Pacific Northwest National Laboratory

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Project W420 Air Sampler Probe Placement Qualification Tests for Four 6-inch Diameter Stacks: 296-A-25, 296-B-28, 296-S-22, and 296-T-18

J.A. Glissmeyer
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September 1998

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Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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Placement Qualification Tests for
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296-B-28, 296-S-22, and 296-T-18**

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

The W420 project covers the upgrading of effluent monitoring systems at six ventilation exhaust stacks in tank-farm facilities at the U.S. Department of Energy's Hanford Site. The discharge stacks of five of the six systems will be completely replaced. Four of these (296-A-25, 296-B-28, 296-S-22, and 296-T-18) will be of the same size, 6-inches in diameter and about 12-ft high. This report documents tests that were conducted to verify that these four stacks meet the applicable regulatory criteria regarding the placement of the air sampling probe. These criteria ensure that the contaminants in the stack are well mixed with the airflow at the location of the probe such that the extracted sample represents the whole. There are also criteria addressing the transport of the sample to the collection device. These are not covered in this report, but will need to be addressed later. These tests were conducted by Pacific Northwest National Laboratory on a full-scale model of the 6-inch stack. The sequence of tests addresses the acceptability of the flow angle relative to the probe and the uniformity of air velocity and gaseous and particle tracers in the cross section of the stack. All tests were successful, and all acceptance criteria were met.

Acknowledgments

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1.0 Introduction

The W420 project covers the upgrading of effluent monitoring systems at six ventilation exhaust stacks in tank-farm facilities at the U.S. Department of Energy's (DOE's) Hanford Site. The discharge stacks of five of the six systems will be completely replaced. Four of these (296-A-25, 296-B-28, 296-S-22, and 296-T-18) will be of the same size, 6 inches in diameter and about 13-ft high. This report documents tests that were conducted to verify that these four stacks meet the applicable regulatory criteria regarding the placement of the air-sampling probe. These criteria ensure that the contaminants in the stack are well mixed with the airflow at the probe location such that the extracted sample represents the whole. There are also criteria addressing the transport of the sample to the collection device. These are not covered in this report, but will need to be addressed later. The specific performance criteria relating to placement of the sampling probe are described in detail in the report. The test methods, results, and conclusions are discussed. The detailed test procedures and data sheets are included in the appendices. These tests were conducted by Pacific Northwest National Laboratory on a full scale-model of the 6-inch stack.

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 H requires the use of isokinetic^(a) sampling nozzles as described in ANSI N13.1-1969 (American National Standards Institute 1982). More recent research (Rodgers et al. 1996; Glissmeyer and Ligothe 1995) indicates poor performance for isokinetic nozzles relative to that of the shrouded nozzle. The U.S. Environmental Protection Agency (EPA) has approved a DOE alternative-method petition that allows the use of a sampling probe with a single shrouded nozzle in applications that previously required a probe with several isokinetic nozzles^(b). This single-point sample-extraction approach is applicable where the potential contaminants in the effluent are of a uniform concentration at the sampling location. The alternative method is a significant departure from the ANSI N13.1-1969 approach in that the sampling system must meet specific performance criteria. The approach taken in the

-
- (a) Air samples are extracted from the bulk airflow through a probe having a round orifice that is aerodynamically designed. The opening is generally pointed directly into the airflow. The term isokinetic means that the air velocity through the probe orifice matches that of the approaching airstream. This theoretically ensures that the sample airstream has the same concentration of particles of all sizes per unit air volume as the bulk airstream. If the probe-orifice air velocity is lower than that of the bulk airstream, it is operating "subisokinetically." In this case, particles with significant inertia will be present in the sample airstream in a concentration greater than in the bulk airstream.
- (b) U. S. Environmental Protection Agency. 1994. Letter from Mary Nichols to Raymond Pelletier (11/21/94). EPA, Washington.

alternative method was incorporated in a functional requirements document (FRD) for air sampling systems (Glissmeyer et. al. 1994) and in the Draft HPS/ANSI N13.1 to be published soon..

Performance Criteria

The qualification criteria for placing the sampling probe are as follows:

1. 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 sampling nozzle by more than 20°.
2. 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 COV value, the more uniform the velocity. The acceptance criterion is that the COV of the air velocity must be $\leq 20\%$ across the center two-thirds of the area of the stack.
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 to represent gaseous effluents. The fan is a good mixer, so injecting the tracer downstream of the fan provides worst-case results. The acceptance criteria are that 1) the COV of the measured tracer gas concentration is $\leq 20\%$ 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^(a) (AD) are used by default unless it is known that larger particles are present in the airstream. The acceptance criterion is that the COV of particle concentration is $\leq 20\%$ across the center two-thirds of the sampling plane.

Additional criteria would apply if scale-model testing had been conducted. This was not the case for the 6-inch stack.

(a) The aerodynamic diameter of a particle of arbitrary shape and density is the diameter of a spherical water droplet that has the same sedimentation velocity in quiescent air as the arbitrary particle. Particles with the same aerodynamic diameter will exhibit the same aerodynamic behavior even if they vary in shape and density.

Not covered in this report is the compliance demonstration to show that the extracted sample reaches the sample filter. The sample transport system is required to deliver more than 50% of 10- μ m-AD particles from the stack to the sample collector. Also, the sampling nozzle must have the following characteristics:

- transmission ratio at 10 μ m is 0.8 to 1.3
- nozzle aspiration ratio at 10 μ m is 0.8 to 1.5.

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. The overall particle transport is required to be verified experimentally or with the DEPOSITION code (Riehl et al. 1996). The code does not address system components such as flow splitters or valves. These items will be addressed experimentally and documented in a later report.

Exhauster-Stack Description

The sampling probe-placement tests were done on a full-scale model of the exhauster stack as shown in Figure 1.1. The model was tested at the Numatec Hanford Company's 305 Building. The stack has an internal diameter of 6.328 inches and is about 13-feet tall. The exhauster is equipped with a single fan. The diameter of the top portion of each stack is 4 inches. This was done to increase the air velocity at the outlet to facilitate the use of flow instrumentation and dispersion of the effluent.

The tip of the sampling nozzle would be about 51.5 inches (about 8.1 stack diameters) above the top of the duct entering the stack at a 45° upward angle. Additional ports are built into the model to facilitate the testing. A small hood and fan were placed over the discharge end of the stack as needed to vent the tracers outside of the building to prevent tracer recirculation.

On the four actual exhausters, the airflow is not controlled. Measurements at the four exhausters show mean air flows as listed in Table 1.1. The limits of the range are estimated by adding or subtracting two standard deviations from the means. The range is similar for the four exhausters. The qualification tests were conducted over the range of 100 to 400 cfm to cover the range of field conditions. The table also gives the air velocity corresponding to the air flow through the 6-inch section of the stack.

Table 1.1. Range of Flow Conditions for the 6-inch Stacks

Stack	Description/ Design Flow cfm	Current Stack in.	Current range of flowrate, cfm	Planned		
				Stack ID, in.	Velocity, fpm	Velocity, m/s
296-A-25	244-A DCRT 150	4	Min. 107	6	545	2.77
			Avg. 161	6	820	4.17
			Max. 215	6	1095	5.56
296-B-28	244-BX DCRT 125 - 250	6	Min. 143	6	728	3.70
			Avg. 203	6	1034	5.25
			Max. 263	6	1339	6.80
296-S-22	244-S DCRT 165	6	Min. 106	6	540	2.74
			Avg. 148	6	754	3.83
			Max. 190	6	968	4.92
296-T-18	244-TX DCRT 125 - 250	6	Min. 158	6	805	4.09
			Avg. 266	6	1355	6.88
			Max. 374	6	1905	9.68

Figure 1.1. Model of 6-in. Exhauster Stack

2.0 Qualification Tests

The qualification test methods and results are described below. Tests were conducted to determine compliance with performance criteria covering angular flow, air-velocity uniformity, gaseous-tracer uniformity, particle-tracer uniformity, and particle penetration.

2.1 Angular Flow

2.1.1 Method

The air-velocity vector approaching the sample nozzle should be aligned with the axis of the nozzle within an acceptable angle so sample extraction performance is not degraded. The test method used was based on 40 CFR 60, Appendix A, Method 1, Section 2.4, "Verification of the Absence of Cyclonic Flow."

This test was conducted at the extremes of flowrate in the model stack. Measurements were made using a type-S pitot tube, a slant tube or electronic manometer, and a protractor level attached to the pitot tube. The flow angle was measured at the elevation of the sampling nozzle. The measurement grid of 17 points, in an "x"-shaped pattern, was laid out in accordance with the EPA procedure. The pitot tube was rotated until a null differential pressure reading was obtained, and the angle of rotation was then recorded. Appendix A provides the detailed procedure and the data sheets.

2.1.2 Results

The grid of measurement points on the model stack was aligned with the direction of the stack inlet and perpendicular. The side of the stack with the inlet was designated as "South." The results for average flow angles are shown in Table 2.1. The $<20^\circ$ -flow-angle acceptance criterion was met in all cases, and the average angle measured ranged from 5.4° to 9.8° . The greater angle was found at the lower stack flow.

Table 2.1. Mean-Flow-Angle Results

Fan Control Setting, Hz	Flow rate, cfm	Mean Flow Angle, degrees
10	99	9.8
28	297	5.4
38	411	7.7

2.2 Uniformity of Air Velocity

2.2.1 Method

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. To determine uniformity, air velocity was measured at the same points as those used for the angular flow test. The method used was based on 40 CFR 60, Appendix A, Method 1. The equipment included a standard Prandtl-type pitot tube and a calibrated electronic manometer. The procedure is detailed in Appendix B.

2.2.2 Results

The grid of measurement points on the model stack was aligned the same as in the flow-angle test and at the sampling-probe elevation. These final results for air-velocity uniformity are summarized in Table 2.2. The results for the other orientation are similar and are summarized in Appendix B. The criterion that the air velocity COV be $\leq 20\%$ across the center two-thirds of the area of the model stack was met with the results ranging from 2.6% to 4.6%.

Table 2.2. Air-Velocity-Uniformity Results

Fan Control Setting, Hz	Mean Velocity, ft/min	Flow rate, cfm	COV
10	452	99	2.7
20	956	209	2.6
28	1360	297	2.9
38	1883	411	4.6

Figure 2.1 shows bar graphs of the velocity profiles measured at the four stack flowrates. Note that the area of maximum velocity is at the north side at the low flowrates and moves to the west side at the higher flowrates.

Figure 2.1. Velocity Profile at Four Stack Flowrates

2.3 Uniformity of Tracer Gases

2.3.1 Method

A uniform contaminant concentration at the sampling plane enables the extraction of samples that represent the true concentration. The gaseous contaminant concentration uniformity was demonstrated using sulfur hexafluoride as a tracer gas. The tracer gas was injected into the air just downstream of the fan discharge as shown in Figure 1.1. The tracer was injected along the centerline of the duct and 0.5 in. (approximately 12% of a hydraulic diameter) from the corners of the rectangular fan outlet.

The tracer concentration was measured at points in the sampling plane using a Bruel and Kjaer (Naerum, Denmark) Model 1302 gas analyzer calibrated for the tracer gas. The grid of measurement points was the same as that used for the other tests described above. The tests were done at the extremes of the scale-model flowrate. The procedure is detailed in Appendix C.

2.3.2 Results

Table 2.3 summarizes the results, and the data sheets for the individual test runs are included in Appendix C. The acceptance criteria are that 1) the COV of the tracer gas concentration be $\leq 20\%$ across the center two-thirds of the sampling plane and 2) at none of the measurement points does the average concentration differ from the mean concentration by $>30\%$. The COV results ranged from 0.4% to 12.0% for the center 2/3 of the stack, and the largest deviation of any single-point concentration from the mean concentration in any one run ranged from 0.7 to 23.4%. The acceptance criteria were met in all cases.

Table 2.3. Tracer Gas Mixing Results

Gas tracer test results, % COV (run number)					
Injection point	4-inch reducer on top			Open on top	
	99 cfm	297 cfm (28)	411 cfm (38)	99 cfm	411 cfm
Center	1.8 (14-1)	0.8 (12-1)	1.3 (14-2)		
Top left	2.5 (13-3)	2.1 (12-2)	2.0 (18-3)		
Top right	1.3 (13-5)	0.5 (12-3)	0.4 (18-2)		1.8 (20-1)
Bottom left	12.0, 11.8, 10.9 (13-2, 19-1, 19-2)	8.3 (13-1)	7.4 (14-3)	8.3 (20-2)	
Bottom right	6.9 (13-4)	5.0 (12-4)	4.8 (18-1)		

Some trends could be observed in the results. First, the mixing was better at higher flow. The mixing was worst when the tracer was injected at the bottom corners of the fan outlet duct, especially the left corner. There was no evidence that mixing was better with the reducer at the top of the stack than without it. The results were fairly reproducible in the case of injection at the bottom left corner.

Figure 2.2 is a comparison of tracer concentrations measured at each point when the injection was at the top/right, bottom/left, and bottom/right positions. The vertical axis is exaggerated to enhance the differences. It appears that in this small stack, increasing the flowrate causes greater uniformity.

Figure 2.2. Gaseous-Tracer Concentration with the Injection at Three Injection Positions and Two Flowrates

2.4 Uniformity of Tracer Particles

2.4.1 Method

The test for uniformity of tracer particles is similar to the test for uniformity of tracer gases. The general approach is to inject particles of a range of sizes, including the size of interest, into the test stack just downstream of the fan. The concentration of the particles of the size of interest is then measured at several points in the cross section of the sampling plane using an optical particle counter (OPC, Met-One Model A2408, Grants Pass, Oregon). The particles were made by spraying vacuum-pump oil through a nozzle.

A simple probe was used to extract the sample and transport it to the OPC. The OPC and its probe were moved from point to point in random order, first in one traverse direction and then the other. Because the generation rate for tracer particles may vary with time, a second OPC was used to observe the particle concentration from a fixed point in the stack. The data from the mobile OPC can then be adjusted if a temporal trend is observed with the fixed OPC.

The tracer injection points were the same as for the gaseous tracer, except the centerline injection is required by the Draft ANSI N13.1. The layout of sampling points was the same as for all of the tests, except that the size of the probe did not permit sampling as close to the inside of the stack wall.

The OPC's sort the number of particles into six size channels. Each concentration reading was the count of particles collected in the 9- to 11- μm channel. Three readings were taken at each point and averaged. The coefficient of variance of the average concentration readings at each point is calculated and the result compared to the acceptance criterion for uniformity. The particle mixing is acceptable if the COV of the tracer particles of 10- μm aerodynamic diameter (AD) is less than 20% across the center two-thirds of the sampling plane. The detailed procedure is included in Appendix D.

2.4.2 Results

The particle-concentration uniformity was measured at extremes of the flowrate. The data sheets for each run are included in Appendix D, and Table 2.4 summarizes the test results. The row labeled "raw data" shows results without any normalization with time. The results after normalization are also shown. The normalization method adjusted all of the concentration readings by the same amount so that the centerpoint readings taken via the two traverse directions equaled their average. The effect of normalization is more pronounced in cases where there was a shift in concentration with time.

Table 2.4. Results of Mixing Tracer Particles over the Center Two-Thirds of the Stack

	% Coefficient of Variation at Flowrate Given	
	105 cfm	411 cfm
Raw data	21.1, 15.5, 7.5	16.6, 8.2
Normalized	9.9, 12.5, 5.8	4.5, 8.2
Run	PT6Aug10_2 PT6Aug10_3 PT6Sep28_1	PT6Aug10_1 PT6Sep28_2

Figure 2.3 shows plots of gas and particle concentration and velocity for the condition of low flow and center tracer injection. This illustrates that the results of one type of test do not predict the results of another in terms of where the peaks are located. The COV's are 2.7%, 1.8%, and 15.5% for the velocity, gas, and tracer tests respectively, and all meet the acceptance criteria. The high COV for particles indicates that the particles mix slower, probably because of their inertial and drag properties. The gas mixes very well with the air, so the concentration is quite uniform, even though the velocity is less uniform. This underscores the value of the separate tests because the results of one test do not predict those of the others.

Figure 2.3. Comparison of Velocity, Gas, and Particle Profiles

3.0 Conclusions

The tests conducted on the full-scale model stack demonstrated that the locations for the air-sampling probe for the Project W420 6-inch exhaust stacks (296-A-25, 296-B-28, 296-S-22, and 296-T-18) meets all applicable regulatory performance criteria for air sampling systems at nuclear facilities. The conclusions are summarized for each performance criterion. The individual criteria were explained earlier in the report.

The performance criteria and conclusions are as follows:

1. Angular Flow - The acceptance criterion was that the average air velocity angle must not exceed 20° relative to the long axis of the stack or sampling nozzle. The results met the criterion— $\leq 9.8^\circ$ for the flowrate ranges covered (99 to 411 cfm).
2. Uniform Air Velocity - The acceptance criterion was that the percent COV of the air velocity be $\leq 20\%$ across the center two-thirds of the area of the stack. The results met the criterion— $\leq 4.6\%$ for the flowrate ranges covered (99 to 411 cfm).
3. Uniform Concentration of Tracer Gases - The acceptance criteria were that a) the COV of the measured tracer gas concentration be $\leq 20\%$ across the center two-thirds of the sampling plane, and b) at no point in the sampling nozzle elevation does the concentration vary from the mean by $>30\%$. The results met the criterion with the COV ranging from 0.4% - 12.0% depending on the injection point used. The largest deviation of any single point concentration from the mean concentration in any run was 23.4%.
4. Uniform Concentration of Tracer Particles - The acceptance criterion was that the COV of particle concentration be $\leq 20\%$ across the center two-thirds of the sampling plane. The results normalized for concentration fluctuations with time met the criterion with the COV ranging from 4.5% to 12.5% depending on the flowrate used on the full-scale model.

One additional observation that was expected and unrelated to the performance criteria was that the particle tracer does not mix as well as the gaseous tracer. This was expected because of the inertia of the 10- μm -AD particles.

4.0 References

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

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Appendix A

Description and Data for Angular Flow Tests

Appendix A: Description and Data for Angular Flow Tests

Procedure for Angular Flow Test

May 19, 1998

Angular Flow Test

The acceptance criterion for the absence of angular or cyclonic flow is that the average flow angle shall not exceed 20° (relative to the long axis of the stack). This is so the air-velocity vector approaching the sample nozzle is within an acceptable angle so sample extraction performance is not degraded. The test method is that of 40 CFR 60, Appendix A, Method 1, Section 2.4, "Verification of the Absence of Cyclonic Flow."

If the maximum and minimum stack flowrates differ by no more than a small percentage (assume less than 25%), then conduct this test at the average flowrate. If there is a greater range of stack flowrates, then conduct the test at the minimum and maximum conditions and optionally at the average. Fill out a data sheet for each test. The climatological data are not needed to evaluate the results.

Equipment

Type-S pitot tube

Slant tube manometer or calibrated electronic manometer

Device for reading angle of pitot tube (a protractor level is convenient)

(A three-dimensional directional velocity probe capable of measuring both pitch and yaw angles of gas flows is also acceptable equipment. The method outlined below would then be modified accordingly.)

Method

Lay out the measurement points following Method 1 in 40 CFR 60, Appendix A, and add the centerpoint. Prepare a data sheet for recording operating parameters and two or more measurements for each point.

If a fluid-filled manometer is used, it must be leveled. The manometer should be checked to verify that it reads zero when the pressure differential across it is zero. It should also read non-zero when the pressure differential is non-zero (on the order of 0.01 inches of water or less). Connect the manometer to the pitot tube. The pitot tube should be inserted into the stack and the opening sealed.

Position the pitot tube at each measurement point, in succession, so that the face openings of the pitot tube are perpendicular to the stack cross-sectional plane. In this position, it is at "0" reference. Note the differential pressure reading. If the reading is not zero at "0" reference, rotate the pitot tube (up to a 90° yaw angle) until a null reading is obtained. Record the rotation angle to the nearest degree. Assign the value of 0° to those points for which no rotation was required. Assign positive values for rotation in the clockwise direction and negative for rotation in the other direction. Perform two or three repetitions at each measurement point, two if it is highly repeatable, three if not so repeatable.

Calculate the average of the absolute values of the rotation angles at all traverse points. If the result is less than 20° , then the test criterion is satisfied.

Exceptions taken to this method should be noted on the data sheets.

ANGULAR FLOW TEST RESULTS

Site	W420 6 inch Stack	Run No.	AFMay12_1
Date	5/12/98	Stack Temp	73 deg F
Tester	Maughan	Stack RH%	NA
Stack Dia.	6.357 in	Baro Press	
Stack X-Area	31.7 in ²	Fan Setting	28 Hz (about 301 cfm)
Elevation		Offset to index	
El. above disturbance	48.6 in	Units	degrees counter-clockwise

Traverse→

Trial →

Point	Depth, in.	cm	E>W			S>N		
			1	2	3	1	2	3
1	0.50	1.27	11	10	11.5	9	9	8
2	0.67	1.70	10	9	9.5	8	8.5	8
3	1.23	3.13	7	7.5	8	7	8	6.5
4	2.05	5.22	4	4	4	4.5	5	5
5	4.30	10.93	3	5	4	4	5	4
6	5.12	13.01	7	7.5	7.5	4.5	5	4.5
7	5.69	14.45	5	6	6	2	0.5	2
8	5.86	14.88	0	-1	0	0	-0.5	-0.5

west

north

Absolute Average of all data
w/o points by wall

5.9	6.3	6.3	4.9	5.2	4.8
6.0	6.5	6.5	5.0	5.3	4.9

All
5.5
5.7

Centerpoint: 3.18

8.07	4.5	3	2	3	4	3.5
------	-----	---	---	---	---	-----

Center 2/3 with centerpoint

Absolute Average	5.8	6.0	5.9	4.7	5.1	4.7
------------------	-----	-----	-----	-----	-----	-----

All
5.4

Instruments Used:

Cal Exp. Date:

Parallel-tube pitot with 90-deg. bends at sample ends, 24-inches in length.
Dwyer Instruments 0-5 inch inclined manometer with red gauge oil
placed on an adjustable platform, zero'd and leveled (with tubes uninstalled
on the pitot tube fittings) before and between runs. Angles were made with
an Empire #36 circular protractor in the tests run in Bldg. 305.

NA

Note:

To make sure the hoses are connected properly between the manometer and pitot tube connectors, the following applies—turning the pitot tube assembly clockwise drives the meniscus to the right (to higher numerical readings).

ANGULAR FLOW TEST RESULTS

Site	W420 6 inch Stack	Run No.	AFMay13_1
Date	5/13/98	Stack Temp	73 deg F
Tester	Maughan	Stack RH%	NA
Stack Dia.	6.357 in	Baro Press	
Stack X-Area	31.7 in ²	Fan Setting	10 Hz (about 100 cfm)
Elevation		Offset to index	
El. above disturbance	48.6 in	Units	degrees counter-clockwise

Traverse →

Trial →

Point	Depth in.	cm	E>W			S>N		
			1	2	3	1	2	3
1	0.50	1.27	4	8	8	-3	-2	-4
2	0.67	1.70	2	6	6.5	-1	-2	-7
3	1.23	3.13	6	4	4	-6	-5	-6
4	2.05	5.22	6.5	9	7.5	-9	-6.5	-9
5	4.30	10.93	10	15	14	-12	-12	-16
6	5.12	13.01	15	14	16	-17	-15	-19
7	5.69	14.45	8	12	9	-17	-18	-16
8	5.86	14.88	12	8	13	-8	-15	-6

west

north

Absolute Average of all data	7.9	9.5	9.8	9.1	9.4	10.3	9.3
w/o points by wall	7.9	10.0	9.5	10.3	9.8	12.1	9.9

Centerpoint	3.18	8.07	8	10	9	-10	-5	-12
-------------	------	------	---	----	---	-----	----	-----

Center 2/3 with centerpoint

Absolute Average	7.9	10.0	9.4	10.3	9.1	12.1	9.8
------------------	-----	------	-----	------	-----	------	-----

Instruments Used:

Cal Exp. Date:

Parallel-tube pitot with 90-deg. bends at sample ends, 24-inches in length.
 Dwyer Instruments 0-5 inch inclined manometer with red guage oil
 placed on an adjustable platform, zero'd and leveled (with tubes uninstalled
 on the pitot tube fittings) before and between runs. Angles were made with
 an Empire #36 circular protractor in the tests run in Bldg. 305.

NA

Notes:

These readings, taken at slow velocity (100 cfm), are variable, and it is difficult to read the protractor angle. Again for the slow velocity, inclined manometer meniscus changes are small and difficult to accurately read. It was necessary to let the inclined manometer come to equilibrium (~30 sec) before taking a reading. To make sure the hoses are connected properly between the manometer and pitot tube connectors, the following applies—turning the pitot tube assembly clockwise drives the meniscus to the right (to higher numerical readings).

Appendix B

Test to Determine Uniformity of Air Velocity

Appendix B: Test to Determine Uniformity of Air Velocity

Procedure to Calibrate Flow Controller and Determine the Uniformity of Air Velocity

May 20, 1998

Calibration of Fan Controller

A fan speed or flow controller should be used if the qualification tests are to be conducted at various flowrates. The purpose of this procedure is to determine the stack flowrate versus flow-controller setting and to enable rapid and repeatable changes in stack flow. This procedure is written specifically for the use of a variable-frequency drive controller. If a variable-frequency drive is not used, this procedure may be adapted to other flow or fan controllers.

The fan speed will be indicated by the frequency setting on the variable-frequency controller. A calibration of approximate stack flow versus frequency will enable quicker execution of subsequent experiments. It is acknowledged that as the inlet filter loads, the calibration may change and may need to be repeated. A series of velocity and flow measurements should be made at various frequency settings. Frequency settings can vary from 0 to 60 Hz.

Use the following procedure to calibrate the fan controller:

1. Obtain a calibrated slant tube or electronic manometer and a pitot tube. Measure the stack inside diameter and the distance (offset) from the external index point at the traverse ports. Lay out the velocity traverse points per 40 CFR 60, Appendix A, Method 1, and add a center point. Mark the pitot tube for each traverse point. Prepare a data sheet for recording operating parameters and two or more measurements for each point.
2. At a midpoint control setting for the expected operating range (e.g., a frequency setting of 30), perform a full velocity traverse along both directions. Seal off all stack and duct openings, remove the top stack cover, and remove the inlet cover.
3. Call the weather station to obtain the barometric pressure for the 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.
4. Position the pitot tube at each measurement point, in succession, so that the face opening of the pitot tube is aligned with the axis of the stack. Record the velocity or differential pressure reading at each measurement point. If the electronic manometer has an averaging feature, record the average reading of a series of several readings. Perform two or three repetitions of the measurements in each traverse direction, two if it is highly repeatable, three if not so repeatable. Fill out a data sheet for each test. 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.

5. Calculate the mean velocity, and identify a location where the measured velocity is closest to the calculated mean.
6. Place the pitot tube at the location of the average velocity reading determined above. Record the velocity reading for several fan-controller settings covering the control range (e.g., at 5-Hz increments over the range of 5- to 60-Hz). Repeat three times. Calculate the average velocity and flow at each controller setting. Plot the average reading versus controller frequency.

Determination of Uniform Velocity

From the plot of flow versus controller setting, select the control settings corresponding to the desired test flowrates for which the angular-flow, gas, and particle-mixing tests will be conducted. At each flowrate, conduct a velocity traverse as in Steps 1, 3, and 4 above. Calculate the average velocity and flowrate, omitting the data from the center point.

For each flow setting or test condition, calculate the coefficient of variance for each velocity traverse using the average velocity data from all points in the inner two-thirds of the cross-section area (including the centerpoint). The acceptance criterion for the COV is $\leq 20\%$ for the inner two-thirds of the stack diameter. The COV is 100 times the mean divided by the standard deviation.

Exceptions to this method should be noted on the data sheets.

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	ftpm		

Trial -->		East				South			
		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
Traverse Averages -->		West				North			
		946.70				966.00			

Average of all data	956.35			<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Upper Limit 1.3 x mean	1243.26	Max Point	1012.33	Mean	960.00	975.14	967.57
Lower Limit 0.7 x mean	669.45	Min Point	897.67	Std. Dev.	30.363	18.967	25.559
				COV %	3.2	1.9	2.6

Flow 209 cfm
Flow 355 m³/hr

Notes: _____

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

VELOCITY TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. VT6May5_2
 Date May 5, 1998 Stack Temp 73 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 28 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 ftpm

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	1333	1327	1311	1323.7	1460	1382	1409	1417.0
2	0.66	1318	1333	1310	1320.3	1383	1409	1396	1396.0
3	1.23	1319	1327	1328	1324.7	1422	1380	1373	1391.7
4	2.04	1334	1338	1360	1344.0	1382	1364	1366	1370.7
Center	3.16	1352	1328	1325	1335.0	1385	1377	1389	1383.7
5	4.28	1401	1404	1390	1398.3	1376	1342	1378	1365.3
6	5.10	1492	1466	1469	1475.7	1341	1404	1396	1380.3
7	5.66	1376	1352	1381	1369.7	1325	1338	1349	1337.3
8	5.83	1281	1262	1256	1266.3	1260	1304	1251	1271.7
		West				North			
Traverse Averages -->		1350.85				1368.19			

Average of all data	1359.52	<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Upper Limit 1.3 x mean	1767.37	Mean	1366.81	1375.00	1370.90
Lower Limit 0.7 x mean	951.66	Std. Dev.	55.257	19.805	40.104
		COV %	4.0	1.4	2.9

Flow 297 cfm
 Flow 505 m³/hr

Notes: _____

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

VELOCITY TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. VT6May5_3
 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 10 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	445	452	440	445.7	439	413	434	428.7
2	0.66	461	465	445	457.0	456	426	435	439.0
3	1.23	448	471	475	464.7	461	424	460	448.3
4	2.04	446	464	464	458.0	455	443	446	448.0
Center	3.16	454	456	469	459.7	438	434	450	440.7
5	4.28	457	469	458	461.3	444	450	468	454.0
6	5.10	479	466	484	476.3	471	487	493	483.7
7	5.66	467	449	468	461.3	452	465	464	460.3
8	5.83	437	419	412	422.7	427	418	430	425.0
		West				North			
Traverse Averages -->		456.30				447.52			

Average of all data	451.91		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Upper Limit 1.3 x mean	587.48 Max Point	483.67	Mean	462.62	453.43	458.02
Lower Limit 0.7 x mean	316.34 Min Point	422.67	Std. Dev.	6.547	15.214	12.221
			COV %	1.4	3.4	2.7

Flow 99 cfm
 Flow 168 m³/hr

Notes:

Instruments Used:

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

VELOCITY vs. FREQUENCY DATA FORM

Site W420 6-inch Stack, Bldg. 305
 Date 5/6/98
 Tester D. Maughan
 Stack Dia. 6.375 inch
 Stack X-Area 31.9 sq. in.
 Elevation _____
 El. above disturbance _____

Run No. VFMay6_1
 Stack Temp 72 deg. F
 Stack RH% 44 % outdoor
 Baro Press 995 mbar, sta. 300A;
 static 5 Hz 0.05 mbar
 Fan Setting Various
 Offset to index _____

Reference point used from velocity traverses:

Pt. 5 on S>N Transect

Velocity Readings, units = ftpm

rpm	Hz	1	2	3	Mean	StDev	2 StDev
	5	231	217	204	217.3	13.5	27.0 static P = 0.05
	10	470	459	453	460.7	8.6	17.2
	15	720	756	731	735.7	18.4	36.9
	20	978	973	1003	984.7	16.1	32.1
	25	1200	1204	1219	1207.7	10.0	20.0
	30	1481	1478	1517	1492.0	21.7	43.4 static P = 2.17
	35	1730	1731	1747	1736.0	9.5	19.1
	40	2014	2017	2022	2017.7	4.0	8.1
	45	2217	2232	2301	2250.0	44.8	89.6
	50	2461	2498	2495	2484.7	20.6	41.1
	55	2703	2706	2717	2708.7	7.4	14.7
	60	2988	3007	3103	3032.7	61.6	123.3 static P = 8.59
	10	478	515	497	496.7	18.5	37.0
	30	1488	1488	1486	1487.3	1.2	2.3
	50	2475	2492	2498	2488.3	11.9	23.9
	10	470	463	476	469.7	6.5	13.0 w/out inlet filter
	30	1515	1525	1490	1510.0	18.0	36.1 w/out inlet filter
	50	2487	2513	2532	2510.7	22.6	45.2 w/out inlet filter

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:

Solomat Zephyr Ser# 12951472, Cal# 521-28-09-001

Cal Exp. Date:

2/7/98

VELOCITY TRAVERSE DATA FORM

Site	W420 6" Model in 305 Building	Run No.	VT6Aug28_4
Date	Aug. 28, 1998	Stack Temp	70 deg F
Tester	Maughan	Stack RH	43 %
Stack Dia.	6.328 in.	BP (sta. + static)	1003 + 4.1 ~ 1007 mbars
Stack X-Area	31.5 in.	Fan Setting	38 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	ftpm		

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	1773.0	1763.0	1735.0	1757.0	1935.0	2029.0	1969.0	1977.7
2	0.66	1779.0	1794.0	1810.0	1794.3	1962.0	1970.0	1999.0	1977.0
3	1.23	1763.0	1758.0	1803.0	1774.7	1917.0	1960.0	1990.0	1955.7
4	2.04	1779.0	1823.0	1791.0	1797.7	1872.0	1892.0	1903.0	1889.0
Center	3.16	1880.0	1860.0	1867.0	1869.0	1873.0	1895.0	1880.0	1882.7
5	4.28	1948.0	1928.0	1970.0	1948.7	1892.0	1908.0	1862.0	1887.3
6	5.10	2016.0	2023.0	2048.0	2029.0	1845.0	1968.0	1887.0	1900.0
7	5.66	2062.0	2013.0	2050.0	2041.7	1806.0	1768.0	1822.0	1798.7
8	5.83	1914.0	1922.0	1990.0	1942.0	1686.0	1664.0	1678.0	1676.0
Traverse Averages ----->		West				North			
		1883.78				1882.67			

Average of all data	1883.22	Center 2/3	E/W	S/N	All
Upper Limit 1.3 x mean	2448.19	Max Point	2041.67	Mean	1893.57 1898.62 1896.10
Lower Limit 0.7 x mean	1318.26	Min Point	1676.00	Std. Dev.	113.355 57.539 86.403
				COV %	6.0 3.0 4.6

Flow 411 cfm
Flow 699 m³/hr

Notes:

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

Appendix C

Test to Determine Uniformity of Tracer Gases

Appendix C: Test to Determine Uniformity of Tracer Gases

Procedure to Determine Uniformity of Gas Concentration

May 20, 1998

A uniform contaminant concentration at the sampling plane enables the extraction of samples that represent the true concentration. This will be tested first using a tracer gas. The acceptance criteria are that 1) the coefficient of variance (COV) of the tracer gas concentration is within $\pm 20\%$ 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 more than 30%.

Potential Test Conditions

This test can be repeated using various tracer injection points to determine if the COV is sensitive to "streaming" at the point where contaminants can be released downstream of the final ventilation filters. The test should include the range of stack flowrates that is observed at the facility. For any given injection plane, five injection points should be used, including the centerline and a point within 20% of a diameter from the wall at four orthogonally spaced points. Initial tests can be performed at the average stack flowrate with tracer injection at the centerline of the duct.

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 recirculating of the tracer to the inlet of the fan. This may result in a false indication of good mixing.

Equipment

Sulfur hexafluoride calibration gas (Matheson 100 ppmv in air)
Sulfur hexafluoride bulk gas (Matheson Instrument purity)
Gas analyzer calibrated for sulfur hexafluoride (Brüel and Kjær Model 1302)
Gas regulator and flowmeter for metering sulfur hexafluoride
Sampling probe for intake to gas analyzer
Gas injection probe

Check Gas Analyzer

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 plotting the concentrations at the measurement points. The instrument's response should be checked each day of testing against a calibration standard.

The calibration check equipment consists of the calibration standard sulfur hexafluoride gas, the gas regulator, the valve, and a tee with one leg feeding the flowmeter and the other leg attached to the inlet of the Model 1302. To begin, set the Model 1302's clock (part 4.4.2 in manual). Although the

Model 1302 has a gas-concentration display, it is convenient to record the data on a printer or computer. See the Manual Part 12 (especially Part 12.2.5) for connecting to a printer in data log mode.

Check the zero and calibration of the gas analyzer with the sulfur hexafluoride calibration gas using either the calibration procedure in the analyzer's manual (Part 2.2.4 and 2.5) or using the Model 1302 in continuous measurement mode. To set up for continuous measurements, follow the manual procedures starting in Part 4.2. The measurements should be done using the SF₆ filter (Filter B) with (except in dry climates) water vapor correction. Set up the units of measurement as in Part 4.2.3. Enter the barometric pressure, standard temperature (that used by the calibration gas vendor), and the sampling tube length into the environmental setup (Part 4.2.4). Set up a continuous monitoring task (4.2.5), and initiate monitoring (4.2.6). Monitor room conditions, and record the data for several measurements. The SF₆ concentration in the room should be several orders of magnitude below the calibration-gas content. The humidity should be close to ambient. Set the calibration gas flow just enough to excess a slight amount of the gas into the outdoor atmosphere (keep the float in the rotameter up while the analyzer is pulling its sample). The SF₆ reading should be within 10% of the calibration-gas concentration, and the water content should be much lower than ambient.

Setup for Stack Measurements

Use the same layout of measurement points as used for the velocity uniformity test (40 CFR 60, Appendix A, Method 1), including a center point.

The injection equipment consists of a cylinder of pure sulfur hexafluoride gas, a gas regulator, flowmeter, valve, flexible tubing, and an injection probe (short length of ¼ in. stainless steel tubing with a 90° bend at the discharge end) attached to an injection port on the stack mockup. The connections must be made using fittings that will ensure that the connections cannot be inadvertently broken. It would be prudent to leak check the delivery system.

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 into the flow in 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, valve, and vacuum pump. The rotameter and vacuum pump should be sized for about a 2- to 3-lpm flow of air. 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, locate the gas analyzer and printer near the test port on the stack.

Mark the sampling probe so the inlet can be placed at each successive measurement point. Prepare a data sheet on which to enter gas concentration readings and other information relevant to the test.

Estimate the SF₆ injection rate so the average diluted concentration will be within the range of 10 to 100% of the concentration of the calibration gas according to the following equation:

$$\text{injection flowrate} = \text{stack flowrate} \times \frac{\text{target ppmv}}{10^6} \quad (\text{C-1})$$

The rotameter reading should be adjusted for the density of the SF₆. The air equivalent reading is

$$\text{rotameter reading} = k \times \text{actual flowrate} \quad (\text{C-2})$$

where k is 2.25 for SF₆. For example, for a stack flowrate of 955 cfm (27,046 lpm) and a target concentration of 35 ppmv, the injection flowrate should be about 0.95 lpm. For an injection flowrate of about 1 lpm SF₆, the rotameter reading will be about 2.25 lpm air.

Measurements

On the data record sheet, record the test conditions, including the injection point, stack flow control setting, starting pressure in the tracer gas tank, date, time, ambient temperature, pressure, and humidity. Also record the equipment used and names of the test operators. With the flow controller set as needed for the test conditions, verify the centerline air velocity at the sampling plane.

Start the sampling train and the analyzer to warm it up and achieve equilibrium. The probe can be in any position in the stack. Using the analyzer, record the background level of the tracer gas after the readings stabilize. Do not proceed with the test if the background exceeds 5% of the anticipated average concentration in the stack. Readings also can be made with and without water-vapor correction. If the air is dry enough where the water vapor contribution is negligible, the balance of the readings can be done without the correction, thus reducing the time to make each run.

Position the injection probe as directed in the test conditions. Start the injection of the tracer gas at the desired flowrate. Observe the concentration readings in the stack. When they stabilize, adjust the injection rate if the readings are not within 50% of the target concentration.

Position the probe at each measurement point, in succession, so that the face opening of the probe is aligned with the axis of the stack. Record the reading of the tracer gas concentration at each measurement point. Perform two or three repetitions of the measurements in each traverse direction, two if it is highly repeatable, three if not so repeatable. Fill out a data sheet for each test. 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.

At the end of the test, record a measurement of the ambient concentration of the tracer. Record the climatic conditions if they have changed. Also record the rotameter settings, the elapsed time since the start of injection, and the final pressure in the tracer gas tank. Deviations from the procedure should be noted on the data sheet.

For each test condition, calculate the coefficient of variance for each tracer concentration traverse using the average concentration data from all points in the inner two-thirds of the cross section area (including the centerpoint). The acceptance criterion for the COV is $\leq 20\%$ for the inner two-thirds of the stack diameter. The COV is 100 times the mean divided by the standard deviation. Another acceptance criterion is that no point differ from the mean by more than 30%. This is determined by inspection of the average concentration at each measurement point.

Exceptions to this method should be noted on the data sheets.

CAUTION

The American Conference of Governmental Industrial Hygienists (ACGIH) time-weighted average limit for human exposure to sulfur hexafluoride gas is 1000 ppm. It is colorless and odorless.

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug12_1
 Date 8/12/98 Injection point Center
 Tester Maughan Fan Setting 28 Hz Top fan at 30 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	26.5	26.7	26.5	26.6	26.2	26.3	26.3	26.3
2	0.66	26.1	26.2	26.2	26.2	26.2	25.8	26.1	26.0
3	1.23	26.1	26.2	26.1	26.1	26.0	25.7	25.9	25.9
4	2.04	26.1	26.1	26.0	26.1	25.8	26.0	25.9	25.9
Center	3.16	25.8	25.7	25.6	25.7	25.6	25.7	25.9	25.7
5	4.28	25.7	25.4	25.7	25.6	25.8	25.6	25.8	25.7
6	5.10	25.5	25.5	25.4	25.5	25.8	25.7	25.8	25.8
7	5.66	25.8	25.4	25.6	25.6	25.7	26.2	26.1	26.0
8	5.83	26.0	25.6	25.5	25.7	25.6	25.9	26.3	25.9
West						North			
Traverse Averages ----->					25.89				

Average of all data	25.90	<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	2.6% Max Point 26.6	Mean	25.82	25.86	25.84
Maximum Negative Deviation	1.7% Min Point 25.5	Std. Dev.	0.293	0.124	0.217
		COV %	1.1	0.5	0.8

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10 10 lpm [glass ball in meter]
 Sampling flowmeter 8 8 lpm Sierra
 Ambient pressure 755.4 755.4 mm Hg
 Ambient humidity 32% 32% RH
 Centerline vel. 1406 1406 fpm
 B&K vapor correction No

Notes: _____

Instuments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug12_2
 Date 8/12/98 Injection point Top Left
 Tester Maughan Fan Setting 28 Hz Top fan at 30 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

Trial →		East				South			
Point	Depth, in.	1	2	3	Mean	1	2	3	Mean
1	0.50	26.4	26.5	26.5	26.5	26.2	25.9	25.7	25.9
2	0.66	26.6	26.7	26.1	26.5	26.0	25.6	26.1	25.9
3	1.23	26.1	26.3	25.9	26.1	25.6	25.7	25.7	25.7
4	2.04	25.5	25.9	25.8	25.7	25.7	25.6	25.8	25.7
Center	3.16	25.4	25.5	25.3	25.4	25.3	25.7	25.3	25.4
5	4.28	24.8	24.7	25.0	24.8	25.4	25.5	25.5	25.5
6	5.10	24.6	24.6	24.8	24.7	25.3	25.7	25.8	25.6
7	5.66	24.5	24.4	24.8	24.6	26.1	25.3	24.9	25.4
8	5.83	24.4	24.8	25.0	24.7	25.5	25.7	25.5	25.6
Traverse Averages →		West 25.44				North 25.63			

Average of all data	25.54	<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	3.6% Max Point 26.5	Mean	25.40	25.60	25.50
Maximum Negative Deviation	3.8% Min Point 24.6	Std. Dev.	0.741	0.172	0.527
		COV %	2.9	0.7	2.1

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10 10 lpm [glass ball in meter]
 Sampling flowmeter 8 8 lpm Sierra
 Ambient pressure 755.4 755.4 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 1383 1378 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug12_3
 Date 8/12/98 Injection point Top Right ..
 Tester Maughan Fan Setting 28 Hz Top fan at 30 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	26.1	25.8	25.6	25.8	25.8	25.7	25.7	25.7
2	0.66	25.9	25.4	25.9	25.7	25.7	25.9	26.0	25.9
3	1.23	25.7	26.0	25.7	25.8	25.9	26.1	25.9	26.0
4	2.04	25.8	25.7	25.9	25.8	26.0	25.9	25.9	25.9
Center	3.16	26.0	25.9	25.6	25.8	25.9	25.8	25.8	25.8
5	4.28	25.8	25.9	25.9	25.9	25.8	25.4	25.9	25.7
6	5.10	25.7	26.1	25.9	25.9	26.0	25.5	25.7	25.7
7	5.66	25.6	25.1	25.9	25.5	26.1	26.0	25.9	26.0
8	5.83	25.4	25.8	25.9	25.7	26.0	26.0	25.4	25.8
West						North			
Traverse Averages ----->					25.78				

Average of all data	25.81		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	0.7% Max Point	26.0	Mean	25.78	25.86	25.82
Maximum Negative Deviation	1.1% Min Point	25.5	Std. Dev.	0.121	0.115	0.121
			COV %	0.5	0.4	0.5

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10 10 lpm [glass ball in meter]
 Sampling flowmeter 8 8 lpm Sierra
 Ambient pressure 755.4 755.4 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 1421 1436 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug12_4
 Date 8/12/98 Injection point Bottom Right
 Tester Maughan Fan Setting 28 Hz Top fan at 30 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 Center 2/3 from 0.58 to: 5.75
 El. above disturbance 49.25 in. Points in Center 2/3 2 to: 7
 Concentration units ppm SF₆

Trial -->		East				South			
Point	Depth, in.	1	2	3	Mean	1	2	3	Mean
1	0.50	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	0.50	23.7	24.4	24.0	24.0	25.7	26.5	26.3	26.2
2	0.66	24.2	23.7	23.1	23.7	25.7	25.7	25.4	25.6
3	1.23	23.8	23.6	24.0	23.8	25.6	25.1	25.5	25.4
4	2.04	24.5	24.0	24.4	24.3	25.3	25.1	25.6	25.3
Center	3.16	25.0	25.1	25.2	25.1	24.7	24.6	25.0	24.8
5	4.28	26.1	26.5	26.1	26.2	25.2	24.7	25.1	25.0
6	5.10	27.7	27.5	27.0	27.4	25.2	25.1	24.6	25.0
7	5.66	28.4	28.5	28.1	28.3	25.0	25.2	25.0	25.1
8	5.83	28.3	29.8	28.4	28.8	25.7	24.9	24.4	25.0
Traverse Averages -->		West				North			
		25.74				25.26			

Average of all data	25.50		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	13.1% Max Point	28.8	Mean	25.55	25.16	25.35
Maximum Negative Deviation	7.2% Min Point	23.7	Std. Dev.	1.826	0.291	1.272
			COV %	7.1	1.2	5.0

Tracer tank pressure 310 Start 310 Finish 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10 10 lpm [glass ball in meter]
 Sampling flowmeter 8 8 lpm
 Ambient pressure 755.4 755.4 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 1436 1381 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug13_1
 Date 8/13/98 Injection point Bottom left
 Tester Maughan Fan Setting 28 Hz Top fan at 30 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	28.8	29.1	28.0	28.6	24.6	24.7	25.3	24.9
2	0.66	28.4	28.3	27.8	28.2	25.4	24.8	25.2	25.1
3	1.23	28.0	27.8	27.6	27.8	24.7	25.1	24.1	24.6
4	2.04	26.9	26.9	27.0	26.9	24.7	24.7	24.4	24.6
Center	3.16	25.5	25.5	25.6	25.5	24.8	25.0	25.1	25.0
5	4.28	24.5	24.3	23.6	24.1	28.2	27.8	27.5	27.8
6	5.10	23.4	23.1	23.9	23.5	29.8	29.5	28.8	29.4
7	5.66	23.3	23.4	23.3	23.3	30.4	30.5	28.4	29.8
8	5.83	23.7	22.7	22.9	23.1	30.9	30.3	30.5	30.6
Traverse Averages ----->		West				North			
		25.68				26.86			

Average of all data	26.27		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	16.4% Max Point	30.6	Mean	25.62	26.61	26.12
Maximum Negative Deviation	12.1% Min Point	23.1	Std. Dev.	2.043	2.305	2.155
			COV %	8.0	8.7	8.3

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10.0 10.0 lpm [glass ball in meter]
 Sampling flowmeter 8 8 lpm Sierra
 Ambient pressure 753.6 753.6 mm Hg
 Ambient humidity 35% 35% RH
 Centerline vel. 1416 1459 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug13_2
 Date 8/13/98 Injection point Bottom left
 Tester Maughan Fan Setting 10 Hz Top fan at 20 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	65.9	66.5	65.0	65.8	55.1	54.8	57.1	55.7
2	0.66	64.5	67.3	64.4	65.4	56.3	56.9	56.5	56.6
3	1.23	64.3	65.2	63.8	64.4	55.0	53.3	57.8	55.4
4	2.04	60.6	61.6	60.4	60.9	56.4	57.6	55.0	56.3
Center	3.16	53.0	54.5	55.0	54.2	55.4	55.6	54.0	55.0
5	4.28	50.6	51.0	49.4	50.3	62.5	56.9	59.5	59.6
6	5.10	46.0	46.4	47.0	46.5	67.1	65.2	63.4	65.2
7	5.66	43.0	45.0	45.1	44.4	67.6	59.8	67.0	64.8
8	5.83	44.7	41.7	44.9	43.8	66.5	61.9	65.4	64.6
Traverse Averages ----->		West				North			
		55.07				59.24			

Average of all data	57.16		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	15.1% Max Point	65.8	Mean	55.15	58.99	57.07
Maximum Negative Deviation	23.4% Min Point	43.8	Std. Dev.	8.561	4.380	6.831
			COV %	15.5	7.4	12.0

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 4.0 4.0 lpm [glass ball in meter]
 Sampling flowmeter 5 5 lpm Sierra
 Ambient pressure 753.6 753.6 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 482 478 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug13_3
 Date 8/13/98 Injection point Top left ~
 Tester Maughan Fan Setting 10 Hz Top fan at 20 Hz
 Stack Dia. 6.328 in. Stack Temp 69 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

Trial →		East				South			
Point	Depth, in.	1	2	3	Mean	1	2	3	Mean
1	0.50	56.3	55.9	58.0	56.7	56.5	55.0	53.9	55.1
2	0.66	56.0	55.9	54.7	55.5	54.7	56.1	54.7	55.2
3	1.23	55.5	56.3	56.9	56.2	53.3	55.0	54.0	54.1
4	2.04	54.4	54.0	54.6	54.3	54.4	53.2	53.8	53.8
Center	3.16	54.3	53.5	53.6	53.8	53.5	54.3	54.0	53.9
5	4.28	53.1	53.5	53.1	53.2	53.4	53.1	53.2	53.2
6	5.10	53.2	51.0	51.5	51.9	52.9	52.8	52.0	52.6
7	5.66	52.1	51.9	52.3	52.1	52.2	52.8	50.7	51.9
8	5.83	52.0	50.8	52.3	51.7	51.9	51.4	51.6	51.6
Traverse Averages →		West 53.95				North 53.50			

Average of all data	53.72	<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	5.6% Max Point 56.7	Mean	53.88	53.53	53.70
Maximum Negative Deviation	3.9% Min Point 51.6	Std. Dev.	1.633	1.073	1.340
		COV %	3.0	2.0	2.5

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 69 69 F
 Injection flowmeter 4.0 4.0 lpm [glass ball in meter]
 Sampling flowmeter 5 5 lpm Sierra
 Ambient pressure 753.6 753.6 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 478 478 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug13_4
 Date 8/13/98 Injection point Bottom right --
 Tester Maughan Fan Setting 10 Hz Top fan at 20 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

Trial -->		East				South			
		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.	Conc.
1	0.50	47.7	51.3	48.0	49.0	54.2	56.9	56.5	55.9
2	0.66	49.3	49.6	49.5	49.5	54.7	54.3	53.9	54.3
3	1.23	49.0	49.9	48.0	49.0	54.2	54.2	52.3	53.6
4	2.04	52.2	49.7	49.5	50.5	51.6	51.7	52.4	51.9
Center	3.16	50.1	51.8	49.6	50.5	51.3	51.4	53.1	51.9
5	4.28	54.2	53.7	55.3	54.4	52.9	51.9	54.5	53.1
6	5.10	57.9	56.9	60.2	58.3	55.8	53.7	54.6	54.7
7	5.66	64.1	60.6	62.6	62.4	59.2	56.5	56.0	57.2
8	5.83	64.3	61.2	62.7	62.7	58.6	53.4	58.5	56.8
Traverse Averages -->		West				North			
		54.03				54.38			

Average of all data	54.21	<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	15.7% Max Point 62.7	Mean	53.51	53.82	53.66
Maximum Negative Deviation	9.7% Min Point 49.0	Std. Dev.	5.148	1.848	3.719
		COV %	9.6	3.4	6.9

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 4.0 4.0 lpm [glass ball in meter]
 Sampling flowmeter 5 5 lpm Sierra
 Ambient pressure 753.6 753.6 mm Hg
 Ambient humidity 30% 130% RH
 Centerline vel. 478 515 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
 B & K Model 1302 #1765299
 Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug13_5
 Date 8/13/98 Injection point Top right
 Tester Maughan Fan Setting 10 Hz Top fan at 20 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	54.4	55.7	54.6	54.9	55.9	55.1	54.3	55.1
2	0.66	56.4	56.3	55.5	56.1	55.4	54.8	55.4	55.2
3	1.23	56.5	54.9	55.5	55.6	55.3	56.8	56.8	56.3
4	2.04	55.6	56.0	55.7	55.8	55.3	55.5	55.5	55.4
Center	3.16	55.2	55.0	56.8	55.7	55.7	55.8	56.3	55.9
5	4.28	54.6	54.4	55.2	54.7	55.5	56.1	56.3	56.0
6	5.10	54.5	55.6	54.9	55.0	55.5	55.0	54.6	55.0
7	5.66	53.2	54.0	54.1	53.8	52.8	54.0	56.4	54.4
8	5.83	54.4	55.1	54.1	54.5	55.8	54.4	54.7	55.0
		West				North			
Traverse Averages ----->		55.12				55.37			

Average of all data	55.24		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	1.9% Max Point	56.3	Mean	55.23	55.47	55.35
Maximum Negative Deviation	2.7% Min Point	53.8	Std. Dev.	0.794	0.653	0.709
			COV %	1.4	1.2	1.3

Tracer tank pressure Start 310 Finish 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 4.0 4.0 lpm [glass ball in meter]
 Sampling flowmeter 5 5 lpm Sierra
 Ambient pressure 753.6 753.6 mm Hg
 Ambient humidity 30% 130% RH
 Centerline vel. 515 501 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
 B & K Model 1302 #1765299
 Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug14_1
 Date 8/14/98 Injection point Center
 Tester Maughan Fan Setting 10 Hz Top fan at 20 Hz
 Stack Dia. 6.328 in. Stack Temp 71 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	56.2	56.2	57.7	56.7	56.9	56.8	56.7	56.8
2	0.66	57.8	57.3	58.5	57.9	55.8	56.0	57.1	56.3
3	1.23	56.6	56.6	56.7	56.6	55.8	56.0	55.9	55.9
4	2.04	56.3	55.3	55.2	55.6	55.7	55.8	55.5	55.7
Center	3.16	54.9	54.6	54.4	54.6	55.0	54.2	54.5	54.6
5	4.28	54.5	54.4	55.0	54.6	54.9	54.9	54.4	54.7
6	5.10	55.5	55.5	55.7	55.6	53.8	54.7	53.6	54.0
7	5.66	54.8	55.3	55.0	55.0	54.8	54.9	54.3	54.7
8	5.83	55.0	56.3	56.1	55.8	53.6	53.7	52.9	53.4
Traverse Averages ----->		West				North			
		55.83				55.12			

Average of all data	55.47		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	4.3% Max Point	57.9	Mean	55.71	55.12	55.42
Maximum Negative Deviation	3.7% Min Point	53.4	Std. Dev.	1.177	0.831	1.025
			COV %	2.1	1.5	1.8

Tracer tank pressure Start 310 Finish 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 71 71 F
 Injection flowmeter 4.0 4.0 lpm [glass ball in meter]
 Sampling flowmeter 5. 5 lpm Sierra
 Ambient pressure 754 754 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 503 485 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
 B & K Model 1302 #1765299
 Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug14_2
 Date 8/14/98 Injection point Center
 Tester Maughan Fan Setting 38 Hz Top fan at 45 Hz
 Stack Dia. 6.328 in. Stack Temp 71 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	19.6	19.7	19.5	19.6	19.4	19.5	19.5	19.5
2	0.66	19.5	19.8	19.7	19.7	19.4	19.4	19.3	19.4
3	1.23	19.5	19.7	19.5	19.6	19.2	19.3	19.2	19.2
4	2.04	19.2	19.5	19.4	19.4	19.2	19.1	19.2	19.2
Center	3.16	19.0	19.3	19.1	19.1	19.1	19.0	19.1	19.1
5	4.28	18.8	18.9	19.0	18.9	19.0	19.0	18.7	18.9
6	5.10	18.9	18.8	18.9	18.9	18.9	19.1	19.3	19.1
7	5.66	18.9	19.0	18.9	18.9	19.2	19.2	19.2	19.2
8	5.83	18.9	19.1	19.0	19.0	19.4	19.2	19.3	19.3
Traverse Averages ----->		West				North			
		19.23				19.20			

Average of all data	19.21	Center 2/3	E/W	S/N	All	
Maximum Positive Deviation	2.4% Max Point	19.7	Mean	19.20	19.15	19.18
Maximum Negative Deviation	1.8% Min Point	18.9	Std. Dev.	0.331	0.146	0.248
			COV %	1.7	0.8	1.3

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 71 71 F
 Injection flowmeter 10.0 10.0 lpm [glass ball in meter]
 Sampling flowmeter 10 10 lpm
 Ambient pressure 746.8 746.8 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 1881 1996 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug14_3
 Date 8/14/98 Injection point Bottom left
 Tester Maughan Fan Setting 38 Hz Top fan at 45 Hz
 Stack Dia. 6.328 in. Stack Temp 71 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	21.2	21.6	21.1	21.3	18.6	18.2	18.4	18.4
2	0.66	21.0	21.2	21.1	21.1	18.7	18.6	18.6	18.6
3	1.23	21.1	20.6	20.6	20.8	18.1	18.0	18.4	18.2
4	2.04	19.7	19.9	19.9	19.8	18.2	18.2	18.4	18.3
Center	3.16	19.0	18.8	18.7	18.8	18.6	18.7	18.6	18.6
5	4.28	18.5	18.5	18.7	18.6	20.4	20.1	20.4	20.3
6	5.10	18.1	17.7	18.3	18.0	21.6	22.1	21.9	21.9
7	5.66	18.5	18.2	18.5	18.4	21.6	22.7	22.2	22.2
8	5.83	18.2	18.1	18.4	18.2	22.3	22.2	22.3	22.3
West						North			
Traverse Averages ----->					19.45				

Average of all data	19.65		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	13.3% Max Point	22.3	Mean	19.36	19.72	19.54
Maximum Negative Deviation	8.2% Min Point	18.0	Std. Dev.	1.212	1.723	1.443
			COV %	6.3	8.7	7.4

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 71 71 F
 Injection flowmeter 10.0 10.0 lpm [glass ball in meter]
 Sampling flowmeter 10 10 lpm Sierra
 Ambient pressure 746.8 746.8 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 1996 1936 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug18_1
 Date 8/18/98 Injection point Bottom right ~
 Tester Maughan Fan Setting 38 Hz Top fan at 45 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	17.6	17.5	17.3	17.5	18.9	18.7	18.9	18.8
2	0.66	17.0	17.5	17.4	17.3	18.6	18.6	18.8	18.7
3	1.23	17.3	17.5	17.4	17.4	18.5	18.7	18.5	18.6
4	2.04	17.5	18.1	17.8	17.8	18.5	18.3	18.4	18.4
Center	3.16	18.4	18.4	18.4	18.4	18.3	18.3	18.4	18.3
5	4.28	19.4	19.4	19.1	19.3	18.2	18.5	18.4	18.4
6	5.10	19.7	19.9	20.3	20.0	18.6	18.5	17.9	18.3
7	5.66	20.5	20.5	20.7	20.6	19.2	18.6	18.5	18.8
8	5.83	20.6	20.9	21.0	20.8	18.3	18.0	18.6	18.3
Traverse Averages -->		West				North			
		18.78				18.51			

Average of all data	18.64		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	11.7% Max Point	20.8	Mean	18.68	18.49	18.58
Maximum Negative Deviation	7.2% Min Point	17.3	Std. Dev.	1.291	0.176	0.890
			COV %	6.9	1.0	4.8

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10.0 10.0 lpm [glass ball in meter]
 Sampling flowmeter 10 10 lpm Sierra
 Ambient pressure 751.4 751.4 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 1964 2050 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
 B & K Model 1302 #1765299
 Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug18_2
 Date 8/18/98 Injection point Top right Top fan at 45 Hz
 Tester Maughan Fan Setting 38 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

Trial -->		East				South			
Point	Depth, in.	1	2	3	Mean	1	2	3	Mean
1	0.50	19.0	18.9	19.2	19.0	19.0	18.9	19.1	19.0
2	0.66	18.8	19.2	18.9	19.0	19.0	18.8	19.0	18.9
3	1.23	18.7	19.0	18.8	18.8	19.1	19.2	19.0	19.1
4	2.04	19.0	19.0	18.9	19.0	18.9	18.9	19.0	18.9
Center	3.16	19.0	18.8	18.9	18.9	18.9	18.9	18.9	18.9
5	4.28	19.0	18.9	18.9	18.9	19.0	18.9	18.9	18.9
6	5.10	18.9	18.6	18.7	18.7	18.4	19.0	19.1	18.8
7	5.66	18.8	18.7	19.0	18.8	18.8	19.0	18.9	18.9
8	5.83	18.8	19.2	18.9	19.0	19.0	19.2	18.5	18.9
Traverse Averages -->		West				North			
		18.91				18.94			

Average of all data	18.92		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	0.9% Max Point	19.1	Mean	18.88	18.93	18.91
Maximum Negative Deviation	1.0% Min Point	18.7	Std. Dev.	0.086	0.082	0.085
			COV %	0.5	0.4	0.4

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10.0 10.0 lpm [glass ball in meter]
 Sampling flowmeter 10 10 lpm Sierra
 Ambient pressure 751.4 751.4 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 2050 1911 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug18_3
 Date 8/18/98 Injection point Top left
 Tester Maughan Fan Setting 38 Hz Top fan at 45 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	19.6	19.4	19.6	19.5	19.1	19.3	19.1	19.2
2	0.66	19.4	19.5	19.5	19.5	19.0	19.3	19.3	19.2
3	1.23	19.3	19.3	19.6	19.4	19.1	19.0	19.1	19.1
4	2.04	19.2	19.0	19.1	19.1	19.0	18.9	19.0	19.0
Center	3.16	18.6	18.6	18.7	18.6	18.7	18.9	18.7	18.8
5	4.28	18.3	18.6	18.4	18.4	18.6	18.5	18.8	18.6
6	5.10	18.1	18.2	18.4	18.2	18.7	18.6	18.5	18.6
7	5.66	18.4	18.3	18.4	18.4	18.8	18.9	18.7	18.8
8	5.83	18.3	18.3	18.2	18.3	18.7	18.7	18.9	18.8
West						North			
Traverse Averages ----->					18.83				

Average of all data	18.86		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	3.6% Max Point	19.5	Mean	18.80	18.86	18.83
Maximum Negative Deviation	3.3% Min Point	18.2	Std. Dev.	0.511	0.224	0.380
			COV %	2.7	1.2	2.0

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 10.0 10.0 lpm [glass ball in meter]
 Sampling flowmeter 10 10 lpm
 Ambient pressure 751.4 751.4 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 1911 1912 fpm
 B&K vapor correction No
 Sierra flow setting 10 lpm

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug19_1D (Dup of GT6Aug13_2)
 Date 8/19/98 Injection point Bottom left
 Tester Maughan Fan Setting 10 Hz Top fan at 45 Hz
 Stack Dia. 6.328 in. Stack Temp 70 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

Trial →		East				South			
Point	Depth, in.	1	2	3	Mean	1	2	3	Mean
1	0.50	65.5	63.9	64.2	64.5	57.0	56.4	58.1	57.2
2	0.66	64.7	65.1	64.2	64.7	57.0	54.0	56.2	55.7
3	1.23	66.5	64.2	64.8	65.2	55.8	58.8	56.3	57.0
4	2.04	62.4	61.8	60.5	61.6	53.2	54.0	55.3	54.2
Center	3.16	53.9	55.2	53.9	54.3	53.6	54.3	53.6	53.8
5	4.28	51.1	50.8	48.7	50.2	55.1	56.8	58.9	56.9
6	5.10	45.5	46.3	46.7	46.2	63.0	61.3	62.0	62.1
7	5.66	44.3	44.1	44.0	44.1	67.9	61.5	64.0	64.5
8	5.83	44.8	44.7	45.9	45.1	66.5	64.5	65.6	65.5
Traverse Averages →		West				North			
		55.10				58.54			

Average of all data	56.82		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	15.3% Max Point	65.5	Mean	55.18	57.74	56.46
Maximum Negative Deviation	22.3% Min Point	44.1	Std. Dev.	8.749	4.032	6.679
			COV %	15.9	7.0	11.8

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 70 70 F
 Injection flowmeter 4.0 3.5 lpm [glass ball in meter]
 Sampling flowmeter 5 5 lpm Sierra
 Ambient pressure 753 753 mm Hg
 Ambient humidity 42% 42% RH
 Centerline vel. 505 517 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug19_2D (Dup of GT6Aug13_2)
 Date 8/19/98 Injection point Bottom left
 Tester Maughan Fan Setting 10 Hz Top fan at 45 Hz
 Stack Dia. 6.328 in. Stack Temp 69 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7

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	64.8	64.8	69.0	66.2	54.5	56.9	55.8	55.7
2	0.66	67.5	65.2	65.0	65.9	56.1	54.8	57.3	56.1
3	1.23	62.1	66.2	62.2	63.5	58.1	54.4	55.7	56.1
4	2.04	61.9	61.5	59.2	60.9	57.0	57.0	53.9	56.0
Center	3.16	55.5	55.4	53.7	54.9	55.1	54.8	53.5	54.5
5	4.28	50.7	50.2	49.9	50.3	55.0	58.7	57.3	57.0
6	5.10	44.5	45.7	47.2	45.8	64.4	62.1	61.4	62.6
7	5.66	46.5	44.5	45.6	45.5	59.2	64.5	59.3	61.0
8	5.83	44.7	44.3	43.3	44.1	66.4	66.0	63.5	65.3
		West				North			
Traverse Averages ----->		55.23				58.25			

Average of all data	56.74		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	16.7% Max Point	66.2	Mean	55.25	57.60	56.42
Maximum Negative Deviation	22.3% Min Point	44.1	Std. Dev.	8.384	3.012	6.174
			COV %	15.2	5.2	10.9

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 69 69 F
 Injection flowmeter 4.0 4.0 lpm [glass ball in meter]
 Sampling flowmeter 5 5 lpm Sierra
 Ambient pressure 480 480 mm Hg
 Ambient humidity <30% <30% RH
 Centerline vel. 505 517 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug20_1
 Date 8/20/98 Injection point Top right
 Tester Maughan Fan Setting 38 Hz Top fan at 45 Hz
 Stack Dia. 6.328 in. Stack Temp 71 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7
 Same as GT6Aug18_2 but without 4" top reducer

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	13.0	12.9	13.0	13.0	13.0	13.0	12.8	12.9
2	0.66	13.2	13.1	13.1	13.1	13.0	12.9	13.1	13.0
3	1.23	13.2	13.3	13.3	13.3	13.4	13.2	13.2	13.3
4	2.04	13.5	13.3	13.1	13.3	13.5	13.5	13.6	13.5
Center	3.16	13.7	13.4	13.5	13.5	13.6	13.7	13.8	13.7
5	4.28	13.4	13.3	13.3	13.3	13.6	13.5	13.5	13.5
6	5.10	13.0	13.2	13.0	13.1	13.2	13.5	13.6	13.4
7	5.66	13.0	12.8	12.8	12.9	13.3	13.1	13.3	13.2
8	5.83	12.7	12.8	12.7	12.7	13.0	13.2	13.3	13.2
Traverse Averages ----->		West				North			
		13.13				13.31			

Average of all data	13.22	<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	3.6% Max Point 13.7	Mean	13.21	13.39	13.30
Maximum Negative Deviation	3.7% Min Point 12.7	Std. Dev.	0.214	0.235	0.234
		COV %	1.6	1.8	1.8

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 71 71 F
 Injection flowmeter 10.0 9.5 lpm [glass ball in meter]
 Sampling flowmeter 10 10 lpm Sierra
 Ambient pressure 748.5 748.5 mm Hg
 Ambient humidity 21% 21% RH
 Centerline vel. 2761 2728 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
B & K Model 1302 #1765299
Sierra Inc. Constant Flow Air Sampler

TRACER GAS TRAVERSE DATA FORM

Site W420 6" Model in 305 Building Run No. GT6Aug20_2
 Date 8/20/98 Injection point Bottom left
 Tester Maughan Fan Setting 10 Hz Top fan at 20 Hz
 Stack Dia. 6.328 in. Stack Temp 71 deg F
 Stack X-Area 31.5 in.
 Elevation _____
 El. above disturbance 49.25 in. Center 2/3 from 0.58 to: 5.75
 Concentration units ppm SF₆ Points in Center 2/3 2 to: 7
 Same as GT6Aug18_2 but without 4" top reducer

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	43.5	44.3	43.7	43.8	36.6	36.5	36.6	36.6
2	0.66	43.1	44.0	43.3	43.5	36.1	38.1	36.4	36.9
3	1.23	42.5	43.4	42.4	42.8	36.7	36.5	37.4	36.9
4	2.04	41.5	42.6	42.2	42.1	36.9	37.8	37.8	37.5
Center	3.16	43.6	43.4	43.6	43.5	41.7	40.2	40.9	40.9
5	4.28	44.2	44.0	45.5	44.6	46.0	46.3	46.1	46.1
6	5.10	43.5	42.1	44.2	43.3	47.3	47.0	48.6	47.6
7	5.66	42.3	42.3	40.3	41.6	47.5	46.9	47.8	47.4
8	5.83	40.7	44.2	44.4	43.1	48.9	47.1	48.5	48.2
Traverse Averages ----->		West				North			
		43.14				42.01			

Average of all data	42.57		<u>Center 2/3</u>	<u>E/W</u>	<u>S/N</u>	<u>All</u>
Maximum Positive Deviation	13.1% Max Point	48.2	Mean	43.05	41.90	42.48
Maximum Negative Deviation	14.1% Min Point	36.6	Std. Dev.	0.978	5.033	3.534
			COV %	2.3	12.0	8.3

Tracer tank pressure 310 310 psig Gas analyzer checked June 10-18; Aug 27, 1998
 Ambient Temp 71 71 F
 Injection flowmeter 4.0 4.0 lpm [glass ball in meter]
 Sampling flowmeter 5 5 lpm Sierra
 Ambient pressure 748.5 500 mm Hg
 Ambient humidity <21% <21% RH
 Centerline vel. 680 658 fpm
 B&K vapor correction No

Notes: _____

Instruments Used:

Solomat Zephyr #12951472
 B & K Model 1302 #1765299
 Sierra Inc. Constant Flow Air Sampler

Appendix D

Test to Determine Uniformity of Tracer Particles

Appendix D: Procedure to Test the Uniformity of Particle Concentrations

Using a Polydispersed Aerosol

July 9, 1998

A uniform contaminant concentration at the sampling plane (i.e., the plane of the sampling-probe nozzle) enables the collection of samples that represent the true concentration. This uniformity is demonstrated by measuring the mixing or uniformity of air momentum and the concentrations of gas and particle contaminants. This procedure addresses the particle-concentration uniformity test.

The general approach is to inject particles of a range of sizes, including the size of interest, into the test stack just downstream of the fan. The concentration of the particles of the size of interest is then measured at several points in the cross section of the sampling plane using an optical particle counter (OPC). A simple sampling probe will extract an aliquot of the stack airflow for counting by the OPC. Because the generation rate for tracer particles may vary with time, a second OPC may optionally be used to observe the particle concentration from a fixed point in the stack. The data from the traversing OPC can then be adjusted if there is a temporal trend observed with the fixed OPC. Several particle injection points and stack flowrates may be tested as additional parameters affecting the mixing determination. The coefficient of variance of the concentration readings at the individual points is calculated and the result compared to the acceptance criterion for uniformity. The particle mixing is acceptable if the coefficient of variance (COV) of the tracer 10- μ m aerodynamic diameter (AD) particles is less than 20% across the center two-thirds of the sampling plane.

Potential Test Conditions

For any given injection plane, use a particle injection point at the duct centerline as a minimum. Where the tracer-gas tests show borderline acceptable mixing, suggested additional points should be within 20% of a diameter from the wall at four orthogonally spaced points. This test can be repeated using various tracer injection points to determine if the COV is sensitive to "streaming" at the point where contaminants can be released downstream of the final ventilation filters. Initial tests should be performed at the average or the extremes of the stack flowrate range.

Equipment

- Aerosol generator
- Two calibrated OPCs
- Sampling probes for the particle counters
- Particle injection probe
- Aerosol generator feed oil

Setup for Optical Particle Counter

The absolute calibration of the OPC is not especially important because the concentration data are used in a relative manner to calculate the COV and to plot the particle concentrations at the measurement points. The instrument's response may be checked against calibrated standard particles

(e.g., polystyrene latex spheres from Duke Scientific) to address relative accuracy. Here, it is assumed sufficient to determine the accuracy with which the tracer particles of a known size are consistently counted in the same OPC particle-size channel. This can be determined by an annual factory calibration of the OPC channels.

The sampling probes for both OPCs should be identical and of a simple design. The elevation of the intake nozzle of the traversing unit should be the same as the sampling plane. The intake nozzle for the fixed unit may be located anywhere within the stack at an elevation near that of the sampling plane. 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 subisokinetic or shrouded design to optimize the collection of the 10- μ m particles. Mark the traversing OPC's sampling probe to aid in placing the inlet at each measurement point.

The aerodynamic characteristics of the probes for both OPCs should be the same and have similar line-loss (penetration) values. A flexible tube probe could have changing shape, which would result in variable line-loss problems during the tests. To keep the line loss fixed and comparable, the probes should be of a fixed and rigid configuration. The use of the traversing OPC is facilitated by mounting it on a sliding platform, allowing movement along the axis of the sampling port.

The settings for the parameters and operation of the OPCs and aerosol generator are detailed in other procedures. The OPC data can be recorded initially on either the internal paper tape or using the RS232 connection to a computer serial port.

Setup for Aerosol Generator

The aerosol generator consists of a spray nozzle with a compressed air and oil reservoir. The compressed air supply should be filtered and controlled by a regulator. A non-hazardous oil with a low vapor pressure (such as vacuum pump oil) should be used in the reservoir. The level in the oil reservoir should cover the intake screen. The nozzle is mounted in a large diameter pipe (4-inches diameter or larger). The compressed air passing through the nozzle draws the oil into the nozzle and conveys the aerosol out the end of the pipe and to the injection tube. The quantity of aerosol is controlled by the compressed air pressure. The oil reservoir should be mounted to avoid spills. The aerosol generator output should connect to an injection tube with an inside diameter of at least 0.5 inches.

Setup for Stack Measurements

Lay out the sampling points using the same method as for a velocity traverse (40 CFR 60, Appendix A, Method 1) with the addition of the center point. These can be the same points as those used for the gaseous tracer experiment. Points closer to the stack wall than one-half the width of the traversing OPC's sampling probe should be omitted. As a minimum, the points in the central 2/3 of the duct area must be sampled.

Measurements

On the data record sheet, record the test conditions of injection point, stack-flow control setting, date, time, and stack temperature. Also record the equipment used and the names of test operators. After the fan controller is set as needed for the test conditions, verify the centerline air velocity at the sampling

plane using a pitot tube or other anemometer. At the end of the test, re-record any test parameters if they have changed.

Start the OPCs and make a series of measurements of the background level of aerosol in the stack after the readings stabilize. Do not proceed with the test if the background exceeds 5% of the anticipated average concentration in the stack when the aerosol generator is started.

Position the injection probe as directed for the test conditions. Start the injection of the tracer particles. Adjust the aerosol generator output so the particle count is well above background and at least 200 particles per cubic foot.

Position the probe of the traversing OPC at each measurement point, in succession, so that the face opening of the probe is aligned with the axis of the stack. Record the reading for the concentration of tracer particles at each measurement point in the 9- to 11- μm channel of the OPC. Perform two or three repetitions of the measurements in each traverse direction, two if it is highly repeatable, three if not so repeatable. Fill out a data sheet for each test. 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.

At the end of the test, turn off the aerosol generator and record the background particle count in the stack. 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 recirculating of the tracer to the inlet of the fan, which may result in a false indication of good mixing. The use of an inlet filter upstream of the fan should significantly reduce the background.

For each test, calculate the coefficient of variance for each tracer-concentration traverse using the average concentration data from all points in the inner two-thirds of the cross section area (including the centerpoint). The acceptance criterion for the COV is $\leq 20\%$ for the inner two-thirds of the stack diameter. The COV is 100 times the mean divided by the standard deviation.

Exceptions to this method should be noted on the data sheets.

CAUTION - The American Conference of Governmental Industrial Hygienists (ACGIH) time weighted average limit for human exposure to mineral oil mist is 5 mg/m³.

PARTICLE TRAVERSE RESULTS SUMMARY

Site 6' W420 Model Stack in Bldg. 305
 Testers: Maughan and Huckaby
 Stack Dia. 6.357 in.
 Stack X-Area 31.74 in²
 Measurement elevation in.
 El. above disturbance 49.25 in.
 Injection Point: Centerline Near

Run No. PT6Aug10_1
 Date Sept. 10, 1998

Oil Fisherbrand 19

Fan Setting 38 Hz
 Center 2/3 from 0.58 inches to: 5.77
 Points in Center 2/3 2 to: 7

Each OPC data point includes: 1-min concentration counts/ft³ in 9 - 11 micron size channel

Point	South				East				
	1	2	3	Avg.	1	2	3	Avg.	
2	1374	1394	1225	1331.0	1046	1119	945	1036.7	
3	1374	1385	1321	1360.0	973	957	947	959.0	
4	1313	1282	1316	1303.7	1058	917	708	894.3	
Center	1332	1342	1318	1330.7	1051	1074	813	979.3	
5	1296	1380	1284	1320.0	1135	1101	924	1053.3	
6	1321	1303	1354	1326.0	873	1060	803	912.0	
7	1294	1224	1163	1227.0	763	1160	805	909.3	
North					West				
Center 2/3									Grand
Mean	1329.14	1330.00	1283.00	1314.05	985.57	1055.43	849.29	963.43	1138.74
Std. Dev.	33.40	63.29	66.54	41.91	127.72	87.82	90.99	63.33	189.10
C.O.V	2.51	4.76	5.19	3.19	12.96	8.32	10.71	6.57	16.61

Note: A filter was installed on the fan inlet for this test.

Adjusted so Centerpoints Equal					
Point	South		East		
	Avg.	Adj.	Avg.	Adj.	
2	1331.0	1155.3	1036.7	1212.3	
3	1360.0	1184.3	959.0	1134.7	
4	1303.7	1128.0	894.3	1070.0	
Center	1330.7	1155.0	979.3	1155.0	
5	1320.0	1144.3	1053.3	1229.0	
6	1326.0	1150.3	912.0	1087.7	
7	1227.0	1051.3	909.3	1085.0	
North			West		
Center 2/3					Grand
Mean	1314.0	1138.4	963.4	1139.1	1138.7
Std. Dev.	41.9	41.9	63.3	63.3	51.6
C.O.V	3.2	3.7	6.6	5.6	4.5

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Site 6' W420 Model Stack in Bldg. 305
 Testers: Maughan and Huckaby
 Stack Dia. 6.357 in.
 Stack X-Area 31.74 in²
 Measurement elevation in.
 El. above disturbance 49.25 in.
 Injection Point: Centerline Near

Run No. PT6Aug10_2
 Date Sept. 10, 1998

Oil Fisherbrand 19

Fan Setting 11^a Hz

Center 2/3 from 0.58 inches to: 5.77
 Points in Center 2/3 2 to: 7

Each OPC data point includes: 1-min concentration counts/ft³ in 9 - 11 micron size channel

Point	South				East				
	1	2	3	Avg.	1	2	3	Avg.	
2	2756	2400	2025	2393.7	3209	2793	2970	2990.7	
3	2001	2108	1822	1977.0	2665	3011	3248	2974.7	
4	1910	1959	1889	1919.3	2790	3208	2641	2879.7	
Center	1689	2047	1978	1904.7	2719	3130	2666	2838.3	
5	1750	1936	1804	1830.0	2907	3106	3273	3095.3	
6	1716	1648	1692	1685.3	3241	2212	2987	2813.3	
7	3057	2997	1921	2658.3	3408	2856	2927	3063.7	
North					West				
Center 2/3									Grand
Mean	2125.57	2156.43	1875.86	2052.62	2991.29	2902.29	2958.86	2950.81	2501.71
Std. Dev.	551.72	433.26	113.10	344.73	292.01	338.92	248.67	109.84	526.90
C.O.V	25.96	20.09	6.03	16.79	9.76	11.68	8.40	3.72	21.06

Notes: ^a The fan frequency was increased from 10 to 11 Hz because an inlet filter was installed for particle tests.

Adjusted so Centerpoints Equal					
Point	South		East		
	Avg.	Adj.	Avg.	Adj.	
2	2393.7	2860.5	2990.7	2523.8	
3	1977.0	2443.8	2974.7	2507.8	
4	1919.3	2386.2	2879.7	2412.8	
Center	1904.7	2371.5	2838.3	2371.5	
5	1830.0	2296.8	3095.3	2628.5	
6	1685.3	2152.2	2813.3	2346.5	
7	2658.3	3125.2	3063.7	2596.8	
North			West		
Center 2/3					Grand
Mean	2052.6	2519.5	2950.8	2484.0	2501.7
Std. Dev.	344.7	344.7	109.8	109.8	246.5
C.O.V	16.8	13.7	3.7	4.4	9.9

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 Stack Dia. 6.357 in.
 Stack X-Area 31.74 in²
 Measurement elevation in.
 El. above disturbance 49.25 in.
 Injection Point: Centerline Near

Run No. PT6Aug10_3
 Date Sept. 10, 1998

Oil Fisherbrand 19

Fan Setting 11^a Hz
 Center 2/3 from 0.58 inches to: 5.77
 Points in Center 2/3 2 to: 7

Each OPC data point includes: 1-min concentration counts/ft³ in 9 - 11 micron size channel

Point	South				East				
	1	2	3	Avg.	1	2	3	Avg.	
2	1548	1781	1741	1690.0	1952	1561	1712	1741.7	
3	1643	1588	1508	1579.7	1298	1140	1319	1252.3	
4	1760	1667	1526	1651.0	1852	1241	1224	1439.0	
Center	1627	1694	1586	1635.7	1233	1181	1086	1166.7	
5	1528	1559	1634	1573.7	1535	1064	1078	1225.7	
6	1634	1447	1274	1451.7	1262	1002	946	1070.0	
7	1562	1699	1908	1723.0	1207	1257	1360	1274.7	
North					West				
Center 2/3									Grand
Mean	1614.57	1633.57	1596.71	1614.95	1477.00	1206.57	1246.43	1310.00	1462.48
Std. Dev.	78.72	110.48	198.43	90.04	311.00	181.02	251.59	220.91	226.50
C.O.V	4.88	6.76	12.43	5.58	21.06	15.00	20.18	16.86	15.49

Notes: ^a The fan frequency was increased from 10 to 11 Hz because an inlet filter was installed for particle tests.

Adjusted so Centerpoints Equal					
Point	South		East		
	Avg.	Adj.	Avg.	Adj.	
2	1690.0	1455.5	1741.7	1976.2	
3	1579.7	1345.2	1252.3	1486.8	
4	1651.0	1416.5	1439.0	1673.5	
Center	1635.7	1401.2	1166.7	1401.2	
5	1573.7	1339.2	1225.7	1460.2	
6	1451.7	1217.2	1070.0	1304.5	
7	1723.0	1488.5	1274.7	1509.2	
North			West		
Center 2/3					Grand
Mean	1615.0	1380.5	1310.0	1544.5	1462.5
Std. Dev.	90.0	90.0	220.9	220.9	183.1
C.O.V	5.6	6.5	16.9	14.3	12.5

PARTICLE TRAVERSE RESULTS SUMMARY

Site 6' W420 Model Stack in Bldg. 305
 Testers: Maughan
 Stack Dia. 6.357 in.
 Stack X-Area 31.74 in²
 Measurement elevation in.
 El. above disturbance 49.25 in.
 Injection Point: Centerline Near

Run No. PT6Sep28_1
 Date Sept. 28, 1998

Oil Fisherbrand 19

Fan Setting 11^a Hz
 Center 2/3 from 0.58 inches to: 5.77
 Points in Center 2/3 2 to: 7

Each OPC data point includes: 1-min concentration counts/ft³ in 9 - 11 micron size channel

Point	South				East				
	1	2	3	Avg.	1	2	3	Avg.	
2	1304	1560	1622	1495.3	1858	1777	1723	1786.0	
3	1530	1400	1397	1442.3	1508	1774	1685	1655.7	
4	1456	1317	1299	1357.3	1320	1628	1668	1538.7	
Center	1425	1339	1418	1394.0	1697	1536	1708	1647.0	
5	1456	1420	1361	1412.3	1508	1594	1576	1559.3	
6	1558	1335	1559	1484.0	1234	1552	1813	1533.0	
7	1555	1555	1559	1556.3	1274	1687	1812	1591.0	
North					West				
Center 2/3									Grand
Mean	1469.14	1418.00	1459.29	1448.81	1485.57	1649.71	1712.14	1615.81	1532.31
Std. Dev.	89.94	102.14	120.62	67.96	230.90	99.24	83.17	89.57	115.51
C.O.V	6.12	7.20	8.27	4.69	15.54	6.02	4.86	5.54	7.54

Notes: ^a The fan frequency was increased from 10 to 11 Hz because an inlet filter was installed for particle tests.

Adjusted so Centerpoints Equal					
Point	South		East		
	Avg.	Adj.	Avg.	Adj.	
2	1495.3	1621.8	1786.0	1659.5	
3	1442.3	1568.8	1655.7	1529.2	
4	1357.3	1483.8	1538.7	1412.2	
Center	1394.0	1520.5	1647.0	1520.5	
5	1412.3	1538.8	1559.3	1432.8	
6	1484.0	1610.5	1533.0	1406.5	
7	1556.3	1682.8	1591.0	1464.5	
North			West		
Center 2/3					Grand
Mean	1448.8	1575.3	1615.8	1489.3	1532.3
Std. Dev.	68.0	68.0	89.6	89.6	88.5
C.O.V	4.7	4.3	5.5	6.0	5.8

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 El. above disturbance 49.25 in.
 Injection Point: Centerline Near

Run No. PT6Sep28_2
 Date Sept. 28, 1998

Oil Fisherbrand 19

Fan Setting 38 Hz
 Center 2/3 from 0.58 inches to: 5.77
 Points in Center 2/3 2 to: 7

Each OPC data point includes: 1-min concentration counts/ft³ in 9 - 11 micron size channel

Point	South				East				
	1	2	3	Avg.	1	2	3	Avg.	
2	856	906	871	877.7	760	732	822	771.3	
3	1001	746	733	826.7	804	737	830	790.3	
4	862	879	810	850.3	818	758	706	760.7	
Center	881	810	791	827.3	827	835	810	824.0	
5	879	852	821	850.7	796	801	916	837.7	
6	815	801	822	812.7	873	809	844	842.0	
7	930	869	768	855.7	903	1106	1153	1054.0	
North					West				
Center 2/3									Grand
Mean	889.14	837.57	802.29	843.00	825.86	825.43	868.71	840.00	841.50
Std. Dev.	60.11	54.89	44.01	22.01	48.21	129.60	139.80	99.61	69.32
C.O.V	6.76	6.55	5.49	2.61	5.84	15.70	16.09	11.86	8.24

Notes: ^a The fan frequency was increased from 10 to 11 Hz because an inlet filter was installed for particle tests.

Adjusted so Centerpoints Equal					
Point	South		East		
	Avg.	Adj.	Avg.	Adj.	
2	877.7	876.0	771.3	773.0	
3	826.7	825.0	790.3	792.0	
4	850.3	848.7	760.7	762.3	
Center	827.3	825.7	824.0	825.7	
5	850.7	849.0	837.7	839.3	
6	812.7	811.0	842.0	843.7	
7	855.7	854.0	1054.0	1055.7	
North			West		
Center 2/3					Grand
Mean	843.0	841.3	840.0	841.7	841.5
Std. Dev.	22.0	22.0	99.6	99.6	69.3
C.O.V	2.6	2.6	11.9	11.8	8.2

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