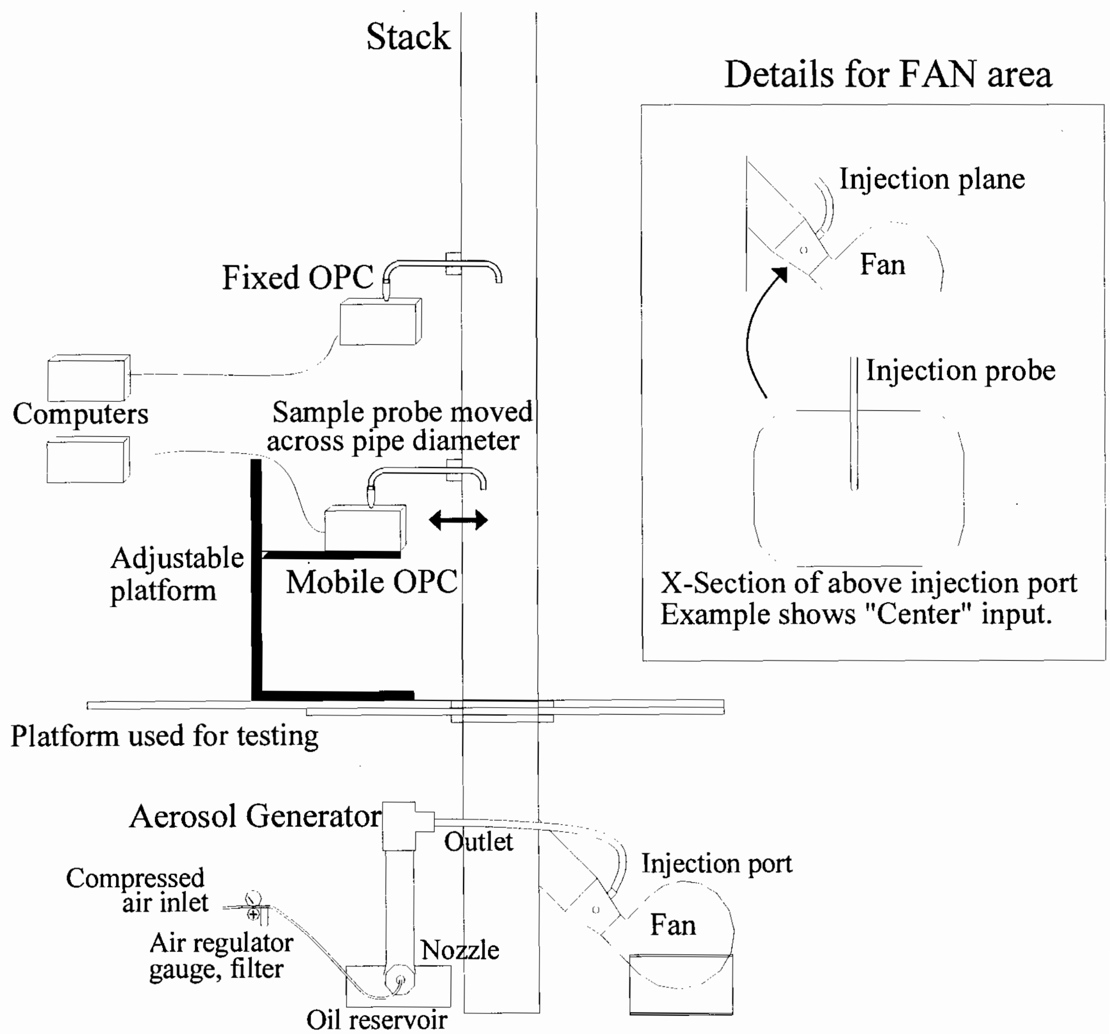


Exhibit B – Illustrative Data Collection Sheet

TRACER GAS TRAVERSE DATA FORM

Site		Run No.	PT-		
Date		Injection point			
Tester		Fan Setting	Hz		
Stack Dia.	28 in.	Stack Temp	F		
Stack X-Area	615.8 in.	Center 2/3 from	2.57	to:	25.43
Elevation		Pts in Center 2/3	3	to:	10
Dirstance to disturbance	in.	Data Files:			
Conc. units	Particles per minute	Oil type			

Traverse	Sampling	**Aerosol notes:**	Start	Finish	
1	4				
2	9	Record Stack flow			cfm
3	12	Ambient Temp			F
4	2	Dispersion air			psi
5	10	Carrier air			psi
6	13	Ambient pressure			mbars
C	1	Ambient humidity			RH
7	3	Stack centerline vel.			fpm
8	7	Back-Gd level (OPC-M)			cpm
9	8	Back-Gd level (OPC-F)			cpm
10	5	No. Bk-Gd samples			n
11	11	OPC-M flowrate			fpm
12	6	OPC-F flowrate			fpm

Traverse	N>S			E>W		
Order	F/M	F/M	F/M	F/M	F/M	F/M
C						
4						
7						
1						
10						
12						
8						
9						
2						
5						
11						
3						
6						

Instuments Used: Cal Exp. Date:

Solomat Zephyr #12951472 (stack center velocity)

OPC- A (M/F:)

OPC - B (M/F:)

Signing/dating signifies compliance with sections 6.1.1-6.4.5 in the PNNL Procedure No. EMS-JAG-02 (11/10/98).

Signature/Date:

Exhibit C – Illus trative Data Reporting Form

PARTICULATE TRAVERSE DATA REPORT FORM

Site		Run No.	PT-		
Date		Injection point			
Tester		Fan Setting	Hz		
Stack Dia.	27.25 in.	Stack Temp	F		
Stack X-Area	583.2 in.	Center 2/3 from	2.50	to:	24.75
Elevation		Pts in Center 2/3	3	to:	10
Distance to disturbance	in.	Data Files:			
Conc. units	Particles per minute (cpm)	Oil			

Traverse-->		East				South			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	1.00								
2	1.83								
3	3.22								
4	4.82								
5	6.81								
6	9.70								
Center	13.63								
7	17.55								
8	20.44								
9	22.43								
10	24.03								
11	25.42								
12	26.25								
		West				North			
Traverse Averages --------->									

Average of all data		*Center 2/3*	E/W	S/N	All
Maximum Positive Deviation	Max Point	Mean			
Maximum Negative Deviation	Min Point	Std. Dev.			
		COV %			

	Start	Finish	
Record stack flow			cfm
Ambient temp			F
Dispersion air			psi
Carrier air			psi
Ambient pressure			mbars
Ambient humidity			RH
Stack centerline vel.			fpm
Bk-Gd level (OPC-M)			cpm
Bk-Gd level (OPC-F)			cpm
No. Bk-Gd samples			n
OPC-M flowrate			fpm
OPC-F flowrate			fpm

Gas analyzer checked

Notes:

Instuments Used:

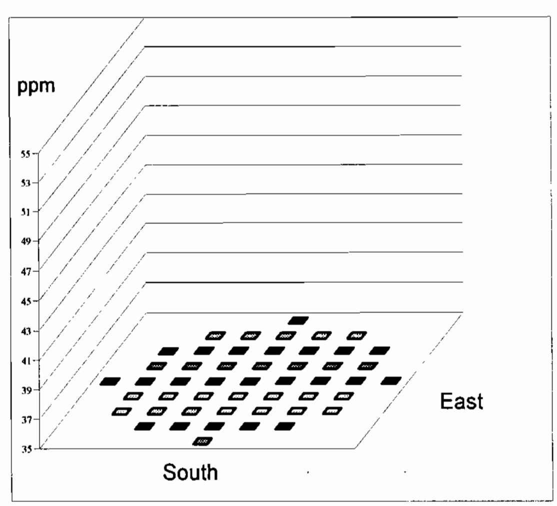
Solomat Zephyr #12951472

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Signing/dating signifies compliance with Sec. 6.1.1-6.4.5 in the PNNL Procedure No. EMS-JAG-02 (11/10/98).

Signature/Date:



Attachment A – Illustrative Test Instructions

Test Instruction

Project: Canister Storage Stack Qualification, 29303	Date: November 10, 1998	Work Package: K97052

Tests: Tracer Gas Uniformity of Full-Scale Stack

Staff: David Maughan, John Glissmeyer

Reference Procedures:

1. Procedure EMS-JAG-02, Rev. 0, Test to Determine Uniformity of a Particulate Aerosol at a Sampler, Nov. 10, 1998
2. Operating Manual for Met-One Optical Particle Counter (OPC), Model A2408

Equipment:

1. Canister Storage Stack and inspected work platforms
2. Vacuum pump oil, oil mist generator, air lines, regulator, precision pressure gauge
3. Oil mist injection probe, OPC sample probes, probe/stack couplers
4. OPCs with computers and links
5. Velocity measurement device

Safety Considerations:

Review and observe the applicable Duke Job Hazard Analysis for the project

Instructions:

1. Verify training on the procedure and that instrumentation is within calibration
2. Obtain Fisherbrand 19 Mechanical Pump Fluid
3. Obtain climatic information from the Hanford Weather Service, phone 373-2716 or http://etd.pnl.gov:2080/HMS/lastob.htm
4. Install equipment as directed in the procedures
5. Mark sampling probe for the measurement points shown on the data sheet
6. Verify that stack flow is about the target flowrate 9000 (2232 fpm)
7. Initially set the injection system input psi at 5 and vary to obtain particle counts at the sampling ports that are about 10 times background for 10-micron particles.
8. Set the sampler flowrate at approximately 10 lpm
9. Conduct one or more tracer mixing tests at the following sets of conditions:

Stack Flow	Injection point at duct from fan to stack
Normal	Centerline

(The injection plane should be at the fittings provided in the rectangular discharge of the fan)

10. Record data on copies of the attached the data sheet
11. Repeat the test
12. Diagram mounting fixtures and retain assembly for any subsequent re-tests

Desired Completion Date: 11/30/98

Approvals: ______________________________ ____________
John Glissmeyer, Project Manager Date

Test completed by: Date:

Appendix G

Calculations for Scale Model Criteria

Calculations for Scale Model Criteria

Reynolds Number Calculations
Re = rho * V * D/ u
Where Re = Reynolds Number
D = hydraulic diameter = diameter for cylinders
rho = air density = 1.1769 kg/m3
u = air viscosity = 1.85E-05 Pa s
Density and viscosity of air at 300K from Fundamentals of Momentum, Heat, and Mass Transfer, Welty, Wicks, and Wilson 1976
V = velocity = Q/A in m/s
Q = stack flow rate m3/s
A = stack area = $\pi * r^2$ in m

Configuration	Stack Flow cfm	Stack Flow m3/s	Diameter in	Hydraulic Diameter ft	Hydraulic Diameter m	Area m2	V ft/min	V m/s	Re
High Flow (Actual)	145,400	68.34	96	8.00	2.44	4.667	2894	14.6	2,275,629
Low Flow (Actual)	133,000	62.51	96	8.00	2.44	4.667	2647	13.4	2,081,559
High - 1 fan (Proposed)	48,467	22.78	96	8.00	2.44	4.667	965	4.9	758,543
Low - 1 fan (Proposed)	44,333	20.84	96	8.00	2.44	4.667	882	4.5	693,853
Scale Model - 3 fan	5,823	2.74	18	1.50	0.46	0.164	3297	16.7	486,052
Scale Model - 3 fan	4,391	2.06	18	1.50	0.46	0.164	2486	12.6	366,521
Scale Model - 1 fan	1,370	0.64	18	1.50	0.46	0.164	776	3.9	114,355
Scale Model - 1 fan	1,413	0.66	18	1.50	0.46	0.164	800	4.0	117,945
Scale Model - 1 fan	1,100	0.52	18	1.50	0.46	0.164	623	3.2	91,818

Flow range using scale model:

Test	Hz	Average Velocity, fpm	hydraulic diameter, ft	Velocity x diam ft2/min	Six Times	One-Sixth	stack diam ft	Stack Vel fpm		Stack flow cfm	
								High	Low	High	Low
VT-LOW1	30	622	1.5	933	5598	155.5	8	699.8	19.4	35155	977
VT-1	37.1	786	1.5	1179	7074	196.5	8	884.3	24.6	44425	1234
VT-3	37.1	804	1.5	1206	7236	201	8	904.5	25.1	45442	1262
VT-2	37.1	755	1.5	1132.5	6795	188.75	8	849.4	23.6	42673	1185
VT-4	37.1	756	1.5	1134	6804	189	8	850.5	23.6	42729	1187
						area (ft2)=	50.24				

Appendix H

Computational Fluid Dynamics Model Details

Computational Fluid Dynamics Model Details

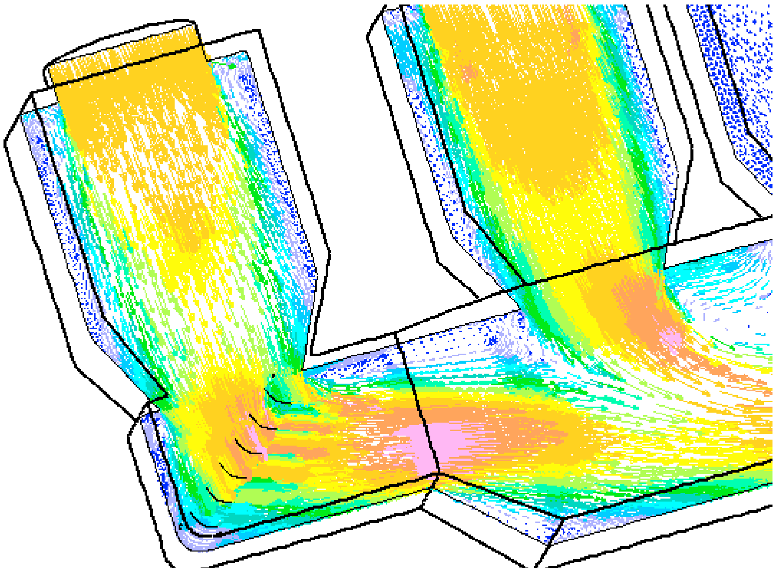


Figure H.1. Detail of flow vectors entering the main duct via fans #1 and #2 (for configuration of fans 1 & 2 farthest from the stack operational).

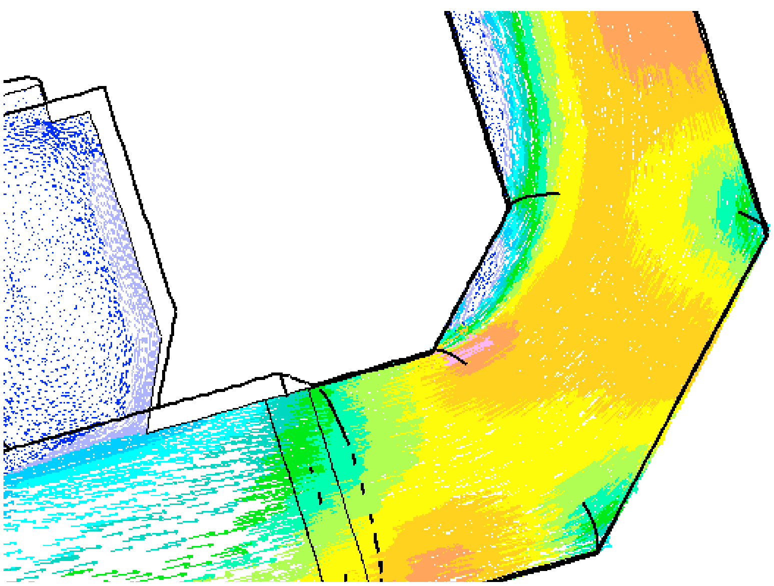


Figure H.2. Detail of flow vectors in the 90° bend in the horizontal duct (for configuration of fans 1 & 2 farthest from the stack operational).

Results: Operation of Fans 1 and 2

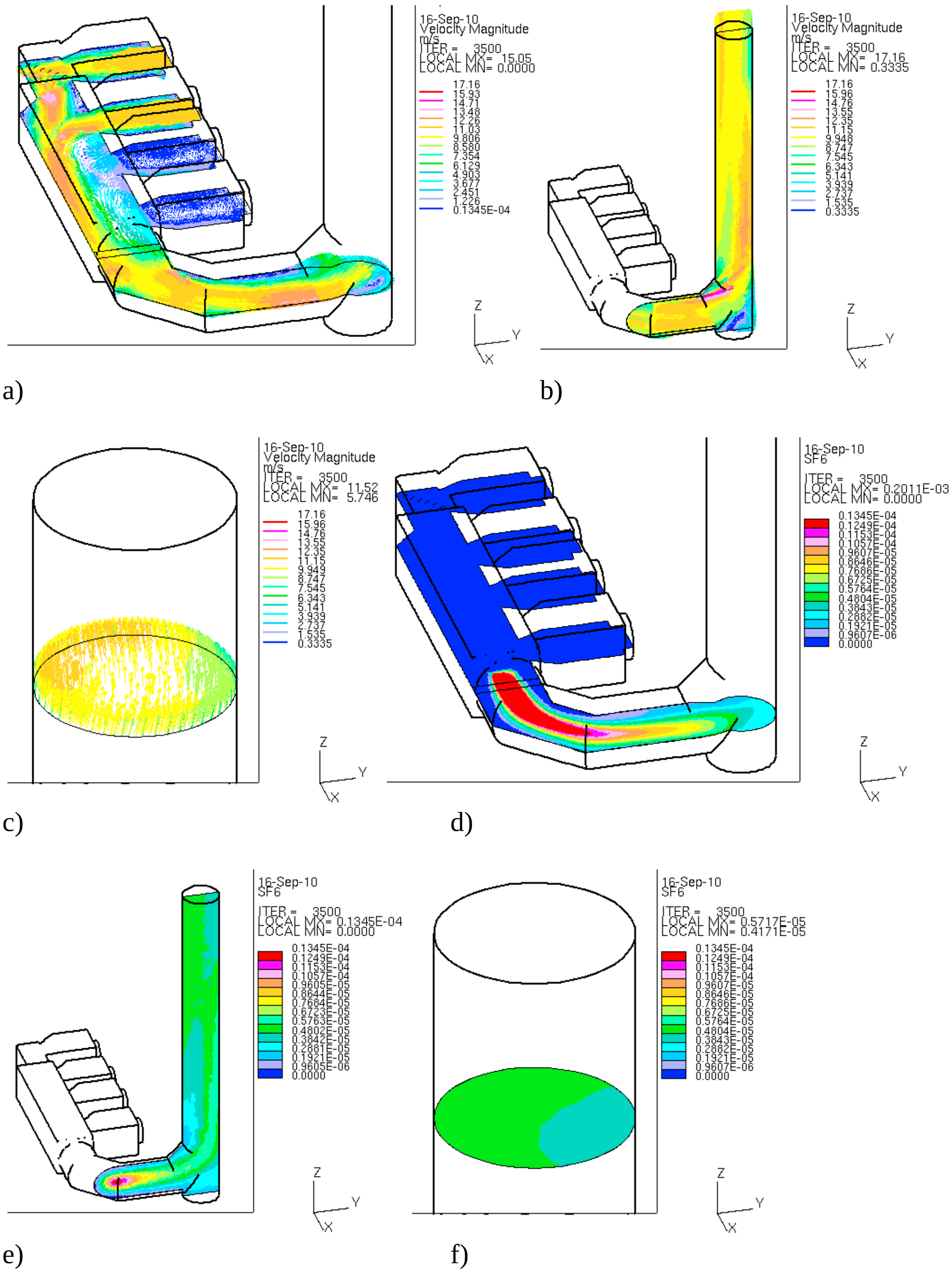
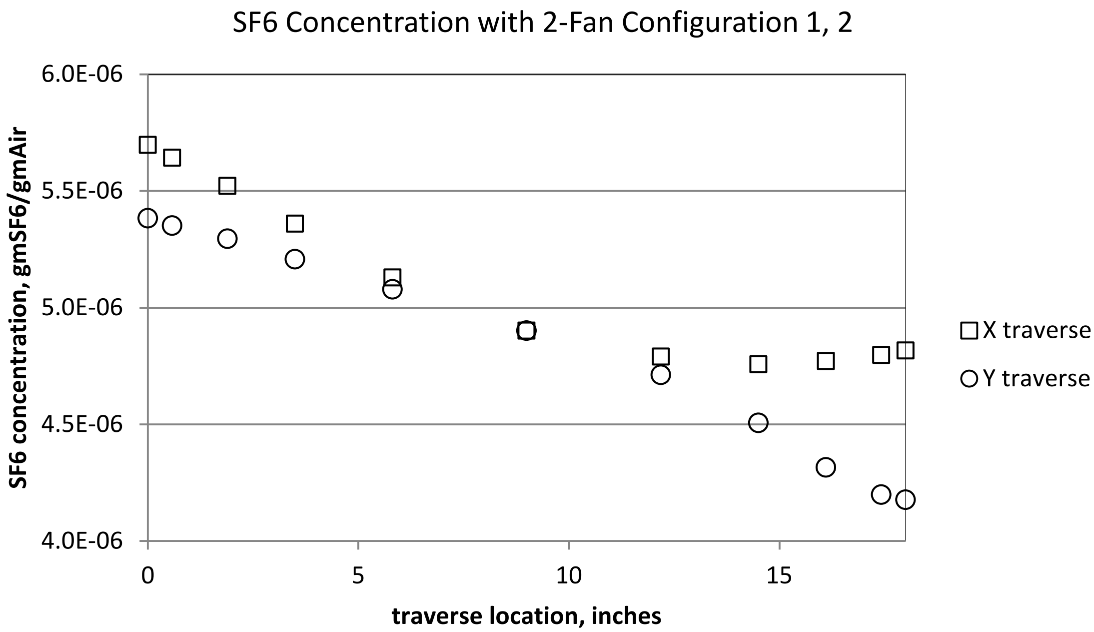


Figure H.3. Simulated flow velocity vectors and tracer gas concentrations for the case with fans 1 and 2 in operation: a) flow velocity in fans and lower ductwork, b) flow velocity in stack, c) velocity distribution in the stack at the elevation of the sampling system, d) tracer gas concentrations in the lower ductwork; tracer gas injected downstream of the fan nearest the stack, e) tracer gas concentrations in the stack, f) tracer gas distribution in the stack at the elevation of the sampling system.



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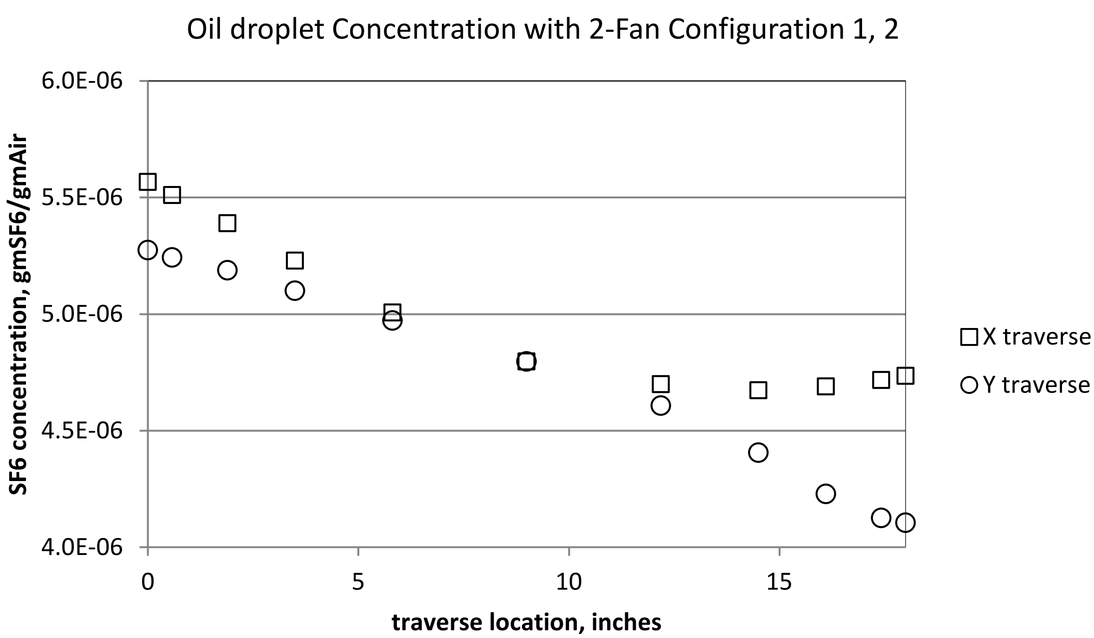


b)

Figure H.4. Simulated results for the 2-fan configuration 1,2: Concentrations of a) SF6 tracer gas, and b) oil droplets at the elevation of the sampling system.

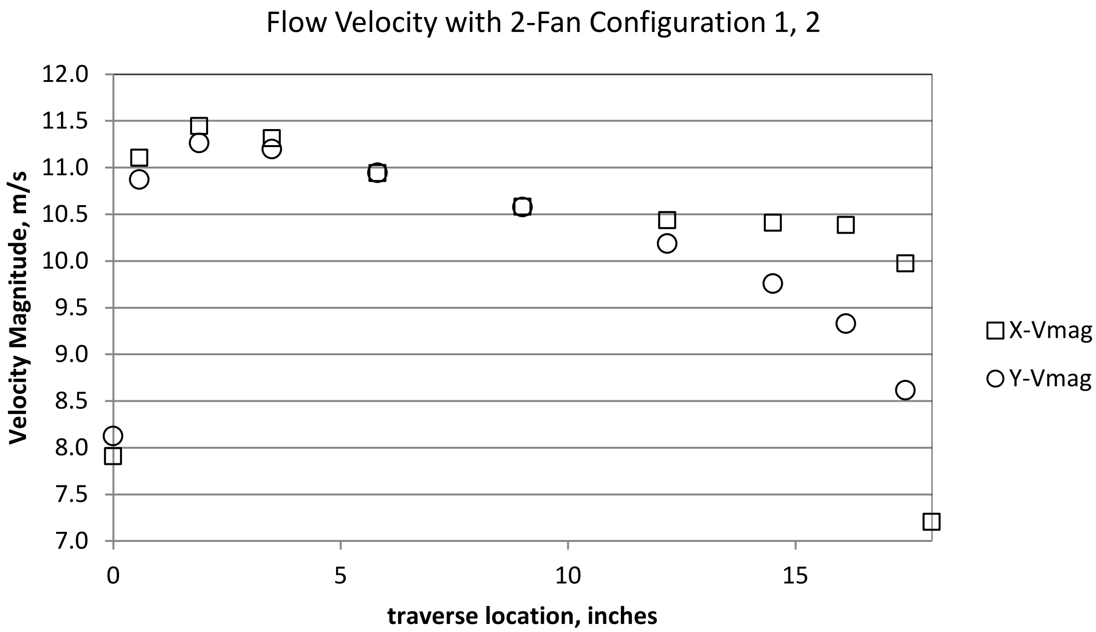


Figure H.5. Simulated results for the 2-fan configuration 1, 2: Flow velocity distribution at the elevation of the sampling system.

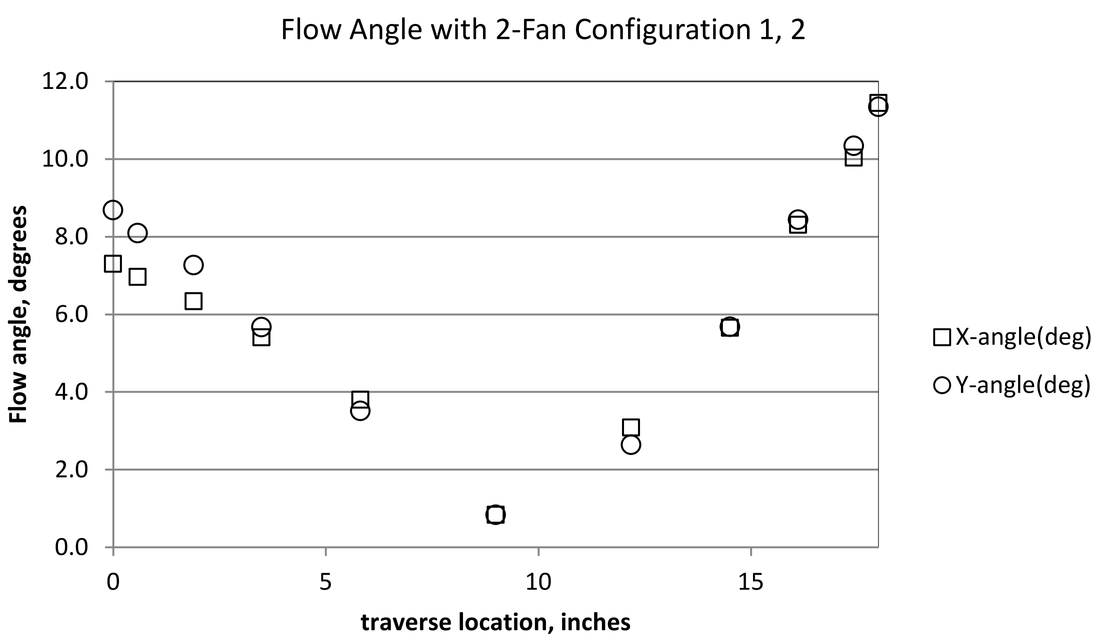


Figure H.6. Simulated results for the 2-fan configuration 1, 2: Cyclonic flow angle at the elevation of the sampling system.

Results: Operation of Fans 1 and 3

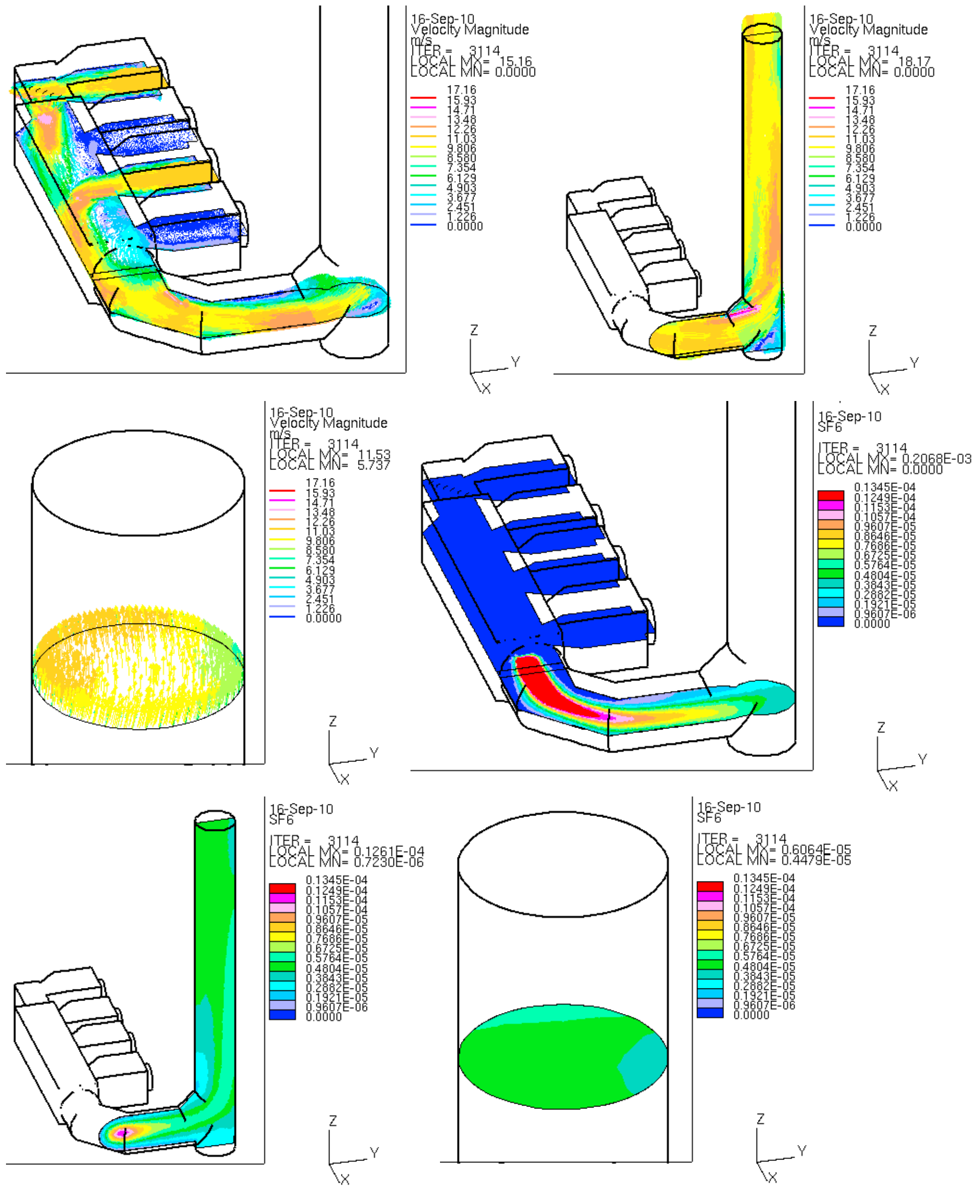
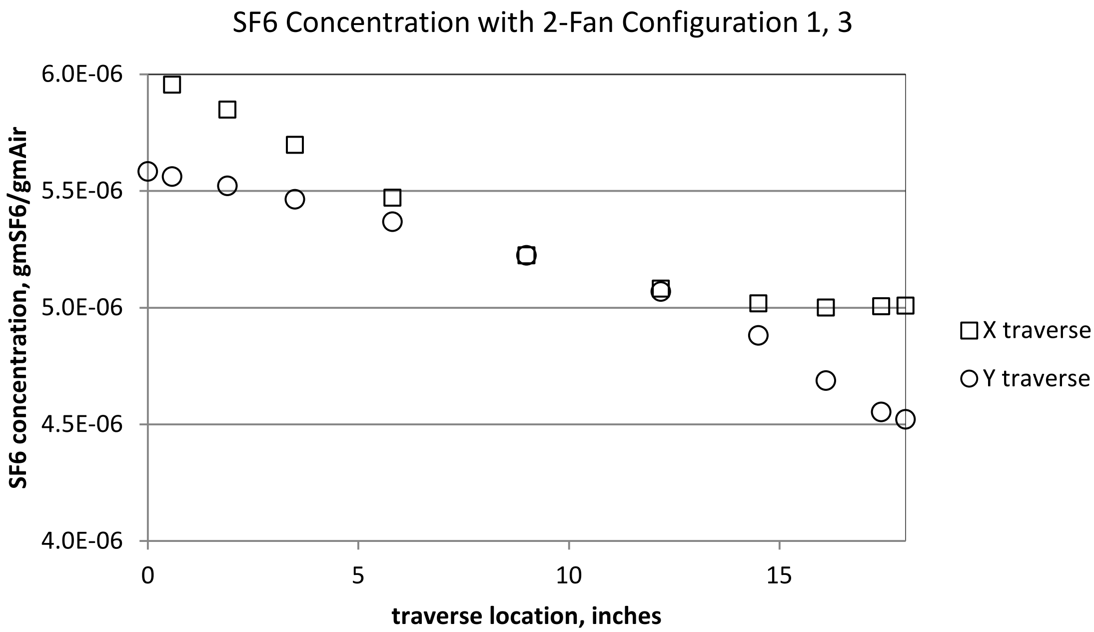
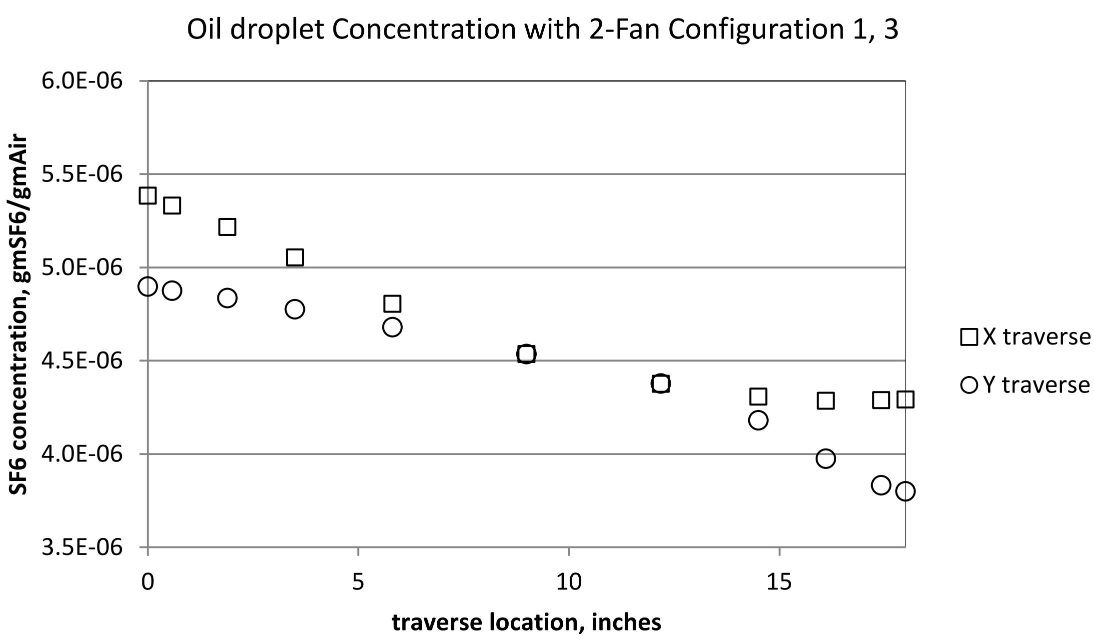


Figure H.7. Simulated flow velocity vectors and tracer gas concentrations for the case with fans 1 and 3 in operation: a) flow velocity in fans and lower ductwork, b) flow velocity in stack, c) velocity distribution in the stack at the elevation of the sampling system, d) tracer gas concentrations in the lower ductwork; tracer gas injected downstream of the fan nearest the stack, e) tracer gas concentrations in the stack, f) tracer gas distribution in the stack at the elevation of the sampling system.



a)



b)

Figure H.8. Simulated results for the 2-fan configuration 1, 3: Concentrations of a) SF6 tracer gas, and b) oil droplets at the elevation of the sampling system.

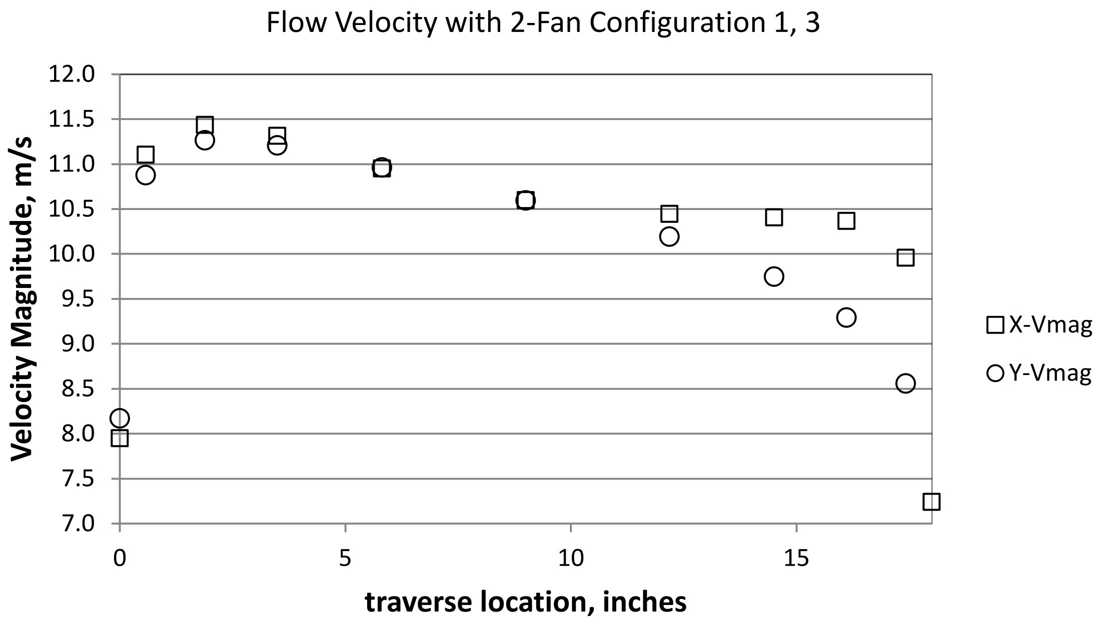


Figure H.9. Simulated results for the 2-fan configuration 1, 3: Flow velocity distribution at the elevation of the sampling system.

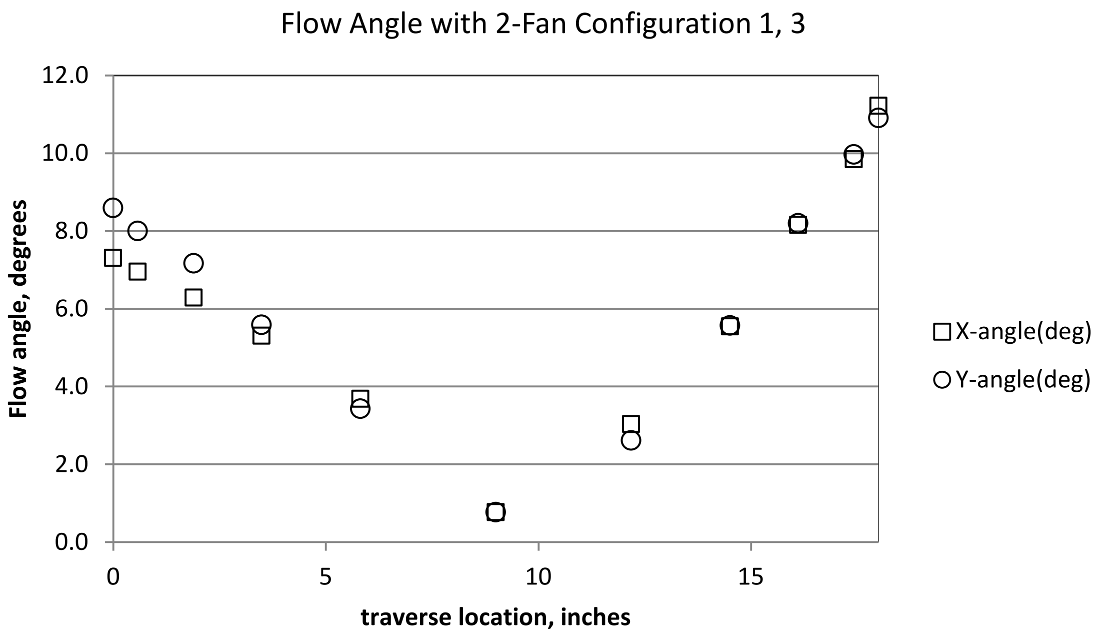


Figure H.10. Simulated results for the 2-fan configuration 1, 3: Cyclonic flow angle at the elevation of the sampling system.

Results: Operation of Fans 1 and 4

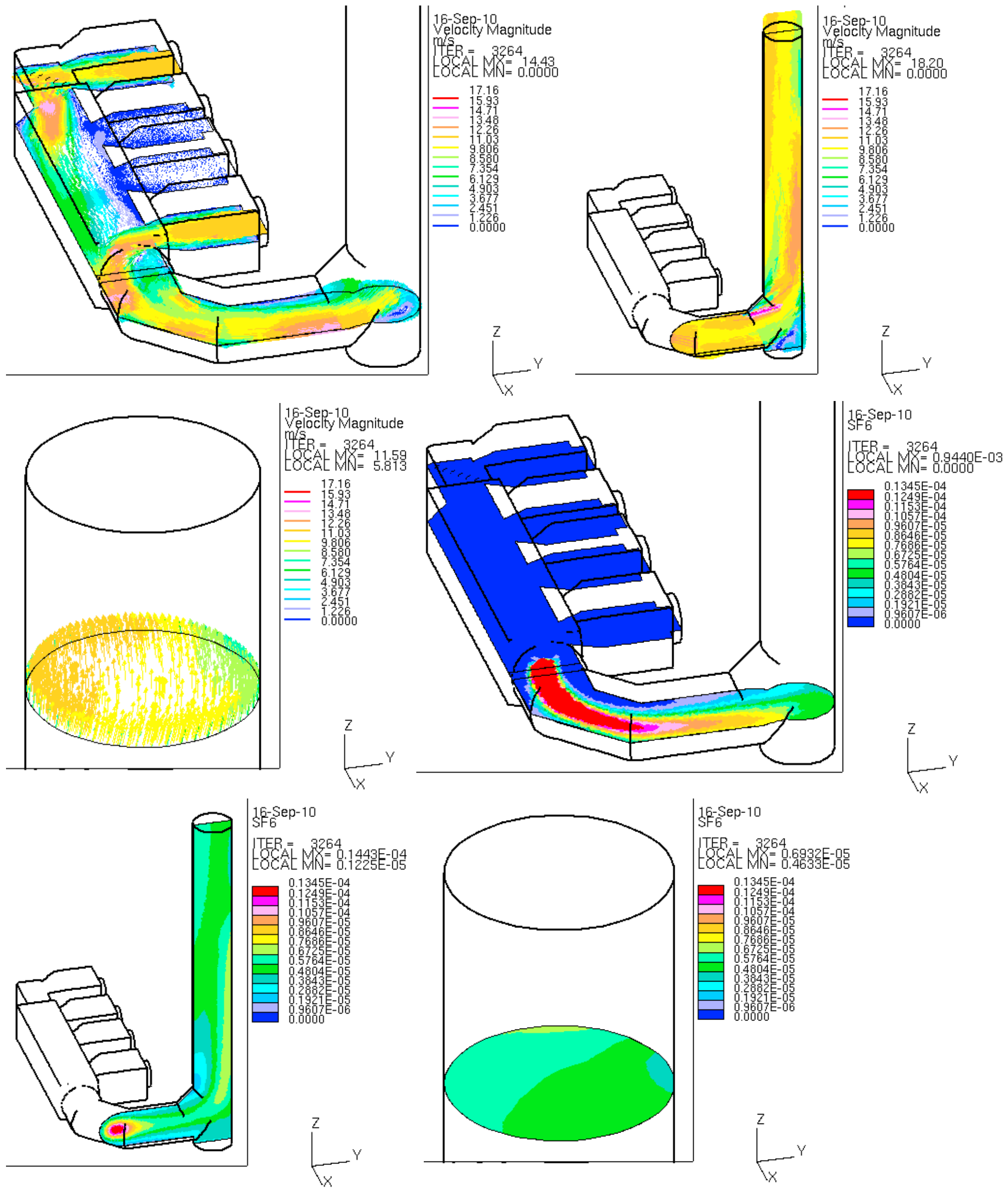
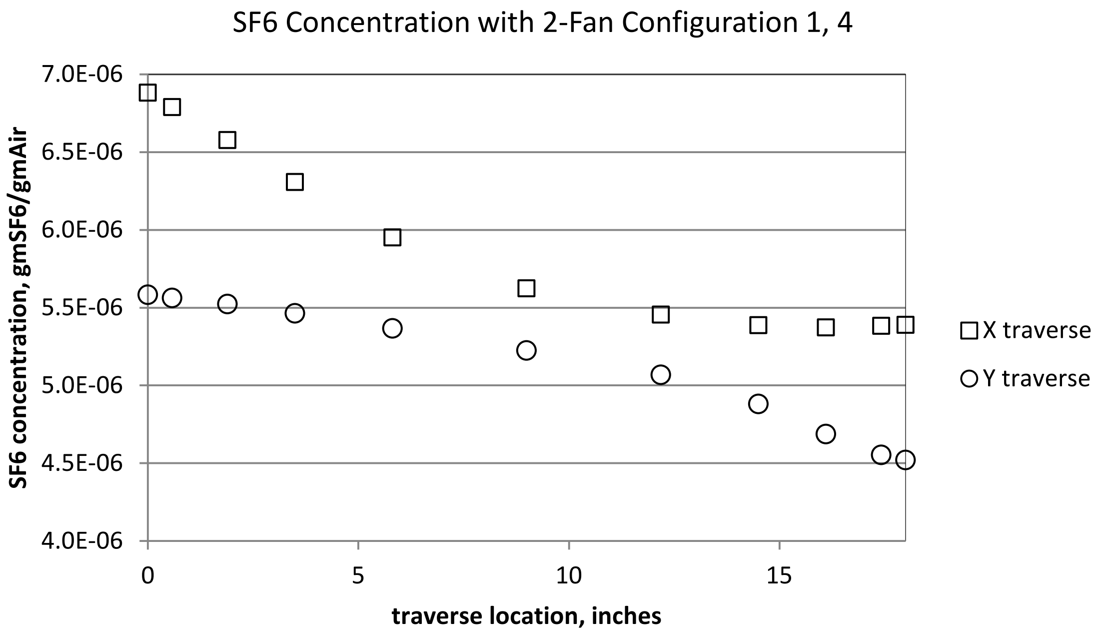
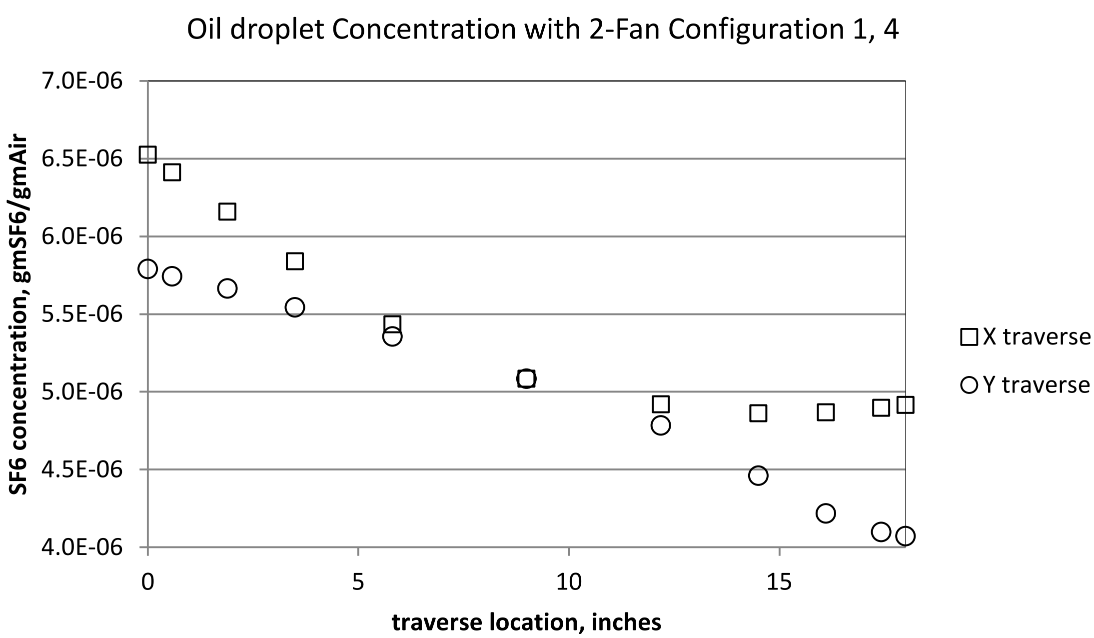


Figure H.11. Simulated flow velocity vectors and tracer gas concentrations for the case with fans 1 and 4 in operation: a) flow velocity in fans and lower ductwork, b) flow velocity in stack, c) velocity distribution in the stack at the elevation of the sampling system, d) tracer gas concentrations in the lower ductwork; tracer gas injected downstream of the fan nearest the stack, e) tracer gas concentrations in the stack, f) tracer gas distribution in the stack at the elevation of the sampling system.



a)



b)

Figure H.12. Simulated results for the 2-fan configuration 1, 4: Concentrations of a) SF6 tracer gas, and b) oil droplets at the elevation of the sampling system.

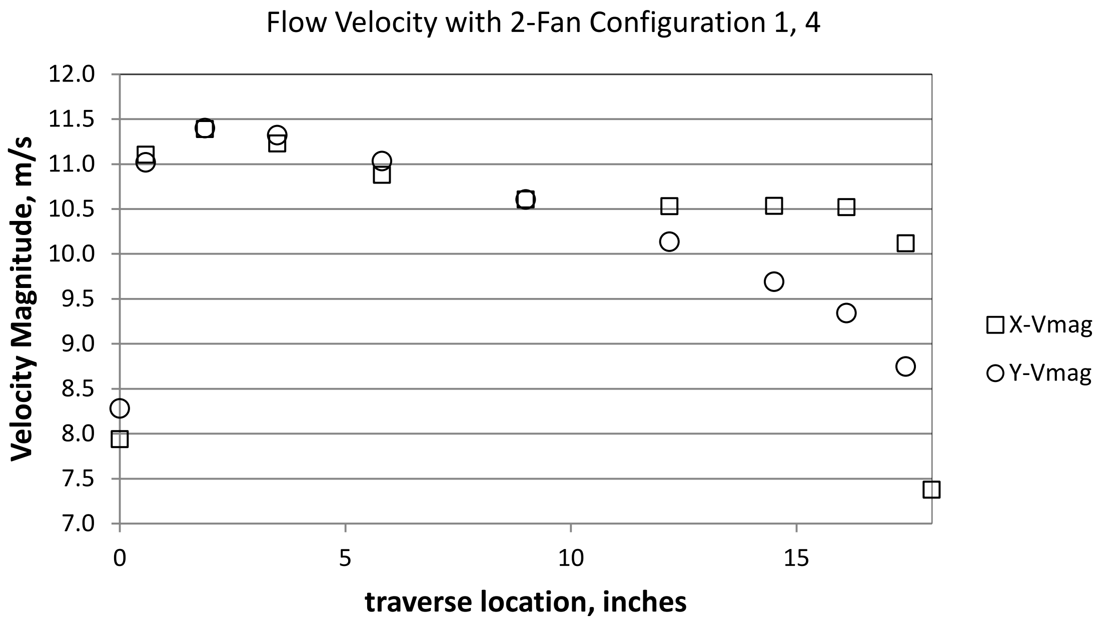


Figure H.13. Simulated results for the 2-fan configuration 1, 4: Flow velocity distribution at the elevation of the sampling system.

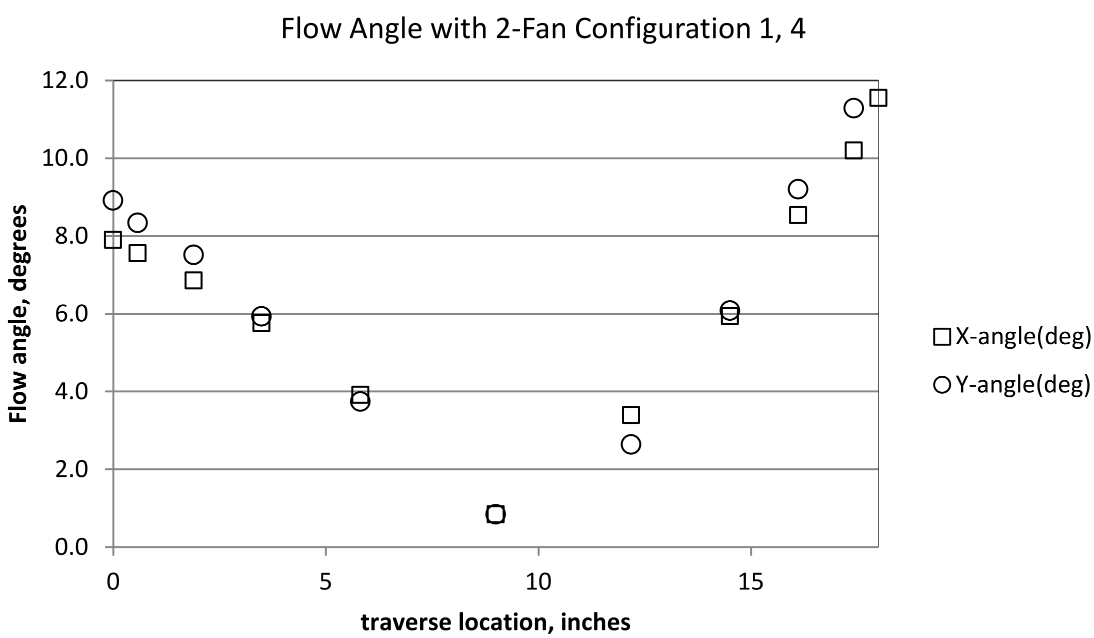


Figure H.14. Simulated results for the 2-fan configuration 1, 4: Cyclonic flow angle at the elevation of the sampling system.

Results: Operation of Fans 2 and 3

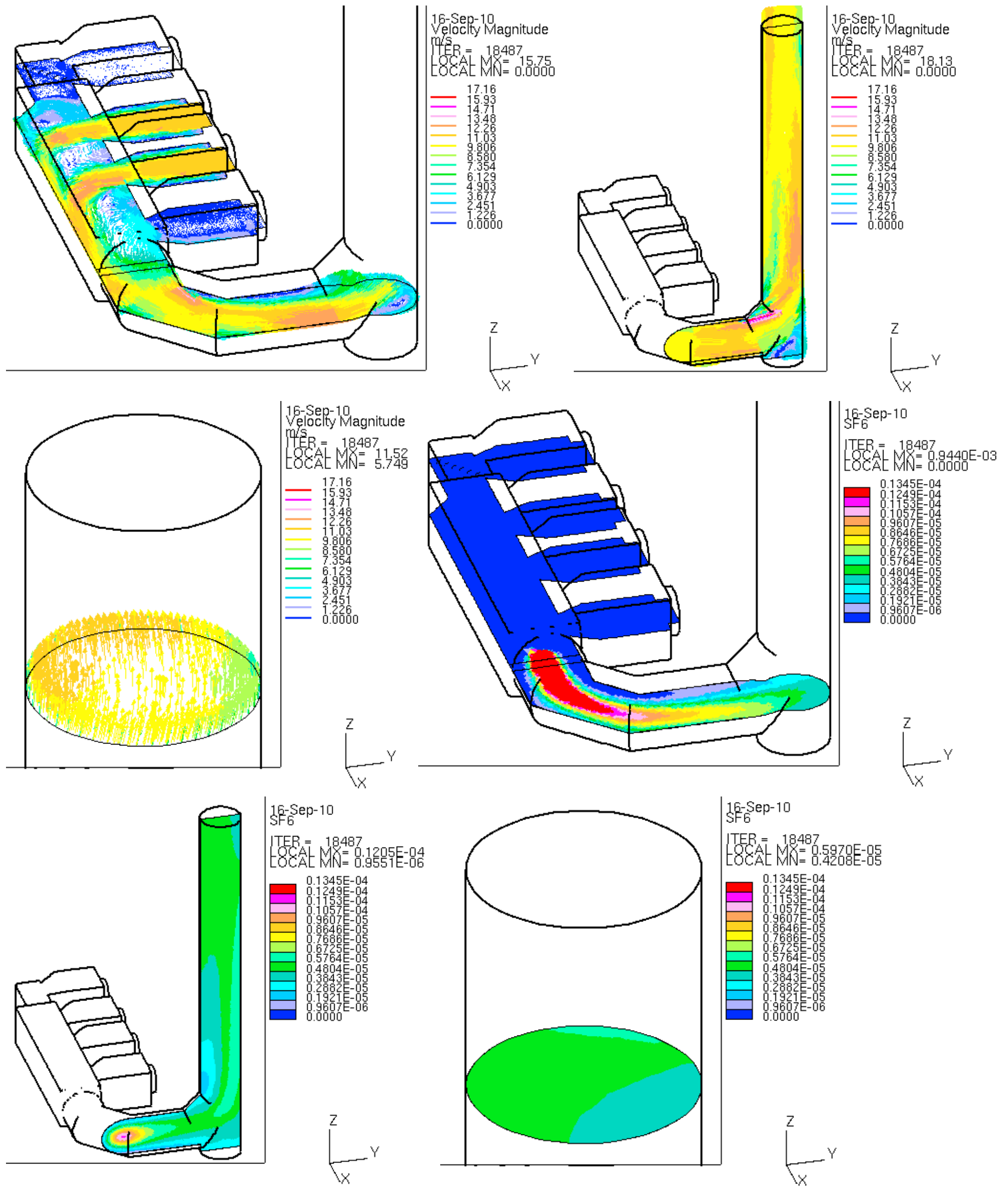
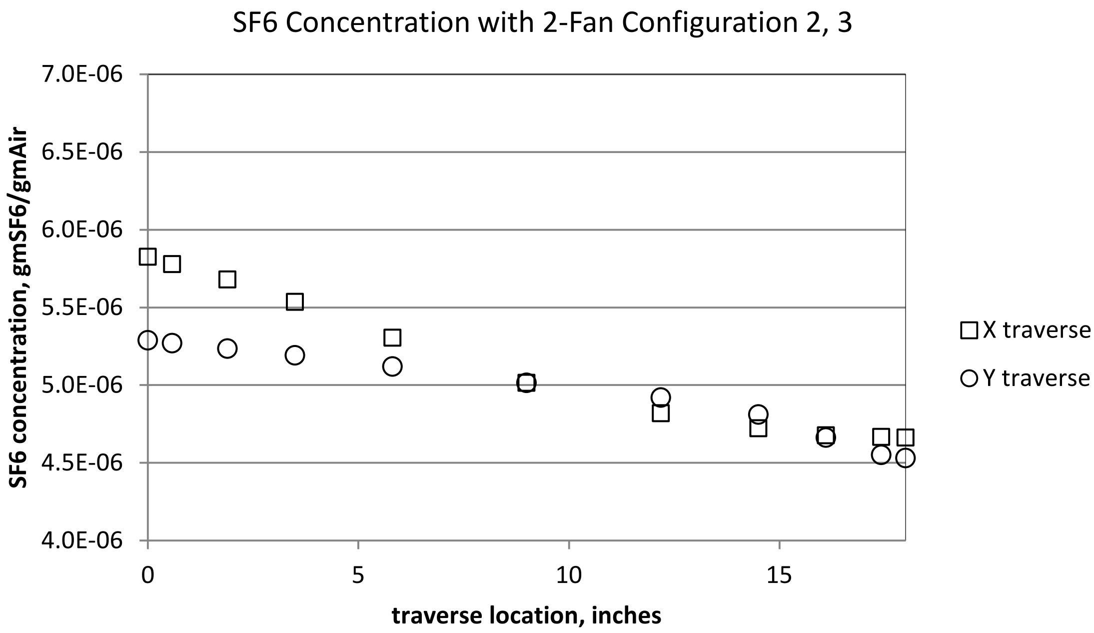
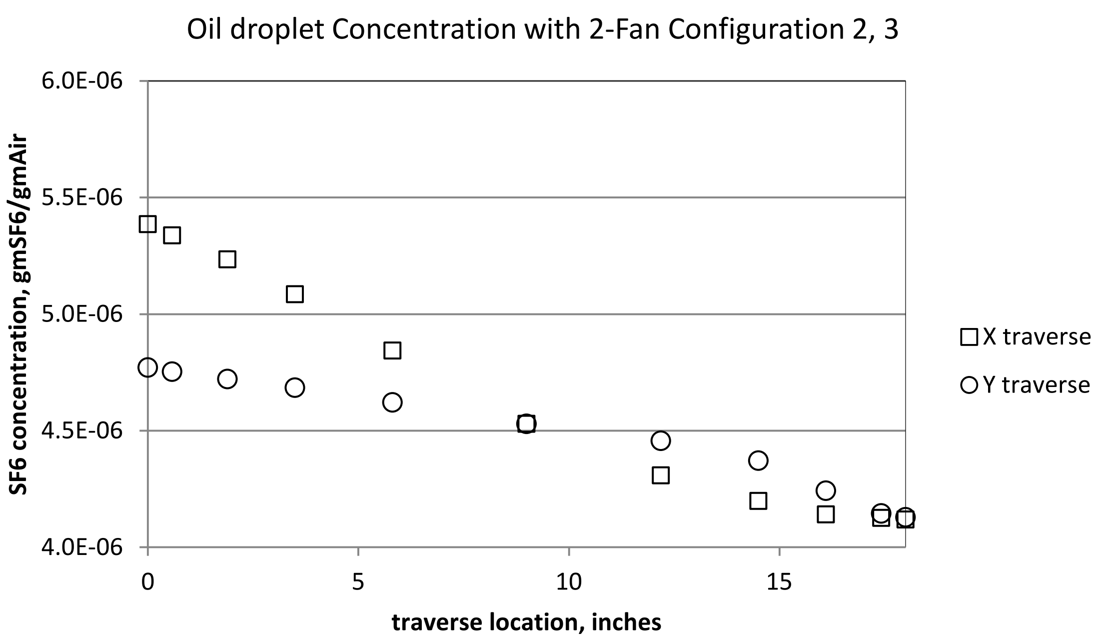


Figure H.15. Simulated flow velocity vectors and tracer gas concentrations for the case with fans 2 and 3 in operation: a) flow velocity in fans and lower ductwork, b) flow velocity in stack, c) velocity distribution in the stack at the elevation of the sampling system, d) tracer gas concentrations in the lower ductwork; tracer gas injected downstream of the fan nearest the stack, e) tracer gas concentrations in the stack, f) tracer gas distribution in the stack at the elevation of the sampling system.



a)



b)

Figure H.16. Simulated results for the 2-fan configuration 2, 3: Concentrations of a) SF6 tracer gas, and b) oil droplets at the elevation of the sampling system.

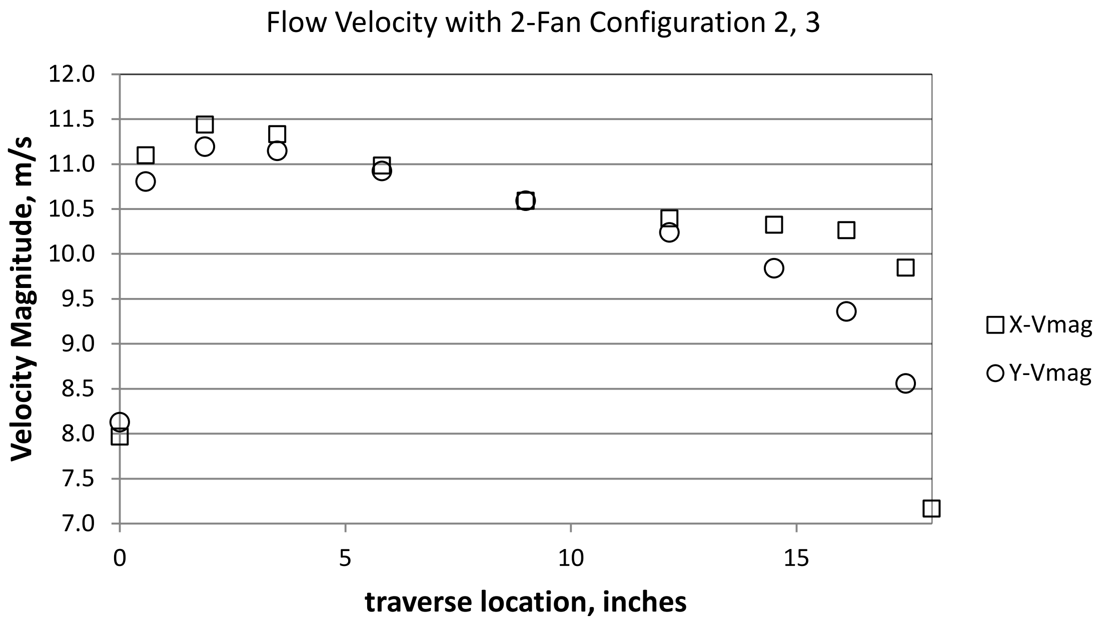


Figure H.17. Simulated results for the 2-fan configuration 2, 3: Flow velocity distribution at the elevation of the sampling system.

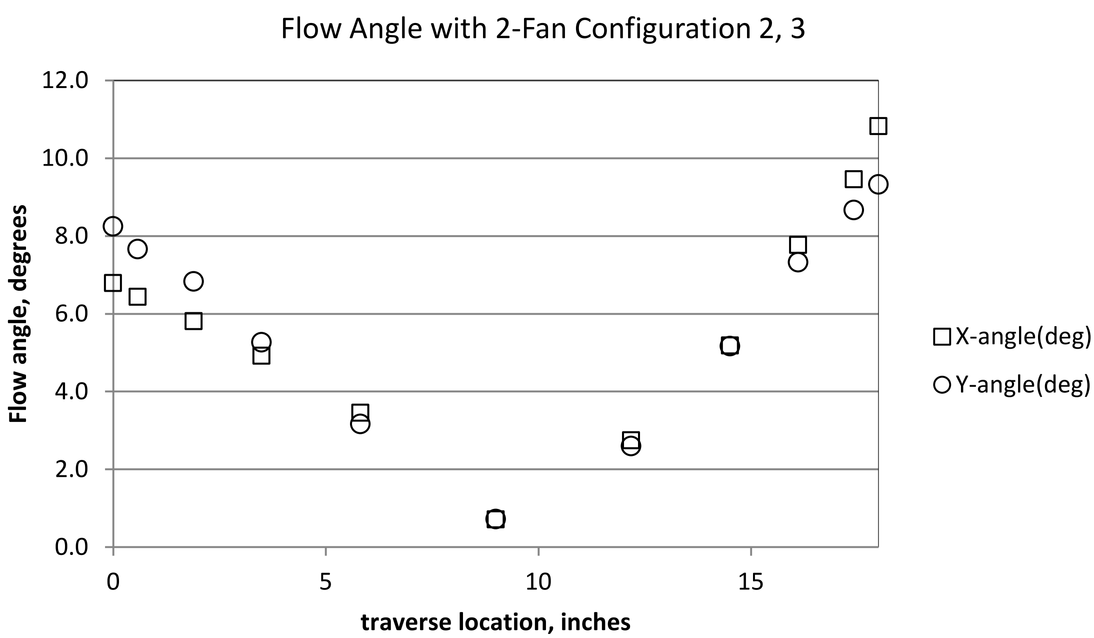


Figure H.18. Simulated results for the 2-fan configuration 2, 3: Cyclonic flow angle at the elevation of the sampling system.

Results: Operation of Fans 2 and 4

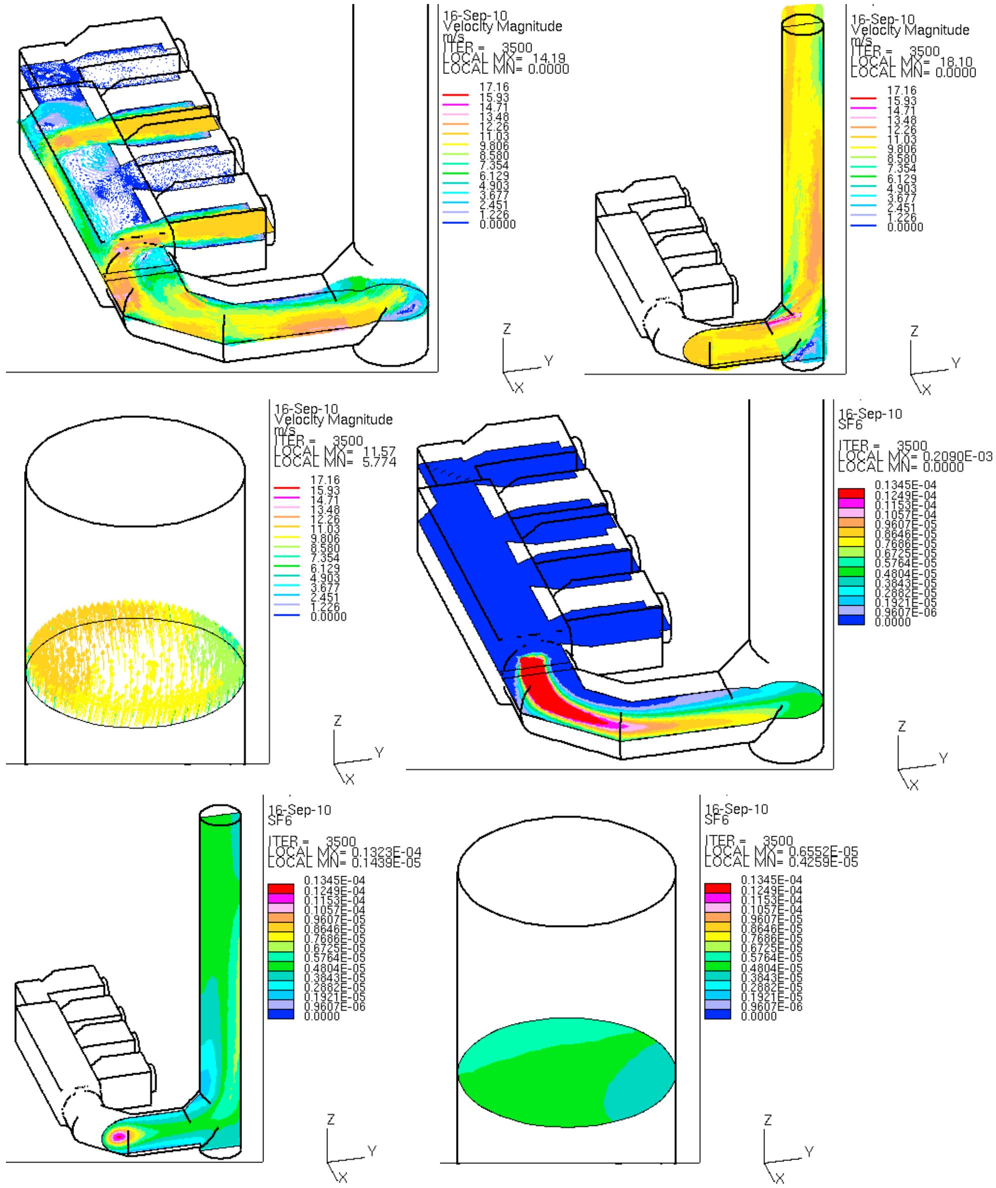
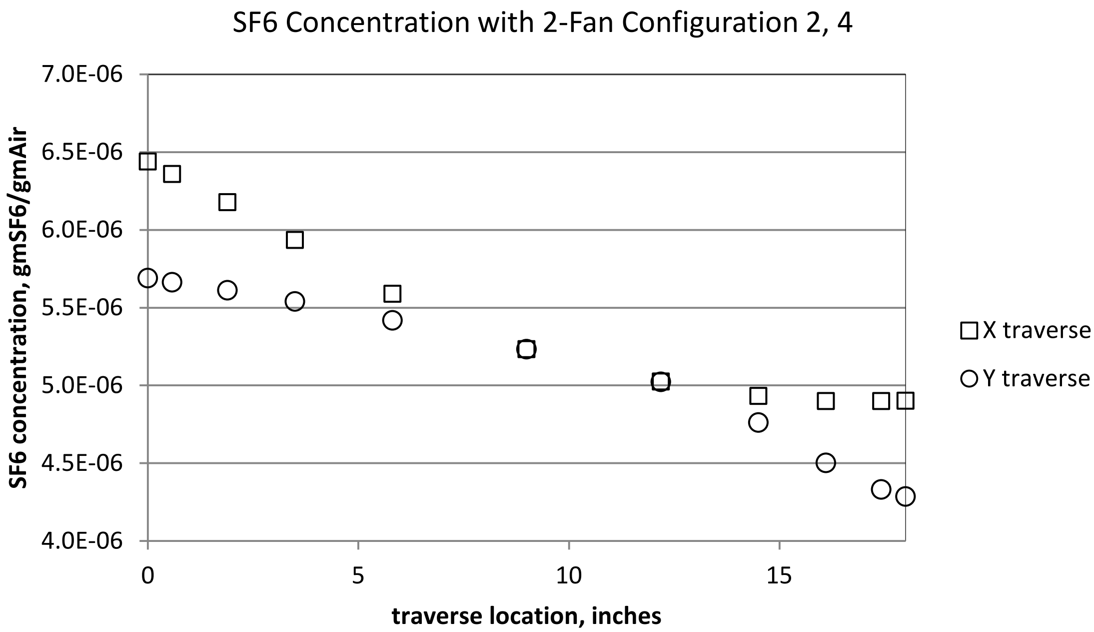
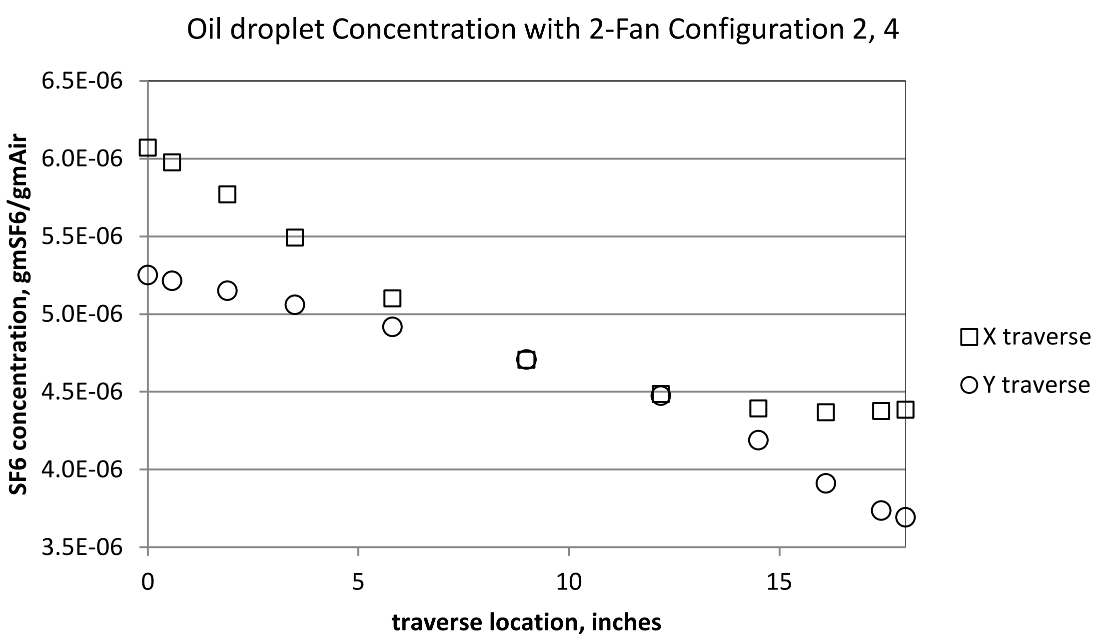


Figure H.19. Simulated flow velocity vectors and tracer gas concentrations for the case with fans 2 and 4 in operation: a) flow velocity in fans and lower ductwork, b) flow velocity in stack, c) velocity distribution in the stack at the elevation of the sampling system, d) tracer gas concentrations in the lower ductwork; tracer gas injected downstream of the fan nearest the stack, e) tracer gas concentrations in the stack, f) tracer gas distribution in the stack at the elevation of the sampling system.



a)



b)

Figure H.20. Simulated results for the 2-fan configuration 2, 4: Concentrations of a) SF6 tracer gas, and b) oil droplets at the elevation of the sampling system.

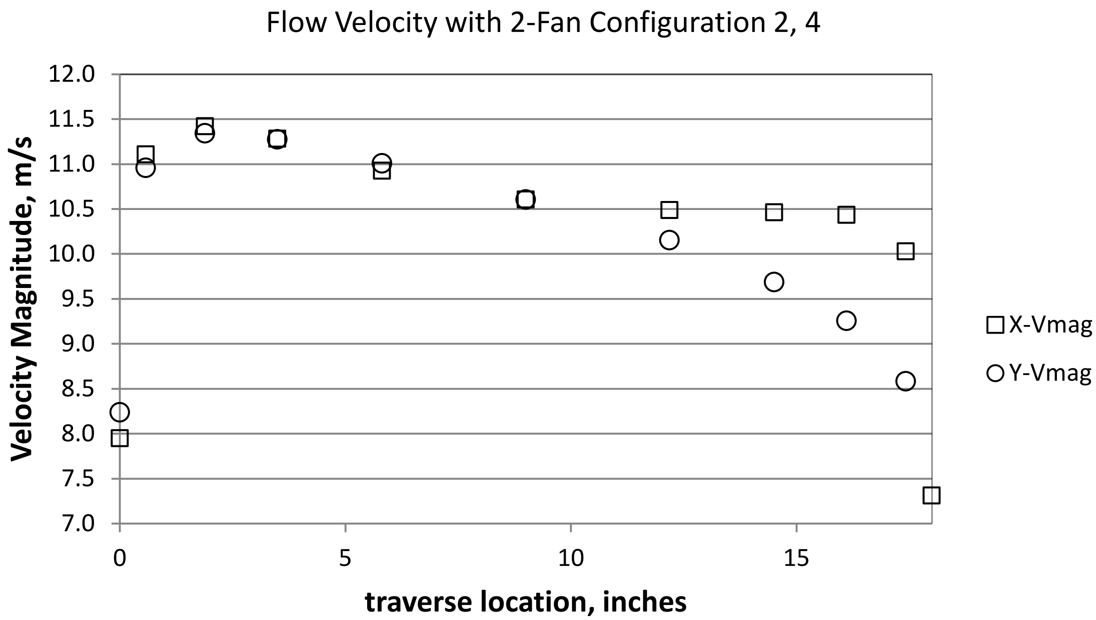


Figure H.21. Simulated results for the 2-fan configuration 2, 4: Flow velocity distribution at the elevation of the sampling system.

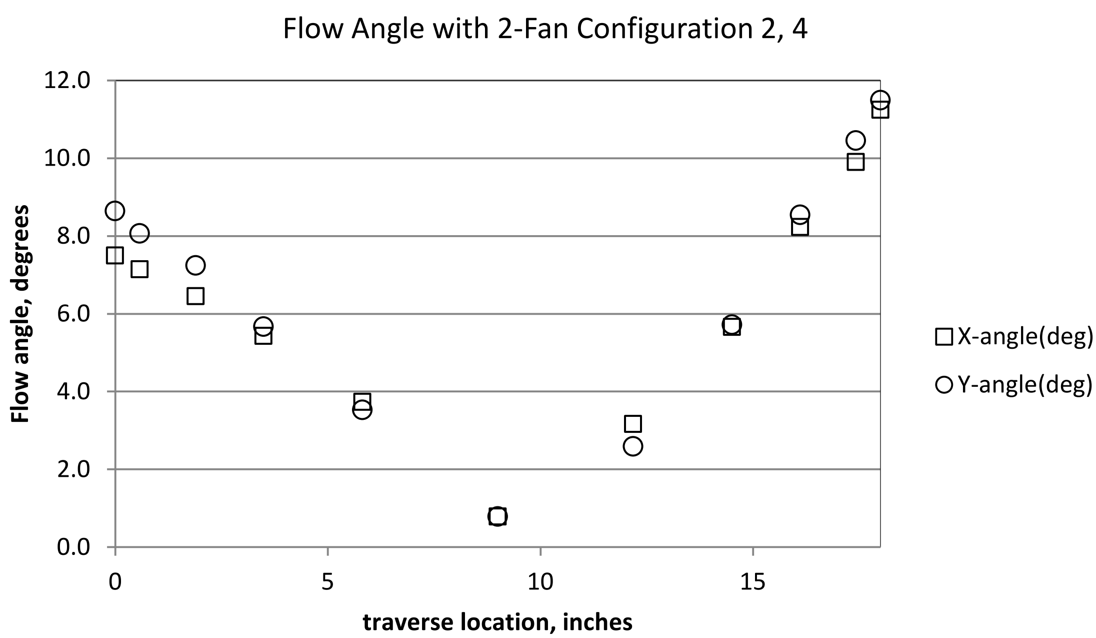


Figure H.22. Simulated results for the 2-fan configuration 2, 4: Cyclonic flow angle at the elevation of the sampling system.

Results: Operation of Fans 3 and 4

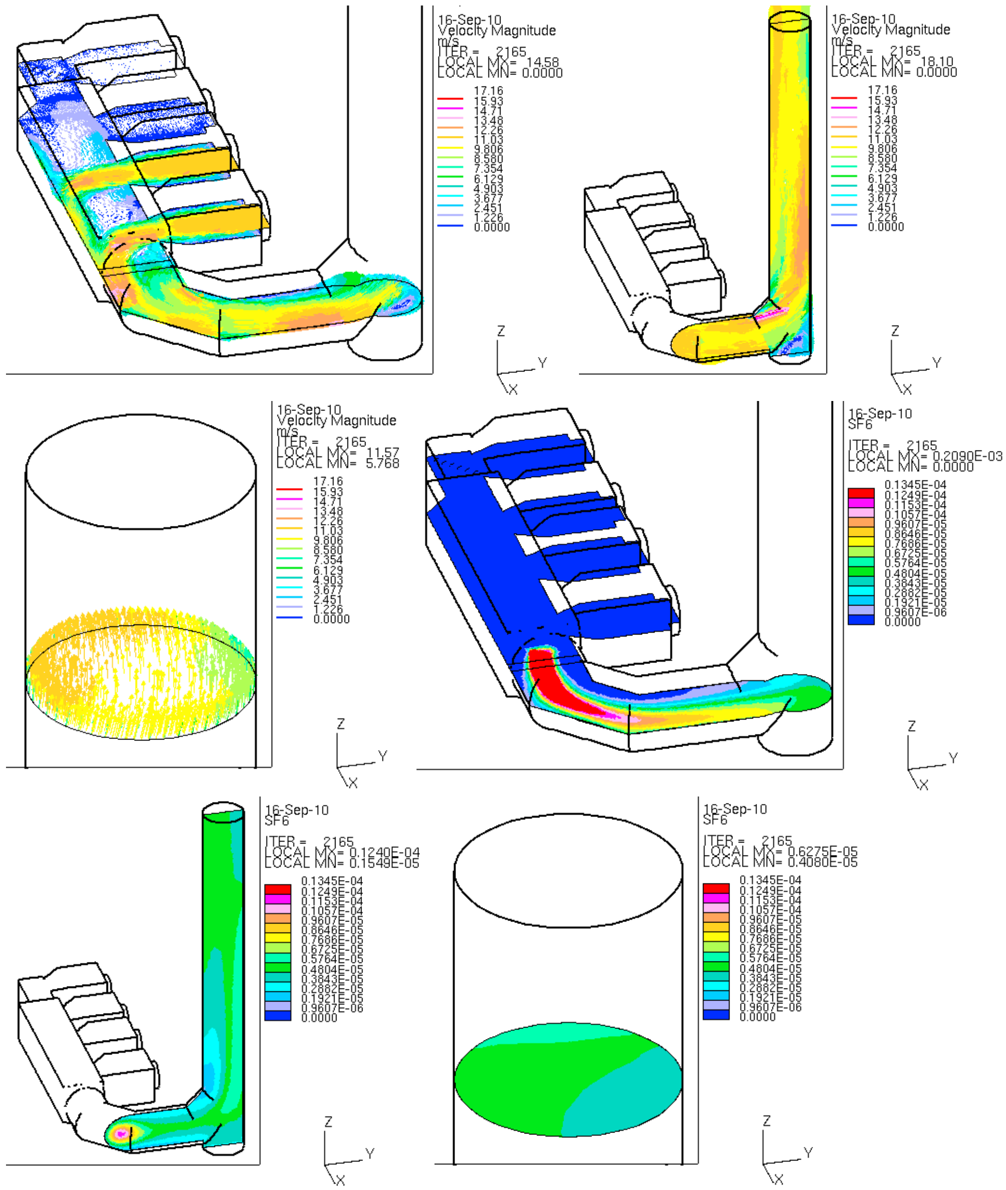
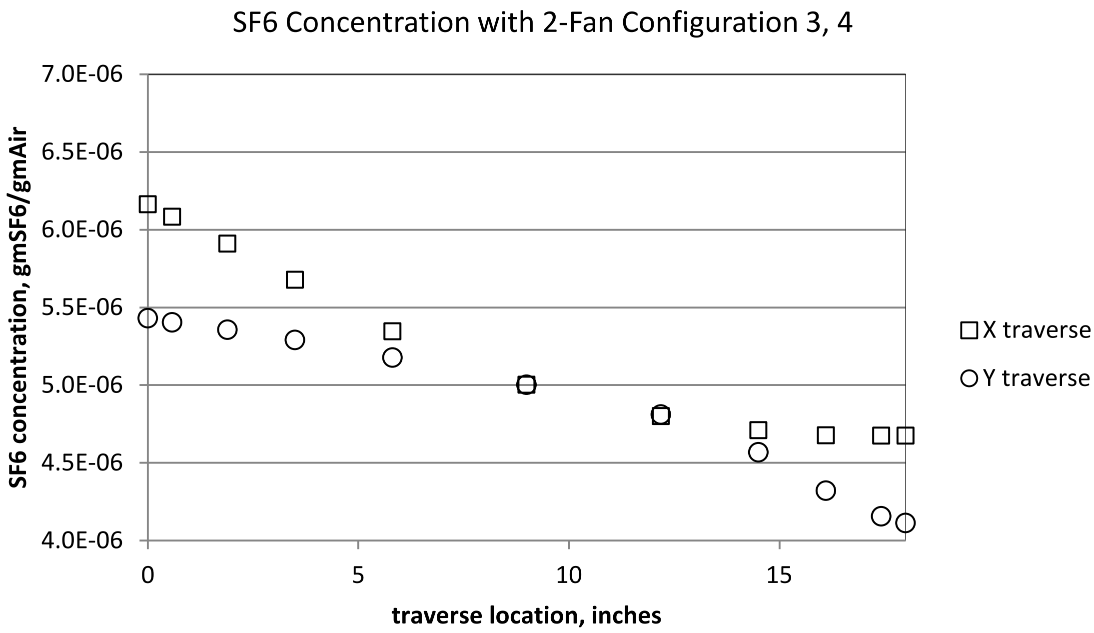
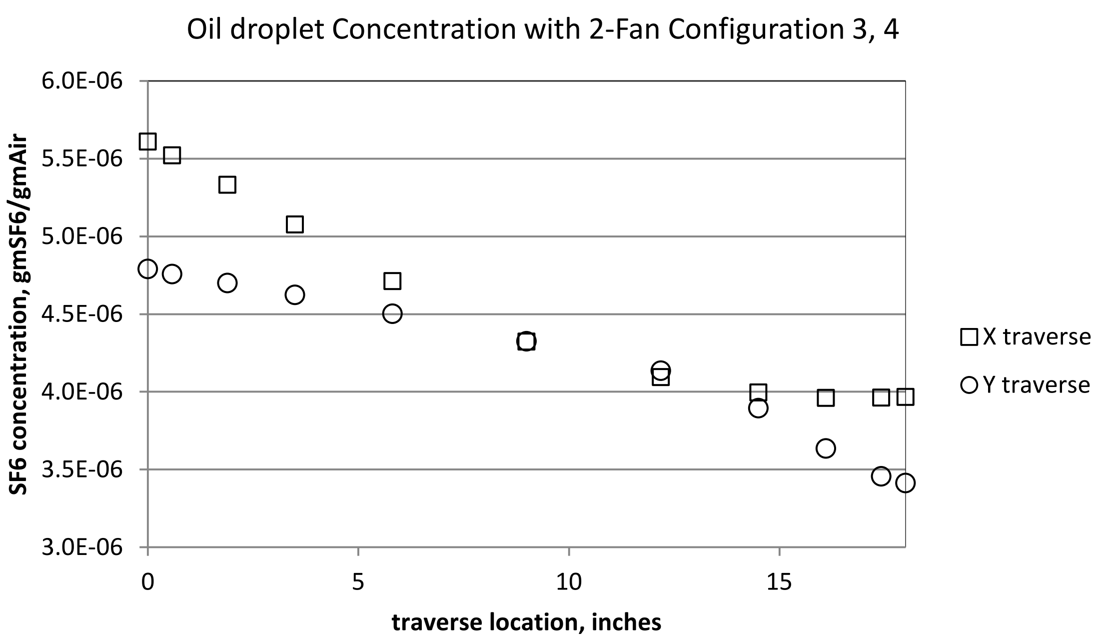


Figure H.23. Simulated flow velocity vectors and tracer gas concentrations for the case with fans 3 and 4 in operation: a) flow velocity in fans and lower ductwork, b) flow velocity in stack, c) velocity distribution in the stack at the elevation of the sampling system, d) tracer gas concentrations in the lower ductwork; tracer gas injected downstream of the fan nearest the stack, e) tracer gas concentrations in the stack, f) tracer gas distribution in the stack at the elevation of the sampling system.



a)



b)

Figure H.24. Simulated results for the 2-fan configuration 3, 4: Concentrations of a) SF6 tracer gas, and b) oil droplets at the elevation of the sampling system.

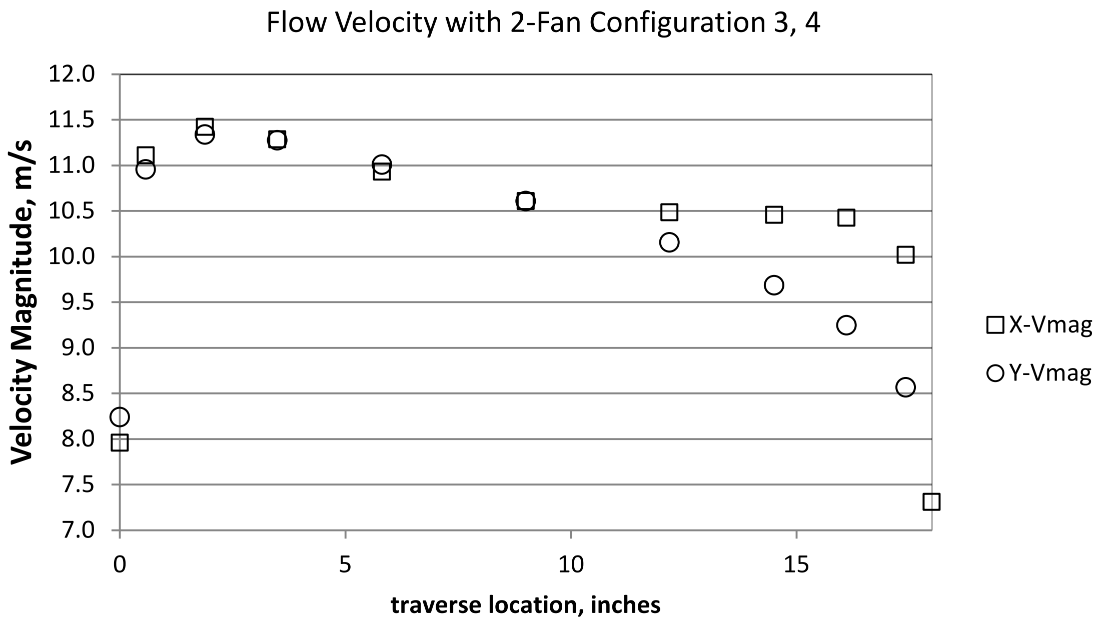


Figure H.25. Simulated results for the 2-fan configuration 3, 4: Flow velocity distribution at the elevation of the sampling system.

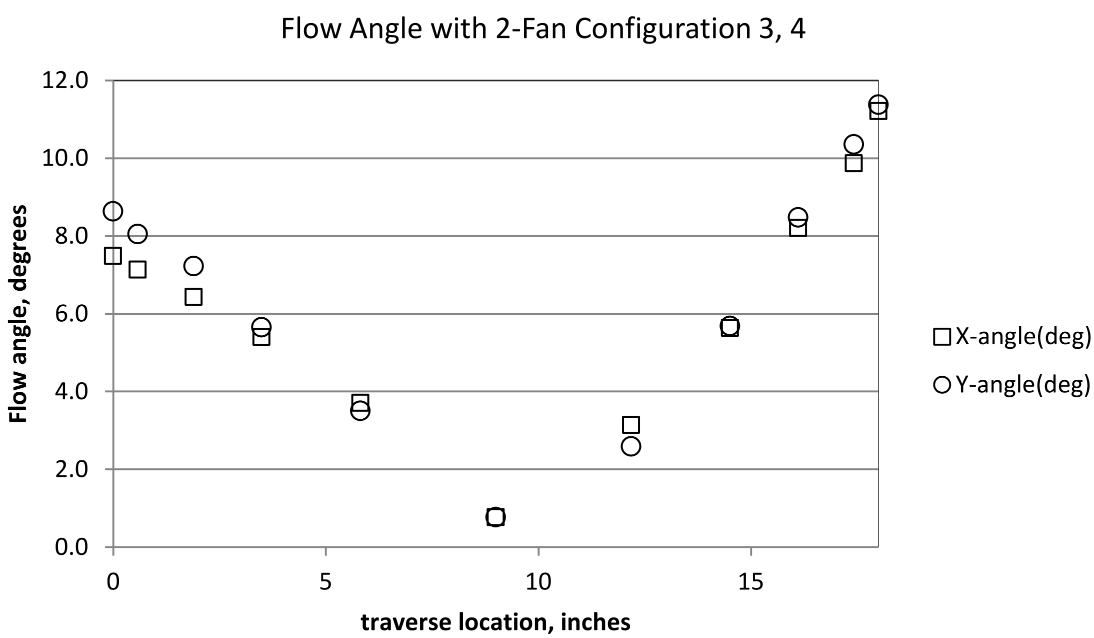


Figure H.26. Simulated results for the 2-fan configuration 3, 4: Cyclonic flow angle at the elevation of the sampling system.

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