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Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Qualification Tests for the New Air Sampling System at the 296-Z-1 Stack

J. A. Glissmeyer
A. D. Maughan
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September 2002

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Summary

This report documents tests performed by Pacific Northwest National Laboratory to verify that the replacement air monitoring system for the 296-Z-1 ventilation exhaust stack meets the applicable regulatory criteria regarding the placement of the air sampling probe and sample transport. These criteria ensure that the contaminants in the stack are well mixed with the airflow at the location of the probe (at approximately the 50-ft level of the stack) so that the collected sample represents the whole. The sequence of tests addresses the

- acceptability of the flow angle relative to the probe
- uniformity of air velocity and gaseous and particle tracers in the cross section of the stack
- delivery of the sample from the sampler nozzle to the collection filter.

The tests conducted on the air monitoring system demonstrated that the location for the air-sampling probe meets all performance criteria for air sampling systems at nuclear facilities. The performance criterion for particle transport was also met. All tests were successful and all acceptance criteria were met.

Acknowledgments

This work was supported by the U.S. Department of Energy under Contract DE-AC06-76RL01830, with project funding from the Nuclear Materials Stabilization Project managed by Fluor Hanford, Inc. The authors wish to acknowledge the technical assistance of Roni Swan, Karl Hadley, and James W. Kelly of Environmental Compliance; and Johnny D. Dick and craft services of the Plutonium Finishing Plant, Fluor Hanford, Inc. for invaluable technical assistance.

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1.0 Introduction

The Plutonium Finishing Plant is in the 200 West Area at the U.S. Department of Energy's (DOE) Hanford Site, near Richland, Washington. Radiological work is conducted within the Plutonium Finishing Plant (PFP). PFP's main ventilation exhaust stack is designated 296-Z-1 and is located to the south of the building and adjacent to the exhaust fan building. The stack monitoring system that measures any radiation escaping via the stack is the subject of this report.

In 2000 and 2001, brief increases in emissions, as measured with the stack monitoring system, occurred that did not correlate with plant operations. Visual examination of sample filters showed visible deposits. During the previous decades of plant operations, ventilation filter and ductwork failures are suspected of causing a buildup and deposition of airborne particulate residues in the ventilation system (Mahoney, et al.. 1996). It was suspected that a buildup of particulate in the air-monitoring probe might also have occurred. In December 2001, a visual inspection of the probe interior was made with a fiber-optic camera. The inspection showed some buildup of deposited particulate in the probe.

It was determined that the deposited material would have to be removed and analyzed to assess the effect on reported emissions. This would be accomplished by removal of the existing probe for analysis and installation of a new probe. It was determined to replace the probe with a probe compliant with ANSI/HPS N13.1-1999 (ANSI 1999). To do so would require a demonstration that the probe location would meet the criteria for uniform mixing for potential contaminants. Consequently, a test program was implemented to determine the compliance with mixing and particle transport criteria.

The size and access limitations of the 291-Z-1 stack make it impractical to conduct the qualification tests on the stack. Therefore, the ANSI/HPS N13.1-1999 criteria for scale model qualification testing were also applied to this stack. A scale model was built and used for the complete qualification testing. Repeating the velocity uniformity test on the actual stack is required for the scale model data to apply.

This report verifies that the proposed new air monitoring system at the 296-Z-1 ventilation exhaust stack will meet the applicable criteria regarding the placement of the air-sampling probe and the transport of the sample to the collection device. The performance criterion, test methods, results, and conclusions are discussed. The detailed test procedures and data sheets are included in the appendices. The governing standard is ANSI/HPS N13.1-1999 (ANSI 1999). Pacific Northwest National Laboratory[1] staff conducted these tests.

[1] Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy.

1.1 Background

On December 15, 1989, 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities," came into effect. This regulation governs portions of the design and implementation of facility effluent air sampling. Further, 40 CFR 61, Subpart H requires the use of isokinetic sampling nozzles as described in American National Standards Institute (ANSI) N13.1-1969 (ANSI 1982). This standard has been replaced by ANSI/HPS N13.1-1999 (ANSI 1999), though this version has yet to be formally incorporated into the U.S. Environmental Protection Agency (EPA) regulation (40 CFR 61, Subpart H). In the interim, EPA has accepted the key features of the updated standard as an accepted alternative to the older version (Nichols[2])[3].

1.2 Ventilation Exhaust Stack Description

Historically, the 296-Z-1 stack has discharged airborne emissions from the process glovebox and the general ventilation air from the 232-Z, 234-5Z, and 236-Z buildings. Currently, there is no airflow coming from the 232-Z building. All exhaust air is filtered through two-stage, high-efficiency particulate air (HEPA) filters prior to discharge.

Fans located in the 291-Z building power the ventilation exhaust flow as diagrammed in Figure 1.1. The air enters a central plenum through ducts from the 232-Z, 234-5Z, and 236-Z buildings. Fans draw the exhaust air from the plenum and force it up the stack. In normal operation, four of seven electric fans are operating and the system airflow is about 280,000 cfm. The operating fans are rotated among the seven fans available. In case of the failure of electrical power, two steam driven fans are automatically started to ensure the flow of air through the plant and the maintenance of the direction of air flow from non-process to process areas to the HEPA filters. The steam driven fans are tested at least monthly, and have a combined airflow of about 192,000 cfm.

The stack has an internal diameter of 16-ft at the base and is about 200 feet tall. Figure 1.2 shows the stack and the shack housing the air sampling probe and monitoring systems. The approximate number of stack diameters from the bottom of the stack to the sampling probe is 3.3.

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[2] Letter from M. D. Nichols (EPA, Assistant Administrator for Air Radiation) to R. F. Pelletier (DOE). 1994, Washington, D.C.

[3] 40CFR61, Subpart H, has been amended to incorporate the newer version of the standard. The effective date is October 9, 2002.

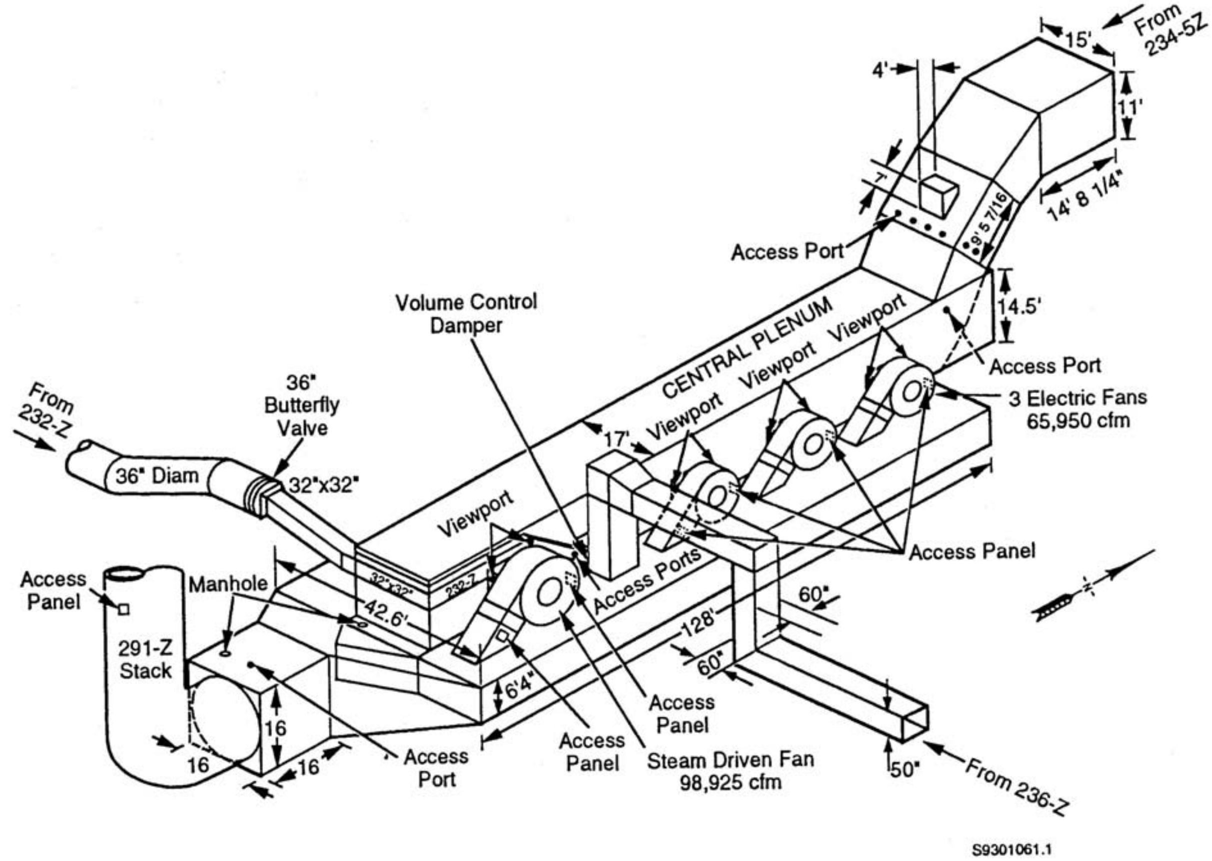

Figure 1.1 Diagram of 291-Z Fan House.

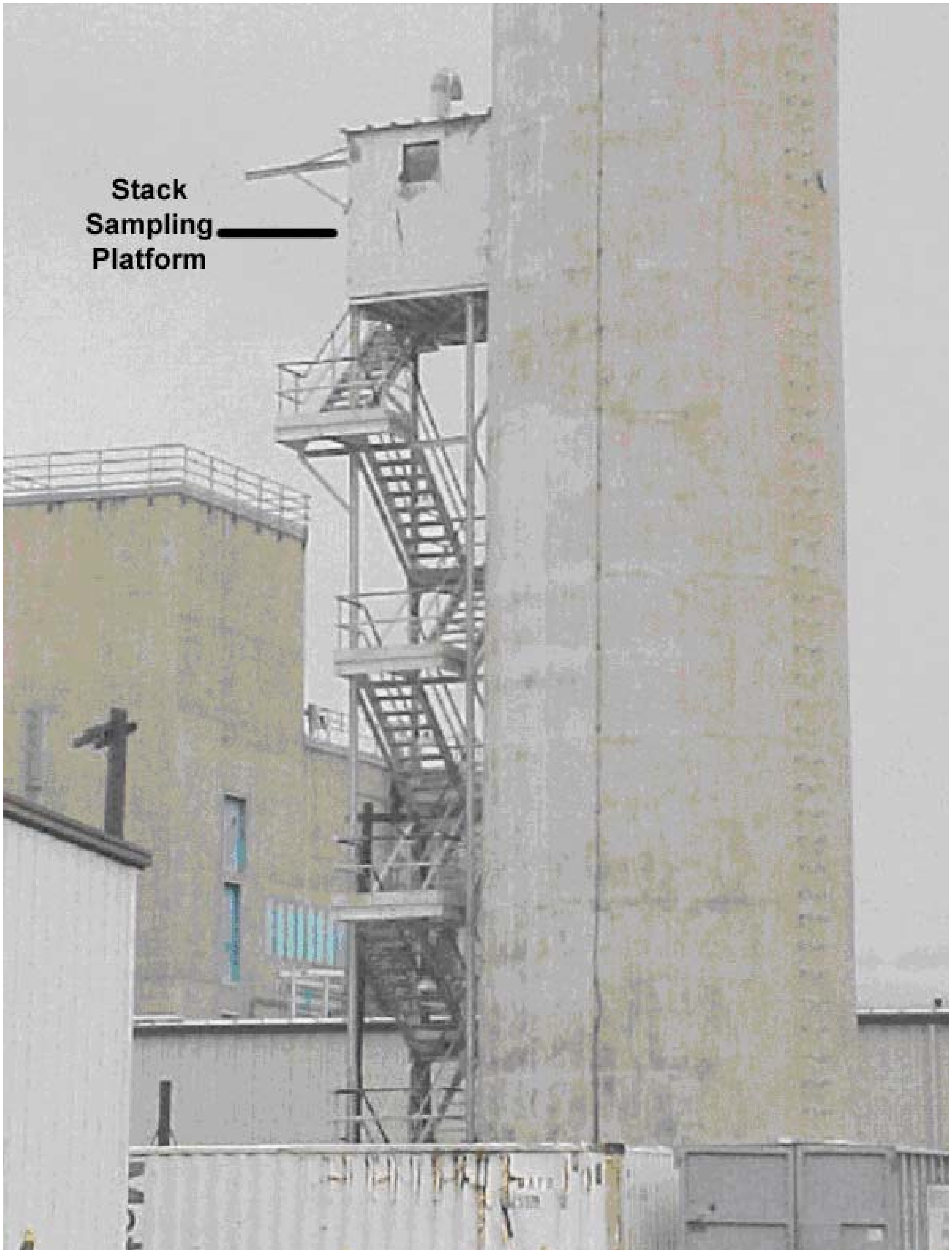

Figure 1.2 296-Z-1 Ventilation Exhaust Stack.

2.0 Qualification Tests

2.1 Performance Criteria

The ANSI/HPS N13.1-1999 performance criteria for sampling nozzle placement and particle transport are described as follows.

1. Uniform Air Velocity – 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 coefficients of variation value, the more uniform the velocity. The acceptance criterion is that the coefficient of variation of the air velocity must be ≤20% across the center two-thirds of the area of the stack.

2. Angular Flow – 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 stack and sampling nozzle by more than 20°.

3. Uniform Concentration of Tracer Gases – A uniform contaminant concentration in the sampling plane enables the extraction of samples that represent the true concentration. This is first tested using a tracer gas. The fan is a good mixer, so injecting the tracer downstream of the fan provides worst-case results[4]. The acceptance criteria are that 1) the coefficient of variation 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. Uniform Concentration of Tracer Particles – 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 air stream. The acceptance criterion is that the coefficient of variation of particle concentration is ≤20% across the center two-thirds of the sampling plane.

5. Sample Extraction and Transport System Performance – The criteria are that 1) nozzle transmission ratio for a 10-µm AD particle is 0.8 to 1.3, 2) nozzle aspiration ratio for a 10-µm AD particle is 0.8 to 1.5, and 3) the test particle penetration through transport system is ≥50% for 10-µm AD particles.

Because a scale model was used to qualify the stack-sampling location, the following additional criteria from ANSI/HPS N13.1-1999 apply.

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[3] Worst-case results are those that might be observed if the fan itself became contaminated and later released contaminants.

1. The model is geometrically similar to the actual stack.
2. The model meets all of the qualification requirements.
3. The actual sampling location is geometrically similar to the model.
4. The product of mean velocity times the hydraulic diameter for the actual stack and the scale model is within a factor of 6.
5. The velocity uniformity of the actual stack meets the qualification requirements.
6. The difference between the actual and model stack velocity coefficients of variation is not more than 5%.

Measurements of velocity uniformity at the actual stack are compared with those from the model to validate the applicability of the model.

Appendix A presents the scaling parameters and performance requirements of the scale model, while Appendix B presents the performance data that supports the model's use. The scale model was approximately 23-feet long and 5-feet wide (i.e., constructed of plywood). The model's 24-inch stack was 9-feet tall and constructed of 24-inch polyvinyl chloride (PVC) duct. All joints were caulked and painted to provide a smooth inside surface. Four 5-horsepower fans were utilized in two configurations for the stack airflow tests. The fans were controlled with a variable speed drive to produce the scaled stack air velocities. The two tracers (gas and particle) were injected in the fan discharge and collected at the stack probe.

In the actual fan house, there are seven electric fans, four of which are used at a time. There are also two steam driven fans for emergency backup that would be used at the same time. The capacities of the electric fans are about 66,000 cfm each. The capacity of the steam-driven fans is about 96,000 cfm each. The fans are located alongside both sides of a central plenum, from which they draw air. In turn, the central plenum draws from 234-5Z. The fans draw from the central plenum and discharge down into ducts on both sides of the central plenum. These side ducts join and discharge into the stack. Table 2.1 is a representation of the fan positions. The turbine fans are denoted as ET8 and ET9. The electric fans are denoted as EF1 through EF7.

When the electric fans are used, which is by far most of the time, the operating fans are typically EF1; one of EF3 or EF4; and EF6 and EF1 or EF5 and EF2 for a total of four at a time. The steam-driven fans are usually only run 15 to 30 min per month for testing. The housings of fans EF1 and EF5 have been found to more contaminated than the others. Also, EF4 and EF3 have modulating dampers for control of negative pressure in 234-5Z.

Table 2.1. Fan Schematic

To Stack				
Side Duct East	ET8	**Central Plenum (Air from 234-5Z)**	ET9	**Side Duct West**
			EF4	
	EF7		EF3	
	EF6		EF2	
	EF5		EF1	

Table 2.2 and Table 2.3 schematically show the two fan configurations tested, with the fans operating as indicated by highlighted backgrounds. Table 2.2 is the emergency backup operating condition, while Table 2.3 is the worst case of normal operation conditions because EF4 is the fan closest to the stack.

Table 2.2. Fan Configuration for Emergency Backup Operating Condition

To Stack				
Side Duct East	ET8	**Central Plenum (Air from 234-5Z)**	ET9	**Side Duct West**
			EF4	
	EF7		EF3	
	EF6		EF2	
	EF5		EF1	

Table 2.3. Fan Configuration for Normal Operating Conditions

To Stack				
Side Duct East	ET8	**Central Plenum (Air from 234-5Z)**	ET9	**Side Duct West**
			EF4	
	EF7		EF3	
	EF6		EF2	
	EF5		EF1	

2.2 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.

2.2.1 Method

To facilitate the performance of this and subsequent tests, it was first necessary to correlate fan speed control (a variable frequency drive) settings and the desired stack flowrates. Following the procedure in Appendix C, the first velocity uniformity measurement (Run VT-1) was made at the maximum set point 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 control setting. The results are plotted in Appendix D. Set points for the desired flowrates were estimated from the plot and used in the test runs (Runs VT-2 to VT-4) to measure velocity uniformity. Run VT-1 also provided a data point for velocity uniformity.

The method to determine velocity uniformity is an adaptation of 40 CFR 60, Appendix D, Methods 1 and 2. The equipment included a standard Prandtl-type pitot tube and a calibrated electronic manometer as shown in Figure 2.1. The procedure is detailed in Appendix E. The grid of measurement points was laid out in accordance with the 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 north-east/south-west direction and also along the south-east/north-west direction.

To verify the applicability of the scale model results, air velocity data was obtained on the actual stack by plant forces. Only one test port was available on the stack, limiting the data obtained to that single direction across the stack. These data were otherwise obtained in accordance with the EPA methods. Data was also obtained from 1976 and 1977 measurements (Glissmeyer, 1992) taken with a thermal anemometer and not in accordance with EPA methods. These data are compared in the following section (PNL 1992).

2.2.2 Results of scale model tests

The acceptance criterion for uniformity of air velocity is:

1) coefficient of variation of the air velocity must be ≤20% across the center two-thirds of the area of the stack.

The measured coefficients of variation across the center two-thirds of the area of the scale model stack are listed in Table 2.4. The data sheets are included in Appendix F. All of the scale model test results for velocity uniformity meet the criterion that the air velocity coefficient of variation be ≤20%. Figure 2.2 shows a bar graph of the mean velocity measured at each point for Run VT-4, one of the scale model results, which most closely correspond to the actual stack.

Table 2.4 Velocity Uniformity Results

Runs	Fan Frequency Setting, Hz	Stack Flow rate acfm	% COV
Four Electric Fan Configuration			
VT-1	51	5973	7.5
VT-2	30	3462	7.5
VT-3	50	5868	7.2
VT-4	50	5750	7.1
Two Turbine Fan Configuration			
VT-5	60	4036	13.7
VT-6	60	4031	12.4
VT-7 30-degree port	60	4077	13.5

Figure 2.1. Velocity Uniformity Measuring Equipment

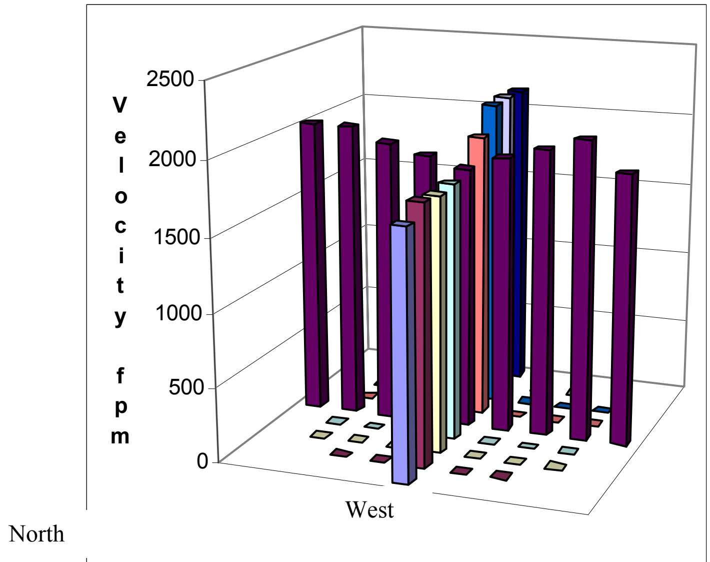


Figure 2.2. Bar graph of velocity measurements from Run VT-4

2.2.3 Comparison of model and actual stack results

Only the single port (30º east of north) was available for measurements on the actual stack, and only four of the electric fans were operating. The velocity data from the recently obtained measurements (PNL 1992) and the scale model results are tabulated in Appendix F. The uniformity results for these data are listed in Table 2.5 for comparison. The upper portion of Table 2.5 show the velocity uniformity results from the scale model, using only the data from the electric fan configuration and for the single transect (the ports 15 degrees from North, except as noted). The recent measurements from the actual stack and the data from PNL (1992) are also listed in the lower portion of Table 2.5. The average of the data from the scale model was 9.4% coefficient of variation, and the acceptance range is then 4.4 to 14.4 % coefficient of variation. The scale model and the actual stack data all fall within the acceptance range and met the criterion for the validity of the scale model tests.

2.3 Angular Flow

Angular flow testing assures an absence of cyclonic flow at the sampling location. That is, 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. Cyclonic flow must be absent so the contaminant concentration is nearly uniform across the stack. Testing was conducted on the scale model stack.

Table 2.5. Velocity Uniformity Comparison of Scale Model and Stack Tests

% Coefficient of Variation Results for North/South Direction	
2001 Scale Model - Electric Fans	
VT 1	9.8
VT 2	9.6
VT 3	9.0
VT 4	9.3
Actual Stack – Electric Fans	
1977 12-Point Method 1 Grid	7.5
2001 8-Point Method 1 Grid 30 degree port	12.8
2001 16-Point Method 1 Grid 30 degree port	11.1

2.3.1 Method

The test method used was based on 40 CFR 60, Appendix D, Method 1, Section 2.4, "Verification of the Absence of Cyclonic Flow." This test was conducted at the normal flow rate in the 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 as shown in Figure 2.3. 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 G provides the detailed procedure.

2.3.2 Results

The acceptance criteria for angular flow is:

1) an average flow-angle of <20° across the sampling plane.

Measurements were made at the same grid points as for the velocity uniformity, and for the grid rotated around the stack another 15º. The acceptance criterion (≤20 degrees) was met in all cases. The results range from 1.8 to 3.9 degrees. Table 2.6 shows a summary of the angular flow testing results. Data sheets for angular flow are presented in Appendix H.

2.4 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.

Table 2.6. Flow Angle Results

Runs	Fan Frequency Setting, Hz	Mean Flow Angle
Four Electric Fan Configuration		
FA-1	50	2
Two Turbine Fan Configuration		
FA-2	60	1.8
FA-3 30-degree port	60	3.9

Figure 2.3. Type-S pitot tube and protractor level used to measure Angular Flow

2.4.1 Method

The concentration uniformity is demonstrated with a tracer gas (sulfur hexafluoride) injected into the exhaust duct, downstream of the fan, between the dampers and the stack as shown if Figure 2.4. The concentration of the tracer gas is then measured near the sampling probe using the same grid of points as used in the other tests. From the measurements, the coefficient of variation 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 shown in Figure 2.5. A Bruel and Kjaer (Naerum, Denmark) Model 1302 gas analyzer, calibrated for the tracer gas, is used for the measurements. The procedure data sheets are detailed in Appendix I and Appendix J, respectively.

2.4.2 Results

The acceptance criteria for uniformity of tracer gases are:

1) the coefficient of variation 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 2.7 lists the tests performed and their results. In the electric fan configuration, detailed tests were performed with the tracer injected at the outlets of Fans EF4 (assumed to be the worst case) and EF7 (assumed to be the next worst case). Five injection points were used in each case – centerline or the indicated corners. Corner injections were made within 1.5 inches (25% of a hydraulic diameter) of the corners of the duct from the fan to the plenum (see Figure 2.4). Tests were also made with centerline injections at the other two fans. Uniformity results ranged from 0.7 to 4.0 % coefficient of variation. The maximum deviations from the means ranged from 1.6 to 5.3 %.

In the turbine fan configuration, it was assumed that the two fans were symmetrically discharging to the stack. Multiple injection positions were used for Fan ET9 and just the centerline position was used for Fan ET8. As expected, the uniformity results and maximum deviations were somewhat higher for this configuration than for the electric fan configuration. This was because these fans are the closest to the stack base. The results when the measurement ports were rotated 15º farther around the stack were comparable to those for the ports 15º from North.

In all cases, the acceptance criteria were met. This was surprising given that the sampling point was only 3.3 stack diameters above the base of the stack and that the airflow from both sides of the fan house joins just upstream of the stack base. It is speculated that this junction of the two streams is turbulent enough to provide good mixing, even when the tracer is injected on one side of the fan house.

Figure 2.4 Tracer Gas Injection Location

Figure 2.5 Tracer Gas Probe and Analyzer

Table 2.7. Summarization of Gas Tracer Uniformity Results

Four Electric Fan Configuration

Run	Injection Point	% COV	Max % Dev
	Fan EF4		
GT-1	Center	0.8	-1.9
GT-2	Top-west	1.9	4.2
GT-3	Top-east	1.8	-2.9
GT-4	Bottom-west	1.7	3.9
GT-5&13	Bottom East	4.0, 0.8	-5.3, 2.2
	Fan EF7		
GT-6	Center	0.7	1.6
GT-7	Top-west	1.2	-3.3
GT-8	Top-east	0.7	-1.4
GT-9	Bottom-west	1.5	2.7
GT-10	Bottom-east	1.3	2.9
GT-11	EF5 Center	1.0	2.4
GT-12	EF1 Center	1.0	1.8

Two Turbine Fan Configuration

Run	Injection Point	% COV	Max % Dev
	Fan ET9		
GT-14	Center	5.0	9.0
GT-15	West side	4.4	-8.9
GT-16	East side	3.6	7.5
GT-17	Bottom-east	4.3	8.3
GT-18	Bottom-west	4.6	-9.3
GT-19	Top-west	4.3	9.9
GT-20	Top-east	4.1	8.1
	Fan ET8		
	Centerline		
GT-21, 22	15 degree port	4.6, 4.0	-8.2, 8.0
GT-23	30 degree port	3.7	7.1

2.5 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.

2.5.1 Method

The test method for uniformity of tracer particles is similar to the test for uniformity 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 2.6.

A simple probe was used to extract the sample from the stack and transport it to the optical particle counter[5] arranged as shown in Figure 2.7. The optical particle counter sorts the number of particles into six size channels. Only the reading from the size channel that measures particles in the 9 to 11 um 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 coefficient of variation 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 K and Appendix L, respectively.

[5] Optical Particle Counter (OPC), Met-One Model A2408, Grants Pass, Oregon.

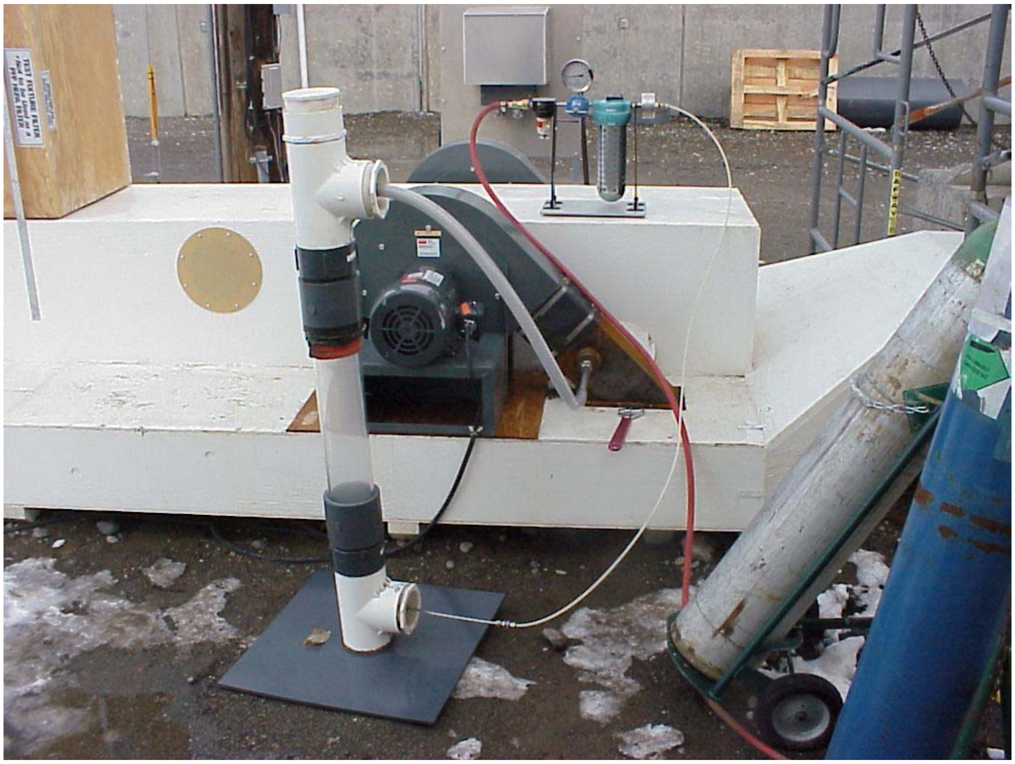


Figure 2.6. Particle Generator and Injection Point

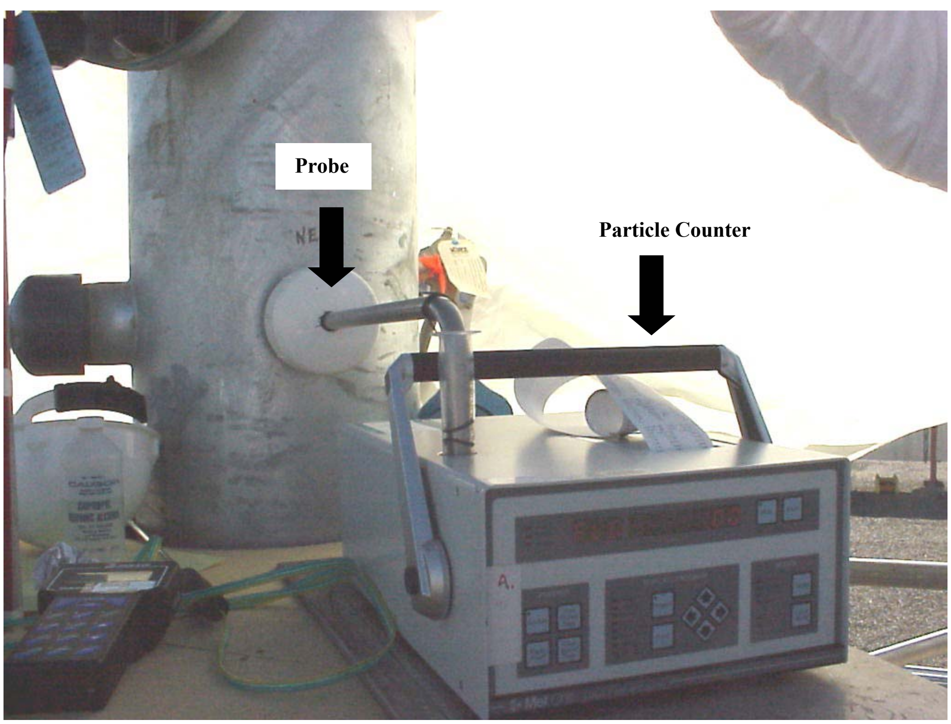


Figure 2.7. Optical Particle Counter and Probe Arrangement for a Particle Uniformity Test

2.5.2 Results

The acceptance criteria for uniformity of tracer particle is:

1) a coefficient of variation less than 20%, for the tracer particles of the 10-µm ranges, across the center two-thirds of the sampling plane.

Tests were conducted for both fan configurations. The results are summarized in Table 2.8 and the data sheets are included in Appendix L. The results show slightly more uniformity for the electric fan configuration than for the turbine fan configuration. However, in all cases, the performance criterion was easily met. Figure 2.8 is a bar chart showing the normalized concentration data for the first test at 1733 acfm.

The coefficients of variation results labeled "raw" are 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.

Table 2.8. Particle Tracer Uniformity Results for the Center Two-Thirds of the Stack

Runs	Injection Point	Un-normalized % COV	Normalized % COV
Four Electric Fan Configuration			
PT-1	EF-4 Center	5.8	3.0
PT-2	EF-7 Center	9.1	3.1
PT-3	EF-7 Center	8.1	2.6
PT-4	EF-7 Center	11.7	2.9
Two Turbine Fan Configuration			
PT-5	ET-8 Center	7.5	5.6
PT-6	ET-9 Center	6.7	5.6
PT-7	ET-8 Center	10.3	4.6
PT-8	ET-9 Center-30 degree port	5.8	5.8

2.6 Sample Extraction and Transport System Performance

The acceptance criteria for sample extraction and transport system performance are:

1) nozzle transmission ratio for a 10 µm AD particle is 0.8 to 1.3
2) nozzle aspiration ratio for a 10 µm AD particle is 0.8 to 1.5
3) the test particle penetration through transport system is ≥50% for 10 µm AD particles.

The nozzle characteristics are inherent in the design and were verified in wind-tunnel tests (McFarland et al. 1989; Glissmeyer and Ligotke 1995) and in the manufacturer's submittals.

Particle penetration through the sampling lines was assessed using the DEPOSITION 2001a code (McFarland, et. al., 2002). The sample transport elements modeled in the code include sampling nozzles, straight tubes at any angle to the horizontal plane, bends, splitters, and expansions and contractions in tube size. The nozzle design factors are addressed in DEPOSITION; however, the results are combined into the overall transmission result for the nozzle and not stated separately.

Figure 2.8 is a DEPOSITION 2001a rendered diagram of the segments of the sampler tubing. The DEPOSITION input parameters and characteristics of the sampling system elements are listed in Table 2.9. Total penetration results were calculated assuming a constant sample flow rate (2 cfm per branch of the splitter) and a stack velocity of 5 and 9.2 m/s (992 and 1811 fpm). This range of stack velocity should cover the range of conditions using either the electric or turbine fans. The total penetration results at 9.2 m/s were 86.2% and 84.3% for the left and right branches of the splitter outlet. The results at 5 m/s were 80.7% and 78.8% for the left and right branches respectively. These exceed the acceptance criterion. Figures 2.9 and 2.10 show the detailed output of the code for the two stack air velocities.

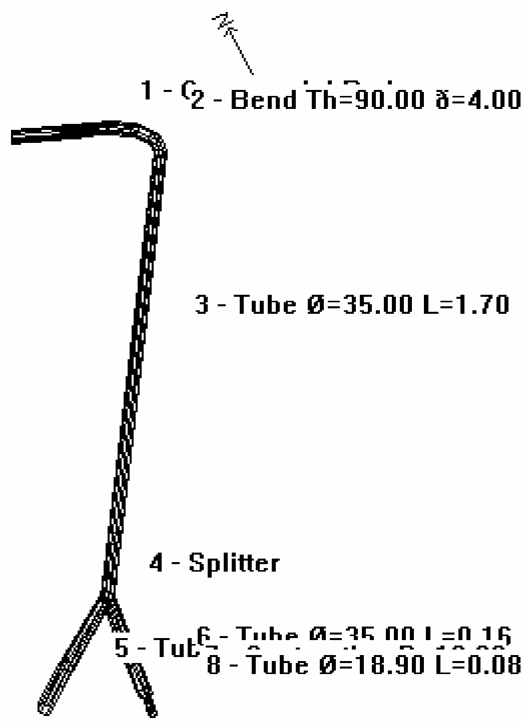


Figure 2.8. Diagram of the Sampling System Tubing Elements (view distorted to show all) parts)

Table 2.9. DEPOSITION 2001a Input Parameters

Element #	Element	Notes
1.	Probe	Probe diameter: 18.3 mm, Shroud diameter: 53.8 mm, Velocity reduction ratio 3.31
2.	Bend	Bend angle: 90.000°
3.	Tube	Length: 1.700 m, At 0.000 degrees from horizontal
4.	Splitter	30º angle, Outlet Diameter: 24 mm
Right Branch		
5.	Tube	Length: 0.160 m, At 0.000 degrees from horizontal
6.	Contraction	Half angle of contraction: 45.000 degrees, Area ratio: 0.292, Outlet Diameter: 18.9mm
7.	Tube	Length: 0.083 m, At 0.000 degrees from horizontal
Left Branch		
8.	Tube	Length: 0.186 m
Ambient temperature (deg. C): 25.0		
Ambient pressure (mm Hg): 760		
Flow rate (L/min): 113.2		
Free stream velocity (m/s): 5 – 9.2		
Particle diameter (µm): 10.0		

```
TOTAL PENETRATION-LEFT BRANCH

Total Penetration:    86.2%
#          Component           Penetration
1          Commercial Probe     98.8%
2          Bend                 98.5%
3          Tube                 90.9%
4          Splitter            98.4%
5          Tube                 99.0%
Stokes Number:      0.0168
Reynolds Number:      4380


NOTES:

1. Penetration is only valid for the flow rate of 114.


<< Calculations were made with the best possible >>
<< extrapolations of the model(s).               >>
TOTAL PENETRATION-RIGHT BRANCH

Total Penetration:    84.3%
#          Component           Penetration
1          Commercial Probe     98.8%
2          Bend                 98.5%
3          Tube                 90.9%
4          Splitter            98.4%
5          Tube                 99.1%
6          Contraction          98.6%
7          Tube                 99.0%
Stokes Number:      0.1069
Reynolds Number:      8111


NOTES:

1. Penetration is only valid for the flow rate of 114.


<< Calculations were made with the best possible >>
```

Figure 2.9 DEPOSITION 2001a results for 9.2 m/s

```
TOTAL PENETRATION-LEFT BRANCH

Total Penetration:     80.7%
#          Component            Penetration
1          Commercial Probe      92.5%
2          Bend                  98.5%
3          Tube                  90.9%
4          Splitter             98.4%
5          Tube                  99.0%
Stokes Number:       0.0168
Reynolds Number:       4380


NOTES:

1. Penetration is only valid for the flow rate of 114.


<< Calculations were made with the best possible >>
<< extrapolations of the model(s).               >>
TOTAL PENETRATION-RIGHT BRANCH

Total Penetration:     78.8%
#          Component            Penetration
1          Commercial Probe      92.5%
2          Bend                  98.5%
3          Tube                  90.9%
4          Splitter             98.4%
5          Tube                  99.1%
6          Contraction           98.6%
7          Tube                  99.0%
Stokes Number:       0.1069
Reynolds Number:       8111


NOTES:

1. Penetration is only valid for the flow rate of 114.


<< Calculations were made with the best possible >>
```

Figure 2.10 Deposition 2001a results for 5 m/s

3.0 Conclusions

The tests conducted for the replacement air sampling probe for the 291-Z-1 stack demonstrated that the location for the air-sampling probe meets all performance criteria for air sampling systems at nuclear facilities. The tests on the scale model were shown to apply to the actual stack as indicated by the comparison of velocity uniformity results. Table 3.1 summarizes the conclusions for these tests.

With regard to the last row in the table, the compliance of the sampling nozzle with certain detailed acceptance criteria were not separately tested in connection with this installation. These two acceptance criteria for nozzles are that the transmission be in the 0.8 to 1.3 range and that the aspiration ratio be in the 0.8 to 1.5 range for 10-µm-AD particles. The nozzle characteristics are inherent in the design and were verified previously in wind tunnel tests (McFarland et al. 1989; Glissmeyer and Ligotke 1995) and in the manufacturer's submittals. These factors are addressed in the modeling done with DEPOSITION 2001a; however, the results are combined into the overall transmission result for the nozzle and not stated separately. This study concludes that these criteria are met.

Table 3.1. Conclusions on Air Sampling System Tests

Test	Runs/Configuration	Results	Criteria	Meets
Flow angle on model stack	1 w/electric fan	2°	<20°	Yes
	2 w/turbine fan	1.8° and 3.9°		Yes
Velocity uni-formity on model stack	4 w/electric fan	7.1, 7.2, 7.5, 7.5 % COV	COV ≤20%	Yes
	3 w/turbine fan	13.7, 12.4, 13.5 % COV		Yes
Velocity uni-formity comparison, single transect	4 w/model stack, electric fan	9.8, 9.6, 9.0, 9.3 % COV	Agree within +/- 5 % COV	Yes
	2 EPA grid measurements on actual stack	12.8, 11.1 % COV		
Gas tracer uni-formity on model stack	6 w/electric fan, injected downstream of EF4	0.8 - 4.0 %COV 1.9 - 5.3 % deviation from mean	COV ≤20% in center 2/3 of stack ≤30% maximum deviation from mean	Yes
	5 w/electric fan injected downstream of EF7	0.7 – 1.5 % COV, 1.4 – 2.9 % deviation from mean		Yes
	1 w/electric fan injected downstream of EF5	1.0 % COV, 2.4 % deviation from mean		Yes

	5 w/electric fan injected downstream of EF1	1.0 % COV, 1.8 % deviation from mean		Yes
	7 w/turbine fan injected downstream of ET9	3.6 – 5.0 % COV, 8.1 – 9.9 % deviation from mean		Yes
	3 w/turbine fan injected downstream of ET8	3.7 – 4.6 % COV, 7.1 – 8.2 % deviation from mean		Yes
Particle tracer uniformity on model stack. Time normalized results.	1 w/electric fan, injected downstream of EF4	3.0 % COV	COV ≤20% in center 2/3 of stack	Yes
	3 w/electric fan, injected downstream of EF7	2.6 – 3.1 % COV		Yes
	2 w/turbine fan injected downstream of ET8	4.6 – 5.6 % COV		Yes
	2 w/turbine fan injected downstream of ET9	5.6 – 5.8 % COV		Yes
Particle pene-tration from free stream to filter	5 m/s	80.7 & 78.8 % L & R branches	≥50% for 10 µm AD particles Yes	Yes
	9.2 m/s	86.2 & 84.3 % L & R branches		Yes

4.0 References

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

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

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

American National Standards Institute (ANSI). 1982. *Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities*. AANSI N13.1-1969, American National Standards Institute, New York.

American National Standards Institute (ANSI). 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, New York.

Glissmeyer, J. A., and M. W. Ligotke. 1995. *Generic Air Sampler Probe Tests*. PNL-10816, Pacific Northwest Laboratory, Richland, Washington.

McFarland, A. R., C. A. Ortiz, M. E. Moore, R. E. DeOtte, Jr., and A. Somasundaram. 1989. "A Shrouded Aerosol Sampling Probe." *Environ. Sci. Technol*. 23:1487-1492.

McFarland, A. R., A. M. Nagaraj, H. Ramakrishna, J. L. Rea, J. Thompson. 2002. *Deposition 2001*. Aerosol Technology Laboratory, Department of Mechanical Engineering Texas A&M University College Station TX. http://www.mengr.tamu.edu/research/AerosolLab/index.html

PNL. 1992. *Experimental Performance Evaluation of Two Stack Sampling Systems in a Plutonium Facility,* PNL-8037. J. A. Glissmeyer, Pacific Northwest Laboratory, Richland, Washington.

Appendix A
Scaling Parameters Stack Model Schematics

A.1 Discussion

A scaling factor of 1:8.5 was selected so the model's velocity at the scaled flowrate was about the same as in the actual stack. The key scaled dimensions are listed in Tables A.1 and A.2. Figure A.1 shows the assembled scale model with filters mounted on central plenum Figures A.2 and A.3 show the model's transition from round stack to side plenums, while Figure A.4 shows the key dimensions of the model.

Table A.1 Model Parameters

Section	Prototype	Scale 1:X 8.50
Round Duct Section	Stack base	24
Diam, ft	16.00	1.958
Area, ft2	201.1	3.01
Flow at min Q/D, cfm	280000	5712
Vel fpm	1393	1896
Re	2.4E+06	3.9E+05
Ratio Re		6.00
Rectangular Duct Section		South end, 2 electric fans running
height or diam., ft	6.50	0.76
width or diam., ft	14.83	1.75
Hyd Dia ft	9.04	1.06
Area, ft2	96.4	1.3
Flow at min Q/D, cfm	140000	2745
Vel fpm	1452	2057
Re	1.4E+06	2.3E+05
Ratio Re		6.00
Rectangular Duct Section		South end, turbine fan running
height or diam., ft	6.50	0.76
width or diam., ft	14.83	1.74
Hyd Dia ft	9.04	1.06
Area, ft2	96.4	1.3
Flow at min Q/D, cfm	96000	1882
Vel fpm	996	1411
Re	9.5E+05	1.6E+05
Ratio Re		6.00

Table A.2. Key Scaled Dimensions

Dimension scaling, 1:x		Final ft	Final in.
Section	**Prototype**	8.50	8.50
Stack diam base	16	1.882	22 9/16
Stack diam at probe	15.7	1.847	22 3/16
El. Of probe	53.333	6.274	75 5/16
Round horzntl length	7	0.824	9 14/16
Square block at base	16	1.882	22 9/16
block length	16	1.882	22 9/16
slope length	19.333	2.274	27 5/16
prow length	9.66667	1.137	13 10/16
side width	14.8333	1.745	20 15/16
side height	6.5	0.765	9 3/16
side length	129.833	15.274	183 5/16
plenum width	15	1.765	21 3/16
plenum height	20	2.353	28 4/16
plenum length	129.833	15.274	183 5/16
El Fan Dis Ht	5.5417	0.652	7 13/16
El Fan Dis Width	3.0833	0.363	4 6/16
Plenum to El. Fan C.L.	5	0.588	7 1/16
Plenum-Steam fan CL	6	0.706	8 8/16
Ldg Edge Fan fr Transtn	6.5	0.765	9 3/16
Ldg Edge Fan fr Transtn	27.167	3.196	38 6/16
Ldg Edge Fan fr Transtn	51.167	6.020	72 4/16
Ldg Edge Fan fr Transtn	75.167	8.843	106 2/16
Ldg Edge Fan fr Transtn	99.167	11.667	140

Figure A.1 Assembled scale model with filters mounted on central plenum

Figure A.2 Transition from round stack to side plenums

Figure A.3 Transition from round stack to side plenums

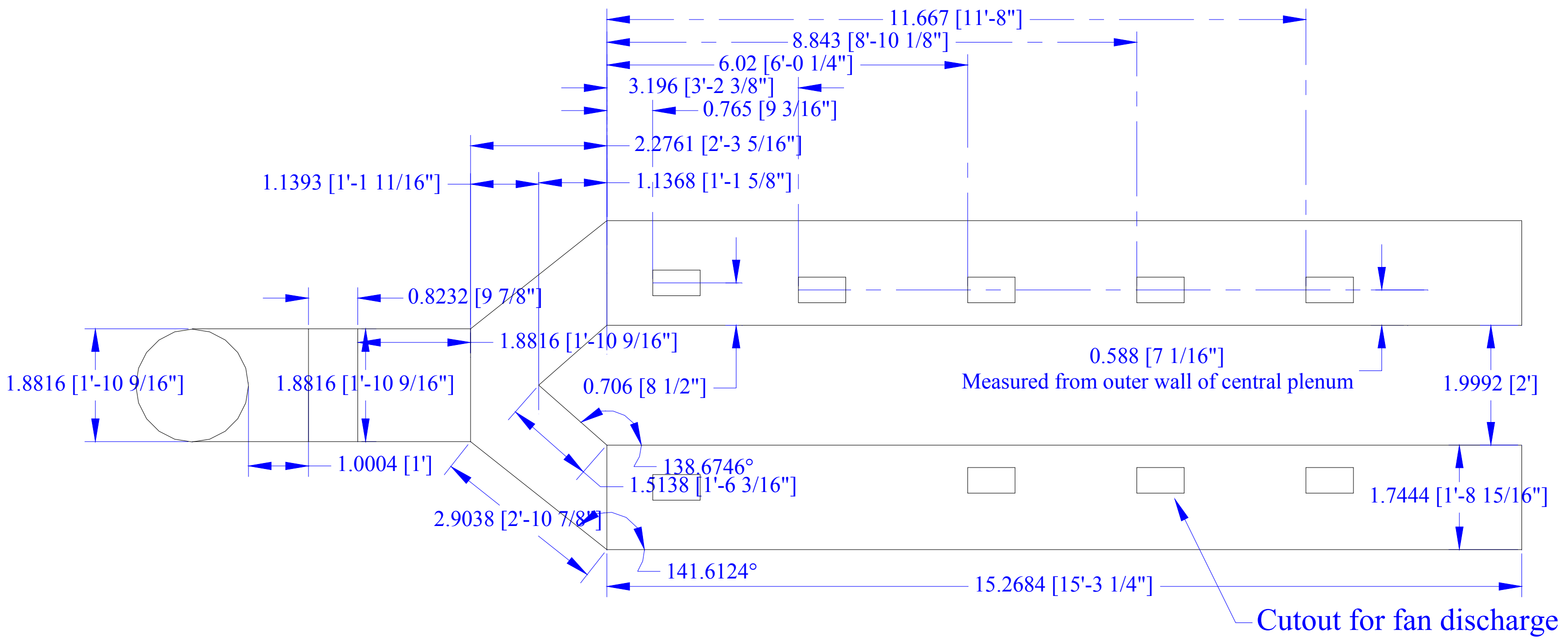


Figure A.4 Key model dimensions

Appendix B
Fan Speed vs. Flow Rate Correlation Procedure

B.1 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 is used when needed to facilitate testing these characteristics. This procedure is a means to quickly correlate flow control device settings with the ventilation flowrate in a stack or duct. This correlation is determined prior to other tests of the stack monitoring system. This correlation makes it easier to set the flow control to achieve repeatable values of flowrate. Other procedures that may follow address flow angle, uniformity of gas velocity, and uniformity of gas and aerosol contaminants.

B.2 Applicability

This procedure can be used in the field or on modeled stacks and ducts to determine the correlation between stack flow control settings and the measured stack flowrate. The tests are applicable to effluent stacks or ducts within the following constraints:

- The available range of adjustment in the ventilation flowrate of the system being tested or modeled.
- The operating limits of the air velocity measurement device used.

This procedure may need to be repeated if there are significant changes made in the ventilation system or loading of the ventilation filters.

B.3 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.

B.4 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.

B.5 Equipment Used for Measurements

The following are essential items of equipment:

- Calibrated slant tube or electronic manometer,
- Pitot tube,
- Platform, ladders, or manlifts as needed to access the test ports,
- Fittings to limit leakage around the pitot tube in the test port and to stabilize the pitot tube so it can be positioned repeatedly.

B.6 Work Instructions for Setup, Measurements, and Data Reduction

Job specific instructions given in the test instruction, illustrated in Exhibit D, will provide specific details and operating parameters necessary to perform this procedure.

> **Note.** The grid of velocity measurement points is calculated in accordance with 40 CFR 60, Appendix A, Method 1. A center point is also added.

Preliminary Steps:

Verify that the interior dimensions of the stack or duct at the measurement location agree with those used in calculating the grid of measurement points given in the test instruction or data sheet. The measurement location should be approximately the same as the air sampling nozzle openings.

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

Verify that the flow control device is capable of the flow control settings given in the Test Instruction, particularly that setting to be used for the detailed velocity traverse.

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. 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.

Mark the pitot tube for each point in the measurement grid. Use a permanent marker so the inlet can be placed at each successive measurement point.

Obtain barometric, temperature, and relative humidity information for the flow measurement location. Air temperature can be measured in the stack with a calibrated instrument during the velocity traverses.

Attach the manometer to the pitot tube. Insert the pitot tube in the stack and seal the opening around the pitot tube.

Flow Measurement

Set the flow controller as instructed for the detailed velocity traverse.

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

Measure and record, on the data sheet, the velocity or differential 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.

Repeat Step 6.2.3. Perform two or three repetitions of the measurements in each traverse direction, two if it is highly repeatable, three if not so repeatable.

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

Calculate the average air velocity and identify the point(s) where the velocity most nearly equals the average.

Estimated Flow at Other Settings

Prepare a data sheet for recording average air velocity measured over the range of flow control settings. (See Exhibit B.)

Place the pitot tube at the point of average velocity as determined in Step 6.2.6.

Record the velocity reading for each flow controller setting specified in the Test Instruction.

Repeat Step 6.3.3 two times for a total of three replicate measurements at each flow setting.

Calculate the mean velocity and flowrate corresponding to each flow controller setting.

Plot the mean velocity and flow versus flow controller setting as illustrated in Exhibit C. Calculate the equation of the line fitting the data.

Review the datasheets for completeness.

Sign and date the datasheets attesting to their validity.

Figure B.1. 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		

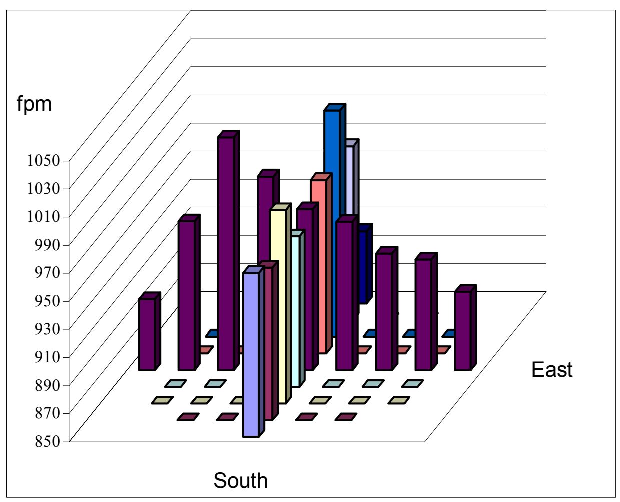
Traverse-->		East				South			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.								
1	0.50	892	884	932	902.7	970	980	950	966.7
2	0.66	909	935	933	925.7	955	961	960	958.7
3	1.23	948	912	930	930.0	979	1005	979	987.7
4	2.04	946	961	951	952.7	963	951	957	957.0
Center	3.16	955	970	960	961.7	978	955	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-03

Signature/Date

Figure B.2. Illustration of Velocity vs. Flow Controller Setting Data Sheer

VELOCITY vs. FLOW CONTROL SETTING DATA FORM

Site	W420 6-inch Stack, Bldg. 305	Run No.	**VFMay6_1**
Date	5/6/98	Stack Temp	72 deg. F
Tester	D. Maughan	Stack RH%	44 % outdoor
Stack Dia.	6.375 inch	Baro Press	995 mbar, sta. 300A;
Stack X-Area	31.9 sq. in.		static 5 Hz 0.05 mbar
Elevation		Fan Setting	
El. above disturbance		Offset to index	

Reference point used from detailed velocity traverse: Pt. 5 on S>N Transect

Velocity Readings, units = fpm

Controller Hz	1	2	3	Mean	StDev	Flow, cfm	Static Pressure	Other Conditions
5	231	217	204	217.3	13.5	48	0.1	With inlet filter
10	470	459	453	460.7	8.6	102		
15	720	756	731	735.7	18.4	163		
20	978	973	1003	984.7	16.1	218		
25	1200	1204	1219	1207.7	10.0	268		
30	1481	1478	1517	1492.0	21.7	331	2.2	
35	1730	1731	1747	1736.0	9.5	385		
40	2014	2017	2022	2017.7	4.0	447		
45	2217	2232	2301	2250.0	44.8	498		
50	2461	2498	2495	2484.7	20.6	550		
55	2703	2706	2717	2708.7	7.4	600		
60	2988	3007	3103	3032.7	61.6	672	8.6	

Notes:

Each reading is the running average of approximately 40 points

The stack inlet filter, before the HEPA, has a moderate dust loading.

Instuments Used:	**Cal Exp. Date:**
Solomat Zephyr Ser# 12951472, Cal# 521-28-09-001	2/7/99

Signature signifying compliance with Procedure EMS-JAG-03

Signature/Date

Figure B.3. Plot of Flowrate vs. Controller Setting

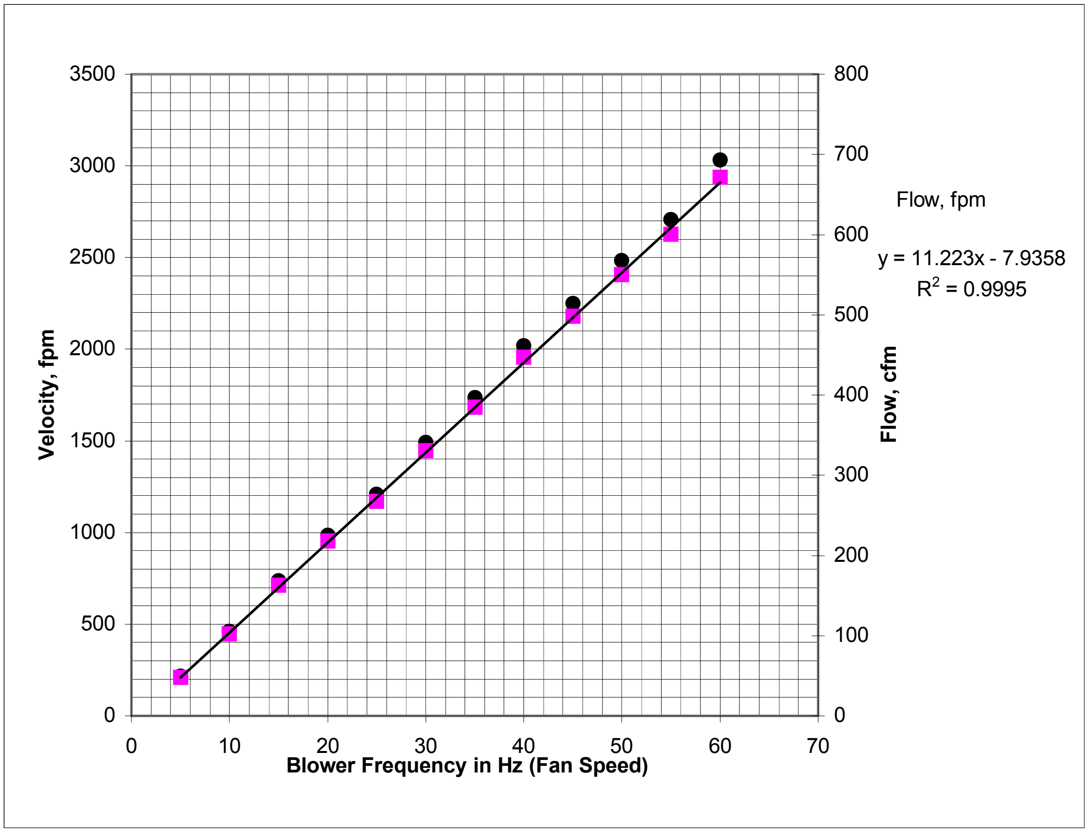
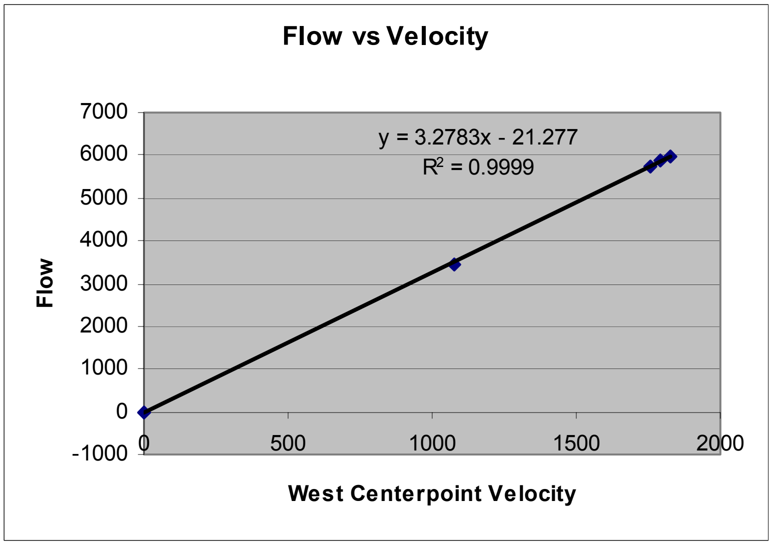


Figure B.4. Illustrative Test Instruction

Test Instruction		
Project: W420 6" Stack Calibration 28361	Date: August 19, 1998	Work Package: **K83017**
Tests: Calibration of Ventilation Flow Controller for W420 6" Full-Scale Model Stack		
Staff: David Maughan		
Reference Procedures: 1. Operating Manual for Solomat Zephyr 2. Procedure EMS-JAG-03 Test to Calibrate Ventilation Flow Controller, Rev. 0, Nov. 20, 1998		
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 flow controller calibration 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 with the flow controller set at 30 Hz. 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 on the controller over the 5 - 60 Hz range 7. Record and plot the data 6. Diagram mounting fixtures and retain assembly for subsequent tests		
Desired Completion Date:		
Approvals: ______________________________ ____________ John Glissmeyer, project manager Date		
Test completed by: Date:		

Appendix C
Fan Speed vs. Flow Rate Correlation Data Plots

Figure C.1. Flow vs. Velocity Correlations for Electric Fans



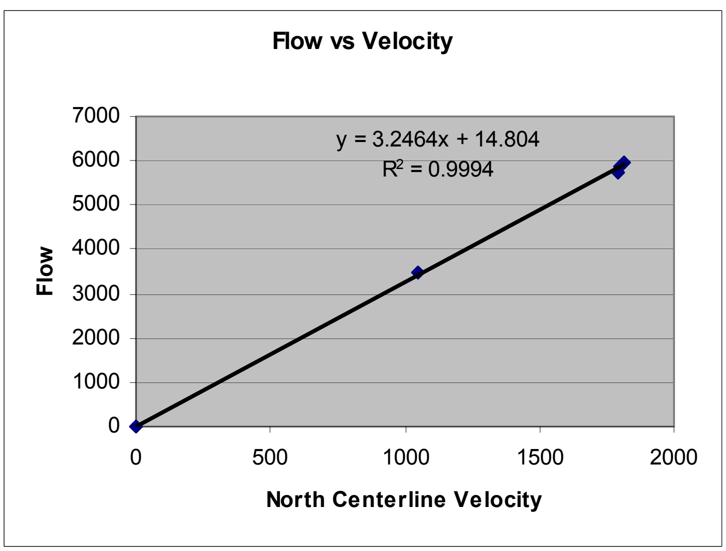
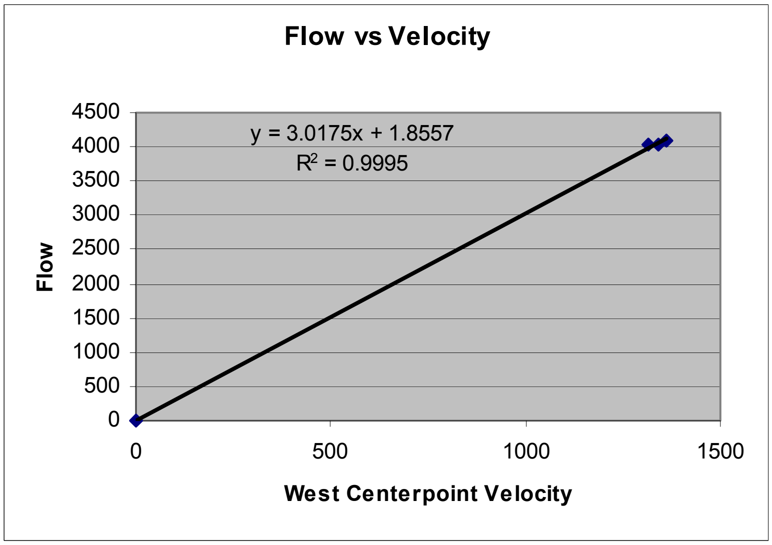


Figure C.2. Flow vs. Velocity Correlations for Turbine Fans



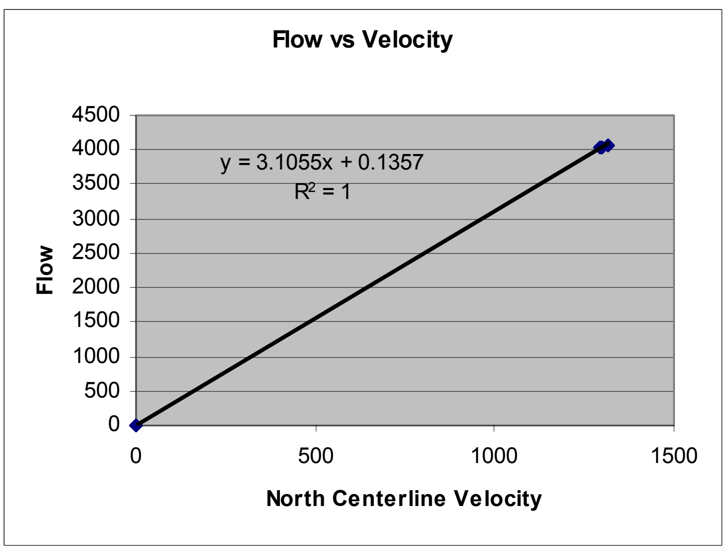
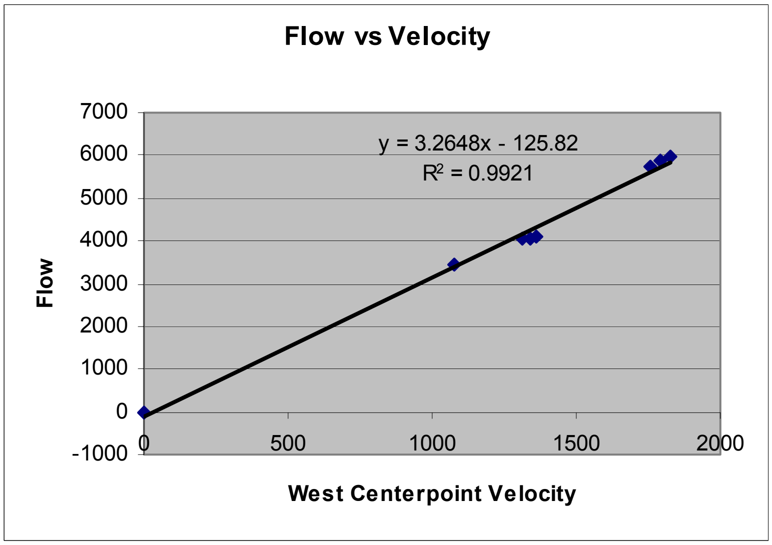
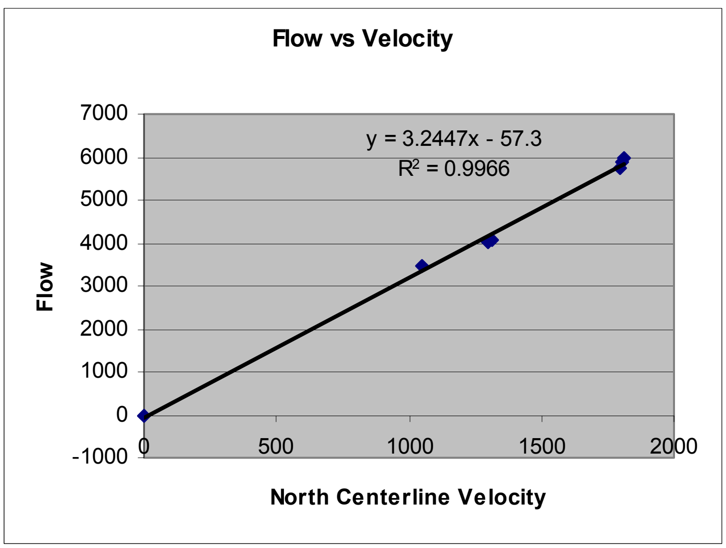


Figure C.3. Flow vs. Velocity Correlations for All Fans





Appendix D
Air Velocity Uniformity Testing Procedure

D.1 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.

D.2 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.

D.3 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.

D.4 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.

D.5 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.

D.6 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.

Preliminary Steps:

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.

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).

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

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

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

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

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

Velocity Uniformity Measurement

Set the flow controller per the test instruction.

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

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.

Repeat Step 6.2.3.

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.

Calculate the average air velocity for each measurement point.

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

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).

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.

Review the datasheets for completeness.

Sign and date the datasheets attesting to their validity.

Figure D.1. 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		

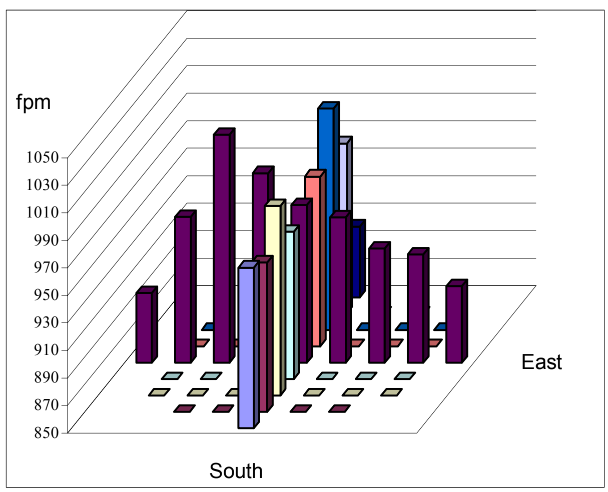
Traverse-->		East				South			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	0.50	892	884	932	902.7	970	980	950	966.7
2	0.66	909	935	933	925.7	955	961	960	958.7
3	1.23	948	912	930	930.0	979	1005	979	987.7
4	2.04	946	961	951	952.7	963	951	957	957.0
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

Figure D.2. Illustrative Test Instruction

<table>
<tr><td colspan="3" align="center">Test Instruction</td></tr>
<tr><td>Project: W420 6" Stack Calibration 28361</td><td>Date: August 19, 1998</td><td>Work Package: K83017</td></tr>
<tr><td colspan="3" align="center">Tests: Velocity Uniformity High Flow in W420 6" Full-Scale Model Stack</td></tr>
<tr><td colspan="3">Staff: David Maughan</td></tr>
<tr><td colspan="3">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</td></tr>
<tr><td colspan="3">Equipment:
1. W420 6" Full-Scale Model Stack, Fan and Fan Speed Controller located in 305 Bldg.
2. Solomat Zephyr and pitot tube</td></tr>
<tr><td colspan="3">Safety Considerations:
Review and observe the applicable Numatec Job Hazard Analysis for the project</td></tr>
<tr><td colspan="3">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</td></tr>
<tr><td colspan="3">Desired Completion Date: 12/5/98</td></tr>
<tr><td colspan="3">Approvals: ___________________________________ _____________
John Glissmeyer, project manager Date</td></tr>
<tr><td colspan="3">Test completed by: Date:</td></tr>
</table>

Appendix E
Air Velocity Uniformity Data Sheets

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Model**	Run No.	**VT-1**
Date	**Oct. 16, 2001**	Fan Configuration	**4-fan: EF1, EF4, EF5, EF7**
Testers	Glissmeyer and Maughan	Fan Setting	**51 Hz**
Stack Dia.	23.5 in.	Stack Temp	71.7 deg F
Stack X-Area	433.7 in.2	Start/End Time	1432-1530 hours
Elevation		Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Data Files:	NA

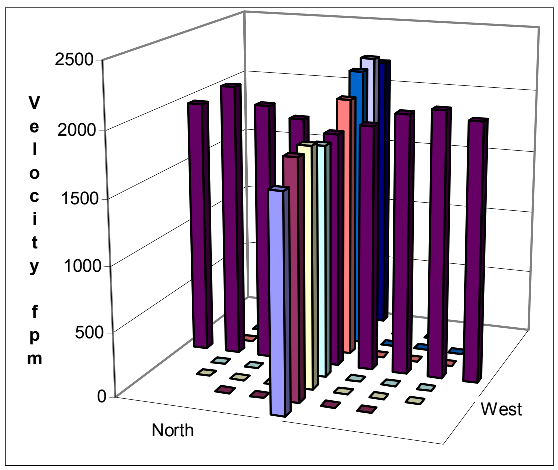
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.75	2044	1990	1967	2000.3	1603	1611	1734	1649.3
2	2.47	2058	2067	2069	2064.7	1768	1877	1825	1823.3
3	4.56	2036	2067	1941	2014.7	1849	1830	1859	1846.0
4	7.59	1892	1965	1855	1904.0	1811	1723	1823	1785.7
Center	11.75	1868	1808	1793	1823.0	1783	1892	1769	1814.7
5	15.91	1982	1875	1892	1916.3	1997	1998	2070	2021.7
6	18.94	1972	2016	2009	1999.0	2193	2220	2157	2190.0
7	21.03	2096	2181	2099	2125.3	2241	2235	2258	2244.7
8	22.75	1960	1978	1987	1975.0	2193	2132	2174	2166.3
Averages ---------->		1989.8	1994.1	1956.9	1980.3	1937.6	1946.4	1963.2	1949.1

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	1964.7		Mean	1978.1	1960.9	1969.5
Min Point	1649.3	-16.1%	Std. Dev.	103.5	191.9	148.4
Max Point	2244.7	14.3%	COV as %	5.2	9.8	**7.5**

Flow w/o C-Pt 5973 acfm
Vel Avg w/o C-Pt 1983 fpm

	Start	Finish	
Stack temp	72.5	70.8	F
Equipment temp	71.6	75	F
Ambient temp	70	70.7	F
Stack static	0.5	0.52	mbars
Ambient pressure	986.3	985.8	mbars
Total Stack pressure	986.8	986.3	mbars
Ambient humidity	38%	36%	RH

Instuments Used:
Pitot #5, 36-in. standard
Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes:
Initial trial run to evaluate stack and instrument configuration.

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Model**	Run No.	**VT-2**		
Date	**18 Oct. 2001**	Fan Configuration	**4-fan: EF1, EF4, EF5, EF7**		
Testers	Maughan	Fan Setting	**30 Hz**		
Stack Dia.	23.5 in.	Stack Temp	52.4 deg F		
Stack X-Area	433.7 in.2	Start/End Time	850 - 945 hrs		
Elevation		Center 2/3 from	2.16	to:	21.34
Distance to disturbance	75 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
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.75	1188	1178	1126	1164.0	959	1002	996	985.7
2	2.47	1212	1250	1194	1218.7	1054	1101	1039	1064.7
3	4.56	1141	1213	1163	1172.3	1054	1046	1014	1038.0
4	7.59	1196	1129	1104	1143.0	1045	1095	1036	1058.7
Center	11.75	1103	1083	1050	1078.7	1055	1056	1040	1050.3
5	15.91	1097	1091	1054	1080.7	1205	1211	1129	1181.7
6	18.94	1108	1199	1101	1136.0	1251	1224	1237	1237.3
7	21.03	1257	1226	1221	1234.7	1350	1309	1281	1313.3
8	22.75	1068	1180	1131	1126.3	1270	1201	1231	1234.0
Averages ---------->		1152.2	1172.1	1127.1	1150.5	1138.1	1138.3	1111.4	1129.3

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	1139.9		Mean	1152.0	1134.9	1143.4
Min Point	985.7	-13.5%	Std. Dev.	61.2	109.4	85.6
Max Point	1313.3	15.2%	COV as %	5.3	9.6	**7.5**

Flow w/o C-Pt 3462 acfm

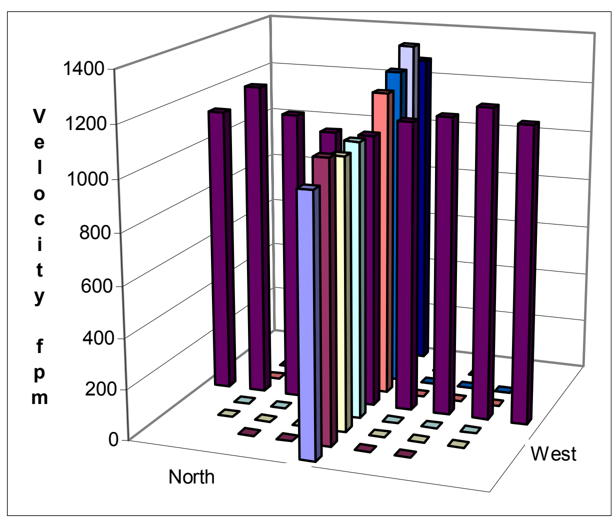
Vel Avg w/o C-Pt 1149 fpm

	Start	Finish	
Stack temp	53	51.8	F
Equipment temp		66.3	F
Ambient temp	40	48	F
Stack static	0.16	0.15	mbars
Ambient pressure	1000.5	1000.3	mbars
Total Stack pressure	1000.6	1000.4	mbars
Ambient humidity	58%	47%	RH

Instuments Used:

Pitot #5, 36-in. standard

Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes: E/W dimension = 23 5/16 inches

N/S dimension = 23 9/16 inches

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Model**	Run No.	**VT-3**		
Date	**18 Oct. 2001**	Fan Configuration	**4-fan: EF1, EF4, EF5, EF7**		
Testers	Glissmeyer/Maughan	Fan Setting	**50 Hz**		
Stack Dia.	23.5 in.	Stack Temp	69.5 deg F		
Stack X-Area	433.7 in.2	Start/End Time	1320 - 1405 hrs		
Elevation		Center 2/3 from	2.16	to:	21.34
Distance to disturbance	75 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
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.75	1766	1906	1772	1814.7	1590	1654	1635	1626.3
2	2.47	1971	2041	2063	2025.0	1848	1918	1821	1862.3
3	4.56	2035	2016	2105	2052.0	1751	1869	1821	1813.7
4	7.59	1928	1922	1927	1925.7	1737	1764	1725	1742.0
Center	11.75	1837	1827	1720	1794.7	1794	1846	1764	1801.3
5	15.91	1908	1777	1869	1851.3	1944	1940	1975	1953.0
6	18.94	1909	2043	2000	1984.0	2120	2100	2096	2105.3
7	21.03	2070	2147	2036	2084.3	2168	2186	2273	2209.0
8	22.75	1973	1933	1998	1968.0	2128	2171	2164	2154.3
Averages ---------->		1933.0	1956.9	1943.3	1944.4	1897.8	1938.7	1919.3	1918.6

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	1931.5		Mean	1959.6	1926.7	1943.1
Min Point	1626.3	-15.8%	Std. Dev.	107.3	172.7	139.2
Max Point	2209.0	14.4%	COV as %	5.5	9.0	**7.2**

Flow w/o C-Pt 5868 acfm

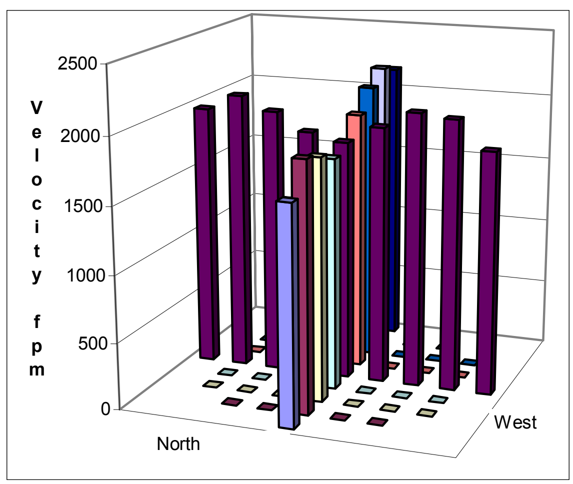
Vel Avg w/o C-Pt 1948 fpm

Instuments Used:

Pitot #5, 36-in. standard

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

	Start	Finish	
Stack temp	67.1	71.9	F
Equipment temp	82.4	75.7	F
Ambient temp	67.4	68	F
Stack static	0.469	0.00	mbars
Ambient pressure	997.6	996.2	mbars
Total Stack pressure	998.1	996.2	mbars
Ambient humidity	30%	37%	RH



Notes: Static P entry 0.469 is in error because a sample line to the sampling probe was connected to the wrong port. The error does not change the pressure correction on the Solomat.

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Model**	Run No.	**VT-4**
Date	**10/18/01**	Fan Configuration	**4-fan: EF1, EF4, EF5, EF7**
Testers	Glissmeyer/Maughan	Fan Setting	**50 hz**
Stack Dia.	23.5 in.	Stack Temp	70.0 deg F
Stack X-Area	433.7 in.2	Start/End Time	1510 - 1550 hours
Elevation		Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 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
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.75	1951	1728	1742	1807.0	1688	1710	1639	1679.0
2	2.47	1997	2025	2001	2007.7	1764	1763	1760	1762.3
3	4.56	1995	1860	1920	1925.0	1778	1757	1677	1737.3
4	7.59	1893	1856	1795	1848.0	1757	1822	1679	1752.7
Center	11.75	1724	1684	1863	1757.0	1774	1847	1764	1795.0
5	15.91	1842	1734	1893	1823.0	1955	1992	1917	1954.7
6	18.94	1874	1804	1986	1888.0	2134	2109	2123	2122.0
7	21.03	1997	2007	1937	1980.3	2154	2121	2121	2132.0
8	22.75	1910	2017	2019	1982.0	2124	2123	2132	2126.3
Averages ---------->		1909.2	1857.2	1906.2	1890.9	1903.1	1916.0	1868.0	1895.7

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	1893.3		Mean	1889.9	1893.7	1891.8
Min Point	1679.0	-11.3%	Std. Dev.	88.7	175.1	133.4
Max Point	2132.0	12.6%	COV as %	4.7	9.2	**7.0**

Flow w/o C-Pt 5747 acfm

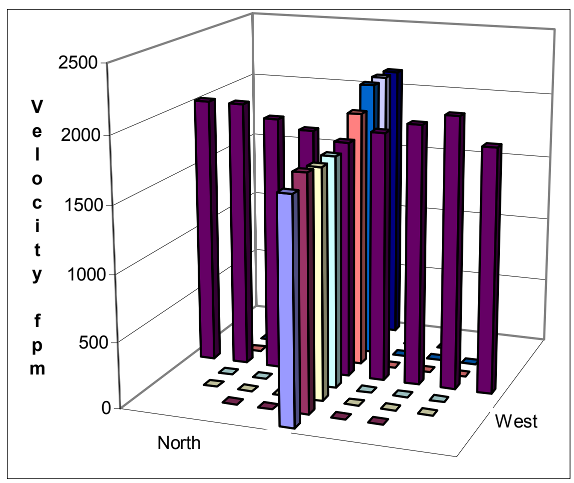
Vel Avg w/o C-Pt 1908 fpm

Instuments Used:

Pitot #5, 36-in. standard

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

	Start	Finish	
Stack temp	71.9	68	F
Equipment temp	75.7	76.1	F
Ambient temp	68.0	68.7	F
Stack static	0.00	0.00	mbars
Ambient pressure	996.2	995.5	mbars
Total Stack pressure	996.2	995.5	mbars
Ambient humidity	37%	27%	RH



Notes: E/W dimension = 23 5/16 inches
N/S dimension = 23 9/16 inches

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Model**	Run No.	**VT-5**
Date	**11/13/2001**	Fan Configuration	**Turbine Fans**
Testers	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	61.0 deg F
Stack X-Area	433.7 in.2	Start/End Time	1011/1100
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 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
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.75	1132	1327	1313	1257.3	856	905	946	902.3
2	2.47	1371	1448	1360	1393.0	1038	1027	1043	1036.0
3	4.56	1332	1385	1318	1345.0	1062	1053	1077	1064.0
4	7.59	1251	1365	1402	1339.3	1142	1073	1160	1125.0
Center	11.75	1300	1366	1363	1343.0	1263	1320	1302	1295.0
5	15.91	1372	1319	1374	1355.0	1500	1504	1470	1491.3
6	18.94	1475	1347	1462	1428.0	1578	1575	1676	1609.7
7	21.03	1537	1503	1462	1500.7	1631	1668	1670	1656.3
8	22.75	1377	1425	1407	1403.0	1561	1582	1461	1534.7
Averages ---------->		1349.7	1387.2	1384.6	1373.8	1292.3	1300.8	1311.7	1301.6

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	1337.7		Mean	1386.3	1325.3	1355.8
Min Point	902.3	-32.5%	Std. Dev.	60.0	261.7	185.2
Max Point	1656.3	23.8%	COV as %	4.3	19.7	**13.7**

Flow w/o C-Pt 4036 acfm

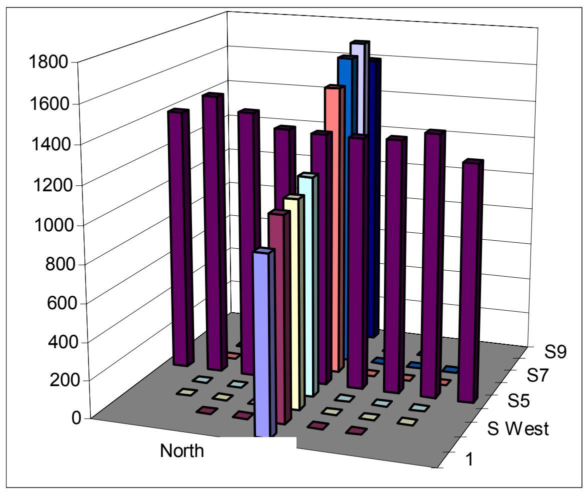
Vel Avg w/o C-Pt 1340 fpm

	Start	Finish	
Stack temp	57	65	F
Equipment temp	66	76	F
Ambient temp	44	50	F
Stack static	-0.006	-0.01	mbars
Ambient pressure	985.9	985.6	mbars
Total Stack pressure	985.9	985.6	mbars
Ambient humidity	84%	70%	RH

Instuments Used:

Pitot #5, 36-in. standard

Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes:

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Model**	Run No.	**VT-6**
Date	**11/13/2001**	Fan Configuration	**Turbine Fans**
Testers	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	66.0 deg F
Stack X-Area	433.7 in.2	Start/End Time	1325/1400
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Data Files:	NA

Traverse-->		West				1st North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.75	1292	1245	1345	1294.0	944	927	999	956.7
2	2.47	1366	1348	1391	1368.3	977	1108	1110	1065.0
3	4.56	1206	1318	1277	1267.0	1027	1142	1198	1122.3
4	7.59	1302	1307	1263	1290.7	1224	1196	1183	1201.0
Center	11.75	1313	1323	1310	1315.3	1366	1201	1334	1300.3
5	15.91	1402	1378	1409	1396.3	1450	1593	1487	1510.0
6	18.94	1433	1508	1535	1492.0	1545	1615	1618	1592.7
7	21.03	1463	1442	1484	1463.0	1628	1659	1626	1637.7
8	22.75	1366	1323	1202	1297.0	1517	1438	1425	1460.0
Averages ---------->		1349.2	1354.7	1357.3	1353.7	1297.6	1319.9	1331.1	1316.2

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	1335.0		Mean	1370.4	1347.0	1358.7
Min Point	956.7	-28.3%	Std. Dev.	85.8	232.7	168.9
Max Point	1637.7	22.7%	COV as %	6.3	17.3	**12.4**

Flow w/o C-Pt 4031 acfm

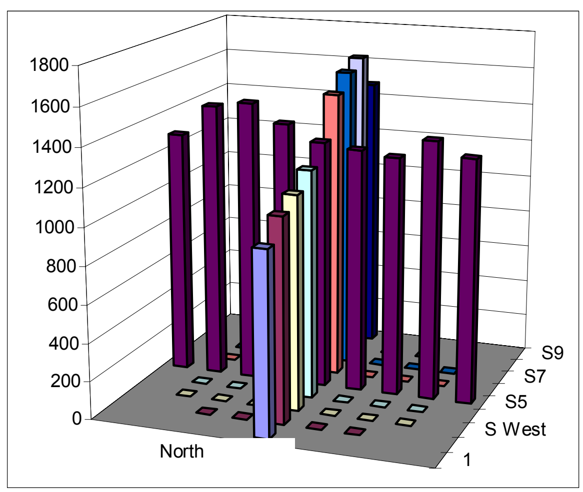
Vel Avg w/o C-Pt 1338 fpm

	Start	Finish	
Stack temp	65	67	F
Equipment temp	64	70	F
Ambient temp	58	60	F
Stack static	-0.002	-0.002	mbars
Ambient pressure	985.5	983.9	mbars
Total Stack pressure	985.5	983.9	mbars
Ambient humidity	51%	44%	RH

Instuments Used:

Pitot #5, 36-in. standard

Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes:

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Model**	Run No.	**VT-7**
Date	**11/26/01**	Fan Configuration	**Turbine Fans, 30 DEGREES EAST PORT**
Testers	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	55.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1430/1515
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Velocity units	ft/min	Data Files:	NA

1st

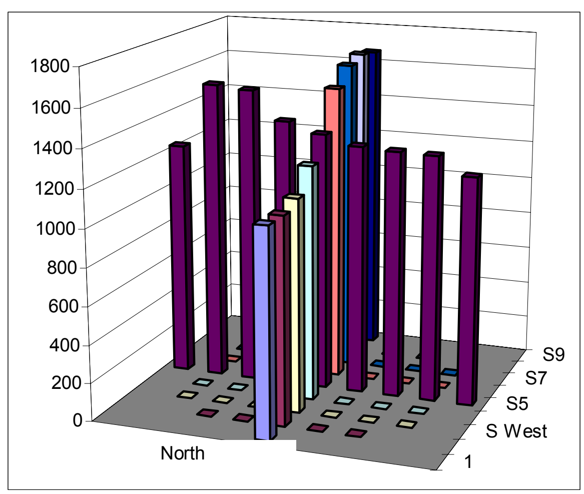
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
CorrectLabel	Depth, in.	Velocity				Velocity			
1	0.75	1195	1219	1207	1207.0	1082	1074	995	1050.3
2	2.47	1281	1280	1340	1300.3	1049	1090	1007	1048.7
3	4.56	1291	1331	1290	1304.0	1088	1036	1129	1084.3
4	7.59	1282	1297	1367	1315.3	1212	1216	1170	1199.3
Center	11.75	1352	1368	1371	1363.7	1313	1369	1263	1315.0
5	15.91	1366	1431	1459	1418.7	1548	1475	1504	1509.0
6	18.94	1519	1564	1621	1568.0	1610	1583	1594	1595.7
7	21.03	1546	1610	1596	1584.0	1657	1619	1590	1622.0
8	22.75	1326	1161	1245	1244.0	1632	1602	1579	1604.3
Averages ---------->		1350.9	1362.3	1388.4	1367.2	1354.6	1340.4	1314.6	1336.5

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	1351.9		Mean	1407.7	1339.1	1373.4
Min Point	1048.7	-22.4%	Std. Dev.	122.2	239.5	186.1
Max Point	1622.0	20.0%	COV as %	8.7	17.9	**13.5**

Flow w/o C-Pt 4077 acfm
Vel Avg w/o C-Pt 1353 fpm

Instuments Used:
Pitot #5, 36-in. standard
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

	Start	Finish	
Stack temp	55	56	F
Equipment temp	68	63	F
Ambient temp	47	46	F
Stack static	0.017	-0.016	mbars
Ambient pressure	1000.5	1000.9	mbars
Total Stack pressure	1000.5	1000.9	mbars
Ambient humidity	63%	59%	RH



Notes:

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Main Stack**	Run No.	**VT-MS**	
Date	**12/19/01**	Fan Configuration	**30 DEGREES EAST PORT**	
Testers	Carrick	Fan Setting	**EF1,EF4,EF6,EF7**	
Stack Dia.	189.75 in.	Stack Temp	73.0 deg F	
Stack X-Area	28278.3 in.2	Start/End Time	1030/1100	
Elevation	50 ft	Center 2/3 from	17.41 to:	172.34
Distance to disturbance	54 ft	Points in Center 2/3	2 to:	7
Velocity units	ft/min	Data Files:	NA	
	1st			

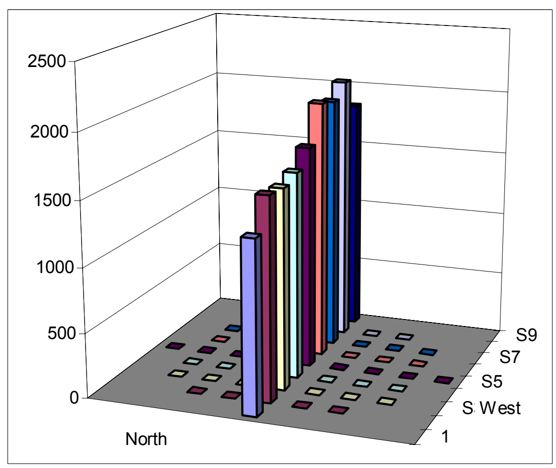
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
CorrectLabel	Depth, in.	Velocity				Velocity			
1	6.00				#DIV/0!	1328	1328	1328	1328.0
2	19.88				#DIV/0!	1602	1602	1499	1567.7
3	36.63				#DIV/0!	1551	1551	1551	1551.0
4	61.00				#DIV/0!	1602	1602	1602	1602.0
Center	94.50	0			0.0	1746	1746	1699	1730.3
5	128.00				#DIV/0!	2042	2003	2003	2016.0
6	152.38				#DIV/0!	1962	2003	1962	1975.7
7	169.12				#DIV/0!	2081	2081	2081	2081.0
8	183.00				#DIV/0!	1835	1835	1835	1835.0
Averages ---------->		0.0	#DIV/0!	#DIV/0!	#DIV/0!	1749.9	1750.1	1728.9	1743.0

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	#DIV/0!		Mean	#DIV/0!	1789.1	#DIV/0!
Min Point	#DIV/0!	#DIV/0!	Std. Dev.	#DIV/0!	229.4	#DIV/0!
Max Point	#DIV/0!	#DIV/0!	COV as %	#DIV/0!	12.8	**#DIV/0!**

Flow w/o C-Pt	#DIV/0!	acfm
Vel Avg w/o C-Pt	#DIV/0!	fpm

Instuments Used:

	Start	Finish	
Stack temp	73	73	F
Equipment temp			F
Ambient temp			F
Stack static	0.130		IN WG
Ambient pressure			mbars
Total Stack pressure			mbars
Ambient humidity	29%		RH



Notes:

VELOCITY TRAVERSE DATA FORM

Site	**291Z1 Main Stack**	Run No.	**VT-MS**
Date	**12/19/01**	Fan Configuration	**30 DEGREES EAST PORT**
Testers	Carrick	Fan Setting	**EF1,EF4,EF6,EF7**
Stack Dia.	189.75 in.	Stack Temp	73.0 deg F
Stack X-Area	28278.3 in.2	Start/End Time	1030/1100
Elevation	50 ft	Center 2/3 from	17.41 to: 172.34
Distance to disturbance	54 ft	Points in Center 2/3	4 to: 13
Velocity units	ft/min	Data Files:	NA

	1st								
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
CorrectLabel	Depth, in.	Velocity				Velocity			
1	3.00				#DIV/0!	1266	1266	1266	1266.0
2	9.00				#DIV/0!	1444	1444	1499	1462.3
3	16.00				#DIV/0!	1499	1499	1551	1516.3
4	25.38				#DIV/0!	1602	1551	1551	1568.0
5	32.00				#DIV/0!	1551	1602	1602	1585.0
6	41.62				#DIV/0!	1551	1602	1651	1601.3
7	53.50				#DIV/0!	1551	1602	1551	1568.0
8	70.88				#DIV/0!	1602	1602	1602	1602.0
Center	94.50	0			0.0	1746	1746	1746	1746.0
9	118.12				#DIV/0!	1921	1921	1921	1921.0
10	135.50				#DIV/0!	1921	1962	1921	1934.7
11	147.38				#DIV/0!	1921	2003	1962	1962.0
12	157.00				#DIV/0!	2003	2003	2003	2003.0
13	165.38				#DIV/0!	2081	2003	2042	2042.0
14	173.00				#DIV/0!	2003	2042	2003	2016.0
15	180.00				#DIV/0!	1921	1921	1921	1921.0
16	186.00				#DIV/0!	1651	1651	1651	1651.0
Averages ---------->		0.0	#DIV/0!	#DIV/0!	#DIV/0!	1719.6	1730.6	1731.9	1727.4

All	ft/min	Dev. from mean	***Center 2/3***	West	North	All
Mean	#DIV/0!		Mean	#DIV/0!	1775.7	#DIV/0!
Min Point	#DIV/0!	#DIV/0!	Std. Dev.	#DIV/0!	196.9	#DIV/0!
Max Point	#DIV/0!	#DIV/0!	COV as %	#DIV/0!	11.1	**#DIV/0!**

Flow w/o C-Pt #DIV/0! acfm

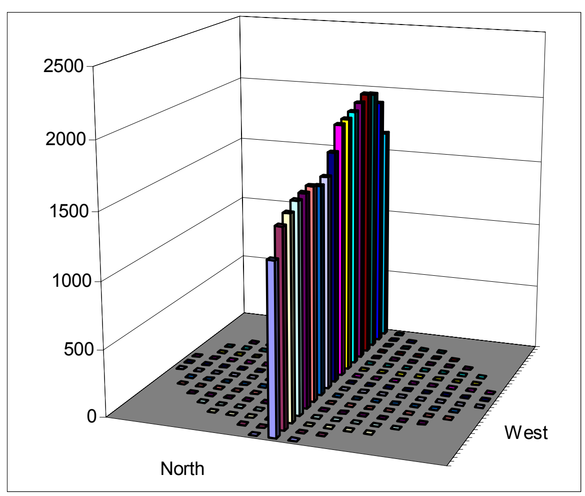
Vel Avg w/o C-Pt #DIV/0! fpm

	Start	Finish	
Stack temp	73	73	F
Equipment temp			F
Ambient temp			F
Stack static	0.130		in wg
Ambient pressure	29.4		in Hg
Total Stack pressure			mbars
Ambient humidity	29%		RH

Instuments Used:

Pitot #5, 36-in. standard

Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes:

Appendix F
Angular Flow Testing Procedure

F.1 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.

F.2 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.

F.3 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.

F.4 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.

F.5 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.

F.6 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.

Preliminary Steps:

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

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).

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

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".

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

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.

<u>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.</u>

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

<u>Establish a convention for representing the angular direction of flow.</u>

> **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

<u>Position the inclined manometer on a stable platform and level the device using the spirit level.</u>

> **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

<u>Connect the flexible tubes to the inclined manometer but disconnect them from the pitot tube.</u>

<u>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.)</u>

<u>Reconnect the flexible tubes to the pitot tube.</u>

Angular Flow Measurements

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

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.

Repeat Step 6.3.3.

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.

Calculate the absolute average air-flow angle for each measurement point.

Calculate the average absolute flow angle for all measurement points.

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

Review the datasheets for completeness.

Sign and date the datasheets attesting to their validity.

Figure F.1. 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:		

Figure F.2. Illustration 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	0.0

Instuments Used: **Cal Exp. Date:**

Parallel-tube pitot with 90-deg. bends at sample ends, 24-inches in length. NA

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.

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 G
Angular Flow Data Sheets and Plots

FLOW ANGLE DATA FORM

Site	**291Z1 Model**	Run No.	**FA-1**
Date	10/19/02	Fan Setting	**50 Hz**
Tester	Maughan	Fan configuration	**4-fan: EF1, EF4, EF5, EF7, 15 deg port**
Stack Dia.	23.5 in	Approx. stack flow	~5860 cfm
Stack X-Area	433.7 in2	Units	degrees (clockwise > pos. nos.)
Elevation	ft		992.4 mb
Distance to disturbance	75 in		57% RH
			55 F

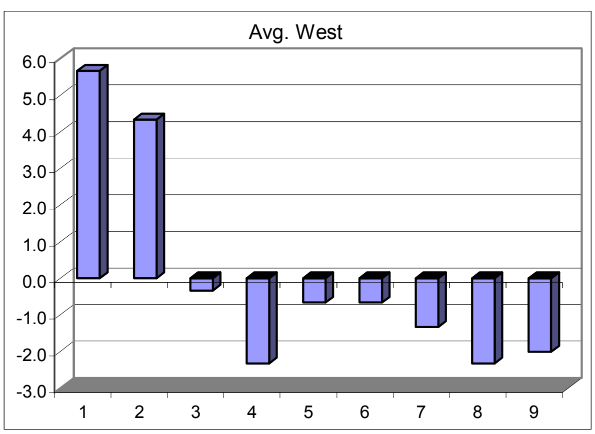
Traverse-->		**West**				**North**			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	0.75	7	4	6	5.7	2	2	4	2.7
2	2.47	4	5	4	4.3	-1	1	0	0.0
3	4.56	-2	0	1	-0.3	-2	-1	-2	-1.7
4	7.59	-2	-2	-3	-2.3	-3	-4	-3	-3.3
Center	11.75	-1	0	-1	-0.7	0	-1	-1	-0.7
5	15.91	0	-1	-1	-0.7	-1	-1	-1	-1.0
6	18.94	-1	-1	-2	-1.3	-3	-2	-2	-2.3
7	21.03	-2	-3	-2	-2.3	-3	-2	-1	-2.0
8	22.75	-2	-2	-2	-2.0	-2	-1	-1	-1.3
Mean of absolute values		2.3	2.0	2.4		1.9	1.7	1.7	
w/o points by wall:		1.7	1.7	2.0		1.9	1.7	1.4	
								all	2.0
								w/o wall pts	1.7

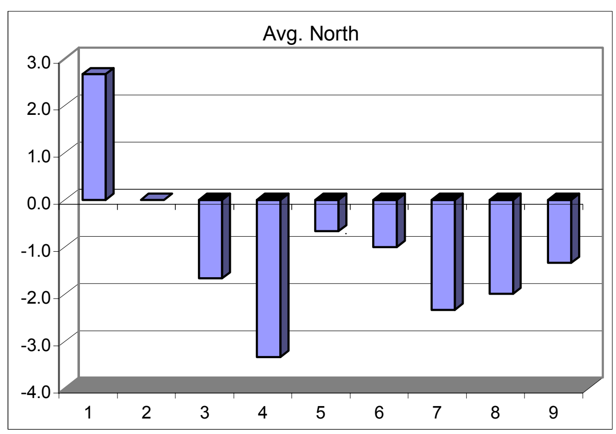
Instuments Used:

S-type pitot	Pitot-2	36 inch
Stanley protractor level	Prot-1	
Manometer	Man-1	S/N 14591

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 July 25, 2002





FLOW ANGLE DATA FORM

Site	**291Z1 Model**		Run No.	**FA-2**
Date	11/26/01		Fan Setting	**60 Hz**
Tester	Glissmeyer		Fan configuration	**2 Turbine fan, 15 degree port**
Stack Dia.	23.5	in	Approx. stack flow	cfm
Stack X-Area	433.7	in2	Units	degrees (clockwise > pos. nos.)
Elevation	NA	ft		
Distance to disturbance	75	in		

1st

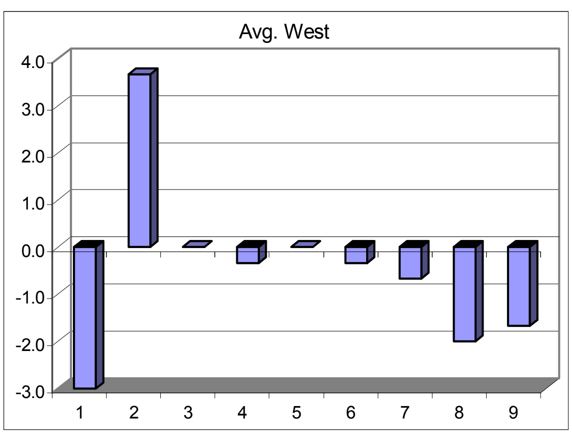
Traverse-->		West				North			
Trial ---->		1	2	3		1	2	3	
Point	Depth, in.	deg. cw	deg. cw	deg. cw	Avg.	deg. cw	deg. cw	deg. cw	Avg.
1	0.75	-3	-3	-3	-3.0	0	-1	0	-0.3
2	2.47	4	4	3	3.7	0	0	-1	-0.3
3	4.56	0	0	0	0.0	-3	-2	-1	-2.0
4	7.59	-1	1	-1	-0.3	-6	-6	-4	-5.3
Center	11.75	1	-2	1	0.0	-4	-3	-3	-3.3
5	15.91	-1	0	0	-0.3	-3	-3	-2	-2.7
6	18.94	0	-1	-1	-0.7	-3	-1	-2	-2.0
7	21.03	-1	-2	-3	-2.0	-1	-1	-1	-1.0
8	22.75	0	-2	-3	-1.7	-2	-2	-1	-1.7
Mean of absolute values		1.2	1.7	1.7		2.4	2.1	1.7	
w/o points by wall:		1.1	1.4	1.3		2.9	2.3	2.0	
								all	1.8
								w/o wall pts	1.8

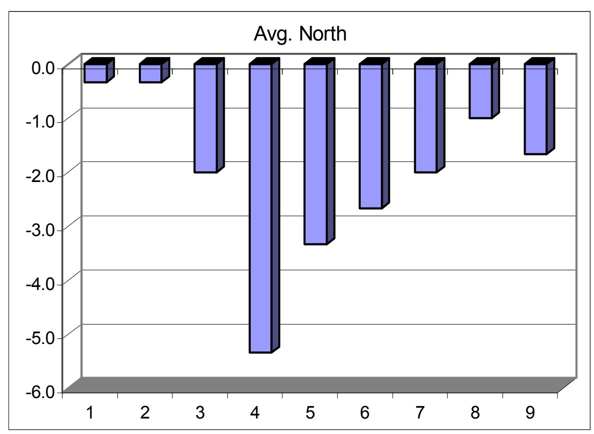
Instuments Used:

S-type pitot	Pitot-2	36 inch
Stanley protractor level	Prot-1	
Manometer	Man-1	S/N 14591

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 July 25, 2002





FLOW ANGLE DATA FORM

Site	**291Z1 Model**	Run No.	**FA-3**
Date	11/26/01	Fan Setting	**60 Hz**
Tester	Glissmeyer	Fan configuration	**2 Turbine fan, 30 degree port**
Stack Dia.	23.5 in	Approx. stack flow	cfm
Stack X-Area	433.7 in2	Units	degrees (clockwise > pos. nos.)
Elevation	NA ft		
Distance to disturbance	75 in		

1st

Traverse-->		West				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	0.75	-1	2	1	0.7	-11	-12	-8	-10.3
2	2.47	-2	3	2	1.0	-9	-12	-11	-10.7
3	4.56	-3	-1	2	-0.7	-7	-10	-9	-8.7
4	7.59	-3	-1	0	-1.3	-9	-8	-8	-8.3
Center	11.75	-2	-1	-1	-1.3	-5	-7	-6	-6.0
5	15.91	-2	-1	-1	-1.3	-3	-4	-6	-4.3
6	18.94	-2	-2	-1	-1.7	-2	-3	-5	-3.3
7	21.03	-2	-1	-1	-1.3	-2	-1	-4	-2.3
8	22.75	-2	-1	-2	-1.7	-2	-2	-2	-2.0
Mean of absolute values		2.1	1.4	1.2		5.6	6.6	6.6	
w/o points by wall:		2.3	1.4	1.1		5.3	6.4	7.0	

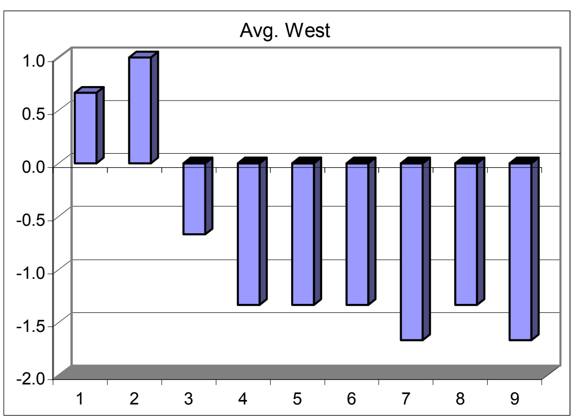
all	3.9
w/o wall pts	3.9

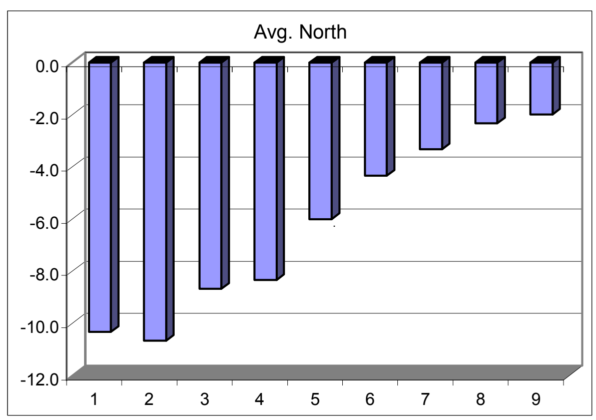
Instuments Used:

S-type pitot	Pitot-2	36 inch
Stanley protractor level	Prot-1	
Manometer	Man-1	S/N 14591

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 July 25, 2002





Appendix H
Tracer Gas Uniformity Testing Procedure

H.1 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%.

H.2 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.

H.3 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.

H.4 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.

H.5 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.

H.6 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.

Preliminary Steps:

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).

Fill in test information on data form.

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

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.

System Startup

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.

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

Turn-on the gas analyzer.

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.

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-

Daily Tracer Gas Background Concentration Measurement

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.

Record these readings in the logbook designated for the tests.

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.

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

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.

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

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

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.

Perform two additional repetitions of Step 6.4.5. above

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

Check the data sheet for completeness.

Record the final

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

Shut down the delivery of tracer gas.

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

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

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

Enter the centerline stack velocity flow on the data sheet.

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

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

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).

Review the raw data sheets for completeness.

Enter the data into the electronic data sheet.

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).

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.

Sign and date the data sheet attesting to its validity.

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

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.
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.

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).

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

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

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.

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.

Figure H.1. Overview of Stack and Injection/Sampling Setups

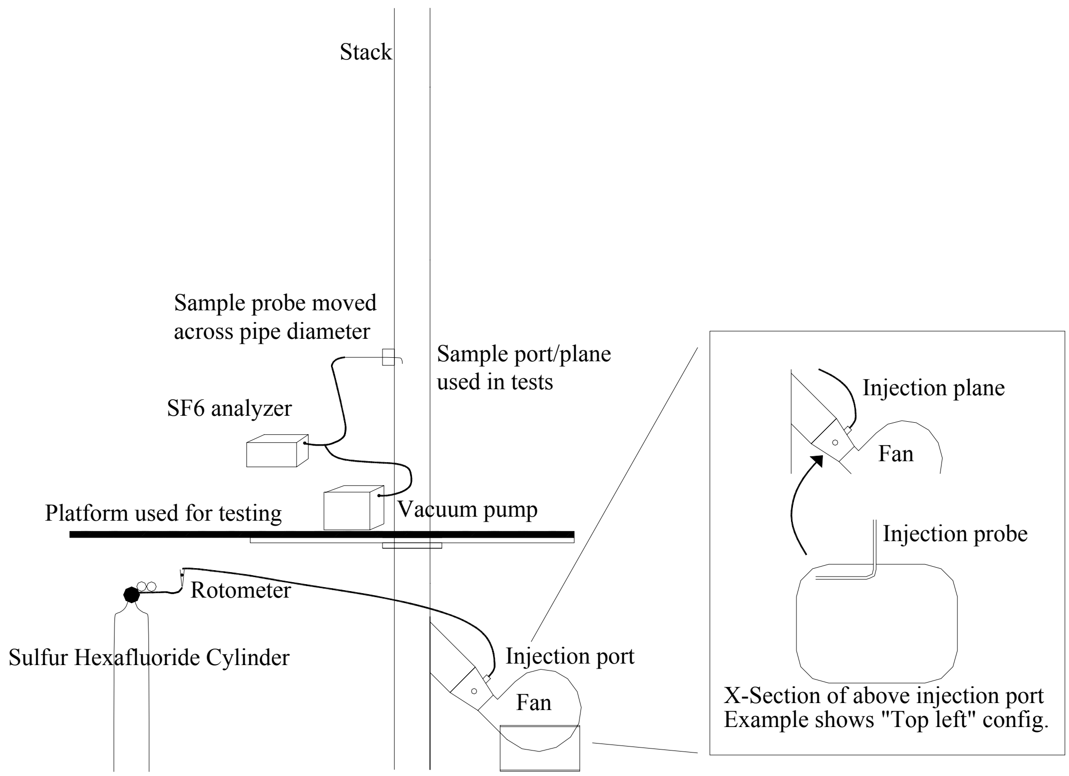


Figure H.2. Details for Stack Sampling Probe and Gas Analyzer Setup

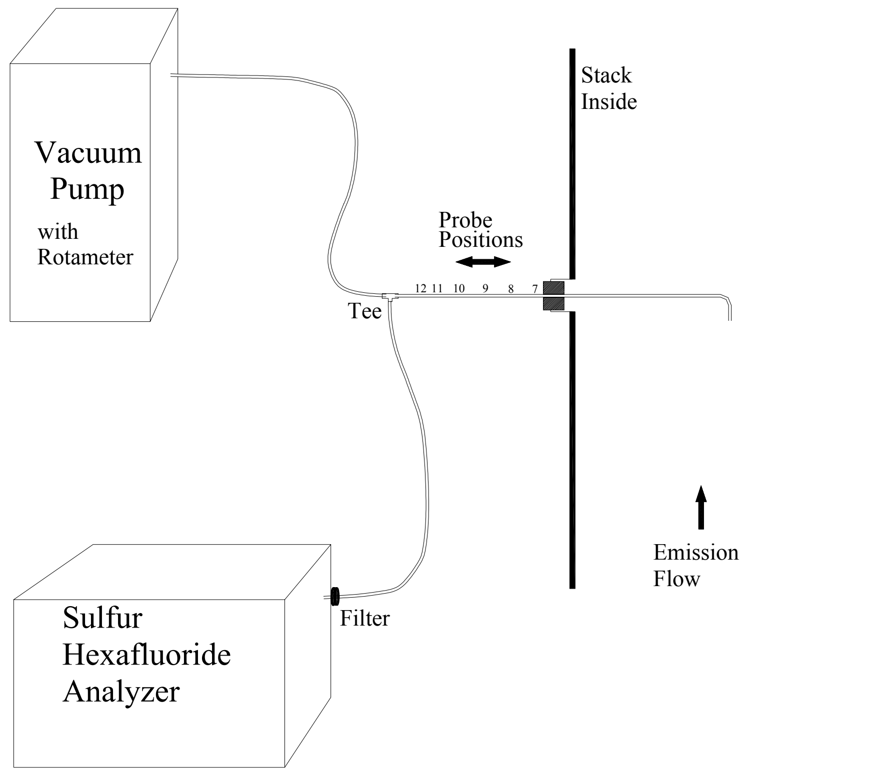


Figure H.3. Example EXCEL Data Sheet

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		

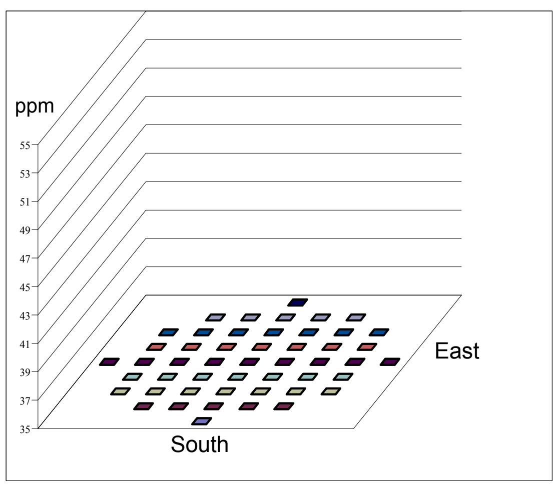
Traverse-->		East				South			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	1.00								
2	1.83								
3	3.22								
4	4.82								
5	6.81								
6	9.70								
Center	13.63								
7	17.55								
8	20.44								
9	22.43								
10	24.03			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

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	
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:

Figure H.4. 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:

Appendix I
Tracer Gas Uniformity Data Sheets

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-1**
Date	10/22/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	65 deg F
Stack X-Area	433.7 in.2	Start/End Time	1240/1407
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**Centerline EF4**

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.11	2.06	2.08	2.083	2.12	2.05	2.13	2.100
2	2.47	2.11	2.08	2.12	2.103	2.11	2.06	2.07	2.080
3	4.56	2.07	2.07	2.06	2.067	2.05	2.11	2.07	2.077
4	7.59	2.05	2.13	2.08	2.087	2.06	2.08	2.10	2.080
Center	11.75	2.05	2.05	2.13	2.077	2.12	2.10	2.06	2.093
5	15.91	2.05	2.07	2.03	2.050	2.09	2.08	2.12	2.097
6	18.94	2.08	2.11	2.10	2.097	2.13	2.11	2.10	2.113
7	21.03	2.13	2.09	2.10	2.107	2.08	2.13	2.09	2.100
8	22.75	2.06	2.10	2.07	2.077	2.08	2.10	2.16	2.113
Averages ---------->		2.079	2.084	2.086	2.083	2.093	2.091	2.100	2.095

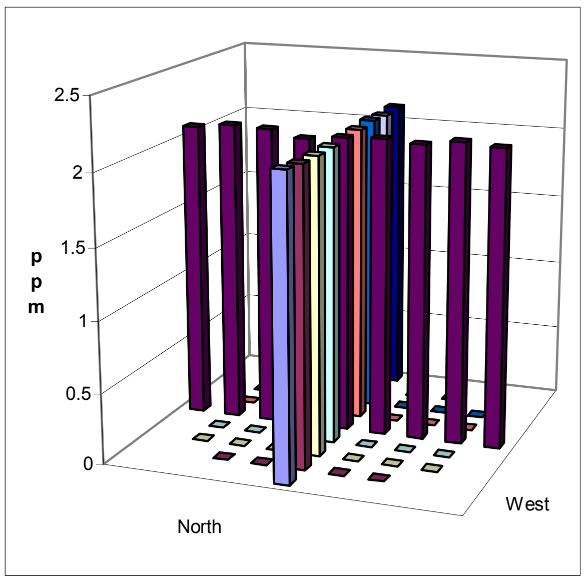
All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.09		Mean	2.08	2.09	2.09
Min Point	2.05	-1.9%	Std. Dev.	0.02	0.01	0.02
Max Point	2.11	1.2%	COV as %	1.0	0.6	**0.8**

Avg. Conc. 2.089 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	65	65	F
Centerline vel.	N 1756	W 1595	fpm
Injection flowmeter	20	18	ball**
Stack flow	5700	5200	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	738.7	736.5	mm Hg
Ambient humidity	45	57	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas level	12,12,12,13,13,12	32,31,33,32	ppb
No. Bk-Gd samples	6	4	n
Ambient pressure	984.9	982.0	mbar

Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes:
Centerline velocity should be in range 1757 - 1801 fpm

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-2**
Date	10/22/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	65 deg F
Stack X-Area	433.7 in.2	Start/End Time	1420/1525
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**Top West EF4**

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.11	2.05	2.17	2.110	2.10	2.06	2.04	2.067
2	2.47	2.07	2.10	2.17	2.113	2.12	2.06	2.06	2.080
3	4.56	2.12	2.12	2.19	2.143	2.08	2.08	2.03	2.063
4	7.59	2.08	2.24	2.16	2.160	2.09	2.12	2.04	2.083
Center	11.75	2.09	2.13	2.21	2.143	2.10	2.08	2.07	2.083
5	15.91	2.01	2.21	2.16	2.127	2.07	2.13	2.07	2.090
6	18.94	2.09	2.22	2.18	2.163	2.10	2.11	2.09	2.100
7	21.03	2.10	2.27	2.25	2.207	2.14	2.12	2.12	2.127
8	22.75	2.16	2.22	2.08	2.153	2.04	2.13	2.17	2.113
Averages ---------->		2.092	2.173	2.174	2.147	2.093	2.099	2.077	2.090

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.12		Mean	2.15	2.09	2.12
Min Point	2.06	-2.6%	Std. Dev.	0.03	0.02	0.04
Max Point	2.21	4.2%	COV as %	1.4	0.9	**1.9**

Avg. Conc. 2.119 ppm

Gas analyzer checked: 19-Oct-01

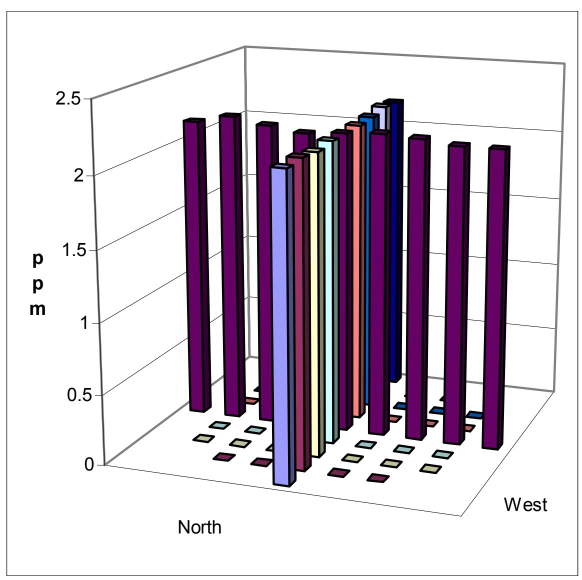
	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	65	65 *	F
Centerline vel.	W 1595	N 1646	fpm
Injection flowmeter	20	20	ball**
Stack flow	5200	5400	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	736.5	734.5	mm Hg
Ambient humidity	57	70	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas level	25,28,22,22	72,31,29,27	ppb
No. Bk-Gd samples	4	4	n
Ambient pressure	982.0	979.3	mbar

Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes:

Centerline velocity should be in range 1757 - 1801 fpm

* Solomat temperature sensor wet and not functional for awhile, then stabilized

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-3**
Date	10/25/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer/Maughan	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	59.15 deg F
Stack X-Area	433.7 in.2	Start/End Time	0952/1120
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF4 Top East**

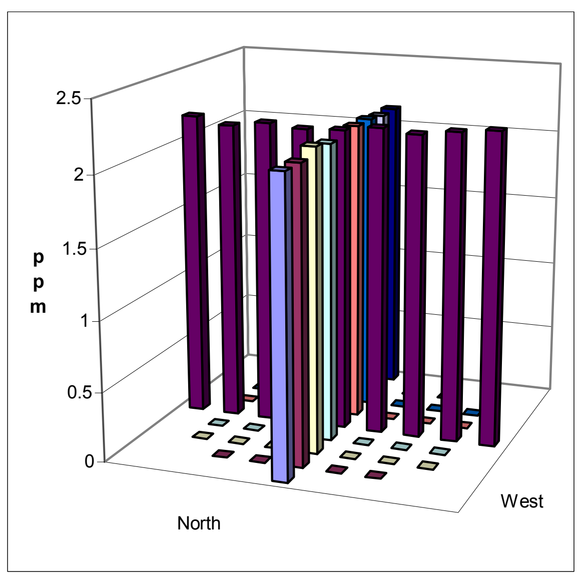
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.16	2.14	2.10	2.133	2.04	2.15	2.12	2.103
2	2.47	2.11	2.10	2.11	2.107	2.06	2.13	2.12	2.103
3	4.56	2.08	2.09	2.05	2.073	2.10	2.19	2.18	2.157
4	7.59	2.13	2.10	2.07	2.100	2.09	2.13	2.15	2.123
Center	11.75	2.10	2.07	2.03	2.067	2.17	2.18	2.14	2.163
5	15.91	2.10	2.04	2.03	2.057	2.16	2.16	2.11	2.143
6	18.94	2.07	2.11	2.06	2.080	2.18	2.14	2.11	2.143
7	21.03	2.06	2.10	1.98	2.047	2.13	2.11	2.12	2.120
8	22.75	2.19	2.05	2.04	2.093	2.15	2.04	2.18	2.123
Averages ---------->		2.111	2.089	2.052	2.084	2.120	2.137	2.137	2.131

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.11		Mean	2.08	2.14	2.11
Min Point	2.05	-2.9%	Std. Dev.	0.02	0.02	0.04
Max Point	2.16	2.6%	COV as %	1.1	1.0	**1.8**

Avg. Conc. 2.107 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	180	200	psig
Sample Port Temp	57.3	61	F
Centerline vel.	N 1740	W 1736	fpm
Injection flowmeter	20	20	ball**
Stack flow	5700	5700	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	997.1	998.0	mbar
Ambient humidity	79	47	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	15/13/22/4	67/64/72/72/58/59	
No. Bk-Gd samples	4	6	n



Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: Equipment on stack covered in layer of sand. At 9:00 AM, B&P wouldn't start. Took it indoors to warm up. Then it operated properly.

Injection flow adjusted up from 19 to 20 shortly after switching from West to North traverse.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-4**	
Date	10/25/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**	
Tester	Glissmeyer/Maughan	Fan Setting	**50 Hz**	
Stack Dia.	23.5 in.	Stack Temp	66 deg F	
Stack X-Area	433.7 in.2	Start/End Time	1240/1350	
Elevation	N.A.	Center 2/3 from	2.16 to:	21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to:	7
Measurement units	ppm SF6	Injection Point	**EF4 Bottom West**	

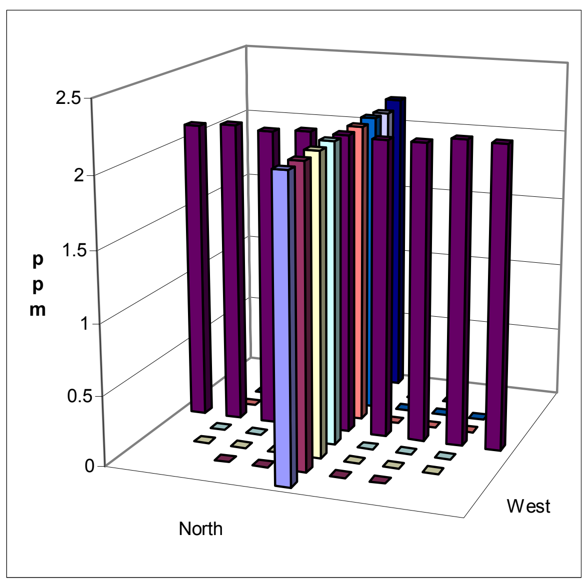
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.11	2.06	2.09	2.087	2.16	2.11	2.07	2.113
2	2.47	2.11	2.08	2.10	2.097	2.17	2.11	2.07	2.117
3	4.56	2.13	2.03	2.01	2.057	2.15	2.17	2.07	2.130
4	7.59	2.06	2.04	2.07	2.057	2.14	2.21	2.07	2.140
Center	11.75	2.09	2.10	2.02	2.070	2.15	2.12	2.12	2.130
5	15.91	2.06	2.10	2.07	2.077	2.19	2.17	2.05	2.137
6	18.94	2.10	2.04	2.04	2.060	2.15	2.16	2.14	2.150
7	21.03	2.09	2.06	2.10	2.083	2.17	2.13	2.11	2.137
8	22.75	2.08	2.09	2.02	2.063	2.22	2.17	2.17	2.187
Averages ---------->		2.092	2.067	2.058	2.072	2.167	2.150	2.097	2.138

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.11		Mean	2.07	2.13	2.10
Min Point	2.06	-2.3%	Std. Dev.	0.02	0.01	0.03
Max Point	2.19	3.9%	COV as %	0.7	0.5	**1.7**

Avg. Conc. 2.106 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	64	68	F
Centerline vel.	w 1737	n 1733	fpm
Injection flowmeter	20	20	ball**
Stack flow	5700	5600	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	998.0	997.6	mbar
Ambient humidity	47	42	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	17/2/3/3	2/-3/25/43/7/19	
No. Bk-Gd samples	4	6	n



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-5**
Date	10/25/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer/Maughan	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	67 deg F
Stack X-Area	433.7 in.2	Start/End Time	1350/1500
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF4 Bottom East**

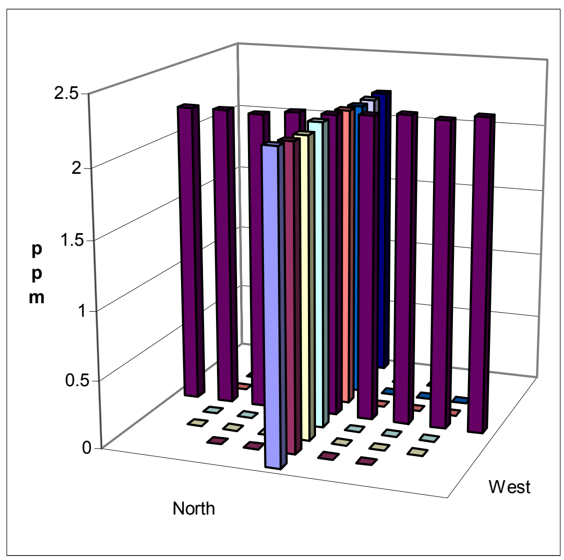
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.15	2.11	2.04	2.100	2.22	2.23	2.23	2.227
2	2.47	2.12	2.05	2.02	2.063	2.14	2.25	2.22	2.203
3	4.56	2.15	2.10	2.00	2.083	2.18	2.19	2.21	2.193
4	7.59	2.06	2.09	2.04	2.063	2.22	2.22	2.26	2.233
Center	11.75	2.09	2.04	2.02	2.050	2.23	2.24	2.23	2.233
5	15.91	2.07	2.01	2.07	2.050	2.19	2.23	2.23	2.217
6	18.94	2.07	2.02	1.97	2.020	2.18	2.21	2.21	2.200
7	21.03	2.05	2.05	2.00	2.033	2.15	2.23	2.22	2.200
8	22.75	2.15	1.98	1.97	2.033	2.16	2.23	2.22	2.203
Averages ---------->		2.101	2.050	2.014	2.055	2.186	2.226	2.226	2.212

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.13		Mean	2.05	2.21	2.13
Min Point	2.02	-5.3%	Std. Dev.	0.02	0.02	0.08
Max Point	2.23	4.7%	COV as %	1.0	0.7	**4.0**

Avg. Conc. 2.133 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	68	66	F
Centerline vel.	n 1733	w 1672	fpm
Injection flowmeter	20	21	ball**
Stack flow	5600	5500	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	997.6	997.3	mbar
Ambient humidity	42	40	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	-3/25/43/7/19/-3	2/28/19/36/28	
No. Bk-Gd samples	6	5	n



Instuments Used:

B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:

Injection flow adjusted up from 19 to 20 shortly after switching traverse directions.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-6**
Date	10/25/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer/Maughan	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	68.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1510/1610
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF7 Center**

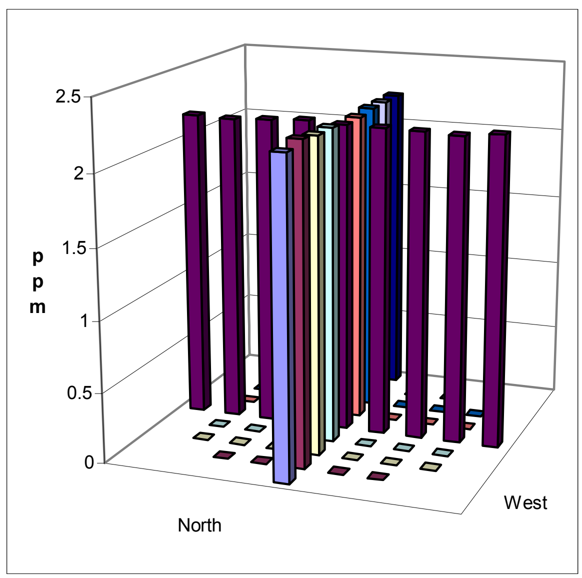
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.23	2.20	2.16	2.197	2.25	2.14	2.18	2.190
2	2.47	2.17	2.19	2.15	2.170	2.21	2.21	2.25	2.223
3	4.56	2.17	2.17	2.20	2.180	2.22	2.20	2.17	2.197
4	7.59	2.22	2.12	2.22	2.187	2.21	2.20	2.18	2.197
Center	11.75	2.20	2.18	2.19	2.190	2.16	2.15	2.19	2.167
5	15.91	2.18	2.26	2.17	2.203	2.17	2.17	2.17	2.170
6	18.94	2.19	2.15	2.23	2.190	2.24	2.20	2.12	2.187
7	21.03	2.19	2.21	2.13	2.177	2.19	2.16	2.20	2.183
8	22.75	2.16	2.20	2.20	2.187	2.25	2.16	2.15	2.187
Averages ---------->		2.190	2.187	2.183	2.187	2.211	2.177	2.179	2.189

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.19		Mean	2.19	2.19	2.19
Min Point	2.17	-1.0%	Std. Dev.	0.01	0.02	0.02
Max Point	2.22	1.6%	COV as %	0.5	0.9	**0.7**

Avg. Conc. 2.189 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	66	71	F
Centerline vel.	w 1672	n 1650	fpm
Injection flowmeter	21	20	ball**
Stack flow	5500	5400	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	997.3	997.0	mbar
Ambient humidity	40	41	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	2/28/19/36/28	53/16/21	
No. Bk-Gd samples	5	3	n



Instuments Used:

B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-7**
Date	10/29/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	57 deg F
Stack X-Area	433.7 in.2	Start/End Time	1245/1400
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF7 Top West**

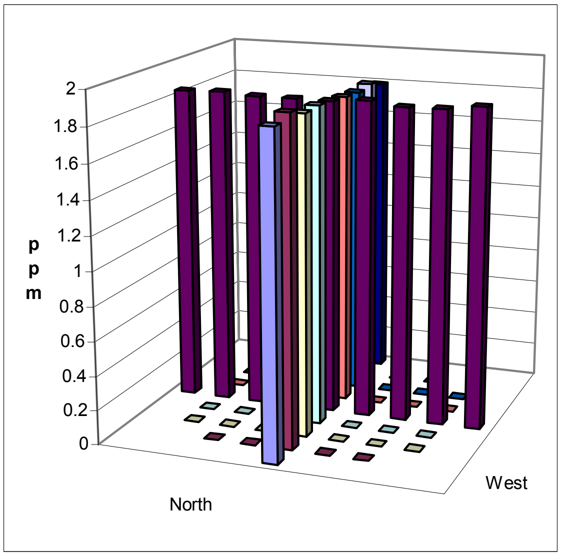
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	1.90	1.84	1.85	1.863	1.80	1.85	1.86	1.837
2	2.47	1.84	1.86	1.81	1.837	1.86	1.86	1.89	1.870
3	4.56	1.87	1.81	1.82	1.833	1.85	1.83	1.80	1.827
4	7.59	1.92	1.83	1.82	1.857	1.82	1.84	1.83	1.830
Center	11.75	1.80	1.88	1.84	1.840	1.83	1.81	1.81	1.817
5	15.91	1.87	1.83	1.82	1.840	1.83	1.79	1.79	1.803
6	18.94	1.89	1.83	1.80	1.840	1.77	1.80	1.81	1.793
7	21.03	1.86	1.80	1.90	1.853	1.82	1.82	1.78	1.807
8	22.75	1.82	1.83	1.89	1.847	1.76	1.80	1.75	1.770
Averages ---------->		1.863	1.834	1.839	1.846	1.816	1.822	1.813	1.817

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	1.83		Mean	1.84	1.82	1.83
Min Point	1.77	-3.3%	Std. Dev.	0.01	0.03	0.02
Max Point	1.87	2.1%	COV as %	0.5	1.4	**1.2**

Avg. Conc. 1.832 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	57	57	F
Centerline vel.	N1807	W 1884	fpm
Injection flowmeter	20	18	ball**
Stack flow			cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	997.5	997.3	mbar
Ambient humidity	58	78	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	13/5/18/19	72/24/27/21/14/16	
No. Bk-Gd samples	4	6	n



Instuments Used:

B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:

After delays in the morning, this test was finally started at 1245, so the starting parameters had to be updated.
New prefilters were installed on the intakes of the HEPA filters.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-8**
Date	10/29/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	57.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1400/1513
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF7 Top East**

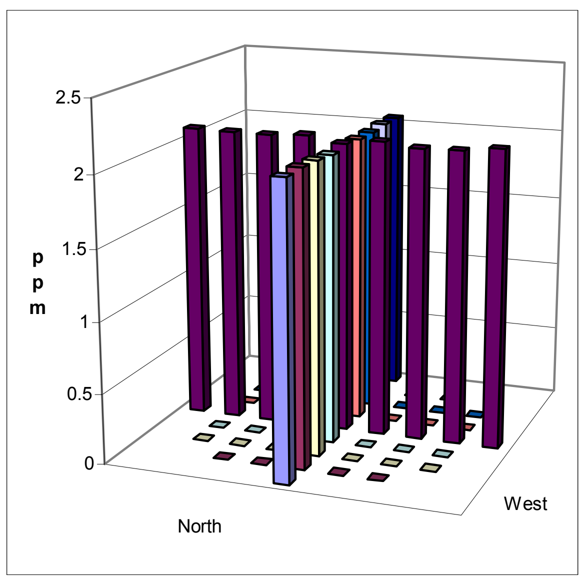
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.08	2.07	2.03	2.060	2.08	2.07	2.04	2.063
2	2.47	1.98	2.06	2.05	2.030	2.06	2.06	2.09	2.070
3	4.56	2.00	2.02	2.05	2.023	2.09	2.04	2.05	2.060
4	7.59	2.02	2.07	2.07	2.053	2.07	2.02	2.04	2.043
Center	11.75	2.03	2.01	2.02	2.020	2.08	2.06	2.06	2.067
5	15.91	2.02	2.08	2.08	2.060	2.06	2.05	2.03	2.047
6	18.94	2.08	2.04	2.01	2.043	2.06	2.03	2.04	2.043
7	21.03	2.09	2.03	2.02	2.047	2.04	2.05	2.07	2.053
8	22.75	2.00	2.09	2.06	2.050	2.08	1.99	2.08	2.050
Averages ---------->		2.033	2.052	2.043	2.043	2.069	2.041	2.056	2.055

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.05		Mean	2.04	2.05	2.05
Min Point	2.02	-1.4%	Std. Dev.	0.02	0.01	0.02
Max Point	2.07	1.0%	COV as %	0.8	0.5	**0.7**

Avg. Conc. 2.050 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	57	58	F
Centerline vel.	w 1884	n 1820	fpm
Injection flowmeter	20	20	ball**
Stack flow	6200	5900	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	997.3	996.3	mbar
Ambient humidity	78	72	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	72/24/27/21/14/16	25/21/17/19	
No. Bk-Gd samples	6	4	n



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-9**
Date	11/1/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	62 deg F
Stack X-Area	433.7 in.2	Start/End Time	1047 - 1150
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF7 Bottom West**

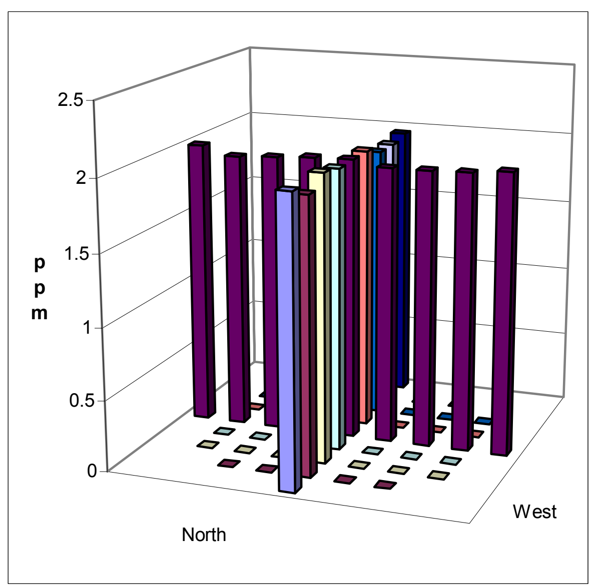
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	1.98	1.94	1.94	1.953	2.02	1.99	1.98	1.997
2	2.47	1.96	1.89	1.93	1.927	1.91	1.87	1.97	1.917
3	4.56	1.91	1.92	1.93	1.920	1.97	2.01	2.03	2.003
4	7.59	1.92	1.92	1.91	1.917	1.97	1.95	2.00	1.973
Center	11.75	1.97	1.94	1.96	1.957	1.98	1.97	1.99	1.980
5	15.91	1.94	2.00	1.91	1.950	2.03	1.92	2.00	1.983
6	18.94	1.92	1.96	1.92	1.933	1.89	1.94	1.94	1.923
7	21.03	1.94	1.87	1.94	1.917	1.94	1.93	1.91	1.927
8	22.75	1.98	2.01	1.94	1.977	1.93	1.94	2.00	1.957
Averages ---------->		1.947	1.939	1.931	1.939	1.960	1.947	1.980	1.962

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	1.95		Mean	1.93	1.96	1.94
Min Point	1.92	-1.7%	Std. Dev.	0.02	0.03	0.03
Max Point	2.00	2.7%	COV as %	0.8	1.8	**1.5**

Avg. Conc. 1.948 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	63	61	F
Centerline vel.	W 1794	N 1759	fpm
Injection flowmeter	20	20	ball**
Stack flow	5900	5700	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	992.0	991.8	mbar
Ambient humidity	55	48	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	21/36/28/56/27/32	41/12/22/5	
No. Bk-Gd samples	6	4	n



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: On start, the B&K had pump test and vibration errors. Water drained from the bottom of the stack when the fans wre started. Ran fans @60Hz to dry stack. Run restarted later to get new regulator installed on gas cylinder Starting parameters were updated. It rained steadily yesterday.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-10**		
Date	10/31/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**		
Tester	Maughan	Fan Setting	**50 Hz**		
Stack Dia.	23.5 in.	Stack Temp	67.1 deg F		
Stack X-Area	433.7 in.2	Start/End Time	1425/1535		
Elevation	N.A.	Center 2/3 from	2.16	to:	21.34
Distance to disturbance	75 inches	Points in Center 2/3	2	to:	7
Measurement units	ppm SF6	Injection Point	**EF7 Bottom East**		

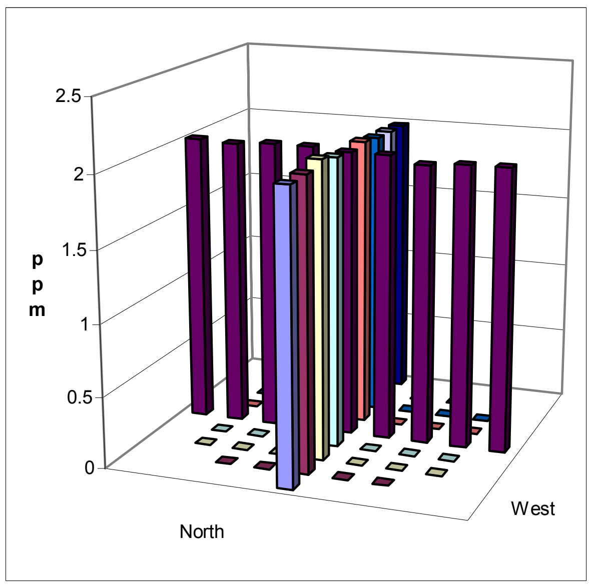
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.02	2.00	1.92	1.980	2.00	1.99	2.05	2.013
2	2.47	1.97	1.98	1.98	1.977	2.02	2.04	2.00	2.020
3	4.56	1.96	1.93	1.97	1.953	2.06	2.09	2.04	2.063
4	7.59	1.99	2.01	2.01	2.003	2.00	2.02	2.04	2.020
Center	11.75	1.97	2.05	1.99	2.003	2.01	1.98	2.01	2.000
5	15.91	2.04	1.99	2.04	2.023	2.01	2.02	2.03	2.020
6	18.94	2.05	2.01	2.01	2.023	1.98	2.00	2.00	1.993
7	21.03	1.97	2.04	2.00	2.003	2.02	1.99	1.96	1.990
8	22.75	2.01	2.06	1.98	2.017	1.98	2.01	1.95	1.980
Averages ---------->		1.998	2.008	1.989	1.998	2.009	2.016	2.009	2.011

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.00		Mean	2.00	2.02	2.01
Min Point	1.95	-2.6%	Std. Dev.	0.03	0.02	0.03
Max Point	2.06	2.9%	COV as %	1.3	1.2	**1.3**

Avg. Conc. 2.005 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	67.2	67	F
Centerline vel.	N1728	W1804	fpm
Injection flowmeter	20	20	ball**
Stack flow	5600	5900	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	982.3	983.2	mbar
Ambient humidity	38	36	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	18/11/12/25	64/9/21/20	
No. Bk-Gd samples	4	4	n



Instuments Used:

B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: On start, the B&K had pump test and vibration errors. Water drained from the bottom of the stack when the fans wre started. Ran fans @60Hz to dry stack. Run restarted later to get new regulator installed on gas cylinder Starting parameters were updated. It rained steadily yesterday.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-11**			
Date	11/1/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**			
Tester	Glissmeyer	Fan Setting	**50 Hz**			
Stack Dia.	23.5 in.	Stack Temp	63 deg F			
Stack X-Area	433.7 in.2	Start/End Time	1200 - 1305			
Elevation	N.A.	Center 2/3 from	2.16	to:	21.34	
Distance to disturbance	75 inches	Points in Center 2/3	2	to:	7	
Measurement units	ppm SF6	Injection Point	**EF5 - Centerline**			

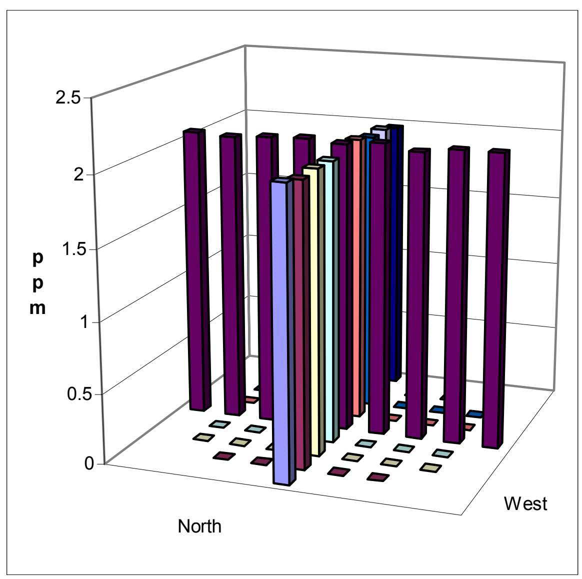
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.00	2.06	2.02	2.027	2.01	2.03	2.05	2.030
2	2.47	2.09	2.01	1.98	2.027	2.00	1.99	1.98	1.990
3	4.56	1.99	2.00	1.99	1.993	2.03	1.99	2.00	2.007
4	7.59	2.02	2.03	2.05	2.033	2.01	1.99	2.00	2.000
Center	11.75	1.99	2.01	2.03	2.010	2.09	2.08	2.02	2.063
5	15.91	2.00	2.03	2.06	2.030	2.06	2.03	2.04	2.043
6	18.94	2.02	2.01	2.03	2.020	2.02	1.98	2.02	2.007
7	21.03	2.00	2.01	2.00	2.003	2.03	1.99	2.02	2.013
8	22.75	2.02	2.05	1.98	2.017	1.95	1.98	1.99	1.973
Averages ---------->		2.014	2.023	2.016	2.018	2.022	2.007	2.013	2.014

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.02		Mean	2.02	2.02	2.02
Min Point	1.97	-2.1%	Std. Dev.	0.01	0.03	0.02
Max Point	2.06	2.4%	COV as %	0.7	1.3	**1.0**

Avg. Conc. 2.013 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	61	65	F
Centerline vel.	N 1759	W 1826	fpm
Injection flowmeter	20	20	ball**
Stack flow	5700	6000	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	991.8	991.0	mbar
Ambient humidity	48	52	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	5/25/9/-3	17/2/4/6	
No. Bk-Gd samples	4	4	n



Instuments Used:

B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: On start, the B&K had pump test and vibration errors. Water drained from the bottom of the stack when the fans wre started. Ran fans @60Hz to dry stack. Run restarted later to get new regulator installed on gas cylinder Starting parameters were updated. It rained steadily yesterday.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-12**
Date	11/1/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	65 deg F
Stack X-Area	433.7 in.2	Start/End Time	1305 - 1415
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF1 Centerline**

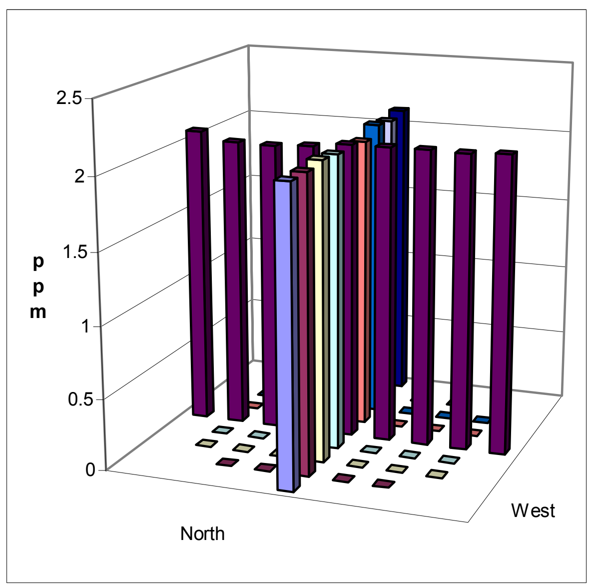
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.08	2.09	2.07	2.080	2.03	2.02	2.05	2.033
2	2.47	1.99	2.09	2.12	2.067	1.98	2.05	2.07	2.033
3	4.56	2.05	2.07	2.10	2.073	2.02	2.10	2.05	2.057
4	7.59	2.06	2.11	2.04	2.070	2.04	2.05	2.03	2.040
Center	11.75	2.03	2.12	2.06	2.070	2.04	2.06	2.06	2.053
5	15.91	2.02	2.05	2.05	2.040	2.05	1.99	2.02	2.020
6	18.94	2.02	2.02	2.03	2.023	2.07	2.09	2.10	2.087
7	21.03	2.03	2.04	2.02	2.030	2.07	2.06	2.07	2.067
8	22.75	2.04	2.13	2.09	2.087	2.12	2.10	2.06	2.093
Averages ---------->		2.036	2.080	2.064	2.060	2.047	2.058	2.057	2.054

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.06		Mean	2.05	2.05	2.05
Min Point	2.02	-1.8%	Std. Dev.	0.02	0.02	0.02
Max Point	2.09	1.8%	COV as %	1.0	1.1	**1.0**

Avg. Conc. 2.056 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	65	65	F
Centerline vel.	W 1826	N 1732	fpm
Injection flowmeter	20	21	ball**
Stack flow	6000	5600	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	991.0	991.1	mbar
Ambient humidity	52	57	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	17/2/4/6/6	102/22/22/22	
No. Bk-Gd samples	5	4	n



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: On start, the B&K had pump test and vibration errors. Water drained from the bottom of the stack when the fans wre started. Ran fans @60Hz to dry stack. Run restarted later to get new regulator installed on gas cylinder Starting parameters were updated. It rained steadily yesterday.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-13**
Date	11/1/01	Fan Configuration	**4 fan: EF1, EF4, EF5, EF7**
Tester	Maughan	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	66 deg F
Stack X-Area	433.7 in.2	Start/End Time	1450 - 1558
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**EF1 Bottom East**

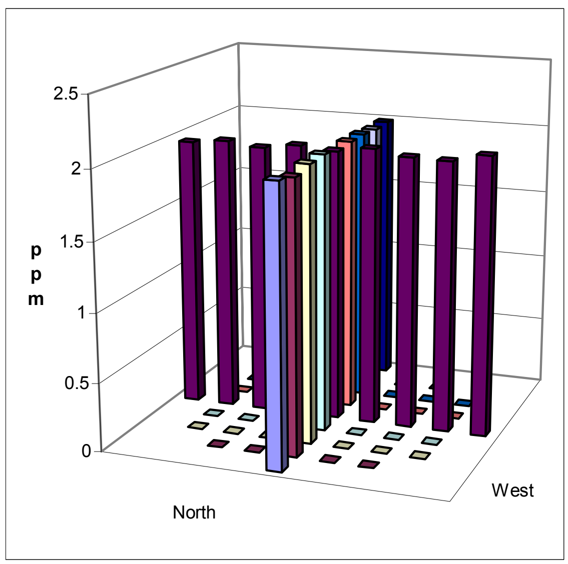
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.03	2.01	2.04	2.027	2.02	1.96	2.00	1.993
2	2.47	1.99	1.94	1.97	1.967	1.96	1.97	1.94	1.957
3	4.56	1.97	2.00	1.95	1.973	2.00	1.98	1.99	1.990
4	7.59	2.02	1.99	2.03	2.013	1.99	1.98	2.03	2.000
Center	11.75	1.98	1.98	1.97	1.977	1.97	1.99	1.94	1.967
5	15.91	2.01	1.97	2.02	2.000	2.01	1.96	1.98	1.983
6	18.94	1.97	1.98	1.94	1.963	2.02	1.96	1.97	1.983
7	21.03	1.98	1.98	2.02	1.993	1.97	1.95	1.99	1.970
8	22.75	1.98	1.96	1.96	1.967	1.97	1.97	1.99	1.977
Averages ---------->		1.992	1.979	1.989	1.987	1.990	1.969	1.981	1.980

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	1.98		Mean	1.98	1.98	1.98
Min Point	1.96	-1.3%	Std. Dev.	0.02	0.01	0.02
Max Point	2.03	2.2%	COV as %	0.9	0.8	**0.8**

Avg. Conc. 1.985 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	200	200	psig
Sample Port Temp	65	67	F
Centerline vel.	N 1690	W 1732	fpm
Injection flowmeter	20	20	ball**
Stack flow	5500	5700	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	991.1	991.0	mbar
Ambient humidity	55	56	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	10/4.1/17.6/-4.1/31.2	19.4/15.3/28.6/16	
No. Bk-Gd samples	5	4	n



Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: Duplicate run on GT-5

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-14**
Date	11/15/01	Fan Configuration	**Turbine Fans**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	65.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1040/1255
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET9 Centerline**

1st

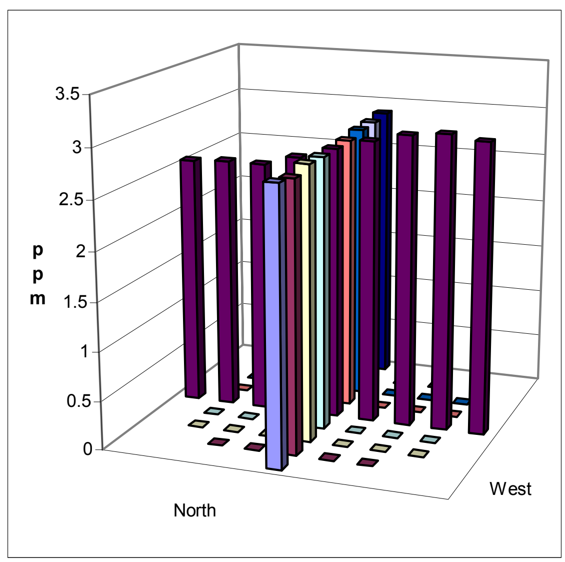
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.93	2.97	3.01	2.970	2.76	2.67	2.84	2.757
2	2.47	3.03	3.00	3.03	3.020	2.70	2.78	2.67	2.717
3	4.56	2.99	2.97	2.99	2.983	2.74	2.77	2.81	2.773
4	7.59	2.89	2.89	2.91	2.897	2.81	2.72	2.76	2.763
Center	11.75	2.82	2.79	2.77	2.793	2.75	2.81	2.74	2.767
5	15.91	2.67	2.69	2.68	2.680	2.73	2.80	2.80	2.777
6	18.94	2.58	2.55	2.61	2.580	2.81	2.80	2.83	2.813
7	21.03	2.57	2.57	2.61	2.583	2.82	2.81	2.84	2.823
8	22.75	2.57	2.56	2.55	2.560	2.81	2.89		2.850
Averages ---------->		2.783	2.777	2.796	2.785	2.770	2.783	2.786	2.782

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.78		Mean	2.79	2.78	2.78
Min Point	2.56	-8.0%	Std. Dev.	0.18	0.04	0.13
Max Point	3.02	8.5%	COV as %	6.6	1.3	**4.6**

Avg. Conc. 2.784 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	150	180	psig
Sample Port Temp	63	68	F fpm
Centerline vel.	N 1304	W 1300	fpm
Injection flowmeter	20	20	ball**
Stack flow	4000	4000	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	984.4	984.3	mbar
Ambient humidity	75	59	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	11/11/10/11/13/12	24/20/19/17	
No. Bk-Gd samples	6	4	n
Ambient Temperature	54	60	F



Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: Prefilters replaced today. Flow is up.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-15**
Date	11/15/01	Fan Configuration	**Turbine Fans**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	68.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1300/1500
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET9 west side**

Traverse-->		West				North 1st			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	3.01	3.07	3.00	3.027	2.76	2.75	2.76	2.757
2	2.47	2.95	2.98	3.01	2.980	2.85	2.76	2.70	2.770
3	4.56	2.96	2.99	2.96	2.970	2.86	2.76	2.79	2.803
4	7.59	2.93	2.90	2.91	2.913	2.78	2.81	2.75	2.780
Center	11.75	2.80	2.79	2.80	2.797	2.80	2.81	2.83	2.813
5	15.91	2.66	2.70	2.63	2.663	2.83	2.85	2.85	2.843
6	18.94	2.62	2.63	2.59	2.613	2.87	2.81	2.86	2.847
7	21.03	2.57	2.56	2.53	2.553	2.83	2.86	2.84	2.843
8	22.75	2.56	2.54	2.55	2.550	2.86	2.89	2.77	2.840
Averages ---------->		2.784	2.796	2.776	2.785	2.827	2.811	2.794	2.811

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.80		Mean	2.78	2.81	2.80
Min Point	2.55	-8.9%	Std. Dev.	0.18	0.03	0.12
Max Point	3.03	8.2%	COV as %	6.3	1.1	**4.4**

Avg. Conc. 2.797 ppm

Gas analyzer checked: 19-Oct-01

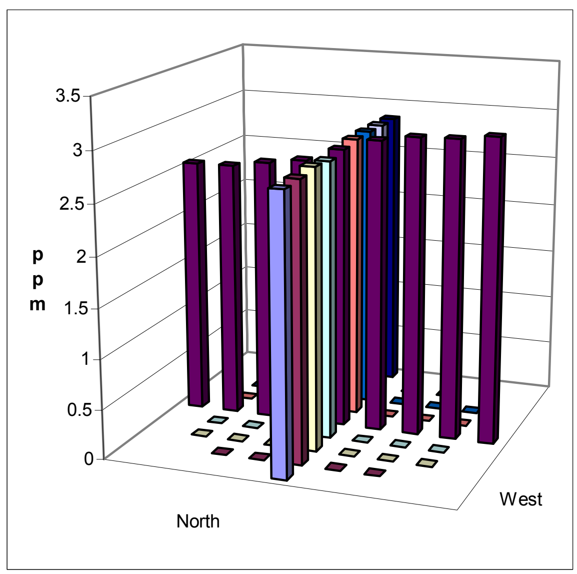
	Start	Finish	
Tracer tank pressure	180	180	psig
Sample Port Temp	68	69	F
Centerline vel.	W 1320	N 1304	fpm
Injection flowmeter	20	20	ball**
Stack flow	4000	4000	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	984.3	983.2	mbar
Ambient humidity	59	45	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	18/17/17/17	27/34/8/33	
No. Bk-Gd samples	4	4	n
Ambient Temperature	60	63	F

Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02



Notes: Quite windy.

TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-16**
Date	11/15/01	Fan Configuration	**Turbine Fans**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	69 deg F
Stack X-Area	433.7 in.2	Start/End Time	1504/1604
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET9 east side**

1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	3.08	2.98	3.00	3.020	2.80	2.81	2.70	2.770
2	2.47	2.95	3.00	2.97	2.973	2.77	2.74	2.74	2.750
3	4.56	2.95	2.98	2.96	2.963	2.78	2.78	2.75	2.770
4	7.59	2.89	2.92	2.93	2.913	2.76	2.76	2.78	2.767
Center	11.75	2.80	2.84	2.80	2.813	2.80	2.79	2.83	2.807
5	15.91	2.73	2.75	2.71	2.730	2.83	2.78	2.87	2.827
6	18.94	2.63	2.64	2.67	2.647	2.89	2.85	2.85	2.863
7	21.03	2.66	2.65	2.62	2.643	2.84	2.84	2.82	2.833
8	22.75	2.63	2.67	2.60	2.633	2.84	2.86	2.84	2.847
Averages ---------->		2.813	2.826	2.807	2.815	2.812	2.801	2.798	2.804

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.81		Mean	2.81	2.80	2.81
Min Point	2.63	-6.3%	Std. Dev.	0.14	0.04	0.10
Max Point	3.02	7.5%	COV as %	5.1	1.5	**3.6**

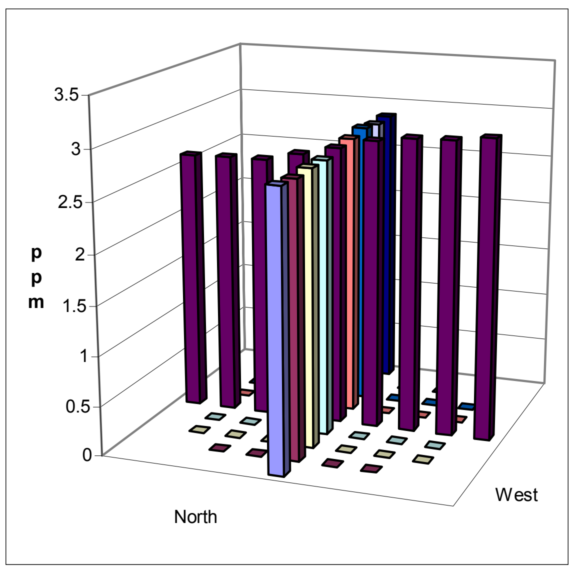
Avg. Conc. 2.809 ppm

Gas analyzer checked:
19-Oct-01

	Start	Finish	
Tracer tank pressure	180	180	psig
Sample Port Temp	69	69	F
Centerline vel.	N 1304	W 1341	fpm
Injection flowmeter	20	20	ball**
Stack flow	4000	4000	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	983.2	983.3	mbar
Ambient humidity	59	49	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	27/34/8/33	32/19/20/20	
No. Bk-Gd samples	4	4	n
Ambient Temperature	63	60	F

Instuments Used:
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler
Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes: Calm to light winds.



TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-17**
Date	11/16/01	Fan Configuration	**Turbine Fans**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	61.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	0936/1046
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET9 Bottom East**
			1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	3.12	3.11	3.15	3.127	2.85	2.78	2.81	2.813
2	2.47	3.09	3.09	3.12	3.100	2.76	2.87	2.83	2.820
3	4.56	3.13	3.09	3.14	3.120	2.85	2.88	2.86	2.863
4	7.59	2.98	3.02	3.01	3.003	2.87	2.88	2.87	2.873
Center	11.75	2.92	2.90	2.86	2.893	2.91	2.90	2.91	2.907
5	15.91	2.76	2.73	2.80	2.763	2.93	2.90	2.88	2.903
6	18.94	2.72	2.69	2.71	2.707	2.90	2.87	2.88	2.883
7	21.03	2.65	2.70	2.75	2.700	2.83	2.92	2.94	2.897
8	22.75	2.68	2.69	2.67	2.680	2.87	2.90	2.97	2.913
Averages ---------->		2.894	2.891	2.912	2.899	2.863	2.878	2.883	2.875

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.89		Mean	2.90	2.88	2.89
Min Point	2.68	-7.2%	Std. Dev.	0.18	0.03	0.12
Max Point	3.13	8.3%	COV as %	6.2	1.0	**4.3**

Avg. Conc. 2.885 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	170	170	psig
Sample Port Temp	60	63	F
Centerline vel.	w 1323	n 1309	fpm
Injection flowmeter	20	21	ball**
Stack flow	4100	4000	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	998.0	989.1	mbar
Ambient humidity	96	93	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	18/13/10/14/13/11	144/34/26/21	
No. Bk-Gd samples	6	4	n
Ambient Temperature	51	53	F

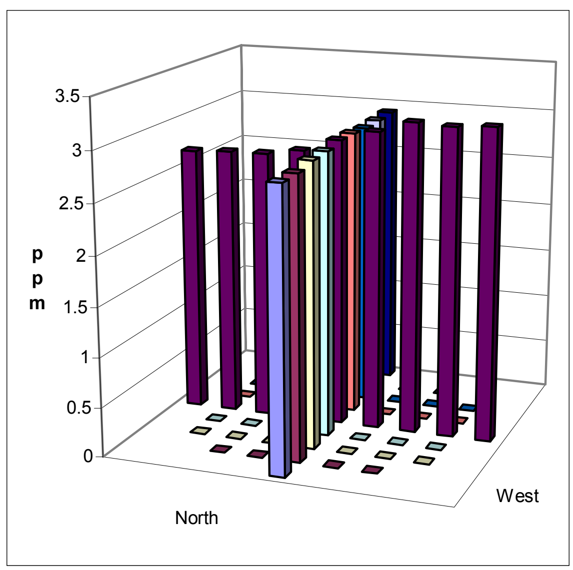
Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:



TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-18**
Date	11/16/01	Fan Configuration	**Turbine Fans**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	61.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1050/1245
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET9 Bottom West**

Traverse-->		1st West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	3.02	2.95	3.07	3.013	2.72	2.67	2.88	2.757
2	2.47	2.96	2.98	3.00	2.980	2.75	2.77	2.73	2.750
3	4.56	2.91	2.97	2.93	2.937	2.80	2.80	2.76	2.787
4	7.59	2.84	2.87	2.92	2.877	2.76	2.79	2.83	2.793
Center	11.75	2.77	2.79	2.69	2.750	2.83	2.82	2.82	2.823
5	15.91	2.63	2.60	2.65	2.627	2.82	2.85	2.86	2.843
6	18.94	2.51	2.55	2.58	2.547	2.79	2.80	2.85	2.813
7	21.03	2.57	2.55	2.54	2.553	2.79	2.75	2.87	2.803
8	22.75	2.53	2.50	2.53	2.520	2.71	2.84	2.96	2.837
Averages ---------->		2.749	2.751	2.768	2.756	2.774	2.788	2.840	2.801

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.78		Mean	2.75	2.80	2.78
Min Point	2.52	-9.3%	Std. Dev.	0.18	0.03	0.13
Max Point	3.01	8.5%	COV as %	6.6	1.1	**4.6**

Avg. Conc. 2.777 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	170	170	psig
Sample Port Temp	63	60	F
Centerline vel.	n1309	w 1302	fpm
Injection flowmeter	20	20	ball**
Stack flow	4100	3900	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	989.1	988.8	mbar
Ambient humidity	93	93	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	26/21/15/18/12	15/7/12/18	
No. Bk-Gd samples	5	4	n
Ambient Temperature	53	52	F

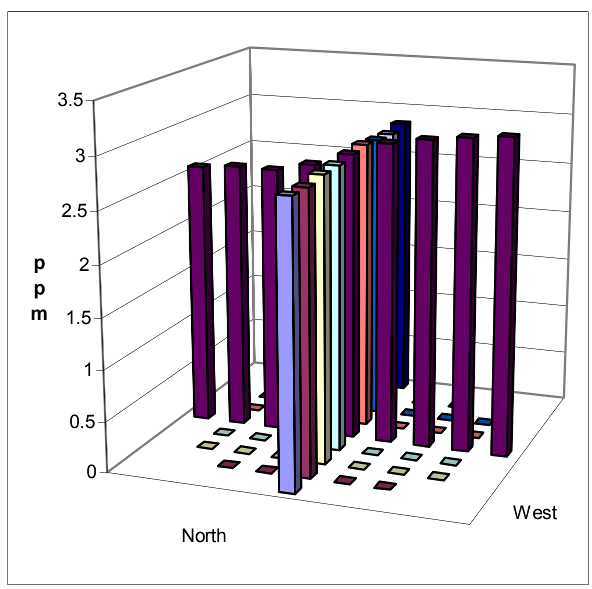
Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:



TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-19**
Date	11/19/01	Fan Configuration	**Turbine Fans**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	54.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	957/1245
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET9 Top West**
			1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.98	2.91	2.91	2.933	2.62	2.55	2.54	2.570
2	2.47	2.89	2.90	2.90	2.897	2.53	2.50	2.64	2.557
3	4.56	2.83	2.87	2.85	2.850	2.59	2.57	2.48	2.547
4	7.59	2.82	2.80	2.84	2.820	2.60	2.64	2.63	2.623
Center	11.75	2.71	2.71	2.72	2.713	2.57	2.61	2.66	2.613
5	15.91	2.59	2.72	2.59	2.633	2.58	2.63	2.73	2.647
6	18.94	2.64	2.67	2.53	2.613	2.63	2.68	2.72	2.677
7	21.03	2.52	2.53	2.49	2.513	2.68	2.63	2.62	2.643
8	22.75	2.57	2.51	2.56	2.547	2.62	2.67	2.69	2.660
Averages ---------->		2.728	2.736	2.710	2.724	2.602	2.609	2.634	2.615

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.67		Mean	2.72	2.62	2.67
Min Point	2.51	-5.9%	Std. Dev.	0.14	0.05	0.11
Max Point	2.93	9.9%	COV as %	5.2	1.8	**4.3**

Avg. Conc. 2.671 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	170	170	psig
Sample Port Temp	51	58	F
Centerline vel.	w 1349	n 1342	fpm
Injection flowmeter	20	20	ball**
Stack flow	4100	4200	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	996.3	994.7	mbar
Ambient humidity	84	88	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	12/37/21/19/15/17	44/36/36/34	
No. Bk-Gd samples	6	4	n
Ambient Temperature	42	44	F

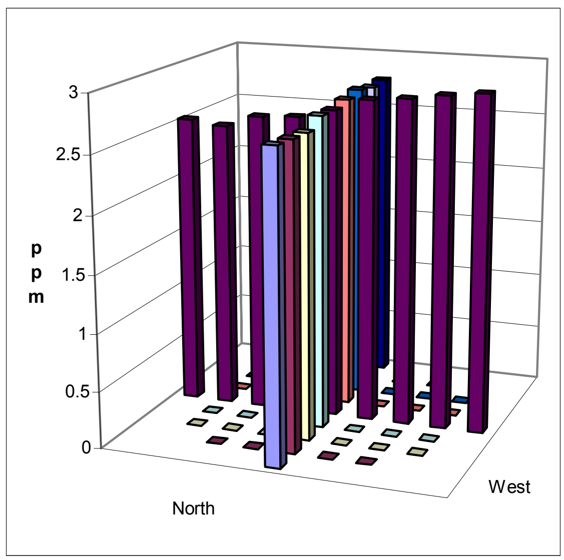
Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:



TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-20**
Date	11/20/01	Fan Configuration	**Turbine Fan Configuration**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	62.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1010/1240
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET9 Top East**

1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.75	2.87	2.81	2.810	2.57	2.58	2.53	2.560
2	2.47	2.79	2.92	2.83	2.847	2.60	2.60	2.62	2.607
3	4.56	2.76	2.79	2.85	2.800	2.62	2.64	2.61	2.623
4	7.59	2.69	2.69	2.74	2.707	2.64	2.64	2.63	2.637
Center	11.75	2.57	2.62	2.64	2.610	2.70	2.62	2.63	2.650
5	15.91	2.50	2.54	2.60	2.547	2.67	2.67	2.63	2.657
6	18.94	2.45	2.49	2.49	2.477	2.67	2.67	2.61	2.650
7	21.03	2.41	2.45	2.45	2.437	2.63	2.73	2.74	2.700
8	22.75	2.44	2.41	2.44	2.430	2.74	2.65	2.64	2.677
Averages ---------->		2.596	2.642	2.650	2.629	2.649	2.644	2.627	2.640

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.63		Mean	2.63	2.65	2.64
Min Point	2.43	-7.8%	Std. Dev.	0.16	0.03	0.11
Max Point	2.85	8.0%	COV as %	6.0	1.1	**4.1**

Avg. Conc. 2.635 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	130	130	psig
Sample Port Temp	62	63	F
Centerline vel.	N 1365	W 1380	fpm
Injection flowmeter	20	20	ball**
Stack flow	4200	4200	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	991.1	988.7	mbar
Ambient humidity	53	64	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	25/27/16/18/14/26	17/34/13/23	
No. Bk-Gd samples	6	4	n
Ambient Temp	54	53	F

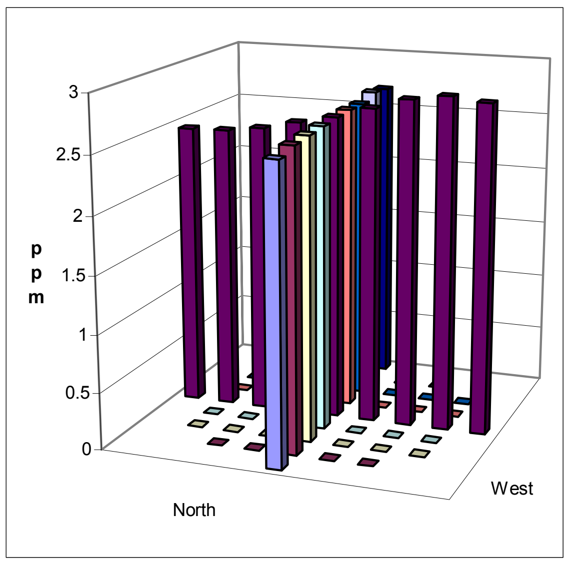
Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:



TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-21**
Date	11/20/01	Fan Configuration	**Turbine Fan Configuration**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	63 deg F
Stack X-Area	433.7 in.2	Start/End Time	1258/1400
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET8 Centerline** 1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.60	2.53	2.58	2.570	2.77	2.82	2.82	2.803
2	2.47	2.56	2.60	2.50	2.553	2.83	2.82	2.79	2.813
3	4.56	2.57	2.57	2.60	2.580	2.81	2.73	2.74	2.760
4	7.59	2.67	2.65	2.67	2.663	2.81	2.78	2.84	2.810
Center	11.75	2.77	2.78	2.76	2.770	2.79	2.79	2.75	2.777
5	15.91	2.92	2.92	2.90	2.913	2.77	2.78	2.79	2.780
6	18.94	2.98	2.94	2.99	2.970	2.76	2.77	2.75	2.760
7	21.03	3.00	3.00	2.99	2.997	2.83	2.77	2.80	2.800
8	22.75	2.98	2.96	3.01	2.983	2.75	2.83	2.77	2.783
Averages ---------->		2.783	2.772	2.778	2.778	2.791	2.788	2.783	2.787

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.78		Mean	2.78	2.79	2.78
Min Point	2.55	-8.2%	Std. Dev.	0.19	0.02	0.13
Max Point	3.00	7.7%	COV as %	6.7	0.8	**4.6**

Avg. Conc. 2.784 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	130	130	psig
Sample Port Temp	63	63	F
Centerline vel.	W 1380	n 1370	fpm
Injection flowmeter	20	20	ball**
Stack flow	4200	4300	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	988.7	987.1	mbar
Ambient humidity	64	64	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	17/34/13/23	40/31/20/19	
No. Bk-Gd samples	4	4	n
Ambient Temp	53	53	F

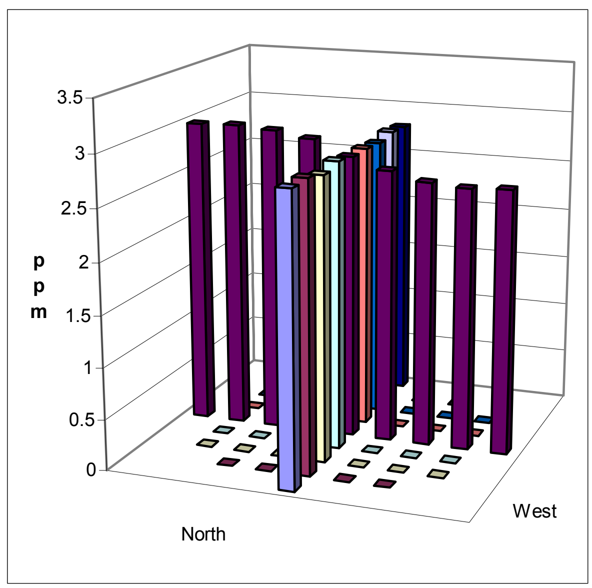
Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:



TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-22**
Date	11/20/01	Fan Configuration	**Turbine Fan Configuration**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	62.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1445/1550
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET8 Centerline**

1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.63	2.57	2.64	2.613	2.82	2.86	2.84	2.840
2	2.47	2.61	2.61	2.58	2.600	2.80	2.93	2.76	2.830
3	4.56	2.66	2.62	2.63	2.637	2.80	2.81	2.79	2.800
4	7.59	2.68	2.70	2.67	2.683	2.84	2.82	2.82	2.827
Center	11.75	2.81	2.77	2.81	2.797	2.81	2.80	2.85	2.820
5	15.91	2.87	2.91	2.92	2.900	2.80	2.82	2.83	2.817
6	18.94	2.97	2.98	2.99	2.980	2.86	2.82	2.83	2.837
7	21.03	3.02	3.00	3.00	3.007	2.83	2.84	2.82	2.830
8	22.75	3.06	3.00	3.06	3.040	2.81	2.78	2.85	2.813
Averages ---------->		2.812	2.796	2.811	2.806	2.819	2.831	2.821	2.824

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.82		Mean	2.80	2.82	2.81
Min Point	2.60	-7.6%	Std. Dev.	0.17	0.01	0.11
Max Point	3.04	8.0%	COV as %	5.9	0.4	**4.0**

Avg. Conc. 2.816 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	130	130	psig
Sample Port Temp	63	62	F
Centerline vel.	n 1370	w 1380	fpm
Injection flowmeter	20	20	ball**
Stack flow	4300	4200	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	987.1	985.2	mbar
Ambient humidity	64	68	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	31/20/19	28/41/32	
No. Bk-Gd samples	3	3	n
Ambient Temp	53	50	F

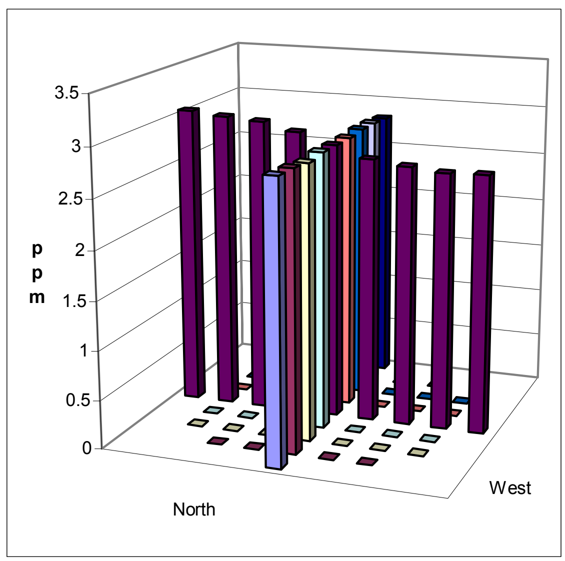
Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:



TRACER GAS TRAVERSE DATA FORM

Site	**291-Z-1 Model**	Run No.	**GT-23**
Date	11/27/01	Fan Configuration	**Turbine Fans, 30 degree from North port**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	49 deg F
Stack X-Area	433.7 in.2	Start/End Time	1315/1428
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	ppm SF6	Injection Point	**ET8 centerline**

1st

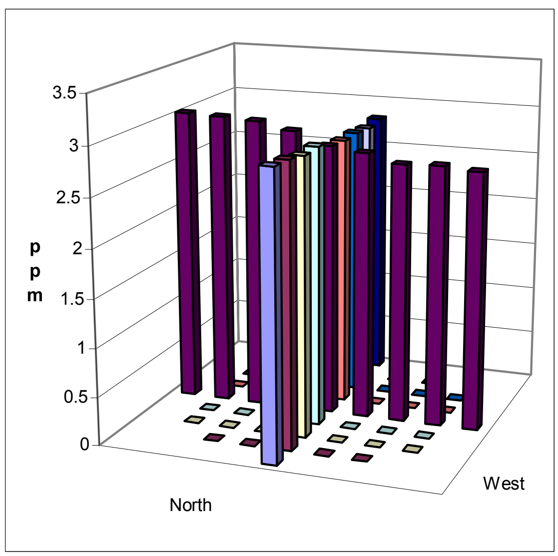
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	ppm				ppm			
1	0.75	2.70	2.64	2.64	2.660	2.95	2.87	2.93	2.917
2	2.47	2.72	2.68	2.67	2.690	2.97	2.82	2.92	2.903
3	4.56	2.66	2.70	2.66	2.673	2.89	2.85	2.85	2.863
4	7.59	2.81	2.76	2.71	2.760	2.87	2.88	2.88	2.877
Center	11.75	2.82	2.78	2.81	2.803	2.80	2.82	2.79	2.803
5	15.91	2.94	2.93	2.92	2.930	2.80	2.76	2.79	2.783
6	18.94	3.03	3.02	2.97	3.007	2.76	2.79	2.82	2.790
7	21.03	2.96	3.03	3.09	3.027	2.78	2.78	2.75	2.770
8	22.75	3.07	3.03	3.02	3.040	2.80	2.79	2.82	2.803
Averages ---------->		2.857	2.841	2.832	2.843	2.847	2.818	2.839	2.834

All	ppm	Dev. from mean	***Center 2/3***	West	North	All
Mean	2.84		Mean	2.84	2.83	2.83
Min Point	2.66	-6.3%	Std. Dev.	0.15	0.05	0.11
Max Point	3.04	7.1%	COV as %	5.2	1.9	**3.7**

Avg. Conc. 2.843 ppm

Gas analyzer checked: 19-Oct-01

	Start	Finish	
Tracer tank pressure	100	100	psig
Sample Port Temp	49	48/38	F*
Centerline vel.	n 1285	w 1364/1330	fpm*
Injection flowmeter	20	20	ball**
Stack flow	4000	4100	cfm
Sampling flowmeter	10	10	lpm Sierra
Ambient pressure	1001.5	1000.1	mbar
Ambient humidity	98	99	RH
B&K vapor correction	Y	Y	Y/N
Back-Gd gas ppb	21/21/14/20/16/16	44/49/30/18/12/31	
No. Bk-Gd samples	6	6	n
Ambient Temp, F	31	30 (33 on VelociCalc)	



Instuments Used:

B & K Model 1302 #1765299

Sierra Inc. Constant Flow Air Sampler

Solmat Zephyr SN 12951472 Cal. Due 7/26/02

Notes:

*First readings from Solomat. Second from out of cal TSI Velocicalc SN 305039. Solomat suspected of reading several degrees high. This has no effect on the particle uniformity results.

Appendix J
Tracer Particle Uniformity Testing Procedure

J.1 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.

J.2 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.

J.3 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.

J.4 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.

J.5 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.

J.6 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.

Preliminary Steps:

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).

Fill in test information on dataform.

Observe the current flow setting for the test stack and record on the data sheet.

Obtain barometric, temperature, and relative humidity information for the particle counter location.

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

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

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.

Turn-on the mobile and reference optical particle counters.

> **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.

Program and synchronize the OPCs for

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

Daily Particulate Background Concentration Measurement

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.

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

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

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.

<u>Position the injection probe, according to the test instruction.</u>

<u>Start injection of the aerosol and adjust the flowrate to the input capabilities of the OPCs.</u>

> **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

<u>Record the initial</u>

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

<u>On the data sheet, label the columns of data according to the directions of the traverses.</u>

<u>Verify that the directional orientations and the numbered sample positions are consistent.</u>

<u>Position the OPC and sample probe at each measurement point in succession, and record the reading on the data form.</u>

> **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.

Perform two additional repetitions of Step 6.3.6.

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

Check the data sheet for completeness.

Record the final

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

Shut off the air pressure to the aerosol generator.

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

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

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

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

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

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

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).

Review the raw data sheets for completeness.

Enter the data into the electronic data sheet.

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).

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.

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.

Figure J.1. Overview of Stack and Injection Setup and Particle Counters

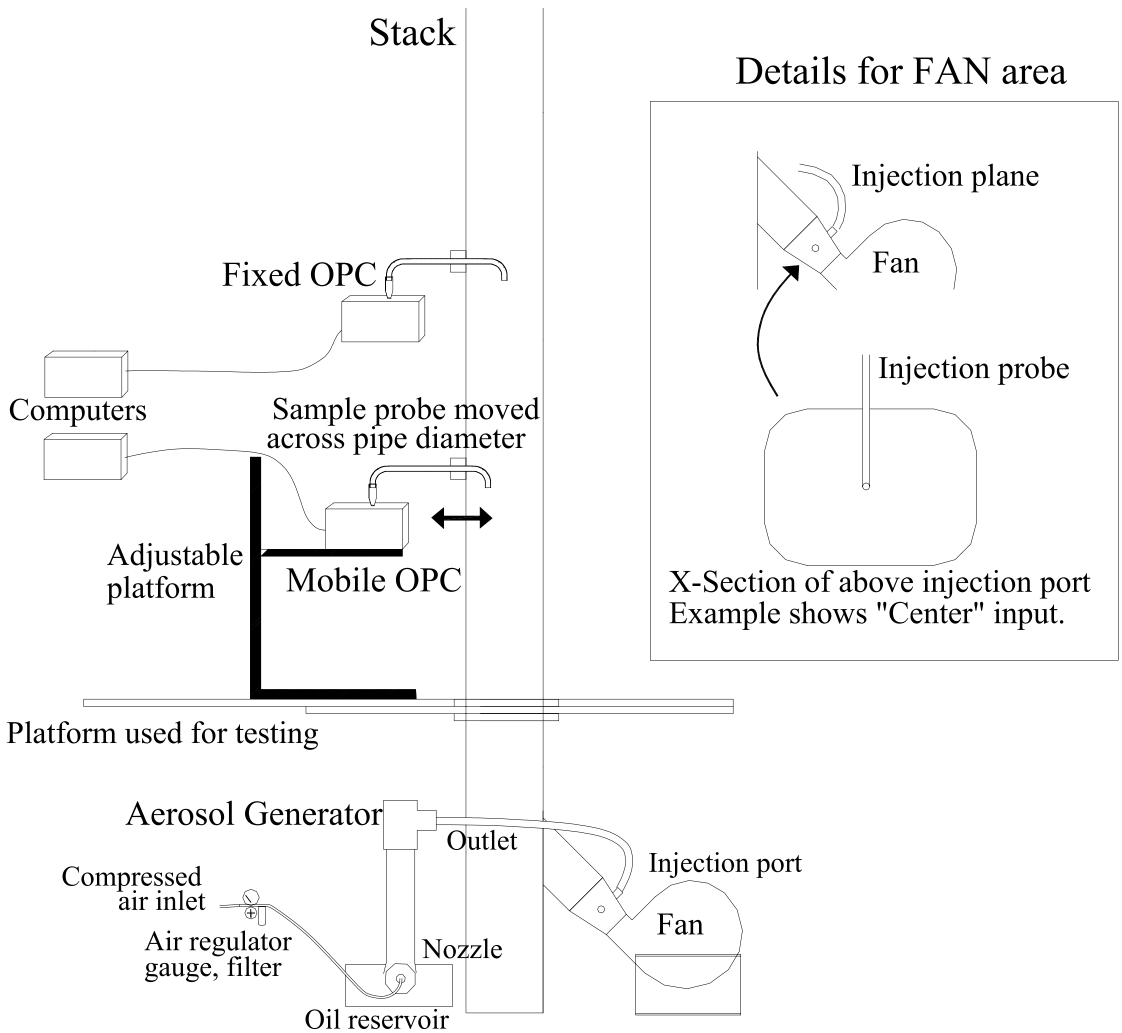


Figure J.2. Illustrative Data Collection Sheet

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:

Figure J.3. Illustrative 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			

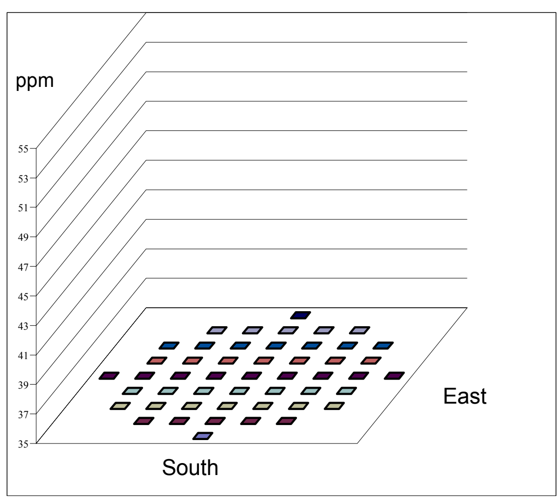
Traverse-->		East				South			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	1.00								
2	1.83								
3	3.22								
4	4.82								
5	6.81								
6	9.70								
Center	13.63								
7	17.55								
8	20.44								
9	22.43								
10	24.03			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

Figure J.4. 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 K
Tracer Particle Uniformity Data Sheets

PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-1**
Date	11/5/01	Fan configuration	**4-fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	62 deg F
Stack X-Area	433.7 in.2	Start/End Time	1427/1556
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Centerline EF-4**

		2nd				1st			
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	323	331	332	328.7	290	340	303	311.0
2	2.47	341	340	333	338.0	296	282	325	301.0
3	4.56	332	327	339	332.7	288	319	267	291.3
4	7.59	374	334	354	354.0	332	309	288	309.7
Center	11.75	348	362	316	342.0	314	292	338	314.7
5	15.91	348	338	350	345.3	302	316	286	301.3
6	18.94	310	328	353	330.3	316	320	321	319.0
7	21.03	344	316	345	335.0	326	325	313	321.3
8	22.75	324	344	347	338.3	306	287	329	307.3
Averages ---------->		338.2	335.6	341.0	338.3	307.8	310.0	307.8	308.5

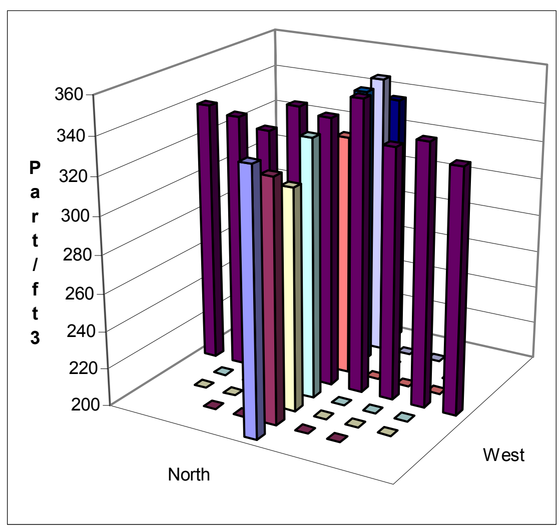
All	pt/ft3	Dev. from mean	***Center 2/3***	North	West	All	Normlzd
Mean	323.4		Mean	339.6	308.3	323.98	337.37
Min Point	291.3	-9.9%	Std. Dev.	8.2	10.9	18.70	10.08
Max Point	354.0	9.5%	COV as %	2.4	3.5	**5.77**	**2.99**

Avg Conc 323 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

	Start	Finish	
Generator Inlet Press	10	10	psig
Stack Temp	62	62	F
Centerline vel.	w 1829	n 1889	fpm
Ambient pressure	997	997.5	mbar
Ambient humidity	36	33	RH
Ambient temp	58	57	F
Back-Gd aerosol	1/3/0/1/0/2	0/0/0/0/0	pt/ft3
No. Bk-Gd samples	6	5	



Optical Particle Counters:(Cal due 7/13/02)

OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

The clock on the OPC is 1-hr fast.

Oil Used: FisherBrand 19

After end of run and before aerosol turned off, the following readings were take in succession at position West 4

320, 322, 347, 329, 356

Sequence at North #4

1509, 1501, 1468, 1620, 1560

PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-3**
Date	11/7/01	Fan configuration	**4-fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	54 deg F
Stack X-Area	433.7 in.2	Start/End Time	1456/1610
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Centerline EF-7**

		2nd				1st			
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	1974	1891	1476	1780.3	1510	1462	1411	1461.0
2	2.47	1926	2056	1459	1813.7	1581	1542	1405	1509.3
3	4.56	1963	1984	1611	1852.7	1506	1465	1599	1523.3
4	7.59	2083	1965	1479	1842.3	1482	1521	1654	1552.3
Center	11.75	1959	1875	1515	1783.0	1484	1530	1640	1551.3
5	15.91	2000	1692	1514	1735.3	1410	1515	1554	1493.0
6	18.94	2072	1545	1546	1721.0	1483	1578	1608	1556.3
7	21.03	2092	1521	1555	1722.7	1573	1525	1631	1576.3
8	22.75	1786	1437	1492	1571.7	1445	1440	1472	1452.3
Averages ---------->		1983.9	1774.0	1516.3	1758.1	1497.1	1508.7	1552.7	1519.5

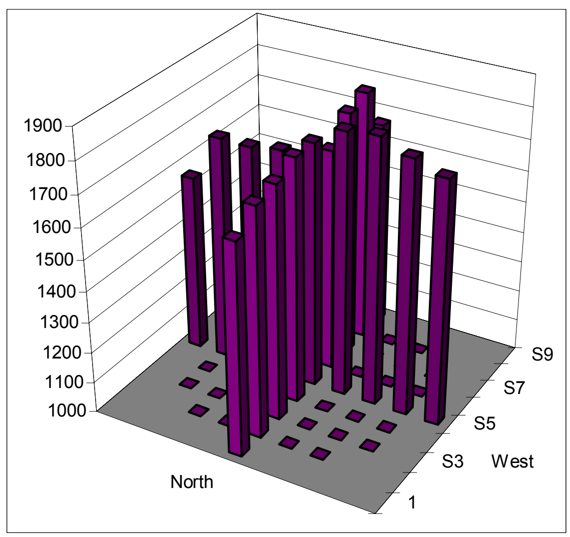
All	pt/ft3	Dev. from mean	*Center 2/3*	North	West	All	Normlzd
Mean	1638.8		Mean	1781.5	1537.4	1659.48	1774.27
Min Point	1452.3	-11.4%	Std. Dev.	56.4	29.6	133.83	45.34
Max Point	1852.7	13.1%	COV as %	3.2	1.9	**8.06**	**2.56**

Avg Conc 1635 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

	Start	Finish	
Generator Inlet Press	10	10	psig
Stack Temp	53	55	F
Centerline vel.	w 1905	n 1900	fpm
Ambient pressure	1008.4	1007.7	mbar
Ambient humidity	62	67	RH
Ambient temp	46	43	F
Back-Gd aerosol	1/1/0/1/0/2/1	0/0/0	pt/ft3
No. Bk-Gd samples	7.0	3.0	



Optical Particle Counters:(Cal due 7/13/02)

OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

Oil Used: FisherBrand 19

At 1549 the scaffold was at 52 F, the sun was low.

The clock on the OPC is 1-hr fast.

Sequence at North #4

1509, 1501, 1468, 1620, 1560

PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-2**
Date	11/7/01	Fan configuration	**4-fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	54 deg F
Stack X-Area	433.7 in.2	Start/End Time	1300/1430
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**EF-7 Centerline**

		1st				2nd			
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	1799	1860	1896	1851.7	1542	1590	1568	1566.7
2	2.47	1838	1815	1892	1848.3	1488	1509	1536	1511.0
3	4.56	1866	1908	1844	1872.7	1564	1474	1562	1533.3
4	7.59	1935	1784	1860	1859.7	1568	1705	1516	1596.3
Center	11.75	1869	1819	1904	1864.0	1578	1708	1562	1616.0
5	15.91	1912	1889	1907	1902.7	1617	1578	1546	1580.3
6	18.94	1941	1944	1924	1936.3	1696	1723	1681	1700.0
7	21.03	1811	1988	1952	1917.0	1629	1535	1626	1596.7
8	22.75	1861	1808	1826	1831.7	1522	1648	1419	1529.7
Averages ---------->		1870.2	1868.3	1889.4	1876.0	1578.2	1607.8	1557.3	1581.1

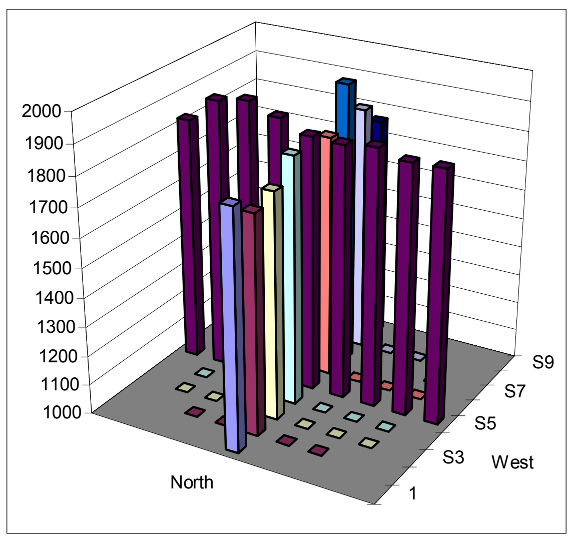
All	pt/ft3	Dev. from mean	***Center 2/3***	North	West	All	Normlzd
Mean	1728.6		Mean	1885.8	1590.5	1738.17	1860.21
Min Point	1511.0	-12.6%	Std. Dev.	33.0	61.1	160.32	59.18
Max Point	1936.3	12.0%	COV as %	1.8	3.8	**9.22**	**3.18**

Avg Conc 1727 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

	Start	Finish	
Generator Inlet Press	10	10	psig
Stack Temp	55	53	F
Centerline vel.	n 1800	w 1905	fpm
Ambient pressure	1008	1008.4	mbar
Ambient humidity	61	62	RH
Ambient temp	47	46	F
Back-Gd aerosol	0/0/2/3/5/4	1/1/0/1/0/2/1	pt/ft3
No. Bk-Gd samples	6	7	



Optical Particle Counters:(Cal due 7/13/02)

OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

The clock on the OPC is 1-hr fast.

Oil Used: FisherBrand 19

Sequence at North #4
1509, 1501, 1468, 1620, 1560

PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-4**
Date	11/8/01	Fan configuration	**4-fan: EF1, EF4, EF5, EF7**
Tester	Glissmeyer	Fan Setting	**50 Hz**
Stack Dia.	23.5 in.	Stack Temp	53.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1306/1515
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Centerline EF-7**

		1st				2nd			
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	1475	1468	1464	1469.0	1211	1119	1188	1172.7
2	2.47	1571	1546	1473	1530.0	1212	1210	1193	1205.0
3	4.56	1524	1601	1440	1521.7	1188	1163	1241	1197.3
4	7.59	1452	1623	1421	1498.7	1236	1183	1163	1194.0
Center	11.75	1436	1566	1424	1475.3	1179	1140	1218	1179.0
5	15.91	1493	1448	1518	1486.3	1309	1252	1245	1268.7
6	18.94	1524	1604	1563	1563.7	1298	1236	1284	1272.7
7	21.03	1503	1540	1478	1507.0	1300	1282	1252	1278.0
8	22.75	1438	1361	1391	1396.7	1186	1099	1178	1154.3
Averages ---------->		1490.7	1528.6	1463.6	1494.3	1235.4	1187.1	1218.0	1213.5

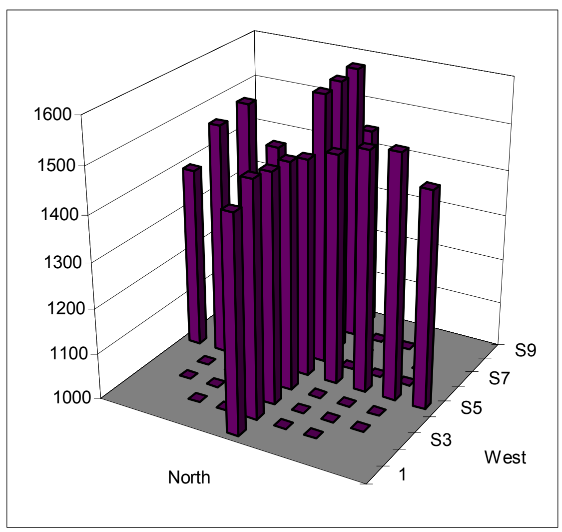
All	pt/ft3	Dev. from mean	***Center 2/3***	North	West	All	Normlzd
Mean	1353.9		Mean	1511.8	1227.8	1369.81	1524.11
Min Point	1154.3	-14.7%	Std. Dev.	29.7	43.2	151.60	43.77
Max Point	1563.7	15.5%	COV as %	2.0	3.5	**11.07**	**2.87**

Avg Conc 1357 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

	Start	Finish	
Generator Inlet Press	8	8	psig
Stack Temp	52	55	F
Centerline vel.	n 1856	w 1817	fpm
Ambient pressure	1005.1	1002.6	mbar
Ambient humidity	64	55	RH
Ambient temp	46	48	F
Back-Gd aerosol	0/0/0/0/0/0/0	0/0/2/0/0	pt/ft3
No. Bk-Gd samples	7	5	



Optical Particle Counters:(Cal due 7/13/02)

OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

The clock on the OPC is 1-hr fast.

Oil Used: FisherBrand 19

Was 53 F on scaffold at start

Lowered aerosol generator pressure from 10 psi to 8 psi because was getting too much aerosol, resulting in "sensor" light on OPC.

PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-5**
Date	11/13/01	Fan configuration	**Turbine fan config**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	66 deg F
Stack X-Area	433.7 in.2	Start/End Time	1430/1600
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**Centerline ET-8**
			1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	333	270	306	303.0	281	280	266	275.7
2	2.47	283	283	268	278.0	276	313	288	292.3
3	4.56	304	304	274	294.0	291	288	236	271.7
4	7.59	286	284	325	298.3	261	273	292	275.3
Center	11.75	306	313	300	306.3	285	257	246	262.7
5	15.91	327	310	323	320.0	294	282	241	272.3
6	18.94	339	321	337	332.3	296	277	308	293.7
7	21.03	308	323	337	322.7	253	273	282	269.3
8	22.75	301	348	336	328.3	273	275	252	266.7
Averages ---------->		309.7	306.2	311.8	309.2	278.9	279.8	267.9	275.5

All	pt/ft3	Dev. from mean	***Center 2/3***	North	West	All	Normlzd
Mean	292.4		Mean	307.4	276.8	292.07	315.08
Min Point	262.7	-10.2%	Std. Dev.	18.9	11.8	21.93	17.76
Max Point	332.3	13.7%	COV as %	6.1	4.2	**7.51**	**5.64**

Avg Conc 293 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

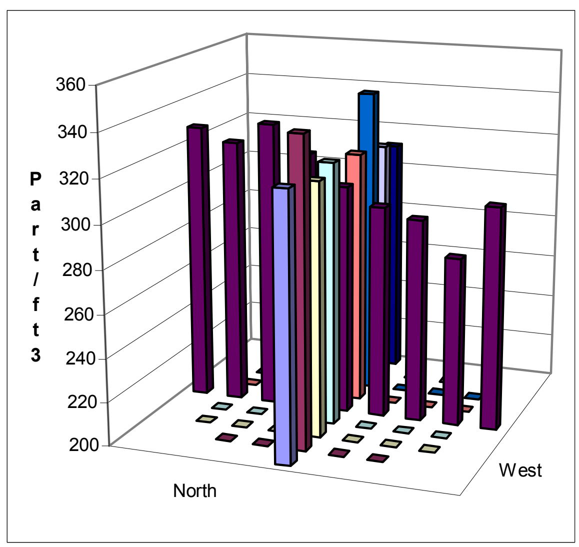
	Start	Finish	
Generator Inlet Press	8	8	psig
Stack Temp	67	65	F
Centerline vel.	W 1310	N 1296	fpm
Ambient pressure	983.9	984.1	mbar
Ambient humidity	44	58	RH
Ambient temp	60	57	F
Back-Gd aerosol	3/5/1/3/1/4	1/0/2/2	pt/ft3
No. Bk-Gd samples	6.0	4.0	

Optical Particle Counters:(Cal due 7/13/02)

OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

OPC clock about 1-hr fast

Oil Used: FisherBrand 19



PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-6**
Date	11/14/01	Fan configuration	**Turbine fan config**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	72.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**ET9 Centerline**

	1st								
Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	650	627	656	644.3	559	604	646	603.0
2	2.47	640	641	661	647.3	574	603	672	616.3
3	4.56	620	603	615	612.7	558	555	662	591.7
4	7.59	582	613	618	604.3	587	662	629	626.0
Center	11.75	561	583	596	580.0	546	629	676	617.0
5	15.91	587	538	579	568.0	593	652	639	628.0
6	18.94	530	529	539	532.7	582	636	712	643.3
7	21.03	533	565	590	562.7	632	729	725	695.3
8	22.75	506	560	537	534.3	558	682	686	642.0
Averages ---------->		578.8	584.3	599.0	587.4	576.6	639.1	671.9	629.2

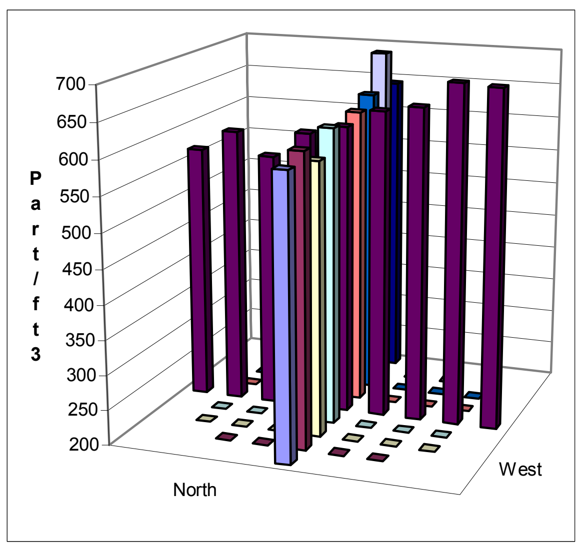
All	pt/ft3	Dev. from mean	***Center 2/3***	North	West	All	Normlzd
Mean	608.3		Mean	586.8	631.1	608.95	627.67
Min Point	532.7	-12.4%	Std. Dev.	37.8	32.4	40.86	35.22
Max Point	695.3	14.3%	COV as %	6.4	5.1	**6.71**	**5.61**

Avg Conc 610 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

	Start	Finish	
Generator Inlet Press	5.5	5.5	psig
Stack Temp	72	73	F
Centerline vel.	N 1056	w 935	fpm
Ambient pressure	986.3	985.9	mbar
Ambient humidity	49	43	RH
Ambient temp	64	67	F
Back-Gd aerosol	4/11/12/2/9/8/3	62/41/16/25	pt/ft3
No. Bk-Gd samples	7.0	4.0	



Optical Particle Counters:(Cal due 7/13/02)

OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

OPC clock about 1-hr fast

Oil Used: FisherBrand 19

Had problem getting low enough aerosol output to eliminate censor alarms. See sequence below to determine stability.

Static sequence at west #1

642,613,640,605

PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-7**
Date	11/14/01	Fan configuration	**Turbine fan config**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	71.5 deg F
Stack X-Area	433.7 in.2	Start/End Time	1405/1650
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**ET8 Centerline**

1st

Traverse-->		West				North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	907	816	796	839.7	766	766	721	751.0
2	2.47	907	826	772	835.0	716	739	690	715.0
3	4.56	916	871	811	866.0	758	769	743	756.7
4	7.59	930	757	845	844.0	769	736	689	731.3
Center	11.75	924	903	803	876.7	696	697	685	692.7
5	15.91	953	900	885	912.7	816	764	701	760.3
6	18.94	967	910	943	940.0	755	728	752	745.0
7	21.03	911	917	912	913.3	740	742	750	744.0
8	22.75	935	884	920	913.0	747	735	688	723.3
Averages ---------->		927.8	864.9	854.1	882.3	751.4	741.8	713.2	735.5

All	pt/ft3	Dev. from mean	***Center 2/3***	North	East	All	Normlzd
Mean	808.9		Mean	884.0	735.0	809.48	907.10
Min Point	692.7	-14.4%	Std. Dev.	39.2	24.1	83.37	41.42
Max Point	940.0	16.2%	COV as %	4.4	3.3	**10.30**	**4.57**

Avg Conc 812 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

	Start	Finish	
Generator Inlet Press	3.5	3	psig
Stack Temp	73	70	F
Centerline vel.	W 807	N 788	fpm
Ambient pressure	985.9	987.2	mbar
Ambient humidity	43	52	RH
Ambient temp	67	65	F
Back-Gd aerosol	3/6/12/7/15/2	1/2/3/2	pt/ft3
No. Bk-Gd samples	6.0	4.0	

Optical Particle Counters:(Cal due 7/13/02)

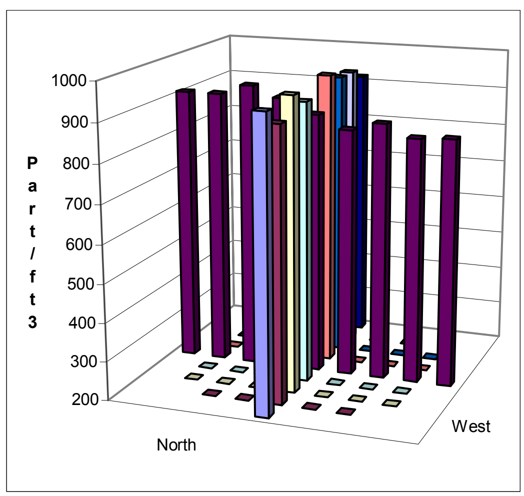
OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

OPC clock about 1-hr fast

Very windy, died down just when switched from north to west. Prior to that, wind averaged 15-20 mph with gusts

Oil Used: FisherBrand 19

to 34 mph. Prefilters were extremely dirty and reduced the flow considerably.



PARTICLE TRACER TRAVERSE DATA FORM

Site	**291-Z-1 Model Stack**	Run No.	**PT-8**
Date	11/29/01	Fan configuration	**Turbine fan config, 30 degree port**
Tester	Glissmeyer	Fan Setting	**60 Hz**
Stack Dia.	23.5 in.	Stack Temp	Estimated as 47 F
Stack X-Area	433.7 in.2	Start/End Time	1430/1600
Elevation	N.A.	Center 2/3 from	2.16 to: 21.34
Distance to disturbance	75 inches	Points in Center 2/3	2 to: 7
Measurement units	particles/ft3	Injection Point	**ET9 Centerline**

Traverse-->		West				1st North			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	particles/ft3				particles/ft3			
1	0.75	437	408	431	425.3	395	401	378	391.3
2	2.47	428	401	425	418.0	362	326	352	346.7
3	4.56	417	407	409	411.0	401	405	384	396.7
4	7.59	415	394	448	419.0	390	410	394	398.0
Center	11.75	368	381	388	379.0	363	368	414	381.7
5	15.91	379	390	381	383.3	406	369	423	399.3
6	18.94	384	375	363	374.0	423	401	423	415.7
7	21.03	378	405	378	387.0	401	429	478	436.0
8	22.75	367	378	422	389.0	407	435	415	419.0
Averages ---------->		397.0	393.2	405.0	398.4	394.2	393.8	406.8	398.3

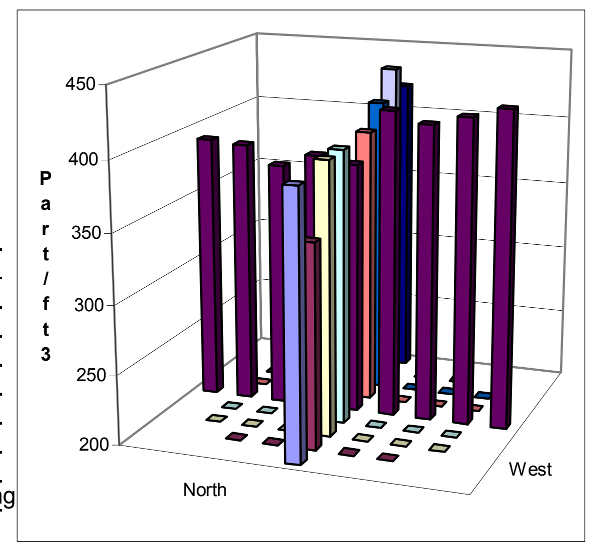
All	pt/ft3	Dev. from mean	***Center 2/3***	North	West	All	Normlzd
Mean	398.3		Mean	395.9	396.3	396.10	397.49
Min Point	346.7	-13.0%	Std. Dev.	19.4	27.8	23.03	23.11
Max Point	436.0	9.5%	COV as %	4.9	7.0	**5.81**	**5.82**

Avg Conc 401 pt/ft3

Instuments Used:

Solmat Zephyr SN 12951472 Cal due 7/26/02

	Start	Finish	
Generator Inlet Press	5	5	psig
Stack Temp*	55/48	54/46	F
Centerline vel.*	W1365/1360	N1324/1370	fpm
Ambient pressure	975.2	978.3	mbar
Ambient humidity	68	54	RH
Ambient temp	42	40	F
Back-Gd aer pt/ft3	3/1/2/1/1/1	16/15/11/7/9/1/0	
No. Bk-Gd samples	6	7	



Optical Particle Counters:(Cal due 7/13/02)

OPC A (9/5/01) MetOne A2408-1 Serial No.96258675

OPC clock about 1-hr fast

Oil Used: FisherBrand 19

Seqence of readings at point West 3:

467, 415, 433, 413, 414

*First readings from Solomat. Second from out of cal TSI Velocicalc SN 305039. Solomat suspected of reading several degrees high. This has no effect on the particle uniformity results.

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