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Life Sciences Laboratory 2 Fan Exhaust Mixing Study

June 2016

JE Flaherty
EJ Antonio

U.S. DEPARTMENT OF ENERGY

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

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Acknowledgments

Performing these tests involved a significant amount of planning and preparation, and contributions from many individuals was necessary to successfully execute this effort. Some of these individuals are acknowledged here. Planning and project oversight was expertly executed by Robert Ford, Eric Damberg, Jeff Renken, Adam Gemmel, Leslie Schwartz, Brad Atencio, Jerry Hall, and Robert McKinney. Our crafts support team included John Valdez, Mike Stocke, Chris Coodey, Kurk Watts, and Tom Cunningham. We also acknowledge data reviews by Carmen Arimescu. Heather Culley provided editorial support in drafting this report.

We also would like to acknowledge the staff with offices and laboratories in the LSL-II building; they have endured numerous building outages in recent months, including the weekend during which the tests described in this report were performed.

Acronyms and Abbreviations

cfm	cubic feet per minute
GM-	Gas Mixing test
HDI	How Do I…? PNNL lab-level requirements, procedures and considerations for conducting work.
HEPA	high efficiency particulate air
LSL-II	Life Sciences Laboratory 2
mph	miles per hour
PNNL	Pacific Northwest National Laboratory
ppb	parts per billion
ppm	parts per million
SF_6	sulfur hexafluoride
SLPM	standard liters per minute

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1.0 Introduction

While performing work on the Pacific Northwest National Laboratory (PNNL) Life Sciences Laboratory 2 (LSL-II) building exhaust system in December 2015, there was a concern that workers could be exposed to exhaust air. This concern was raised while exhaust Fan 4 was offline and a wooden platform was being constructed for the installation of a replacement fan. To investigate the potential exposure concentrations at various locations near the fan exhaust, a mixing study was performed. This report describes the objectives of these tests, provides an overview of how the tests were executed, and presents the results of the tests.

The exposure concern was raised, in part, because the LSL-II exhaust does not terminate with a ductwork stack, which typical exhaust systems employ. Instead, the fans exhaust into a corridor constructed of cinder block with 9-foot walls without a ceiling. There are three partitions in this stack/corridor, none of which meet the roof deck. There are hatches in each of the partitions that allow passage between the stack/corridor sections. The corridor is accessed with full size doors on either end. Figure 1.1 shows a plan view of a portion of the LSL-II rooftop with the fan exhaust configuration. As a result of this stack design, workers must pass through portions of the corridor, which is effectively the exhaust stack, to perform regular maintenance activities.

The basic elements of the mixing study of the LSL-II exhaust system included a release of tracer gas inside a laboratory fume hood and tracer gas measurements at the outlet of an operating fan, as well as at a variety of work locations where staff could have become exposed to exhaust system air. Several objectives were expected to be achieved through these tests. First, the maximum potential exposure concentration relative to a given release rate was experimentally determined. Although this can be mathematically determined from the release rate and duct flow rate, a calibrated duct flow rate was not available for this system, and other ventilation system uncertainties may contribute to a difference between the mathematically and experimentally determined values. The physical measurement for this objective was the concentration at the outlet of an operating fan.

Second, concentrations at a variety of likely work locations were experimentally determined. Several categories of potential exposure are embedded within this objective. These include the December 2015 work activities, which involved construction of a platform in the Fan 4 vestibule, as well as historical routine work activities (such as daily checks of fan function by the power operator). The physical measurements for this objective were the concentrations at various work locations. In addition to building ventilation conditions, the concentrations at these locations are potentially influenced by atmospheric conditions. The local wind speed and direction during the measurement periods were assessed with the measurement results.

A final objective was to glean characteristics of the ventilation system from these testing activities. The time of travel from the fume hood to the exhaust location was observed at the start of tracer gas injections. After the tracer gas injection was terminated, the time necessary for the fan outlet concentration to return to background levels was also monitored.

The tests reported here only describe the concentrations at various locations relative to the fan exhaust concentration. To quantify worker exposures from chemical use at this facility, information about the concentration of chemical compounds within the exhaust system must be determined. This involves measurements of chemical compounds in the exhaust system, along with an evaluation of the current chemical inventory in the facility and estimates of the historical emissions and chemical inventory. These efforts are separate but related activities that will be reported elsewhere.

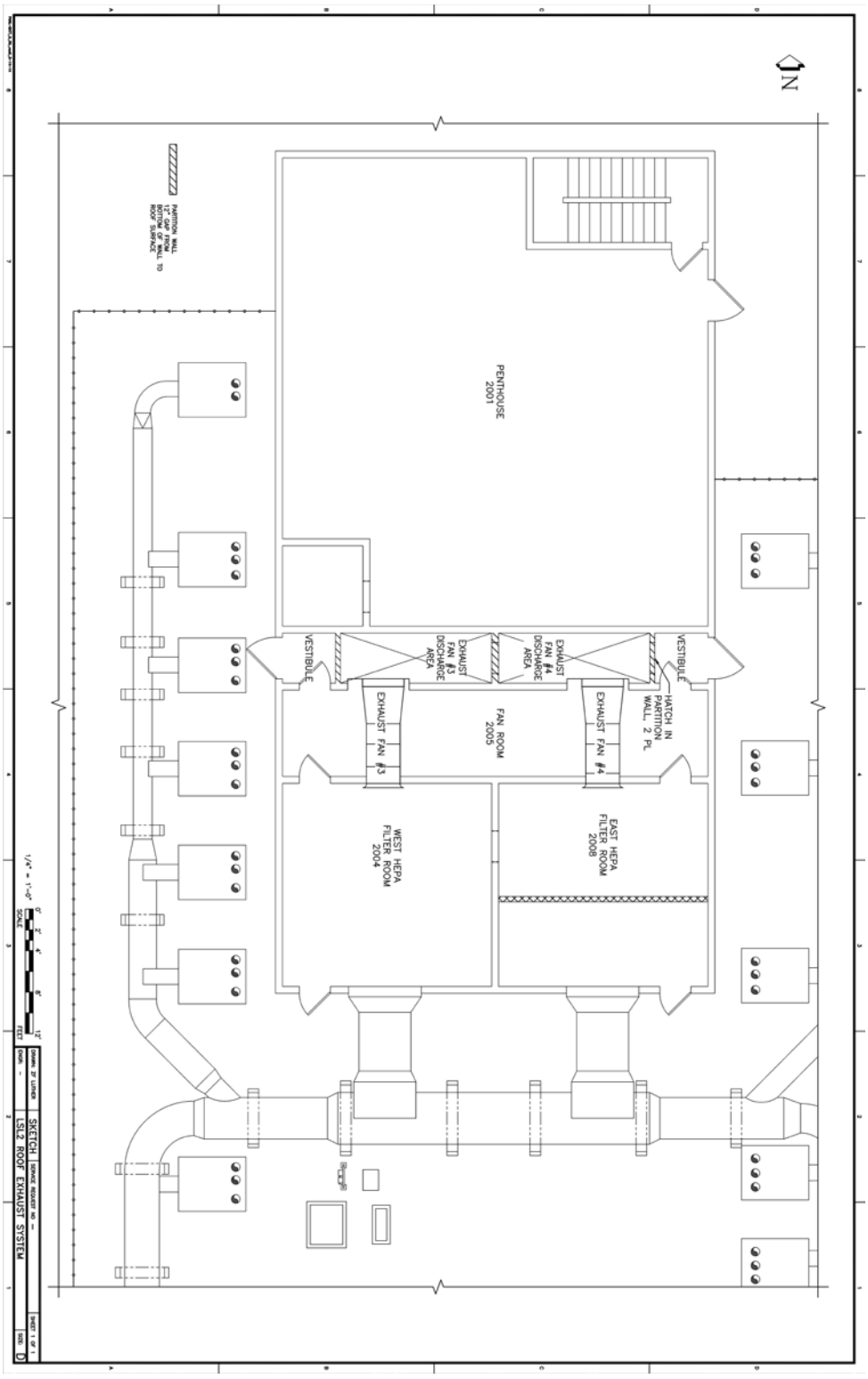

Figure 1.1. Plan View of a Portion of the LSL-II Rooftop

2.0 Methods

To support the determination of potential worker exposure levels from the LSL-II exhaust, a mixing study that experimentally determines concentrations at potential work locations due to the introduction of a known gas source was performed. This section describes, in general, the testing methods employed in this study. Some of the specific steps employed in executing the test may be found in the test plan (Flaherty and Antonio 2016).

2.1 LSL-II Exhaust Configuration

The LSL-II exhaust system tested in this report ventilates the first floor laboratories and offices. As shown in Figure 1.1, there are four branches of duct work (two to the west, two to the east) that combine to a common duct south of the high efficiency particulate air (HEPA) filter rooms. There are two fans downstream of the HEPA rooms; the most common operating condition is to have one fan operational while one is in standby. Each fan is rated to 55,000 cfm. Historically, there have been occasions when both fans are operating simultaneously. With either configuration, the variable frequency drives adjust the fan speed such that the total flow rate through the system is constant at around 48,000 cfm. This control is determined by a pressure set point in the common duct south of the HEPA rooms.

The HEPA rooms are separated by a wall with an opening that permits some air to move between the HEPA rooms. Although this opening is maintained during normal operation, the December 2015 work activities, which involved the replacement of Fan 4, blocked this opening as well as the opening from the common duct into the Fan 4 HEPA room. Prior to the tests reported here, the Fan 3 HEPA room was re-lined with new sheet metal and the HEPA rack was removed. At the time of testing, the Fan 4 HEPA room had its old lining (which has subsequently been replaced) as well as the HEPA rack with no HEPA filters installed.

Figure 2.1 shows a subset of the rooftop duct system with colored markers representing sample positions for these tests. Note that the concentrations of gas, relative to the highest possible gas concentration, were the measurements of interest. The blue markers (I and II) represent measurements made directly within the un-diluted fan exhaust, which are the highest concentrations among the stack locations. The measurements at locations I and II were made using an existing vacuum air sampling system, which was installed and used when the facility contained radiological materials. This air sampling system included a rake across the duct near the duct outlet (see Figure 2.2) and a sampling line with a filter holder (see Figure 2.3). This system was no longer in use, so the sampling line was disconnected at the filter holder to allow the installation of a separate, flexible tube sampling line specific for these tests. The filters on each exhaust fan were surveyed for radiological contamination, and both filters were measured (see Figure 2.4) at background levels.

The green markers in Figure 2.1 represent the various sampling points for this study, which were selected based on the potential for workers to frequent these locations. A worker may exit the Penthouse onto the roof, enter the stack/corridor into the vestibule, and either proceed into the fan discharge area to peer through an open center hatch to verify the backdraft damper in the neighboring fan, or proceed into the Fan Room to verify fan operation for the current fan. The three partition walls shown in the stack/corridor do not reach the roof deck, and instead there is a 1-foot gap that allows air to pass between sections. The partition walls also contain a hatch for workers to move between sections. The hatches between the vestibule and the fan discharge areas are typically closed, but the middle hatch between the Fan 3 and Fan 4 discharge areas is typically left open.

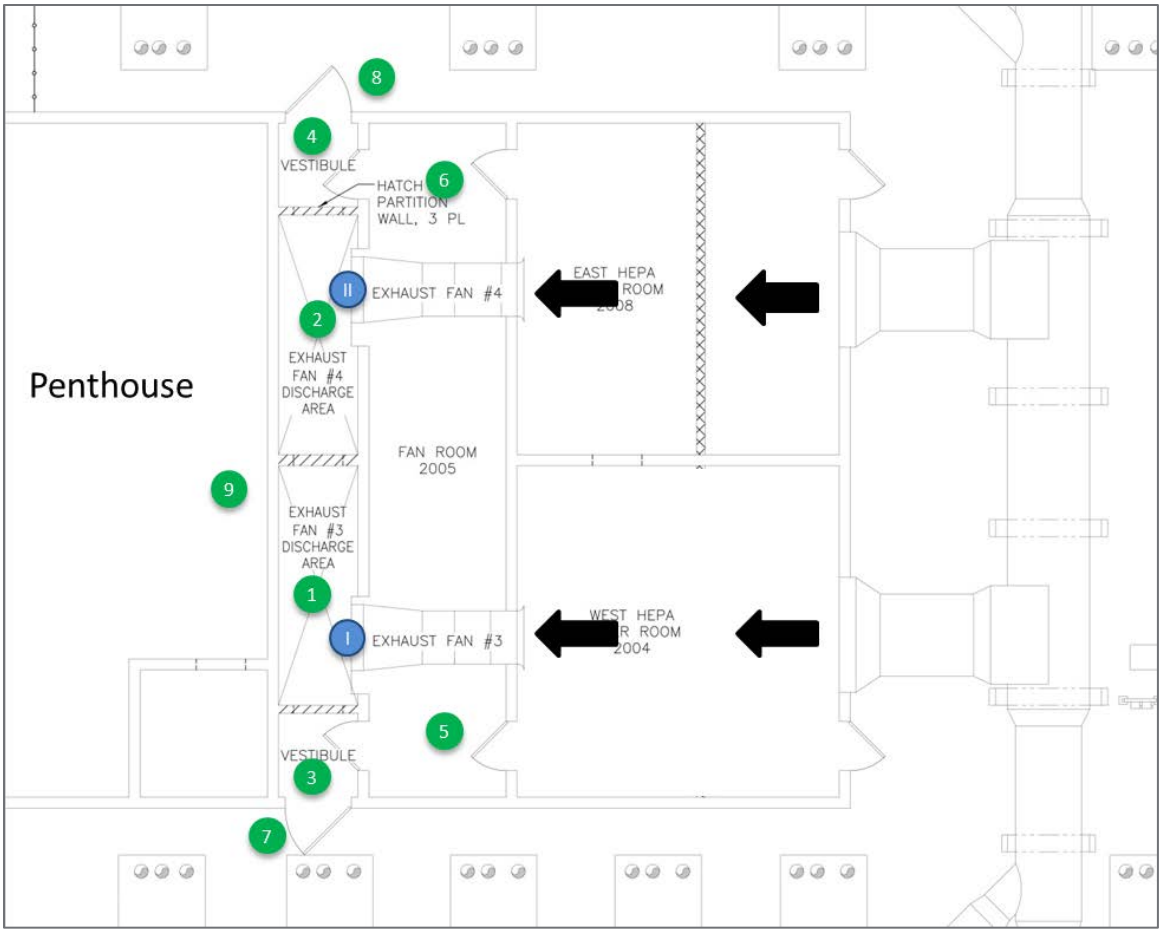

Figure 2.1. Plan View of the Near Fan Portion of the LSL-II Building Rooftop with Sample Locations. Blue markers represent fan exhaust sample locations, while green markers represent potential worker exposure sample locations.

Figure 2.2. Vacuum Air Sampling System Rake Used for Exhaust Measurements from Fan 4. Similar equipment is installed in Fan 3.

Figure 2.3. Vacuum Air Sampling Line. The filter holder located upstream of the rotameter was removed so that the sample line could be installed.

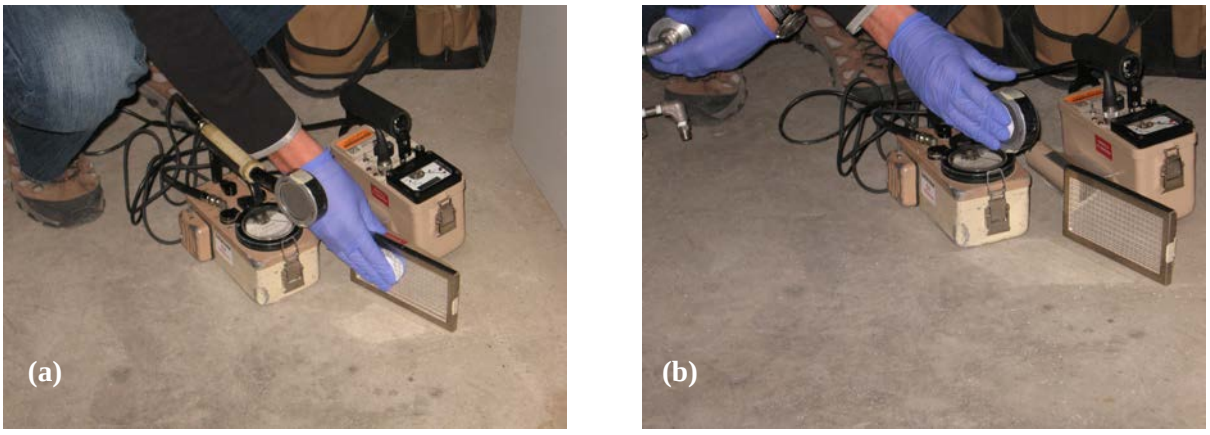

Figure 2.4. Surveys of Filter Paper Removed from Filter Cartridge on the Vacuum Air Sampling Lines. a) Portable Alpha Meter Survey; b) Geiger Mueller Meter Survey.

In general, the worker breathing zone while standing upright was the anticipated potential exposure height; therefore, sampling points were positioned at 5 feet above the roof deck. For the December 2015 work activities, a platform was being built, so one person was breathing near the 1-foot level in the

vestibule area near Fan 4 while Fan 3 was operating. As a result, an additional sampling point at 1 foot above the roof deck was located at this position. The sampling locations indicated by the green markers in Figure 2.1 had a tripod with an inlet of a sampling line secured to it. Each tripod was weighted with a can of rocks hanging from its center to ensure that the tripod remained in place through any wind gusts over two days and two evenings. Photos depicting the sample locations and the sampling tube positioning on the tripods are included in Figure 2.5 through Figure 2.10.

Figure 2.5 shows the sampling location outside of the Fan 3 door. The door was closed for the duration of the test. The sampling location outside of the Fan 4 door was positioned similarly, so a photo was not included here. In these and all sampling positions with tripods, the tubing was looped at the top of the tripod and the sample line inlet was pointed downward at the 5-foot mark to ensure that any overnight precipitation would be unlikely to enter the tubing. Figure 2.6 shows the sampling location in the Fan 4 vestibule. As mentioned previously, this location had a measurement at both 1-foot and 5-foot heights. This photo also shows the hatch between the vestibule and the fan discharge area (behind the tripod). Additionally, although difficult to discern, the photo shows that there is a gap at the bottom of the partition wall at the roof deck. The tubing for the other sampling locations can be seen routed under the hatch.

Figure 2.7 shows the sampling location in the Fan 3 Fan Room. The tripod on the left was used to mount the gaseous sampling line, while the tripod on the right was used to mount a camera, which was pointed at the stack flow sensor. The door to the vestibule (not shown) was left open during the test to provide a conservative estimate of the gas concentration in this space.

The remaining two stack sampling locations were in front of each fan, and were designated the fan discharge areas. Figure 2.8 shows the sampling tripod for the Fan 3 Discharge area. The sample point was in front of the fan, but rather than being centered on the fan, where there may be a low flow region (and corresponding concentration minimum) due to the configuration of the backdraft dampers (see Figure 2.9), the sample point was approximately halfway between the edge and center of the fan face. When the fan is not operating, the backdraft damper closes and when the fan is running, the backdraft damper opens up (Figure 2.9).

Finally, sampling was performed in the Penthouse, which shares a wall with the fan exhaust stack/corridor. During a walk-down of the Penthouse in January 2016, cracks were noted in the south wall of the Penthouse. The wall and the sampling position in the Penthouse are shown in Figure 2.10. The tripod was located approximately in the east-west center of the Penthouse, and approximately 10 feet from the south wall.

Figure 2.5. Sample Location 7: Fan 3 Near Door

Figure 2.6. Sample Location 4: Fan 4 Vestibule. Sample tubing at both 5 feet and 1 foot above the roof deck.

Figure 2.7. Sample Location 6: Fan 3 Fan Room

Figure 2.8. Sample Line Location 1: Fan 3 Discharge

Figure 2.9. Fan 3 Backdraft Damper. (a) Closed, (b) Open (with sampling rake visible).

Figure 2.10. Sample Line Location 9 within the Penthouse.

2.2 Testing Methods

The basic test process was to inject gas in a fume hood and measure that gas in and around the exhaust stack/corridor. The gas injection equipment included a cylinder of pure sulfur hexafluoride (SF_6), a regulator, a mass flow controller, and tubing. The tubing was secured to a bench stand, which was

positioned within a fume hood with the sash mostly down. For all tests, the SF_6 was released at a rate of 6 standard liters per minute (SLPM), which was necessary to achieve the target fan exit concentration of approximately 5 ppm. Most tests used the least distant fume hood (Room 1411); however, two tests used the most distant fume hood (Room 1436). A photo of the equipment setup in Room 1436 is included in Figure 2.11.

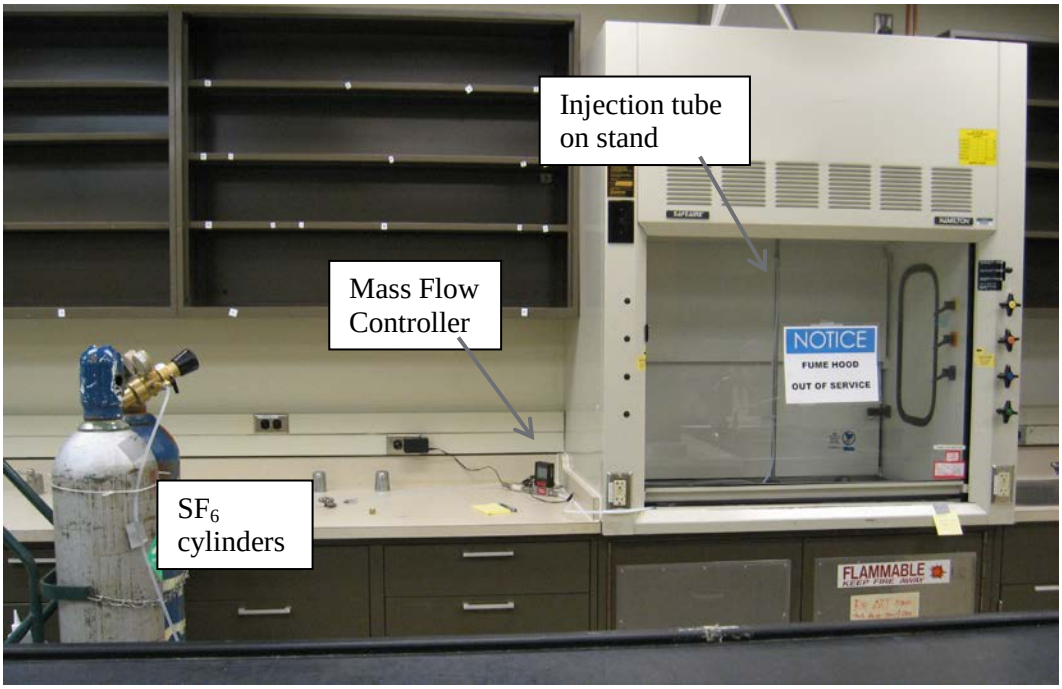

Figure 2.11. LSL-II Fume Hood Injection Setup in Room 1436

As described in the previous section, sample tubing was positioned at each of the 12 unique sampling positions in and near the fan exhaust on the LSL-II rooftop. All sample lines were the same length (200 feet) to ensure identical sample lag times for each sample location. Gas sampling was performed with a small rocking piston pump to draw air through the sample lines and a photoacoustic gas analyzer that sampled from the pump exhaust (see Figure 2.12).

Three Brüel and Kjær gas analyzers (Model 1302, Denmark) were used to simultaneously measure rooftop concentrations from three locations. This equipment was staged in the LSL-II loading dock (see Figure 2.13). Note that any sample lines that were not in use were capped and all exhaust lines were routed outside to a pipe "stack" attached to LSL-II A, approximately 50 feet from the loading dock door. All measurements made in these tests used the water correction feature in the gas analyzer. With this mode of operation, the SF_6 detection limit for the instrument is 5 ppb. The instrument collects near-instantaneous samples by drawing just enough air to fill its sample cell and provides analysis results in approximately 55 seconds.

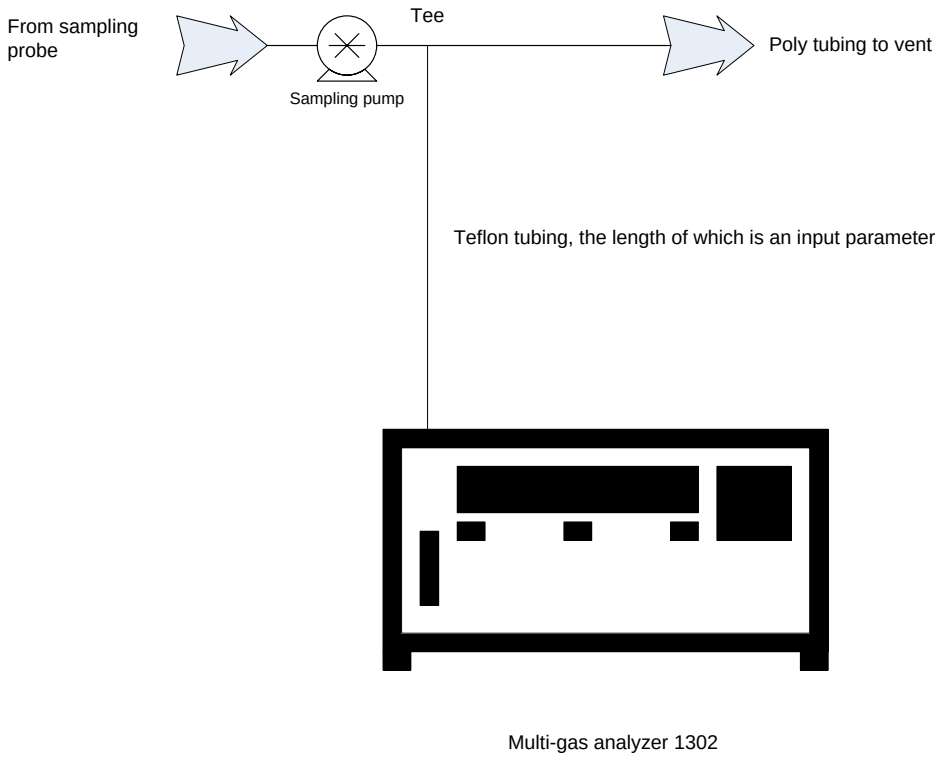

Figure 2.12. Diagram of Gas Analyzer Setup for One Pump and Instrument

Figure 2.13. Photo of Pumps and Gas Analyzers at the LSL-II Loading Dock

2.3 Test Configurations

These tests were performed under five fan configurations, as noted in Table 2.1. The purpose of these five configurations, indicated by separate columns in this table, was to capture the configuration that existed during the December 2015 work activities, as well as historical, routine work activities, and to demonstrate that gas tracer results are insensitive to the state of the HEPA room liner, which has now been removed and replaced. Each row of Table 2.1 represents the pair of simultaneous measurements that were performed for each fan configuration. Three gas analyzers were available for these tests; however,

one analyzer was dedicated to the fan outlet measurement. This means that two gas analyzers remained for capturing the concentrations at the various potential exposure locations. For each measurement pair, approximately 25 minutes of sampling was planned for observing the variability of concentrations at that location. The intent of these pairings was not meant to be prescriptive, but simply to capture the total number of measurement locations in a systematic manner.

The second column (Configuration 1) in Table 2.1 represents the operating conditions during the December 2015 work. Fan 3 was operating during this period and workers were primarily in the area of Fan 4. A block had been placed in the opening between the Fan 3 and Fan 4 HEPA rooms, and a second block was placed in the inlet to the Fan 4 HEPA room. The third column in Table 2.1 represents typical single-fan operating conditions, which has no blocks. The results of this test will serve as a contrast to the first configuration with blocks.

The fourth column (Configuration 3) in Table 2.1 serves to contrast the December 2015 configuration (column 2). All of the tests described in this report occurred after the Fan 3 HEPA room liner replacement, but prior to the Fan 4 HEPA room liner replacement. Although the liner surface itself has no impact on the tracer gas dilution, a configuration that can be used to directly compare the results between a new Fan 3 liner and an old Fan 4 liner will confirm this with measurements. The fifth column in Table 2.1 (running Fan 4) was similarly planned as a comparison against the typical single-fan operation with Fan 3. Finally, a case where both fans were operating was performed.

2.4 Quality Assurance and Quality Control

The work presented in this report was performed according to quality assurance guidance listed in PNNL's How Do I…? (HDI) system. A test plan (Flaherty and Antonio 2016) was written to document the scope of the work and the steps for executing the test. Data from these tests were recorded onto data sheets; test equipment used (with serial numbers) and calibration due dates were included. All data entry blocks on each data form contained an entry or marking to indicate that it was intentionally left blank. Finally, each sheet was signed by one of the data takers indicating the form is complete.

After tests were completed, the handwritten data were transcribed into a spreadsheet and all electronic datasheets were reviewed for transcription errors. A signature on the data sheet was used to indicate the completion of this review. Additionally, calculations performed with the spreadsheet were independently verified with a hand-calculation (using a calculator).

Prior to and after performing the rooftop gas tests, a calibration check of the three B&K Model 1302 gas analyzers was performed. These checks were performed using gas mixtures from an A2LA-accredited supplier. This ensured that the instrument responds appropriately to SF_6 at two concentrations that were separated by over an order of magnitude in concentration difference. This also provides data to demonstrate that the instruments respond similarly to each other. The results of these tests are included in Appendix B.

An additional quality assurance check was performed during the rooftop gas test period. For this test, the sample line from Fan 3 Exhaust (Location I) was connected to a cross and routed through all three Hi-Q pumps (see Figure 2.14). This was an additional check of the response of all three gas analyzers while measuring the same sampling location.

Table 2.1. Test Matrix for Evaluating Air Mixing From LSL-II Fan Exhaust. The numbers preceding the measurement location names indicates the numbered locations (blue, green markers) in Figure 2.1. A measurement at the test reference location (I or II) was performed during each Test Pair measurement.

Configuration	**1**	**2**	**3**	**4**	**5**
Operating Fan(s) Plenum Blocks Liner Condition	**Fan 3 With Blocks New Fan 3 Liner**	**Fan 3 No Blocks New Fan 3 Liner**	**Fan 4 With Blocks Old Fan 4 Liner**	**Fan 4 No Blocks Old Fan 4 Liner**	**Fan 3 & Fan 4 No Blocks New Fan 3 Liner, Old Fan 4 Liner**
Test Reference	I – Fan 3 Exhaust	I – Fan 3 Exhaust	II – Fan4 Exhaust	II – Fan4 Exhaust	II – Fan4 Exhaust
Test Pair 1	4-Fan 4 Vestibule (5ft) 4-Fan 4 Vestibule (1ft)	4-Fan 4 Vestibule (5ft) 6-Fan 4 Fan Room	4-Fan 4 Vestibule (5ft) 6-Fan 4 Fan Room	4-Fan 4 Vestibule (5ft) 6-Fan 4 Fan Room	4-Fan 4 Vestibule (5ft) 6-Fan 4 Fan Room
Test Pair 2	6-Fan 4 Fan Room 2-Fan 4 Discharge	2-Fan 4 Discharge 7-Fan 3 Near Door	8-Fan 4 Near Door 1-Fan 3 Discharge	8-Fan 4 Near Door 1-Fan 3 Discharge	8-Fan 4 Near Door 7-Fan 3 Near Door
Test Pair 3	7-Fan 3 Near Door 3-Fan 3 Vestibule	3-Fan 3 Vestibule 5-Fan 3 Fan Room	3-Fan 3 Vestibule 5-Fan 3 Fan Room	3-Fan 3 Vestibule 5-Fan 3 Fan Room	3-Fan 3 Vestibule 5-Fan 3 Fan Room
Test Pair 4	5-Fan 3 Fan Room 9-Penthouse	9-Penthouse 1-Fan 3 Discharge	9-Penthouse 2-Fan 4 Discharge	9-Penthouse 2-Fan 4 Discharge	9-Penthouse I- Fan 3 Exhaust

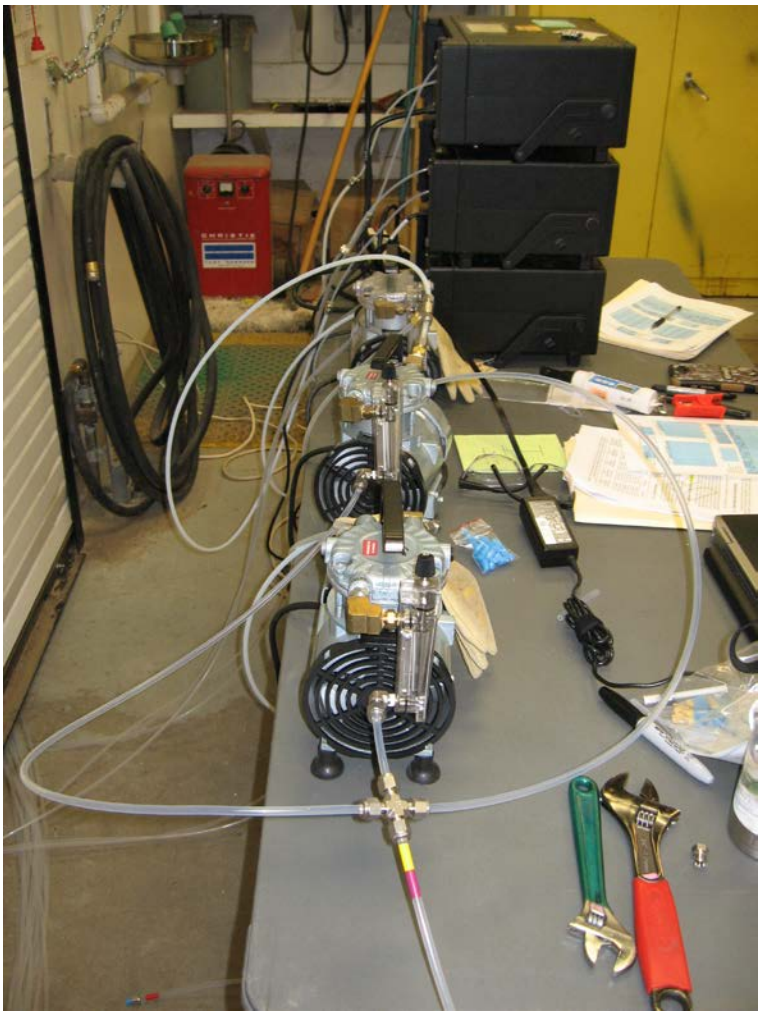

Figure 2.14. Sample Line Coming into a Cross and Routed to All Three Hi-Q Pumps

3.0 Test Results

The primary reportable results from the LSL-II mixing study include the average concentrations and the ratio of concentrations measured at an operating fan discharge to a sampling location. This section describes the meteorology during the tests, along with the concentration measurements from the tests. The completed data sheets for the tests are included in Appendix A.

3.1 Local Meteorology

The measurements described in subsequent sections were performed over the course of two days. Since most of the measurement locations were open to the atmosphere, the potential influence of meteorology was considered. Figure 3.1 and Figure 3.2 show some of the meteorological data available from the 300A tower on the two study dates. The 300A tower is operated as part of the Hanford Meteorological Network and is located approximately 2.1 km NNW of the LSL-II building. Temperatures were moderate on each of the test days, with high temperatures around 60° Fahrenheit. The wind was blowing out of the southeast for much of March 5, although it shifted toward the northeast in the afternoon. The wind direction was distinctly different on March 6, with winds coming out of the southwest (225 degrees) for most of the day. The wind speed from each day is the variable of most influence for the mixing study. On March 5, the wind speed was generally between 5 and 12 miles per hour (mph), while on March 6, the wind speed had picked up, with many periods measuring 15 to 20 mph.

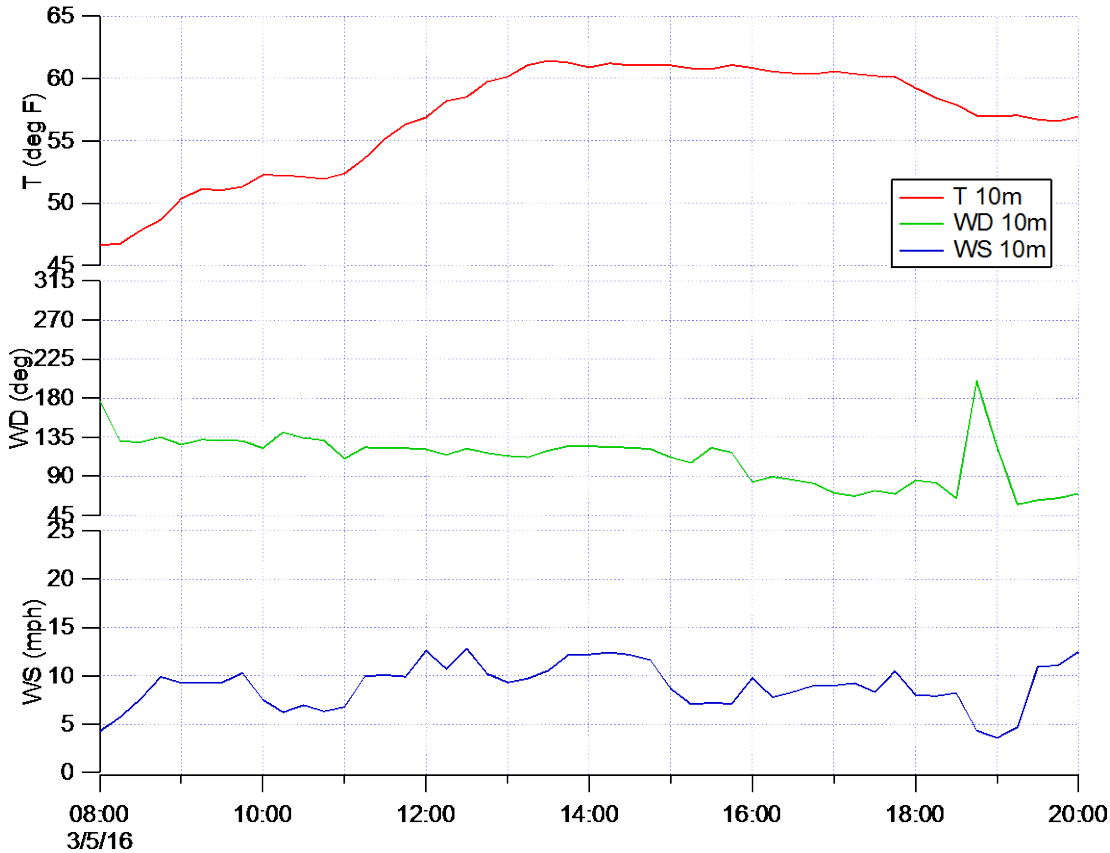

Figure 3.1. 300A Tower Temperature, Wind Direction, and Wind Speed from 3/5/16

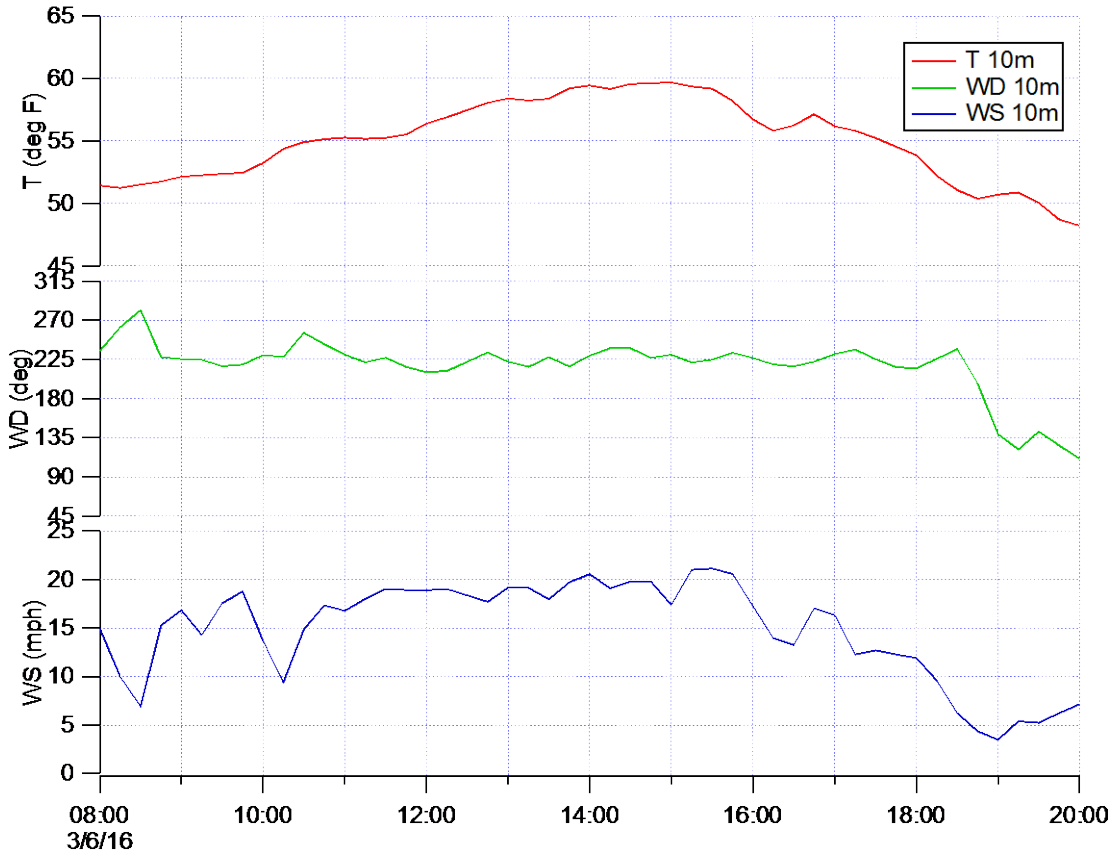

Figure 3.2. 300A Tower Temperature, Wind Direction, and Wind Speed from 3/6/16

3.2 Mean and Relative Concentration Results

The mean concentrations and the relative concentrations from the test configurations described in Table 2.1 are presented in this section. Mean concentrations for the reference positions, (the Fan 3 or Fan 4 Exhaust Locations) tabulated in this section were an average of the 104 samples from four data sheets. The reference position measurement was included with each pair of potential worker location measurements, and for each fan configuration, four pairs of worker location measurements were made. Each measurement set included 26 samples to observe any concentration trends. Over the course of the 26-sample measurement set, the concentrations remained generally stable with no particular trends. The variability about the mean, expressed by the standard deviation, was generally between 0.10 ppm and 0.60 ppm. These standard deviations, as well as the calibration checks using gas mixtures, indicate that there is approximately a ±5% error in the measurement technique.

Table 3.1 lists both the absolute and relative concentrations from the two Fan 3 configurations (with and without blocks). These tests were both performed on March 5. For all tests, the mass flow controller was set to deliver 6 SLPM of SF_6 into the fume hood. The stack flow measurements indicated that the total system flow was approximately 48,000 cfm. If 6 SLPM of SF_6 is diluted into 48,000 cfm of ventilation air, the resulting SF_6 concentration is 4.4 ppm. Both of the Fan 3 Exhaust concentrations were approximately 4.4 ppm, which confirms that the system flow rate was approximately 48,000 cfm. The relative concentration values are the ratios of the concentration at each of the potential worker locations to the concentration at the Fan 3 Exhaust. This represents the fraction of the maximum concentration (directly out of the stack) that a worker may experience if their work took them to these locations.

The highest relative concentration location measured for Fan 3 operations was the Fan 3 Discharge Area, which had essentially the same concentration as the Exhaust. The absolute concentration at this location was actually slightly higher than the Exhaust concentration; however, the difference is within instrument errors. This location was only measured during the configuration that included blocks; normally, workers would not stand directly in front of an operating fan. The next highest concentrations were in the Fan 3 Vestibule and Fan Room near Fan 3. These locations had concentrations that were 80% or more of the maximum concentration. The Fan 4 Vestibule and Fan Room near Fan 4 had slightly lower concentrations, at around 60% of the maximum in the case with blocks and around 70% in the case without blocks. For both Fan 3 configurations, the Penthouse measurement was approximately 25% of the maximum ventilation system concentration. Measurements outside the door to the corridor were at relatively low levels, which mean that the material within the stack does not "spill" over to the top of the wall and impact workers directly next to the stack. The data sheets for the Fan 3 tests with blocks are included in Appendix A as gas mixing (GM) run numbers GM-2A through GM-2D. The data sheets for the Fan 3 tests without blocks are included in Appendix A as GM-3A through GM-3D.

Table 3.1. Measurements with Fan 3 Running

	With Blocks (Configuration 1)		**Without Blocks (Configuration 2)**	
Sampling Location	**Mean Concentration (ppm)**	**Ratio to Fan 3 Exhaust**	**Mean Concentration (ppm)**	**Ratio to Fan 3 Exhaust**
Fan 3 Exhaust	4.44	1.00	4.26	1.00
Fan 3 Discharge Area	N/A	N/A	4.49	1.05
Fan 4 Discharge Area	3.32	0.75	2.65	0.62
Fan 3 Vestibule	3.74	0.84	3.91	0.92
Fan 4 Vestibule – 5 feet	2.54	0.57	3.12	0.73
Fan 4 Vestibule – 1 foot	2.97	0.67	N/A	N/A
Fan Room near Fan 3	3.58	0.81	4.36	1.02
Fan Room near Fan 4	2.66	0.60	2.94	0.69
Fan 3 Near Door	0.08	0.02	0.13	0.03
Penthouse	1.07	0.24	1.17	0.27

Table 3.2 lists the absolute and relative concentrations from the two Fan 4 configurations (with and without blocks). The SF_6 flow rate was also 6 SLPM for these tests; however, the Fan 4 Exhaust concentrations were higher in these tests compared with the Fan 3 values. To achieve a mean concentration of 5.5 ppm, the dilution flow rate would need to be 38,500 cfm. Although the stack flow sensor measurements for Fan 4 appeared to be functioning well and point to a flow rate of 48,000 cfm, the concentrations are slightly higher than expected.

The highest relative concentrations are slightly different between the two Fan 4 configurations. For the Fan 4 operating with blocks, most of the measurements in the stack/corridor, as well as the fan rooms, had similar concentrations, between 70 and 86% of the maximum concentration. The Fan 3 Discharge Area

had the lowest concentration among the measurements made in the stack/corridor, with only approximately 50% of the maximum concentration. For the Fan 4 operating without blocks, several locations had significantly lower relative concentrations compared with the measurements when Fan 4 was operating with blocks. The Fan 3 Vestibule and Fan Room near Fan 3 were 34% and 44% of the maximum concentration, respectively. These values were approximately half of the values from the Fan 4 operating with blocks. This difference may be attributable to differences in meteorology. Measurements for Fan 4 with Blocks were performed on March 5, while the measurements for Fan 4 without Blocks were performed on March 6. As described previously, there was both a wind direction shift and a wind speed increase between March 5 and 6. The winds were nearly 20 mph on March 6, and primarily out of the southwest. The concentrations on the west side of the stack were lower than on the east side, pointing to the possibility that the wind biased the exhaust toward one side.

For both Fan 4 configurations, the Penthouse measurement was approximately 20% of the maximum ventilation system concentration, which was similar to the values from the Fan 3 measurements. Measurements outside the door to the corridor were low values (instrument noise, in the case of Configuration 3), which again means that the material within the stack does not "spill" over to the top of the wall and impact workers directly next to the stack. The data sheets for the Fan 4 tests with blocks are included in Appendix A as GM run numbers GM-1A through GM-1D. The data sheets for the Fan 4 tests without blocks are included in Appendix A as GM-5A through GM-5D.

Table 3.2. Measurements with Fan 4 Running

	With Blocks (Configuration 3)		**Without Blocks (Configuration 4)**	
Sampling Location	**Mean Concentration (ppm)**	**Ratio to Fan 4 Exhaust**	**Mean Concentration (ppm)**	**Ratio to Fan 4 Exhaust**
Fan 4 Exhaust	5.56	1.00	4.91	1.00
Fan 3 Discharge Area	2.71	0.49	2.47	0.50
Fan 4 Discharge Area	4.35	0.78	4.22	0.86
Fan 3 Vestibule	3.91	0.70	1.69	0.34
Fan 4 Vestibule – 5 feet	4.40	0.79	4.57	0.93
Fan Room near Fan 3	4.78	0.86	2.14	0.44
Fan Room near Fan 4	4.60	0.83	4.19	0.85
Fan 4 Near Door	0[a]	0[a]	0.02	0.00
Penthouse	1.29	0.23	0.96	0.20

a. Measurements at Fan 4 Near Door for Configuration 3 were below the instrument detection limit, and is therefore reported as "0."

The relative concentrations have been plotted as colored dots in an approximation to the plan view of the stack exhaust area in Figure 3.3 to provide a sense of the spatial distribution of the measurements. Each colored dot is positioned at the approximate measurement location, and the color itself represents the fraction of the Exhaust concentration as listed in Table 3.1 and Table 3.2. Note that the general trend in

the concentrations is as one would expect. The highest concentrations tend to be in the vestibule and the fan room on the same side as the operating fan. The fan room concentrations tend to be comparable or slightly higher than the neighboring vestibule, which is perhaps more of a function of instrument error than concentrating effects, although the latter is also possible. The relative concentrations as one moves to the opposite fan vestibule and fan room decrease, and are generally lower than the side with the operating fan. Each of the exterior measurement locations outside the door were measured at very low concentrations, as represented by the purple markers. The next lowest concentration in each case (at approximately 0.25 relative concentration) was the Penthouse, which is generally represented by the darker blue shade.

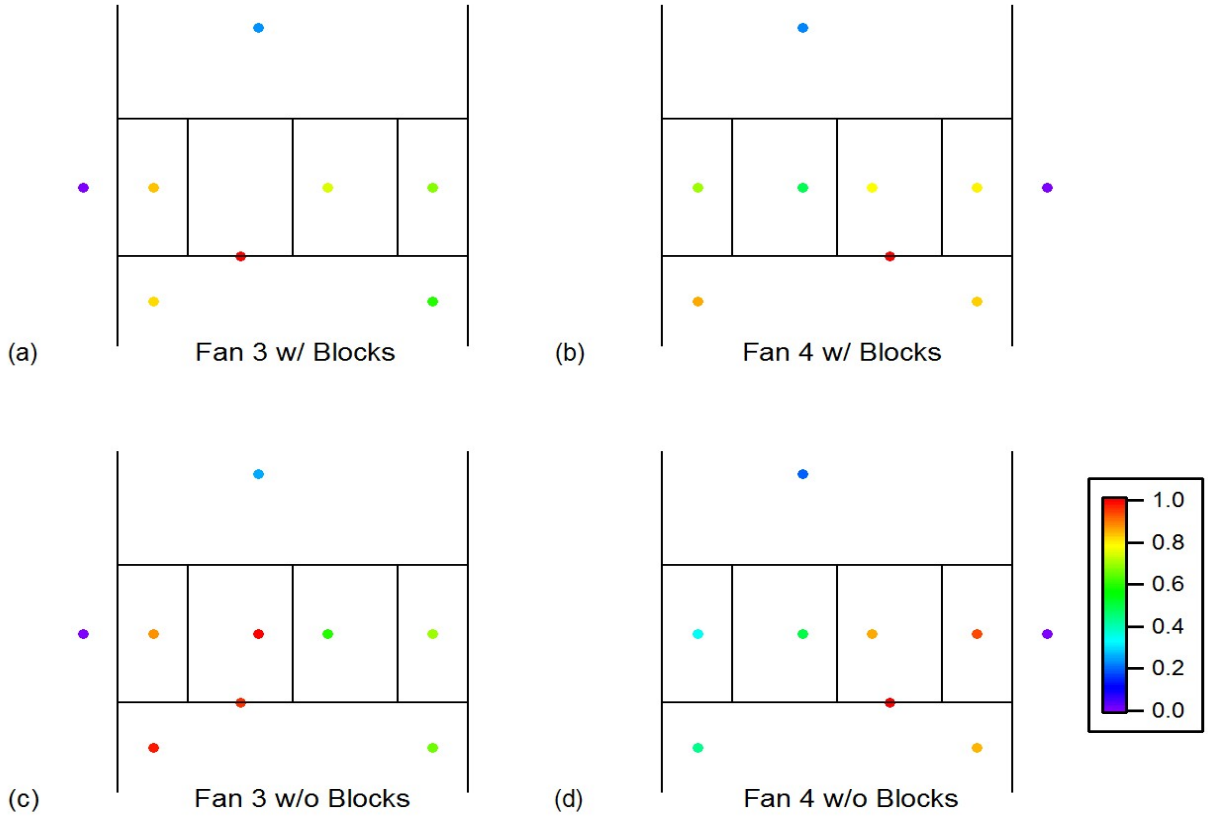

Figure 3.3. Colored Dot Plots Representing Concentration Ratios for the Four Base Configurations. Sample positions are illustrative, and not to scale.

Table 3.3 lists the absolute and relative concentrations from the dual fan test. Note that the release location was in Room 1411, which is on the east side of the building, and the released material preferentially flowed to Fan 4, which was the east fan. This preferential flow resulted in a concentration at the Fan 4 Exhaust location that was essentially twice as high as during the single-fan configurations, since the effective dilution flow rate was half of the total system flow rate. While the bulk of the SF_6 was transported through Fan 4, a smaller amount (6% of the Fan 4 concentration) crossed into the Fan 3 side, either through the opening between the fan rooms or through the primary duct before entering the fan rooms. The Fan 4 vestibule and Fan Room relative concentrations were somewhat lower than expected compared with the previous, single-fan cases. However, this was attributable to the fact that the Exhaust absolute concentration was twice as high, so the relative concentrations at these locations tended to be twice as low. Note that the Fan 3 Near Door concentration in this case was approximately 5 ppb, which is

approximately the instrument detection limit, so it was listed as 0.00 in this table. The Fan 4 Near Door measurement was below the instrument detection limit, so that value is listed as 0 in the table. The data from this test is included in Appendix A as the data sheet labeled GM-5.

Table 3.3. Measurements with Both Fans, Configuration 5

Sampling Location	Mean Concentration (ppm)	Ratio to Fan 4 Exhaust
Fan 3 Exhaust	0.52	0.06
Fan 4 Exhaust	8.40	1.00
Fan 3 Vestibule	0.23	0.03
Fan 4 Vestibule – 5 feet	4.45	0.53
Fan Room near Fan 3	0.35	0.04
Fan Room near Fan 4	4.07	0.48
Fan 3 Near Door	0.00	0.00
Fan 4 Near Door	0 [a]	0 [a]
Penthouse	1.87	0.22

a. Measurements at Fan 4 Near Door for Configuration 5 were below the instrument detection limit, and is therefore report as "0."

Finally, Table 3.4 lists the absolute and relative concentrations from an added dual fan test to confirm the preferential flow based on fume hood location. In this test (GM-6), both fans were operating, but the injection was re-located to the Room 1436 fume hood, which was a more distant fume hood, and was located on the west side of the building. The measurements demonstrated that injections from the west side laboratories preferentially flow through Fan 3, with a small amount of material going through Fan 4 (9%). The Penthouse concentration was also measured during this test, but in this case, the Penthouse concentration was not at a steady-state level prior to the first measurement. Instead, the concentration began at an elevated level, but continued to increase as measurements proceeded. The final concentration was 1.25 ppm, which is 15% of the mean Fan 3 Exhaust concentration.

Table 3.4. Measurements to Confirm Two-Fan Flow Preference. SF_6 injection in Lab 1436.

Sampling Location	Mean Concentration (ppm)	Ratio to Fan 3 Exhaust
Fan 3 Exhaust	8.28	1.00
Fan 4 Exhaust	0.73	0.09
Penthouse	0.82*	0.10*

*Penthouse measurement was not steady-state: includes a concentration trend.

3.3 Transit Time Results

As part of the start of each test configuration, several measurements were made to confirm that stack concentrations were at background levels. After background level confirmation, the SF_6 gas was turned on in the lab, with one operator communicating the gas start time and the other operator at the gas analyzer. At the nearest fume hood in Room 1411, the gas was observed within one measurement cycle (approximately one minute) of the gas start. At the farther fume hood in Room 1436, the gas was observed between one and two measurement cycles (approximately one to two minutes) of the gas start. There is approximately 100 feet of duct between the nearest hood and the fan exhaust and approximately 200 feet of duct between the farthest hood and the fan exhaust; for both locations, the exhaust velocity is sufficiently high and the distance is not a significant contributor to transport time. For some of the tests (GM-4D and GM-5D), the time necessary to clear the system of SF_6 after the release was terminated was observed. In these cases, it took approximately 3 minutes for the concentrations to return to background levels.

Finally, measurements of the Penthouse indicate that it took over 15 minutes to stabilize to a steady-state concentration. Fan 5 is located in the Penthouse, which helps to draw air into the room through the cracks in the shared wall to the stack/corridor. This fan was operating continuously; however, it appeared that it takes nearly an hour for elevated Penthouse concentrations to return to background levels. Note that the investigation of transit times was not an explicit measurement made during these tests, so the times described here are meant to be guides for the approximate timeframes.

4.0 Summary

An SF_6 tracer release was performed in the LSL-II ventilation stack over the weekend of March 5, 2016. The primary purpose of this study was to experimentally determine the gaseous concentration of material from a fume hood to the fan outlet, as well as at typical worker locations, to gain an understanding of potential worker exposures. Five different fan operating configurations were utilized to ensure that the full spectrum of historical operating configurations was addressed. Some summary points from this study include:

- Relatively high concentrations were observed within the stack area.
  - Between 50 and 100% of the exhaust concentration may be observed within the stack.
- Background concentrations were observed outside the stack area.
  - Workers outside the stack itself, but on the roof, are unlikely to be impacted by the exhaust.
- Elevated concentrations on the order of 25% of the exhaust concentrations were observed within the Penthouse.
- Transport time from a laboratory fume hood to the exhaust fan is within one to two minutes.
- Penthouse concentrations climb from background levels to steady-state over 15+ minutes.
- Wind speed and wind direction did not play a significant role in the test outcomes.
  - A slight bias in the concentration distribution may be discernable based on wind speed and direction.
- When both fans are operating, material from fume hoods on the east side preferentially flows through the east fan, while material from fume hoods on the west side preferentially flows through the west fan. This effectively doubles the concentration at that fan.

This mixing study will inform other study components to develop a more complete picture of a worker's potential exposure from LSL-II rooftop activities. Estimating the mean concentration in the stack from chemical inventories and fume hood emissions for both current and historical laboratory activities is a separate effort. These estimates of mean ventilation concentrations will utilize this mixing study to estimate the potential exposure to workers working in and around the LSL-II stack.

5.0 References

Flaherty, JE and EJ Antonio. 2016. Life Sciences Laboratory 2 Fan Exhaust Mixing Study Test Plan. 98668-TP-001. Pacific Northwest National Laboratory, Richland WA 99352

Appendix A

Gas Mixing Data Sheets

Appendix A

Gas Mixing Data Sheets

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-1A**
Date	**3/5/16**	Fan Configuration	**3, Fan 4 with Blocks on 3**
Start/End Time	0947 / 1013	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	II	4	6
1	5.52	4.06	3.26
2	6.08	4.13	4.18
3	5.43	4.76	4.96
4	6.99	3.92	4.41
5	6.00	4.47	4.91
6	5.91	4.39	5.00
7	5.55	4.36	5.01
8	5.42	4.63	4.97
9	5.56	4.50	4.82
10	6.38	4.50	4.66
11	5.93	4.35	4.81
12	6.35	4.66	5.09
13	5.30	4.54	4.87

Sample No.	Sample Locations		
	II	4	6
14	5.42	4.76	4.69
15	4.93	4.07	4.56
16	5.10	4.18	4.78
17	5.21	4.51	4.63
18	5.52	4.29	4.64
19	5.46	4.29	4.17
20	5.74	4.62	4.07
21	5.71	4.12	4.25
22	5.71	4.72	4.57
23	5.08	4.45	4.53
24	5.00	4.62	4.44
25	5.87	4.49	4.51
26	5.58	3.97	4.68
Averages ---------->	5.64	4.40	4.60
Standard Deviation ---->	0.47	0.25	0.39

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	74.6	76.0	F
Ambient pressure	989.9	990.3	mbar
Ambient humidity	33%	29%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2 (4)	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3 (6)	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1 (I)	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: Background 1: -2E-3, -3E-3, -2E-3

Background 2: -6E-3, -7E-3, -6E-3

Background 3: 6E-3, 3E-3, -88E-6

Wind is 9 mph at 300A tower.

B&K sample line was connected to the pump outlet w/ a tee for excess exhaust. Low flow error if connected to the suction side (and pump pulled on sample line). Hi-W, 10 LPM.

Entries made by:	Ernest Antonio		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	*On File w/ Original*	3/5/2016	Signature/date	3/10/2016	

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-1B**
Date	**3/5/16**	Fan Configuration	**3, Fan 4 with Blocks on 3**
Start/End Time	1015 / 1046	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	II	8	1
1	4.22	5.0E-03	2.54
2	5.93	-1.1E-03	2.61
3	5.51	-3.6E-04	2.62
4	5.76	-2.1E-03	2.65
5	5.80	-1.3E-03	2.78
6	5.86	9.1E-03	2.47
7	5.53	-4.9E-03	2.57
8	6.18	-1.4E-03	2.69
9	5.56	-3.7E-03	2.60
10	5.37	-1.1E-03	3.08
11	5.78	-1.1E-03	2.61
12	5.33	-4.2E-03	2.72
13	5.16	-5.2E-03	2.63

Sample No.	Sample Locations		
	II	8	1
14	5.50	-2.8E-03	2.75
15	5.19	-2.8E-03	2.68
16	5.17	-1.2E-03	2.92
17	5.73	-2.0E-03	2.96
18	5.07	-4.1E-03	3.18
19	5.88	-5.1E-03	2.47
20	4.71	-3.5E-03	2.84
21	5.47	-3.3E-03	2.96
22	5.42	-2.8E-03	3.25
23	5.28	-5.7E-04	2.46
24	5.11	-6.1E-03	2.35
25	5.60	-3.8E-03	2.46
26	5.50	-7.1E-04	2.49
Averages ---------->	5.45	-1.97E-03	2.71
Standard Deviation ---->	0.41	3.15E-03	0.23

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	76.0	75.9	F
Ambient pressure	990.3	990.3	mbar
Ambient humidity	29%	31%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #8 Fan 4 near door = Red Tape

#1 Fan 3 discharge = Black Tape

At start of this run we had an "air flow too low" message on #3 B&K (Sample Location 1)

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-1C**
Date	**3/5/16**	Fan Configuration	**3, Fan 4 with Blocks on 3**
Start/End Time	1046 / 1110	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	II	3	5
1	6.10	4.23	5.03
2	5.46	4.26	4.97
3	5.30	4.43	4.81
4	5.96	3.54	4.85
5	6.37	3.96	4.87
6	5.74	4.42	5.04
7	4.96	4.64	4.94
8	5.17	4.51	4.98
9	5.67	4.20	4.87
10	5.71	4.48	4.66
11	5.25	3.88	4.83
12	6.00	3.53	4.82
13	5.01	3.53	4.68

Sample No.	Sample Locations		
	II	3	5
14	5.50	4.15	4.59
15	6.01	3.43	4.99
16	5.61	4.34	4.96
17	5.30	4.05	4.42
18	5.97	3.55	4.86
19	5.59	3.37	4.55
20	5.83	3.75	4.75
21	5.83	3.96	4.98
22	5.43	4.27	5.00
23	5.51	3.05	4.29
24	5.95	3.05	4.53
25	5.05	3.17	4.38
26	5.02	3.81	4.65
Averages ---------->	5.59	3.91	4.78
Standard Deviation ---->	0.38	0.47	0.21

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	75.9	72.7	F
Ambient pressure	990.3	989.6	mbar
Ambient humidity	31%	37%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #3 Fan 3 Vestibule = Green Tape

#5 Fan 3 Fan Room = White Tape

Air flow too low error message on #3 - recurring

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-1D**
Date	**3/5/16**	Fan Configuration	**3, Fan 4 with Blocks on 3**
Start/End Time	1110 / 1140	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	II	9	2
1	5.70	1.34	4.26
2	5.90	1.28	4.45
3	5.54	1.06	4.16
4	5.32	1.34	4.08
5	5.64	1.33	4.41
6	5.87	1.27	4.61
7	5.33	1.20	4.45
8	5.78	1.42	4.40
9	5.24	1.27	4.22
10	5.45	1.32	4.41
11	5.59	1.13	4.59
12	5.81	1.16	4.08
13	6.06	1.12	4.42

Sample No.	Sample Locations		
	II	9	2
14	5.57	1.28	4.35
15	5.59	1.29	4.35
16	5.40	1.51	4.34
17	5.45	1.24	4.45
18	5.49	1.21	4.23
19	5.60	1.21	4.31
20	5.78	1.33	4.22
21	5.48	1.35	4.08
22	5.12	1.36	4.56
23	4.93	1.30	4.42
24	5.38	1.43	4.58
25	5.32	1.32	4.38
26	6.06	1.42	4.24
Averages ---------->	5.55	1.29	4.35
Standard Deviation ---->	0.27	0.10	0.15

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	72.7	75.8	F
Ambient pressure	989.6	989.3	mbar
Ambient humidity	36.7%	34.7%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #9 Penthouse = Yellow Tape

#2 Fan 4 Exhaust Discharge Area = Blue Tape

Dropping to background after shutting off SF6:

B&K #1 257 62 49 35 24 22 26 26 ppb

B&K #2 943 816 679 622 572 507 ppb

B&K #3 109 66 48 38 34 30 84 ppb

Entries made by:	Ernest Antonio		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	*On File w/ Original*	3/5/2016	Signature/date	3/10/2016	

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-2A**
Date	**3/5/16**	Fan Configuration	**1, Fan 3, Blocks on 4**
Start/End Time	1400 / 1435	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	I	4a	4b
1	4.48	2.28	3.30
2	4.41	2.63	2.69
3	4.50	2.92	3.31
4	4.64	2.19	3.37
5	4.54	2.31	2.43
6	4.43	2.18	2.46
7	4.69	2.97	3.00
8	4.35	2.78	2.68
9	4.40	2.34	3.00
10	4.33	2.60	3.06
11	4.47	2.78	3.01
12	4.23	3.36	3.10
13	3.98	2.17	3.84

Sample No.	Sample Locations		
	I	4a	4b
14	4.11	2.07	2.63
15	4.54	3.33	2.66
16	4.18	1.90	3.20
17	4.41	3.08	2.61
18	4.44	3.32	2.54
19	4.55	2.55	2.92
20	4.37	2.14	2.63
21	4.26	1.98	3.09
22	4.72	2.36	2.86
23	4.54	2.93	3.84
24	4.33	2.40	2.74
25	4.41	2.30	3.38
26	4.17	2.08	2.99
Averages ---------->	4.40	2.54	2.97
Standard Deviation ---->	0.18	0.44	0.38

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	72.0	76.0	F
Ambient pressure	986.7	986.4	mbar
Ambient humidity	40%	33%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #4a Fan 4 Vestibule @ 5 ft = Orange Tape

#4b Fan 4 Vestibule @ 1 ft = Brown Tape

Bkg at start-up:	7.7E-3, 2.7E-3, 3.4E-3, 578E-6	B+K 1
	-2.4E-3, 3.0E-3, -2.8E-3, 953E-6	B+K 2
	8.5D-3, 5.0E-3, 8.7E-3, 8.45E-3	B+K 3

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-2B**
Date	**3/5/16**	Fan Configuration	**1, Fan 3, Blocks on 4**
Start/End Time	1438 / 1502	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	I	6	2
1	4.33	2.70	3.40
2	4.74	2.70	4.02
3	4.40	2.29	3.00
4	4.19	2.64	3.90
5	4.26	2.50	3.35
6	4.44	2.65	3.47
7	4.47	2.59	2.83
8	4.36	2.65	3.01
9	4.63	2.61	3.31
10	4.61	2.60	2.99
11	4.41	2.16	3.19
12	4.38	2.73	3.34
13	4.90	2.66	3.05

Sample No.	Sample Locations		
	I	6	2
14	4.30	2.69	3.35
15	4.48	2.74	3.39
16	4.26	2.73	3.46
17	5.02	2.86	2.52
18	4.37	3.18	3.26
19	4.52	2.59	3.21
20	4.39	2.91	3.03
21	4.30	2.80	3.17
22	4.66	2.57	3.41
23	4.15	2.61	3.41
24	4.55	2.65	3.56
25	4.69	2.84	3.76
26	4.80	2.60	3.81
Averages ---------->	4.49	2.66	3.32
Standard Deviation ---->	0.22	0.19	0.33

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	76	76	F
Ambient pressure	986.4	986.1	mbar
Ambient humidity	33%	32%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #6 Fan 4 Fan Room = Purple Tape

#2 Fan 4 Discharge = Blue Tape

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-2C**
Date	**3/5/16**	Fan Configuration	**1, Fan 3, Blocks on 4**
Start/End Time	1506 / 1531	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	I	7	3
1	4.46	0.103	3.82
2	4.75	0.177	3.79
3	4.40	0.148	3.78
4	4.47	0.309	3.57
5	4.09	0.303	3.81
6	4.64	0.035	3.84
7	4.54	0.070	3.62
8	4.47	0.323	3.83
9	4.40	0.002	3.69
10	4.62	0.146	3.98
11	4.53	0.015	3.76
12	4.74	0.003	3.96
13	4.77	0.060	3.81

Sample No.	Sample Locations		
	I	7	3
14	4.28	0.04	3.75
15	4.33	0.01	3.73
16	4.59	0.03	3.70
17	4.32	0.04	3.65
18	4.69	0.04	3.72
19	4.56	0.01	3.80
20	4.63	-0.01	3.72
21	4.85	0.00	3.86
22	4.34	0.01	3.68
23	4.44	0.00	3.56
24	4.16	0.03	3.67
25	4.50	0.05	3.50
26	3.72	0.06	3.61
Averages ---------->	4.47	0.08	3.74
Standard Deviation ---->	0.24	0.10	0.12

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	76.0	74.0	F
Ambient pressure	986.1	986.2	mbar
Ambient humidity	32%	37%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #7 Fan 3 Near Door = Orange + Green Tape

#3 Fan 3 Vestibule = Green Tape

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-2D**
Date	**3/5/16**	Fan Configuration	**1, Fan 3, Blocks on 4**
Start/End Time	1532 / 1606	Fan Setting	**60** **Hz**
Testers	JEF, EA, JAG	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	I	5	9
1	3.88	3.14	1.16
2	4.13	3.11	1.04
3	4.43	3.31	1.12
4	4.18	3.23	1.02
5	4.13	3.23	1.09
6	4.90	3.51	1.11
7	4.47	3.74	1.11
8	4.49	3.72	1.16
9	4.44	3.79	1.15
10	4.59	3.85	1.12
11	4.17	3.70	1.12
12	4.62	3.58	1.13
13	4.49	3.62	1.22

Sample No.	Sample Locations		
	I	5	9
14	4.33	3.70	1.05
15	4.29	3.61	1.04
16	4.48	3.59	1.05
17	4.71	3.74	1.03
18	4.42	3.59	1.04
19	4.29	3.55	1.08
20	4.34	3.62	0.99
21	4.60	3.66	1.03
22	4.34	3.72	1.02
23	4.17	3.76	0.96
24	4.57	3.60	0.96
25	4.28	3.62	0.97
26	4.38	3.68	1.02
Averages ---------->	4.39	3.58	1.07
Standard Deviation ---->	0.21	0.20	0.07

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	74.0	73.3	F
Ambient pressure	986.2	985.0	mbar
Ambient humidity	37%	39%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #5 Fan 3 Fan Room = White Tape
#9 Penthouse = Yellow Tape

Gas off at 1559h	1.13, 0.0966, 0.0594, 0.0372, 0.0226	B&K 1
	3.06, 1.69, 0.536, 0.173, 0.0705	B&K 2
	1.15, 0.918, 0.967, 0.896, 1.06	B&K 3

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-3A**
Date	**3/5/16**	Fan Configuration	**2, Fan 3, No Blocks**
Start/End Time	1715 / 1747	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	I	4a	6
1	4.65	3.14	2.64
2	3.65	3.28	3.06
3	4.62	3.50	3.04
4	5.06	3.04	2.92
5	3.57	3.13	3.27
6	3.71	2.74	2.87
7	5.52	3.04	2.96
8	4.55	3.12	2.67
9	5.00	2.87	2.78
10	4.36	3.12	2.95
11	4.10	3.35	3.19
12	4.23	3.32	3.20
13	4.76	2.90	2.87

Sample No.	Sample Locations		
	I	4a	6
14	4.43	3.22	2.93
15	5.62	3.29	3.22
16	4.67	2.99	2.90
17	4.12	3.11	2.78
18	3.95	3.17	2.95
19	5.00	3.20	2.95
20	4.90	3.16	2.88
21	5.15	2.96	2.71
22	3.66	3.08	2.94
23	4.67	2.93	2.88
24	4.21	3.19	2.91
25	4.85	3.05	2.88
26	3.34	3.11	3.00
Averages ---------->	4.48	3.12	2.94
Standard Deviation ---->	0.60	0.16	0.16

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	71.7	76.2	F
Ambient pressure	983.3	982.5	mbar
Ambient humidity	43%	34%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #4a Fan 4 Vestibule @ 5 ft = Orange Tape

#6 Fan 4 Fan Room = Purple Tape

Background Values: B&K 1 3.9, 3.3, -2.2 ppb

B&K 2 1.6, -1.1, -4.5 ppb

B&K 3 10.5, 5.4, -0.7 ppb

"Pump Test Failed" msg on B&K 3…

Gas on at 1720h.

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-3B**
Date	**3/5/16**	Fan Configuration	**2, Fan 3, No Blocks**
Start/End Time	1747 / 1814	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	1	2	7
1	4.63	2.75	0.48
2	4.25	2.25	0.14
3	3.94	2.36	0.39
4	3.54	3.09	0.09
5	4.00	2.42	0.05
6	4.44	2.58	0.28
7	4.44	2.58	0.18
8	3.58	3.19	0.17
9	4.45	2.54	0.13
10	5.45	2.30	0.06
11	4.08	2.37	0.09
12	3.83	3.19	0.04
13	4.86	2.67	0.07

Sample No.	Sample Locations		
	1	2	7
14	4.78	2.98	0.07
15	4.49	3.07	0.09
16	4.44	2.05	0.17
17	3.50	2.79	0.04
18	3.93	2.25	0.05
19	3.81	2.82	0.24
20	4.29	2.96	0.12
21	4.85	2.75	0.12
22	4.34	3.31	0.05
23	5.04	2.47	0.07
24	4.25	2.47	0.10
25	3.93	2.45	0.03
26	3.47	2.17	0.13
Averages ---------->	4.25	2.65	0.13
Standard Deviation ---->	0.50	0.35	0.11

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	76.2	75.0	F
Ambient pressure	982.5	982.4	mbar
Ambient humidity	34%	38%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #2 Fan 4 Discharge = Blue Tape

#7 Fan 3 Near Door = Orange + Green Tape

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-3C**
Date	**3/5/16**	Fan Configuration	**2, Fan 3, No Blocks**
Start/End Time	1816 / 1841	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	I	3	5
1	3.96	3.95	4.12
2	3.62	3.57	4.00
3	3.56	4.03	4.31
4	3.11	3.74	4.52
5	4.27	4.50	4.48
6	3.62	3.56	4.23
7	4.24	4.03	4.43
8	4.15	3.79	4.44
9	4.56	4.11	4.73
10	4.47	4.05	4.45
11	3.52	3.81	4.38
12	5.11	4.00	4.57
13	3.92	3.55	4.38

Sample No.	Sample Locations		
	I	3	5
14	3.96	3.80	4.61
15	4.25	3.83	4.55
16	4.18	3.72	4.45
17	3.82	4.42	4.54
18	4.73	3.64	4.12
19	3.83	3.72	4.36
20	3.67	3.83	4.34
21	4.49	4.07	4.28
22	3.97	4.20	4.36
23	3.41	4.23	4.35
24	3.76	4.19	4.23
25	4.65	3.93	4.28
26	4.53	3.44	3.74
Averages ---------->	4.05	3.91	4.36
Standard Deviation ---->	0.47	0.27	0.21

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	75.0	76.3	F
Ambient pressure	982.4	982.0	mbar
Ambient humidity	38%	38%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #3 Fan 3 Vestibule = Green Tape

#5 Fan 3 Fan Rooom = White Tape

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/5/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-3D**
Date	**3/5/16**	Fan Configuration	**2, Fan 3, No Blocks**
Start/End Time	1844 / 1927	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	I	9	1
1	3.66	1.18	4.47
2	3.39	1.40	4.46
3	3.86	1.05	4.66
4	4.29	1.08	4.48
5	4.20	1.47	4.31
6	4.64	1.13	4.75
7	4.28	1.20	4.28
8	3.94	1.02	4.37
9	4.71	1.01	4.49
10	4.68	1.17	4.36
11	4.07	1.09	4.87
12	4.29	1.20	4.55
13	3.77	1.40	4.96

Sample No.	Sample Locations		
	I	9	1
14	4.26	1.34	4.12
15	4.46	0.98	4.37
16	4.48	1.02	4.49
17	4.78	1.35	4.41
18	4.05	0.88	4.58
19	4.49	1.00	4.47
20	5.01	1.18	4.58
21	4.00	1.18	4.58
22	4.06	1.44	4.89
23	3.62	0.97	4.32
24	4.75	1.31	4.17
25	3.67	1.14	4.31
26	5.00	1.15	4.37
Averages ---------->	4.25	1.17	4.49
Standard Deviation ---->	0.44	0.16	0.21

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	76.3	75.0	F
Ambient pressure	982.0	980.2	mbar
Ambient humidity	38%	38%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: # 9 Penthouse = Yellow Tape

#1 Fan 3 Discharge = Black Tape

Turn off gas at 1922 Back to background:

B&K 1: 4.86, 1.12, 0.0678, 0.0258, 0.0124 ppm

B&K 2: 1.25, 1.07, 0.844, 0.840, 0.802 ppm

B&K 3: 4.70, 0.270, 0.0408, 0.0190, 0.0142 ppm

(First 4 measurements redone due to incorrect atmospheric pressure on B&K#1)

w3

Entries made by:	Ernest Antonio		Technical Data Review performed by:	Carmen Arimescu	
Signature/date	*On File w/ Original*	3/5/2016	Signature/date	3/10/2016	

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-4A**
Date	**3/6/16**	Fan Configuration	**5, Both Fans, No Plugs**
Start/End Time	0800 / 0833	Fan Setting	**47** **Hz**
Testers	JEF, EA	Stack Flow	48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	II	4a	6
1	8.62	4.21	3.82
2	8.29	4.53	4.03
3	8.92	4.79	4.47
4	8.21	4.21	4.57
5	8.31	3.26	4.28
6	8.43	4.25	3.45
7	7.90	3.34	3.93
8	8.11	3.38	3.03
9	8.39	4.48	3.35
10	8.05	5.88	3.28
11	8.36	4.21	3.91
12	8.23	5.23	4.59
13	9.62	4.67	4.76

Sample No.	Sample Locations		
	II	4a	6
14	7.90	4.86	4.46
15	8.16	4.32	4.01
16	8.01	3.13	3.87
17	7.92	3.13	3.64
18	8.49	3.21	2.93
19	8.25	5.12	3.97
20	8.16	5.55	3.98
21	8.04	6.65	5.21
22	8.71	5.85	5.45
23	8.07	4.53	3.95
24	8.33	3.99	4.38
25	8.27	3.77	3.95
26	9.37	5.04	4.51
Averages ---------->	8.35	4.45	4.07
Standard Deviation ---->	0.42	0.93	0.60

	Start	Finish	
Stack flow	48000	48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	76.0	77.0	F
Ambient pressure	985.3	985.7	mbar
Ambient humidity	25%	23%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: II Fan 4 = Red + Blue Tape
#4 Fan Vestibule @ 5 ft = Orange Tape
#6 Fan Room near Fan 4 = Purple Tape

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-4B**
Date	**3/6/16**	Fan Configuration	**5, Both Fans, No Plugs**
Start/End Time	0834 / 0902	Fan Setting	**47** **Hz**
Testers	JEF, EA	Stack Flow	48000 **cfm**
Concentration units	ppm, ppb @ 8 & 7	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	II	8	7
1	8.74	24.8	13.8
2	8.28	10.4	4.29
3	8.07	28.4	4.63
4	8.99	3.89	5.51
5	8.19	63.5	4.55
6	8.50	19.7	4.60
7	8.12	16.3	3.67
8	8.47	79.3	4.60
9	8.45	-680	4.88
10	8.56	8.58	1.93
11	8.21	9.87	7.35
12	8.49	16.4	4.60
13	7.51	-2.50	3.52

Sample No.	Sample Locations		
	II	8	7
14	8.17	-1.6	3.22
15	8.41	1.22	3.90
16	8.85	3.70	4.49
17	8.06	10.6	4.45
18	7.79	6.48	2.89
19	8.50	75.5	3.01
20	8.52	6.59	2.51
21	8.43	22.3	6.12
22	8.79	17.4	3.94
23	8.99	17.8	9.86
24	8.59	28.3	5.30
25	8.57	126	5.98
26	8.88	16.5	2.45
Averages ---------->	8.43	-2.71	4.85
Standard Deviation ---->	0.35	141.30	2.45

	Start	Finish	
Stack flow	48000	48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	77.0	77.8	F
Ambient pressure	985.7	986.8	mbar
Ambient humidity	23%	22%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #8 Fan 4 Near Door = Red Tape

#7 Fan 3 Near Door = Orange + Green Tape

Injection in Lab 1411 preferentially flows through Fan 4.

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-4C**
Date	**3/6/16**	Fan Configuration	**5, Both Fans, No Plugs**
Start/End Time	0903 / 0927	Fan Setting	**47** **Hz**
Testers	JEF, EA	Stack Flow	48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations II	3	5
1	8.56	0.142	0.294
2	8.09	0.253	0.400
3	8.99	0.212	0.362
4	8.16	0.300	0.321
5	8.67	0.129	0.317
6	8.06	0.204	0.396
7	8.41	0.358	0.452
8	8.55	0.203	0.325
9	8.27	0.297	0.349
10	8.89	0.214	0.323
11	8.71	0.274	0.410
12	8.54	0.186	0.252
13	8.31	0.133	0.291

Sample No.	Sample Locations II	3	5
14	8.53	0.126	0.349
15	8.74	0.318	0.370
16	8.64	0.317	0.365
17	8.13	0.251	0.352
18	7.74	0.242	0.387
19	8.90	0.354	0.438
20	8.45	0.146	0.303
21	8.97	0.256	0.416
22	8.62	0.218	0.297
23	8.99	0.240	0.429
24	7.77	0.206	0.347
25	8.56	0.233	0.338
26	8.33	0.0863	0.283
Averages ---------->	8.48	0.23	0.35
Standard Deviation ---->	0.35	0.07	0.05

	Start	Finish	
Stack flow	48000	48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	77.8	77.0	F
Ambient pressure	986.8	987.3	mbar
Ambient humidity	22%	23%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #3 Fan 3 Vestibule = Green Tape

#5 Fan 3 Fan Room = White Tape

Injection in Lab 1411 preferentially flows through Fan 4.

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-4D**
Date	**3/6/16**	Fan Configuration	**5, Both Fans, No Plugs**
Start/End Time	0929 / 1002	Fan Setting	**47** **Hz**
Testers	JEF, EA	Stack Flow	48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations II	9	I
1	7.82	1.91	0.593
2	8.28	1.80	0.473
3	8.45	1.98	0.598
4	8.31	2.02	0.430
5	8.18	1.79	0.762
6	8.10	1.73	0.521
7	8.59	1.77	0.576
8	8.47	2.06	0.485
9	8.01	1.77	0.515
10	8.97	1.77	0.414
11	8.89	1.42	0.460
12	8.32	1.89	0.397
13	8.49	1.84	0.620

Sample No.	Sample Locations II	9	I
14	8.48	1.84	0.573
15	8.30	1.98	0.778
16	8.58	1.80	0.423
17	8.02	2.03	0.500
18	8.02	2.05	0.603
19	8.23	1.88	0.457
20	8.29	2.08	0.594
21	8.76	2.05	0.407
22	8.61	1.71	0.510
23	8.68	1.89	0.477
24	8.15	1.87	0.479
25	8.02	1.89	0.531
26	7.97	1.87	0.404
Averages ---------->	8.35	1.87	0.52
Standard Deviation ---->	0.30	0.14	0.10

	Start	Finish	
Stack flow	48000	48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	77.0	78.7	F
Ambient pressure	987.3	987.6	mbar
Ambient humidity	22.5%	21.3%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #9 Penthouse = Yellow Tape

I Fan 3 = Yellow + Purple Tape

Turn off gas at 0955

B&K 1 8.18, .282, 0.042, 0.0199, 0.0138, 0.00871 ppm

B&K 2 1.92, 1.91, 1.81, 1.31, 1.39, 0.995, 0.754 ppm

B&K 3 0.605, 0.0810, 0.0137, 0.00784, 0.00635, 0.00725 ppm

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-5A**
Date	**3/6/16**	Fan Configuration	**4, Fan 4, No Blocks**
Start/End Time	1015 / 1045	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations		
	II	4a	6
1	4.31	4.41	3.44
2	5.30	4.66	4.34
3	4.52	5.15	4.79
4	5.41	4.32	4.22
5	4.82	4.58	3.88
6	4.54	4.86	4.19
7	4.91	4.84	4.71
8	5.58	4.84	4.65
9	5.18	4.68	4.38
10	4.36	4.79	4.38
11	4.52	4.74	4.53
12	5.61	4.51	4.49
13	4.69	4.10	3.64

Sample No.	Sample Locations		
	II	4a	6
14	5.50	4.35	3.47
15	4.97	4.64	3.94
16	3.53	4.59	4.38
17	4.37	4.89	4.45
18	4.96	4.73	4.49
19	4.91	5.24	4.79
20	4.19	4.74	4.70
21	4.02	4.43	4.19
22	5.00	4.12	3.87
23	3.39	4.47	3.83
24	5.31	3.77	4.09
25	4.24	4.09	3.44
26	5.24	4.34	3.70
Averages ---------->	4.75	4.57	4.19
Standard Deviation ---->	0.59	0.33	0.43

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	72.8	81.0	F
Ambient pressure	987.9	988.0	mbar
Ambient humidity	26%	20%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #4a Fan 4 Vestibule @ 5 ft = Orange Tape

#6 Fan 4 Fan Room = Purple Tape

Background values:

B&K 1: .902, 6.29, 6.19, 0.934, 3.00, 4.17 ppb

B&K 2: .682, -.223, .589, 1.37, -2.8, 3.20 ppb

B&K 3: 15.4, 12.6, 13.0, 2.80, 10.1, 1.07 ppb

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-5B**
Date	**3/6/16**	Fan Configuration	**4, Fan 4, No Blocks**
Start/End Time	1048/1113	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations II	8	1
1	5.10	0.0303	1.99
2	5.30	0.0332	2.36
3	4.28	0.0538	2.79
4	4.95	0.0034	2.16
5	3.98	0.0016	2.59
6	4.53	0.0103	2.75
7	4.52	-0.0043	2.53
8	4.83	-0.0027	3.01
9	3.95	-0.0030	2.79
10	4.84	0.0124	2.56
11	6.10	-0.0008	2.33
12	4.99	0.0057	2.27
13	5.75	0.0082	2.68

Sample No.	Sample Locations II	8	1
14	4.83	0.00358	2.26
15	5.55	0.00210	2.85
16	4.91	-0.00480	2.42
17	4.76	0.0170	2.36
18	5.73	0.00007	2.39
19	4.43	0.09930	2.21
20	4.37	0.02330	2.56
21	4.31	0.00996	2.49
22	4.89	0.02320	2.09
23	4.96	0.00405	2.48
24	6.43	0.10800	2.16
25	4.84	0.00203	2.60
26	5.55	-0.00240	2.48
Averages ---------->	4.95	0.02	2.47
Standard Deviation ---->	0.62	0.03	0.25

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	76.0	77.0	F
Ambient pressure	988.1	988.1	mbar
Ambient humidity	23.5%	24.0%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #8 Fan 4 near door = Red Tape

#1 Fan 3 discharge = Black Tape

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-5C**
Date	**3/6/16**	Fan Configuration	**4, Fan 4, No Blocks**
Start/End Time	1114 / 1139	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations II	3	5
1	4.31	1.84	2.34
2	5.18	1.47	1.94
3	5.43	1.15	1.84
4	4.85	2.14	1.83
5	5.26	1.90	2.11
6	6.07	1.49	2.27
7	4.00	1.57	2.08
8	4.93	2.26	2.26
9	4.42	1.66	2.21
10	4.38	1.62	2.19
11	6.18	1.33	1.88
12	4.69	1.91	2.13
13	6.23	1.63	2.18

Sample No.	Sample Locations II	3	5
14	4.23	1.53	2.16
15	4.89	1.30	2.32
16	5.23	1.35	2.06
17	4.57	1.61	2.26
18	5.46	1.30	2.00
19	4.61	1.86	2.04
20	5.18	2.18	2.26
21	3.92	2.28	2.32
22	4.94	2.12	2.43
23	4.19	1.65	2.26
24	5.13	1.75	2.34
25	5.41	1.63	1.92
26	5.52	1.38	2.07
Averages ---------->	4.97	1.69	2.14
Standard Deviation ---->	0.64	0.32	0.17

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	77	75	F
Ambient pressure	988.1	988.2	mbar
Ambient humidity	24.0%	25.0%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #3 Fan 3 Vestibule = Green Tape

#5 Fan 3 Fan Room = White Tape

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-5D**
Date	**3/6/16**	Fan Configuration	**4, Fan 4, No Blocks**
Start/End Time	1140 / 1213	Fan Setting	**60** **Hz**
Testers	JEF, EA	Stack Flow	~48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations II	9	2
1	5.61	0.993	4.22
2	5.57	1.00	4.17
3	5.88	0.942	4.59
4	5.55	0.996	4.33
5	5.81	0.980	4.11
6	5.28	0.856	4.10
7	4.13	0.982	4.17
8	5.48	1.00	4.26
9	4.28	0.919	4.36
10	4.66	0.958	4.37
11	4.69	1.19	4.13
12	4.08	0.815	4.06
13	5.40	0.985	4.03

Sample No.	Sample Locations II	9	2
14	5.38	1.03	4.52
15	4.98	0.964	4.09
16	5.06	1.02	4.24
17	4.20	0.971	4.04
18	4.36	0.884	4.27
19	4.21	0.912	4.03
20	4.43	0.904	4.32
21	4.48	0.907	4.34
22	4.87	0.896	3.64
23	5.44	0.941	4.21
24	5.11	0.969	4.38
25	4.38	0.846	4.45
26	5.47	1.02	4.23
Averages ---------->	4.95	0.96	4.22
Standard Deviation ---->	0.58	0.07	0.19

	Start	Finish	
Stack flow	~48000	~48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	75.0	73.0	F
Ambient pressure	988.2	988.2	mbar
Ambient humidity	25.0%	26.2%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: #9 Penthouse = Yellow Tape

#2 Fan 4 Exhaust Discharge Area = Blue Tape

Gas off at 1208

B&K 1 4.99, 0.350, 0.0330, 0.141, 0.00977

B&K 2 0.973, 1.01, 0.917, 0.743, 0.792

B&K 3 3.84, 0.108, 0.0307, 0.0154, 0.0180

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-6**
Date	**3/6/16**	Fan Configuration	**Both Fans, No Blocks**
Start/End Time	1250 / 1325	Fan Setting	**46** **Hz**
Testers	JEF, EA	Stack Flow	48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations II	9	I
1	0.879	0.248	8.44
2	0.718	0.137	8.07
3	0.665	0.262	8.23
4	0.648	0.191	8.16
5	0.682	0.275	8.12
6	0.658	0.413	8.45
7	0.717	0.709	8.30
8	0.831	0.654	8.26
9	0.767	0.781	8.40
10	0.753	0.710	8.31
11	0.751	0.831	8.25
12	0.646	0.923	8.24
13	0.721	0.979	8.33

Sample No.	Sample Locations II	9	I
14	0.787	1.29	8.25
15	0.768	1.03	8.23
16	0.596	0.939	8.35
17	0.723	1.06	8.14
18	0.755	1.06	8.15
19	0.640	0.991	8.29
20	0.672	0.988	8.34
21	0.760	1.13	8.26
22	0.702	1.07	8.45
23	0.716	1.07	8.05
24	0.805	1.19	8.33
25	0.767	1.24	8.35
26	0.778	1.25	8.49
Averages ---------->	0.73	0.82	8.28
Standard Deviation ---->	0.07	0.36	0.12

	Start	Finish	
Stack flow	48000	48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	73.5	75.0	F
Ambient pressure	988.4	987.7	mbar
Ambient humidity	24.6%	22.7%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: II Fan 4 Exhaust

9 Penthouse

I Fan 3 Exhaust

Test Objectives: 1) Observe Transport time from distant fume hood (injection in Lab 1436)

2) Observe Preferential flow from fume hood on Fan 3 side to Fan 3 Exhaust

Background: B&K 1: 7.73, 5.70, 0.246, 0.981, 4.55, -.265, 3.57, 0.018, 1.89, .696 ppb

2: 27.4, 20.5, 15.8, 13.9, 19.6, 11.7, 9.41, 16.0, 17.1, 14.4 ppb

3: 9.04, 8.15, 8.40, 2.90, 4.44, 5.44, 5.57, 6.48, 3.61, 8.35 ppb

Time to "hit" fan exhaust: 2 measurement cycles.

Penthouse has somewhat elevated SF6 concentrations at the start of this test, and it took about 15 minutes (a few measurements, then Sample No. 1-13) to stabilize after gas was turned on.

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	*On File w/ Original* 3/6/2016	Signature/date	3/10/2016

GAS MIXING DATA FORM

Site	**PNNL LSL2**	Run No.	**GM-7**
Date	**3/6/16**	Fan Configuration	**Both Fans, No Blocks**
Start/End Time	1335 / 1354	Fan Setting	**46** **Hz**
Testers	JEF, EA	Stack Flow	48000 **cfm**
Concentration units	ppm	Stack Static Pressure	4.3 **in wc**

Sample No.	Sample Locations I (1)	I (2)	I (3)
1	8.57	8.06	8.25
2	8.54	7.99	8.03
3	8.45	7.91	8.15
4	8.31	8.00	7.92
5	8.34	7.91	8.14
6	8.62	8.01	8.30
7	8.28	7.85	7.98
8	8.29	7.68	7.94
9	8.70	8.00	8.51
10	8.30	7.85	7.96
11	8.30	7.93	8.00
12	8.34	8.00	8.05
13	8.34	7.65	7.96
Averages ---------->	8.41	7.91	8.09
Standard Deviation ---->	0.14	0.13	0.17

Sample No.	Sample Locations I (1)	I (2)	I (3)
14	8.42	7.75	7.96
15	0.216	1.43	0.188
16	0.0282	0.0533	0.0241
17	0.0282	0.0103	0.0102
18	0.00967	-0.394	0.0115
19			
20			
21			
22			
23			
24			
25			
26			
Averages ---------->	6.56	6.20	6.30
Standard Deviation ---->	3.57	3.28	3.44

	Start	Finish	
Stack flow	48000	48000	cfm
Stack Static Pressure	4.3	4.3	in wc
Ambient temp	75.5	79.1	F
Ambient pressure	987.8	987.5	mbar
Ambient humidity	22%	19%	RH
Mass Flow Rate	6	6	LPM

Instuments Used:		**Cal Due**
B&K 1302 Gas Analyzer	SN 1804888 - 2	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1765299 - 3	Cat2 M&TE
B&K 1302 Gas Analyzer	SN 1788615 - 1	Cat2 M&TE
Control Co. Dew Point Pen, SN 122277883		2/11/2017
Alicat Mass Flow Controller, SN 53382		FIO

Notes: Sample Fan 3 Exhaust (Location I) through all three Hi-Q pumps (using a cross) to observe whether there are any "issues" with our sampling set-up…

1348 turned gas off (during Sample No 14)

stopped measurements after concentrations returned to background (~2-3 samples)

Entries made by:	Ernest Antonio		
Signature/date	*On File w/ Original*	3/6/2016	
Technical Data Review performed by:	Carmen Arimescu		
Signature/date	3/10/2016		

Appendix B

Calibration Check Data Sheets

Appendix B

Calibration Check Data Sheets

SULFUR HEXAFLUORIDE GAS INSTRUMENT CALIBRATION

Site	Q AVEPAD	Instrument	B&K Model 1302
Date/Time	3/4/16 1005h	Serial No.	1788615
Testers	EA	Property No.	WD54624

Setup:
- 6.3 ft — B&K sample inlet tube length
- 1001 mbar station pressure
- 65.3 deg F ambient temp — analyzer corrects to 20 deg C
- 37.3 percent RH ambient humidity

Pre-Test background, ppb
Not compensating for water vapor, monitoring task 2
NA
Compensating for water vapor, monitoring task 1
9.99, 6.03, 5.44, 7.08, 6.97, 7.60, 3.73, 8.57, 4.04, 1.57

	0.105	ppm		5.0	ppm
Cylinder	CLM09744		Cylinder	CLM003104	
start P =	1910	psi	start P =	2000	psi
end P =	1910	psi	end P =	2000	psi

Calibration readings: (ppm) **Compensating for water vapor**	**Calibration readings: (ppm)** **Compensating for water vapor**
0.110	5.05
0.108	5.09
0.108	5.07
0.106	5.07
0.107	5.07
0.108	5.06
0.106	5.06
0.106	5.07
0.106	5.06
0.106	5.05
0.11 = avg	**5.07** = avg
1.020 = avg/standard	**1.013** = avg/standard

Standards Used:	Expiration date:
0.105 ppm SF_6, cylinder CLM09744	2/4/2019
5.0 ppm SF_6, cylinder CLM003104	1/28/2019
Weather Station Used:	
Control Co. Dew Point Pen, SN 122277883, Barcode: 39432	2/11/2017

Entries made by:	E. Antonio	Technical Data Review performed by:	Carmen Arimscu
Signature/date	Signature on file with original 3/4/2016	Signature/date	4/7/2016

SULFUR HEXAFLUORIDE GAS INSTRUMENT CALIBRATION

Site	Q AVEPAD	Instrument	B&K Model 1302
Date/Time	3/4/16 0912	Serial No.	1804888
Testers	EA	Property No.	WD54623

Setup:	6.3 ft	B&K sample inlet tube length
	1001 mbar	station pressure
	64.9 deg F	ambient temp analyzer corrects to 20 deg C
	37 percent	RH ambient humidity

Pre-Test background, ppb
Not compensating for water vapor, monitoring task 2
NA
Compensating for water vapor, monitoring task 1
11.3, 13.6, 12.1, 11.5, 4.25, 7.56, 10.1, 5.62, 9.37, 8.00

	0.105	ppm		5.0	ppm
Cylinder	CLM09744		Cylinder	CLM003104	
start P =	1910	psi	start P =	2000	psi
end P =	1910	psi	end P =	2000	psi

Calibration readings: (ppm)		**Calibration readings: (ppm)**	
Compensating for water vapor		**Compensating for water vapor**	
0.111		4.83	
0.107		4.83	
0.108		4.81	
0.107		4.83	
0.107		4.82	
0.107		4.82	
0.105		4.82	
0.106		4.80	
0.104		4.82	
0.109		4.81	
0.11	= avg	**4.82**	= avg
1.020	= avg/standard	**0.964**	= avg/standard

Standards Used:	Expiration date:
0.105 ppm SF_6, cylinder CLM09744	2/4/2019
5.0 ppm SF_6, cylinder CLM003104	1/28/2019
Weather Station Used:	
Control Co. Dew Point Pen, SN 122277883, Barcode: 39432	2/11/2017

Entries made by:	E. Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	Signature on file with original 3/4/2016	Signature/date	4/7/2016

SULFUR HEXAFLUORIDE GAS INSTRUMENT CALIBRATION

Site	Q AVEPAD	Instrument	B&K Model 1302
Date/Time	3/4/16 0806	Serial No.	1765299
Testers	EA	Property No.	WD17210

Setup:	6.3 ft	B&K sample inlet tube length
	1001 mbar	station pressure
	63 deg F	ambient temp analyzer corrects to 20 deg C
	31 percent	RH ambient humidity

Pre-Test background, ppb
Not compensating for water vapor, monitoring task 2
NA
Compensating for water vapor, monitoring task 1
11.4, 10.7, 10.1, 7.26, 8.21, 9.51, 8.46, 7.69, 6.94, 7.49

	0.105	ppm		5.0	ppm
Cylinder	CLM09744		Cylinder	CLM003104	
start P =	1910	psi	start P =	2000	psi
end P =	1910	psi	end P =	2000	psi

Calibration readings: (ppm) **Compensating for water vapor**	**Calibration readings: (ppm)** **Compensating for water vapor**
0.104	4.86
0.103	4.86
0.102	4.85
0.103	4.86
0.105	4.87
0.103	4.86
0.102	4.86
0.104	4.86
0.099	4.86
0.104	4.86
0.10 = avg	**4.86** = avg
0.980 = avg/standard	**0.972** = avg/standard

Standards Used:	Expiration date:
0.105 ppm SF_6, cylinder CLM09744	2/4/2019
5.0 ppm SF_6, cylinder CLM003104	1/28/2019
Weather Station Used:	
Control Co. Dew Point Pen, SN 122277883, Barcode: 39432	2/11/2017

Entries made by:	E. Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	Signature on file with original 3/4/2016	Signature/date	4/7/2016

SULFUR HEXAFLUORIDE GAS INSTRUMENT CALIBRATION

Site	Q AVEPAD	Instrument	B&K Model 1302
Date/Time	3/8/16 1030h	Serial No.	1788615
Testers	EA	Property No.	WD54624

Setup:	6.3 ft	B&K sample inlet tube length
	1000 mbar	station pressure
	69.5 deg F	ambient temp analyzer corrects to 20 deg C
	31 percent	RH ambient humidity

Pre-Test background, ppb
Not compensating for water vapor, monitoring task 2
NA
Compensating for water vapor, monitoring task 1
39.7, 37.2, 35.2, 36.9, 33.4, 32.6, 36.0, 36.3, 37.7, 34.4

	0.105	ppm		5.0	ppm
Cylinder	CLM09744		Cylinder	CLM003104	
start P =	1900	psi	start P =	2000	psi
end P =	1900	psi	end P =	1990	psi

Calibration readings: (ppm) **Compensating for water vapor**	**Calibration readings: (ppm)** **Compensating for water vapor**
0.110	5.03
0.104	5.05
0.106	5.04
0.104	5.05
0.103	5.04
0.104	5.05
0.106	5.05
0.109	5.07
0.107	5.04
0.105	5.06
0.11 = avg	**5.05** = avg
1.008 = avg/standard	**1.010** = avg/standard

Standards Used:	Expiration date:
0.105 ppm SF_6, cylinder CLM09744	2/4/2019
5.0 ppm SF_6, cylinder CLM003104	1/28/2019
Weather Station Used:	
Control Co. Dew Point Pen, SN 122277883, Barcode: 39432	2/11/2017

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	Signature on file with original 3/8/2016	Signature/date	4/7/2016

SULFUR HEXAFLUORIDE GAS INSTRUMENT CALIBRATION

Site	Q AVEPAD	Instrument	B&K Model 1302
Date/Time	3/8/16 0943h	Serial No.	1804888
Testers	EA	Property No.	WD54623

Setup:	6.3 ft	B&K sample inlet tube length
	1000 mbar	station pressure
	68 deg C	ambient temp analyzer corrects to 20 deg C
	30 percent	RH ambient humidity

Pre-Test background, ppb
Not compensating for water vapor, monitoring task 2
NA
Compensating for water vapor, monitoring task 1
31.6, 33.6, 31.6, 28.6, 28.8, 31.9, 30.5, 32.8, 30.7, 29.2

	0.105	ppm		5.0	ppm
Cylinder	CLM09744		Cylinder	CLM003104	
start P =	1910	psi	start P =	2000	psi
end P =	1900	psi	end P =	2000	psi

Calibration readings: (ppm)		**Calibration readings: (ppm)**	
Compensating for water vapor		**Compensating for water vapor**	
0.101		4.80	
0.101		4.80	
0.100		4.82	
0.100		4.82	
0.103		4.80	
0.0988		4.81	
0.0992		4.80	
0.101		4.81	
0.101		4.79	
0.0986		4.82	
0.100	= avg	**4.81**	= avg
0.956	= avg/standard	**0.961**	= avg/standard

Standards Used:	Expiration date:
0.105 ppm SF_6, cylinder CLM09744	2/4/2019
5.0 ppm SF_6, cylinder CLM003104	1/28/2019
Weather Station Used:	
Control Co. Dew Point Pen, SN 122277883, Barcode: 39432	2/11/2017

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	Signature on file with original 3/8/2016	Signature/date	4/7/2016

SULFUR HEXAFLUORIDE GAS INSTRUMENT CALIBRATION

Site	Q AVEPAD	Instrument	B&K Model 1302
Date/Time	3/8/16 0900h	Serial No.	1765299
Testers	EA	Property No.	WD17210

Setup:	6.3 ft	B&K sample inlet tube length
	1001 mbar	station pressure
	66 deg F	ambient temp analyzer corrects to 20 deg C
	31.4 percent	RH ambient humidity

Pre-Test background, ppb
Not compensating for water vapor, monitoring task 2
NA
Compensating for water vapor, monitoring task 1
29.5, 35.2, 30.4, 29.9, 31.3, 28.9, 33.6, 29.4, 31.7, 33.9

	0.105	ppm		5.0	ppm
Cylinder	CLM09744		Cylinder	CLM003104	
start P =	1910	psi	start P =	2000	psi
end P =	1910	psi	end P =	2000	psi

Calibration readings: (ppm) **Compensating for water vapor**	**Calibration readings: (ppm)** **Compensating for water vapor**
0.104	4.88
0.0985	4.90
0.102	4.90
0.106	4.88
0.103	4.89
0.105	4.88
0.104	4.89
0.101	4.90
0.105	4.89
0.102	4.89
0.103 = avg	**4.89** = avg
0.981 = avg/standard	**0.978** = avg/standard

Standards Used:	Expiration date:
0.105 ppm SF_6, cylinder CLM09744	2/4/2019
5.0 ppm SF_6, cylinder CLM003104	1/28/2019
Weather Station Used:	
Control Co. Dew Point Pen, SN 122277883, Barcode: 39432	2/11/2017

Entries made by:	Ernest Antonio	Technical Data Review performed by:	Carmen Arimescu
Signature/date	Signature on file with original 3/8/2016	Signature/date	4/7/2016

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