PNNL-13775

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

Qualification Tests for the Air Sampling System at the 296-Z-7 Stack, Addendum 1

J. A. Glissmeyer
A. D. Maughan

January 2002

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

PACIFIC NORTHWEST NATIONAL LABORATORY
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BATTELLE
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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

This addendum report documents tests performed by Fluor Hanford to verify that the stack flow monitoring system for the 296-Z-7 ventilation exhaust stack meets the applicable regulatory criteria regarding stack flow measurement accuracy. These criteria ensure that the stack flow measurements have sufficient accuracy for use in estimating stack emissions. The required tests address the

- continuous operability of the flow measurement system
- drift in calibration parameters over a 1-week period
- accuracy of flow measuring system relative to standard EPA method results
- sensitivity of the flow sensor to errors caused by inadvertent rotation of the sensor.

The tests performed demonstrated that operability and accuracy requirements were met. The calibration parameter drift tests were not conducted because the safety of the plant would be compromised; however, the flow measurements were shown to be highly repeatable. The rotational sensitivity test was not conducted, but data from the manufacturer show that such sensitivity meets the EPA requirements.

The 296-Z-7 stack vents the process area and gloveboxes constructed in the Plutonium Stabilization and Handling (W-460) Project. The process area is housed in the 2736-ZB Building, adjacent to the Plutonium Finishing Plant in the 200 West Area of the Hanford Site.

Acknowledgments

This work was supported by the U.S. Department of Energy under Contract DE-AC06-76RL01830, with project funding from the Plutonium Stabilization and Handling Project (W-460) managed by Fluor Hanford, Inc. The authors wish to acknowledge the technical assistance of Johnny D. Dick, Clint D. Stuart, James T. Lilly, and craft services of the Plutonium Finishing Plant, Fluor Hanford, Inc. for invaluable technical assistance.

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1.0 Introduction

This report is an addendum to an earlier report (Glissmeyer and Maughan 2001). The earlier report presented the results of tests showing that the air sampling system for the new 296-Z-7 stack meets standards for single point sampling, ANSI/HPS N13.1-1999, "Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities" (ANSI 1999). This report addendum presents the results of recent tests to verify the accuracy of the stack flow sensor for the 296-Z-7 stack. The performance criteria, test methods, results, and conclusions are discussed. The detailed test procedures and data sheets are included in the appendices. These tests were conducted by Fluor Hanford Ventilation and Balance Staff, with some data reduction performed by Fluor Hanford staff. Further data reduction and reporting are by Pacific Northwest National Laboratory[1] staff.

The method used for the tests is based on 40 CFR 52, Appendix E, which contains acceptance criteria for relative accuracy, continuous operability, zero and calibration drift, and orientation sensitivity. These are described later in the report. Only the tests for relative accuracy and continuous operability were conducted. Calibration drift results are inferred from the accuracy tests. Orientation sensitivity data from the instrument manufacturer is also presented.

The 296-Z-7 stack was recently constructed as part of Project W460, *Plutonium Stabilization and Handling*. The new stack discharges ventilation air from a new process area in the 2736-ZB Building where stabilized Special Nuclear Material is packaged into the latest DOE standard containers. The 2736-ZB Building is located in the 200 West Area at the U.S. Department of Energy's (DOE) Hanford Site.

1.1 Background

Process offgas emission monitoring for radionuclides in DOE facilities is required under federal and state law. A Notice of Construction[2] (NOC) was submitted to the Washington State Department of Health describing the process, the offgas treatment system, and the offgas radionuclide monitoring system. The NOC also describes the standards to which the offgas treatment and monitoring must adhere. Included in the NOC was the requirement to demonstrate the accuracy of the stack flow system using the method outlined in 40 CFR 52, Appendix E. This method, first published in 1975, provides a good basis for testing the calibration of stack flow instrumentation. However, it is dated and its approach is, in part, inappropriate for modern digital instrumentation. A discussion of acceptance criteria and the approach used in the tests is given in the next subsection.

[1] Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy.
[2] NOTICE OF CONSTRUCTION. DOE/RL-2000-42, Rev. 2 – titled: Radioactive Air Emissions Notice of Construction for Plutonium Finishing Plant. Project W0460, "Plutonium Stabilization and Handling."

1.2 Acceptance Criteria

According to 40 CFR 52, Appendix E, the stack flow measurement system must meet five acceptance criteria. These are summarized in Table 1.1.

Table 1.1. Flow-Rate Performance Specifications

Parameter	Specifications
Relative accuracy	<10 percent mean reference value
Continual operability	168 hours minimum
Zero drift (24 hours)	<3 percent of span
Calibration drift (24 hours)	<3 percent of span
Orientation sensitivity	<4 percent of mean reference value when rotated ±10 degrees

The accuracy of the flow measurement system is determined by comparing a series of flow readings paired to simultaneous manual flow measurements made during a one-week period using EPA's Method 2 (40 CFR 60, Appendix A, Method 2).

Zero and calibration drift is determined from changes in the measurement system output before and after a daily (or more frequent) system calibration. Zero drift is the change in measurement system output when the stack flow is zero. Calibration drift is the change in measurement system output when the stack flowrate is at 67% of the measurement system's span. These drift determinations are to be made from observations during a 168-hr period of continuous system operation. This is one way to assess the stability of the measurement system's calibration. Because of the inability to vary stack flow from zero to maximum flow without triggering alarms, the drift tests were not conducted. Instead, the repeatability of the stack flow measurement will be evaluated.

Orientation sensitivity is the angular tolerance to which the sensor can be misaligned from its correct orientation before the specified error occurs relative to the reference manual measurement method. As used in Appendix E, the relative error must be within 4% over an angular rotation of ±10º. Because this requirement is more stringent than the one for the relative accuracy test, it appeared that the wording of the EPA method may be in error. According to a communication with the method's cognizant EPA staff member, the intent was that the variability over the range of rotation angle be <4% of the instrument's own reading at 0º rotation (see Appendix A).

The orientation test was not conducted on this system because the results have little practical value other than meeting a criterion. Once installed, the sensor is fixed, leaving any effect of orientation sensitivity incorporated into the overall relative accuracy result. To satisfy the criterion, orientation sensitivity data provided by the sensor's manufacturer is presented instead.

1.3 Ventilation Exhaust Stack Description

The 296-Z-7 stack exhausts emissions from the process glovebox offgas and the general ventilation air from room 642 of the 2736-ZB Building. The design air flow is about 1550 to 1800 cfm. All exhaust air is filtered through two stages of high-efficiency particulate air (HEPA) filters prior to discharge. The ventilation flow is powered by one of two fans located next to the 296-Z-7 stack. Fan speed and flow are automatically controlled to maintain a set vacuum level in the process ventilation system.

The stack has an internal diameter of 15.25 inches and is about 50-feet tall. Figure 1.1 diagrams the stack, duct leading to the stack, the location of the air sampling probe, flow element, and the location of the test ports used for manual flow measurements.

Figure 1.2 shows the interior of the air monitoring probe cabinet. Shown are the sample lines, record sample filter holder, and the alpha continuous air monitor. The flow sensor is an insertion mass flow sensor on the end of a 1-inch diameter support tube that is 12-inches long[3]. It is mounted on the stack at the location shown in Figure 1.1 using a compression fitting. The signal is linearized, scaled, and displayed[4] in the instrument cabinet shown in Figure 1.2. The signal can be used by the stack sampling system for controlling record sample flow in proportion to stack flow. There is a second separate ventilation flow sensor with readout located inside the 2736-ZB Building.

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[3] Model 452-16-MT, Kurz Instruments Incorporated, Monterey, California.

[4] Model Adam Jr. 155™ Mass Flow Computer, Kurz Instruments Incorporated, Monterey, California.

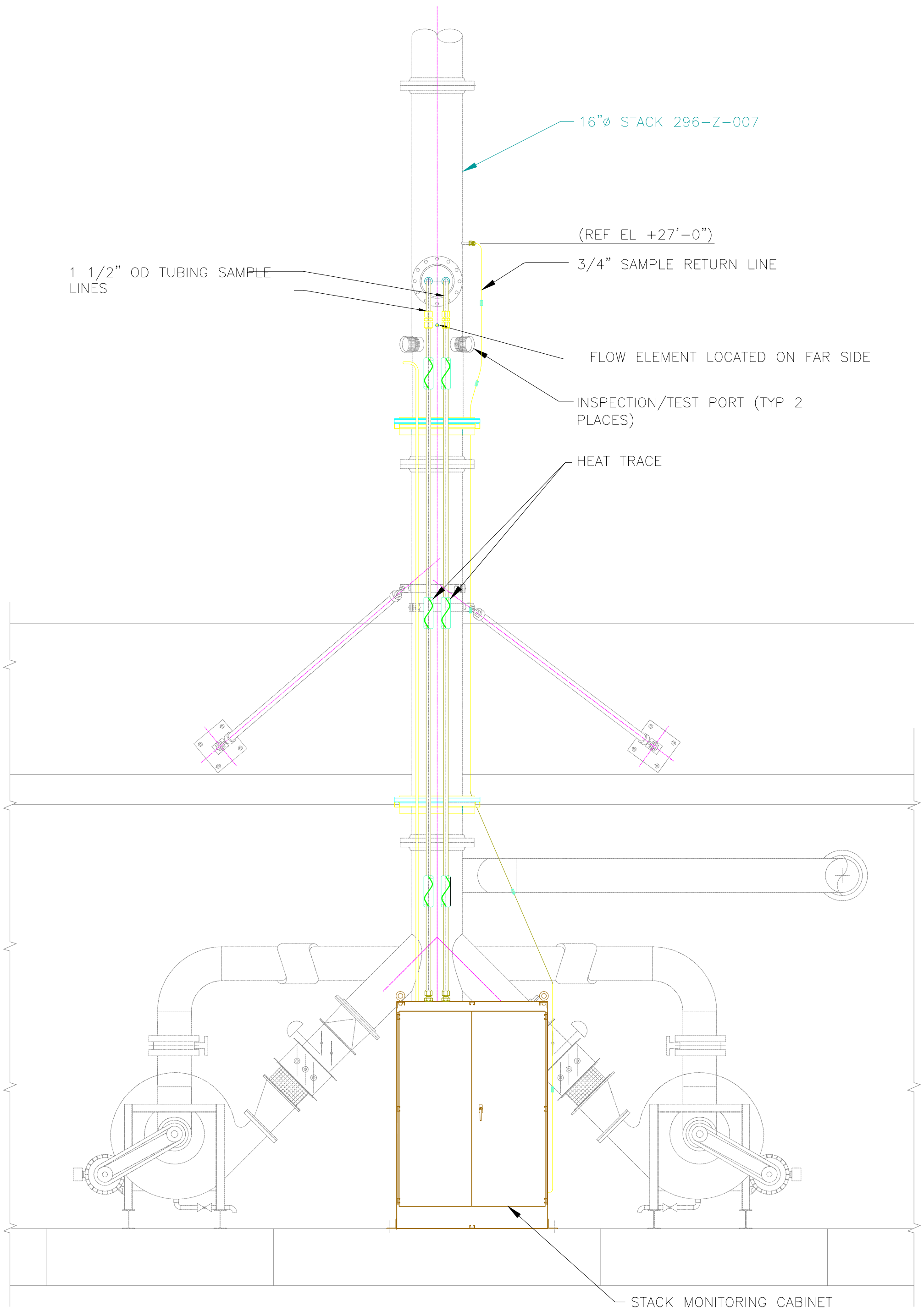

Figure 1.1. 296-Z-7 Ventilation Exhaust Stack

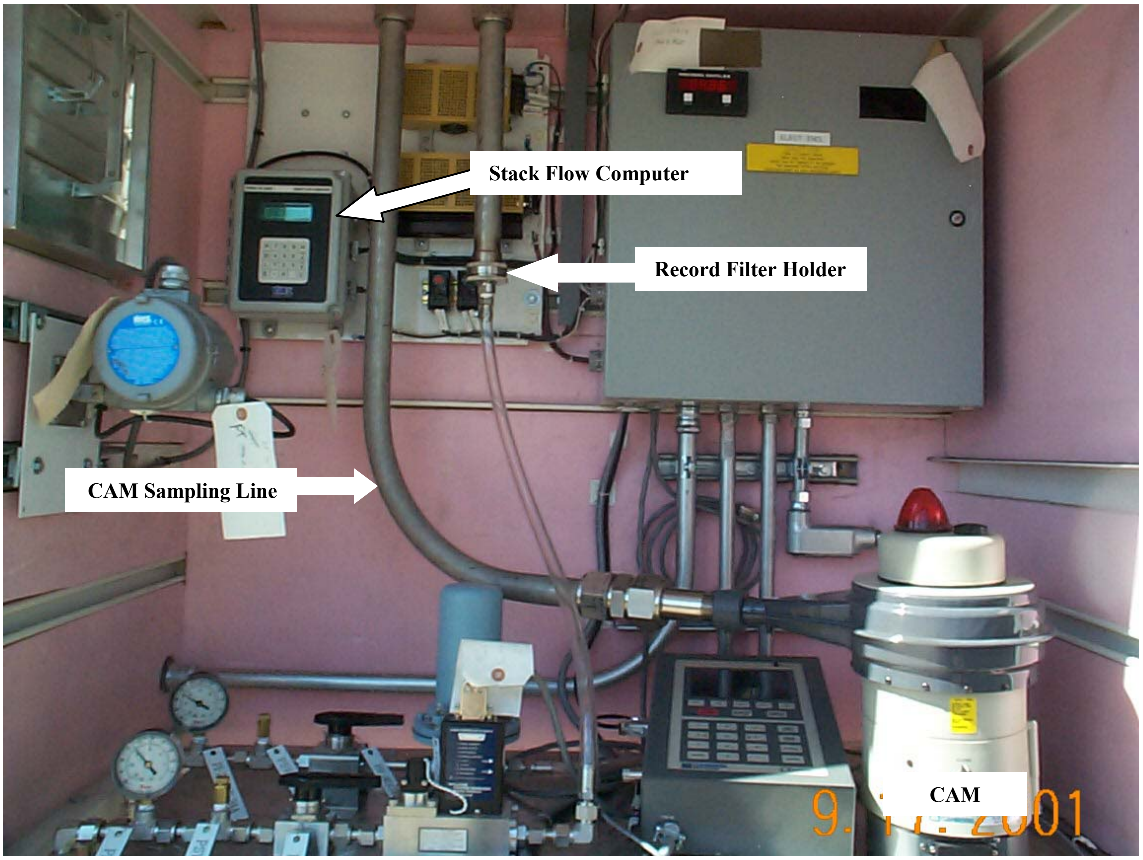

Figure 1.2. Interior of the Air Monitoring Cabinet

2.0 Qualification Test Methods

The relative accuracy of the 296-Z-7 stack flow measurement system was assessed using the methods given in 40 CFR 52, Appendix E. This method was chosen because it was cited in the NOC.

Measurements were made at the test ports shown in Figure 1.1. A temporary scaffold facilitated access to the test ports as shown in Figure 2.1. All tests were performed with one fan operating, the normal condition for the facility.

Figure 2.1. Stack and Temporary Scaffold

During the 168-hour test period, the measurement system must continuously monitor the stack flowrate. During this field test period, 14 pairs of flow readings are obtained. The 14 determinations can be made at any time, one or more hours apart, during the 168-hour period. At least one determination is made on five different days, and one determination is made on the last day of the test period. Each measurement pair consisted of the flow measurements obtained by the manual reference method and the readout of the stack flow measurement system. The tests should be conducted over the range of volumetric flow rates expected during normal operations of the source stack.

2.1 Stack Flow Measurement System Relative Accuracy

Fluor's Vent and Balance Staff performed the manual flow traverses and recorded the stack flow readings. The manual flow traverses were conducted following Work Sequence Plan OTP-2Z-01-1257-24A-168 Hour (shown in Appendix B) which follows the EPA method given in 40 CFR 60, Method 2.

The equipment included a standard prandtl pitot tube and a calibrated electronic manometer. The grid of measurement points was laid out in accordance with the EPA procedure for eight points on each of two linear traverses, arranged perpendicular to each other. The center point was added for additional information between points 4 and 5. Thus, there were nine points along the north-east/ south-west direction and also along the south-east/north-west direction.

The fourteen pairs of readings were obtained over a 168-hour period starting on October 3 and ending on October 10, 2002. Vent and Balance staff recorded velocity pressures at each test point and converted the readings to approximate velocity using a look-up table (ACGIH 1984), which performs the calculation of

Velocity, fpm = 4005 x Sqrt (Velocity pressure, inches of water)

and assumes that the measurement conditions are dry air at 70ºF and 29.92 inches mercury pressure. The point-wise velocity measurements were averaged. The average velocity was multiplied by the stack cross-sectional area to calculate flowrate. These values were later corrected for stack pressure, humidity and temperature to calculate actual volumetric stack flow. A sample data sheet and calculation for Run 14 is included in Appendix C.

Before each manual measurement, the stack flow reading from the measurement system in the instrument cabinet at the stack base was recorded. The flow computer interprets the output of the flow sensor and is programmed with a number of factors including stack area and a correction factor. During this test, the correction factor was set at 1. An additional purpose for performing the relative accuracy test was to determine the needed correction factor. The observed reading was multiplied by the correction factor to determine the measurement system reading used for this test. After the test was completed, the correction factor was programmed into the flow computer so subsequent readings would not need additional correction. The readouts are in terms of standard conditions of 25ºC and 29.92 inches mercury pressure.

The recorded data and calculation of relative accuracy are shown in Table 2.1. The correction factor of 0.8 was used to correct the measurement system data. The differences between the two flow measurements and the square of the differences was calculated. The sum and mean of the differences and the sum of squares of differences were calculated. The 95% confidence interval was then calculated and added to the absolute value of the mean of differences. The percent ratio of this value to the mean reference flow was the percent relative accuracy. The resulting value was 1.35%, meeting the <10% criterion given in the regulation.

2.2 Continual Operability Test

During the above 168-hour test period, the measurement system should undergo no corrective maintenance, repair, replacement or adjustment other than that clearly specified as required in the manufacturer's operation and maintenance manual. Failure of the measurement system to meet this requirement results in a repetition of the 168-hour test period. However, portions of the test which were satisfactorily completed need not be repeated. Any maintenance and system alterations performed shall be noted on pertinent readings before and after all adjustments.

The measurement system operated successfully all during the 168-hour test period.

Table 2.1. Relative Accuracy Data and Calculations

Correction Factor	0.8

Test					Reference Readings			Flow Monitor Readings		Calculations	
Order	Date	Recorded acfm	Relative Humidity	Temp F	Baro in. Hg	Static in. WC	Humidity, pressure, temp and pitot factor corrected scfm	Reading scfm	Corrected Reading, scfm	Differences, di	di^2
1	3-Oct-2001	1631	12.1	90	29.34	0.48	1559	1975	1580.0	-21.0	441
2	4-Oct-2001	1656	10.6	86	29.46	0.5	1594	1950	1560.0	34.0	1156
3	4-Oct-2001	1276	12.0	84	29.48	0.3	1230	1550	1240.0	-10.0	100
4	4-Oct-2001	1218	10.3	84	29.48	0.26	1175	1475	1180.0	-5.0	25
5	5-Oct-2001	1234	13.9	80	29.325	0.25	1190	1490	1192.0	-2.0	4
6	5-Oct-2001	1248	11.6	82	29.385	0.27	1203	1490	1192.0	11.0	121
7	5-Oct-2001	1250	10.3	84	29.367	0.28	1203	1485	1188.0	15.0	225
8	5-Oct-2001	1243	11.0	82	29.325	0.27	1184	1490	1192.0	-8.0	64
9	8-Oct-2001	1211	29.6	74	29.249	0.28	1170	1480	1184.0	-14.0	196
10	8-Oct-2001	1240	29.6	76	29.25	0.27	1196	1490	1192.0	4.0	16
11	8-Oct-2001	1226	27.6	78	29.054	0.3	1176	1500	1200.0	-24.0	576
12	8-Oct-2001	1253	18.3	80	29.261	0.32	1206	1480	1184.0	22.0	484
13	9-Oct-2001	1234	18.0	75	29.458	0.26	1198	1420	1136.0	62.0	3844
14	10-Oct-2001	1210	21.0	73	29.345	0.28	1174	1502	1201.6	-27.6	762
				Mean corrected reference			**1247**				
									Sum of di =	36.4	
									d = Mean di =	2.6	
									Sum di^2 =	8013.8	
									95% Confidence interval	14.2	
									Sum absolute mean difference plus confidence interval	16.8	
									Percentage relative accuracy	**1.35%**	

2.3 Zero and Calibration Drift Tests

The EPA procedure is to perform the flow system calibration procedure at least daily during the 168-hour test period and to record the measurement system's zero and span readings before and after the calibration at zero flow and 67% of maximum flow. The drift in zero and span readings are then calculated in a manner similar to the relative accuracy calculations.

This test was not performed because the stack flowrate could not be reduced without triggering a low flow alarm and risking plant safety by eliminating process area vacuum. However, the flow element and sensor are factory calibrated. The only field calibration methods recommended by the manufacturer are to compare flow readout to manual flow measurements, such as those made during the relative accuracy test or to gas tracer methods. No attempt was made to adjust zero and span settings before or after the fourteen manual flow measurements made.

The relative standard deviation of the readings from Table 2.1 taken following sealing the process gloveboxes (Runs 4 – 14) is 1.5%, giving good indication of the repeatability in indicated flowrate and stability of the calibration. This value may also include any drift in the ventilation flowrate. It is recommended that the measurement system maintenance required in the ANSI N13.1-1999 standard be implemented to monitor for changes in calibration and obstruction of the flow element.

2.4 Orientation Sensitivity Test

In the orientation sensitivity test, the flow element is rotated at -10, -5, 0, 5, and 10 degrees relative to the axis of the stack. The stack flow readout is recorded at each rotation. This is repeated three times at three different stack flowrates, 100%, 67%, and 33% of maximum operating stack flowrate. Before each series of rotations, a manual reference flow measurement is obtained. Thus, there would be nine sets of readings consisting of a manual flow measurement and five measurement system readings.

The orientation test was not conducted on this system. It was felt that the results have little practical value other than meeting a criterion. Once it is installed with the sensor window aligned parallel with the stack flow, any residual orientation effect caused by misalignment with the flow angle becomes part of the overall relative accuracy. If the sensor later becomes loose and rotates, it is unlikely that the flow readings will be corrected because the time of and degree of rotation would be unknown. It is recommended that the orientation of the sensor be inspected as part of an annual accuracy audit (see ANSI/HPS N13.1 Clause 6.2.1).

Orientation sensitivity data has been obtained by the manufacturer under controlled conditions (about 1000 fpm air velocity) in a wind tunnel. Figure 2.2 shows normalized sensor response as function of pitch angle on the x-axis for the flow sensor. The maximum deviation is 1.3% which meets the EPA criterion.

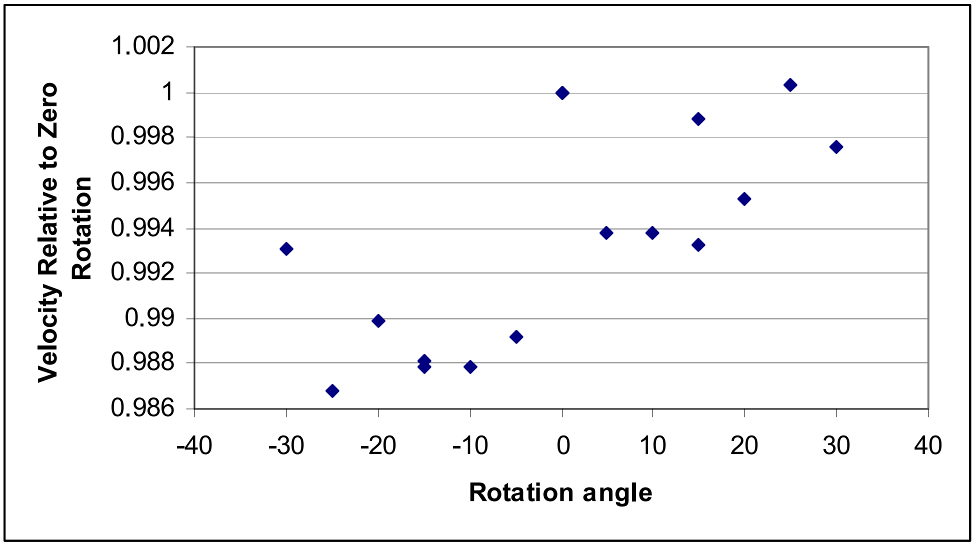

Figure 2.2. Velocity Ratio versus Sensor Rotation Angle

3.0 Conclusions

The tests conducted on the stack flow measurement system demonstrate that the flow measurements are sufficiently accurate. The test results are summarized in Table 3.1. The continual operability and relative accuracy criteria were fully met. The rotational sensitivity test was not conducted; however, the manufacturer's data shows that the sensitivity criterion is met. The zero and calibration drift tests were not conducted; however, the flow system shows excellent repeatability.

Table 3.1. Conclusions on Stack Flow Accuracy

Parameter	Runs/Configuration	Test Results	Criteria	Meets
Rotational Sensitivity	Nine runs. Three reference readings for each of three flow settings, one system reading per five rotational settings per run	Not performed Manufacturer's data shows 1.3% maximum deviation out to 30º rotation	± 4% of reference value	Yes, per manufacturer's data
Continual operability	168-hour period of continual operation	Operated continuously	168-hours minimum	Yes
Relative accuracy	14 paired readings of system and reference measurements over 168-hour period	1.35%	<10% of mean reference value	Yes
Calibration and zero drift	Minimum of five sensor calibration runs	Not performed Repeatability 1.5% relative standard deviation	<3% of span	Not tested

4.0 References

40 CFR 52. 1998. Appendix E, *Performance Specifications and Specification Test Procedures for Monitoring Systems for Effluent Stream Gas Volumetric Flowrate.* U.S. Code of Federal Regulations.

40 CFR 60. 1998. Appendix A, Method 2, as amended. *U.S. Environmental Protection Agency, Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate.* U.S. Code of Federal Regulations.

ACGIH. 1984. *Industrial Ventilation, A Manual of Recommended Practice,* 18th Edition. American Conference of Governmental Industrial Hygienists, Cincinnati, Ohio.

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

Glissmeyer, J.A. and Maughan, A.E. 2001. *Qualification Tests for the Air Sampling System at the 296-Z-7 Stack*. PNNL-13687, Pacific Northwest National Laboratory, Richland, Washington.

Appendix A

EPA Interpretation of Rotational Sensitivity Criterion of 40 CFR 52 Appendix E

Glissmeyer, John A

From: Mcalister.Gary@epamail.epa.gov
Sent: Thursday, December 14, 2000 2:54 PM
To: Glissmeyer, John A
Cc: Harrington.Daric@epamail.epa.gov
Subject: 40CFR52 Appendix E

After reviewing Appendix E of Part 52, Daric and I believe that the requirements for the orientation test need clarification. I am forwarding the guidance that Daric developed. If you have any more concerns about the Performance Specification in Appendix E, please feel free to call either Daric or me. My phone number is (919) 541 -1062.

----- Forwarded by Gary McAlister/RTP/USEPA/US on 12/14/2000 05:33 PM -----

Daric

Harrington   To: Gary McAlister/RTP/USEPA/US@EPA

cc:

12/14/2000   Subject: 40CFR52 Appendix E

05:12 PM

When analyzing orientation sensitivity, according to 40CFR52 Appendix E Section 6.3.5, one must calculate the ratio of each measurement system reading divided by the reference pitot readings, graph the ratio vs. angle of deflection on each side of center (-10, -5, 5, and 10 degrees from center), and report the points at which the ratio differs by more than 4 percent from unity. The reference pitot readings mentioned refer to the pitot readings at zero degrees. Therefore, each measurement system reading must be within four percent of the measurement system reading at zero degrees for a given level of velocity.

Daric Harrington

Appendix B

Work Sequence Plan OTP-2Z-01-1257-24A-168 Hour Operational Test Procedure for the 296-Z-7 Stack Task 1 – 168-Hour Test Procedure

WORK SEQUENCE PLAN OTP-2Z-01-1257-24A-168 Hour

OPERATIONAL TEST PROCEDURE FOR THE 296-Z-7 STACK

TASK 1 – 168-HOUR TEST PROCEDURE

Dally Kincaid
AUG 3 0 2001

2Z-01-01257

2Z-01-01257

1.0 PURPOSE AND SCOPE

1.1 Purpose

This Operational Test Procedure (OTP) has been prepared to demonstrate that the Project W-460 stack monitoring system meets the requirements of 40 CFR 52 Appendix E, 168 hour test.

1.2 Scope

The following characteristics of the stack monitoring system are evaluated as part of this OTP.

1.2.1 40 CFR 52 Appendix E, 168 hour test will be performed.

2.0 REFERENCES

2.1 Drawings

2.1.1 H-2-829482, Rev. 0, "Control Systems Stack Monitoring Cabinet Assembly."

2.1.2 H-2-829443, Rev. 0, "HVAC/Control Systems Airflow & Control Diag. Exhaust Stack Monitoring System."

2.2 W-460-C2, Rev. 1, "Construction Specification Facility Modification to Building 2736-ZB for Plutonium Stabilization and Handling Project"

2.3 HNF-SD-W460-FDC-001, Rev. 2, "Functional Design Criteria Plutonium Stabilization and Handling (PuSH) Project W-460"

2.4 W-460-P13, "Procurement Specification, Exhaust Flow Monitoring System for Plutonium Storage and Handling Project."

2.5 DOE/RL-2000-42 Revision 2, "Radioactive Air Emissions Notice of Construction for Plutonium Finishing Plant Project W-460, 'Plutonium Stabilization and Handling.'"

2.6 WHC-SD-CP-OSR-010, "Plutonium Finishing Plant Operational Safety Requirements."

2.7 HNF-PRO-436, "Radiation Protection Instrumentation Program" (only applicable to calibration).

2.8 HNF-PRO-450, "Air Quality, Radioactive Emissions."

2.9 Codes and Standards

2.9.1 WAC 246-247-075 (3/4/94) "Radiation Protection- Air Emissions, Monitoring, Testing, Quality Assurance."

2.9.2 ANSI N13.1-1999, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities."

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2.9.3 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides other than radon, from DOE Facilities."

2.10 Manuals and Procedures

2.10.1 Canberra CAM System and Alpha Sentry Monitor

2.10.2 Kurz Flow Computer

2.10.3 Hastings Mass Flow Controller

2.10.4 Precision Digital Flow Indicator

3.0 RESPONSIBILITIES

3.1 General

The Test Director of this OTP will designate personnel to assume the responsibilities and duties as defined herein for their respective roles. The designees shall become familiar with this OTP and the systems involved to the extent that they can perform their assigned duties.

3.2 Test Director

3.2.1 Coordinates and directs testing.

3.2.2 Confirms that field-testing and inspections of the system (or portion of the system) to be tested has been completed.

3.2.3 Stops any test, which, in his or her judgment, may cause damage to the system until the problem has been resolved.

3.2.4 After verifying there is no adverse impact, may alter the sequence in which the system or subsystems are tested.

3.2.5 Ensures that required manufacturers specifications are maintained.

3.2.6 If a test is to be suspended for a period of time, ensures that the system is left in a safe mode.

3.2.7 Before restarting suspended test, re-verifies the test prerequisites.

3.2.8 Reviews and approves recorded data, discrepancies, and exceptions.

3.2.9 Obtains information or changes necessary to clear or resolve objections during the performance of the test.

3.2.10 Signs the Execution and Test Approval page when test has been performed.

3.2.11 Signs when test exception has been resolved.

3.2.12 Obtains required signatures on the OTP Master prior to reproduction and distribution.

3.3 Client Representative

3.3.1 Acts as liaison between the participants in operational testing.

3.3.2 Notifies concerned parties when a change is made in the testing schedule.

3.4 Witness (Participating Organizations)

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2Z-01-01257

3.4.1 PFP Safety and QA shall be notified of all portions of the tests and be given the opportunity to select tests they wish to witness.

3.4.2 Witnesses the tests.
3.4.3 Reviews test results.
3.4.4 Assists the Test Director when requested.
3.4.5 Signs when test exception has been resolved.
3.4.6 Signs the Execution and Test Approval page when the test has been performed.

3.5 **Recorder**

3.5.1 Prepares a Field copy from the OTP Master.

3.5.2 Records instrument identification numbers and calibration expiration dates in the applicable sections.

3.5.3 Initials and dates every test step on the Field copy as it is completed next to the step number or on a data sheet, when provided. On data sheets where there is not room for both the initial and date, date may be entered at the bottom of the column.

3.5.4 Records objections and exceptions on a Test Exception Log (Attachment B). Notifies the Test Director at time the objection is observed.
3.5.5 Signs when test exception has been resolved.

3.5.6 Signs the Execution and Test Approval page when the test has been performed.

3.6 **Engineering Manager**

3.6.1 Evaluates results.

3.6.2 Signs for A-E Approval on Execution and Test Approval page for each OTP.

3.7 **Design Authority**

3.7.1 Evaluates results.

3.7.2 Signs for A-E Approval on Execution and Test Approval page for each OTP.

4.0 CHANGE CONTROL

All changes to this Work Sequence Plan shall be made in accordance with FSP-PFP-5-8, Section 13.4, Appendix C.
Technical changes to this document will require a minimum of two Fluor Hanford signatures, one from the Test Director and one from the Stack Monitoring Design Authority. If the Test Director and Design Authority are the same person, the second technical signature must come from the design authority's manager or the chief engineer.

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2Z-01-01257

5.0 TOOLS, EQUIPMENT, AND SUPPLIES

5.1 Tools

5.1.1 Standard hand tools associated with journeyman craftsmen.

5.2 Equipment

5.2.1 2-way Radio Communication.

5.3 Supplies

5.3.1 47 mm filter for record sampler.

5.3.2 Filter for Canberra CAM.

6.0 EXCEPTIONS

6.1 General

6.1.1 Exceptions to the required test results are sequentially numbered and recorded on the Test Exception Log (Attachment B).

6.1.2 Errors/exceptions in the OTP itself are also processed as test exceptions (see Section 4.0 CHANGE CONTROL).

6.1.3 Job Control System (JCS) forms (Work Record, J5 or Work Change Notice, J7) will be used for changes to the procedure.

6.2 Recording

6.2.1 Number each exception sequentially as it occurs and record it on the Test Exception Log (Attachment B).

6.2.2 Enter planned action to resolve each exception when such determination is made on the work package J5 or J7.

6.3 Retest/Resolution

6.3.1 Record the action taken and/or disposition to resolve each exception in the Test Exception Log (Attachment B) and the J5. Action taken may or may not be the same as planned action.

6.3.2 When action taken results in an acceptable retest, individuals indicated in Section 3 sign and date Disposition block on the Test Exception Log.

6.3.3 When action taken does not involve an acceptable retest, do not sign Disposition block and return to step 6.2.2 to determine next planned action.

6.4 Approval And Acceptance

6.4.1 The Design Authority and Quality Control representative provide final approval and acceptance of exceptions. The final disposition will be one of the following:

- Retest Approved and Accepted
- Exception Accepted-As-Is: Requires detailed explanation.
- Other: Requires detailed explanation.

6.4.2 The Design Authority signs and dates for test exception closure.

6.5 Distribution

2Z-01-01257

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6.5.1 All signed originals are attached to the JCS work package.

7.0 SAFETY, PRECAUTIONS, AND LIMITATIONS

7.1 Occupational Safety and Health

Individuals shall carry out their assigned work in a safe manner to protect themselves and others from undue hazards and to prevent damage to property and environment. Facility line managers shall assure the safety of activities within their areas to prevent injury, property damage, or interruption of operation. Performance of test activities shall always include safety and health aspects.

7.2 Personnel

7.2.1 This test will be performed at the PFP Complex, Building 2736-ZB. Personnel Protective Equipment (PPE) will be used as required by applicable PFP work procedures.

7.2.2 Safety Lock and Tag shall be performed in accordance with approved PFP procedures.

7.2.3 All personnel on the test team shall immediately bring any personnel safety concerns to the attention of the Test Director for immediate resolution.

7.3 Personnel Requirements

7.3.1 A qualified PFP HPT with access permission to this CAM system is required for performance of this OTP.

7.3.2 A qualified PFP Instrument Technician with access permission to this CAM system is required for performance of this OTP.

7.3.3 A PFP qualified professional Duty Radiological Control Managers (DRCM) is required to be available (i.e. on call) for this OTP.

7.4 Equipment

7.4.1 Any damage to equipment shall be noted and the Test Director notified.

7.5 Environment

7.5.1 None.

8.0 TEST PROCEDURE

Step		Verified By/ Date
8.1	All open items have been evaluated and verified to not affect the performance of this test (Quality Assurance nonconformance reports, construction punch list, outstanding engineering or design change notices, startup field requests or test deficiency reports).	CT 10-3-01
8.2	Perform a pretest briefing for all personnel involved in the performance of this test.	CaT 10-3-01
8.3	Ensure that all personnel involved in the performance of these tests are informed that the tasks may be worked at the	CT 10-3-01

2Z-01-01257 2Z-01-01257

Step | Verified By/ Date

discretion of the test director (or stack monitor expert), not necessarily in the order given.

8.4 ~~Verify that the CAM system, and record sampler system and related process instrumentation have been calibrated.~~ See New Step 8.4 — 10-3-01

8.5 Verify that one of the exhaust fans is running and the other is on standby.

8.6 Verify that one HEPA filter plenum is operating and the other is on standby.

8.4 CAM system and Record sampler system and Related process instrumentation will be Calibrated during or prior to the sign off of this OTP.

Instrumentation will be calibrated and functionally tested per ZSE-24A-011 and ZSE-24A-012 and data sheet for the Kurz 2Z-7997

Verified By/ Date

10.16.01

2Z-01-01257

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Task IV

GENERAL INFORMATION Run 1

Airflow measurement testing includes 14 stack flow measurements taken over a 168-hour period. For each measurement, velocity and volumetric flow rates are determined per test methods in 40 CFR 60, Appendix A (reference measurement) and compared with a simultaneous, installed instrument reading (system measurement). Differences between reference and system measurements are then averaged to determine relative accuracy of installed airflow monitoring equipment.

The 14 measurements may be made one or more hours apart during the 168-hour test period except that at least one measurement must be made in five different days and one measurement must be made on the last day of the test period.

Installed instrument readings (system measurements) are taken in conjunction with reference airflow measurements. Instruments should be noted and observed for fluctuations at least once per minute while reference airflow measurements are being taken. The average reading observed is entered as the simultaneous system airflow measurement.

This test is performed over a 168-hour period and requires the exhauster to be operating continually throughout this time. If the system shuts-down, the test is void and must be re-started. Contact engineering immediately if this occurs.

PROCEDURE

1.1 168-HOUR FLOW TEST

NOTE - THIS TEST IS REQUIRED TO BE RUN AT LEAST 168-HOURS CONTINUOUSLY. IF THE EXHAUST FAN(S) SHUT(S) DOWN DURING THIS PERIOD CONDUCT STARTUP IMMEDIATELY. THE MEASUREMENT SYSTEM SHALL NOT REQUIRE ANY CORRECTIVE MAINTENANCE, REPAIR, OR ADJUSTMENT DURING THE 168-HOUR PERFORMANCE AND OPERATIONAL TEST PERIOD. FAILURE OF THE MEASUREMENT SYSTEM TO MEET THIS REQUIREMENT SHALL CALL FOR A REPETITION OF THE 168-HOUR TEST PERIOD (SECTION 1.8).

General Procedure Information and Conditions for this Section

Steps 1.2.3 and 1.2.4 will ONLY be performed at the beginning of this test.

Step 1.2.4 will ONLY be performed at the beginning of this test and can be performed out of sequence.

Step 1.2.6 will ONLY be performed at the completion of the test.

1.2 A pre-test leak check of the reference method apparatus shall be performed (Section 1.6) prior to performing Section 1.1 tests.

Note- A post-test leak-check of the reference method apparatus shall be performed (Section 1.10) at the end of taking a set of measurements taken along Test Ports 1 and 2.

Note – A standard pitot tube performance check (Attachment 5) shall be performed during a set of measurements taken along the Test Port 1 and Test Port 2 port traverses.

1.2.1 Perform a pre-test leak-check of the reference method apparatus per Section 1.6 of this procedure.

1.2.2 At the beginning of this test, if the system is not operating, THEN start system per operating instructions. Verify system is running

Typo

1.2.3 Record the start date and start time of test in Step 28 of Attachment ~~12~~. 11 eT

11 10-3-01

1.2.4 Calculate the completion date and time in Step 29 of Attachment ~~12~~. This will include adding 7 days to the start date recorded in Step 28 and adding 2 hours to the start time recorded in Step 28 (An additional 2 hours will be used for conservatism to assure the 168-hours are met). This is to be signed by both the Test Director and Engineering.

1.2.5 Record the end date and end time of test in Step 30 of Attachment ~~12~~. 11 eT 10-3-01 Typo

Note: For this test to be valid, the system must run continuously for 168-hours.

1.3 RECORD TEST EQUIPMENT INFORMATION

1.3.1 RECORD the equipment information and calibration data in Step 1 of Attachment 1.

1.3.2 IF additional or replacement instruments(s) are used. RECORD equipment information and calibration data in Step 2 of Attachment 1 AND EXPLAIN in COMMENTS section of Attachment 1.

1.4 RECORD BAROMETRIC PRESSURE

NOTE - The barometric pressure may be read and recorded at any time before, during or after this procedure is performed. The time of the reading must be recorded along with the barometric pressure value and the elevation and location of the reading verified.

1.4.1 CONTACT the Hanford Weather Forecaster by telephone (373-2716).

1.4.2 REQUEST absolute barometric pressure (P_b) for closest weather station AND RECORD pressure and time of pressure reading in Step 3 of Attachment 2.

1.5 RECORD INSTALLED INSTRUMENTATION READINGS

1.5.1 RECORD instrument readings and information in Step 4 of Attachment 2.

1.5.2 IF installed instruments are NOT in working condition STOP test AND PERFORM repair THEN

NOTE in COMMENTS Section of Attachment 2, Step 4.

1.6 PERFORM PRE-TEST LEAK CHECK

1.6.1 BLOW air into pitot tube impact hole until manometer reads at least ± 3.00 in. WG. AND RECORD impact pressure reading in Step 5 of Attachment 2.

1.6.2 CLOSE OFF hole opening AND WAIT at least 15 seconds.

NOTE - Leak check PASSES if manometer reading remains stable (± 0.2 in. WG.) for at least 15 seconds; otherwise, leak check FAILS.

1.6.3 OBSERVE manometer reading AND RECORD in Step 5 Attachment 2 whether leak check PASSES or FAILS.

1.6.4 APPLY suction to pitot tube static pressure hole until manometer reads at least ± 3.00 in. WG. AND RECORD Static pressure reading in Step 5 of Attachment 2.

1.6.5 CLOSE off hole opening AND WAIT at least 15 seconds.

NOTE - Leak check PASSES if manometer reading remains stable (± 0.2 in. WG.) for at least 15 seconds; otherwise, leak check FAILS.

1.6.6 OBSERVE manometer reading AND RECORD in Step 5 of Attachment 2 whether leak check PASSES or FAILS.

1.6.7 IF either leak check fails, REPAIR OR REPLACE equipment as required AND REPEAT Steps 1.6.1 through 1.6.6.

1.7 TEST FOR ZERO DRIFT AND CALIBRATION DRIFT

The Zero Drift and Calibration Drift tests are required by 40 CFR 52 Appendix E, Sections 3.3 and 3.4, respectively. These tests will not be performed. The code states these tests will be performed only if appropriate. The tests are not appropriate for this case, because if the flow instrument is zeroed, alarms will sound for low flow conditions.

1.8 TEST STACK AIR-FLOW

General Procedure Information and Conditions for this Section

Traverse point intervals on ATTACHMENTS are measured relative to stack or duct internal diameter (I.D.).

1.8.1 MARK temperature probe and pitot tube for traverse point intervals shown on Attachments 3 and 4.

1.8.2 READ relative humidity (RH) in stack air stream, Test Port 1, AND RECORD in Step 6 of Attachment 3.

1.8.3 READ static air pressure (P_g) in stack air stream, Test Port 1, AND RECORD in Step 7 of Attachment 3.

1.8.4 READ stack air temperature (t_s) at each traverse point in order shown on Attachments 3 and 4, Test Ports 1 and 2, respectively, AND RECORD in Step 8 of Attachment 3 and Step 12 of Attachment 4.

1.8.5 READ velocity pressure (VP) at each traverse point in order shown on Attachments 3 and 4 AND RECORD in Step 8 of Attachment 3 and Step 12 of Attachment 4.

1.9 VERIFY STANDARS PITOT TUBE PERFORMANCE

NOTE - If last traverse point reading can be duplicated, this traverse point may be used to verify pitot tube performance. However, if velocity pressure at the last traverse point is unsuitably low (less than 0.04 in. WG.), then the traverse point with the highest velocity pressure value should be used to verify pitot tube performance.

1.9.1 COPY last traverse point measurement from Attachment 4 AND RECORD as VP1 in Step 14 of Attachment 5.

1.9.2 PURGE pitot tube impact and static pressure holes with pressurized air.

1.9.3 REPEAT last traverse point measurement AND RECORD reading as VP2 in Step 14 of Attachment 5.

1.9.4 CALCULATE percent difference (P) between measurements:

$$P=100\frac{(VP_1-VP_2)}{VP_1}$$

NOTE - If percent difference is greater than ± 5% AND velocity pressure at VP1 is less than 0.04 in. WG., repeating Steps 1.8.3 through 1.9.4 is NOT required. Engineering will determine acceptability of VP measurements.

1.9.5 IF percent difference is greater than ± 5% AND VP1 is equal to or greater than 0.04 in. WG., REPEAT Steps 1.8.3 through 1.9.4.

1.9.6 RECORD the time airflow test is completed at the bottom of Attachments 3 and 4.

1.10 PERFORM POST-TEST LEAK CHECK

NOTE -A post-test leak-check shall be performed to validate each traverse run.

1.10.1 BLOW air into pitot tube impact hole until manometer reads at least ± 3.00 in. WG. and RECORD impact pressure reading in Step 15 of Attachment 5.

1.10.2 CLOSE off hole opening and WAIT at least 15 seconds.

NOTE - Leak check PASSES if manometer reading remains stable (± 0.2 in. WG.) for at least 15 seconds; otherwise, leak check FAILS.

1.10.3 OBSERVE manometer reading AND RECORD in Step 15 of ATTACHMENT 5 whether leak check PASSES or FAILS.

1.10.4 APPLY suction to pitot tube static pressure hole until manometer reads at least ± 3.00 in. WG. AND RECORD Static pressure reading in Step 15 of ATTACHMENT 5.

1.10.5 CLOSE OFF hole opening AND WAIT at least 15 seconds.

NOTE - Leak check PASSES if manometer reading remains stable (± 0.2 in. WG.) for at least 15 seconds; otherwise, leak check FAILS.

1.10.6 OBSERVE manometer reading AND RECORD in Step 15 of ATTACHMENT 5 whether leak check PASSES or FAILS.

1.10.7 IF leak check fails, REPAIR OR REPLACE equipment as required AND REPEAT Steps 1.8.3 through 1.10.6.

1.11 RESTORATION

1.11.1 REMOVE test equipment AND RESTORE air system to operating configuration.

1.11.2 WIPE equipment on removal from stack/duct.

1.11.3 INSTALL all caps, plugs, or instrumentation on test ports.

1.12 PERFORM AIR-FLOW TEST CALCULATIONS

1.12.1 DETERMINE Total T_S for the test port(s) and enter value in Step 9 and Step 13 of Attachments 3 and 4.

1.12.2 ADD the Total T_S from Step 9 and Step 13 of Attachments 3 and 4 as applicable, AND ENTER summed value in Step 18 of ATTACHMENT 6.

1.12.3 DETERMINE Average T_S by dividing Total T_S from Step 18 of ATTACHMENT 6 by number of traverses AND ENTER value in Step 19 of ATTACHMENT 6.

1.12.4 CALCULATE Velocity FPM for each traverse point AND ENTER values in Step 8 and Step 12 of Attachments 3 and 4:

$$FPM = 4005 \times (VP)^{1/2}$$

1.12.5 DETERMINE Total FPM for the test port(s) AND ENTER in Step 9 and Step 13 of Attachments 3 and 4.

1.12.6 ADD the Total FPM's from Step 9 and Step 13 of Attachments 3 and 4 as applicable, AND ENTER summed value in Step 20 of ATTACHMENT 6.

1.12.7 DETERMINE Average FPM by dividing Total FPM from Step 20 of ATTACHMENT 6 by number of traverses entries AND ENTER value in Step 21 of ATTACHMENT 6.

1.12.8 CALCULATE Total CFM to determine stack airflow AND ENTER value in Step 22 of ATTACHMENT 6.

TOTAL CFM = AVERAGE FPM x *DUCT AREA (SQ FT)*

1.13 DISPOSITION

1.13.1 Test Director PERFORM the following:

1.13.1.1ENSURE performing personnel restore caps, plugs, and instrumentation to original configuration AND PRINT name, SIGN AND DATE in Step 24 of ATTACHMENT 8.

1.13.1.2INFORM Shift Manager that field work is complete.

1.13.2 Vent & Balance Reviewer ENSURE ATTACHMENTS 2 through 7 are complete, accurate, and legible AND PRINT name, SIGN AND DATE on Step 23 of ATTACHMENT 8.

1.13.3 FORWARD procedure to Engineering for completion of required calculations and data analysis or use an equivalent spreadsheet.

1.13.3.1WHEN calculations are COMPLETE REQUEST Environmental Engineer PRINT name SIGN AND DATE in Step 25 of ATTACHMENT 8.

2.0 TEST COMPLETION

2.1 TEST DIRECTOR ENSURE all tests were completed and passed.

2.1.1 REVIEW all data.

2.1.2 VERIFY all calculations are correct.

2.1.3 COMPLETE Step 26 of ATTACHMENT 8, PRINT name, SIGN AND DATE.

2.1.4 VERIFY Section 1.0 is complete.

Test Director Signature ______ Date 10/10/01

Appendix C

Sample Test Data for Run 14

run #14

ATTACHMENT 1 - INSTRUMENT CALIBRATION DATA

INSTRUMENT CALIBRATION DATA		
Step 1	AIR-FLOW INSTRUMENT	HYGROMETER
	Flow Instrument Type Micro	Equipment Number 1067069
	Instr. Code Number 799-28-09-015	Instr. Code Number 799-28-01-015
	Instr. Cal Due Date 7-19-02	Instr. Cal Due Date 8-8-02
ADDITIONAL INSTRUMENT CALIBRATION DATA		
Step 2		

COMMENTS:

Test completed at 0825 am

Initials/Date : RLW 10-10-01

ATTACHMENT 2 - BAROMETRIC PRESSURE READING

BAROMETRIC PRESSURE READING					
Hanford Weather Forecaster (373-2716)					
Step 3	Location	Station Number	Elevation (ft)	Time of Reading	Barometric Pressure (in. Hg)
	200 WEST	19	675	0805	29.345 (P_b)
	COMMENTS:				

INSTALLED INSTRUMENT READINGS				
Step 4	Operating exhaust fan:	EF-1-25BA		EF-2-25BA
	Instrument	Location	Reading	
	FIT 24A01	STACK CAM	(CFM) 1502	
	Instrument in working condition?		YES	NO
	COMMENTS:			

PRE-TEST PRESSURE LEAK CHECK			
Step 5	[Reading ≥ 3.0 in WG and stable (± 0.2 in WG) for 15 sec.]	Impact Pressure 3.06 PASS FAIL	Static Pressure 3.18 PASS FAIL
	COMMENTS:		

Initials/Date: RLW 10-10-01

ATTACHMENT 3 - STACK AIR-FLOW MEASUREMENTS

STACK AIR-FLOW MEASUREMENTS						
TEST PORT SE						
Step 6	Relative Humidity:		21% (RH)			
Step 7	Static Pressure:		INITIAL		RETEST (IF REQUIRED)	
			+.28" wg (P_g)		(P_g)	
Step 8	Traverse Points* (in.)	Temp.	Velocity (Initial)		Velocity (Retest)	
measured as 2227 ft² EDS 10-10-01	ID = 38.7 cm 15.25 in. Area = 1178 sq cm, 183 sq in, ~~1.27~~ sq. ft.	T_s (°F)	VP (in.WG)	fpm** (ft/min)	VP (in. WG)	fpm** (ft/min)
	1.3 cm, 0.5"	73	.051	909		
	4.1cm, 1.6"	73	.055	939		
	7.6 cm, 3.0"	73	.050	896		
	12.5cm, 4.9"	73	.055	939		
	25.7 cm, 10.1"	73	.056	948		
	30.5 cm, 12.0"	73	.066	1029		
	34.0 cm, 13.4"	73	.070	1060		
	36.8 cm, 14.5"	73	.060	981		
Step 9	T_s(total)	584	fpm(total)	7696	Fpm(total)	

ATTACHMENT 4 - STACK AIR-FLOW MEASUREMENTS

STACK AIR-FLOW MEASURE MENTS						
TEST PORT NE.						
Step 12	Traverse Points* (in.)	Temp.	Velocity (Initial)		Velocity (Retest)	
measured as $1.227 ft^2$, [illegible] 10-10-01	ID = 38.7 cm 1.27 ft., 15.25 in. Area = 1178 sq cm, 183 sq in, ~~1.27~~ sq. ft.	T_S (°F)	VP (in. WG)	fpm** (ft/min)	VP (in. WG)	fpm** (ft/min)
	1.3 cm, 0.5"	73	.054	931		
	4.1cm, 1.6"	73	.058	965		
	7.6 cm, 3.0"	73	.052	913		
	12.5cm, 4.9"	73	.062	997		
	25.7 cm, 10.1"	73	.073	1082		
	30.5 cm, 12.0"	73	.072	1075		
	34.0 cm, 13.4"	73	.070	1060		
	36.8 cm, 14.5"	73	.069 (VP1)	1052	(VP1)	
Step 13	T_S(total)	584	fpm(total)	8075	Fpm(total)	

* Traverse points are measured relative to internal diameter (i.d.); none may be located within 0.5 in. of stack walls.

ATTACHMENT 5 - STANDARD PITOT TUBE PERFORMANCE CHECK

PITOT TUBE PERFORMANCE CHECK		
Step 14	(PASS = P ≤ ± 5%); FAIL = P > ± 5%) P = [(.09 (VP1) - .069 (VP2)) ÷ .069 (VP1)] x 100 = 0 % If P > ± 5% AND VP1 < 0.04 in. WG, air-flow retest is NOT required; Engineer will determine acceptability of pitot tube performance.	PASS/FAIL
	COMMENTS:	

POST-TEST PRESSURE LEAK CHECK			
Step 15	[Reading ≥ 3.0 in. WG and stable (± 0.2 in. WG) for 15 sec.]	Impact Pressure 3.10 PASS / FAIL	Static Pressure 3.00 PASS / FAIL
	COMMENTS:		

Initials/Date RLW 10-10-01

ATTACHMENT 6 - STACK AIR-FLOW CALCULATIONS

STACK AIR-FLOW CALCULATIONS			
Step 18	Total $T_S = T_{S1} + T_{S2}$	$T_{S(total)}$	* 1168
Step 19	Average T_S = Total T_S ÷No. Traverses	$T_{S(AVG)}$	73
Traverse Point Velocity (FPM) = 4005 VP		Attachments 5 & 6	
Step 20	Total fpm = fpm1 + fpm2	$fpm_{(total)}$	* 15771
Step 21	Average fpm = Total fpm ÷No. Traverses	$fpm_{(AVG)}$	986
Step 22	Total CFM = Average fpm • ~~1.27~~ 1,227 sq.ft. stack cross-sectional area e08 10-10-01	$CFM_{(total)}$	1210

* ADD Totals from Step 9 and 13.

Initials/Date : RLW 10-10-01

ATTACHMENT 7 - AIR-FLOW CALCULATION WORKSHEET (Sheet 1 of 2)

ENGINEERING AIR-FLOW CALCULATION WORKSHEET

AVERAGE ACTUAL STACK GAS VELOCITY (V_S)

$$V_S = K_P \bullet C_P \bullet (VP)^{1/2}_{AVG} \bullet (T_{S(AVG)} / \{P_S \bullet M_S\})^{1/2}$$

AVERAGE STACK GAS DRY VOLUMETRIC FLOW RATE (Q_{sd})

$$Q_{SD} = 60 \bullet (1\text{-}B_{WS}) \bullet V_S \bullet A \bullet (T_{STD} / T_{S(AVG)}) \bullet (P_S / P_{STD})$$

$$\cancel{= 60 \bullet (1\text{-}B_{WS}) \bullet K_P \bullet C_P \bullet (VP)^{1/2}_{AVG} \bullet A \bullet (T_{STD} / P_{STD}) \bullet \{P_S / (T_{S(AVG)} / M_S)\}^{1/2}}$$

CDS
10-10-01

Eq. Input	Description	Value
B_{WS}	Stack gas water vapor: $B_{WS} = (RH / 100) \bullet (P_{WS} / P_S)$	5.83×10^{-3}
RH	Stack relative humidity, percent	21 (Page)
P_{WS}	Vapor pressure of H_2O at temperature $T_{S(AVG)}$	0.82
K_P	Pitot tube constant: 85.49 ft/sec • [{(lb) • (in. Hg)} / {(lb-mole) •°R • (in. H_2O)}]$^{1/2}$	85.49
C_P	Pitot tube coefficient, standard	0.99
$(VP)^{1/2}_{AVG}$	Average of velocity pressure sqrt, in. WG: $(VP)^{1/2}_{AVG} = fpm_{(AVG)} / 4005$	0.25
~~fpm(AVG)~~ f/sec avg CDS 10-10-01	Average stack gas velocity, ~~ft/min~~ f/sec CDS 10-10-01	16.50 (Page)
A	Cross-sectional stack area, ft^2	1.227
T_{STD}	Standard absolute temperature, °R	528

ATTACHMENT 7 - AIR-FLOW CALCULATION WORKSHEET (Sheet 2 of 2)

ENGINEERING AIR-FLOW CALCULATION WORKSHEET		
P_{std}	Standard absolute pressure, in. Hg	29.92
P_s	Absolute stack gas pressure, in. Hg: $P_s = P_b + (P_g / 13.6)$	29.37
P_b	Barometric pressure at test port, in. Hg	29.345 (Page)
P_g	Stack static pressure, in. WG	0.28 (Page)
$T_{s(avg)}$	Average absolute stack temperature, °R $T_{s(avg)} = 460 + T_{s(avg)}$	533
$T_{s(avg)}$	Average stack gas temperature, °F	73 (Page)
M_s	Molecular weight stack gas, wet, lb/lb-mole: $M_s = 29 \cdot (1 - B_{ws}) + 18 \cdot B_{ws}$	28.94

CALCULATION (Q_{sd})

Q_{sd} = 1174 dscfm

Q_{sd} – (CF)*(Kurz, Ref Step 4, Attachment 2)= D_i

Calculation (D_i)

D_i = -31 scfm

Environmental Engineer Initials/date: B. Nelson-Maki 10/16/01
ENG Initials/Date: CDB 10-15-01

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