Pacific Northwest National Laboratory

Capability Replacement Laboratory

Review of the Physical Science Facility Stack Air Sampling Probe Locations

CRL-RPT-ESH-002, Rev. 0

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Review of the Physical Science Facility Stack Air Sampling Probe Locations

CRL-RPT-ESH-002 Rev. 0
PNNL-16864

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September 2007

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Abstract

This letter report reviews compliance of the current design of the Physical Science Facility (PSF) stack air sampling locations with the ANSI/HPS N13.1-1999 standard. The review was based on performance criteria used for locating air sampling probes, the design documents provided and available information on systems previously tested for compliance with the criteria. Recommendations are presented for ways to bring the design into compliance with the requirements for the sampling probe placement.

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1.0 Introduction

This letter report documents Pacific Northwest National Laboratory's (PNNL) preliminary design review to assess compliance of the current design of the three Physical Science Facility (PSF) stack air sampling locations with the ANSI/HPS N13.1-1999 standard, *Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stack and Ducts of Nuclear Facilities* (ANSI 1999).

1.1 Criteria for Locating Air Sampling Probes

The approach used for this assessment was to compare the current designs to designs that have previously been tested for compliance with the following criteria presented in the ANSI/HPS N13.1-1999 standard:

1. *Uniform Air Velocity*. It is important that the gas momentum across the stack cross section, where the sample is extracted, be well mixed or uniform. Consequently, the velocity is measured at several points in the stack at the elevation of the sampling nozzle. Uniformity is expressed as the variability of the measurements about the mean. This variability is expressed using the relative coefficient of variance (COV), which is the standard deviation divided by the mean and expressed as a percentage. As the COV value becomes lower, the velocity becomes more uniform. The acceptance criterion is that the COV of the air velocity must be less than or equal to 20 percent across the center two-thirds of the area of the stack.
2. *Angular Flow*. Sampling nozzles are usually aligned with the axis of the stack. If the air travels up the stack in cyclonic fashion, the air velocity vector approaching the nozzle could be misaligned with the sampling nozzles enough to impair 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°.
3. *Uniform Concentration of Tracer Gases*. A uniform contaminant concentration in the sampling plane enables extraction of samples that represent the true concentration. This is demonstrated using a tracer gas to represent gaseous effluents. The acceptance criteria are that 1) the COV of the measured tracer gas concentration is less than or equal to 20 percent 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 greater than 30 percent.
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 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 less than or equal to 20 percent across the center two-thirds of the sampling plane.

1.2 Criteria for Compliance Based on Tests of Other Stacks or Scale Models

To apply data from a previously tested system (i.e., a surrogate), the following additional criteria must be met:

- The surrogate and its sampling location must be geometrically similar to the actual stack.
- The product of the surrogate's mean air velocity times the hydraulic diameter must be within a factor of six of the actual stack.
- The Reynolds number for the prototype and surrogate stacks must greater than 10,000.

Furthermore, the results from tests using a surrogate are considered applicable if in subsequent tests at the sampling probe location on the constructed stack:

- the velocity profile and flow angle in the constructed stack meet the criteria in the ANSI N13.1-1999 standard
- the velocity uniformity COV for the constructed and surrogate stacks agree within 5 COV percentage points .

If applicable test results from previously tested systems are not found, then actual testing using the constructed stacks or scale models is recommended . No testing was performed as part of this review.

2.0 Design Review

2.1 Documents Provided

The documents provided for this design review included:

- Flad Associates Drawing of Mechanical Roof Plan RAD Exhaust Stack for Building 3410
- Flad Associates Drawing of Mechanical Roof Plan RAD Exhaust Stack for Building 3420
- Flad Associates Drawing of Mechanical Roof Plan RAD Exhaust Stack for Building 3430.

2.2 Description of PSF Stacks

According to the supplied documents, the air to be exhausted from the PSF via the three stacks will be a combination of building ventilation and laboratory exhaust air. Table 2.1 provides operating information for each stack.

Table 2.1. Stack Operating Parameters

Operating Parameters	Bldg. 3410	Bldg. 3420	Bldg. 3430
Duct diameter at sampling probe	38 in.	70 in.	64 in.
No. of duct diameters from upstream disturbance to sampling probe	10	10	10
No. duct diameters from sampling probe to downstream disturbance	3	2	3
Discharge diameter	32 in.	58 in.	54 in.
Single fan capacity	19,900 ft^3/m	33,400 ft^3/m	28,100 ft^3/m
No. of operating fans	1	2	2
Total available fans	2	3	3
Operating flowrate	19,900 ft^3/m	66,800 ft^3/m	56,200 ft^3/m
Operating air velocity at sampling probe	2,500 ft/min	2,500 ft/min	2,500 ft/min
Air temperature at coil exit	40–75°F	40–75°F	40–75°F

Appendix A shows the layouts for the three stacks. Each stack, with its exhaust fans and heat recovery coils, is located on the roof of its respective building. Each fan draws air from the heat recovery coil and discharges into a short horizontal duct that connects to another horizontal duct at a 45° angle. The horizontal ducts are sized such that the air velocity is about 2500 ft/min.

The air sampling probe flange is shown located 10 duct diameters downstream from the last duct junction. Two or three duct diameters downstream from this point, the duct turns 90° upward into a short vertical stack that ends 20 ft above the roofline. The stacks end in a concentric reducer that increases the discharge velocity to about 3500 ft/min.

2.3 Availability of Compliance Test Data

Test data are used to document compliance with the performance criteria for locating the air sampling probe as described in the Introduction of this letter report. The data can be obtained through testing on the constructed stack or, alternatively, on another stack or scale model with the same geometry and configuration. The data from previously tested configurations can be used if the criteria given in the

Introduction are met and if the validation step is performed (see section 1.2 above). The validation step consists of showing acceptable results of a flow angle and velocity uniformity tests on the constructed stack and agreement with the velocity uniformity results from the previously tested stack within 5 percent COV units. The flow angle results do not have to match.

Appendix B shows stack sampler configurations that have been tested. Those sampler configurations most closely resembling the stacks proposed for the PSF buildings are shown in Figures B.1 and B.2. In these instances, the mixing test tracers were injected in the 45° angled duct just upstream of the stack. Furthermore, the angled ducts are rectangular in cross section, and the stacks have a constant diameter. The fact that the PSF stacks have reducers in the vertical section should have little impact because that position in the stacks is downstream of a 90º bend that also is downstream of the probe location.

2.3.1 Figure B.1

The sampler configuration in Figure B.1 was the earliest tested for compliance with criteria that were later adopted in the ANSI N13.1-1999 standard. The results were reported by Rodgers et al. (1996). They found that the air sampling location met the criteria at nine or more stack diameters above the junction of the stack and the inlet duct. The original test data have not yet been located, which could be a problem for the validation step.

2.3.2 Figure B.2

The most similar tested configuration is shown in Figure B.2. The data are reported by Glissmeyer and Droppo (2007). Tests were done both with and without control and backflow dampers installed at the fan outlets and with one or both fans operating. Test Ports 1, 2, and 3 were about 4.5, 9.5 and 14.5 duct diameters downstream of the junction with the nearest fan (Fan A).

Descriptions of the differences between the tested model and the PSF designs follow:

- The fan closest to the air monitor connects to the stack via a rectangular duct rather than a round duct. The impact of this difference, if any, should be small. If there is an impact, a decision could be made to rebuild the model.
- There is an expansion from 10.9 to 12 inches in the diameter of the round duct after the most distant fan. No impact would be expected from this slight difference.
- The exhausters for Buildings 3420 and 3430 have a third fan. It is not believed that this difference would have an impact. The model tests indicated that the uniformity results only improved when the more distant fan was used. When the even more distant fan is used, there would be greater improvement in the results.
- The inlet ducts were vertical rather than horizontal. The impact of this design feature is not known; however, the only impact should be that the position of the maximum measured quantities is rotated around the discharge duct about 90°. That change should not impact the uniformity results.

To best match the client's needs, most of the tests were done with the dampers installed and using Test Ports 2 and 3. The test results were more favorable with the dampers installed than without. Also, most tests were done with two operating fans. Therefore, additional tests may need to be performed to fully qualify the PSF exhausters based on this particular scale model. The model is still assembled and is ready to use until it is replaced late in 2007. The recommended tests to complete the evaluation of the new designs are described in Appendix C.

2.4 Alternatives to Using Existing Qualification Tests

If a decision is made to qualify the stack sampling locations by other means, the following alternative approaches could be used to demonstrate compliance with the standard:

- Perform the compliance tests on the constructed stacks.
- Modify the stack designs to conform to an already tested configuration and perform the validation steps on the constructed stacks.
- Perform the compliance tests on a scale model of the stack, followed by the validation tests on the constructed stack. A single scale model would probably suffice for all three stacks.

2.4.1 Perform the Compliance Tests on the Constructed Stacks

At least four types of tests are performed:

1. *Velocity Uniformity*. A minimum of two repeat runs required.
2. *Flow Angle*. A minimum of two repeat runs required.
3. *Gas Tracer Mixing*. A minimum of six repeat runs per effluent stream required.
4. *Particle Tracer Mixing*. A minimum of one run per effluent stream and one repeat required.

The estimated minimum number of test runs is for one stack and operating configuration. Significantly different operating configurations may require additional tests runs. Flow controls also may need to be calibrated. Preparations for testing include the following:

- a quality assurance plan appropriate for the application
- a test plan
- test procedures
- tracer generating equipment
- tracer injection ports in each stream (or just upstream of stack for a worst-case simulation)
- instrumentation calibrated as appropriate for the individual tests
- test ports near the location of the air sampling probe as illustrated in Figure 2.1
- access platforms to the tracer injection and test ports of a size large enough for the work.

The particle tracer test on the constructed stack would require the most preparation for access. In the direction of the transects through the two test ports, a platform would be needed to allow insertion and positioning of a rigid probe outside the stack. The probe would be constructed of 0.75-in. tubing and would have a particle counter attached to the end. In our experience, the depth of the platform at the two test ports would have to equal the width of the stack plus 2 ft. Figure 2.1 shows a typical arrangement for the test ports, and also shows how the sampling probe and a flow sensor may be co-located.

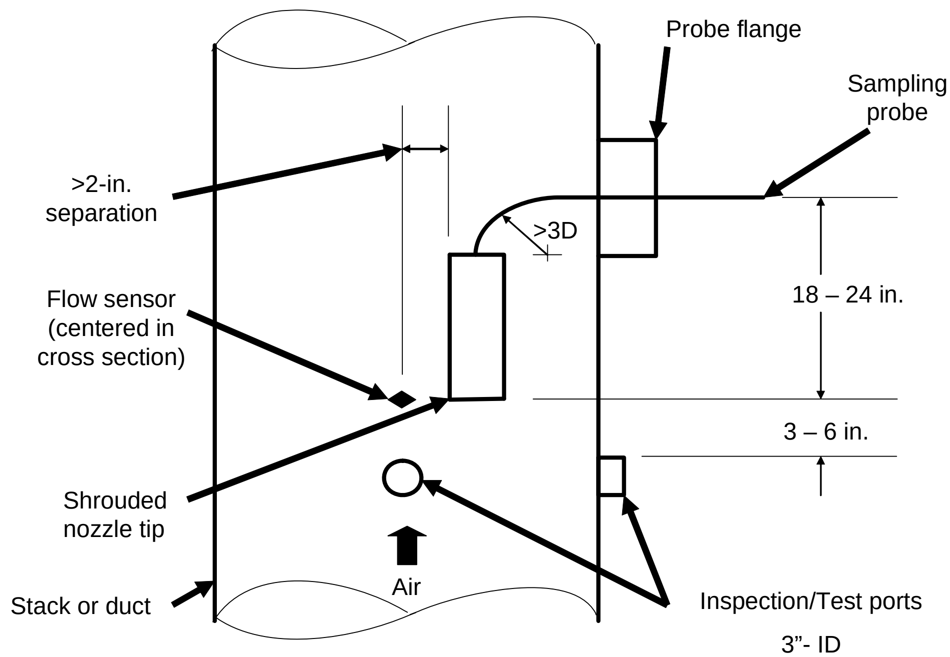


Figure 2.1. Typical Arrangement of Test Ports

2.4.2 Modify the Stack Design to Conform with an Already Tested Configuration

Appendix B shows diagrams of tested stack sampling configurations. The risk in using this approach is that the test data may not cover the operating configurations of the three stacks.

2.4.3 Perform the Compliance Tests on a Scale Model of the Stack

This approach involves fabricating a scale model of the stacks, testing the model and performing the final validation tests. In this case, the scale model would be assembled and tested at a convenient location. The scaling factor for the model would be approximately 5:1, and a single model would probably suffice for the PSF three stacks.

For the validation tests, incorporation of test ports in positions similar those shown in Figure 2.1would be recommended for the constructed stack.

3.0 Conclusions

Regarding the testing for compliance with the ANSI N13.1-1999 standard, the following conclusions and observations can be made:

- Based on the tests with the similar stack (Glissmeyer and Droppo, 2007), the current designs for the air sampling probe locations may meet the criteria of the ANSI N13.1-1999 standard if dampers similar to those tested were added. The verification tests would be needed on the constructed stacks.
- The data of Glissmeyer and Droppo (2007) are not conclusive if dampers are not installed without some additional testing as outlined in Appendix C. The data seem to suggest that, without dampers installed, the following configurations would probably meet the criteria of the ANSI N13.1-1999 standard.
    - Where two fans are operated simultaneously, the sampling probe should be located about 15 duct diameters (or more) downstream of the fan junction nearest to the sampling probe.
    - If only one fan is used at a time, such as in the case of the 3410 Building, the planned sampling locations would be satisfactory
- Application of the results from other previously tested stacks would require some changes to the PSF design.
- Compliance testing could be conducted on a scale model of the PSF stacks, and then followed up with a validation test of velocity uniformity and flow angle on the constructed stack.
- The compliance testing can be performed on the constructed stacks with adequate access provisions and preparations. The test results obtained for the 3420 Building stack would also be applicable to the 3430 Building stack.

It is difficult to recommend a preferred course of action that reflects all cost considerations because we currently do not know the costs for modifying the stack design or for providing suitable platforms to access test ports. Considering only our level-of-effort, the least costly approach may be to install the dampers such as were tested by Glissmeyer and Droppo (2007), apply the test data, and perform the verification test when the stacks are constructed. The constructed stacks should be provided with the appropriate test ports in case the verification tests fail. The next least costly approach would probably be to perform the tests on the existing scale model as recommended in Appendix C or perform them on the constructed stack. The costs to the client for design changes or for facilitating onsite tests may alter the order of preference.

4.0 References

American National Standards Institute (ANSI). 1999. *Sampling and Monitoring Releases of Airborne Radioactive Substances From the Stacks and Ducts of Nuclear Facilities*. ANSI/HPS N13.1–1999, American National Standards Institute, New York.

Glissmeyer JA and JG Droppo. 2007. *Assessment of the HV-C2 Stack Sampling Probe Location*. WTP-RPT-158, Rev. 0, Pacific Northwest National Laboratory, Richland, WA.

Rodgers JC, CI Fairchild, GO Wood, CA Ortiz, A Muyshondt, and AR McFarland. 1996. "Single Point Aerosol Sampling: Evaluation of Mixing and Probe Performance in a Nuclear Stack." *Health Physics* 70(1):25-35.

Appendix A

PSF Stack Drawings Supplied By Subcontractor

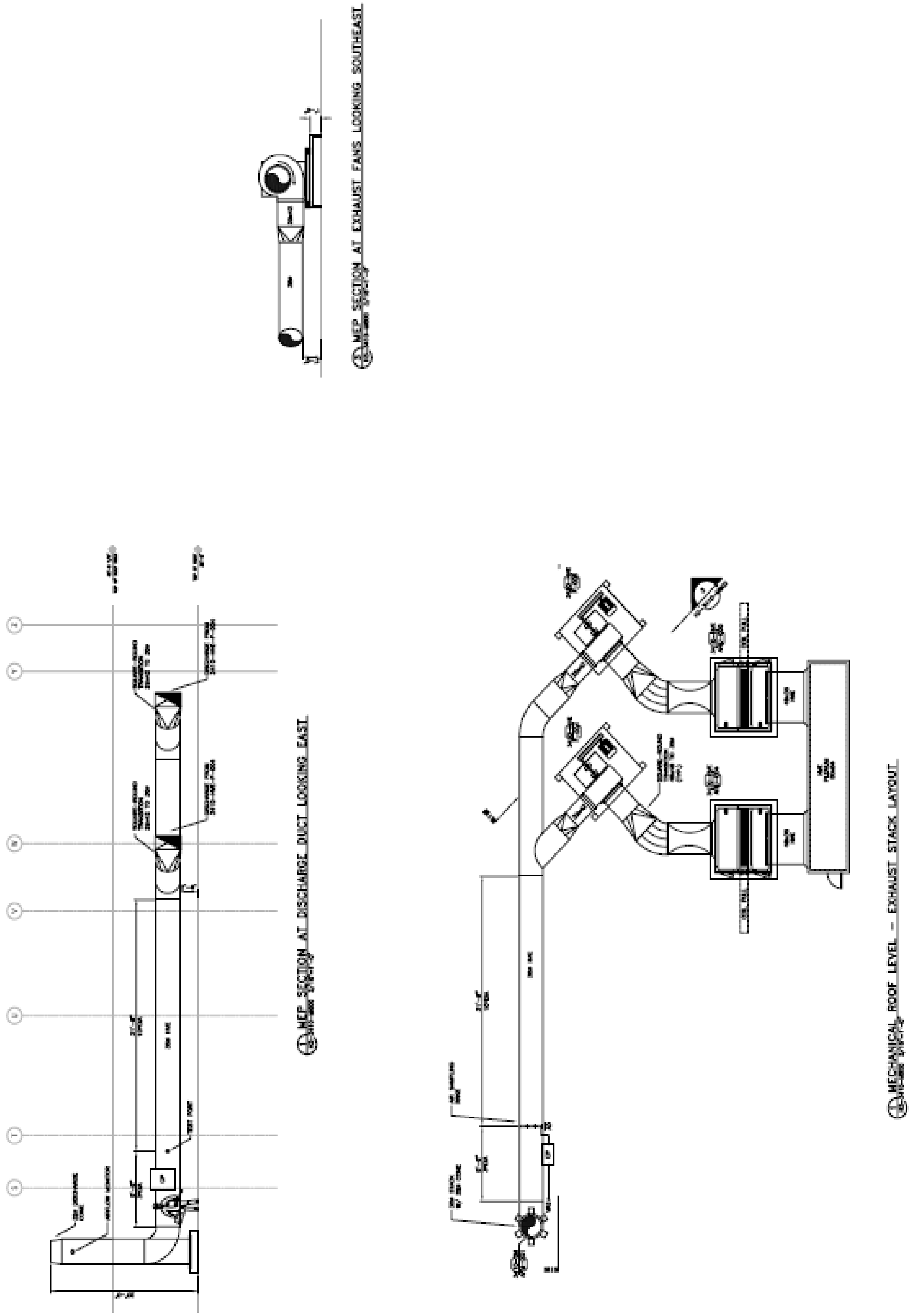


Figure A.1. Stack Layout for Building 3410

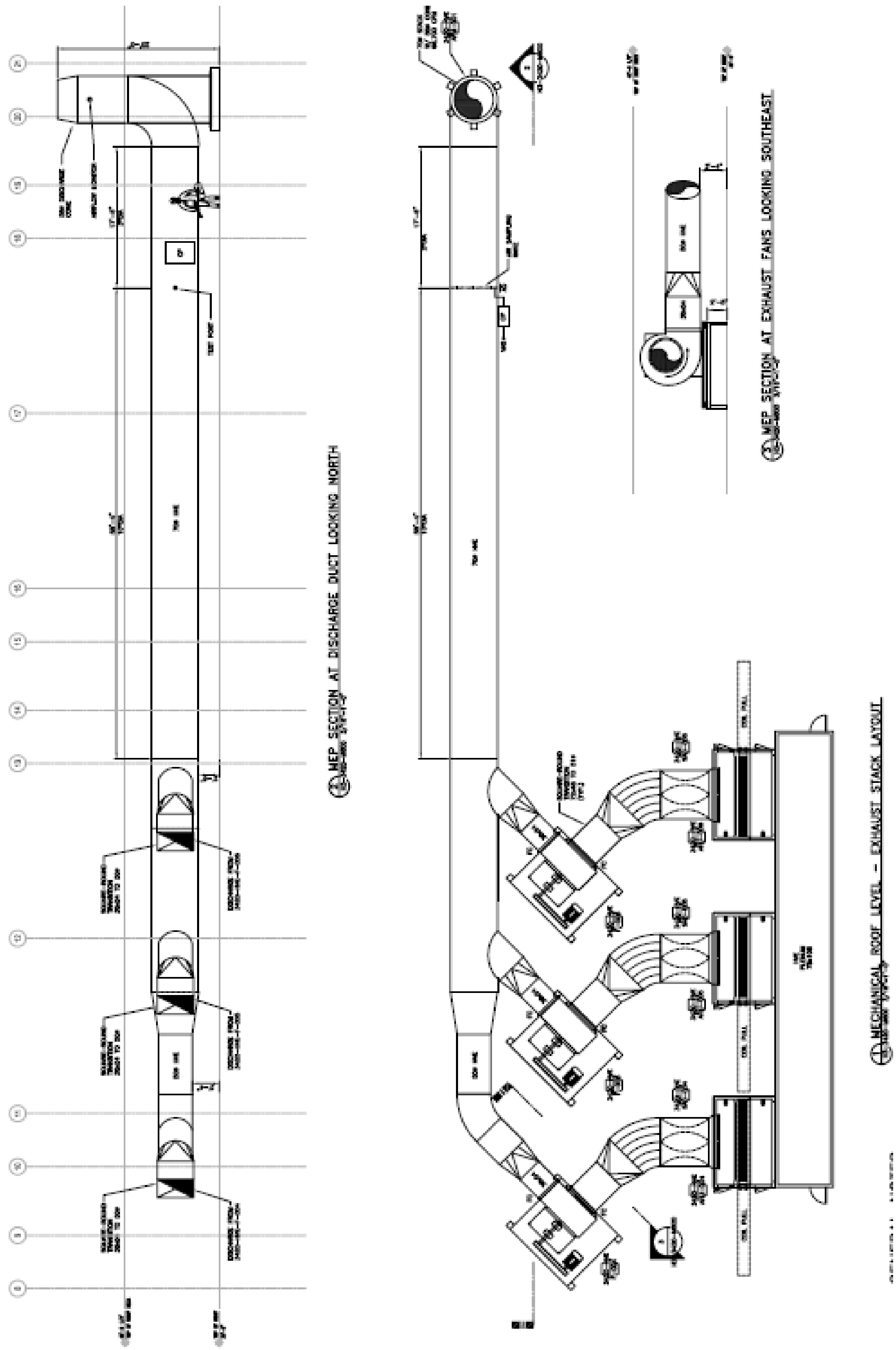


Figure A.2. Stack Layout for Building 3420

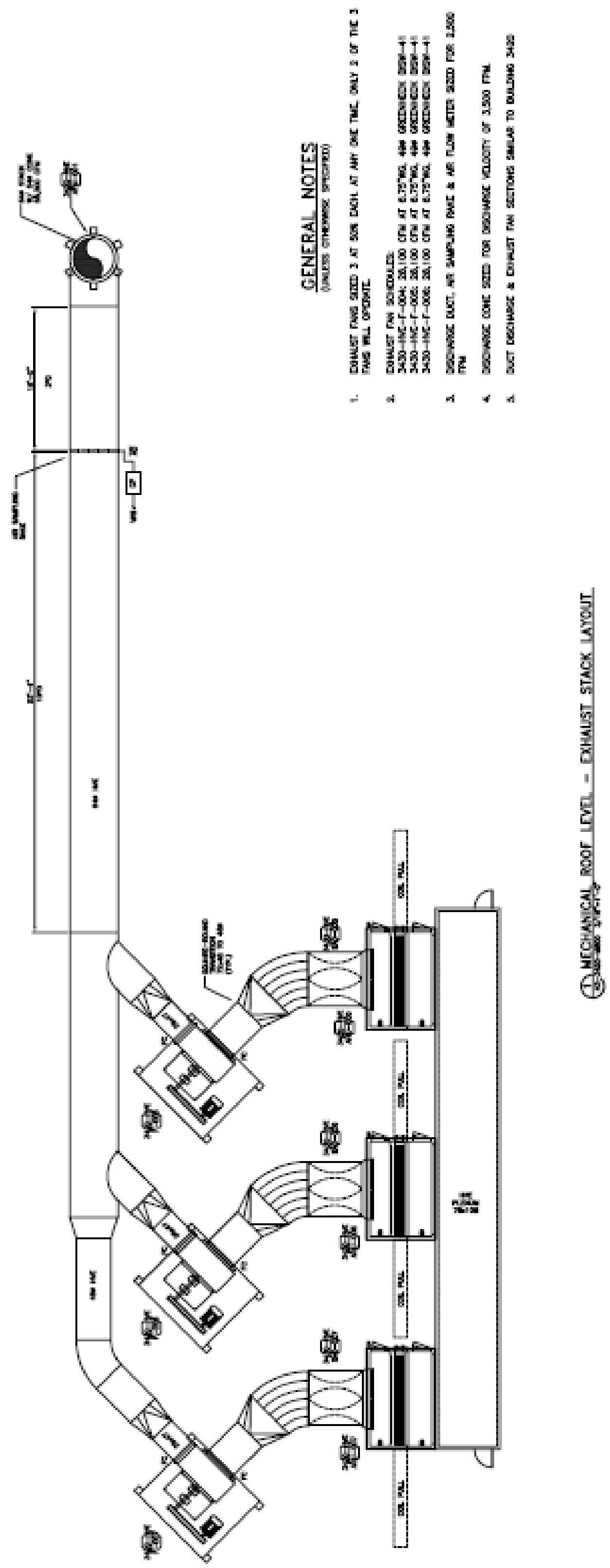


Figure A.3. Stack Layout for Building 3430

Appendix B

Stacks For Which Test Data May Be Available

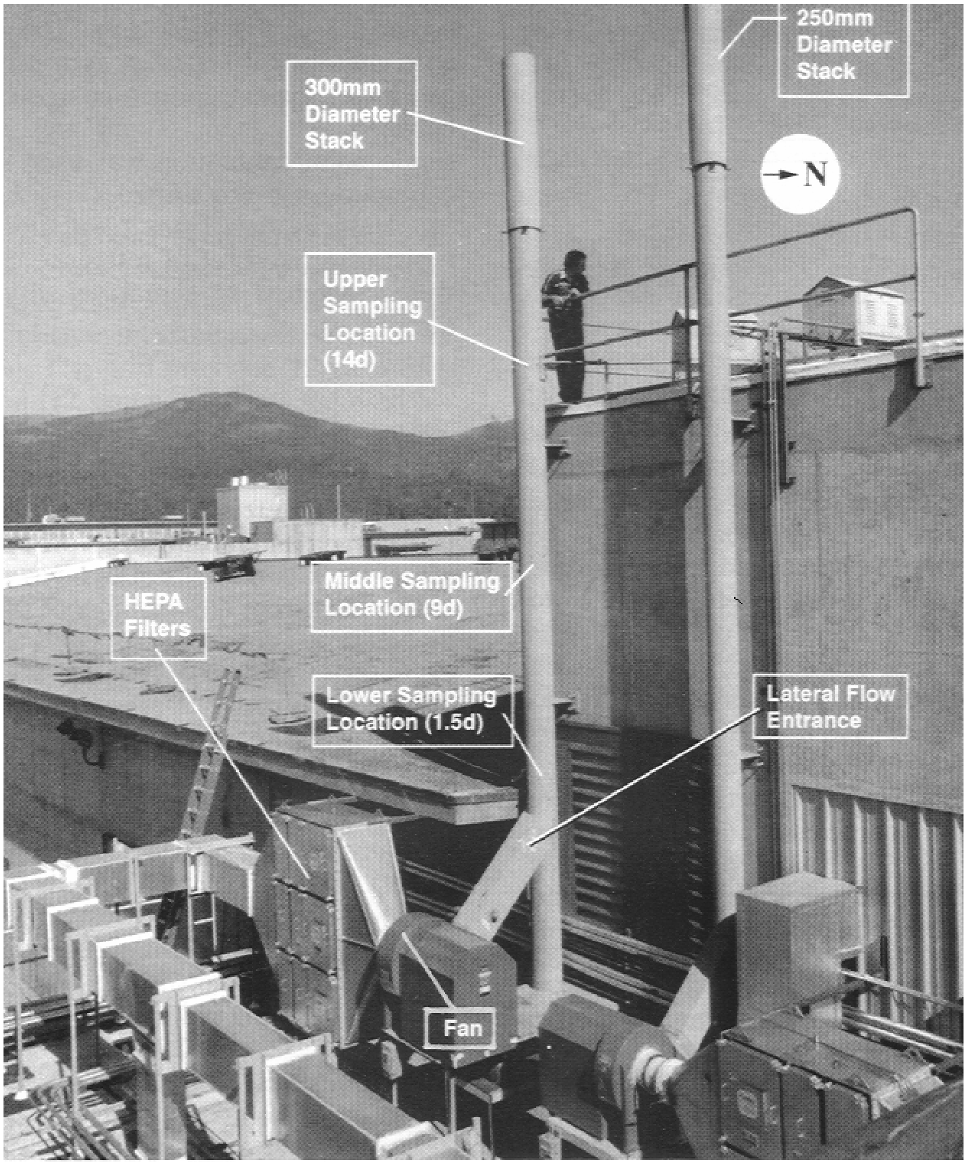


Figure B.1. A Tested Los Alamos Stack – Availability of Data is Being Investigated

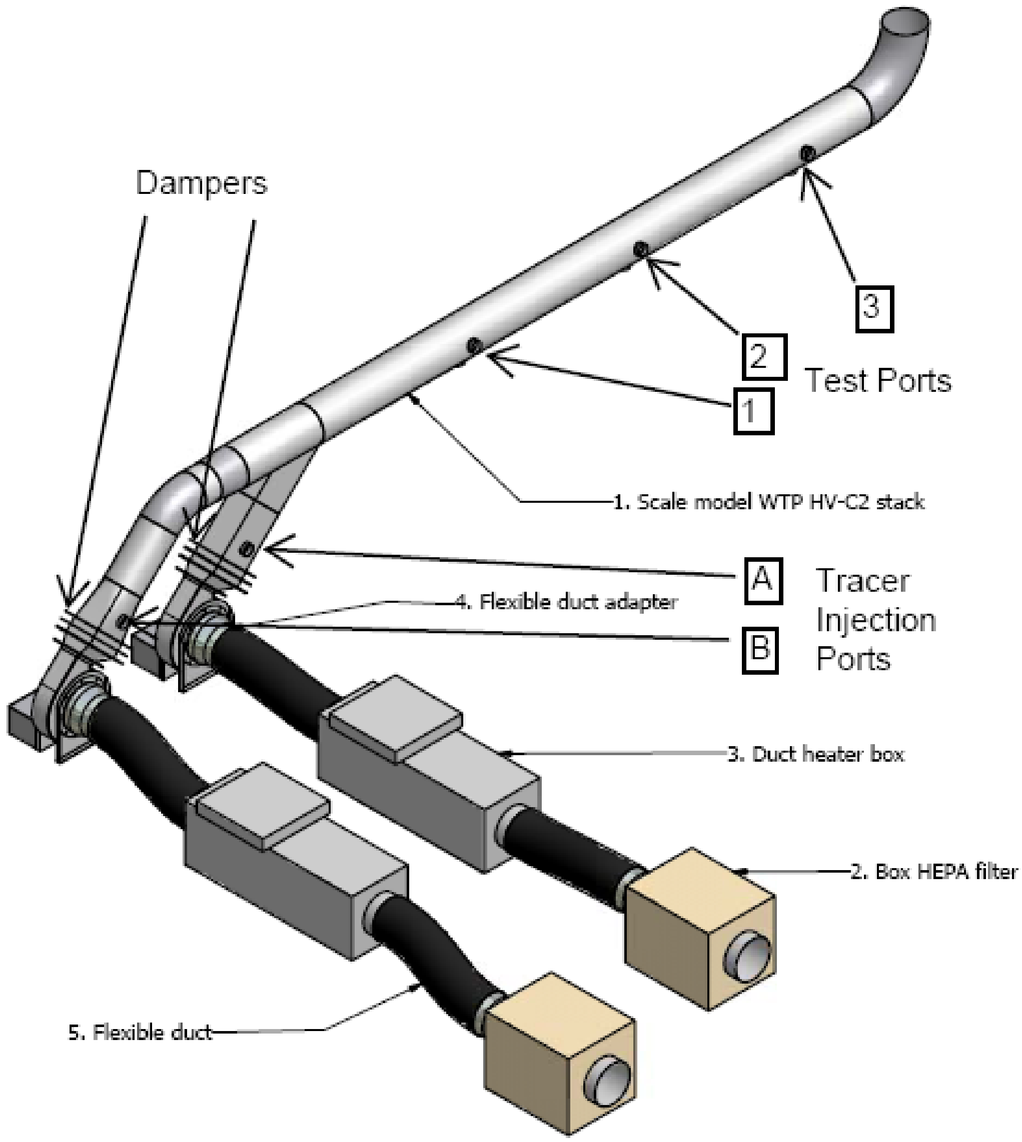
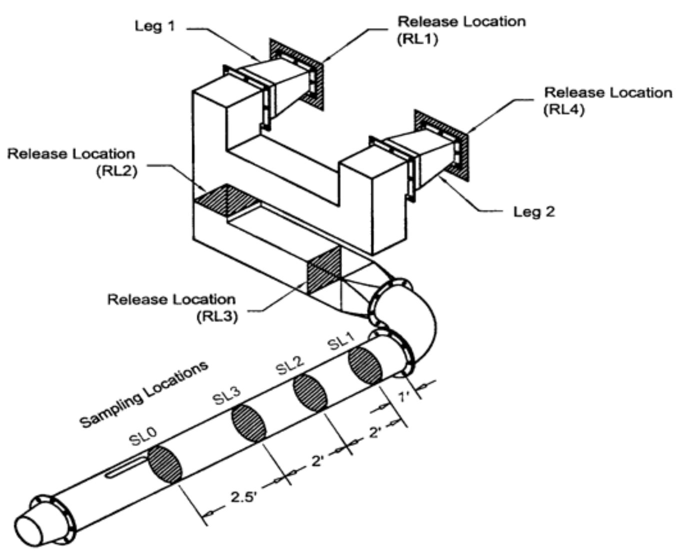


Figure B.2. Scale Model of the Waste Treatment Plant HV-C2 Stack

Figure B.3. HDB-8 Stack at Savannah River – Availability of Data under Investigation



Model of HDB-8 showing sampling locations (SL) and tracer gas release locations (RL). The desired sampling location is designated SL0.

Figure B.4. Scale Model Configuration Used for HDB-8 Stack Tests

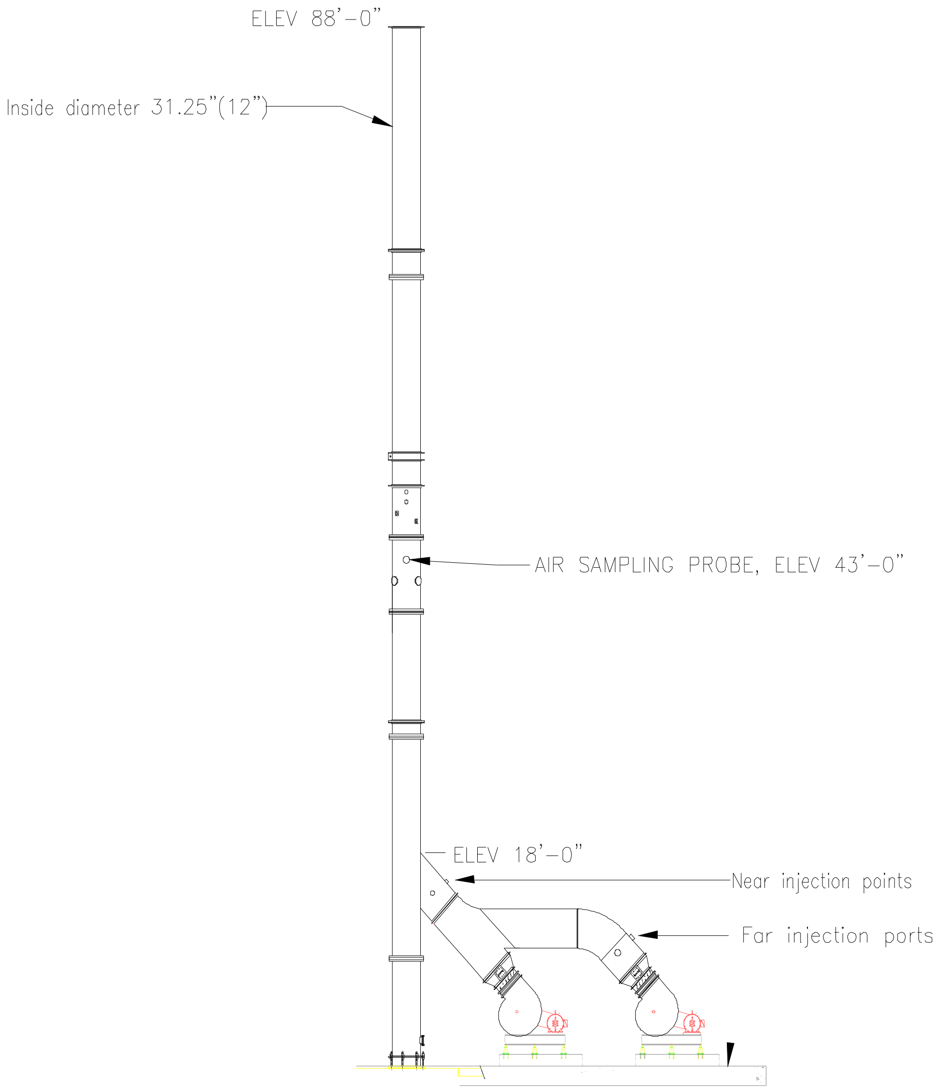


Figure B.5. Hanford Stack Tested at PNNL as a Scale Model

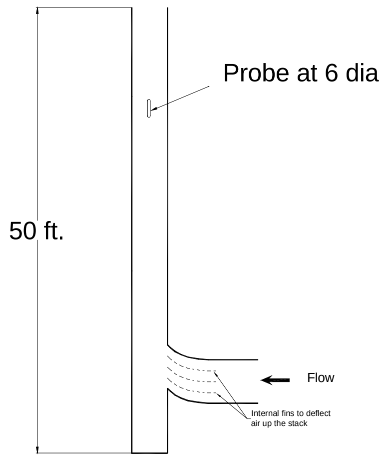


Figure B.6. Unpublished Test Where Turning Vanes Were Used

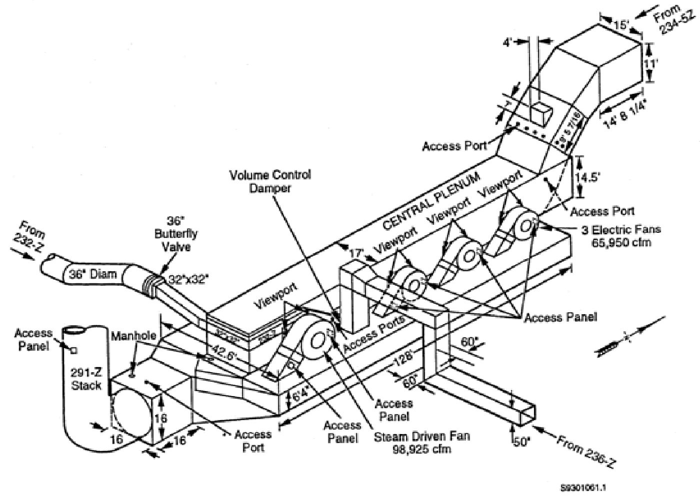


Figure B.7. Downdraft Converging Plenums

Figure B.8. Scale Model of a Four-Fan Hanford Stack

Figure B.9. Horizontal Stack at a PNNL Building

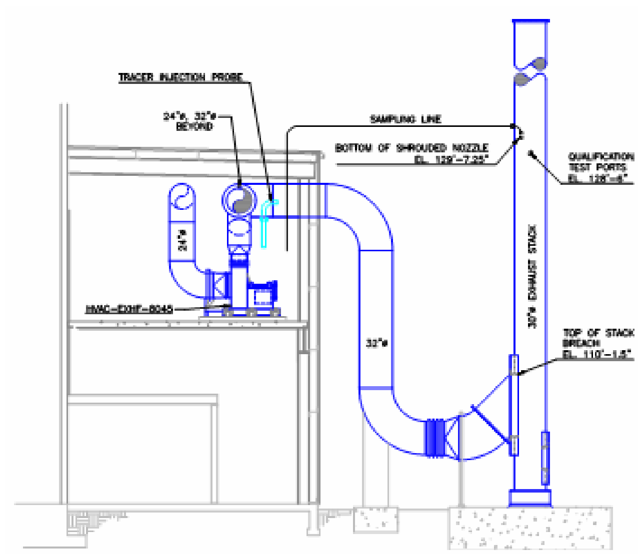


Figure B.10. Stack with Three Bends to Mix the Tracer

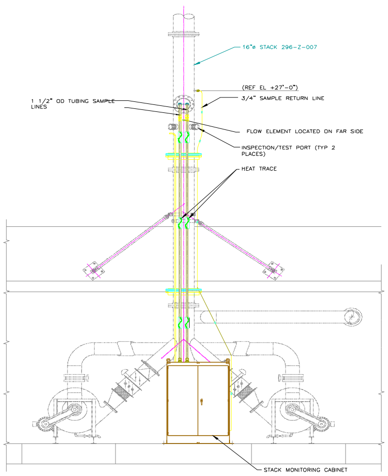


Figure B.11. Dual-Fan Stack

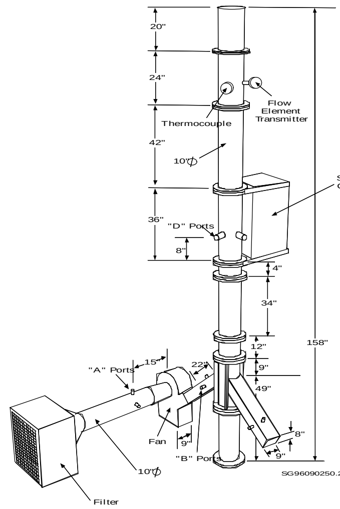


Figure B.12. Small Diameter Dual-Fan Stack

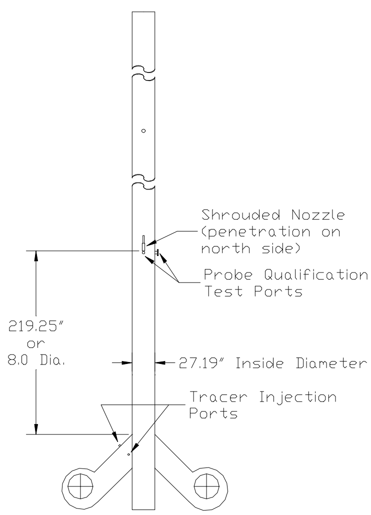


Figure B.13. Large Diameter Dual-Fan Stack

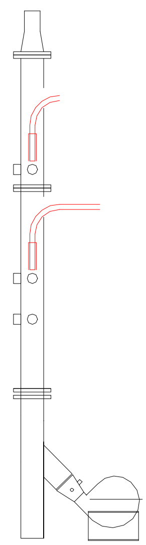


Figure B.14. Small Exhauster with Two Sampling Probes

Figure B.15. Generic Mixers Developed at Texas A&M University as Replacement Rooftop Exhausters

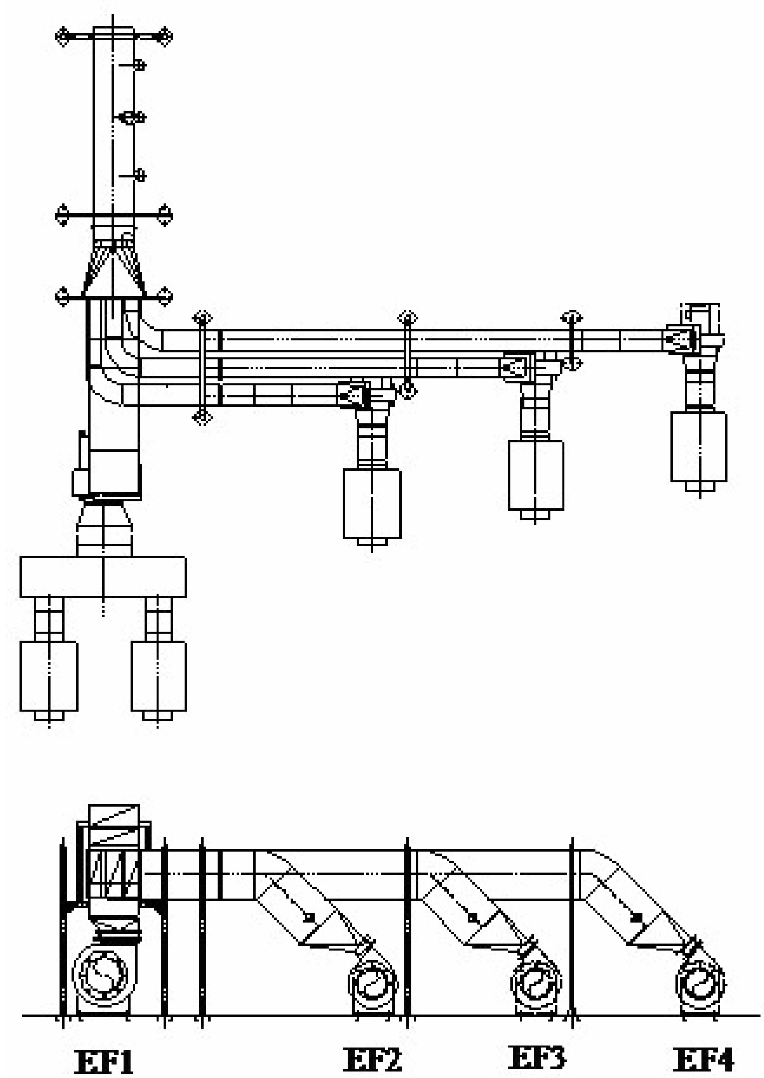


Figure B.16. Plan and End Views of a Scale Model Where Four Effluent Streams Combine at the Base of the Stack

Appendix C

Additional Tests Needed to Complete Qualification Demonstration Using the Model Shown in Figure B.2

Appendix C

Additional Tests Needed to Complete Qualification Demonstration Using the Model Shown in Figure B.2

Most of the tests done with the scale model (Glissmeyer and Droppo – 2007) focused on two operating fans with dampers installed, but a limited number of tests were done without the dampers. It became evident that the presence of dampers produced more favorable results in configurations that otherwise failed the acceptance criteria. This appendix addresses recommended tests that could be undertaken to demonstrate compliance of the PSF air sampling locations if dampers similar to those tested are not installed at the outlets of the fans.

C.1 Building 3410 Exhauster

This stack differs from the other two because it is planned to operate only a single fan at a time for Building 3410. Table C-1 lists the minimum number of each type of test recommended to demonstrate compliance of the air sampling probe location for the 3410 Building exhauster. The single fan tests were only done for Test Port 1, so those results are of no value here because they were not taken at the test port of interest (i.e., Port 2).

Table C.1. Recommended Tests Applicable to the 3410 Building

Configuration		Number of Test Runs			
Operating fans	**Test Port**	**Flow Angle**	**Velocity**	**Gas Tracer**	**Particle Tracer**
Fan A only	2	1	3	6	2
	3	1	1	1	1
Fan B only	2	1	1	1	1
	3	1	1	1	1

C.2 Exhausters for Buildings 3420 and 3430

Table C-2 lists the minimum number of each type of test recommended to demonstrate compliance of the air sampling probe locations in the exhausters for Buildings 3420 and 3430. Already-completed tests are shown in parentheses.

Table C.2. Recommended tests for Buildings 3420 and 3430

Configuration		Number of Test Runs			
Operating fans	**Test Port**	**Flow Angle**	**Velocity**	**Gas Tracer**	**Particle Tracer**
Fans A & B	2	1	3	6 (1)	2 (1)
	3	1	1	1 (1)	1 (1)