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PNNL-32782, Rev 0
WTP-RPT-251, Rev 0

Hanford Waste Treatment Plant Effluent Management Facility Stack Effluent Monitoring

Sampling Probe Location Qualification Evaluation

April 2022

Julia E Flaherty
Ernest J Antonio
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Richard C Daniel
Jennifer Yao

U.S. DEPARTMENT OF ENERGY

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

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Summary

The Hanford Tank Waste Treatment and Immobilization Plant Effluent Management Facility (EMF) stack monitor location was qualified using a combination of scale model stacks to mitigate the risk of identifying that the sampling location does not meet the qualification criteria on the full-scale stack. The LV-S1 scale model stack was used as a baseline, augmented by the LB-S1 and LV-S2 scale model stacks to address the Direct Feed Low Activity Waste Effluent Management Facility Vessel Vent Process (DVP) injection into the main Active Confinement Ventilation (ACV) system duct. As required by the American National Standards Institute/Health Physics Society (ANSI/HPS) N13.1-1999 standard, the scale model and its sampling locations were geometrically similar to the actual stack, and the Reynolds numbers for both the actual and model stacks were >10,000. An additional criterion is that the product of the hydraulic diameter and mean velocity (DV) of the full-scale stack must be between 1/6 DV and 6 DV of the scale model stack tests. The LV-S1, LB-S1, and LV-S2 scale model stack tests have met the criteria of the ANSI/HPS N13.1-1999 standard to demonstrate the stack sampling locations are well mixed. Verification tests of the EMF stack were performed at normal operating conditions. The minimum 1/6 DV value and the maximum 6 DV value from the scale model testing determine the range of stack flow rates for which the full-scale stack may be operated while remaining in compliance with the stack verification criterion. Based on the LV-S1 scale model test DV values, the corresponding stack flow rates for the EMF stack are as listed in Table S1.

Table S1. Effluent Management Facility Stack Qualified Flow Range

Stack Parameter	EM-1
Minimum Qualified Stack Flow (scfm)	781
Maximum Qualified Stack Flow (scfm)	53,432

The remaining criteria for the stack verification to be considered valid involve the flow angle and velocity uniformity results. First, the flow angle at the full-scale stack must be ≤20°. Second, the velocity uniformity at the full-scale stack must be ≤20% coefficient of variance (COV). Finally, the velocity uniformity results for the actual and scale model stack tests must agree within 5% COV. These criteria were met through the full-scale stack test at the EMF. Flow angle results were <5°; all flow angle results were within the ≤20° criterion. The velocity uniformity results for each test condition ranged between 2.2% COV and 4.3% COV, all of which were within the range of the target % COV values from the scale model tests on the LV-S1, LB-S1, and LV-S2 scale models.

Based on these stack verification test results, the EMF filtered exhaust stack sampling location meets the qualification criteria provided in the ANSI/HPS N13.1-1999 standard for all fan operating configurations. This includes each combination of ACV fans with DVP exhausters. Further changes to the system configuration or operating conditions that are outside the qualified flow rates described in this report may require additional tests or analyses to determine compliance with the standard.

Acknowledgments

This effort was performed under the project management of Mike Wentink of Bechtel National, Inc. (BNI). We acknowledge support from Ryan Cioli, Bill Jackson, and Clarke Respess from BNI in facilitating Pacific Northwest National Laboratory staff in observing the stack tests at the Effluent Management Facility. We also acknowledge Zach Harding, Connor Everly, and Kelly Dorsi from Bison Engineering, Inc., who were accommodating to our staff observing in the field during testing and asking questions.

The quality assurance measures employed to produce this document include oversight and guidance from our quality engineer, David MacPherson, as well as independent reviews from Matthew Barnett. Chrissy Charron provided administrative support for this effort. Finally, Cary Counts served as the technical editor for this document.

Acronyms and Abbreviations

Ø	duct diameter
% COV	percent coefficient of variation
acfm	actual cubic feet per minute, an air volume flow unit at actual conditions
ACV	Active Confinement Ventilation (system)
ANSI	American National Standards Institute
BNI	Bechtel National, Inc.
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DV	product of the hydraulic diameter and the mean velocity
DVP	Direct Feed LAW Effluent Management Facility Vessel Vent Process
EM-1	Effluent Management Facility air exhaust stack
EMF	Effluent Management Facility
HPS	Health Physics Society
LAB	Laboratory (facility)
LAW	Low Activity Waste (facility)
M&TE	measuring and test equipment
NESHAP	National Emissions Standards for Hazardous Air Pollutants
PNNL	Pacific Northwest National Laboratory
scfm	standard cubic feet per minute, an air volume flow unit at standard air density (standard conditions used here are 68°F and 14.7 psia)
sfpm	standard feet per minute, an air velocity unit at standard air density (standard conditions used here are 68°F and 14.7 psia)
WTCC	Waste Treatment Closure Company LLC
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WTPSP	Waste Treatment Plant Support Project

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1.0 Introduction

Stack verification tests were performed by a Bechtel National, Inc. (BNI)/Waste Treatment Completion Company (WTCC) contractor at the exhaust stack monitoring location of the Hanford Tank Waste Treatment and Immobilization Plant (WTP) effluent management facility (EMF) stack to evaluate whether it meets applicable regulatory criteria (i.e., Washington Administrative Code, Chapter 246-247) governing effluent monitoring systems.

Emissions from the EMF air exhaust stack, EM-1, are estimated to remain below the threshold limit of 0.1-millirem per year given in Title 40 of the Code of Federal Regulations (CFR), Part 61, National Emissions Standards for Hazardous Air Pollutants (NESHAP), Subpart H, National Emissions Standard for Emissions of Radionuclides Other than Radon from Department of Energy Facilities. However, continuous emissions sampling is planned for the first year of stack operations. The NESHAP rule requires that a sampling probe be located in the exhaust stack according to criteria established by the American National Standards Institute/Health Physics Society (ANSI/HPS) N13.1-1999, Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stack and Ducts of Nuclear Facilities. Compliance with the standard is demonstrated through a series of tests as described in the standard. This standard allows, under certain conditions, for results from previously tested stacks to be used instead of a full series of tests. For the EMF stack, previous scale model test results were used, and verification tests were performed on the full-scale stack.

While a contractor to WTCC performed the verification tests, Pacific Northwest National Laboratory (PNNL) provided guidance for these tests, performed data reduction following the tests, and produced this report to provide an assessment of the compliance of the stack sampling location. PNNL previously performed scale model tests that served as the basis for these full-scale stack verification tests. This prior involvement put PNNL in a unique position to provide the data reduction rigor and process insight to evaluate these stack verification results. This document provides stack flow information, details of the stack qualification criteria, and a review of the scale model tests. Section 2 describes the verification test methods, while Section 3 describes the results of these tests. Section 4 compares the results from the verification tests against the scale model test results, while conclusions are summarized in Section 5.

The EM-1 stack exhausts air from two systems: 1) the Direct Feed Low Activity Waste (LAW) Effluent Management Facility Vessel Vent Process (DVP) and 2) the Active Confinement Ventilation (ACV) systems. The combined unabated radionuclide emission dose for the EM-1 stack is 1.77E-03 mrem/year (Walker 2019). The DVP system, which handles off gas from vessel vents and the EMF evaporator, will have higher radiological emissions (1.54E-03 mrem/year, unabated) compared with the ACV (2.57E-04 mrem/year, unabated), which is the building ventilation system (Walker 2019). Table 1 provides information about EMF stack operations. The most current data sheets for these stacks were used for the flow rates listed in Table 1. Two fans supply the bulk of the air flow to the exhaust duct. One fan operates at a time, while the other serves as a backup. The DVP flow is supplied by two exhausters—one that is in operation while the other serves as backup. The DVP flow is 160 scfm, compared with the 26,870 scfm total stack flow under normal operating conditions. Velocity and flow values presented in this document use standard units, and standard conditions used are 68°F and 14.7 psia.

Table 1. EM-1 Stack Design Parameters as of May 2018

Stack Parameter	Value
Discharge diameter (in.)	38
Duct diameter at sampling probes (in.)[a]	46
Number of duct diameters from sampling probes to upstream disturbance	23.5[b]
Total available fans	2
Number of operating fans	1
Maximum flow rate (scfm)[c]	30,901
Normal operating flow rate (scfm)[a]	26,870

a. DS No: 24590-BOF-JFD-SDJ-81031, Rev 0 (available from PNNL)
b. Based on data reported in Flaherty and Antonio (2019)
c. Assumed as 115% of the normal flow rate

1.1 Qualification Criteria

The qualification criteria for an air monitoring probe location are taken from ANSI/HPS N13.1-1999 and are paraphrased as follows:

1. *Angular Flow* – Sampling nozzles usually are aligned with the axis of the stack. If the air travels up the stack in a cyclonic fashion, the air velocity vector approaching a sampling nozzle could be sufficiently misaligned with the nozzle to impair extraction of particles. The average of the flow angle measurements, made at several discrete points in the duct cross section at the sampling nozzle position, should not exceed 20° relative to the sampling nozzle axis.
2. *Velocity Uniformity* – The air velocity must be uniform across the stack cross section where the sample is extracted. The air velocity is measured at the same grid of points as the flow angle measurements. Uniformity is expressed as the variability of the measurements about the mean. This is expressed using the percent coefficient of variation (% COV),[1] which is the standard deviation divided by the mean and expressed as a percentage. The lower the % COV value, the more uniform the velocity. The acceptance criterion is that the air velocity must be ≤20% COV in the center two-thirds of the duct cross section at the sampling probe location.
3. *Gaseous Tracer Uniformity* – A uniform contaminant concentration in the sampling plane enables the extraction of samples that represent the true concentration within the duct. The uniformity of the concentration is first tested using a tracer gas to represent gaseous effluents. The fan is a good mixer, so injecting the tracer downstream of the fan provides worst-case results. The qualification criteria are that 1) the measured tracer gas concentration is ≤20% COV across the center two-thirds of the duct cross section at the sampling location and 2) the concentrations at any of the measurement points cannot deviate from the mean by >30%.
4. *Particulate Tracer Uniformity* – The second set of tests that address contaminant concentration uniformity at the sampling position uses tracer particles large enough to exhibit inertial effects. Tracer particles of 10-µm aerodynamic diameter are used by default unless it is known that larger contaminant particles will be present in the airstream. The acceptance criterion is that the particle concentration is ≤20% COV across the center two-thirds of the duct at the sampling location.

[1] *Coefficient of variation* is also known as *percent relative standard deviation*. The standard uses the term *coefficient of variation*, so it will likewise be used here.

Tests to determine if Criteria 1 through 4 are met have been conducted on scale model stacks of geometrically similar exhaust ductwork and stacks, from the fans to the planned position of the sampling probes. The use of the LV-S1, LB-S1, and LV-S2 scale model stack results to qualify the EMF stack is documented in Flaherty and Antonio (2019). Scale model test results are documented in Glissmeyer, Flaherty, and Piepel (2011), Glissmeyer and Geeting (2013), and Glissmeyer, Antonio, Flaherty, and Amidan (2014). The ANSI/HPS N13.1-1999 standard establishes additional acceptance criteria for the use of a scale model or another, similar stack as a substitute for the actual stack. The criteria for the use of substitute stacks are:

- The scale model and its sampling location must be geometrically similar to the actual stack.

  The product of the hydraulic diameter and the mean velocity (DV) for the candidate stack must be within a factor of six of that of the tested stack, and the hydraulic diameters of the stack must be at least 250 mm at the sampling location.

  – For clarity, the DV requirement can be expressed as 1/6 DV of scale model stack ≤DV of full-scale stack ≤6 DV of scale model stack.

- The Reynolds number for the actual and model stacks must be >10,000.

Finally, scale model results are considered valid if measurements on the full-scale stack show:

- The flow angle criterion (with a mean value ≤20°) is met.
- The velocity uniformity criterion (with ≤20% COV) is met.
- The velocity uniformity results for the actual and model stacks agree within 5% COV.

1.2 Scale Model Tests

Scale model tests have been performed at PNNL using primarily 12-in.-diameter ducting to represent WTP stacks. The use of the LAW LV-S1, Laboratory (LAB) LB-S1, and LAW LV-S2 scale model stack results to qualify the EMF stack is documented in Flaherty and Antonio (2019). Glissmeyer, Flaherty, and Piepel (2011), Glissmeyer and Geeting (2013), and Glissmeyer, Antonio, Flaherty, and Amidan (2014) report on the complete set of tests that were performed with the scale model stacks. This includes tests of flow angle, velocity uniformity, gaseous tracer uniformity, and particulate tracer uniformity. Tests were performed for a range of conditions, including different combinations of fans and flow rates to account for the range of operating conditions that were reported by BNI at the time of those scale model tests. Test matrices for the scale model tests were designed to provide information concerning the well-mixed nature of the sampling location for each stack. That is, different stack operating condition attributes were varied with different fixed operating conditions so that, in total, the full range of conditions were considered. For example, while three port locations may have been tested, each port location may not have been tested with every fan condition or operating flow rate. The resulting data therefore were used to confirm that the stack location is qualified for well-mixed sampling and monitoring.

Table 2 presents a summary of the duct diameter and range of velocity values measured during the velocity uniformity tests performed with the LV-S1, LB-S1, and LV-S2 scale model stacks. For consistency with the stack data sheets for these stacks and also with the verification test results, the velocity values are presented in standard units (i.e., standard feet per minute [sfpm]; the standard conditions used here are 68°F and 14.7 psia).

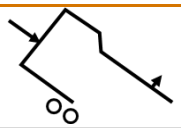
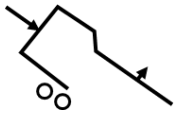
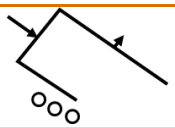
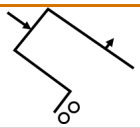
Table 2. Summary of the Acceptable Ranges of Diameter x Velocity Products from Scale Model Stacks used to Qualify the EM-1 Stack

Stack	Diameter (in.)	Velocity Range (sfpm)	1/6 DV (ft^2/min)	6 DV (ft^2/min)
LV-S1	11.8	1,581 – 2,997	259	17,748
LB-S1	11.9	2,602–4,377	434	26,262
LV-S2	12.0	1,501 – 4,769	250	28,540

Note: Because the stack diameter is nominally 1 ft, the Velocity Range column, based on the range of velocities from velocity uniformity tests is essentially equivalent to the DV.

Table 3, which is adapted from Table 2.2 of Flaherty and Antonio (2019), includes simple schematics for the EMF and surrogate stacks. The schematics indicate the location and number of fans (open circles), number of stack bends, injection locations that are most comparable to the introduction of DVP flows (arrows pointed toward the duct), and stack sampling locations (arrows pointed away from the duct). Each stack shares the same basic feature of a "U-shaped" section with stack sampling on the downstream leg. The nominal duct diameter (Ø) and relevant lengths (as multiples of duct diameter) also are included in Table 3.

Table 3. EMF and Surrogate Stack Features (adapted from Flaherty and Antonio, 2019)

	EMF	LV-S1 Scale	LB-S1 Scale	LV-S2 Scale
Simple Stack Schematic				
Ø at Sampling Location	46 in.	48 in. (full scale) 12 in. (scale model)	60 in. (full scale) 12 in. (scale model)	60 in. (full scale) 12 in. (scale model)
Duct Length along Injection	5.3 Ø	1.45·Ø	6.73·Ø	9.62 Ø
Dist. to last disturbance	23.5 Ø	17.4·Ø	10.3·Ø	18.4·Ø
Applicable Stack Qualification Tests				
Velocity Uniformity	N/A	Yes	N/A	N/A
Flow Angle	N/A	Yes	N/A	N/A
Gaseous Tracer Uniformity	N/A	ACV - Yes DVP - Limited	DVP - Yes	DVP - Yes
Particulate Tracer Uniformity	N/A	ACV – Yes DVP - No	DVP - Yes	DVP – Yes

Note: The Simple Stack Schematic row presents line drawings that represent duct arrangements, with open circles representing fans, long arrows pointed toward the duct representing DVP (or comparable) injection locations, and short arrows pointed away from the duct representing stack sampling locations.

The LV-S1 scale model stack geometry is very similar to the EMF stack geometry. LV-S1 scale model test results support the qualification of the stack sampling location for the EM-1 stack for the velocity uniformity and flow angle qualification criteria, as well as the gaseous and particulate tracer uniformity for the ACV flow but had limited data to support gaseous and particulate tracer uniformity for the DVP flow. Stacks LB-S1 and LV-S2 both are functionally

similar to the EMF duct based on features downstream of the DVP injection, and scale model stack results from these stacks are used to support the gaseous and particulate tracer uniformity for the DVP flow. While the LV-S1 scale model stack is used as the primary stack for the EM-1 qualification, the LB-S1 and LV-S2 scale model tracer uniformity results augment the LV-S1 results for the DVP injection.

1.3 Quality Assurance

Work performed by PNNL staff documented in this report was performed in accordance with the Waste Treatment Plant Support Program (WTPSP) Quality Assurance Plan and associated procedures. The WTPSP implements the requirements of ASME NQA-1-2000, Quality Assurance Requirements for Nuclear Facility Applications, graded on the approach presented in NQA-1-2000, Subpart 4.2, Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development.

The WTPSP works in conjunction with PNNL's laboratory-level Quality Management Program, which is based on requirements defined in U.S. Department of Energy (DOE) Order 414.1D, Quality Assurance, and 10 CFR 830, Nuclear Safety Management, Subpart A, Quality Assurance Requirements. PNNL implements these requirements with a graded approach using the consensus standard ASME NQA-1-2000, Quality Assurance Requirements for Nuclear Facility Applications, graded on the approach presented in NQA-1-2000, Subpart 4.2, Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development.

The WTPSP QA Plan describes the technology life-cycle stages, which include the progression of technology development, commercialization, and retirement in process phases of basic and applied research and development, engineering and production, and operation until process completion. The work described in this report has been completed under the QA Technology Level of Development Work.

2.0 Verification Test Methods

Bison Engineering, Inc. (Bison), performed tests at the EM-1 stack during the week-long period of March 22–26, 2021. The Test Plan (Bison Engineering Inc. 2021[1]) provided the test matrix of stack fan configurations to be used for the tests (see Table 4). Fans A and B are in the main stack duct to deliver flow from the ACV system, while exhausters A and B deliver flow from the DVP system. Each fan/exhauster combination was tested at the EM-1 stack. Tests in support of 40 CFR 52, Appendix E, also were performed during this test period, which dictated that 14 stack flow tests be performed as an independent measurement for comparison with the stack flow monitor for the stack. As shown in Table 4, multiple tests were performed for each fan configuration because variations in results are common among field measurements.

Table 4. EM-1 Stack Test Matrix. All tests performed at normal operating flow conditions. The same number of tests were performed for flow angle and velocity uniformity.

Fan Configuration	Number of Flow Angle, Velocity Uniformity Tests
Fan A/Exhauster A	4
Fan B/Exhauster A	3
Fan A/Exhauster B	3
Fan B/Exhauster B	4

Bison followed test measurement practices as guided by Environmental Protection Agency Methods 1 and 2 (40 CFR 60, Appendix A) and did not follow a separate Test Instruction or Test Procedure. Flow angle tests were performed with an s-type pitot tube, a digital level, and an oil-filled slant-tube manometer. Velocity uniformity tests were performed with a standard pitot tube and an electronic manometer, along with a desktop weather station for ambient temperature and pressure measurements and a thermocouple for in-stack temperature measurements. Each stack traverse comprised eight discrete measurement points across the diameter of the duct, plus the center point. Two traverses, positioned 90° apart, were used to complete each measurement set. Figure 1 and Figure 2 show the measurement locations on the north and south sides of the EM-1 stack.

For each traverse, the probe (s-type or standard pitot tube) was inserted completely into the stack such that the tip contacted the far wall, and then backed away the necessary distance from that wall to measure point 1. Triplicate measurements were made at each point before moving to the next point. Method 1 does not specify how measurements should be made and making three measurements at the traverse point is adequate. During tests, the port cover plate was replaced with a relatively thin plate with a hole in the center that was just large enough for the pitot tube, and duct tape was used to seal the opening when the port was not in use.

[1] Bison Engineering, Inc. 2021. Effluent Management Facility Flow Verification Test Plan. 24590-CM-HC4-HX00-00007-01-00006 Rev 00B. Helena, Montana.

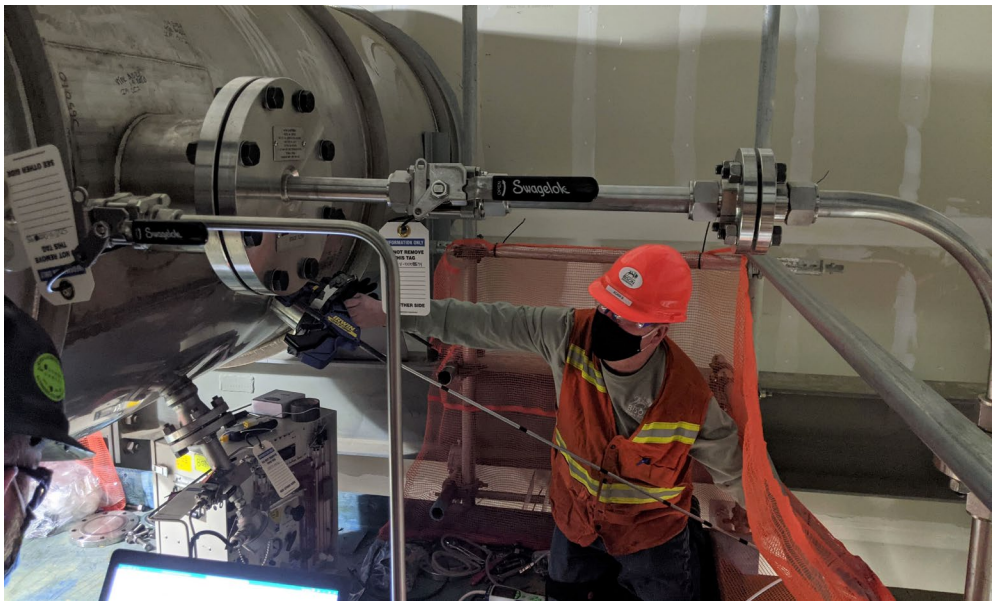


Figure 1. EM-1 Stack Measurements Made from the North Side of the Stack

Figure 2. EM-1 Stack Measurements Made from the South Side of the Stack

While Bison performed the tests under a subcontract from WTCC, PNNL staff were present at most tests to observe how they were executed. Because of obstructions in the test area (e.g., railings, scaffold flooring), the pitot tube was not positioned exactly along the duct diameter during all portions of the test. As a result, measurements in the stack may have been co-planar, but not exactly at the specific, planned positions. This will not have a practical impact on the measurement results because the data collected from each measurement point is used to determine an overall average flow angle or % COV value. Equipment used for these tests generally were marked with calibration information. The barometer, digital manometer, and thermocouple, as well as the pitot tubes were checked in-house before and after each testing trip.

3.0 Verification Test Results

PNNL was directed by BNI to use data collected by Bison to perform the EM-1 verification testing data reduction. PNNL staff were observers during most of the testing so that the equipment used, the measurement techniques, and data recording process could be evaluated. PNNL staff also recorded a subset of measurements from each test when observation was performed to provide secondary quality assurance for the data. The quality assurance process at PNNL included following the procedure for qualification of existing data through data corroboration and sponsor-directed use of data. Test Data Packages were developed to document the observation forms completed by PNNL staff and data sheets provided by the Bison report.

Velocity-uniformity measurements collected by Bison were the delta-pressure values, which were then converted to velocity values by Bison to complete the velocity uniformity data sheets. PNNL performed a spot-check of the conversions from delta-pressure to velocity for these velocity uniformity tests. Data in the Bison report then were used as input to PNNL-controlled Excel spreadsheets to eliminate the possibility that unexpected calculation modifications were made in the spreadsheets transmitted to Bison. These spreadsheets then were subject to calculation reviews to document the accuracy of the calculations from both a theoretical and numerical perspective.

While most of the data in the Bison and PNNL data sheets are identical, there are some instances of minor differences between the values calculated in the Bison report and those calculated by PNNL. The primary source of these differences is that Bison provided velocity values to one decimal point in the data sheets, but the value in the cells appear to have more digits (from the conversion from inches of water). The PNNL data sheets used the single decimal point values in the subsequent calculations. Appendix A contains the flow angle and velocity sheets that were produced by PNNL to support this analysis. Because of errors discovered after the initial issue of the Bison report in 2021,[1] the use of the original velocity data as the starting point for corrections to the velocity values, and the small differences that exist due to the rounding that results from those velocity data, there are instances where the individual velocity values differ by <0.01% between the Bison 2022 report[2] and PNNL velocity data sheets. Average velocities, however, are identical for all tests.

Appendix B contains a table that summarizes the quality assurance documents that have been produced by PNNL as part of this EMF verification effort.

3.1 EM-1 Verification Tests

Table 5 summarizes the flow angle and velocity uniformity test results from the EM-1 stack verification tests. The DV values, calculated from the stack nominal diameter and the velocity computed from Environmental Protection Agency Method 1 measurement points are included in Table 5 for reference. Note that the flow angle and velocity uniformity tests for each numbered test were performed in sequence so the velocity uniformity test flow and DV value is expected to be representative of the flow during the flow angle test as well. All test results meet the criterion of flow angle values ≤20°and velocity uniformity values ≤20% COV.

[1] Bison Engineering, Inc. 2021. Effluent Management Facility Flow Verification. 24590-CM-HC4-HX00-00007-01-00007 Rev 00B. Helena, Montana.
[2] Bison Engineering, Inc. 2022. Effluent Management Facility Flow Verification. 24590-CM-HC4-HX00-00007-01-00007 Rev 00C. Helena, Montana.

Table 5. EM-1 Verification Test Results

Fan Configuration	Test Number	Flow Angle (°)	Velocity Uniformity Test Flow (scfm)	Velocity Uniformity (% COV)	DV (ft^2/min)
Fan A/Exhauster A	7	4.0	27,289	2.2	9,064
	8	4.9	27,108	2.4	9,004
	9	4.0	27,034	2.7	8,979
	10	2.6	26,845	2.5	8,917
Fan B/Exhauster A	1	3.3	26,785	4.1	8,897
	2	3.1	28,121	3.0	9,340
	14	3.1	27,098	2.9	9,000
Fan A/Exhauster B	11	3.9	27,113	2.6	9,006
	12	4.6	27,122	2.6	9,008
	13	3.5	26,787	3.0	8,897
Fan B/Exhauster B	3	2.6	27,401	3.0	9,101
	4	2.9	27,002	4.3	8,969
	5	3.2	27,287	3.8	9,063
	6	3.1	27,113	3.7	9,006

4.0 Comparisons of Verification Test and Scale Model Test Results

While the stack verification test results demonstrate that both the flow angle and velocity uniformity values are acceptable compared with the qualification criteria, the velocity uniformity values must be compared with the scale model test results to accept the full suite of stack qualification test results from the scale model tests. Table 6 presents a summary of the normal operating velocity for the stack, along with the corresponding DV values. Additionally, Table 6 includes the LV-S1 scale model DVs and 6 DV range, which provides the upper limit of the full-scale stack DV values for which the surrogate stack may be used to represent the full-scale stack.

Table 6. Calculation of Acceptable DV Ranges

Stack	Diameter (in.)	Stack Data Sheet		Bison Test Condition		Scale Model[c]	
		Operating Velocity[a] (sfpm)	DV (ft^2/min)	Operating Velocity[b] (sfpm)	DV (ft^2/min)	DV (ft^2/min)	6 DV (ft^2/min)
EM-1	46	2,328	8,924	2,353	9,018	1,557–2,958	9,341-17,747

a. Velocity based on normal operating flow velocity from stack data sheet, DS No: 24590-BOF-JFD-SDJ-81031 (available from PNNL).
b. Velocity based on average velocity measured during velocity uniformity tests performed by Bison.
c. Based on LV-S1 scale model stack values

There was no appreciable difference between the Bison test conditions and the stack design conditions presented on the data sheets. The Bison test conditions were performed under normal operating flow conditions according to the operators at the time of the tests. The Bison test velocity was 2,353 sfpm while the stack data sheet velocity was 2,328 sfpm. While these differences are small, the practice of comparing the scale model stack conditions against both the data sheet and Bison test conditions will be retained in this report.

Note also that the verification of each scale model data point is not required to qualify the sampling location for specific operating configurations or conditions. As noted in Section 1.2, the scale model tests are used to confirm the overall range of conditions for which the stack location is qualified. Table 6 summarizes that DVs from the stack data sheets and the Bison test conditions are within the required 1/6 DV (not shown in Table 6) and 6 DV. While the DV ranges for the LB-S1 and LV-S2 are slightly larger than the LV-S1 DV values, the most geometrically similar scale model stack is used as the basis for the EM-1 qualification, so the LV-S1 scale model will define the range of DV values for the verification.

The EMF stack qualification was based primarily on the LV-S1 scale model stack constructed at a PNNL outdoor facility. The LV-S1 results were reported in Glissmeyer, Flaherty, and Piepel (2011). To address the DVP injection, the LB-S1, and LV-S2 scale model stack results were included to augment the LV-S1 results. The LB-S1 results were reported in Glissmeyer and Geeting (2013), and the LV-S2 results were reported in Glissmeyer, Antonio, Flaherty, and Amidan (2014). The scale model test matrices were not designed to address the EMF stack, and the flow rates considered during the scale model tests were meant only to capture the range of conditions expected for the respective LAW and LAB stacks.

4.1 LV-S1 Scale Model Results

Table 7 presents the results of velocity tests performed on the LV-S1 scale model stack. Scale model tests with this stack were performed with each fan individually and at flows meant to represent the minimum and maximum stack flow rates at the time of the tests. Three test port locations were used during the scale model tests, and these test ports were separated by 5 duct diameters. Test Port 1 was located farthest downstream at 17.4 duct diameters from the upstream disturbance (stack bend) compared with the EMF stack sampling location, which is 23.5 duct diameters from the bend. The LV-S1 scale model results are expected to be conservative, as stack contaminants are expected to be slightly more well-mixed with downstream distance because mixing continues as the air exhaust moves further downstream in the stack or duct.

Table 7. Summary of LV-S1 Scale Model Velocity Uniformity Tests. Adapted from Table 4.14 of Glissmeyer, Flaherty, and Piepel (2011).

Operating Fan(s)	Test Port	Flow Condition[a]	Test Number	Velocity (sfpm)[b]	6 DV[c] (ft^2/min)	% COV	Average % COV	Target % COV
A	1	Max	VT-19	2995	17,690$^{D/B}$	5.9	5.6	0.6≤x≤10.6
		Max	VT-20	2961	17,489$^{D/B}$	5.5		
		Max	VT-21	2940	17,365$^{D/B}$	5.4		
	2	Max	VT-22	2997	17,748$^{D/B}$	4.5	4.5	≤9.5
		Min	VT-18	1768	10,470$^{D/B}$	3.5	3.6	≤8.6
		Min	VT-24	1692	10,020$^{D/B}$	3.7		
	3	Max	VT-23	2893	17,088$^{D/B}$	6.0	6.0	1.0≤x≤11.0
B	1	Max	VT-12	2784	16,444$^{D/B}$	6.5	6.5	1.5≤x≤11.5
		Min	VT-13	1581	9,338$^{D/B}$	4.3	4.3	≤9.3
	2	Max	VT-5	2556	15,137$^{D/B}$	6.2	5.7	0.7≤x≤10.7
		Max	VT-6	2528	14,971$^{D/B}$	6.1		
		Max	VT-7	2523	14,941$^{D/B}$	5.1		
		Max	VT-8	2720	16,108$^{D/B}$	5.7		
		Max	VT-9	2744	16,250$^{D/B}$	5.2		
		Max	VT-10	2731	16,173$^{D/B}$	5.7		
		Min	VT-14	1595	9,446$^{D/B}$	4.8	4.8	≤9.8
	3	Max	VT-11	2840	16,774$^{D/B}$	6.3	6.3	1.3≤x≤11.3
		Min	VT-15	1676	9,899$^{D/B}$	6.4	5.9	0.9≤x≤10.9
		Min	VT-16	1674	9,887$^{D/B}$	4.7		
		Min	VT-17	1658	9,793$^{D/B}$	6.7		

a. Labeling for maximum or minimum flow conditions (i.e., Max or Min) is based on data provided at the time of the scale model tests and may not reflect current maximum or minimum design flow rates.
b. Velocity values previously reported in units of actual feet per minute (afpm) were converted to sfpm using 68°F as the standard temperature and 14.7 psia as the standard pressure.
c. DV values result in the latest data sheet values (D), the Bison test conditions (B) fell within the range for the use of scale model stack qualification data.

LV-S1 scale model velocity uniformity results were similar between Fan A and Fan B operations. The Fan A Test Port 1 results at maximum flow conditions averaged 5.6% COV. With Fan B, there was only one test at maximum flow conditions at Test Port 1, and the test result was 6.5% COV. At Fan B Test Port 1 at minimum flows conditions, the velocity uniformity was 4.3% COV. Overall, velocity uniformity verification tests with results ≤9.3% COV meet the ANSI/HPS N13.1-1999 criterion. Results from EM-1 tests performed by Bison were between 2.2 and 3.0% COV for Fan A operations and were between 2.9 and 4.3% COV for Fan B operations, which meets the criterion.

Scale model tests of gaseous and particulate tracer uniformity were performed at the same conditions used for the velocity uniformity tests.

4.2 LB-S1 Scale Model Results

Table 8 presents the results of velocity tests performed on the LB-S1 scale model stack. Scale model tests with this stack were performed with all three fan combinations of two-fan operations: Fans A and B, Fans A and C, and Fans B and C. Fans A and B were tested for the minimum, normal, and maximum flow conditions, while Fans A and C and Fans B and C were tested only at minimum and maximum stack flow rates according to the data sheets at the time of the tests. Tests were performed at Test Port 1, which is located 10.3 duct diameters from the upstream bend. The EMF stack sampling location is 23.5 duct diameters from the bend. The LB-S1 scale model results are expected to be conservative, as stack contaminants are expected to be slightly more well-mixed with downstream distance because mixing continues as the air exhaust moves further downstream in the stack or duct.

LB-S1 scale model velocity uniformity results were similar between the different fan operations. Maximum flow conditions tended to have slightly higher average % COV results compared with the minimum flows. Results for Fans A and B at maximum flow conditions averaged 5.4% COV. For Fans B and C, the average velocity uniformity of the two tests at maximum flow conditions was 3.7% COV, while for Fans A and C, results were slightly higher with average velocity uniformity of 7.3% COV at maximum flow and 6.4% COV at minimum flow conditions. Overall, velocity uniformity verification tests with results ≤8.3% COV meet the ANSI/HPS N13.1-1999 criterion. Results from EM-1 tests performed by Bison were between 2.2 and 4.3% COV overall, which also meet the criterion.

Scale model tests of gaseous and particulate tracer uniformity were performed at the same conditions used for the velocity uniformity tests.

Table 8. Summary of LB-S1 Scale Model Velocity Uniformity Tests

Operating Fan(s)	Test Port	Flow Condition[a]	Test Number	Velocity (sfpm)	6 DV[b] (ft^2/min)	% COV	Average % COV	Target % COV
A and B	1	Max	VT-1	4,331	25,986$^{D/B}$	5.9	5.4	0.4 ≤ x ≤ 10.4
		Max	VT-2	4,377	26,262$^{D/B}$	7.6		
		Max	VT-3	4,202	25,212$^{D/B}$	5.2		
		Max	VT-4	4,260	25,560$^{D/B}$	5.6		
		Max	VT-19	4,320	25,920$^{D/B}$	4.0		
		Max	VT-20	4,297	25,782$^{D/B}$	4.3		
		Norm	VT-5	3,623	21,738$^{D/B}$	3.9	3.9	≤8.9
		Norm	VT-6	3,633	21,798$^{D/B}$	3.4		
		Norm	VT-7	3,605	21,630$^{D/B}$	4.2		
		Norm	VT-8	3,573	21,438$^{D/B}$	4.2		
		Min	VT-9	2,602	15,612$^{D/B}$	3.5	3.3	≤8.3
		Min	VT-10	2,624	15,744$^{D/B}$	3.3		
		Min	VT-11	2,619	15,714$^{D/B}$	3.3		
		Min	VT-12	2,616	15,696$^{D/B}$	3.1		
A and C	1	Max	VT-13	4,178	25,068$^{D/B}$	7.2	7.3	2.3 ≤ x ≤ 12.3
		Max	VT-14	4,115	24,690$^{D/B}$	7.4		
		Min	VT-15	2,928	17,568$^{D/B}$	6.4	6.4	1.4 ≤ x ≤ 11.4
B and C	1	Max	VT-16	4,222	25,332$^{D/B}$	3.4	3.7	≤8.7
		Max	VT-17	4,361	26,166$^{D/B}$	4.0		
		Min	VT-18	3,008	18,048$^{D/B}$	3.4	3.4	≤8.4

a. Labelling for maximum, normal, or minimum flow conditions (e.g., Max, Norm, or Min) is based on 83%, 100%, or 115%, of the normal stack flow data provided at the time of the scale model tests, which may not reflect current design flow rates.
b. DV values result in the latest data sheet values (D), the Bison test conditions (B) fell within the range for the use of scale model stack qualification data.

4.3 LV-S2 Scale Model Results

Scale model tests with the LV-S2 scale model stack were performed with each fan individually and at flows meant to represent the minimum and maximum stack flow rates. Table 9 presents the results of the LV-S2 scale model stack velocity uniformity tests. Test Port 1 was located 18.2 duct diameters downstream of the nearest upstream disturbance (stack bend), compared with the EMF stack sampling location, which is 23.5 duct diameters from the stack bend. The LV-S2 scale model results are expected to be conservative, as stack contaminants are expected to be slightly more well-mixed with downstream distance because mixing continues as the air exhaust moves further downstream in the stack or duct.

Table 9. Summary of LV-S2 Scale Model Velocity Uniformity Tests. Adapted from Table 4.1 of Glissmeyer, Antonio, Flaherty, and Amidan (2014).

Operating Fan(s)	Test Port	Flow Condition[a]	Test Number	Velocity (sfpm)[b]	6 DV[c] (ft^2/min)	% COV	Average % COV	Target % COV
A	1	Max	VT-7	4778	28,596$^{D/B}$	4.1		
		Max	VT-8	4459	26,682$^{D/B}$	4.6	4.7	≤9.7
		Max	VT-9	4513	27,008$^{D/B}$	5.5		
		Min	VT-4	1639	9,811$^{D/B}$	4.6		
		Min	VT-5	1637	9,797$^{D/B}$	4.7	4.6	≤9.6
		Min	VT-6	1660	9,937$^{D/B}$	4.5		
B	1	Max	VT-10	4590	27,466$^{D/B}$	4.0	4.0	≤9.0
		Min	VT-1	1520	9,099$^{D/B}$	5.1		
		Min	VT-2	1505	9,008$^{D/B}$	5.2	5.1	0.1≤x≤10.1
		Min	VT-3	1504	9,002$^{D/B}$	5.0		

a. Labeling for maximum or minimum flow conditions (i.e., Max or Min) is based on data provided at the time of the scale model tests and may not reflect current maximum or minimum design flow rates.
b. Velocity values previously reported in units of afpm were converted to sfpm using 68°F as the standard temperature and 14.7 psia as the standard pressure.
c. DV values result in the latest data sheet values (D), the Bison test conditions (B) fell within the range for the use of scale model stack qualification data.

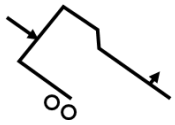
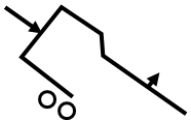
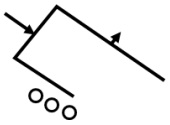
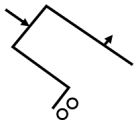
Differences between the velocity uniformity results for minimum and maximum conditions or between Fan A or Fan B operations were relatively minor. The result for Fan A at maximum flow conditions was 4.7% COV, while at minimum flow conditions, the result was 4.6% COV. This means that full-scale verification test results with a velocity uniformity value ≤9.6% COV is clearly acceptable for Fan A cases. The result for Fan B at maximum flow conditions was 4.0% COV, while at minimum flow conditions, the result was 5.1% COV. This means that full-scale verification tests with a velocity uniformity value ≤9.0% COV is clearly acceptable for Fan B cases. Overall, velocity uniformity verification tests with results ≤9.0% COV meet the ANSI/HPS N13.1-1999 criterion. Results for EM-1 tests performed by Bison were between 2.2 and 4.3% COV overall, which meets the criterion.

Scale model tests of gaseous and particulate tracer uniformity were performed at the same conditions used for the velocity uniformity tests and at two different injection port locations.

5.0 Summary/Discussion

The WTP EMF exhaust stack sampling and monitoring location was qualified using a combination of scale model stacks to mitigate the risk of identifying that the sampling location does not meet the qualification criteria on the full-scale stack. The LV-S1 scale model stack was used as a baseline, augmented by the LB-S1 and LV-S2 scale model stacks to address the DVP injection into the main ACV system duct. As required by the ANSI/HPS N13.1-1999 standard, the scale model and its sampling locations were geometrically similar to the actual stack and the Reynolds numbers for both the actual and model stacks were >10,000. Table 10 summarizes the stack design and applicable stack qualification tests for each scale model stack. Table 11 summarizes the stack diameter at the sampling location, operating fans, and flow rates for the EMF and LV-S1 stacks. The LV-S1 scale model stack served as the basis for the qualification of the EM-1 stack, and the full-scale stack flow rates from the stack data sheet are presented for comparison.

Table 10. EMF Stack and Surrogate Applicable Stack Qualification Data Availability

	EMF	LV-S1 Scale	LB-S1 Scale	LV-S2 Scale
Simple Stack Schematic[a]				
Velocity uniformity	N/A	Yes	N/A	N/A
Flow angle	N/A	Yes	N/A	N/A
Gaseous uniformity	N/A	ACV - Yes DVP - Limited	DVP - Yes	DVP - Yes
Particulate uniformity	N/A	ACV – Yes DVP - No	DVP - Yes	DVP – Yes

a. Line drawings representing duct arrangements, with open circles representing fans, long arrows pointing toward ducts to represent DVP (or comparable) injection locations, and short arrows pointed away from ducts to represent stack sampling locations.

Table 11. EMF and Surrogate Stack Design Summary

Stack Parameter	EMF	LV-S1[a]
Duct diameter at sampling probes (in.)	46	48
Number of duct diameters from test port to upstream disturbance	23.5	17.4
Total available fans	2	2
Number of operating fans	1	1
Design Maximum flow rate (scfm)[b]	30,901	48,000
Design Normal operating flow rate (scfm)	26,870	37,905
Design Minimum flow rate (scfm)[c]	18,809	18,950

a. DS No: 24590-LAW-JFD-SDJ-21040, Rev 4
b. Based on 115% of the normal flow rate listed in DS No: 24590-BOF-JFD-SDJ-81031, Rev 0
c. Based on 70% of the normal flow rate listed in DS No: 24590-BOF-JFD-SDJ-81031, Rev 0 (data sheets available from PNNL)

An additional criterion for using scale model test results is that the DV of the full-scale stack must be between 1/6 DV and 6 DV of the scale model tests. Table 12 summarizes the stack flow conditions from the EM-1 verification tests along with the range of DV values from the qualification tests from the LV-S1 scale model stack and the corresponding velocity and flow rates for the full-scale stack. Verification tests were performed at normal operating conditions and did not specifically address maximum or minimum flows. As a result, the average flow rate represents the typical flow rate from those tests. The minimum and maximum qualified stack flow rates are based on the DV values from the scale model tests and do not address other constraints, such as the rated velocity range of the shrouded probe or deposition on the probe. Based on the range of DV values and the corresponding stack flow rate range, the average verification test flow rate was within the acceptable range, and the design flow rates (from Table 11) also are within the acceptable range.

Table 12. EMF Stack Sampling/Monitoring Location Qualification Summary

Stack Parameter	Value
Verification Test Average Flow Rate (scfm)	27,150
Verification Test Average DV (ft^2/min)	9,018
Minimum Allowable DV (1/6 DV, ft^2/min) [a]	259
Maximum Allowable DV (6 DV, ft^2/min) [b]	17,747
Minimum Qualified Stack Velocity (sfpm)	68
Maximum Qualified Stack Velocity (sfpm)	4,630
Minimum Qualified Stack Flow (scfm)	781
Maximum Qualified Stack Flow (scfm)	53,432

a. Minimum DV value for the EM-1 stack based on 1/6 DV from the LV-S1 scale model tests, also found in Table 2.
b. Maximum DV value for the EM-1 stack based on 6 DV from the LV-S1 scale model tests, also found in Table 2 and Table 6.

The remaining criteria for the stack verification to be considered valid involve the flow angle and velocity uniformity results. First, the flow angle at the full-scale stack must be ≤20°. Second, the velocity uniformity at the full-scale stack must be ≤20% COV. Finally, the velocity uniformity results for the actual and scale model stack tests must agree within 5% COV. These criteria were met for the comparison of the LV-S1 scale model tests and the full-scale stack tests at EM-1, as shown in Table 13. The EM-1 results are also within the most conservative results for LB-S1 (≤8.3% COV) and LV-S2 (≤9.0% COV).

Table 13. EMF Stack Sampling/Monitoring Location Qualification Test Result Summary

Operating Fan(s)	Average Flow Angle (deg)	Average Velocity Uniformity (% COV)	LV-S1 Target % COV[a]
Fan A Only	3.9	2.6	0.6 ≤ x ≤ 10.6
Fan B Only	3.1	3.5	0.4 ≤ x ≤ 10.4

a. Based on the most conservative Test Port 1 result.

Based on these stack verification test results, the EM-1 filtered exhaust stack sampling location meets the qualification criteria provided in the ANSI/HPS N13.1-1999 standard for all fan operating conditions. Further changes to the system configuration or operating conditions that are outside the qualified flow rates described in this report may require additional tests or analyses to determine compliance with the standard.

6.0 References

10 CFR 830, Subpart A. “Quality Assurance Requirements.” *Code of Federal Regulations*, U.S. Department of Energy.

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

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

ANSI/HPS N13.1-1999. *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*. American National Standards Institute and the Health Physics Society, McLean, VA (reaffirmed in 2011 as ANSI/HPS N13.1-2011).

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Glissmeyer JA, JE Flaherty, and GF Piepel. 2011. *Assessment of the Group 5-6 (LB-C2, LB-S2, LV-S1) Stack Sampling Probe Locations for Compliance with ANSI/HPS N13.1-1999*. PNNL-20154. WTP-RPT-209 Rev 0. Pacific Northwest National Laboratory. Richland, Washington.

Glissmeyer JA and JGH Geeting. 2013. *Assessment of Waste Treatment Plant LAB D3V (LB-S1) Stack Sampling Probe Location for Compliance with ANSI/HPS N13.1-1999*. PNNL-22167, WTP-RPT-227 Rev 0, Pacific Northwest National Laboratory, Richland, Washington.

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Washington Administrative Code, Chapter 246-247, Radiation Protection – Air Emissions.

Appendix A – Stack Verification Data Sheets

A.1 Flow Angle Data Forms

FLOW ANGLE DATA FORM

Stack	EM-1		Run No.	FA-1	
Date	3/22/2021		Fan Setting	NA	Hz
Start/End Time	11:06	11:43	Fan Configuration	Fan B	Exhauster A
Testers	ZDH/ARB		Stack Temp	70.9	deg F
Stack Dia.	46	in	Approx. air vel.	2408	afpm at point Mean All
Stack X-Area	1661.9	in2	Units	degrees (clockwise > pos. nos.)	
Elevation	691	ft	Port	A & B	
Distance to disturbance	85.67	ft			

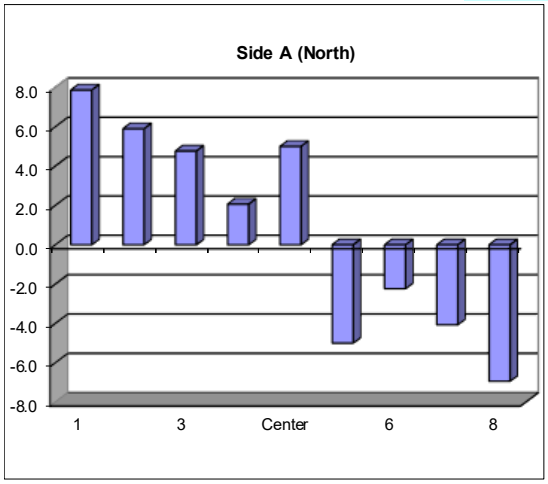
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	8.3	8.7	6.6	7.9	6.6	7.4	10.3	8.1
2	4.83	5.4	6.9	5.4	5.9	2.5	4.2	2.7	3.1
3	8.92	4.9	5.1	4.3	4.8	1.1	3.9	1.8	2.3
4	14.86	2.3	2.1	1.8	2.1	4.1	0.4	0.8	1.8
Center	23.00	4.5	6	4.5	5.0	0.6	1.9	2.4	1.6
5	31.14	-6.4	-5.9	-2.7	-5.0	-0.7	-0.2	-0.9	-0.6
6	37.08	-2.3	-2.2	-2.2	-2.2	-5.3	-1.2	-4.8	-3.8
7	41.17	-8.8	-2.5	-0.9	-4.1	-2.1	-2.8	-7.2	-4.0
8	44.53	-6.7	-6.5	-7.6	-6.9	-5.5	-10.4	-5.4	-7.1
Mean of absolute values:					4.9				3.6
" " w/o points by wall:					4.1				2.5
								Grand mean ABS	4.2
								Grand mean ABS w/o wall pts	3.3

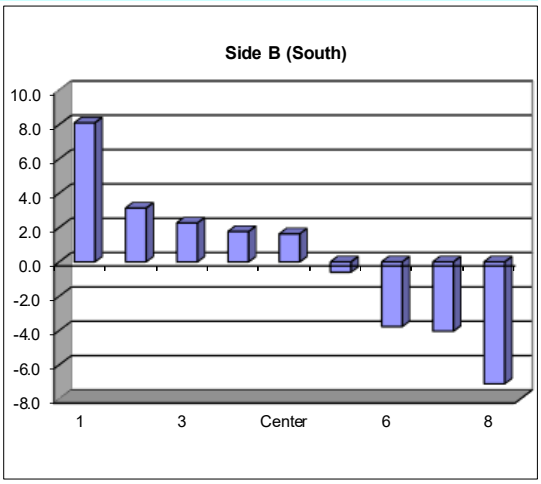
Instruments Used:		Cal. Due
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-2
Date	3/22/2021	Fan Setting	NA Hz
Start/End Time	13:48 14:01	Fan Configuration	Fan B Exhauster A
Testers	ZDH/ARB	Stack Temp	71.55 deg F
Stack Dia.	46 in	Approx. air vel.	2519 afpm at point : Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

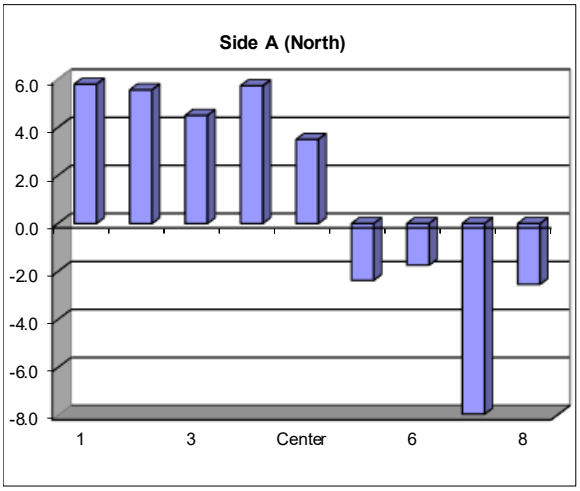
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	5.3	4.5	7.6	5.8	4.1	5.9	4.6	4.9
2	4.83	6.9	5.1	4.7	5.6	1.1	2.5	1.6	1.7
3	8.92	3.3	5.7	4.5	4.5	1.4	0.8	1.9	1.4
4	14.86	4.5	6.4	6.3	5.7	3.7	4.0	4.6	4.1
Center	23.00	4.6	2.9	3.0	3.5	0.9	0.3	0.1	0.4
5	31.14	-4.0	-1.7	-1.4	-2.4	-0.3	-0.1	-0.5	-0.3
6	37.08	-1.3	-0.2	-3.7	-1.7	-1.7	-1.3	-1.5	-1.5
7	41.17	-8.3	-6.9	-8.6	-7.9	-0.5	-5.3	-2.6	-2.8
8	44.53	-1.9	-2.4	-3.3	-2.5	-0.9	-0.6	-0.9	-0.8
Mean of absolute values:					4.4				2.0
" " w/o points by wall:					4.5				1.7
								Grand mean ABS	3.2
								Grand mean ABS w/o wall pts	3.1

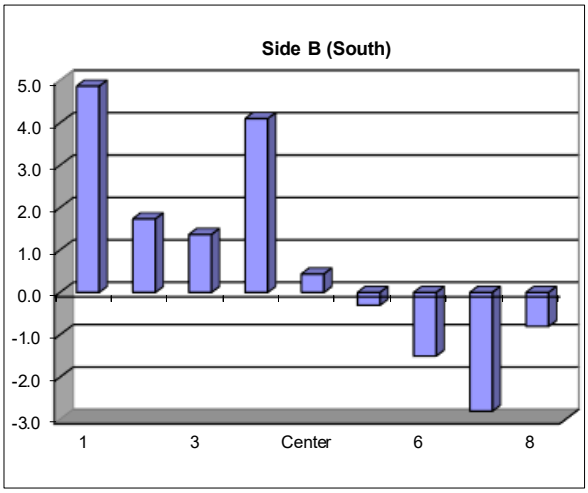
Instruments Used:		Cal. Due
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessary
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

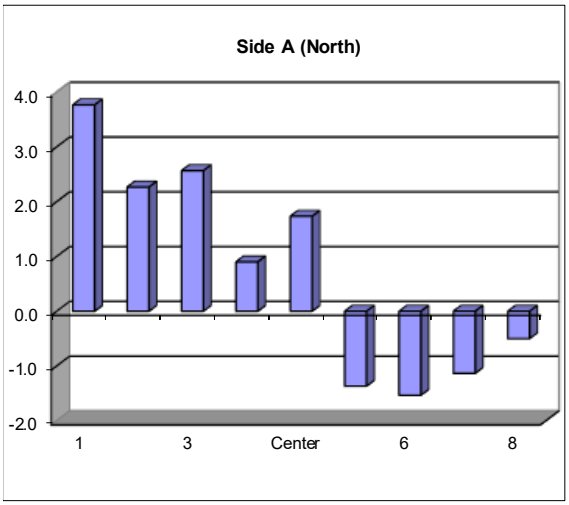
Stack	EM-1	Run No.	FA-3
Date	3/23/2021	Fan Setting	NA Hz
Start/End Time	9:15 9:28	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Stack Temp	69 deg F
Stack Dia.	46 in	Approx. air vel.	2410 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	673 ft	Port	A & B
Distance to disturbance	85.67 ft		

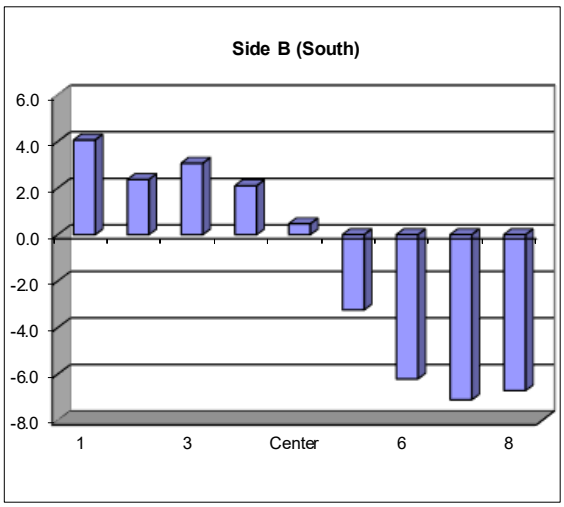
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	4.5	1.6	5.2	3.8	5.5	4.9	1.8	4.1
2	4.83	3.5	2.3	1.0	2.3	5.2	1.1	0.8	2.4
3	8.92	5.0	2.5	0.2	2.6	4.2	4.3	0.7	3.1
4	14.86	0.2	2.2	0.3	0.9	0.3	2.6	3.4	2.1
Center	23.00	0.5	2.4	2.3	1.7	1.1	0.2	0.1	0.5
5	31.14	-1.7	-1.6	-0.8	-1.4	-3.9	-4.2	-1.6	-3.2
6	37.08	-2.4	-1.7	-0.5	-1.5	-8.2	-2.5	-7.9	-6.2
7	41.17	-0.9	-1.1	-1.4	-1.1	-5.2	-8.6	-7.5	-7.1
8	44.53	-0.3	-0.8	-0.4	-0.5	-6.2	-7.7	-6.2	-6.7
Mean of absolute values:					1.8				3.9
" " w/o points by wall:					1.6				3.5
								Grand mean ABS	2.8
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	2.6
S-type pitot	(ID: A100-19, 60")				Pre-test calibration; Post-test inspection.				
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)				Accuracy check prior to each use; field recalibration as necessa				
Manometer	Box 13				Primary standard; leveld and zeroed prior to each use.				

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-4
Date	3/23/2021	Fan Setting	NA Hz
Start/End Time	10:18 10:30	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Stack Temp	68.9 deg F
Stack Dia.	46 in	Approx. air vel.	2376 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	3.1	4.2	7.2	4.8	5.5	6.6	7.2	6.4
2	4.83	5.9	6.1	7.2	6.4	5.1	2.4	2.9	3.5
3	8.92	5.3	2.8	2.9	3.7	5.5	6.5	8.2	6.7
4	14.86	2.9	0.9	2.4	2.1	0.1	0.0	0.1	0.1
Center	23.00	2.9	0.7	2.6	2.1	4.3	6.2	5.4	5.3
5	31.14	-1.5	-2.2	-1.3	-1.7	-1.1	-0.1	-1.7	-1.0
6	37.08	-3.0	-1.5	-0.6	-1.7	-0.9	-1.4	-1.9	-1.4
7	41.17	-0.7	-0.9	-3.0	-1.5	-3.2	-3.9	-4.1	-3.7
8	44.53	-5.3	-4.9	-5.9	-5.4	-1.4	-4.3	-5.1	-3.6
Mean of absolute values:					3.3				3.5
" " w/o points by wall:					2.7				3.1
								Grand mean ABS	3.4
								Grand mean ABS w/o wall pts	2.9

Instruments Used:		Cal. Due
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

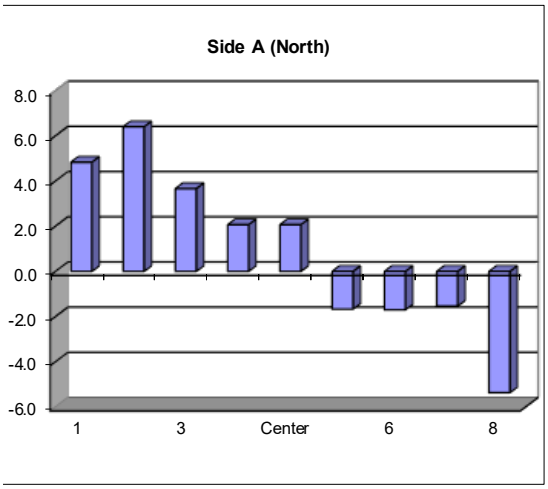
Notes:

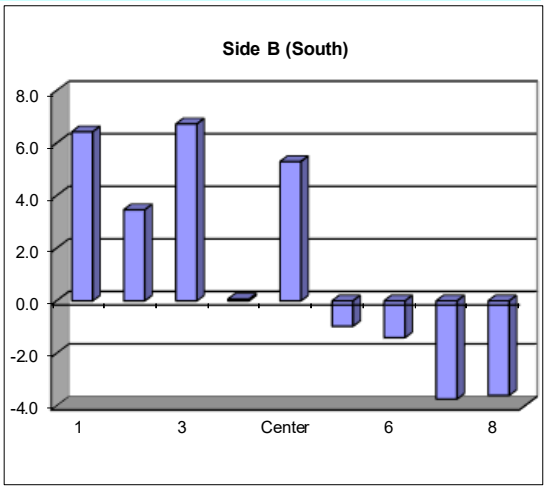
Traverse point depth=the distance from inside stack wall to each point.

First traverse point is all the way into the stack.

Sign of flow angle indicates which direction the pitot was turned to achieve null angle.

Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-5
Date	3/23/2021	Fan Setting	NA Hz
Start/End Time	11:29 11:39	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Stack Temp	69.8 deg F
Stack Dia.	46 in	Approx. air vel.	2400 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	4.6	8.4	0.5	4.5	0.8	0.2	1.3	0.8
2	4.83	1.4	7.7	7.3	5.5	1.9	1.1	2.1	1.7
3	8.92	8.4	7.5	6.2	7.4	1.3	0.9	0.3	0.8
4	14.86	7.9	6.1	6.9	7.0	3.4	4.1	4.1	3.9
Center	23.00	5.5	8.3	6.5	6.8	1.9	3.1	5.1	3.4
5	31.14	4.2	-2.8	-4.5	-1.0	0.0	-0.4	-0.4	-0.3
6	37.08	-2	-1.4	-2.4	-1.9	-1.8	-1.7	-1.9	-1.8
7	41.17	-1.7	-0.2	-0.3	-0.7	-3.2	-3.3	-3.3	-3.3
8	44.53	-6.7	-6.1	-5.6	-6.1	-6.9	-7.2	-8.7	-7.6
Mean of absolute values:					4.5				2.6
" " w/o points by wall:					4.3				2.2
								Grand mean ABS	3.6
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	3.2

S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

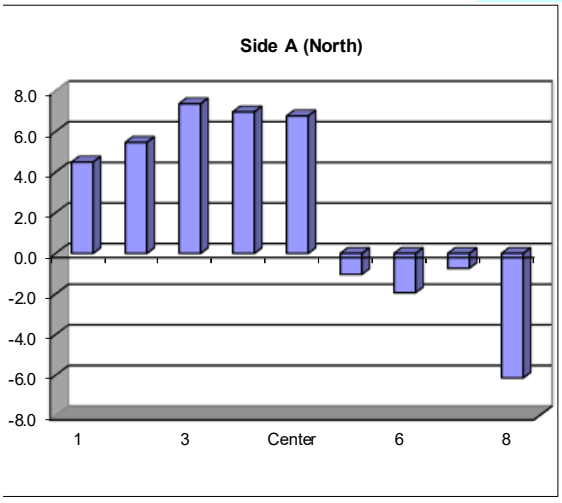
Notes:

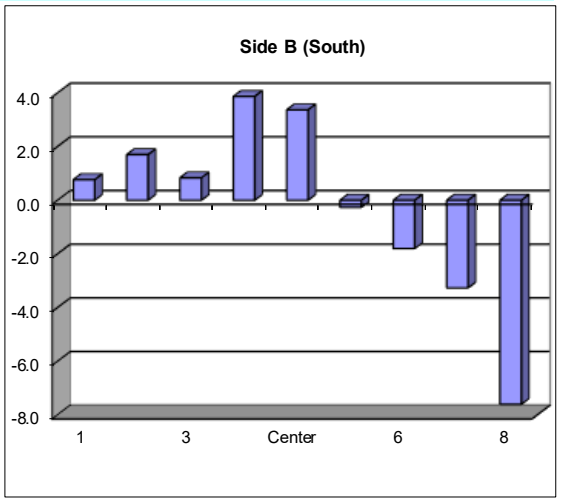
Traverse point depth=the distance from inside stack wall to each point.

First traverse point is all the way into the stack.

Sign of flow angle indicates which direction the pitot was turned to achieve null angle.

Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-6
Date	3/23/2021	Fan Setting	NA Hz
Start/End Time	13:06 13:15	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Stack Temp	70.3 deg F
Stack Dia.	46 in	Approx. air vel.	2393 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

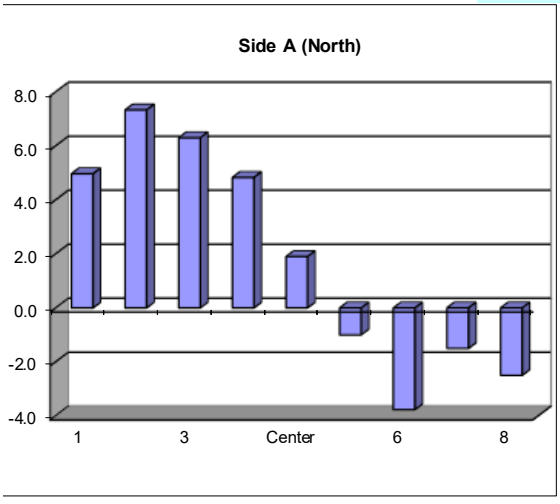
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	4.3	5.2	5.4	5.0	4.1	2.6	1.7	2.8
2	4.83	7.3	6.9	7.8	7.3	2.9	1.6	0.4	1.6
3	8.92	8.7	4.6	5.6	6.3	2.4	3.3	1.6	2.4
4	14.86	6.2	4.4	3.9	4.8	5.8	3.8	1.5	3.7
Center	23.00	4.1	1.4	0.2	1.9	0.4	1.0	1.2	0.9
5	31.14	-2.3	-2.9	2.2	-1.0	-0.4	-4.6	-4.2	-3.1
6	37.08	-8.2	-2.2	-0.9	-3.8	-0.7	-0.8	-1.0	-0.8
7	41.17	-1.8	-1.5	-1.2	-1.5	-4.3	-5.1	-5.1	-4.8
8	44.53	-2.6	-1.7	-3.2	-2.5	-1.7	-1.5	-2.8	-2.0
Mean of absolute values:					3.8				2.5
" " w/o points by wall:					3.8				2.5
								Grand mean ABS	3.1
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	3.1

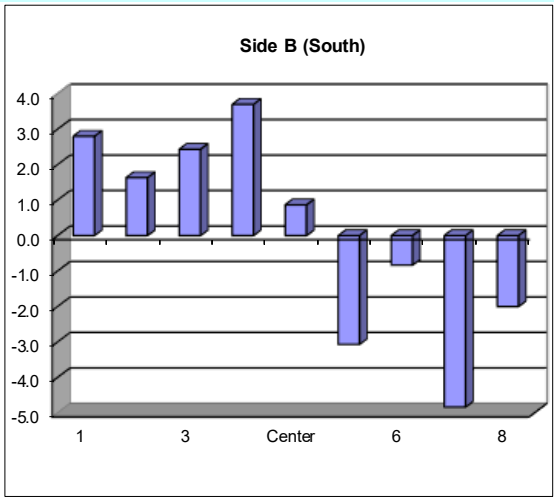
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-7
Date	3/24/2021	Fan Setting	NA Hz
Start/End Time	9:01 9:14	Fan Configuration	Fan A Exhauster A
Testers	ZDH/ARB	Stack Temp	67.7 deg F
Stack Dia.	46 in	Approx. air vel.	2418 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

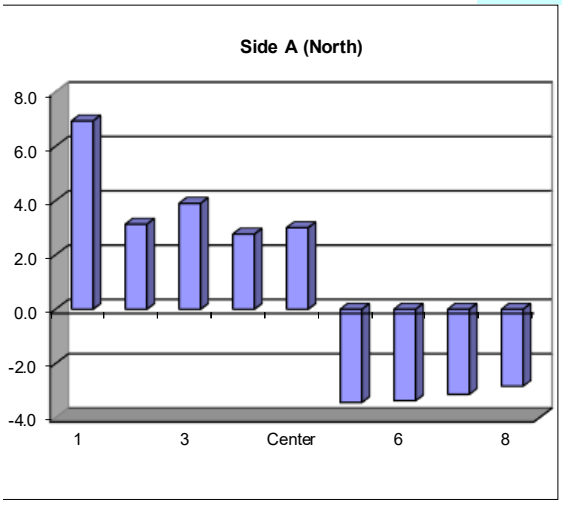
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	7.6	7.5	5.7	6.9	4.2	3.5	7.3	5.0
2	4.83	5.3	1.8	2.3	3.1	4.9	5.2	3.60	4.6
3	8.92	1.5	1.9	8.3	3.9	3.1	3.2	2.3	2.9
4	14.86	2.6	1.9	3.8	2.8	5.9	7.2	6.9	6.7
Center	23.00	2.3	4.2	2.5	3.0	2.2	0.7	0.8	1.2
5	31.14	-3.2	-3.6	-3.5	-3.4	-6.5	-3.7	-6.2	-5.5
6	37.08	-0.7	-3.9	-5.5	-3.4	-5.9	-6.1	-2.8	-4.9
7	41.17	-4.0	-2.9	-2.5	-3.1	-7.0	-8.2	-8.5	-7.9
8	44.53	-3.3	-2.7	-2.5	-2.8	-5.8	-6.4	-6.7	-6.3
Mean of absolute values:					3.6				5.0
" " w/o points by wall:					3.2				4.8
								Grand mean ABS	4.3
								Grand mean ABS w/o wall pts	4.0

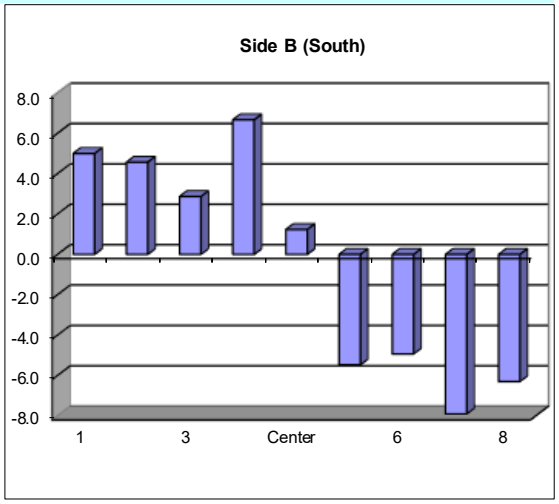
Instruments Used:		Cal. Due
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-8
Date	3/24/2021	Fan Setting	NA Hz
Start/End Time	10:02 10:12	Fan Configuration	Fan A Exhauster A
Testers	ZDH/ARB	Stack Temp	66.8 deg F
Stack Dia.	46 in	Approx. air vel.	2413 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	7.6	7.9	8.1	7.9	3.5	2.8	2.4	2.9
2	4.83	4.6	1.7	5.8	4.0	3.8	6.1	6.5	5.5
3	8.92	6.1	5.9	6.5	6.2	7.1	8.1	6.5	7.2
4	14.86	6.5	6.8	7.2	6.8	6.6	4.3	2.5	4.5
Center	23.00	4.9	0.8	0.2	2.0	2.2	1.9	0.6	1.6
5	31.14	-0.3	-5.5	-1.6	-2.5	-3.8	-1.7	-3.1	-2.9
6	37.08	-7.2	-5.6	-3.3	-5.4	-6.1	-6.5	-5.5	-6.0
7	41.17	-6.9	-7.1	-6.9	-7.0	-7.2	-6.7	-6.1	-6.7
8	44.53	-3.3	-4.8	-5.5	-4.5	-5.3	-5.1	-4.7	-5.0
Mean of absolute values:					5.1				4.7
" " w/o points by wall:					4.8				4.9
								Grand mean ABS	4.9
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	4.9
S-type pitot	(ID: A100-19, 60")				Pre-test calibration; Post-test inspection.				
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)				Accuracy check prior to each use; field recalibration as necessa				
Manometer	Box 13				Primary standard; leveld and zeroed prior to each use.				

Note:

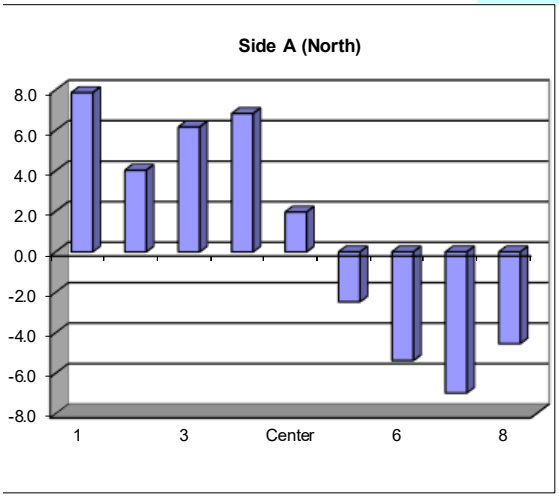
Notes:

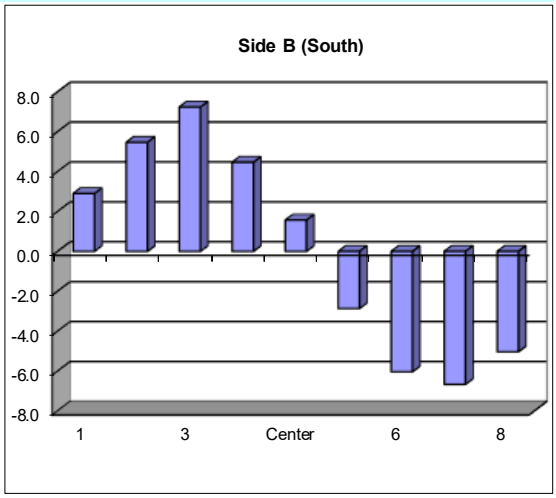
Traverse point depth=the distance from inside stack wall to each point.

First traverse point is all the way into the stack.

Sign of flow angle indicates which direction the pitot was turned to achieve null angle.

Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-9
Date	3/24/2021	Fan Setting	NA Hz
Start/End Time	11:02 11:12	Fan Configuration	Fan A Exhauster A
Testers	ZDH/ARB	Stack Temp	67.0 deg F
Stack Dia.	46 in	Approx. air vel.	2407 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

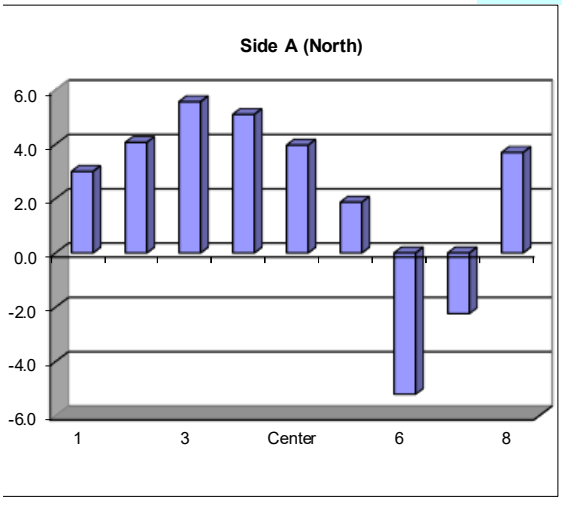
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	1.6	1.3	6.1	3.0	1.7	4.6	4.1	3.5
2	4.83	4.0	4.9	3.3	4.1	7.4	1.6	3.9	4.3
3	8.92	3.9	6.7	6.1	5.6	7.3	4.1	5.5	5.6
4	14.86	5.4	6.1	3.8	5.1	3.6	2.1	1.9	2.5
Center	23.00	2.6	6.4	2.9	4.0	1.8	1.1	1.9	1.6
5	31.14	2.6	1.9	1.1	1.9	-3.7	-2.9	-1.9	-2.8
6	37.08	-3.8	-4.3	-7.5	-5.2	-4.1	-3.8	-5.7	-4.5
7	41.17	-2.9	-2.1	-1.7	-2.2	-5.5	-7.1	-7.0	-6.5
8	44.53	3.6	4.0	3.5	3.7	-4.1	-5.4	-5.1	-4.9
Mean of absolute values:					3.9				4.0
" " w/o points by wall:					4.0				4.0
								Grand mean ABS	3.9
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	4.0

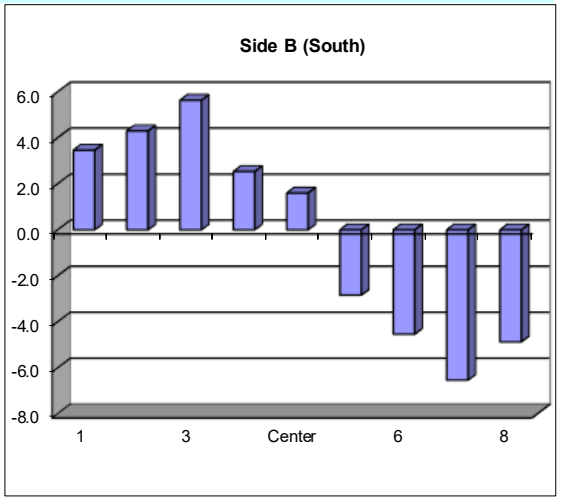
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

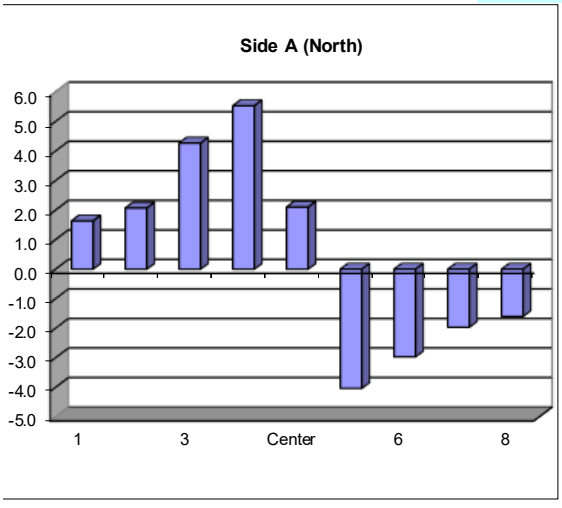
Stack	EM-1	Run No.	FA-10
Date	3/24/2021	Fan Setting	NA Hz
Start/End Time	12:54 13:03	Fan Configuration	Fan A Exhauster A
Testers	ZDH/ARB	Stack Temp	67.0 deg F
Stack Dia.	46 in	Approx. air vel.	2394 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

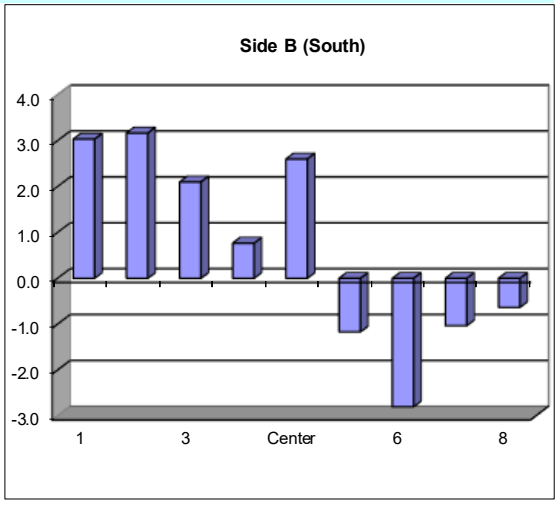
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	2.5	1.5	0.9	1.6	3.1	3.2	2.8	3.0
2	4.83	0.4	1.5	4.3	2.1	4.6	4.5	0.4	3.2
3	8.92	5.7	2.8	4.3	4.3	0.9	3.3	2.1	2.1
4	14.86	5.4	3.7	7.5	5.5	1.8	0.5	0.0	0.8
Center	23.00	4.4	0.4	1.5	2.1	4.3	3.3	0.2	2.6
5	31.14	-1.8	-6.5	-3.8	-4.0	-0.5	0.2	-3.2	-1.2
6	37.08	-4.6	-3.3	-1.0	-3.0	-3.9	-1.9	-2.6	-2.8
7	41.17	-1.9	-0.8	-3.2	-2.0	-0.7	-0.3	-2.1	-1.0
8	44.53	-1.1	-0.1	-3.6	-1.6	-1.5	-0.4	0.0	-0.6
Mean of absolute values:					2.9				1.9
" " w/o points by wall:					3.3				1.9
								Grand mean ABS	2.4
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	2.6
S-type pitot	(ID: A100-19, 60")				Pre-test calibration; Post-test inspection.				
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)				Accuracy check prior to each use; field recalibration as necessa				
Manometer	Box 13				Primary standard; leveld and zeroed prior to each use.				

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-11
Date	3/25/2021	Fan Setting	NA Hz
Start/End Time	8:57 9:07	Fan Configuration	Fan A Exhauster B
Testers	ZDH/ARB	Stack Temp	64.5 deg F
Stack Dia.	46 in	Approx. air vel.	2412 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

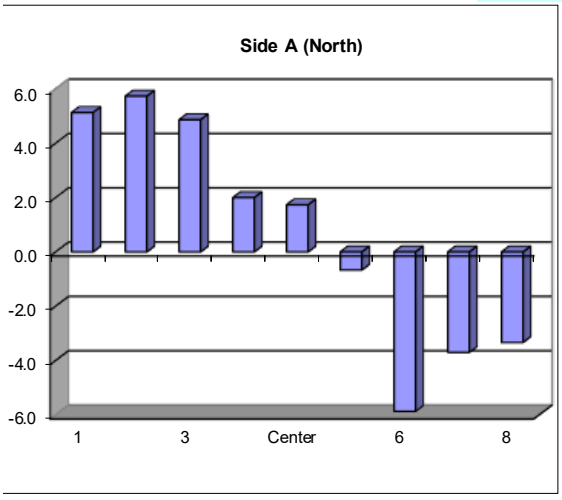
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	7.6	3.2	4.6	5.1	4.1	4.8	4.4	4.4
2	4.83	6.5	5.8	4.9	5.7	1.3	4.9	2.4	2.9
3	8.92	5.8	3.5	5.3	4.9	6.5	3.7	3.4	4.5
4	14.86	1.6	2.5	1.9	2.0	5.8	5.3	3.4	4.8
Center	23.00	0.9	4.3	0.0	1.7	6.1	4.7	5.1	5.3
5	31.14	-0.9	-0.3	-0.8	-0.7	-4.7	-3.3	-3.4	-3.8
6	37.08	-5.0	-6.7	-5.9	-5.9	-7.7	-5.5	-5.1	-6.1
7	41.17	-4.5	-2.9	-3.7	-3.7	-1.8	-1.5	-3.6	-2.3
8	44.53	-4.6	-2.8	-2.6	-3.3	-3.1	-4.6	4.8	-1.0
Mean of absolute values:					3.7				3.9
" " w/o points by wall:					3.5				4.2
								Grand mean ABS	3.8
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	3.9

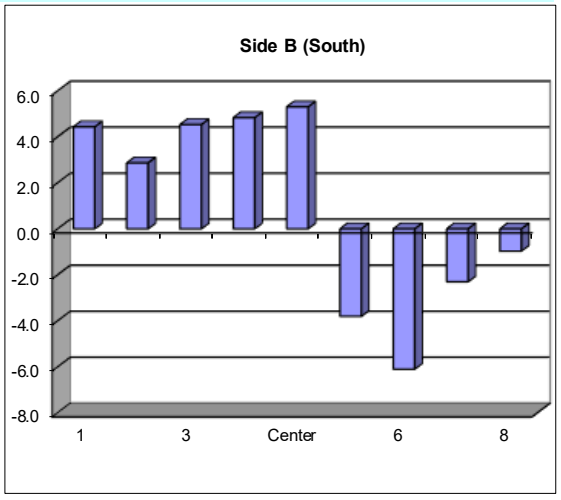
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-12
Date	3/25/2021	Fan Setting	NA Hz
Start/End Time	10:00 10:10	Fan Configuration	Fan A Exhauster B
Testers	ZDH/ARB	Stack Temp	64.4 deg F
Stack Dia.	46 in	Approx. air vel.	2411 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	2.5	4.3	2.0	2.9	7.6	6.5	7.9	7.3
2	4.83	7.2	7.6	8.2	7.7	7.1	7.8	5.9	6.9
3	8.92	6.0	5.5	5.1	5.5	7.1	6.9	6.3	6.8
4	14.86	3.9	6.1	4.3	4.8	1.8	2.1	3.5	2.5
Center	23.00	2.3	4.2	1.4	2.6	2.7	4.2	1.6	2.8
5	31.14	3.4	2.8	3.1	3.1	-6.8	-7.1	-5.9	-6.6
6	37.08	-3.1	-3.5	-3.1	-3.2	-0.2	-2.5	-3.3	-2.0
7	41.17	-5.0	-3.8	-2.5	-3.8	-6.2	-5.9	-6.8	-6.3
8	44.53	-4.6	-3.8	-3.8	-4.1	-8.5	-8.2	-7.6	-8.1
Mean of absolute values:					4.2				5.5
" " w/o points by wall:					4.4				4.8
								Grand mean ABS	4.8
Instruments Used:					**Cal. Due**			Grand mean ABS w/o wall pts	4.6
S-type pitot	(ID: A100-19, 60")				Pre-test calibration; Post-test inspection.				
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)				Accuracy check prior to each use; field recalibration as necessa				
Manometer	Box 13				Primary standard; leveld and zeroed prior to each use.				

Note:

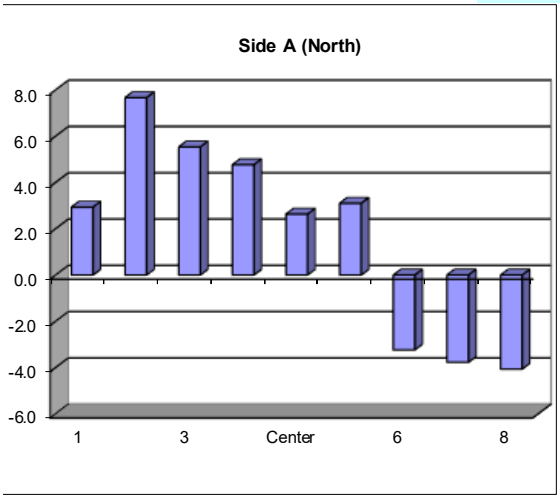
Notes:

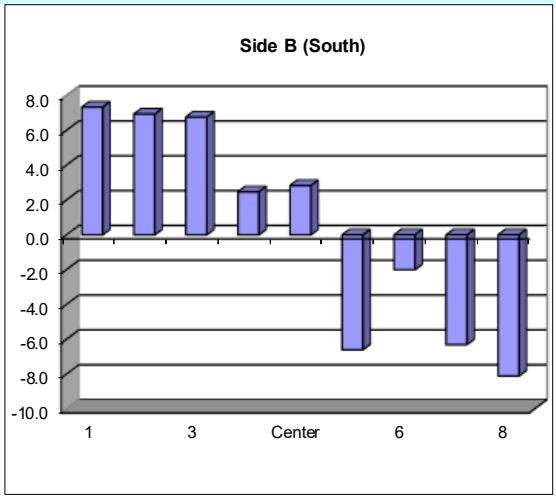
Traverse point depth=the distance from inside stack wall to each point.

First traverse point is all the way into the stack.

Sign of flow angle indicates which direction the pitot was turned to achieve null angle.

Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-13
Date	3/25/2021	Fan Setting	NA Hz
Start/End Time	11:00 11:11	Fan Configuration	Fan A Exhauster B
Testers	ZDH/ARB	Stack Temp	65.2 deg F
Stack Dia.	46 in	Approx. air vel.	2387 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

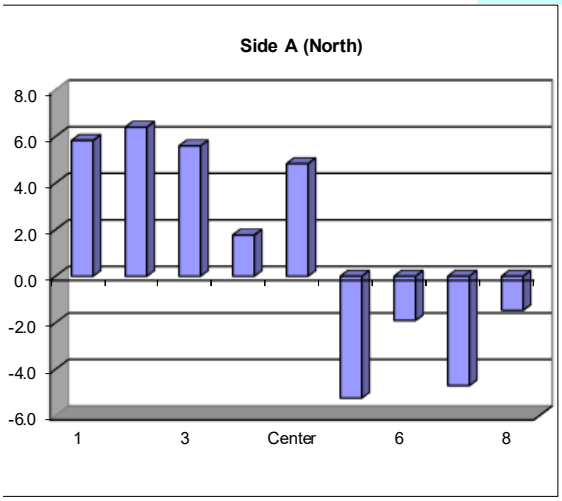
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	3.7	7.5	6.3	5.8	2.4	1.5	2.9	2.3
2	4.83	8.2	6.6	4.4	6.4	1.7	8.6	4.3	4.9
3	8.92	7.1	6.5	3.2	5.6	6.2	8.3	0.1	4.9
4	14.86	1.0	0.0	4.3	1.8	5.4	1.7	1.3	2.8
Center	23.00	3.8	4.2	6.5	4.8	2.6	0.0	0.5	1.0
5	31.14	-5.3	-6.1	-4.3	-5.2	-3.3	-0.1	-1.3	-1.6
6	37.08	-1.4	-2.5	-1.8	-1.9	-1.2	-0.6	-0.2	-0.7
7	41.17	-6.3	-4.5	-3.3	-4.7	-1.8	-2.5	-3.2	-2.5
8	44.53	-2.0	-1.8	-0.6	-1.5	-2.9	-0.6	-6.1	-3.2
Mean of absolute values:					4.2				2.6
" " w/o points by wall:					4.3				2.6
								Grand mean ABS	3.4
								Grand mean ABS w/o wall pts	3.5

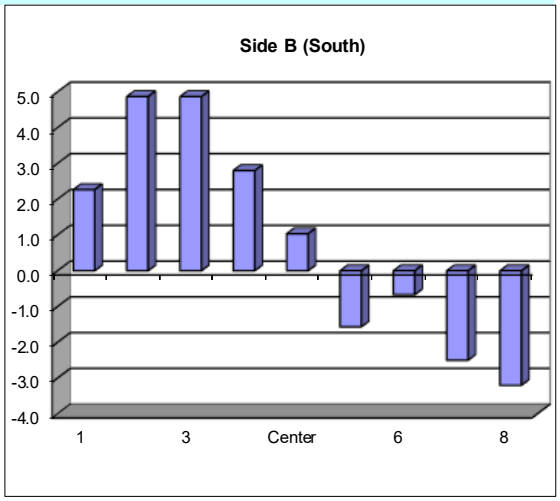
Instruments Used:		Cal. Due
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





FLOW ANGLE DATA FORM

Stack	EM-1	Run No.	FA-14
Date	3/26/2021	Fan Setting	NA Hz
Start/End Time	8:51 8:58	Fan Configuration	Fan B Exhauster A
Testers	ZDH/ARB	Stack Temp	65.7 deg F
Stack Dia.	46 in	Approx. air vel.	2393 afpm at point Mean All
Stack X-Area	1661.9 in2	Units	Degrees
Elevation	691 ft	Port	A & B
Distance to disturbance	85.67 ft		

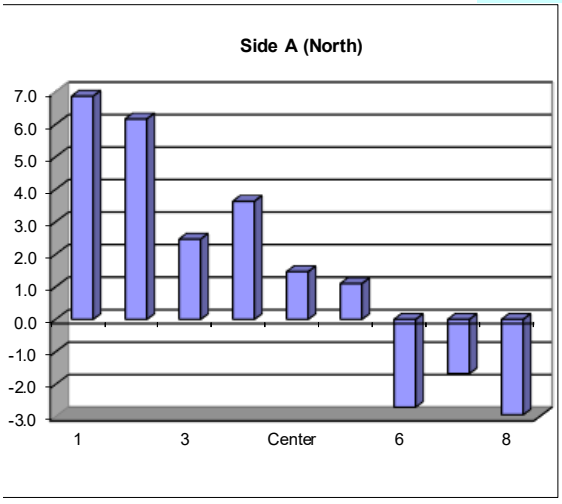
Order -->		First				Second			
Traverse-->		Side A (North)				Side B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	deg. cw				deg. cw			
1	1.47	7.5	7.1	6.0	6.9	4.1	6.2	5.8	5.4
2	4.83	6.5	6.2	5.8	6.2	4.4	1.9	4.1	3.5
3	8.92	2.8	0.9	3.7	2.5	2.9	3.1	2.6	2.9
4	14.86	3.9	4.2	2.8	3.6	2.4	1.5	1.9	1.9
Center	23.00	0.4	1.3	2.7	1.5	-7.7	-8.2	-6.8	-7.6
5	31.14	1.2	0.3	1.8	1.1	-3.3	-4.2	-4.8	-4.1
6	37.08	-0.6	-3.4	-4.1	-2.7	-0.4	-2.7	-1.8	-1.6
7	41.17	-1.1	-1.4	-2.5	-1.7	-2.5	-4.3	-1.7	-2.8
8	44.53	-3.3	-3.8	-1.7	-2.9	-5.8	-6.3	-4.4	-5.5
Mean of absolute values:					3.2				3.9
" " w/o points by wall:					2.7				3.5
								Grand mean ABS	3.6
								Grand mean ABS w/o wall pts	3.1

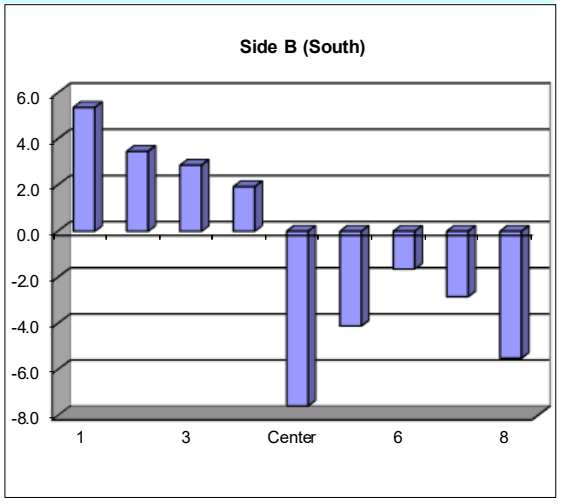
Instruments Used:		Cal. Due
S-type pitot	(ID: A100-19, 60")	Pre-test calibration; Post-test inspection.
Angle indicator	SPI Tronic PRO 360 (SN 31-038-3)	Accuracy check prior to each use; field recalibration as necessa
Manometer	Box 13	Primary standard; leveld and zeroed prior to each use.

Note:

Notes:

Traverse point depth=the distance from inside stack wall to each point.
First traverse point is all the way into the stack.
Sign of flow angle indicates which direction the pitot was turned to achieve null angle.
Approx. air velocity was derived from all points on the Velocity Traverse Forms.





A.2 Velocity Uniformity Data Forms

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-1
Date	3/22/21	Fan Configuration	Fan B Exhauster A
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	70.9 deg F
Stack X-Area	1661.9 in.2	Start/End Time	10:48 11:33
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	1,841.2	1,751.4	1,841.2	1,811.3	1,751.4	1,704.7	1,751.4	1,735.8
2	4.83	2,308.1	2,377.0	2,272.8	2,319.3	2,342.8	2,410.8	2,377.0	2,376.9
3	8.92	2,377.0	2,410.8	2,444.0	2,410.6	2,509.1	2,509.1	2,444.0	2,487.4
4	14.86	2,509.1	2,509.1	2,476.8	2,498.3	2,603.9	2,509.1	2,476.8	2,529.9
Center	23.00	2,509.1	2,541.1	2,541.1	2,530.4	2,603.9	2,603.9	2,665.2	2,624.3
5	31.14	2,509.1	2,541.1	2,572.7	2,541.0	2,665.2	2,695.3	2,754.5	2,705.0
6	37.08	2,476.8	2,572.7	2,541.1	2,530.2	2,634.7	2,603.9	2,603.9	2,614.2
7	41.17	2,444.0	2,476.8	2,541.1	2,487.3	2,444.0	2,444.0	2,342.8	2,410.3
8	44.53	2,272.8	2,272.8	2,237.1	2,260.9	2,444.0	2,476.8	2,476.8	2,465.9
Averages ---------->		2,360.8	2,383.6	2,385.3	2,376.6	2,444.3	2,439.7	2,432.5	2,438.9

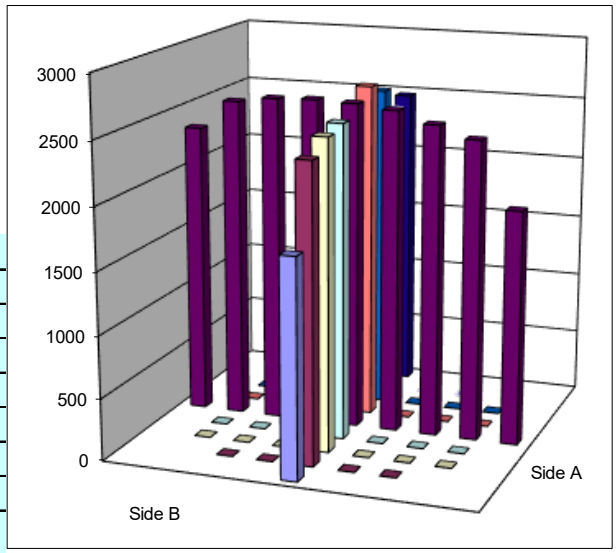
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2407.7		Mean	2473.9	2535.4	2504.7
Min Point	1735.8	-27.9%	Std. Dev.	81.2	119.7	103.3
Max Point	2705.0	12.3%	COV as %	3.3	4.7	**4.1**

Flow w/o C-Pt 27543 cfm

Vel Avg w/o C-Pt 2387 fpm

	Start	Finish	
Stack temp	70.5	71.3	F
Equipment temp	67.8	71.3	F
Ambient temp	67.8	71.3	F
Stack static	0.90	0.67	mbars
Ambient pressure	989.84	990.18	mbars
Total Stack pressure	990.74	990.85	mbars
Ambient humidity	41	42	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-2
Date	3/22/21	Fan Configuration	Fan B / Exhauster A
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	71.6 deg F
Stack X-Area	1661.9 in.2	Start/End Time	13:26 13:41
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

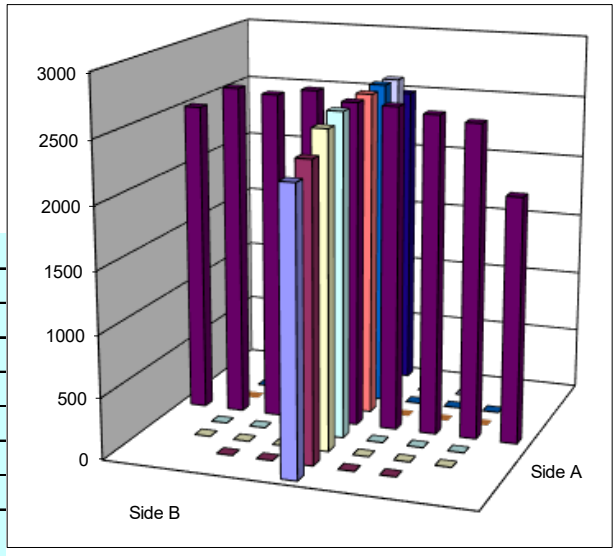
Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,127.2	1,969.5	1,752.3	1,949.7	2,274.1	2,309.4	2,238.3	2,273.9
2	4.83	2,574.1	2,412.0	2,478.1	2,488.1	2,412.0	2,412.0	2,309.4	2,377.8
3	8.92	2,510.6	2,542.6	2,542.6	2,531.9	2,574.1	2,574.1	2,478.1	2,542.1
4	14.86	2,510.6	2,574.1	2,636.2	2,573.6	2,542.6	2,636.2	2,666.7	2,615.1
Center	23.00	2,605.3	2,574.1	2,574.1	2,584.5	2,636.2	2,636.2	2,605.3	2,625.9
5	31.14	2,666.7	2,636.2	2,666.7	2,656.5	2,636.2	2,605.3	2,666.7	2,636.1
6	37.08	2,510.6	2,666.7	2,636.2	2,604.5	2,636.2	2,726.5	2,605.3	2,656.0
7	41.17	2,696.7	2,605.3	2,605.3	2,635.8	2,636.2	2,696.7	2,605.3	2,646.1
8	44.53	2,478.1	2,445.4	2,478.1	2,467.2	2,478.1	2,510.6	2,445.4	2,478.0
Averages ---------->		2,520.0	2,491.8	2,485.5	2,499.1	2,536.2	2,567.5	2,513.4	2,539.0

All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2519.1		Mean	2582.1	2585.6	2583.9
Min Point	1949.7	-22.6%	Std. Dev.	58.2	98.9	78.0
Max Point	2656.5	5.5%	COV as %	2.3	3.8	**3.0**

Flow w/o C-Pt	28948	cfm
Vel Avg w/o C-Pt	2508	fpm

	Start	Finish	
Stack temp	71.4	71.7	F
Equipment temp	69.8	70.4	F
Ambient temp	69.8	70.4	F
Stack static	0.60	0.87	mbars
Ambient pressure	990.18	990.18	mbars
Total Stack pressure	990.78	991.05	mbars
Ambient humidity	30	28	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-3
Date	3/23/21	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	69.0 deg F
Stack X-Area	1661.9 in.2	Start/End Time	8:58 9:09
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,217.7	2,069.7	2,107.6	2,131.7	2,069.7	2,217.7	2,181.6	2,156.3
2	4.83	2,322.6	2,288.1	2,356.4	2,322.4	2,356.4	2,288.1	2,389.9	2,344.8
3	8.92	2,422.8	2,550.5	2,389.9	2,454.4	2,389.9	2,455.4	2,422.8	2,422.7
4	14.86	2,487.4	2,455.4	2,519.1	2,487.3	2,550.5	2,455.4	2,611.9	2,539.3
Center	23.00	2,356.4	2,519.1	2,519.1	2,464.9	2,581.3	2,550.5	2,455.4	2,529.1
5	31.14	2,389.9	2,455.4	2,550.5	2,465.2	2,581.3	2,389.9	2,519.1	2,496.8
6	37.08	2,519.1	2,550.5	2,581.3	2,550.3	2,642.1	2,550.5	2,550.5	2,581.0
7	41.17	2,487.4	2,356.4	2,455.4	2,433.1	2,356.4	2,519.1	2,550.5	2,475.3
8	44.53	2,217.7	2,253.2	2,217.7	2,229.5	2,356.4	2,253.2	2,288.1	2,299.2
Averages ---------->		2,380.1	2,388.7	2,410.8	2,393.2	2,431.6	2,408.8	2,441.1	2,427.2

All	ft/min	Dev. from mean
Mean	2410.2	
Min Point	2131.7	-11.6%
Max Point	2581.0	7.1%

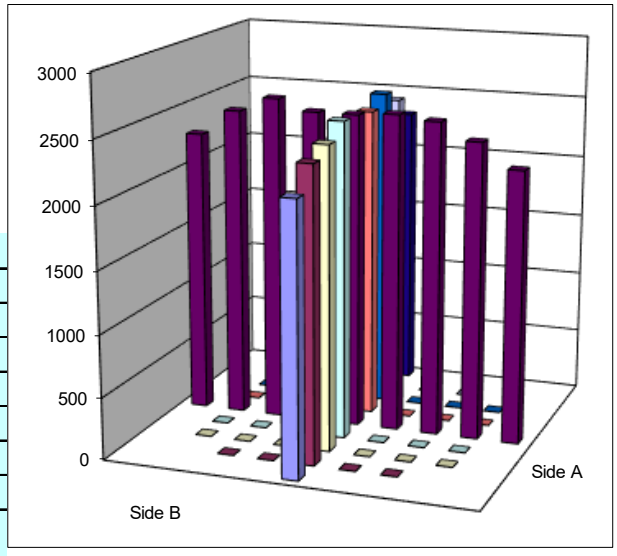
Center 2/3	Side	Bottom	All
Mean	2453.9	2484.1	2469.0
Std. Dev.	68.8	79.4	73.1
COV as %	2.8	3.2	**3.0**

Flow w/o C-Pt 27691 cfm

Vel Avg w/o C-Pt 2399 fpm

	Start	Finish	
Stack temp	69.3	68.7	F
Equipment temp	65.5	66.7	F
Ambient temp	65.5	66.7	F
Stack static	1.05	0.62	mbars
Ambient pressure	1003.73	1003.73	mbars
Total Stack pressure	1004.78	1004.35	mbars
Ambient humidity	27	24	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-4
Date	3/23/21	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	68.9 deg F
Stack X-Area	1661.9 in.2	Start/End Time	10:04 10:14
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,321.4	2,216.6	2,321.4	2,286.4	2,286.9	2,216.6	2,143.8	2,215.8
2	4.83	2,286.9	2,321.4	2,388.7	2,332.3	2,252.0	2,321.4	2,286.9	2,286.8
3	8.92	2,355.2	2,421.6	2,454.1	2,410.3	2,355.2	2,454.1	2,321.4	2,376.9
4	14.86	2,454.1	2,580.0	2,421.6	2,485.2	2,421.6	2,486.1	2,388.7	2,432.1
Center	23.00	2,486.1	2,517.9	2,517.9	2,507.3	2,454.1	2,486.1	2,486.1	2,475.4
5	31.14	2,421.6	2,549.1	2,580.0	2,516.9	2,216.6	2,106.5	2,068.6	2,130.6
6	37.08	2,486.1	2,454.1	2,549.1	2,496.4	2,421.6	2,454.1	2,486.1	2,453.9
7	41.17	2,486.1	2,421.6	2,388.7	2,432.1	2,421.6	2,388.7	2,454.1	2,421.4
8	44.53	2,252.0	2,286.9	2,355.2	2,298.0	2,252.0	2,252.0	2,143.8	2,216.0
Averages ---------->		2,394.4	2,418.8	2,441.8	2,418.3	2,342.4	2,351.7	2,308.8	2,334.3

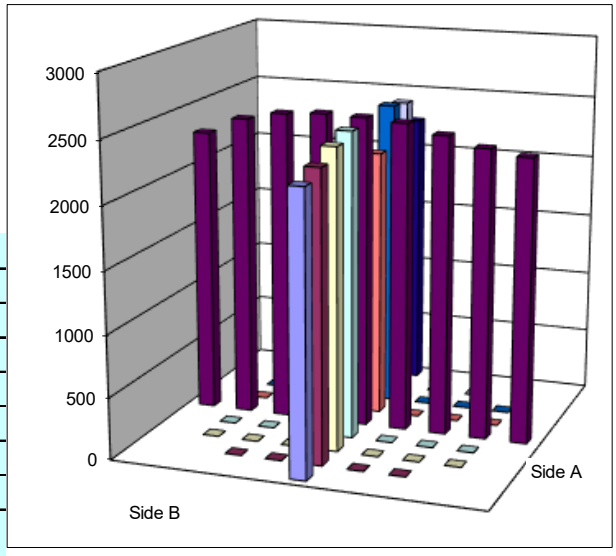
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2376.3		Mean	2454.4	2368.2	2411.3
Min Point	2130.6	-10.3%	Std. Dev.	66.8	121.7	104.4
Max Point	2516.9	5.9%	COV as %	2.7	5.1	**4.3**

Flow w/o C-Pt 27259 cfm

Vel Avg w/o C-Pt 2362 fpm

	Start	Finish	
Stack temp	68.9	68.9	F
Equipment temp	65.2	66.9	F
Ambient temp	65.2	66.7	F
Stack static	0.85	0.85	mbars
Ambient pressure	1004.40	1004.74	mbars
Total Stack pressure	1005.25	1005.59	mbars
Ambient humidity	25	25	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-5
Date	3/23/21	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	69.8 deg F
Stack X-Area	1661.9 in.2	Start/End Time	11:17 11:25
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,253.7	2,356.9	2,356.9	2,322.5	2,031.4	2,070.1	2,108.1	2,069.9
2	4.83	2,356.9	2,390.3	2,288.6	2,345.3	2,288.6	2,145.4	2,253.7	2,229.2
3	8.92	2,455.8	2,390.3	2,423.3	2,423.2	2,253.7	2,487.9	2,390.3	2,377.3
4	14.86	2,455.8	2,550.9	2,487.9	2,498.2	2,519.7	2,550.9	2,487.9	2,519.5
Center	23.00	2,487.9	2,487.9	2,423.3	2,466.4	2,423.3	2,581.8	2,487.9	2,497.7
5	31.14	2,519.7	2,550.9	2,519.7	2,530.1	2,455.8	2,642.6	2,581.8	2,560.1
6	37.08	2,390.3	2,642.6	2,487.9	2,506.9	2,642.6	2,642.6	2,390.3	2,558.5
7	41.17	2,356.9	2,423.3	2,390.3	2,390.2	2,487.9	2,487.9	2,423.3	2,466.4
8	44.53	2,288.6	2,182.0	2,218.2	2,229.6	2,182.0	2,253.7	2,218.2	2,218.0
Averages ---------->		2,396.2	2,441.7	2,399.6	2,412.5	2,365.0	2,429.2	2,371.3	2,388.5

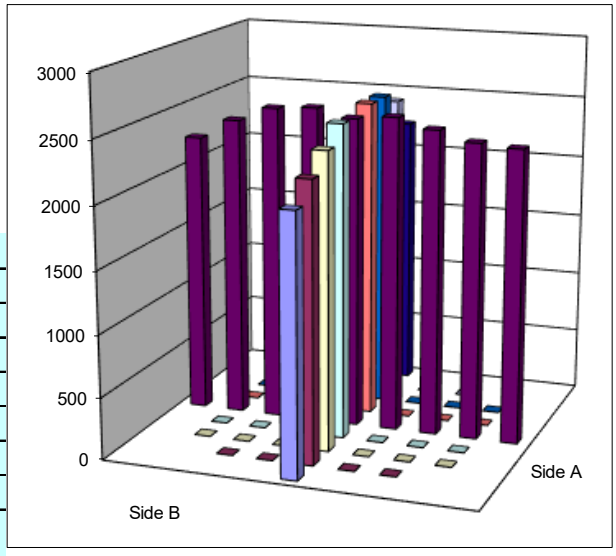
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2400.5		Mean	2451.5	2458.4	2454.9
Min Point	2069.9	-13.8%	Std. Dev.	67.7	118.9	93.0
Max Point	2560.1	6.6%	COV as %	2.8	4.8	**3.8**

Flow w/o C-Pt 27586 cfm

Vel Avg w/o C-Pt 2390 fpm

	Start	Finish	
Stack temp	69.7	69.8	F
Equipment temp	66.3	67.7	F
Ambient temp	66.3	67.7	F
Stack static	0.77	0.92	mbars
Ambient pressure	1004.74	1004.74	mbars
Total Stack pressure	1005.51	1005.66	mbars
Ambient humidity	24	23	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-6
Date	3/23/21	Fan Configuration	Fan B Exhauster B
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	70.3 deg F
Stack X-Area	1661.9 in.2	Start/End Time	12:53 13:01
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

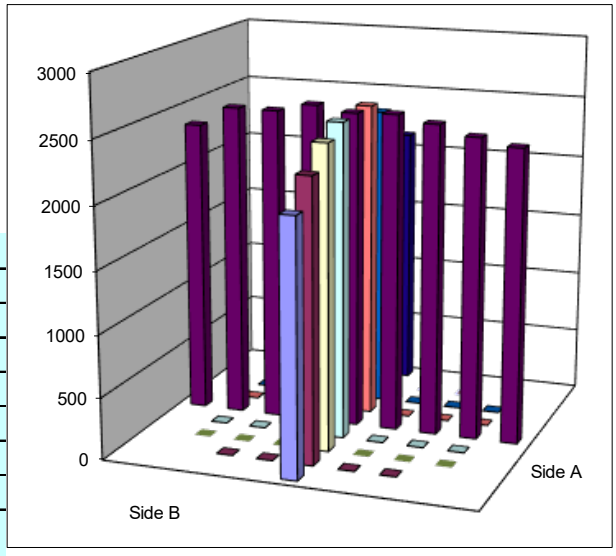
Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,219.6	2,358.5	2,358.5	2,312.2	1,953.0	2,109.4	2,032.7	2,031.7
2	4.83	2,424.9	2,391.9	2,290.1	2,369.0	2,219.6	2,290.1	2,255.1	2,254.9
3	8.92	2,424.9	2,424.9	2,489.6	2,446.5	2,457.4	2,424.9	2,424.9	2,435.7
4	14.86	2,489.6	2,457.4	2,552.6	2,499.9	2,552.6	2,552.6	2,489.6	2,531.6
Center	23.00	2,457.4	2,521.3	2,489.6	2,489.4	2,552.6	2,521.3	2,552.6	2,542.2
5	31.14	2,521.3	2,552.6	2,521.3	2,531.7	2,552.6	2,583.5	2,489.6	2,541.9
6	37.08	2,552.6	2,457.4	2,391.9	2,467.3	2,391.9	2,424.9	2,489.6	2,435.5
7	41.17	2,489.6	2,489.6	2,424.9	2,468.0	2,290.1	2,324.6	2,255.1	2,289.9
8	44.53	2,290.1	2,358.5	2,290.1	2,312.9	2,146.8	2,109.4	2,109.4	2,121.9
Averages ---------->		2,430.0	2,445.8	2,423.2	2,433.0	2,346.3	2,371.2	2,344.3	2,353.9

All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2393.5		Mean	2467.4	2433.1	2450.3
Min Point	2031.7	-15.1%	Std. Dev.	51.3	119.5	90.1
Max Point	2542.2	6.2%	COV as %	2.1	4.9	**3.7**

Flow w/o C-Pt	27446	cfm	
Vel Avg w/o C-Pt	2378	fpm	

	Start	Finish	
Stack temp	69.9	70.7	F
Equipment temp	68.7	69.4	F
Ambient temp	68.7	69.4	F
Stack static	1.15	1.02	mbars
Ambient pressure	1004.40	1004.06	mbars
Total Stack pressure	1005.55	1005.08	mbars
Ambient humidity	23	20	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-7
Date	3/24/21	Fan Configuration	Fan A Exhauster A
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	67.7 deg F
Stack X-Area	1661.9 in.2	Start/End Time	8:46 8:57
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,469.0	2,335.5	2,436.4	2,413.7	2,156.9	2,081.2	1,962.3	2,066.8
2	4.83	2,501.4	2,533.3	2,501.4	2,512.0	2,436.4	2,369.6	2,335.5	2,380.5
3	8.92	2,501.4	2,533.3	2,436.4	2,490.4	2,369.6	2,403.2	2,436.4	2,403.1
4	14.86	2,469.0	2,469.0	2,436.4	2,458.2	2,501.4	2,469.0	2,369.6	2,446.7
Center	23.00	2,369.6	2,469.0	2,403.2	2,414.0	2,501.4	2,436.4	2,436.4	2,458.1
5	31.14	2,436.4	2,564.7	2,436.4	2,479.2	2,369.6	2,469.0	2,564.7	2,467.8
6	37.08	2,501.4	2,533.3	2,469.0	2,501.2	2,469.0	2,564.7	2,469.0	2,500.9
7	41.17	2,469.0	2,533.3	2,501.4	2,501.2	2,369.6	2,300.9	2,300.9	2,323.8
8	44.53	2,501.4	2,335.5	2,369.6	2,402.2	2,265.8	2,369.6	2,300.9	2,312.1
Averages ---------->		2,468.7	2,478.6	2,443.4	2,463.6	2,382.2	2,384.9	2,352.9	2,373.3

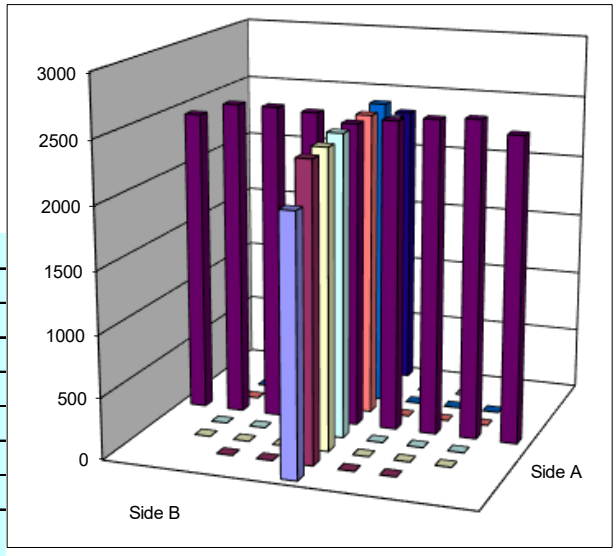
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2418.4		Mean	2479.4	2425.8	2452.6
Min Point	2066.8	-14.5%	Std. Dev.	33.8	60.4	54.6
Max Point	2512.0	3.9%	COV as %	1.4	2.5	**2.2**

Flow w/o C-Pt 27886 cfm

Vel Avg w/o C-Pt 2416 fpm

	Start	Finish	
Stack temp	68.3	67.1	F
Equipment temp	64.2	64.5	F
Ambient temp	64.2	64.5	F
Stack static	0.85	0.77	mbars
Ambient pressure	990.18	990.18	mbars
Total Stack pressure	991.03	990.95	mbars
Ambient humidity	28	28	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-8
Date	3/24/21	Fan Configuration	Fan A Exhauster A
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	66.8 deg F
Stack X-Area	1661.9 in.2	Start/End Time	9:48 9:56
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

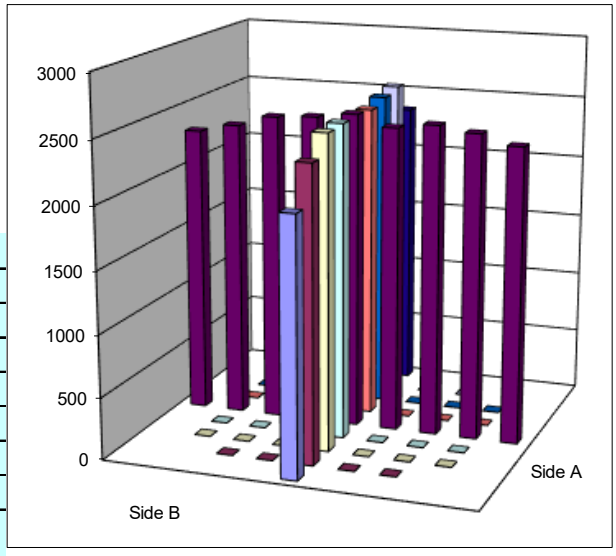
Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,403.8	2,301.5	2,403.8	2,369.7	1,921.3	2,042.9	2,042.9	2,002.4
2	4.83	2,403.8	2,469.7	2,469.7	2,447.7	2,266.3	2,370.2	2,266.3	2,300.9
3	8.92	2,502.0	2,469.7	2,502.0	2,491.2	2,403.8	2,437.0	2,533.9	2,458.2
4	14.86	2,437.0	2,403.8	2,502.0	2,447.6	2,469.7	2,533.9	2,403.8	2,469.1
Center	23.00	2,565.3	2,533.9	2,502.0	2,533.7	2,469.7	2,502.0	2,469.7	2,480.5
5	31.14	2,533.9	2,469.7	2,469.7	2,491.1	2,403.8	2,469.7	2,502.0	2,458.5
6	37.08	2,469.7	2,502.0	2,437.0	2,469.6	2,437.0	2,502.0	2,565.3	2,501.4
7	41.17	2,266.3	2,403.8	2,469.7	2,380.0	2,565.3	2,533.9	2,502.0	2,533.7
8	44.53	2,266.3	2,370.2	2,301.5	2,312.7	2,336.1	2,266.3	2,266.3	2,289.6
Averages ---------->		2,427.6	2,436.0	2,450.8	2,438.1	2,363.7	2,406.4	2,394.7	2,388.3

All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2413.2		Mean	2465.8	2457.5	2461.7
Min Point	2002.4	-17.0%	Std. Dev.	48.2	74.1	60.2
Max Point	2533.7	5.0%	COV as %	2.0	3.0	**2.4**

Flow w/o C-Pt	27715	cfm
Vel Avg w/o C-Pt	2401	fpm

	Start	Finish	
Stack temp	66.8	66.8	F
Equipment temp	63.6	63.8	F
Ambient temp	63.6	63.8	F
Stack static	0.72	0.60	mbars
Ambient pressure	988.15	988.15	mbars
Total Stack pressure	988.87	988.75	mbars
Ambient humidity	30	28	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-9
Date	3/24/21	Fan Configuration	Fan A / Exhauster A
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	67.0 deg F
Stack X-Area	1661.9 in.2	Start/End Time	10:50 – 10:59
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

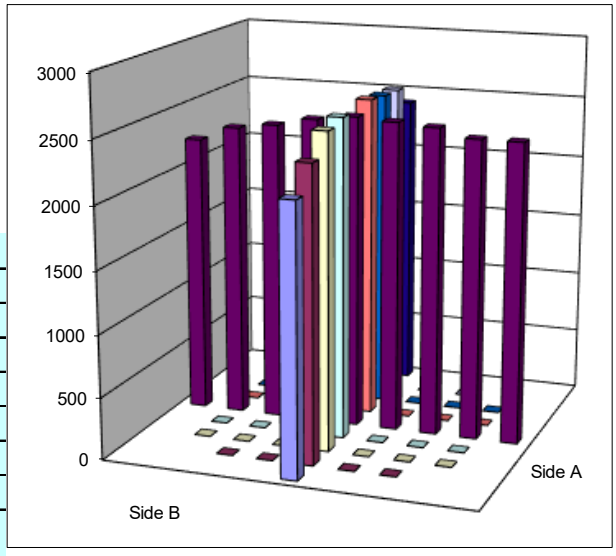
Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,405.4	2,438.5	2,371.7	2,405.2	2,121.4	1,964.0	2,158.9	2,081.4
2	4.83	2,303.0	2,471.3	2,438.5	2,404.3	2,232.1	2,267.8	2,337.6	2,279.2
3	8.92	2,503.7	2,438.5	2,471.3	2,471.2	2,405.4	2,471.3	2,471.3	2,449.3
4	14.86	2,471.3	2,535.5	2,471.3	2,492.7	2,567.0	2,471.3	2,438.5	2,492.3
Center	23.00	2,503.7	2,471.3	2,567.0	2,514.0	2,405.4	2,438.5	2,471.3	2,438.4
5	31.14	2,503.7	2,405.4	2,503.7	2,470.9	2,567.0	2,503.7	2,471.3	2,514.0
6	37.08	2,438.5	2,371.7	2,405.4	2,405.2	2,503.7	2,438.5	2,535.5	2,492.6
7	41.17	2,371.7	2,405.4	2,303.0	2,360.0	2,503.7	2,471.3	2,471.3	2,482.1
8	44.53	2,158.9	2,267.8	2,303.0	2,243.2	2,303.0	2,371.7	2,303.0	2,325.9
Averages ---------->		2,406.6	2,422.8	2,426.1	2,418.5	2,400.9	2,377.6	2,406.5	2,395.0

All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2406.8		Mean	2445.5	2449.7	2447.6
Min Point	2081.4	-13.5%	Std. Dev.	56.1	79.6	66.2
Max Point	2514.0	4.5%	COV as %	2.3	3.3	**2.7**

Flow w/o C-Pt	27676	cfm
Vel Avg w/o C-Pt	2398	fpm

	Start	Finish	
Stack temp	66.9	67.1	F
Equipment temp	63.2	63.8	F
Ambient temp	63.2	63.8	F
Stack static	0.70	0.80	mbars
Ambient pressure	987.13	987.13	mbars
Total Stack pressure	987.83	987.93	mbars
Ambient humidity	29	28	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-10
Date	3/24/21	Fan Configuration	Fan A Exhauster A
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	67.0 deg F
Stack X-Area	1661.9 in.2	Start/End Time	12:42 12:50
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,373.2	2,339.0	2,406.9	2,373.0	1,965.2	1,923.8	1,923.8	1,937.6
2	4.83	2,440.0	2,406.9	2,440.0	2,429.0	2,304.4	2,233.5	2,373.2	2,303.7
3	8.92	2,339.0	2,304.4	2,472.8	2,372.1	2,406.9	2,304.4	2,406.9	2,372.7
4	14.86	2,505.2	2,472.8	2,537.0	2,505.0	2,472.8	2,537.0	2,472.8	2,494.2
Center	23.00	2,406.9	2,505.2	2,505.2	2,472.4	2,472.8	2,505.2	2,440.0	2,472.7
5	31.14	2,440.0	2,472.8	2,406.9	2,439.9	2,406.9	2,505.2	2,505.2	2,472.4
6	37.08	2,505.2	2,440.0	2,406.9	2,450.7	2,537.0	2,472.8	2,568.6	2,526.1
7	41.17	2,339.0	2,472.8	2,406.9	2,406.2	2,406.9	2,505.2	2,440.0	2,450.7
8	44.53	2,233.5	2,160.2	2,160.2	2,184.6	2,373.2	2,472.8	2,440.0	2,428.7
Averages ---------->		2,398.0	2,397.1	2,415.9	2,403.7	2,371.8	2,384.4	2,396.7	2,384.3

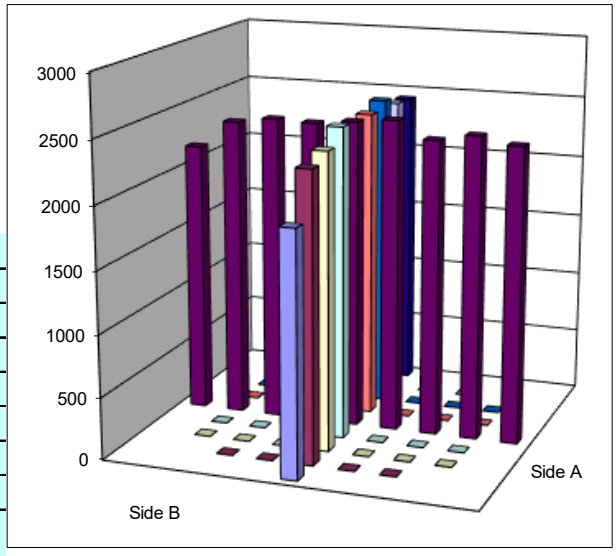
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2394.0		Mean	2439.3	2441.8	2440.6
Min Point	1937.6	-19.1%	Std. Dev.	43.3	77.1	60.1
Max Point	2526.1	5.5%	COV as %	1.8	3.2	**2.5**

Flow w/o C-Pt 27516 cfm

Vel Avg w/o C-Pt 2384 fpm

	Start	Finish	
Stack temp	66.9	67	F
Equipment temp	62.5	63.4	F
Ambient temp	62.5	63.4	F
Stack static	0.60	1.02	mbars
Ambient pressure	985.78	985.78	mbars
Total Stack pressure	986.38	986.80	mbars
Ambient humidity	30	30	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-11
Date	3/25/21	Fan Configuration	Fan A / Exhauster B
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	64.5 deg F
Stack X-Area	1661.9 in.2	Start/End Time	8:45 – 8:53
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,404.9	2,371.2	2,302.4	2,359.5	1,963.5	2,004.0	2,120.9	2,029.5
2	4.83	2,470.7	2,503.0	2,404.9	2,459.5	2,302.4	2,371.2	2,267.3	2,313.7
3	8.92	2,470.7	2,534.9	2,503.0	2,502.9	2,470.7	2,438.0	2,371.2	2,426.6
4	14.86	2,534.9	2,470.7	2,534.9	2,513.5	2,404.9	2,470.7	2,566.4	2,480.6
Center	23.00	2,534.9	2,503.0	2,470.7	2,502.9	2,438.0	2,438.0	2,470.7	2,448.9
5	31.14	2,503.0	2,534.9	2,566.4	2,534.8	2,337.1	2,404.9	2,302.4	2,348.1
6	37.08	2,470.7	2,404.9	2,503.0	2,459.5	2,503.0	2,566.4	2,470.7	2,513.4
7	41.17	2,470.7	2,566.4	2,438.0	2,491.7	2,470.7	2,371.2	2,438.0	2,426.6
8	44.53	2,302.4	2,404.9	2,371.2	2,359.5	2,302.4	2,231.6	2,195.3	2,243.1
Averages ---------->		2,462.5	2,477.1	2,455.0	2,464.9	2,354.8	2,366.2	2,355.9	2,358.9

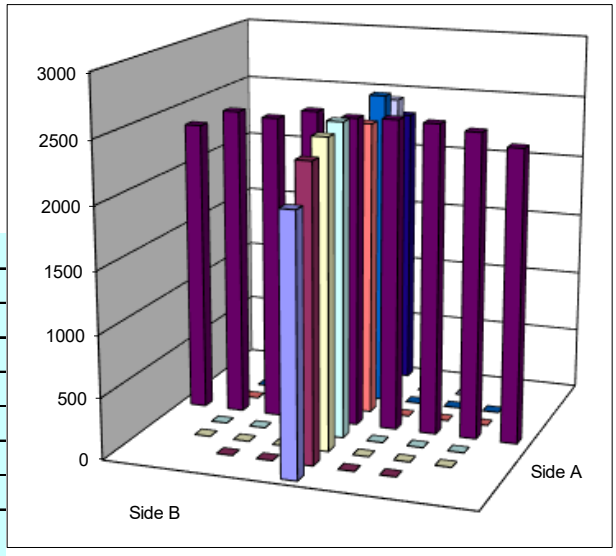
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2411.9		Mean	2495.0	2422.6	2458.8
Min Point	2029.5	-15.9%	Std. Dev.	27.6	70.4	63.6
Max Point	2534.8	5.1%	COV as %	1.1	2.9	**2.6**

Flow w/o C-Pt 27743 cfm

Vel Avg w/o C-Pt 2404 fpm

	Start	Finish	
Stack temp	64.6	64.3	F
Equipment temp	60.1	60.9	F
Ambient temp	60.1	60.9	F
Stack static	0.82	0.52	mbars
Ambient pressure	982.73	983.07	mbars
Total Stack pressure	983.55	983.59	mbars
Ambient humidity	36	35	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-12
Date	3/25/21	Fan Configuration	Fan A / Exhauster B
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	64.4 deg F
Stack X-Area	1661.9 in.2	Start/End Time	9:48 9:57
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,403.6	2,266.1	2,301.3	2,323.7	1,879.0	2,003.0	1,879.0	1,920.3
2	4.83	2,370.0	2,403.6	2,335.8	2,369.8	2,335.8	2,301.3	2,230.4	2,289.2
3	8.92	2,533.6	2,501.7	2,533.6	2,522.9	2,469.4	2,469.4	2,436.8	2,458.5
4	14.86	2,501.7	2,501.7	2,469.4	2,490.9	2,501.7	2,533.6	2,436.8	2,490.7
Center	23.00	2,533.6	2,501.7	2,436.8	2,490.7	2,469.4	2,533.6	2,436.8	2,479.9
5	31.14	2,501.7	2,501.7	2,469.4	2,490.9	2,533.6	2,501.7	2,469.4	2,501.6
6	37.08	2,533.6	2,501.7	2,501.7	2,512.3	2,533.6	2,565.0	2,469.4	2,522.7
7	41.17	2,533.6	2,436.8	2,403.6	2,458.0	2,533.6	2,436.8	2,370.0	2,446.8
8	44.53	2,301.3	2,301.3	2,403.6	2,335.4	2,266.1	2,370.0	2,266.1	2,300.7
Averages ---------->		2,468.0	2,435.1	2,428.3	2,443.8	2,391.3	2,412.7	2,332.7	2,378.9

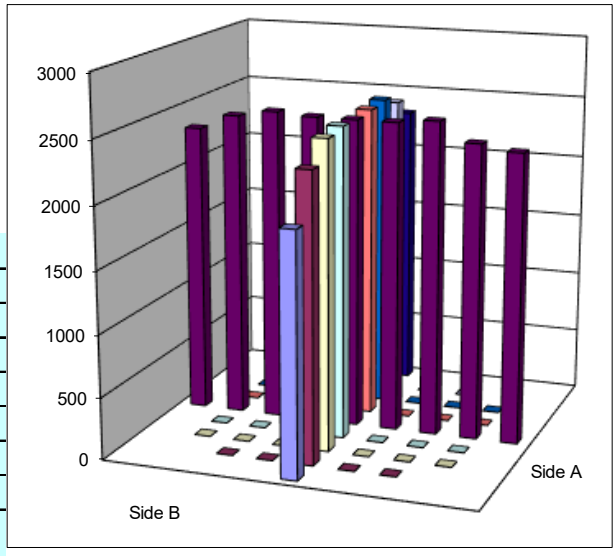
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2411.4		Mean	2476.5	2455.6	2466.1
Min Point	1920.3	-20.4%	Std. Dev.	51.3	77.7	64.2
Max Point	2522.9	4.6%	COV as %	2.1	3.2	**2.6**

Flow w/o C-Pt 27723 cfm

Vel Avg w/o C-Pt 2402 fpm

	Start	Finish	
Stack temp	64.3	64.4	F
Equipment temp	61.2	62.6	F
Ambient temp	61.2	62.6	F
Stack static	0.62	0.70	mbars
Ambient pressure	983.75	983.75	mbars
Total Stack pressure	984.37	984.45	mbars
Ambient humidity	38	35	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-13
Date	3/25/21	Fan Configuration	Fan A / Exhauster B
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	65.2 deg F
Stack X-Area	1661.9 in.2	Start/End Time	10:52 10:58
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,403.9	2,469.8	2,370.3	2,414.7	1,879.2	1,791.8	1,962.8	1,877.9
2	4.83	2,336.1	2,403.9	2,437.1	2,392.4	2,336.1	2,266.4	2,301.6	2,301.4
3	8.92	2,502.1	2,533.9	2,502.1	2,512.7	2,437.1	2,301.6	2,469.8	2,402.8
4	14.86	2,469.8	2,469.8	2,437.1	2,458.9	2,403.9	2,469.8	2,502.1	2,458.6
Center	23.00	2,437.1	2,533.9	2,502.1	2,491.0	2,469.8	2,565.4	2,502.1	2,512.4
5	31.14	2,469.8	2,437.1	2,437.1	2,448.0	2,502.1	2,502.1	2,403.9	2,469.3
6	37.08	2,502.1	2,437.1	2,469.8	2,469.6	2,502.1	2,437.1	2,437.1	2,458.7
7	41.17	2,403.9	2,437.1	2,370.3	2,403.7	2,301.6	2,301.6	2,194.4	2,265.9
8	44.53	2,403.9	2,301.6	2,301.6	2,335.7	2,403.9	2,266.4	2,230.7	2,300.3
Averages ---------->		2,436.5	2,447.1	2,425.2	2,436.3	2,359.5	2,322.4	2,333.8	2,338.6

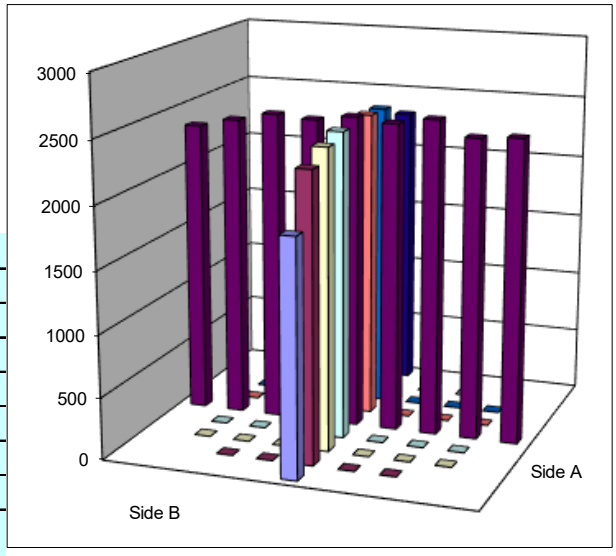
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2387.4		Mean	2453.8	2409.9	2431.8
Min Point	1877.9	-21.3%	Std. Dev.	43.7	92.5	73.1
Max Point	2512.7	5.2%	COV as %	1.8	3.8	**3.0**

Flow w/o C-Pt 27389 cfm

Vel Avg w/o C-Pt 2373 fpm

	Start	Finish	
Stack temp	65.1	65.3	F
Equipment temp	62.7	62.7	F
Ambient temp	62.7	62.7	F
Stack static	1.02	0.95	mbars
Ambient pressure	984.76	984.76	mbars
Total Stack pressure	985.78	985.71	mbars
Ambient humidity	36	36	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

VELOCITY TRAVERSE DATA FORM

Stack	EM-1	Run No.	VT-14
Date	3/26/21	Fan Configuration	Fan B / Exhauster A
Testers	ZDH/ARB	Fan Setting	NA Hz
Stack Dia.	46 in.	Stack Temp	65.7 deg F
Stack X-Area	1661.9 in.2	Start/End Time	8:40 / 8:47
Test Port	A & B	Center 2/3 from	4.22 to: 41.78
Distance to disturbance	85.67 ft	Points in Center 2/3	2 to: 7
Velocity units	ft/min		

Order -->		First Port				Second Port			
Traverse-->		Port A (North)				Port B (South)			
Trial ---->		1	2	3	Mean	1	2	3	Mean
Point	Depth, in.	Velocity				Velocity			
1	1.47	2,359.3	2,425.7	2,392.8	2,392.6	1,783.5	1,870.5	1,953.7	1,869.2
2	4.83	2,392.8	2,458.3	2,425.7	2,425.6	2,325.4	2,290.9	2,359.3	2,325.2
3	8.92	2,359.3	2,325.4	2,359.3	2,348.0	2,359.3	2,458.3	2,392.8	2,403.5
4	14.86	2,522.2	2,553.5	2,458.3	2,511.3	2,522.2	2,458.3	2,490.4	2,490.3
Center	23.00	2,553.5	2,490.4	2,553.5	2,532.5	2,553.5	2,425.7	2,458.3	2,479.2
5	31.14	2,553.5	2,490.4	2,458.3	2,500.7	2,553.5	2,553.5	2,458.3	2,521.8
6	37.08	2,425.7	2,522.2	2,490.4	2,479.5	2,490.4	2,584.5	2,490.4	2,521.8
7	41.17	2,290.9	2,425.7	2,359.3	2,358.6	2,553.5	2,458.3	2,425.7	2,479.2
8	44.53	2,255.9	2,184.3	2,184.3	2,208.2	2,255.9	2,184.3	2,220.4	2,220.2
Averages ---------->		2,412.6	2,430.7	2,409.1	2,417.4	2,377.5	2,364.9	2,361.0	2,367.8

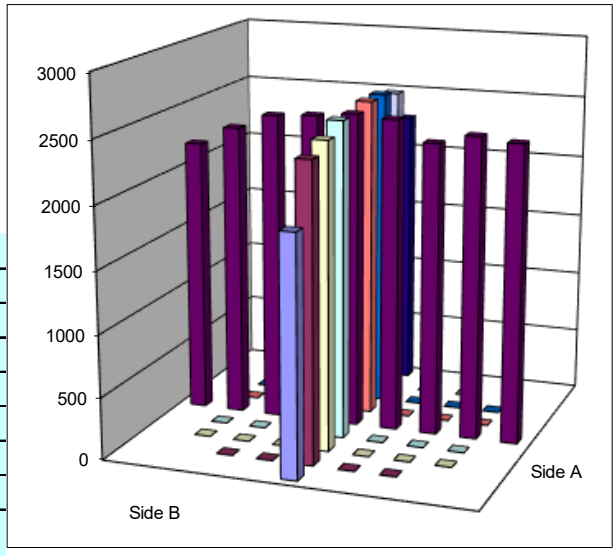
All	ft/min	Dev. from mean	***Center 2/3***	Side	Bottom	All
Mean	2392.6		Mean	2450.9	2460.1	2455.5
Min Point	1869.2	-21.9%	Std. Dev.	74.5	71.5	70.3
Max Point	2532.5	5.8%	COV as %	3.0	2.9	**2.9**

Flow w/o C-Pt 27450 cfm

Vel Avg w/o C-Pt 2378 fpm

	Start	Finish	
Stack temp	65.8	65.5	F
Equipment temp	64.1	64.8	F
Ambient temp	64.1	64.8	F
Stack static	0.67	0.72	mbars
Ambient pressure	994.92	995.26	mbars
Total Stack pressure	995.59	995.98	mbars
Ambient humidity	30	28	RH(%)

Instruments Used:	Cal Due
Standard pitot (ID: 160-60, 60")	Post-test inspection
Digi-sense 20250-13 Manometer (SN: 191212877)	12/3/2021
Control Co. Thermometer (SN: 2204352:	Post-test verification



Notes:

Traverse point depth = the distance from inside stack wall to each point.

Side A port was always measured first.

Direct measurements of differential pressure (in. H2O) were recorded using a digital manometer. Differential pressures were converted to the stack gas velocities (afpm) based on recorded total stack pressure, stack temperature and density of air for each run.

Appendix B – Effluent Management Facility Stack Verification Document Summary

The following table provides a summary of the documents produced by Pacific Northwest National Laboratory (PNNL) during Effluent Management Facility (EMF) Verification Test activities.

Document Title	Document Number	Notes
EMF Verification Test Input Document	Attachment to WTP/RPP-MOA-PNNL-01026, Rev. 0	Test input document to provide information to Bison Engineering (Bison) and Waste Treatment Completion Company (WTCC) concerning the verification tests. Transmitted as an attachment to a memo.
WTP EMF Stack Verification Tests of Velocity Uniformity and Flow Angle Provided by the Waste Treatment Completion Company	TDP-WTPSP-960	Test Data Package to contain the data sheets collected by Bison
Qualification of EMF Stack Verification Testing Data collected by Bison Engineering	DQP-WTPSP-0004, Rev. 0	Data Qualification Plan to describe the qualification of the data from WTCC
Qualification of EMF Stack Verification Testing Data Collected by Bison Engineering	N/A	Data Qualification Evaluation to assess whether the data from WTCC are acceptable using data corroboration method
Qualification of EMF Stack Verification Testing Data Collected by Bison Engineering	DQR-WTPSP-0004, Rev. 0	Data Qualification Report to document results of the data evaluation(s)
WTP EMF Stack Verification Testing Pacific Northwest National Laboratory Observation Form	TDP-WTPSP-961	Test Data Package to contain the data that were input into PNNL observation forms from the Bison sheets
Determination of Velocity Uniformity of EM-1 Stack	CCP-WTPSP-1379, Rev.0	Calculation package to document and review equations and calculations performed to determine velocity uniformity
Determination of Flow Angles in EMF (EM-1) Exhaust Stack	CCP-WTPSP-1378, Rev. 0	Calculation package to document and review equations and calculations performed to determine flow angle
Determine the product of the hydraulic diameter and the mean velocity of EMF Stack EM-01	CCP-WTPSP-1383, Rev 0	Calculation package to document and review equations and calculations performed to determine DV values for the Bison tests and the scale model tests.

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