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Technical Report Documentation Page

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3. Report Date July 2026	4. Performing Organization Code Click or tap here to enter text.
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12. Abstract
United States Government Accountability Office (GAO) report GAO-22-104579 released a recommendation for the Federal Aviation Administration (FAA) to lead research to advance passenger safety and mitigate communicable disease transmission in air travel. In response to this recommendation and in support of a data-driven Safety Management System (SMS) framework to mitigate risks of disease outbreaks, the FAA established an international consortium of industry, academic, and government partners. One of the group's goals is to generate and publish data necessary for realistic parameterization of model simulations, improving quantitative assessments of disease risks and the efficacy of mitigation countermeasures. Ventilation data from across the gate-to-gate air travel journey represent a critical data component, as the air exchange and transport of respiratory pathogens may greatly impact passenger and crew risk exposure. This report by the consortium partner National Research Council of Canada (NRC) presents ventilation data collected from an airport jet bridge and mock-up jet bridge with similar dimensions to an airport jet bridge. Tracer gas and aerosol data were collected inside the mock-up jet bridge with and without heated manikins. Additional ventilation data were collected for airport gate hold room that connects to the airport jet bridge.

13. Key Word Air travel Airport terminals (jet bridge) Communicable diseases Dummies (manikins) Safety Management System (SMS) Ventilation systems		14. Distribution Statement Document is available to the public through the National Transportation Library: https://ntl.bts.gov/ntl
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Aerospace - Flight Research Centre

Communicable Disease Transmission in Air Travel: Jet Bridge Ventilation

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Outline

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2. Operational Review
3. Model Validation Plan
4. Environment: Airport
5. Environment: Lab
6. Methodology: Injection
7. Methodology: Sampling
8. Test Configurations
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    c) Tracer Gas
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1. Introduction

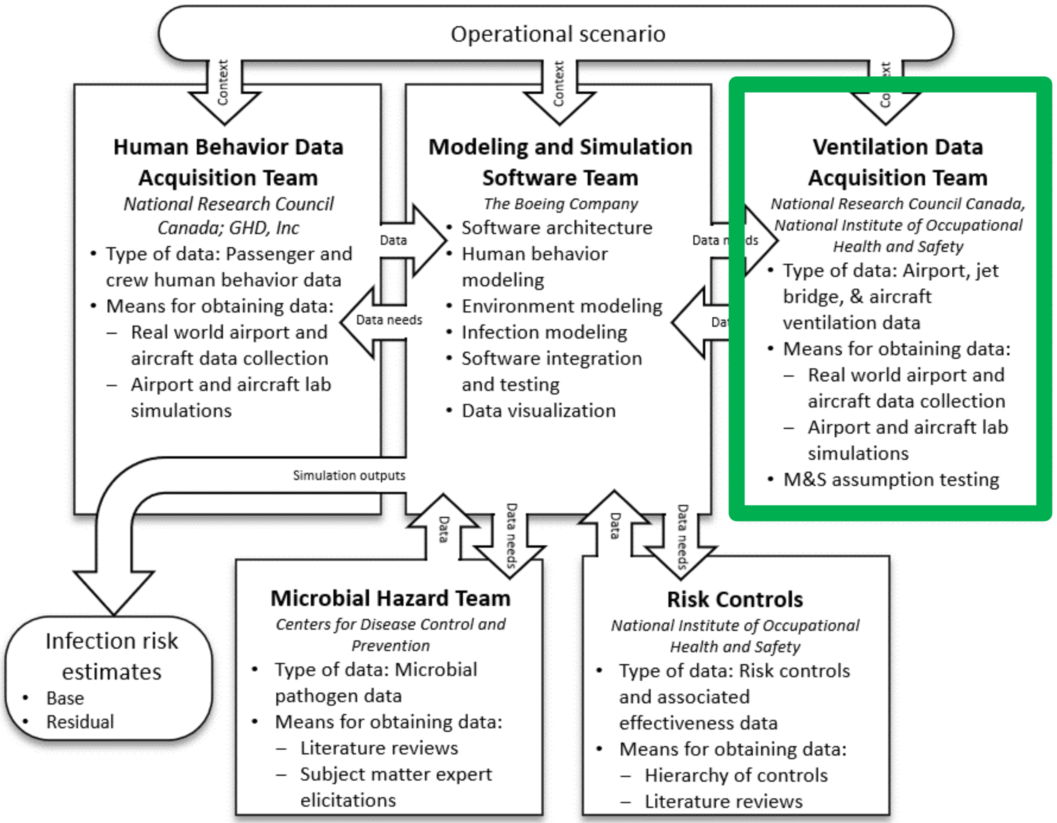
Project Background

To better prepare for future pandemic/disease outbreaks, the Federal Aviation Administration (FAA) is incorporating communicable disease risk management into the Safety Management System (SMS) framework. Central to SMS is the Safety Risk Management (SRM) process, which evaluates baseline risks, identifies controls, and assesses residual risks for mitigation or acceptance (FAA, 2023). Applying SRM to disease transmission necessitates tools that quantitatively analyze risks for passengers and aviation workers. To meet these goals, an international, cross-disciplinary collaboration was established to study real-world scenarios and human behavior in airports and aboard aircraft.

Team Based Execution Framework

Team based execution framework with interfaces/feedbacks used to develop the M&S solution for estimating infection risk.

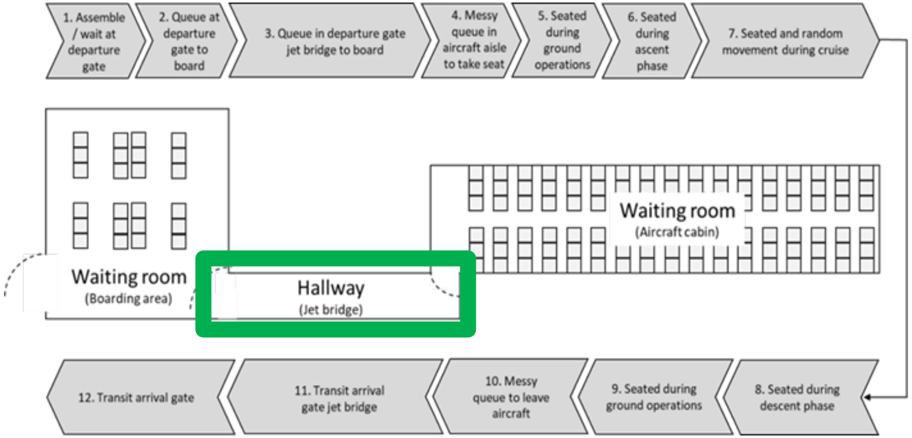
The Green box represents the Ventilation Data Acquisition. This report focuses on the jet bridge aspect of the work.



Scope

The purpose of the work was to:

- Review jet bridge designs at various airports to determine a typical jet bridge environment that connects the boarding area to the aircraft cabin.
- Document jet bridge environment in an operational airport environment.
- Replicate the jet bridge complete with a controlled thermal environment.
- Measure the environmental parameters, carry out tracer gas and aerosol research in the controlled environment.
- Provide data for the Modelling and Simulation Software Team to test several hypothesis to determine how and where the software tools can be simplified.



Report Outline

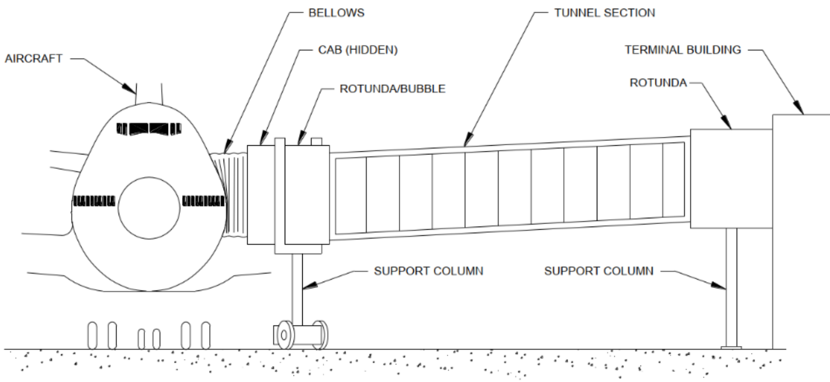
1. Operational review of airport bridges and gate designs.
2. Develop research questions that may be tested with data.
3. Document operational environment for selected design.
4. Describe methodologies and test configurations for collecting data
5. List instrumentation and their technical capabilities.
6. Present data and how it is stored and can be used to answer research questions.
7. Discuss next steps for research beyond the jet bridge.

2. Operational Review

Description

Two types: Stationary and moveable.

Moveable type consists of a rotunda, telescoping tunnel, bubble, cab, and bellows. The bubble is also known as the lower rotunda.



Bellows must surround both the open aircraft door and doorway to protect passengers from the elements.

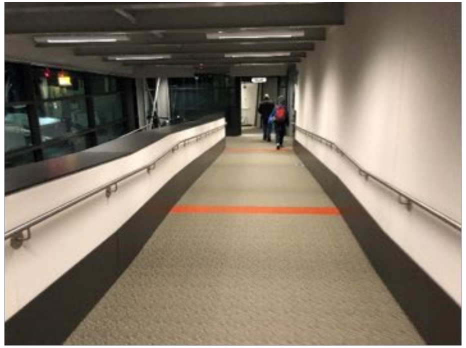
Source: Federal Aviation Administration. (2012). Aircraft Boarding Equipment (AC 150/5220-21C). U.S. Department of Transportation.

Bridge Types

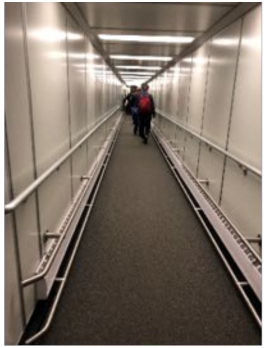
Jet bridges, also known as Passenger Boarding Bridges (PBB), use different designs that were considered for study.

Airstairs & Air-ramps

Covered walkway



Stationary



Moveable

Excluded as it should have the best ventilation rates and believed to have the lowest disease transmission rates.

Focus of this report

Moveable Bridge: General Requirements

Provide a means to protect passengers from the elements when boarding directly from the terminal boarding area to the aircraft door. The bubble height is automatically adjusted as the aircraft height changes with boarding and deplaning.

The table below lists the minimum dimensions of the jet bridge.

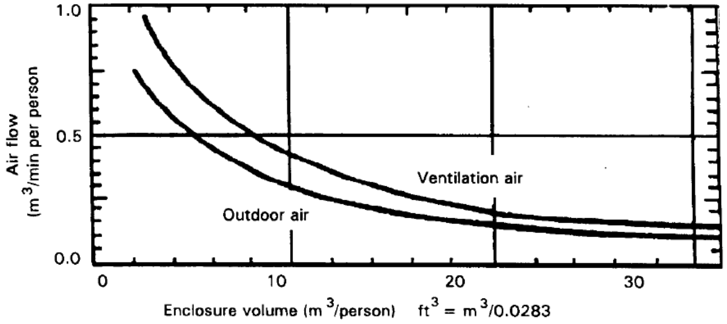
Parameter	Minimum Dimension
Corridor height	200 cm (80”)
Corridor width	130 cm (50”)
Floor width	150 cm (58”)
Telescoping tunnel transition ramp width	140 cm (56”)

Source: Federal Aviation Administration. (2012). Aircraft Boarding Equipment (AC 150/5220-21C). U.S. Department of Transportation.

Ventilation Standards

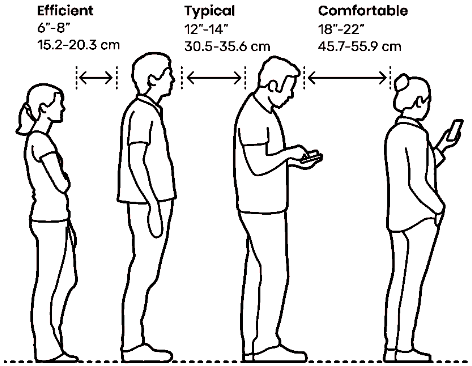
Standards[1,2]

- Velocity must not exceed 30.5 m/s (100 fpm)
- airflow would not exceed 1311 lps (2,778 cfm) with minimum architectural dimensions.
- Design airflow is determined from large enclosure ventilation graph on the right.



Airflow Requirements

- Spacing of 91 cm (36”) single file (due to luggage)[3]
- Volume/person = 3.3 m^3 (using above right figure)
- airflow = 14 lps (30 cfm) for each 3 feet of bridge



Sources:

1) Federal Aviation Administration. (2012). Aircraft Boarding Equipment (AC 150/5220-21C). U.S. Department of Transportation.
2) Federal Aviation Administration. (2016). Human Factors Design Standard (HF-STD-001B). U.S. Department of Transportation.
3) https://www.dimensions.com/element/human-spacing-queue-space-queuing

Estimated Bridge Ventilation Rate

One manufacturer brochure lists bridge length from 12.5 m (48 ft) to 46 m (150 ft)[1].

Jet bridge airflow rate would vary from 227 lps to 708 lps (480 cfm to 1,500 cfm) depending on the bridge specifications and the use of the bridge ventilation standards.

Source: Oshkosh AeroTech. “Oshkosh AeroTech Airport Gate Equipment.” 8 October 2014, https://oshkoshaerotech.com/hubfs/images/Corrugated_Sell-Sheet_2025.pdf.

Ventilation Configurations

Telescoping jet bridges adopt a few different ventilation strategies that were considered for study.

Active ventilation where an exhaust fan (circled in green) draws exhausts air from the bridge.

Combination of conditioned air supply and return with the flow across the width of the bridge.

airflow rates are known and controlled.

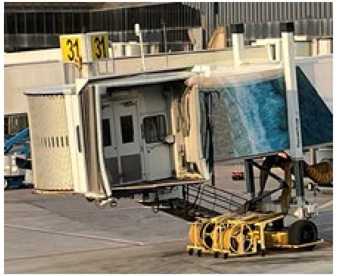
Passive ventilation concept with building pressure driving ventilation rates. Air supply and direction can vary.

Unpredictable and the focus of this report.

Spot Measurements

Jet bridge airflow rates for passive ventilation designs were estimated with data from hand-held air speed probes multiplied over by the jet bridge cross section as air flowed down the bridge.



Test Configuration	1	2	3	4
Aircraft	Dash 8-400	Embraer E195-E2	No aircraft	No aircraft
Bridge doors	Open	Open	Open	Closed
Sample size	9	19	6	13
Average airflow	4300 lps (9111 cfm)	900 lps (1907 cfm)	9600 lps (20341 cfm)	600 lps (1271 cfm)
Std. dev. of air flow	2000 lps (4238 cfm)	450 lps (953 cfm)	600 lps (1271 cfm)	300 lps (636 cfm)

Importance of Bellows and Building Pressure

Jet bridge air speeds (reported as m/s) were similar for the Embraer E2-195 (E295) and the Boeing 737-8 (B38M). Flow direction was believed to be caused by the variable airport pressurization and not the aircraft.

Aircraft at Gate	All Doors Open	Airport Doors Closed	All Doors Closed	Flow Direction
None	3.38	0.35	0.24	Towards aircraft
DH8D	1.17	0.40	0.26	Towards aircraft
E295	0.31	N/A	N/A	Towards aircraft
B38M	0.32	0.19	N/A	From aircraft

Pilot Study

Use case aircraft under study.

Detailed study described later in this report

3. Model Validation Plan

Model Validation Plan Overview

The operational review provided the team guidance into how the data should be gathered. The data presented in this report is to support the testing of the team-developed hypothesis.

The air speed and/or spatial distributions of particles or gas will be independent of:

1) Ventilation configuration (and relative body motion);
2) Aerosol Source;
3) Thermal Effects;
4) Human Occupancy; and,
5) Grid Resolution.

Test Variables Outline

The five themes are broken out to include specific variables that are either controlled or measured. The remainder of this chapter details the research question and hypotheses that may be tested by the team in the future.

1) Ventilation Config.

a) Airflow rate
b) Airflow direction

2) Aerosol Source

a) Plume velocity
b) Plume direction
c) Particle concentration
d) Particle size
e) Plume shape and volume
f) Plume composition

3) Thermal Effects

a) Air speed vs Manikin Temp.
b) Air speed vs Supply Air Temp.
c) Particle vs Manikin Temp.
d) Particle vs Supply Air Temp.

4) Human Occupancy

a) Air speed vs 99th manikin
b) Air speed vs box manikin
c) Particle vs 99th manikin
d) Particle vs box manikin
e) Particle vs airflow direction

5) Grid Resolution

a) Particle spatial distributions vs number of sensors
b) Air speed and CFD
c) Particle and CFD

Ventilation Configuration (and Relative Body Motion) Outline

Research Question:

Does the jet bridge ventilation configuration have a large impact on agent exposure and propagation of communicable disease in a jet bridge?

Item	Hypothesis to be tested
1.a	The spatial particle distribution will be independent of jet bridge total airflow rate.
1.b	The spatial particle distribution will be independent of jet bridge airflow direction.

Aerosol Source Outline

Research Question:

Does the aerosol source momentum and composition have a large impact or change on agent exposure and propagation of a communicable disease in an aviation jet bridge?

Item	Hypothesis to be tested
2.a	The spatial particle distribution will be independent of plume velocity.
2.b	The spatial particle distribution will be independent of plume direction.
2.c	The relative spatial particle distribution will be independent of aerosol particle concentration.
2.d	The spatial particle distribution will be independent of particle size.
2.e	The spatial particle distribution will be independent of plume shape.
2.f	The spatial particle distribution will be independent of plume composition.

Thermal Effects Outline

Research Question:

Does heat convection significantly influence large scale airflow patterns?

Item	Hypothesis to be tested
3.a	The air speed distributions will be independent of manikin temperature.
3.b	The air speed will be independent of supply air temperature.
3.c	Particle spatial distributions will be independent of manikin temperature.
3.d	Particle spatial distributions will be independent of supply air temperature.

Human Occupancy Outline

Research Question:

Do bodies and obstructive volumes in environment cause significant changes in the large-scale airflow and pathogen dispersion patterns as determine the aerosol distribution through the jet bridge?

Item	Hypothesis to be tested
4.a	The air speed distributions will be independent to the presence of 99th percentile manikins
4.b	The air speed distributions will be independent to the presence of a rectangular manikin to emulate a 50th percentile person.
4.c	The particle size concentrations will be independent to the presence of 99th percentile manikins.
4.d	The particle size concentrations will be independent to the presence of a rectangular manikin to emulate a 50th percentile person.
4.e	The particle size concentration will be independent to the change in airflow direction (or relative change due to walking speed)

Grid Resolution Outline

Research Questions:

Does the number of measurement apparatus significantly influence large scale airflow patterns? Do coarse grid measurements taken simultaneously correlate with fine grid measurements taken sequentially? How do multiple planes of sensors affect the jet bridge plug airflow?

Item	Hypothesis to be tested
5.a	Air speed distributions will be independent of the number of air speed sensors.
5.b	Particle spatial distributions will be independent of the number of particle sensors.
5.c	Air speed distributions will agree with CFD results.
5.d	Particle spatial distributions will agree with CFD results.

4. Environment: Airport Jet Bridge

Airport Jet Bridge Environment Overview

Airport provided team access to a moveable bridge overnight between flights for the purposes of measuring airflow inside the jet bridge. Measurements were started at 00h00 and finished around 06h00 on August 13th, 2024. Aircraft was parked at the gate from 23:09 on August 12th and remained until the next day until 07h10.

Measurements were taken inside the rotunda, tunnel, bubble, and cab areas with a Boeing 737-8 (B38M) connected to the bridge. The measurements were taken with two stands with three air speed probes each. Each probe was configured to record a 0.5 second running average every 2 seconds. A total of 60 measurements were collected and averaged at each measurement location.

Outdoor conditions during measurements

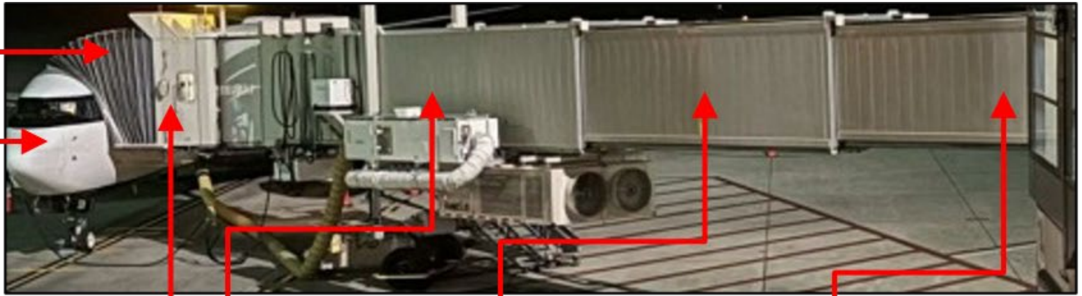
The airport weather station was used to record the outdoor conditions during the airport jet bridge measurements. The data was reported publicly by Environment Canada.

Parameter	Start	End	Average
T_{db}	14.1°C	12.7°C	13.4°C
T_{dp}	8.6°C	9.4°C	9.0°C
α_{wind}	250°	230°	241°
$V_{wind.average}$	8 kph	9 kph	8.6 kph
$V_{wind.gust}$	None	None	None
$P_{station}$	100.21 kPa	100.22 kPa	100.21 kPa

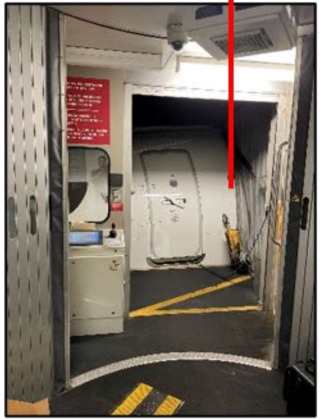
Jet Bridge Cross-Section Views

Bellows

Boeing 737-8 (B38M) ventilated with PCA system



Out of view



Cab & Bubble

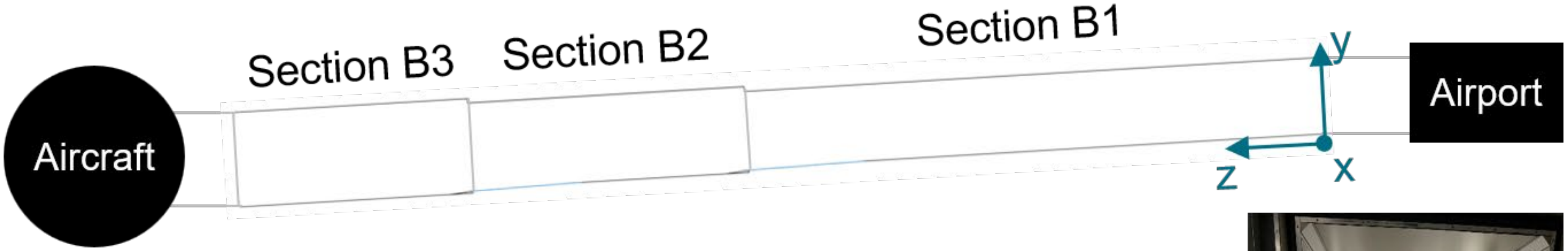
Section B3 (highlighted)

Section B2 (highlighted)

Section B1 (highlighted)

Rotunda

Jet Bridge Cartesian Coordinates

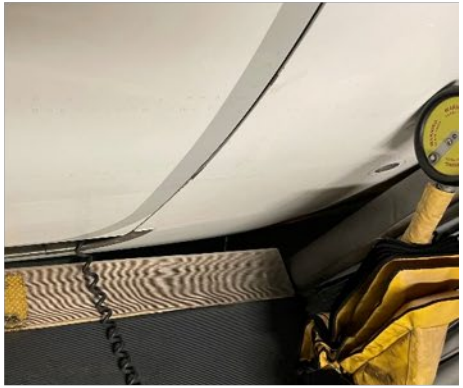


- Bridge frame coordinates are described in the "Bridge - Airport - Frame.txt" file
- X-axis (along floor) and Y-axis (along wall) aligns with section B3 floor and wall.
- Z-axis starts at top of bridge at yellow line and aligned with floor of section B3.

Jet Bridge Supplemental Notes (continued)

Sections B2 and B3 extend at different lengths that is dependent on position of aircraft forward door.

Bellows does not completely seal around aircraft.



Cursory Data

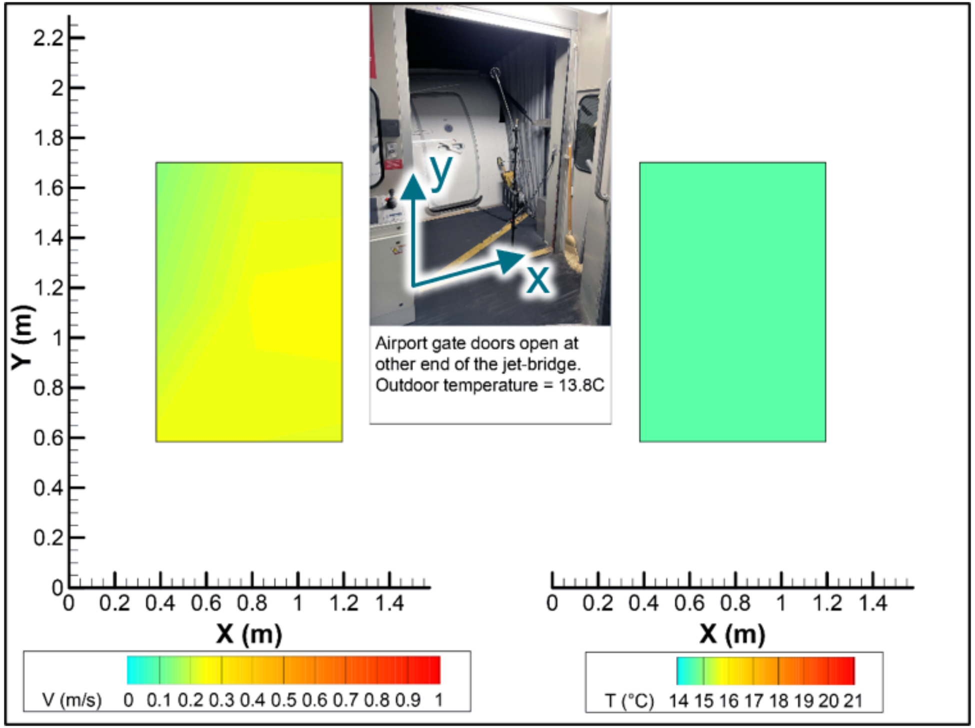
Air speed and temperature measurements were collected around the aircraft door. This was to document how aircraft cabin air and outside air mix when air was flowing towards the airport.

Several spot measurements were conducted around the aircraft doors for later analysis and replication at CATR's Fuselage Lab.

Airport Gate Doors Open: At Rotunda Door

3x3 measurement grid with 3 measurements taken simultaneously at each position along the X-axis.

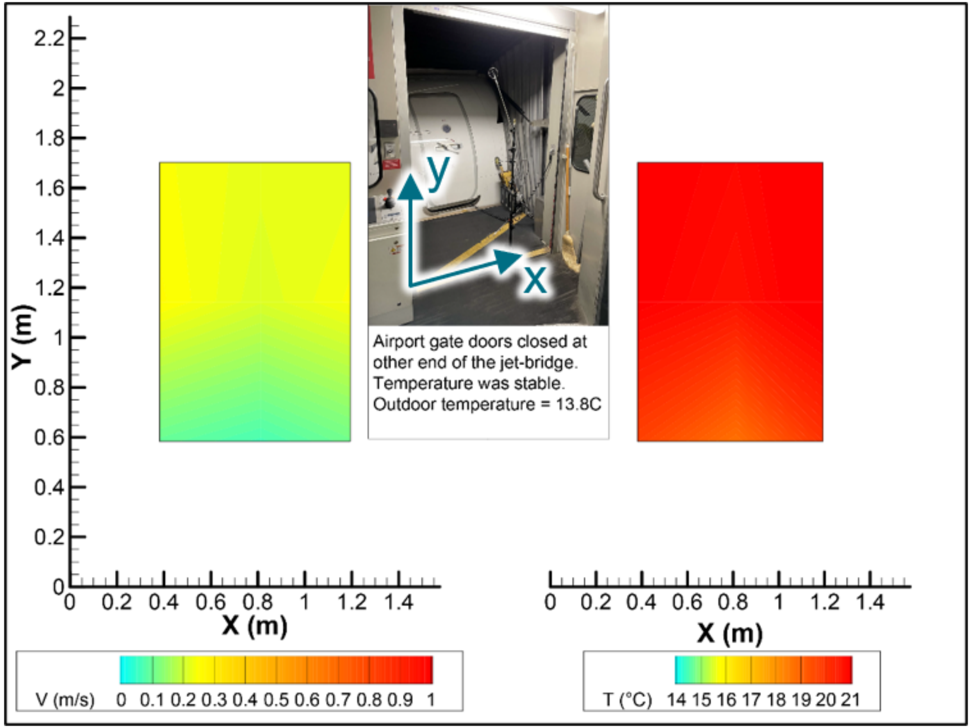
Temperature at roll-up door was consistent with outdoor temperature.



Airport Gate Doors Closed: At Rotunda Door

3x3 measurement grid with 3 measurements taken simultaneously at each position along the X-axis.

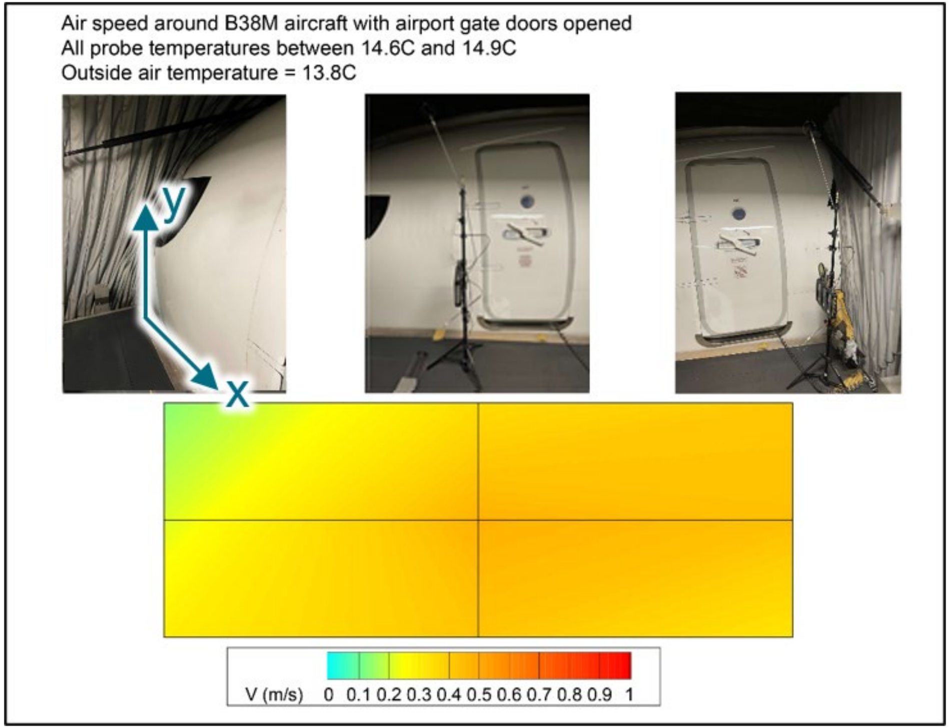
Temperature at roll-up door was consistent with the temperature inside the aircraft cabin.



Airport Gate Doors Open: At Aircraft

3x3 measurement grid with 3 measurements taken simultaneously at each position along the X-axis.

Temperature was slightly higher due to mixing with the warm aircraft cabin air exiting to door flaps.



Spot Measurements Around Aircraft (1/2)

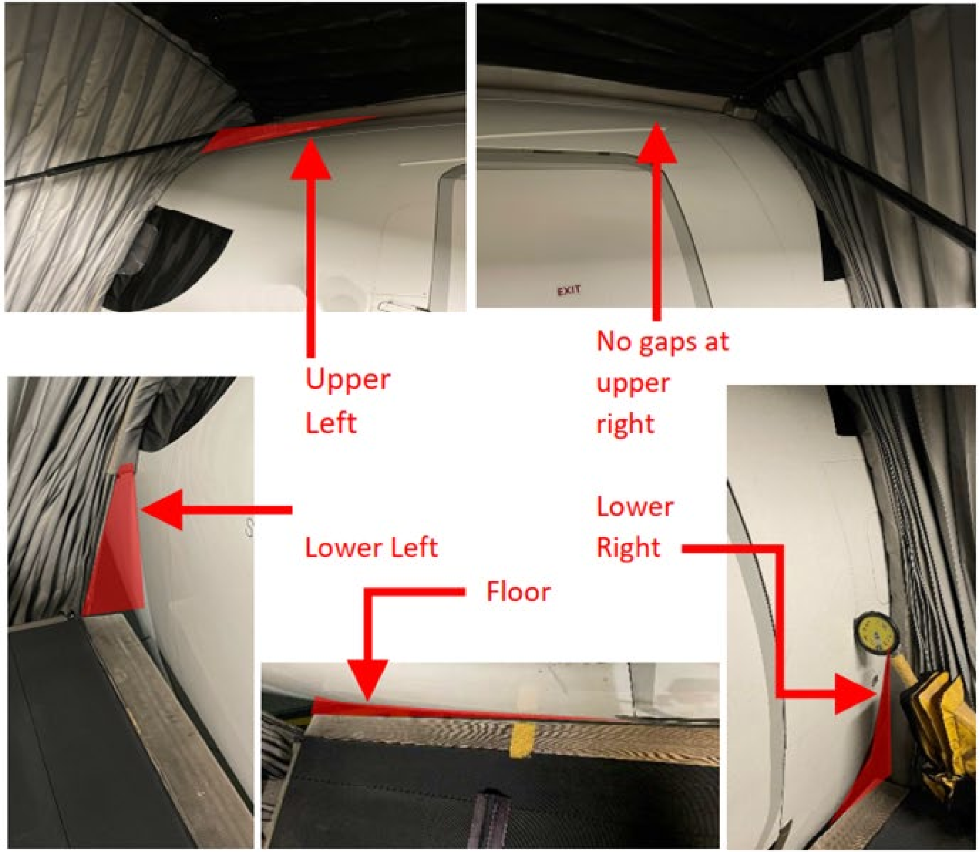
PL4-5 (Airport Gate Doors Open)		
Location	Velocity (m/s)	Temperature (°C)
Lower Slat	1.716	14.8
Upper Slat	0.871	14.6
Average	1.294	14.7

PL12-14 (Airport Gate Doors Closed)		
Location	Velocity (m/s)	Temperature (°C)
Lower Slat	1.104	16.8
Upper Slat	0.535	16.3
Average	0.820	16.6

Spot Measurements Around Aircraft (2/2)

PL6-8 (Airport Gate Doors Open)		
Parameter	Velocity (m/s)	Temperature (°C)
Upper Left	N/A	N/A
Lower Left	1.735	14.8
Floor	0.684	14.8
Lower Right	1.735	14.8
Average	1.385	14.8

PL12 (Airport Gate Doors Closed)		
Parameter	Velocity (m/s)	Temperature (°C)
All	0.367	17.8



Building Pressure

The airport building was instrumented with an air pressure sensor to better understand the conditions that drive the airflow through the jet bridge tunnel. Data was collected from March 17th through April 30th. The data was recorded every 10 seconds by the building automation system.

Building was found to be configured with three airflow conditions:

1) Normal mode with supply and return fans operating at capacity (04h00 to 23h00)

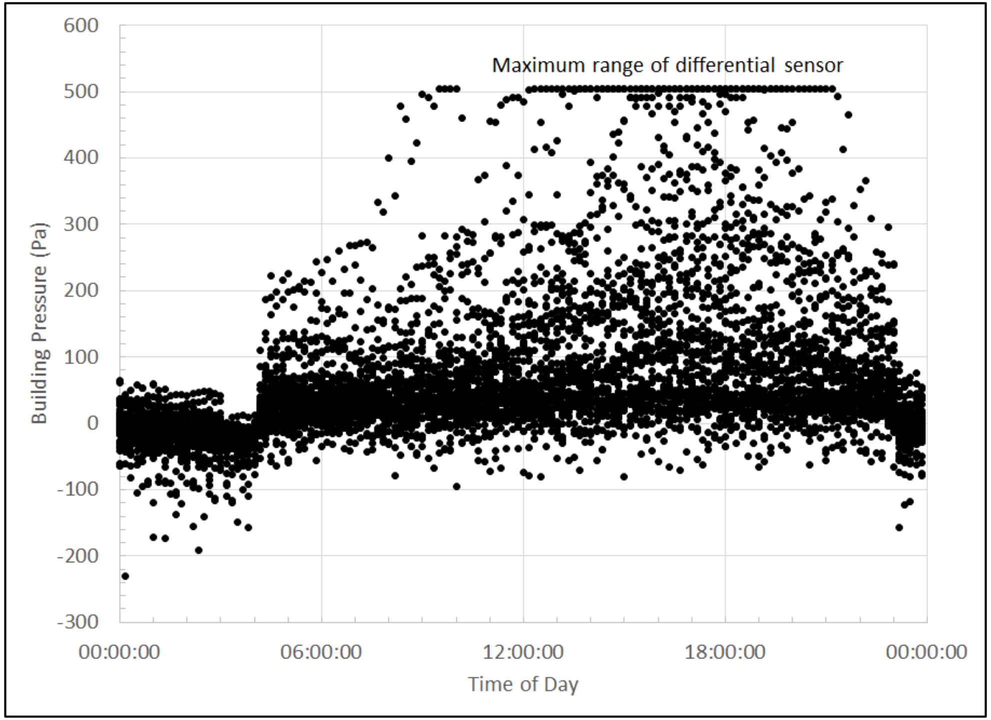
2) Full set-back with supply and return fans turned off (23h00 to 03h00)

3) Partial set-back with fans operating at limited capacity (03h00 to 04h00)

Building Pressure vs Time of Day

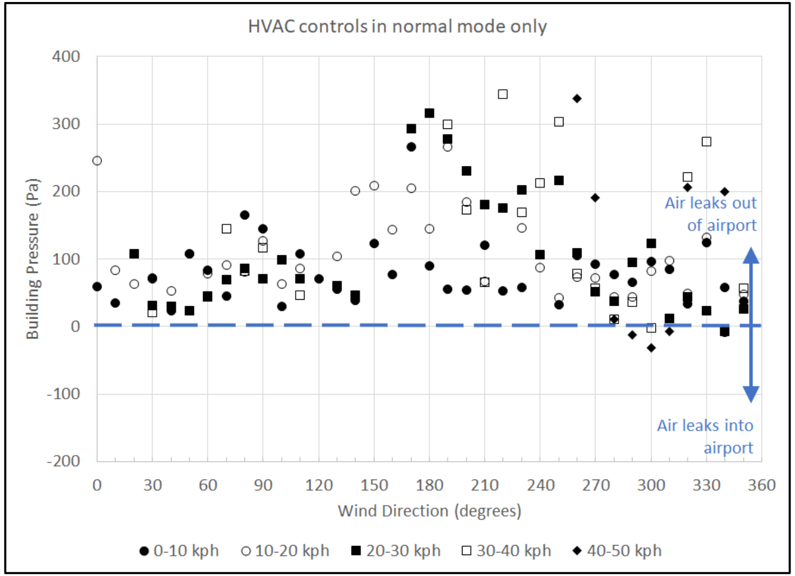
Building pressure is affected by the HVAC mode of operations.

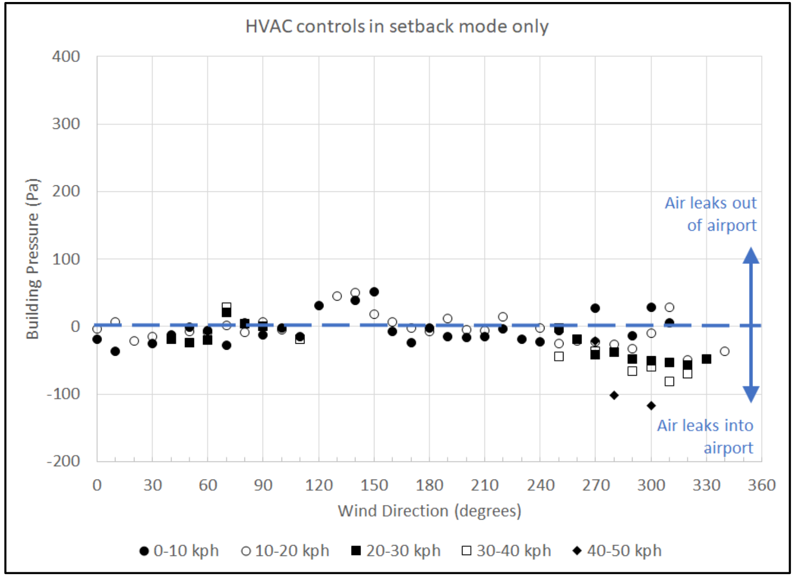
Building pressure tends to be more negative when the building was in partial set-back mode from 03h00 to 04h00.



Building Pressure vs Wind Direction

Wind speed direction may influence building pressure for both HVAC modes of operation.





5. Environment: Lab Jet Bridge

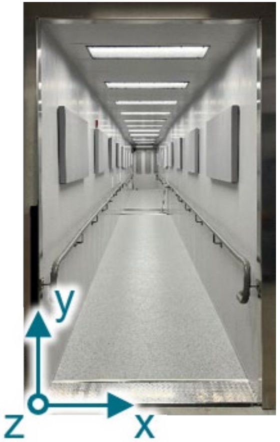
Lab Jet Bridge Environment Overview

The CATR facility includes a model passenger boarding bridge (jet bridge) through which airflow rate, direction, temperature, and humidity can be controlled.

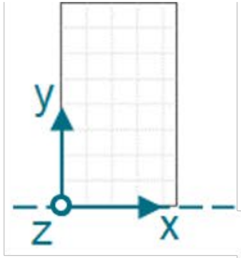
Air speed and particle dispersion patterns are measured within the jet bridge to better understand how they are impacted by air speed, temperature, and human occupancy.

Human occupancy is simulated by the presence of manikins that are clothed and can be heated.

(Note: the cartesian coordinate system is correct as shown. The x-axis starts at the left wall. The y-axis is from the lab floor, not the bridge floor.)



Dimensions

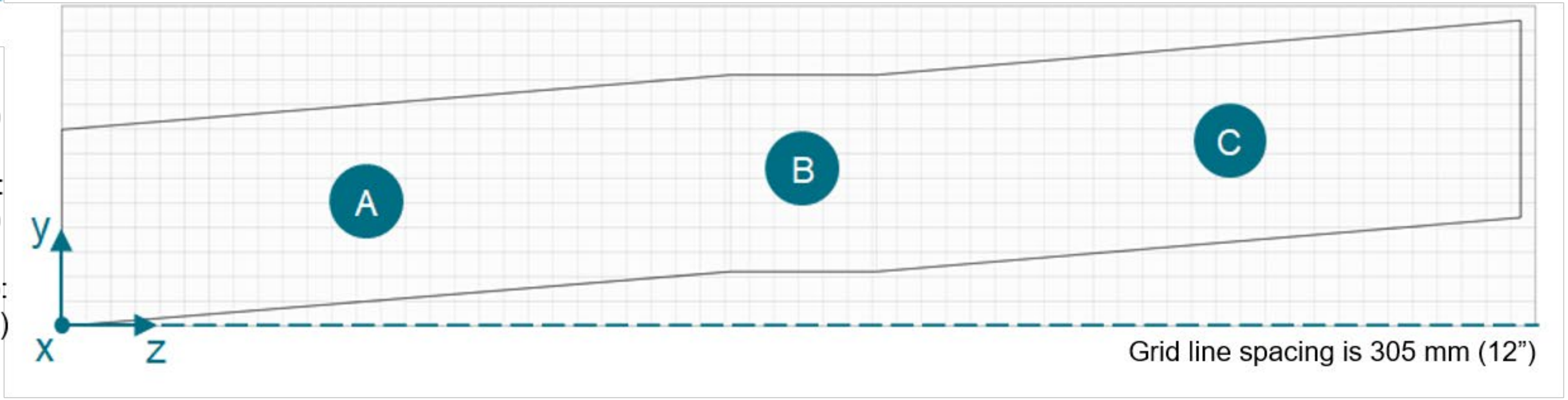


The jet bridge is a sloped hallway 8-feet tall and 4.5-feet wide with a flat center section.
It extends 59.4 feet horizontally between two air manifold door plugs.

Width (x-axis):
1.39 m (4.56 ft)

Height† (y-axis):
2.44 m (8.01 ft)

Length‡ (z-axis):
18.11 m (59.4 ft)



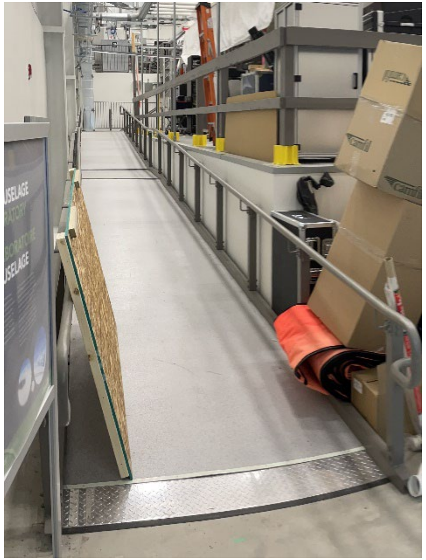
Part A
Floor Height†: 0 to 0.67 m (2.21 ft)
Length‡: 8.29 m (27.21 ft)
Ramp angle: 4.64°

Part B
Floor Height†: 0.67 m (2.21 ft)
Length‡: 1.80 m (5.92 ft)
Ramp angle: 0°

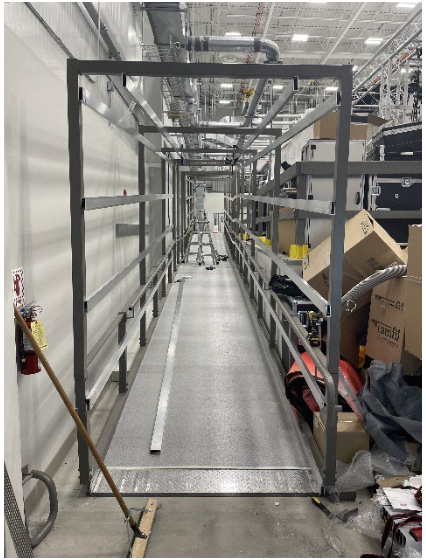
Part C
Floor Height†: 0.67 to 1.34 m (4.41 ft)
Length‡: 8.01 m (26.28 ft)
Ramp angle: 4.78°

† Inside height of bridge is constant but floor elevation is variable.
‡ Measured level with the lab floor (represented as a dashed line)

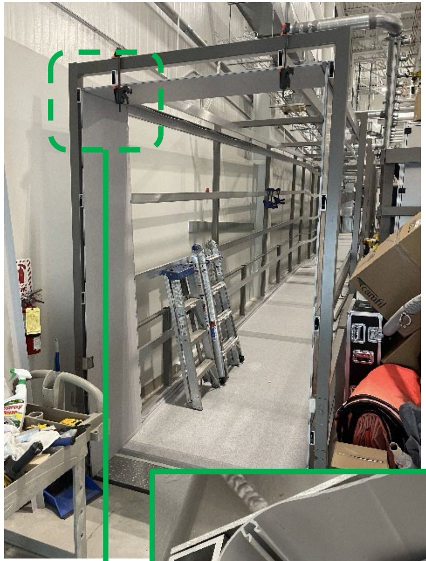
Jet Bridge Construction



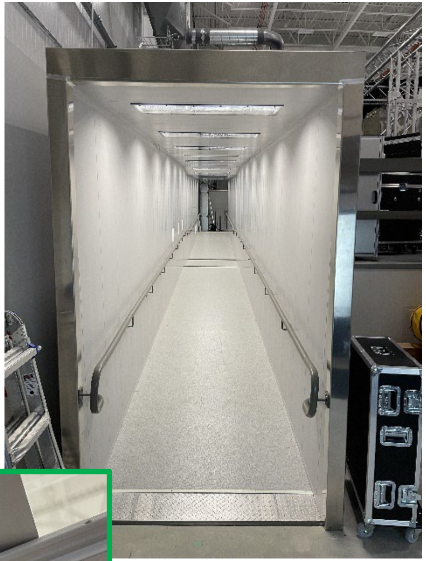
Original ramp before installation of a cover.



Structure installed to support the new walls and ceilings. All surfaces are not insulated.



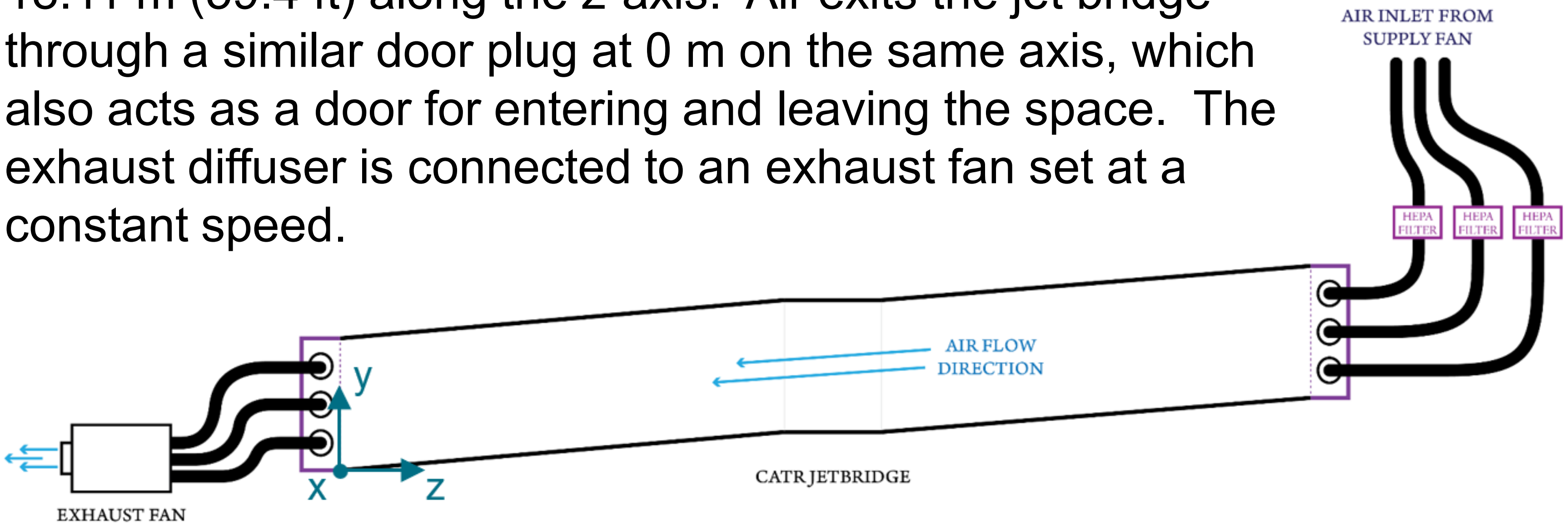
Gasketed corners to minimize leaks.



Finished bridge without ventilated door plugs installed.

Bridge Airflow

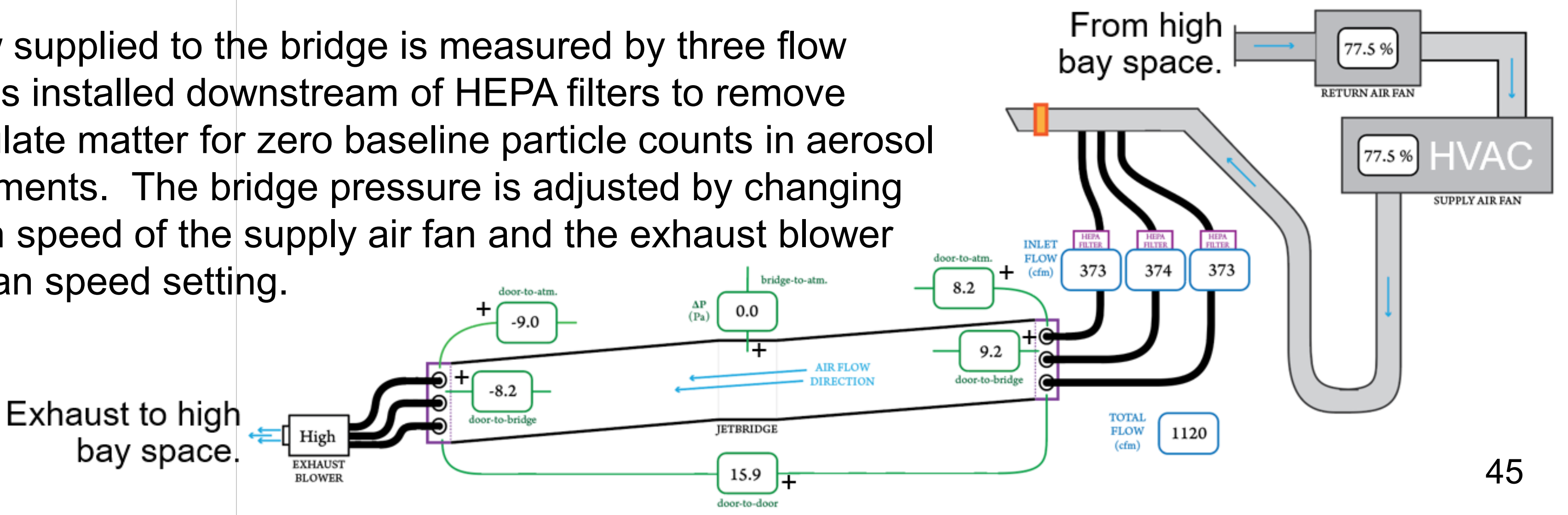
All lab experiments were performed with air flowing downhill (right to left as shown below). Supply air enters the bridge through the upper ventilated door plug, which is located at 18.11 m (59.4 ft) along the z-axis. Air exits the jet bridge through a similar door plug at 0 m on the same axis, which also acts as a door for entering and leaving the space. The exhaust diffuser is connected to an exhaust fan set at a constant speed.



Ventilation Overview

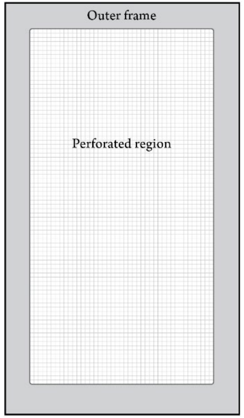
Air is supplied to the lab jet bridge by a dedicated HVAC system used to control dry-bulb temperature, dew-point, and airflow rate. The HVAC system uses two fans, supply air and return air, along with heating coils, cooling coils, and humidification. Exhaust air is driven by an external blower fan that empties into the lab space at a constant speed. The return air fan draws air from below the Flexible Cabin Lab (FCL) floor, which is in the same high bay space as the bridge.

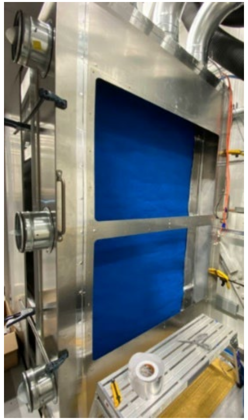
Airflow supplied to the bridge is measured by three flow stations installed downstream of HEPA filters to remove particulate matter for zero baseline particle counts in aerosol experiments. The bridge pressure is adjusted by changing the fan speed of the supply air fan and the exhaust blower fixed fan speed setting.



Ventilated Door Plug

Two 300 mm thick, hollow doors are used to control airflow through the lab jet bridge. Air is supplied or exhausted via three 200 mm round ducts connected to the side. The air enters or leaves the bridge through a grid of 6.9 mm holes laid out in a 84x44 grid at 25.4 mm spacing. The inlet air passes through a 25.4 mm thick layer of polyester non-woven material placed to promote an even distribution of air.

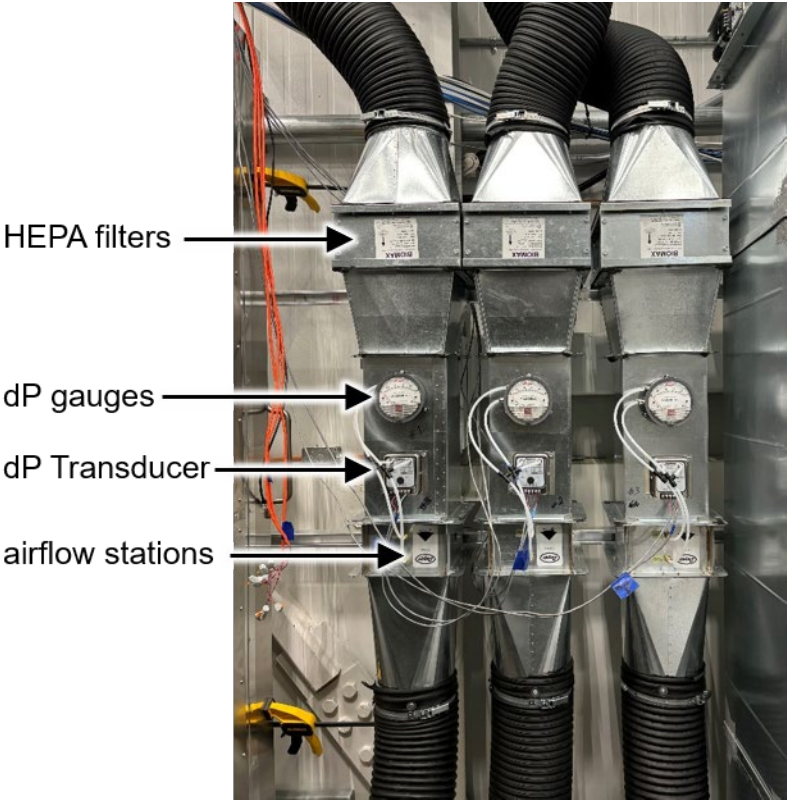




Air Supply

Three airflow measurement stations record the airflow rate to the inlet door plug. Each unit contains:

- HEPA filter
- Visual dP reading
- Omega PX653-0.1D5V differential pressure (dP) transducer
- Dwyer FLST-8x8 airflow station



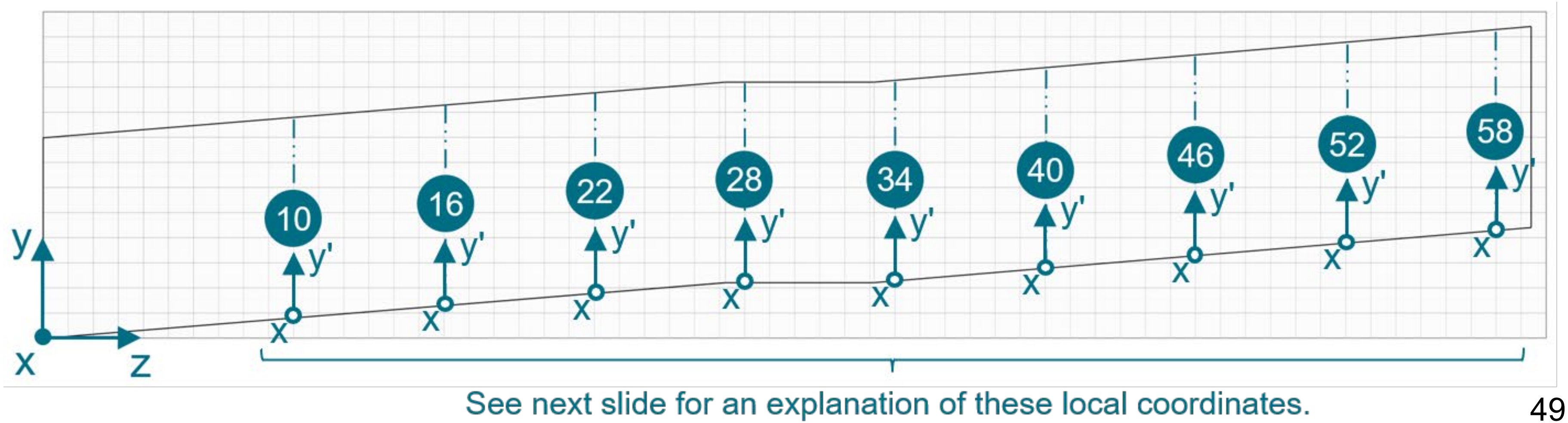
Air Exhaust

Three 200 mm ducts connect the ventilated door plug to a commercial air cleaning system. The system's blower fan draws air from the lower door diffuser and exhausts it into the lab space. The normally equipped HEPA filter is removed to allow for greater flow rates.

The exhaust blower has two speeds, high and low. At high exhaust fan speed, the supply fan setting is adjusted to achieve the desired pressure differential between the jet bridge and the lab. Ideally, the pressure differential is zero to minimize air leaks or infiltration.

Measurement Stations

Nine measurement stations (sensor array locations) are used throughout the experiments. The station numbers denote horizontal position in feet along the z-axis. The station numbers are used to in the file name structure to provide a high-level description of the measurements.



Measurement Stations (cont’d)

While measurement equipment is aligned with the jet bridge floor (y’ axis as shown on previous slide), the height of the jet bridge floor above the lab floor is added to calculate the y-axis measurement.

The table on the right shows the floor elevation along the y-axis for each measurement station.

Measurement Station (ft)	Floor Elevation (m)	Floor Elevation (ft)
10	0.247	0.812
16	0.396	1.299
22	0.544	1.786
28	0.673	2.208
34	0.695	2.282
40	0.848	2.783
46	1.001	3.285
52	1.154	3.787
58	1.307	4.289

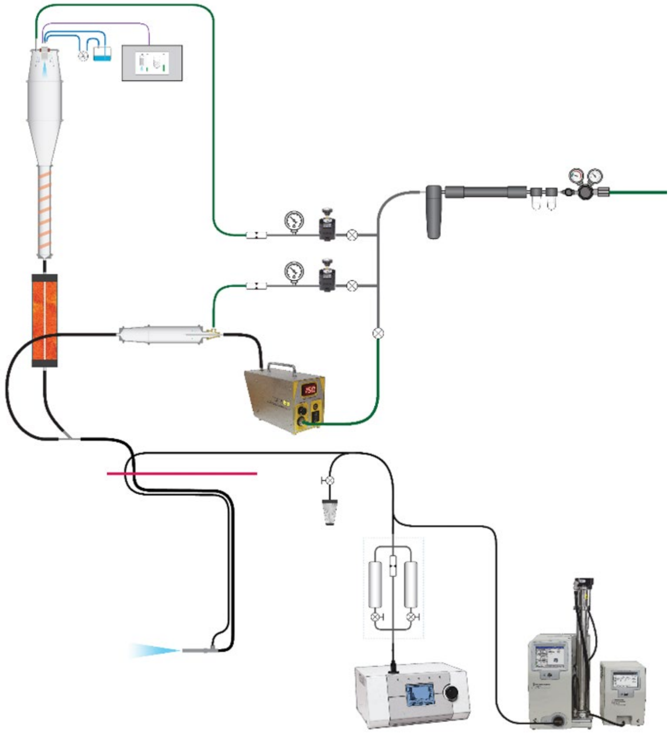
6. Methodology: Injection Systems

Particles

Particle Injection System (PIS): Overview

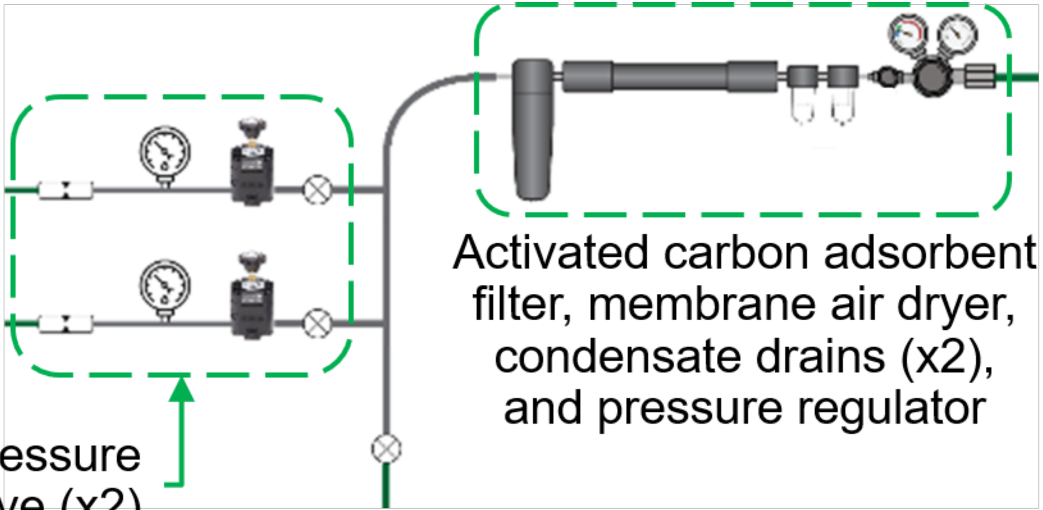
The jet bridge particle injection system consists of two atomizers producing a combined stream of particles across a broad size distribution. Aerosol is dosed at a total flow rate of 5.9 L/min and sampled by scanning mobility particle sizer (SMPS) and aerodynamic particle sizer (APS).

All aerosol generation and airflow control equipment is located outside the jet bridge, with the shortest possible transport tubing lengths. The next few slides detail each part of the system.



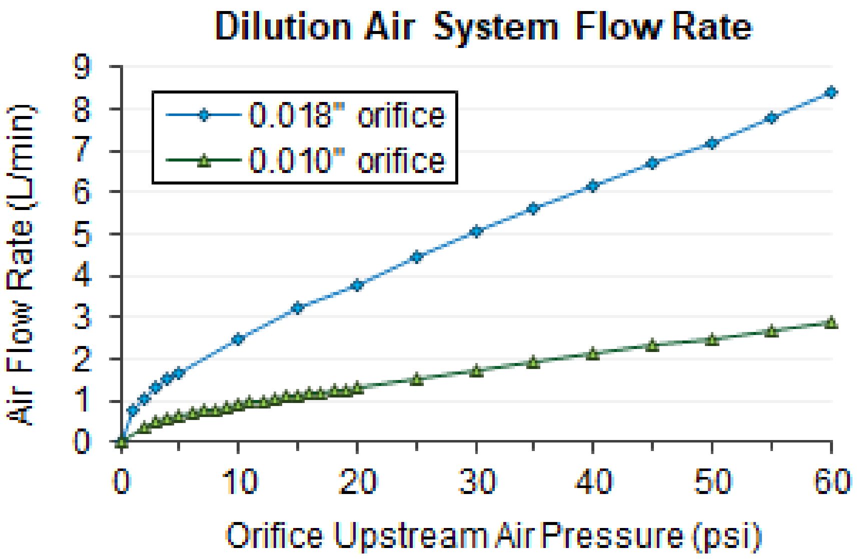
PIS: Air Delivery System

Air pressure to the atomizers and dilution air systems is controlled by a regulated system. Flow rate to the dilution air systems is set by the air pressure upstream of a flow restriction orifice.



PIS: Dilution Airflow Control

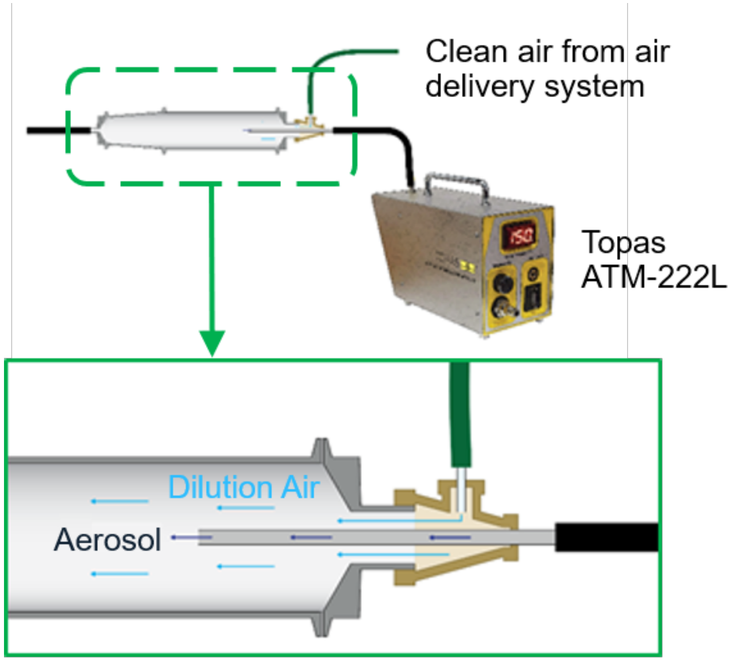
The sub-µm (Topas) atomizer dilution air uses a 0.010” orifice for up to 3.0 L/min, since the atomizer produces additional airflow when operational. The super-µm (Tekceleo) atomizer dilution air uses a 0.018” orifice for up to 8.4 L/min, since this dilution air is the only source of airflow within the spray chamber.



PIS: Sub-micron Generator

The Topas ATM-222L atomizer produces sub-micron aerosols with a 0.3 mm nozzle orifice. The atomizer was loaded with 60 mL of a 2.7% NaCl solution and operated at an orifice pressure differential of 1042 hPa, providing a flow rate of 1.4 L/min.

A downstream concentric mixing chamber provided additional dilution airflow at a rate of 1.9 L/min. Thus, the total flow rate from the sub-μm atomizer was 3.3 L/min.



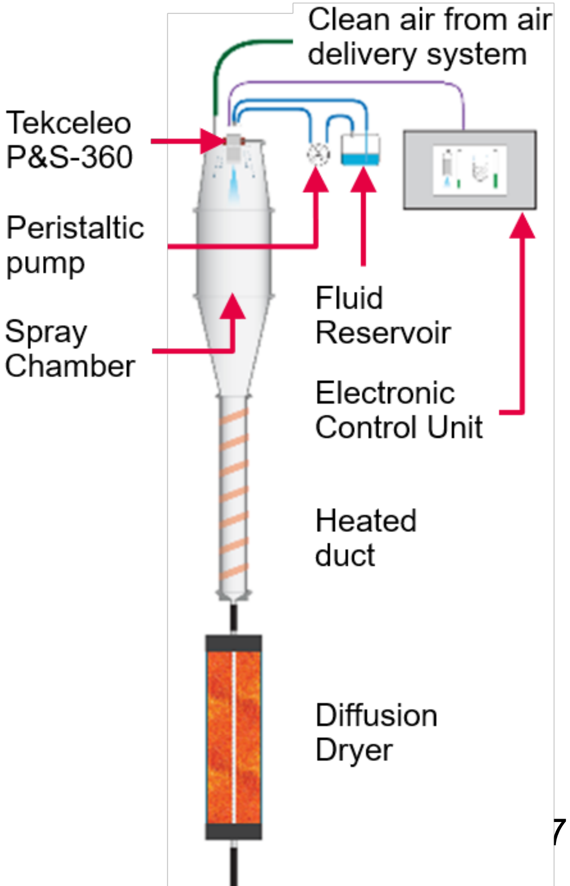
Distribution air mixing chamber

PIS: Super-micron Generator

The super-micron aerosol generation system features the Tekceleo P&S-360 vibrating mesh atomizer. The nozzle features a mesh pore size of 12 µm to produce droplets of the same diameter.

A heated duct (75°C) and diffusion dryer help to desiccate particles as they fall vertically, minimizing large particle losses.

The reservoir was loaded with 250 mL of a 0.9% NaCl solution and the atomizer was operated at an atomizer power of 12% and a pump power of 40%. All particle transport airflow is provided by the dilution air system at a flow rate of 3.2 L/min.

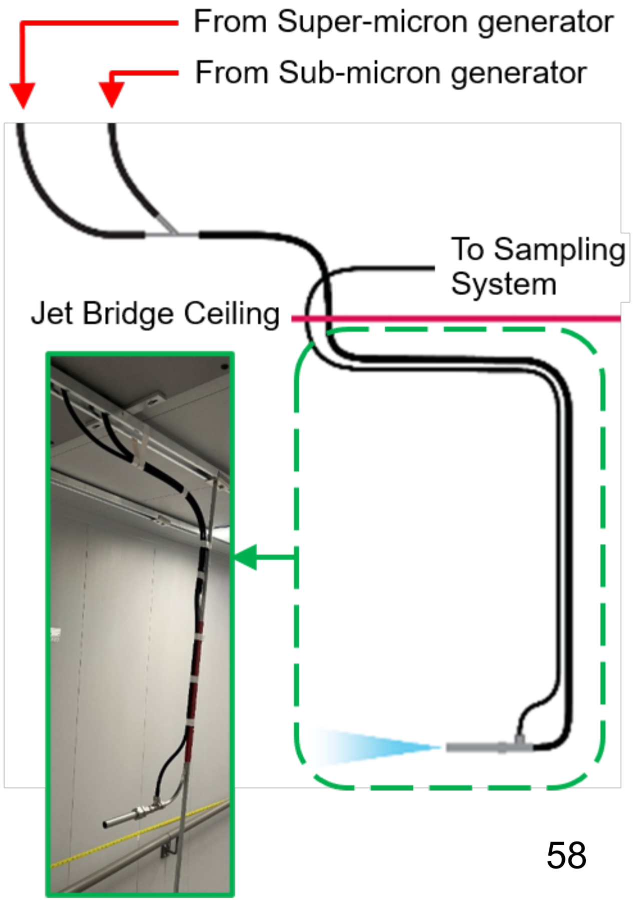


PIS: Aerosol Release Nozzle

The dosing nozzle is designed to maintain a low profile, with all transport tubing aligned with the vertical mounting rod.

The nozzle is made from stainless steel compression hardware, featuring a tee for instrument sampling followed by a round nozzle 152 mm in length that can be swapped for different outlet diameters.

Most tests used a nozzle diameter of 10.9 mm, which provided an aerosol exit velocity of 1.05 m/s at a flow rate of 5.9 L/min. A smaller nozzle diameter of 6.4 mm was tested, increasing aerosol exit velocity to 3.11 m/s at the same flow rate.

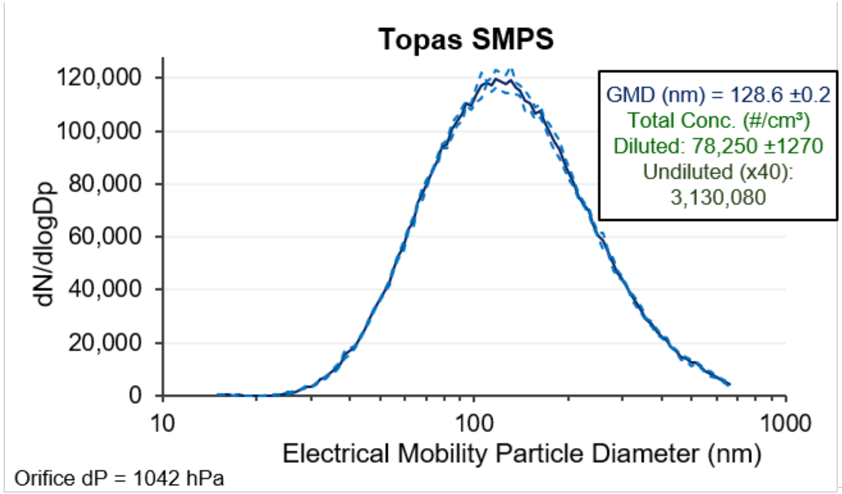


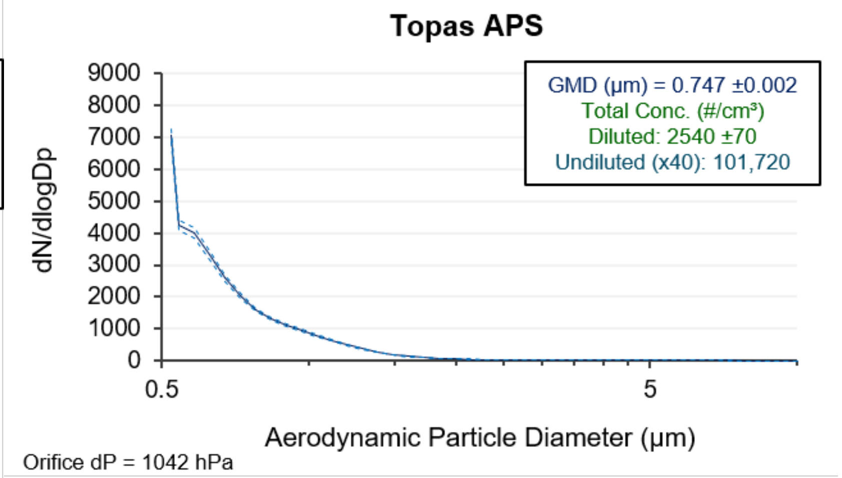
PIS: Sampling System

The sampling system draws an air sample from the aerosol release nozzle to ensure that the aerosol release is consistent throughout all of the test configurations. The sampling system draws a total of 1.3 L/min as the APS draws 1.0 L/min and SMPS draws 0.3 L/min.

PIS: Sub-micron profile

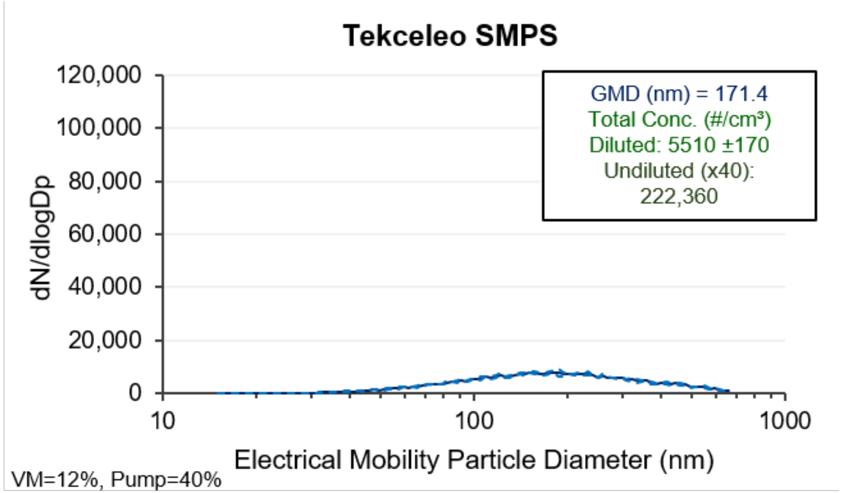
Particle size distribution spectra for the sub-micron profile were acquired by the sampling system to characterize the aerosol size concentration and distribution during the experiments. The graphs below show the total concentration as a function of particle diameter.

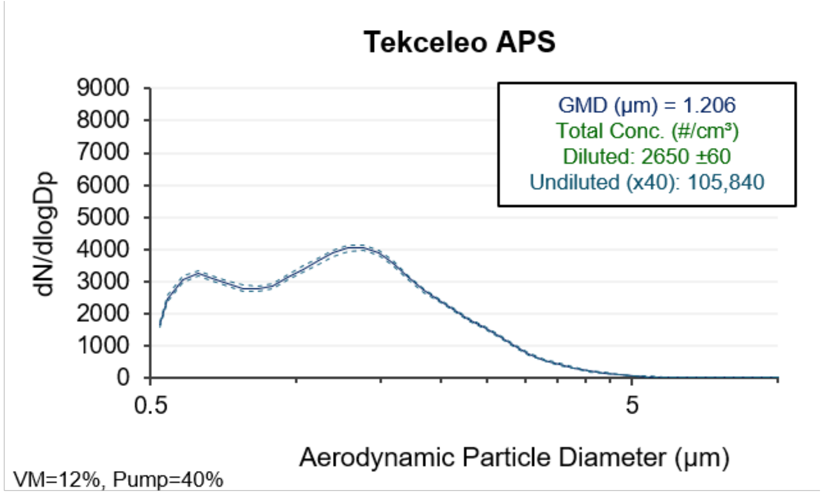




PIS: Super-micron aerosol profile

Particle size distribution spectra for the super-micron profile were acquired by the sampling system to characterize the aerosol size concentration and distribution during the experiments. The graphs below show the total concentration as a function of particle diameter. The information inside the boxes show the geometric mean diameter (GMD), total concentration of the diluted stream, and the calculated total concentration without the dilution air.

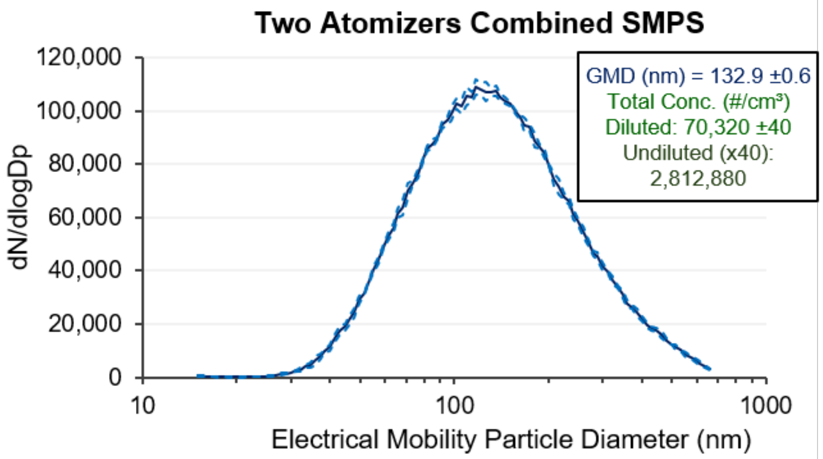


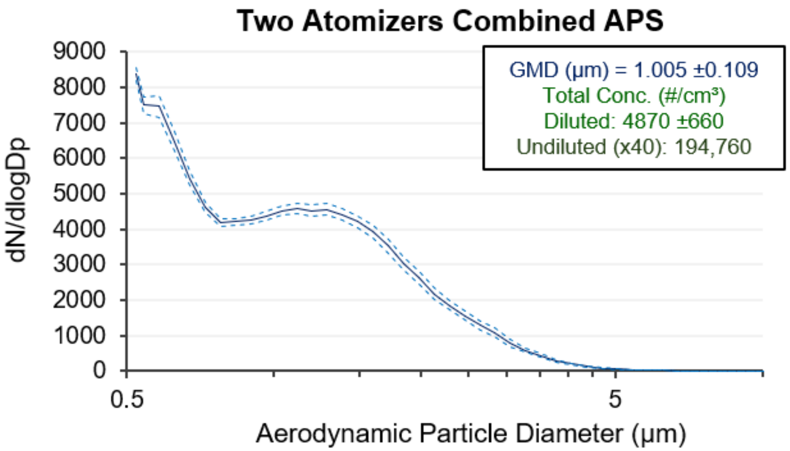


PIS: Combined aerosol profile

The aerosol streams from the sub- and super-micron aerosol generators are combined to produce a bimodal particle size distribution with particles are large as 5 µm. The total combined flow rate from both atomizers was 6.5 L/min. The total sampling rate from the aerosol stream was 0.6 L/min. Thus, the total aerosol dosing rate was **5.9 L/min**. The resulting aerosol plume velocity at dosing nozzle exit (0.430” diameter): **1.05 m/s.**

+





Particle Concentration Measurement Method

The aerosol was diluted before characterization by APS and SMPS using a dilution bridge. The dilution factor was measured to be 97.5 % at 1.5 L/min (40x) using a condensation particle counter (CPC).

Measured (diluted) total particle concentrations for all sizes.

- SMPS (10 – 700 nm): 70,320 per cm^3.
- APS (500 – 5,000 nm): 4,870 per cm^3.

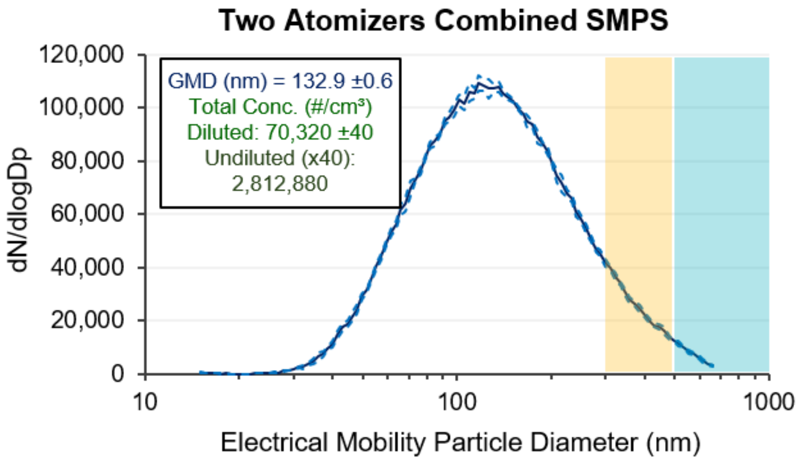
Calculated (undiluted) total particle concentrations for all sizes.

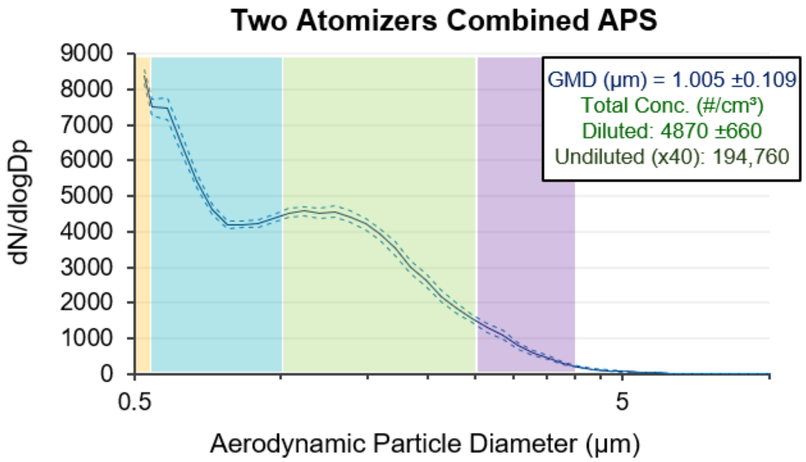
- SMPS (10 – 700 nm): 2,813,000 per cm^3.
- APS (500 – 5,000 nm): 195,000 per cm^3.

Measured Particle Concentrations by Size Bin

Size Range (µm)	Diluted Concentration (#/cm³)	Undiluted Concentration (#/cm³)
0.3 - 0.5	5960	238,320
0.5 - 1.0	880	35,040

Size Range (µm)	Diluted Concentration (#/cm³)	Undiluted Concentration (#/cm³)
0.3 - 0.5	2090	83,680
0.5 - 1.0	1520	60,680
1.0 - 2.5	1420	56,920
2.5 - 4.0	140	5640





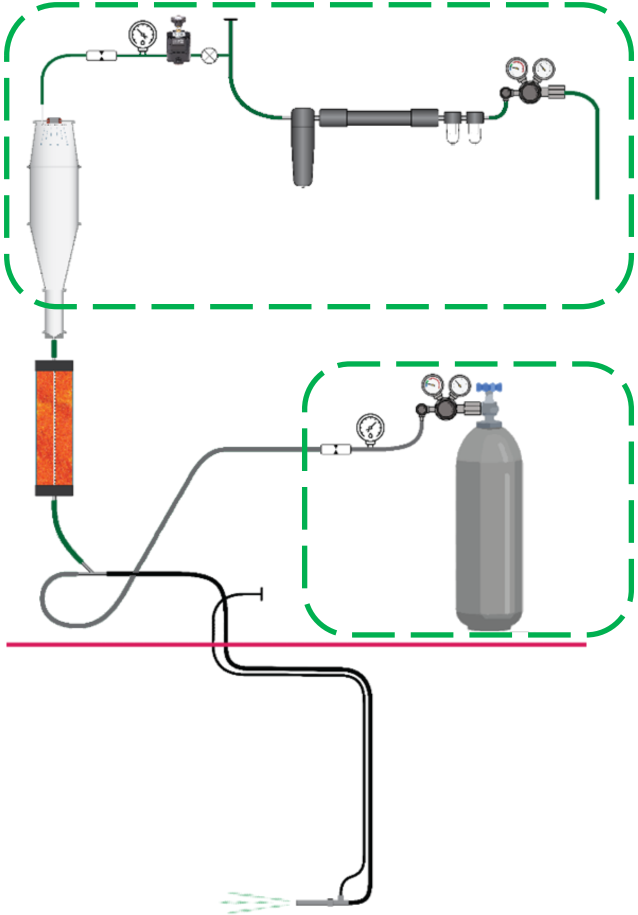
Tracer Gas

Tracer Gas Injection System: Description

Pure carbon dioxide (CO_2) used as tracer gas, supplied through the same dosing line as the sub-micron aerosols.

- Supplied at 6 L/min (39 psi with a 0.018” flow restriction orifice).
- Replicates the gas velocity of the particle injection system.
- Tends to flow towards the floor due to being 1.52 times heavier than air.
- Pure CO_2 was selected to ensure gas concentration could be measured throughout the jet bridge while maintaining the same gas injection velocity into the jet bridge.

Tracer Gas Injection System: Schematic



Purge air system with regulator, moisture trap, valve, 0.018” orifice, and drying system.

CO_2 flow control with regulator and 0.018” orifice

Jet Bridge Ceiling

Mixed carbon dioxide with air (black lines) directed to injection tube located inside jet bridge.

7. Methodology: Sampling

Sampling Methodology Overview

This chapter provides details into the sampling and averaging techniques used to gather and process the data.

1) Airport Environmental Conditions
2) Lab Environmental Conditions
3) Air Speed Measurement
4) Particulate Measurement
5) Tracer Gas Measurement

Airport Conditions

The airport environment was measured with four systems:

1) Aircraft position at gate;
2) PCA (Pre-Conditioned Air) system;
3) HVAC (Heating, Ventilation, and Air-Conditioning) systems; and,
4) Weather Station

The next four slides provides more information into these systems. The ID numbers and parameter names are used in the data set.

Airport Conditions: Flight Data

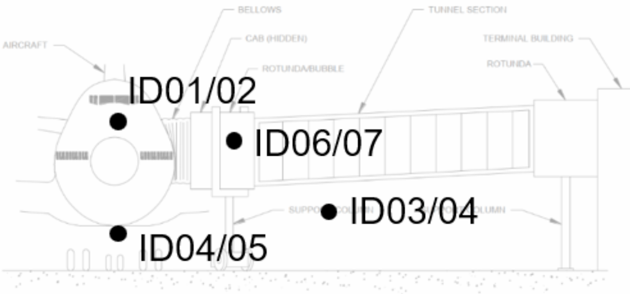
The aircraft position at the gate was recorded by the airport arrival and departure reporting system and compared against the flight data.

One jet bridge (Airport A, Gate 2) was monitored at times for the presence of an aircraft parked at the gate. When available, the aircraft record number is provided in the data set which can be cross-referenced in another report (https://doi.org/10.21949/ra9s-4d52) if more information is required for the aircraft parked at the gate.

Airport Conditions: PCA

The PCA at Airport A, Gate 01, is a bridge mounted unit that provides tempered air to the aircraft parked at the gate. The table below lists the parameters that were recorded by the data acquisition system installed at this gate and the figure shows the approximate locations of these sensors. More details about the PCA measurement system and aircraft record numbers are detailed in another report (https://doi.org/10.21949/ra9s-4d52).

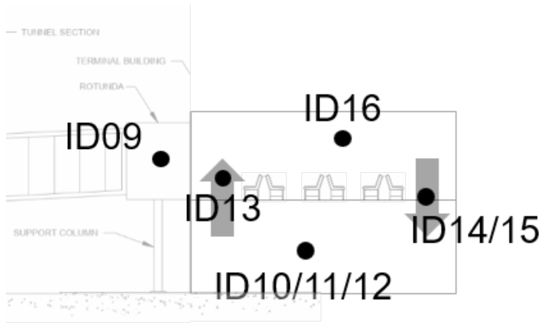
ID	Parameter	Description	Unit
01	A/C	Aircraft status (0 = no aircraft; 1 = aircraft at gate)	N/A
02	A/C #	Record number for aircraft.	N/A
03	Tdb.a.Gate	Dry-bulb temp. of the ambient air at the gate	°C
04	Tdp.a.Gate	Dew point temp. of the ambient air at the gate	°C
05	Tdb.PCA.SA	Dry-bulb temp. of the air supplied to the aircraft	°C
06	Tdp.PCA.SA	Dew point temp. of the air supplied to the aircraft	°C
07	Tdb.Bubble	Dry-bulb temp. in the jet bridge bubble.	°C
08	Tdp.Bubble	Dew point temp. in the jet bridge bubble.	°C



Airport Conditions: HVAC

Various sensors were used to record the environmental conditions within the airport building. All of the sensors are part of the building automation system (BAS) and installed on HVAC equipment that services the airport hold room adjacent to the gate doors that provide access to the jet bridge.

ID	Parameter	Description	Unit
09	Tdb.Gate	Dry-bulb temp. in the jet bridge near doors	°C
10	HVAC Mode	Status of fans (0 = off, 1 = partial, 2 = normal)	N/A
11	S.SA.Fan	Relative supply fan speed	%
12	S.RA.Fan	Relative return fan speed	%
13	Tdb.Gate.SA	Dry bulb temp. of air supplied to the hold room	°C
14	Tdb.Gate.RA	Dry bulb temp. of air returned from the hold room	°C
15	Tdp.Gate.RA	Dew point temp. of air returned from the hold room	°C
16	Tdb.Gate	Dry bulb temp. of air measured in the hold room.	°C
17	dP	Differential pressure of hold room relative to ambient	Pa



Airport Conditions: Weather Station

Outside the building, the local airport weather station was used to record the hypobaric pressure, dry-bulb temperature, dew point temperature, solar load, average air speed, peak air speed, and wind angle.

ID	Parameter	Description	Unit
18	P	Station barometric pressure	hPa
19	Tdb.a.WS	Ambient dry-bulb temperature at the station	°C
20	Tdp.a.WS	Ambient dew point temperature at the station	°C
21	G.A	Solar load at the station	kJ/m^2
22	V.ave	Average wind speed at the station	kph
23	V.peak	Wind gust speed at the station	Kph
24	V.angle	Direction the wind is coming from	°

Lab Conditions

The “lab” refers to the large room at CATR that houses the jet bridge, flexible cabin laboratory, and air handling equipment.

Lab air temperature is controlled by a separate building HVAC control system. The lab air temperature and dew point was measured with a chilled mirror hygrometer set up outside the jet bridge near the center at breathing zone height.

Lab Conditions: HVAC

Several parameters are recorded during each experiment to document the jet bridge conditions. Refer to chapter 5 (Environment: Lab Jet Bridge) for the locations for each sensor.

Parameter	Description	Unit
P	Station barometric pressure at the lab	hPa
Tdb.SA	Dry-bulb temperature of the air supplied to the bridge	°C
Tdp.SA	Dew point temperature of the air supplied to the bridge	°C
Tdb.Lab	Dry-bulb temperature of the lab that houses the bridge	°C
Tdp.Lab	Dew point temperature of the lab that houses the bridge	°C
dP	Differential pressure of the jet bridge relative to the lab	Pa
Q.FS1	Volumetric flow rate of the air by airflow station 1	Lps
Q.FS2	Volumetric flow rate of the air by airflow station 2	Lps
Q.FS3	Volumetric flow rate of the air by airflow station 3	Lps
Q.FS	Sum of the three airflow rates above	Lps

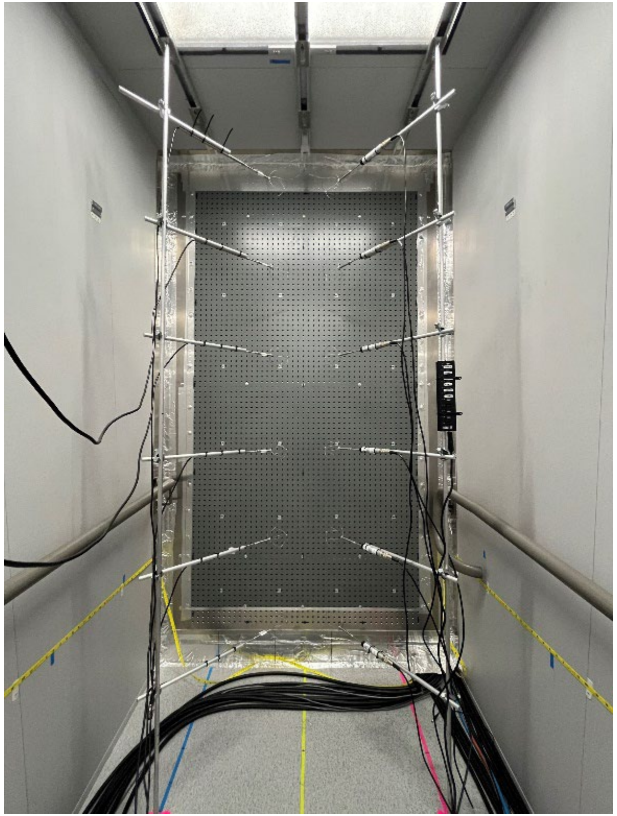
Air Speed: Sensor Mounting

Three longitudinal rails on the ceiling provide support for sensor mounts.

Sensor mount rods are keyed into the ceiling rails and rest on the ground.

All mounting rods have a diameter of 0.5 inches.

Hardware selection seeks to minimize structural impact on airflow.



Air Speed: Lab Measurements

A total of twelve (12) air speed sensors were used for each experiment.

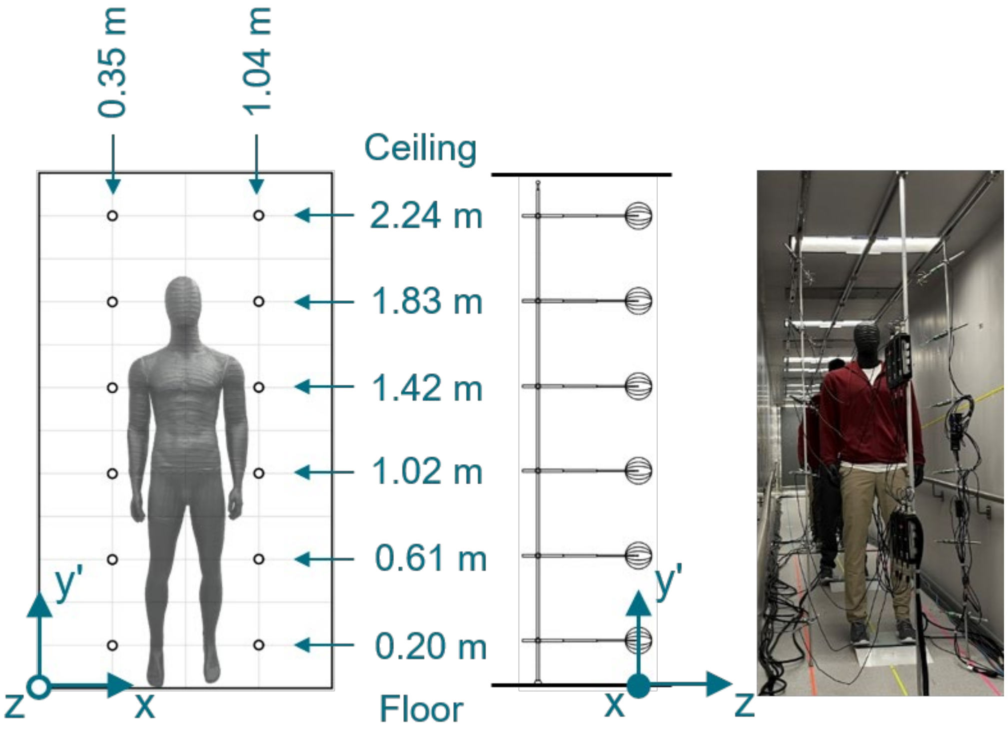
- Six (6) SWA 03 draught sensors connected to a Swema 3000 data logger.
- Six (6) Swema 03+ draught sensors connected to a USB hub.

The full array of twelve (12) sensors was positioned and configured to record data at each measurement station sequentially.

Air Speed: Low Resolution Sensor Arrangement

Two columns of 6 sensors equally spaced and centered to the jet bridge. The sensor width was selected to allow the sensors to be easily moved past the manikins without affecting the position of each manikin.

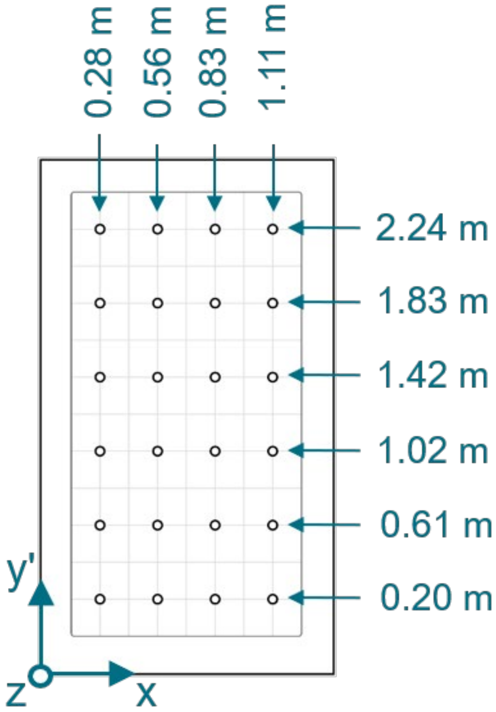
The distance of each probe off of the jet bridge floor (y’) and the left wall (x) are shown in the figure on the right. The y-axis measurement is y’ plus the bridge floor height.

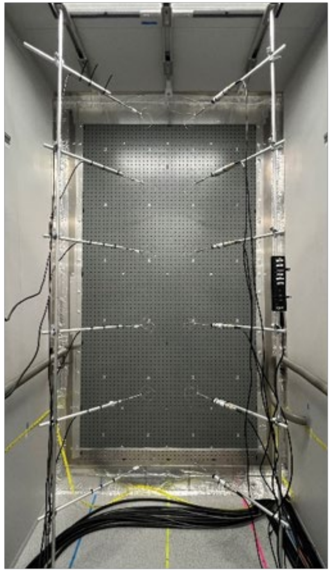


Air Speed: High Resolution Sensor Arrangement

Four columns of 6 sensors equally spaced and centered to the jet bridge. This configuration was only used near the inlet wall at a distance of 305mm.

The distance of each probe off of the jet bridge floor (y’) and the left wall (x) are shown in the figure on the right. The z-axis dimension passes through the center of each air speed sensor (see previous slide). The y-axis measurement is y’ plus the bridge floor height.





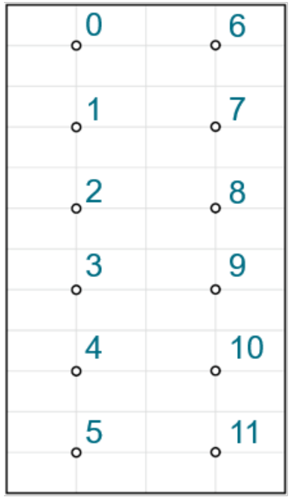
Probes configured to measure the inner two columns. Outer two columns measured in another run.

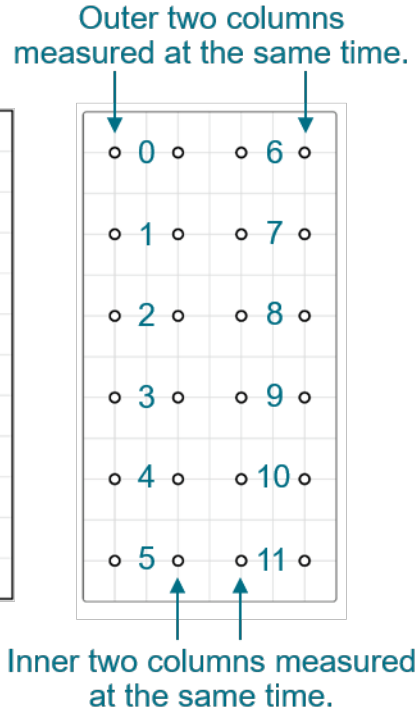
Air Speed: Probe Locations

The probe number and position for the two resolution configurations are shown below.

Left Hand Column(s)

Probe #	Probe S/N	Probe CPU
0	674529	680719
1	674549	680669
2	674509	680679
3	674519	709779
4	674539	680689
5	674559	680699





Right Hand Column(s)

Probe #	Probe S/N	Probe CPU
6	674949	N/A
7	674899	N/A
8	674929	N/A
9	674939	N/A
10	674989	N/A
11	674969	N/A

Air Speed: Field Measurements

Six (6) Swema 3000 data loggers with the SWA03 draught sensors were used to measure conditions in the field with minimal equipment.

Each Swema 3000 measures continuously at 40 Hz. The data loggers were programmed with a running average 0.5 seconds with a log interval of 2 seconds (0.5 Hz). The time constant creates a running average. Each logger operates independently of each other.

Probes 0 through 5 were used (see previous slide) in a 2x3 configuration for measurements across the width of the bridge or in a 1x3 configuration for measurements down the centerline of the jet bridge. Chapters 10 and 11 provide more details.

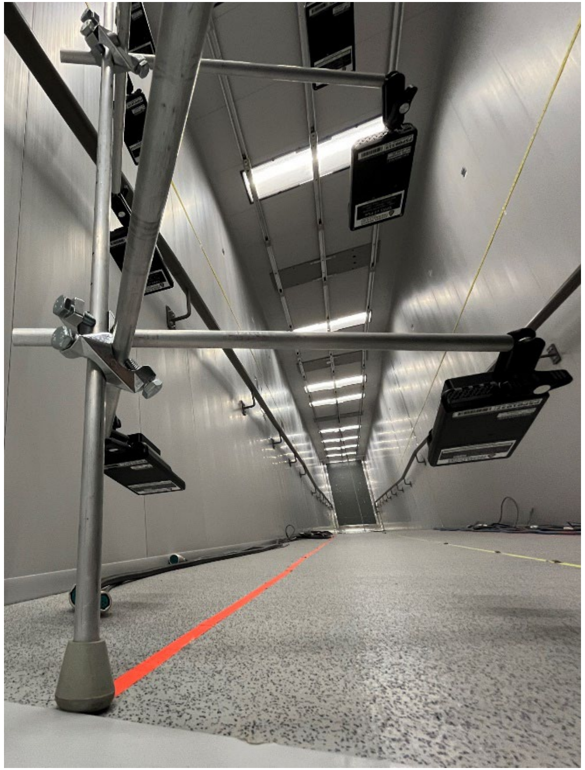
Particle and Tracer Gas (PTG): Sensor Mounting

Three longitudinal rails on the ceiling provide support for sensor mounts.

Sensor mount rods are keyed into the ceiling rails and rest on the ground along a marked path.

All mounting rods have a diameter of 0.5 inches.

Hardware selection seeks to minimize structural impact on airflow.

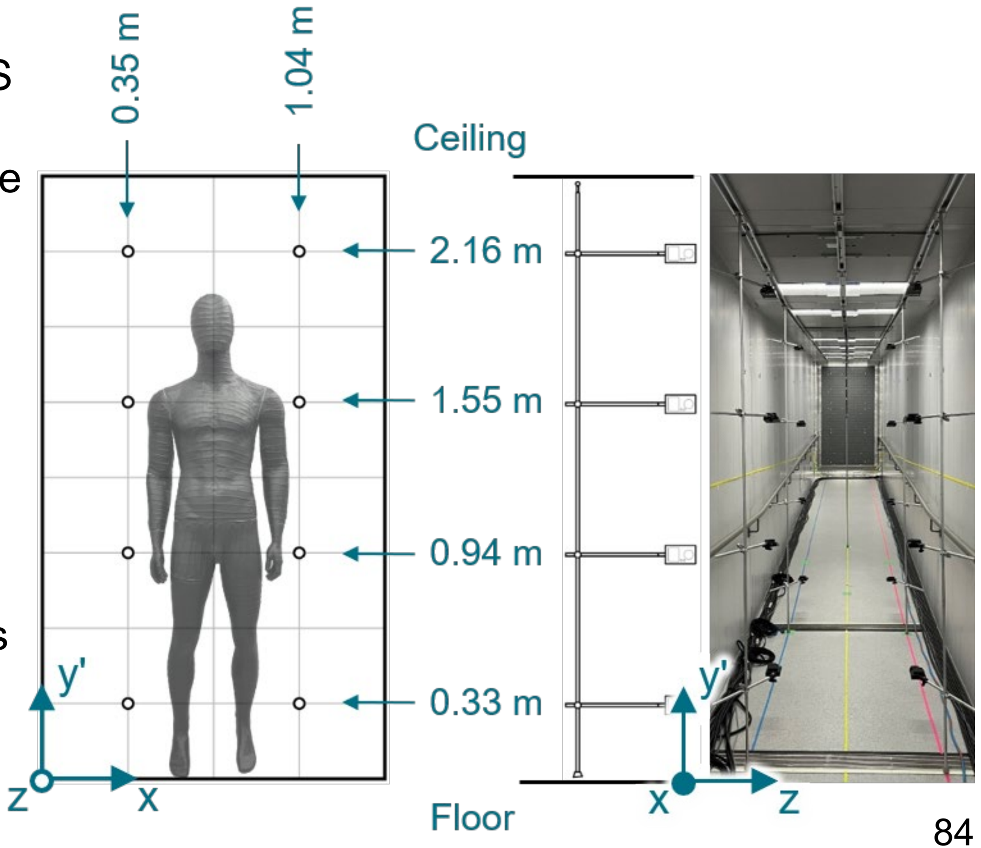


Particle/CO_2 sensors (UPAS)

PTG: Low Resolution Sensor Arrangement

Each station consists of 2x4 grid of 4 UPAS sensors. Five stations were measured simultaneously with 40 UPAS sensors. Like the air speed measurements, the column spacing was set wider than the manikin to facilitate relocation of manikins between experiments without repositioning the sensors.

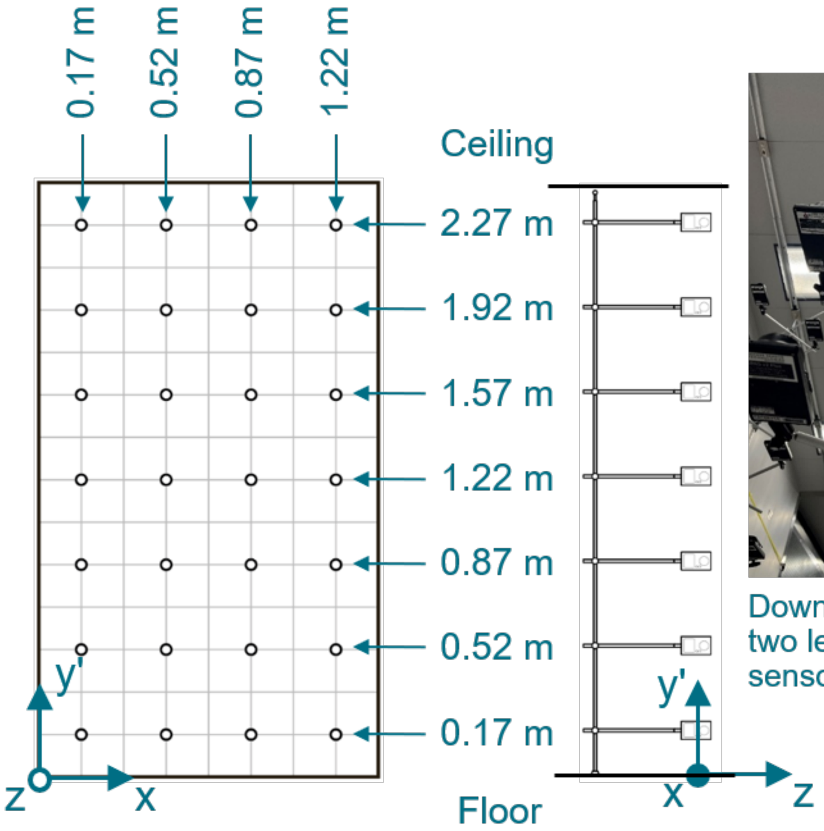
The distance of each probe off of the jet bridge floor (y’) and the left wall (x) are shown in the figure on the right. The z-axis dimension passes through the center of each air speed sensor. The y-axis measurement is y’ plus the bridge floor height.

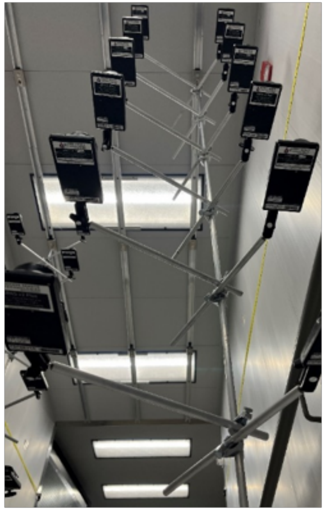


PTG: High Resolution Sensor Arrangement

Same concept as the low resolution sensor arrangement except only one station is measured at a time with a 4x7 configuration of sensors.

The distance of each probe off of the jet bridge floor (y') and the left wall (x) are shown in the figure on the right. The z-axis dimension passes through the center of each air speed sensor. The y-axis measurement is y' plus the bridge floor height.





Downwind view of the two left side column of sensors.

Data Processing: Creating the CSV, TXT, and HVAC Files

All of the air speed, particulate, tracer gas, and HVAC files had the calibration constants applied to all measurements prior to saving the CSV, TXT, and HVAC files.

As the air speed measurements were not collected concurrently, the S* files have the measurement times recorded with each individual sensor. The air speed data was captured live by the computer and the reported times are when the data was received by the computer.

The particulate and tracer gas measurements were collected concurrently with an accuracy of ±0.5 seconds. All of the devices were operating independently. They were synchronized by using the built-in light sensor to coordinate the times based turning the jet bridge lights off and then back on.

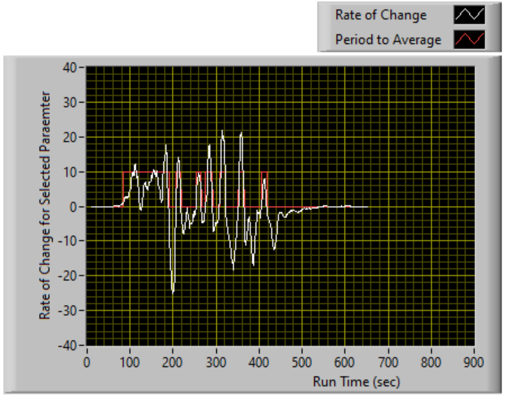
The background concentration was stable (+/- 10 ppm) throughout each experiment but the atmospheric conditions do change throughout the day and the prevailing winds around the airport where the lab is based. To simplify future analysis of the data, all carbon dioxide measurements were subtracted by the background carbon dioxide concentration measured at the jet bridge inlet.

Data Processing: Creating Averaged Data Sets

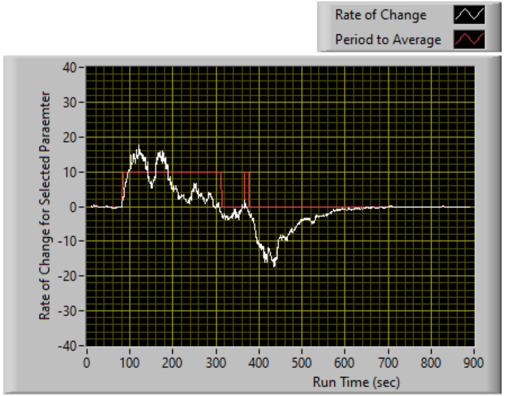
All of the air speed measurements were averaged as the jet bridge conditions were at steady-state conditions prior to each experiment. However, the particulate and tracer gas experiments required a consistent technique to identify when the tracer gas concentrations were at quasi-steady state conditions for each experiment. A program was written to look at the overall relative change in concentrations at each measurement station to determine when the tracer gas concentration stopped increasing (at the start of the run) and started decreasing (at the end of the run). The next slide shows an example of how the start and stop times are determined, which are recorded in the periods folder (see chapter 10 for details). Any user of the data can opt to use a different technique to average the data by applying their algorithms to the CSV and TXT files.

Data Processing: Averaging Technique

The program display on the right shows PM0.5 data (above) and CO_2 data take from randomly selected data files. The white line shows the overall rate of change for the PM0.5 particle measurements. The first red line indicates when to start averaging the data. The last red line indicates when to stop averaging the data. These start and stop times are used to produce the average files and the HVAC averages listed in the periods file. See chapter 10 for additional details on where to find these data sets.



Example from PM0.5 data set



Example from CO_2 data set

Data Processing: Creating Summary Files

There were multiple replicates for most of the test conditions. If multiple replicates are available, then all the averages from each replicate are averaged to create an overall average for each test condition. These average of the averages were saved in the Summary folder.

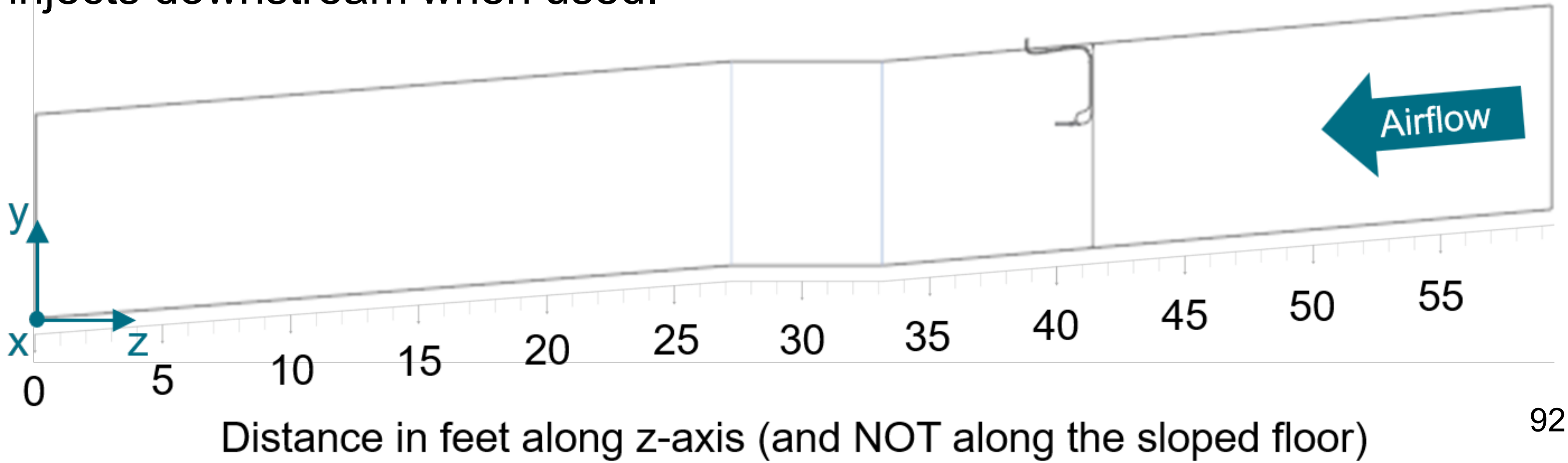
8. Test Configurations

Test Configurations Overview

This chapter describes the eleven different jet bridge configurations that were used in the lab and in the field. They are consistent for all three measurement techniques: air speed, particles, and tracer gas. However, not all eleven bridge configurations were in use for all measurement techniques.

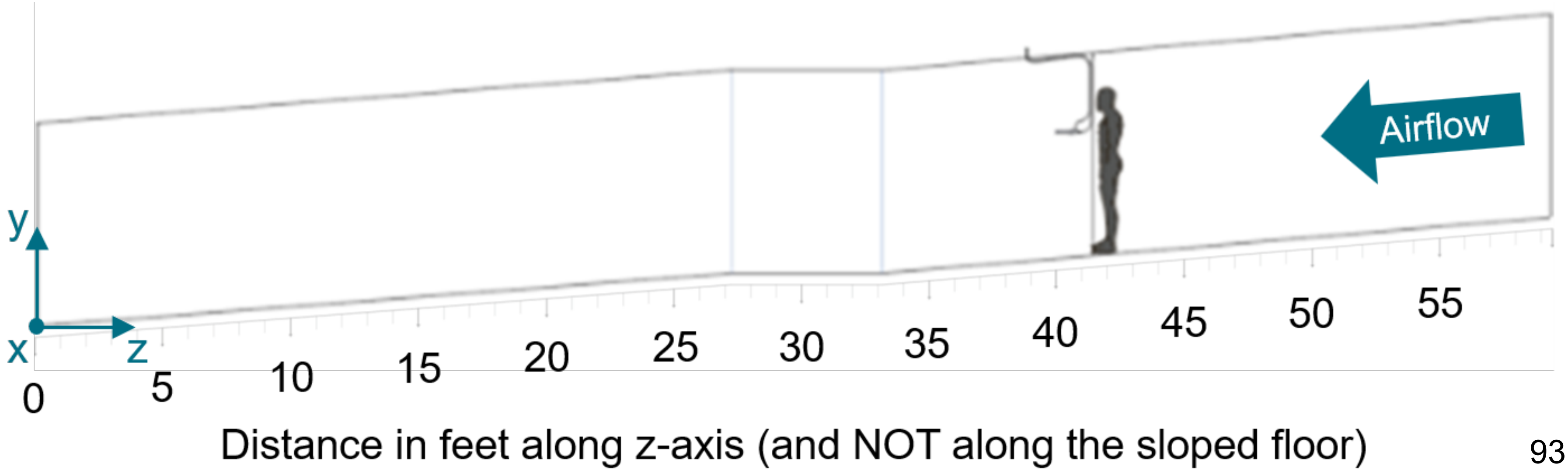
Test Configuration 01 (Empty, Downstream Dose)

Jet bridge mock-up in a lab environment. Aerosol or tracer gas injection outlet is fixed at 12.19 m (40 ft) at a height of 1.52 m (5.0 ft) above jet bridge floor and 2.38 m (7.8 ft) above the lab floor. It is centered laterally at 0.69 m (2.3 ft) along x-axis. The outlet is aligned with the z-axis and injects downstream when used.



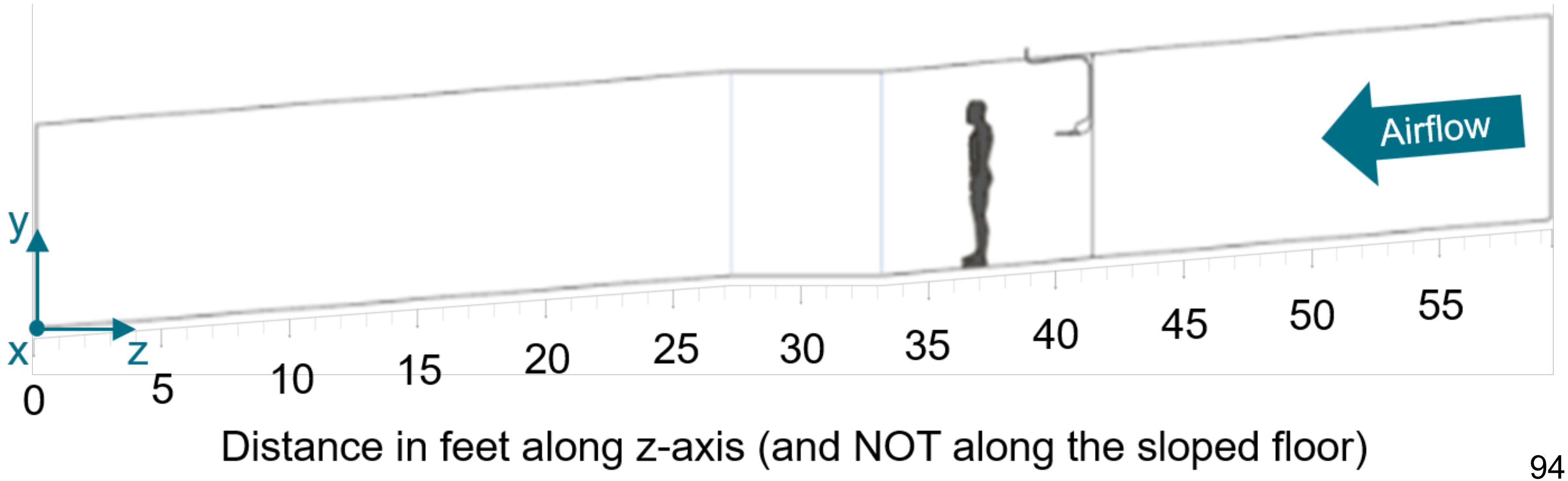
Test Configuration 02 (Manikin at 42 ft)

Same configuration as #01 except a manikin is placed at the 12.80 m (42 ft) position and facing downstream. It is centered laterally at 0.69 m (2.3 ft) along x-axis. The manikin posture is aligned with the y-axis.



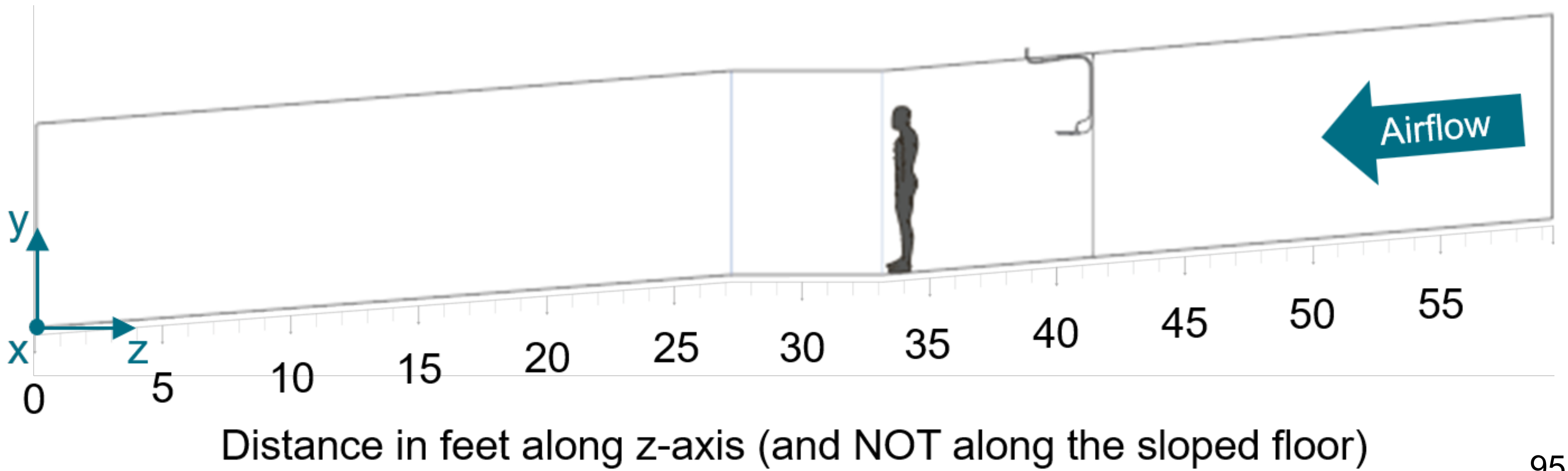
Test Configuration 03 (Manikin at 37 ft)

Same configuration as #02 except the manikin is repositioned to the 11.28 m (37 ft) position.



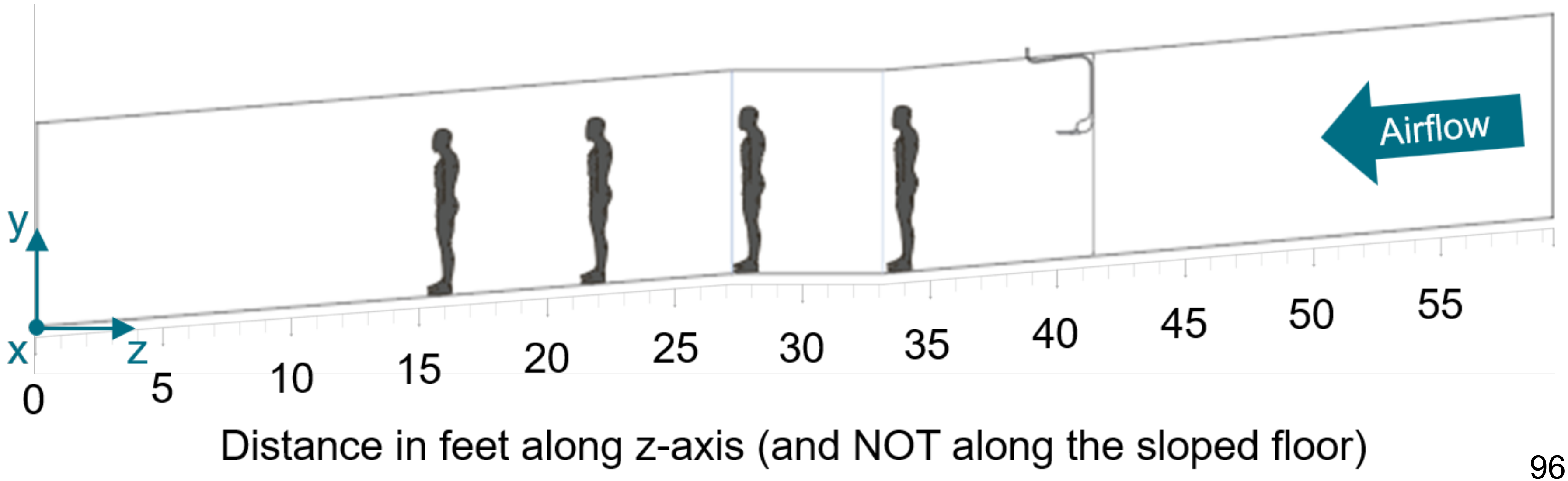
Test Configuration 04 (Manikin at 34 ft)

Same configuration as #02 except the manikin is repositioned to the 10.36 m (34 ft) position.



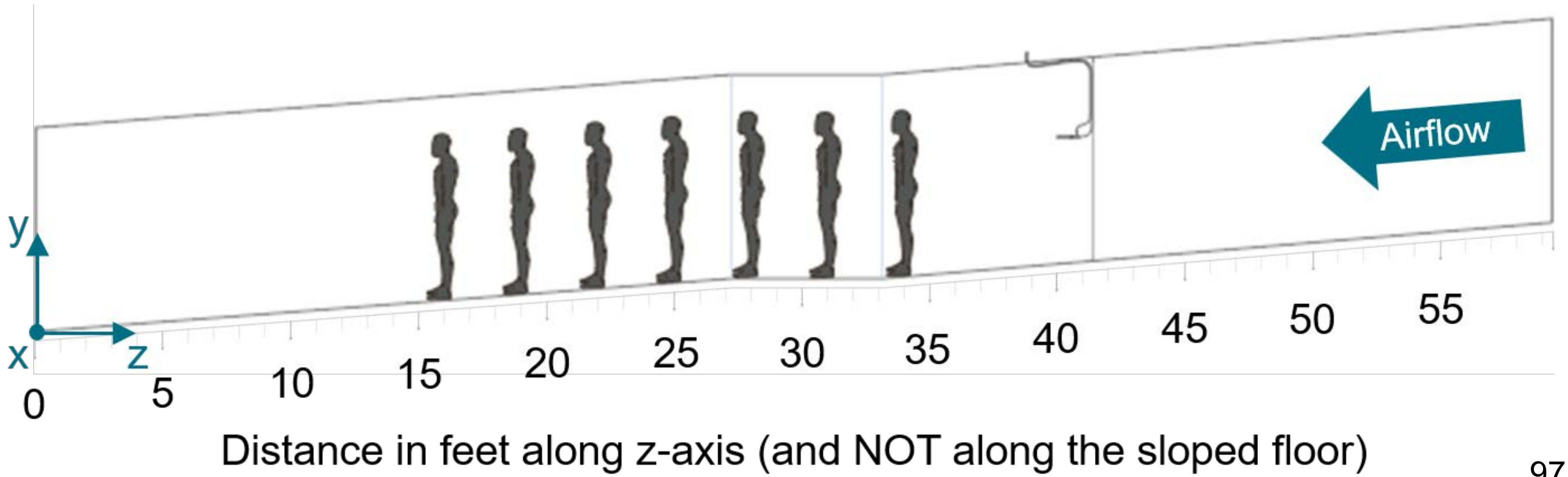
Test Configuration 05 (Four manikins at 6 ft spacing)

Same configuration as #04 except three manikins are added at the 4.88 m (16 ft), 6.71 m (22ft), and 8.53 m (28 ft) positions. All manikins face downstream.



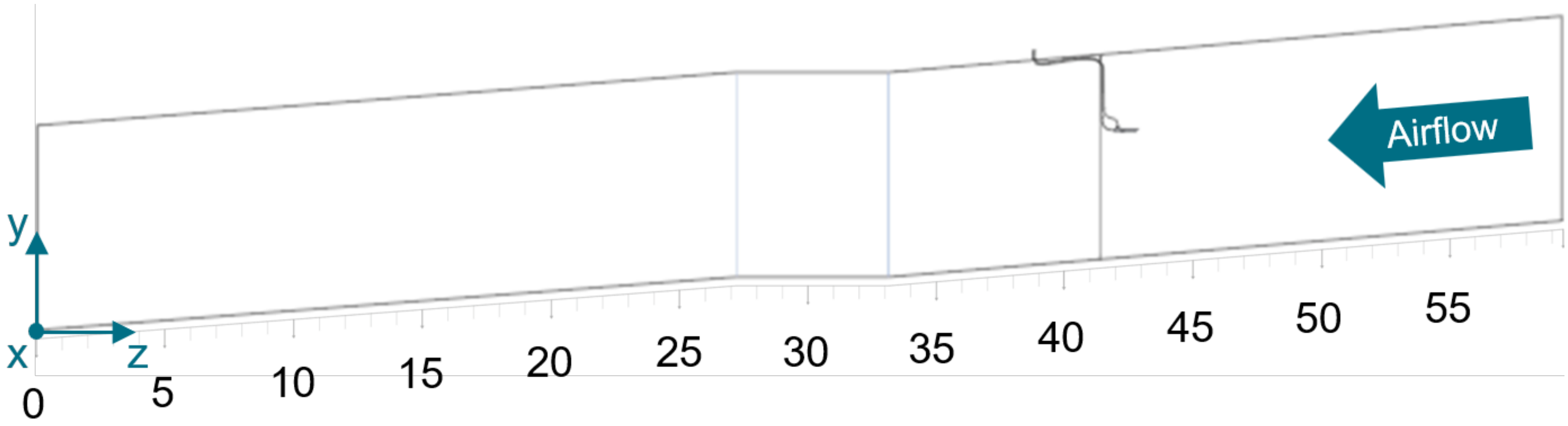
Test Configuration 06 (Seven manikins at 3 ft spacing)

Same configuration as #05 except three manikins are added at the 5.79 m (19 ft), 7.62 m (25 ft), and 9.45 m (31 ft) positions. All manikins face downstream.



Test Configuration 07 (Empty, Downstream Dose)

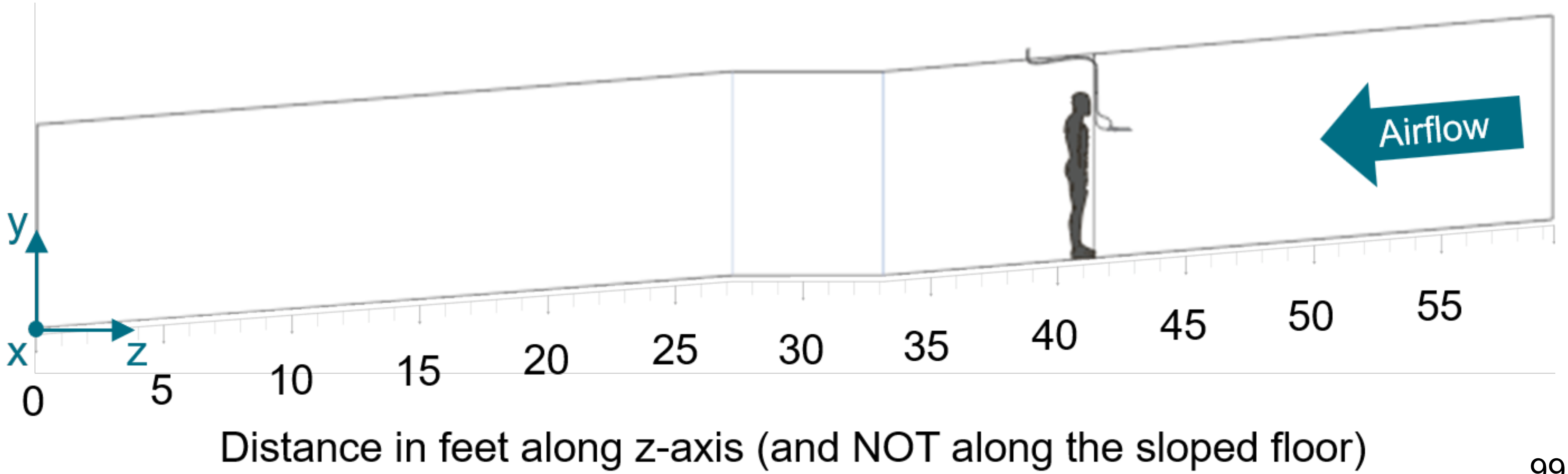
Same configuration as #01 except the dosing is rotated 180°, which moves the outlet location to 12.8 m (42 ft). The outlet is aligned with the z-axis and injects upstream when used.



Distance in feet along z-axis (and NOT along the sloped floor)

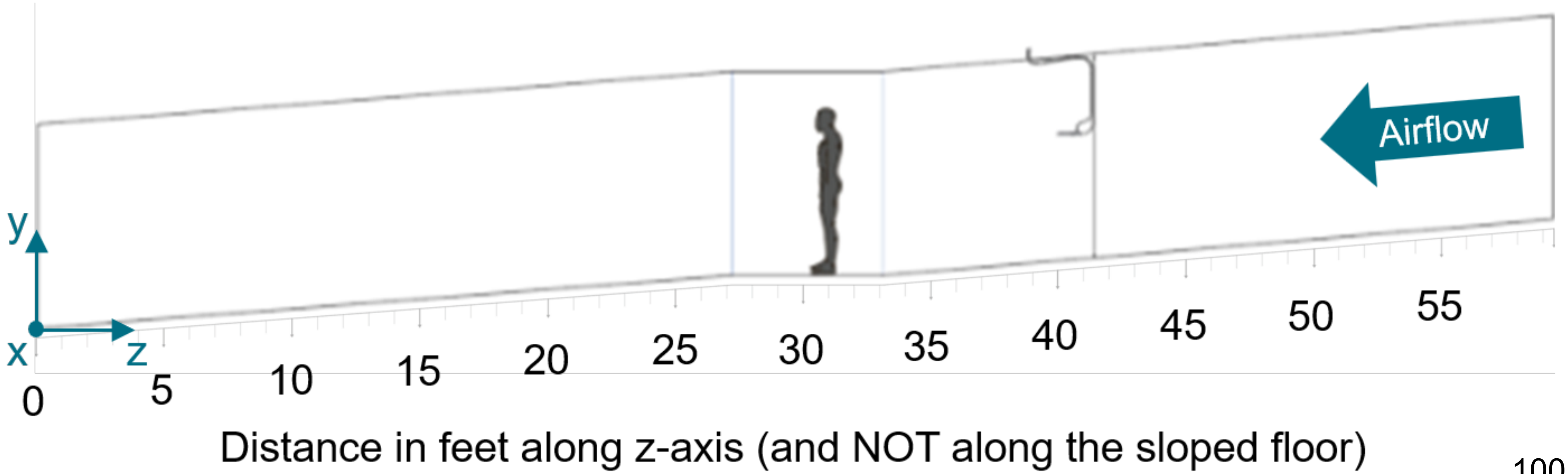
Test Configuration 08 (Manikin at 40 ft)

Same configuration as #07 except a manikin is placed at the 12.80 m (42 ft) position and facing upstream. It is centered laterally at 0.69 m (2.3 ft) along x-axis. The manikin posture is aligned with the y-axis.



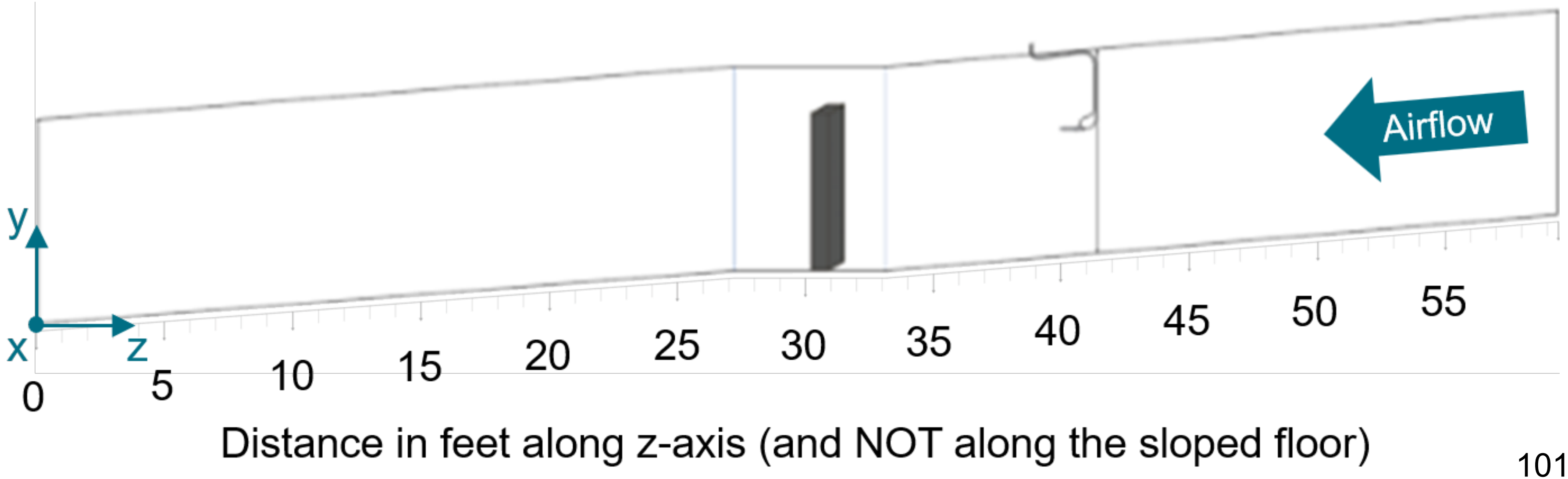
Test Configuration 09 (Manikin at 31 ft)

Same configuration as #02 except the manikin is repositioned to the 9.45 m (31 ft) position.



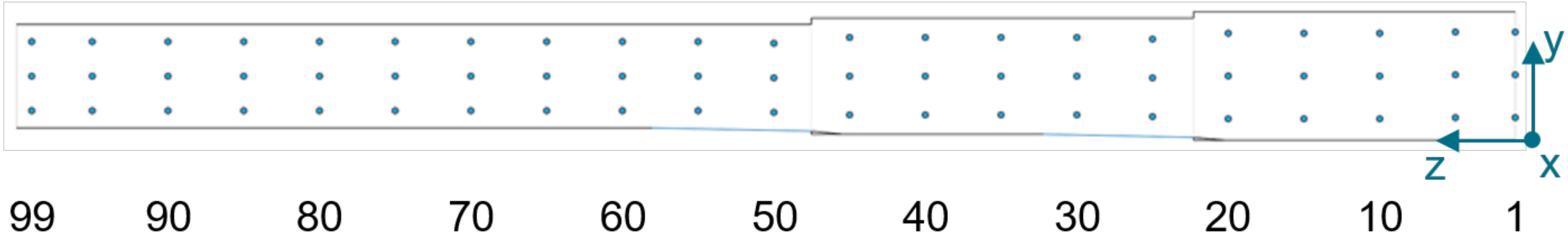
Test Configuration 10 (Manikin at 31 ft)

Same configuration as #08 except the manikin is replaced with a box.



Test Configuration 11 (Airport Jet Bridge)

Airport jet bridge that consists of three sections that telescope out to meet the aircraft. The measured section is between the upper and lower rotundas. The z-axis is aligned with the slope of the bridge. More details are described in a later section of this report.



9. Instrumentation & Equipment

Chilled Mirror Hygrometers

Two hygrometers are used to measure air temperature and dew point in the supply air inlet diffuser and in the lab space external to the jet bridge.

OptiSonde General Eastern Chilled Mirror Hygrometer

- Chilled mirror system measures dewpoint temperature with a 0.2°C accuracy with a dew-point range of -15°C to 25°C.
- Dry-bulb temperature sensor has a 0.15°C accuracy over a range of -100°C to 100°C.

Air Speed Probes

Two sets of air speed and temperature probes are used:

1. Swema SWA03 draught sensor with 3000 data logger.
2. Swema 03+ draught sensor with USB connection.

All sensors have a 90% response time of 0.2 seconds, which meets ISO 7726. The table below provides the specifications for the sensors.

Sensor	Range	Accuracy
Air Speed	0.05 to 3 m/s	±0.04 m/s up to 1.0 m/s (at 15°C to 30°C) ±4% over 1.0 m/s (at 15°C to 30°C)
Temperature	10 to 40°C	±0.1°C
Pressure*	600 to 1200 hPa	±3.5 hPa

* Pressure sensor is available only on the Swema 03+ draught sensor

Air Speed Calibration

Twelve (12) air speed probes were used in this project. The probes were calibrated twice. Once at the start of the project. Again immediately after the jet bridge measurements were completed. The second calibration included an “as-found” measurement as the sensors were past due for calibration. The table below shows the linear calibration slopes for the initial calibration and the as-found condition.

Model	Probe Serial #	CPU Serial #	Calibration Date	Calibration Slope	Calibration Date	As-Found Slope
SWA03	674529	680719	2024-01-31	1.009426	2025-08-05	1.059894
SWA03	674549	680669	2024-01-31	1.010954	2025-07-11	1.000481
SWA03	674509	680679	2024-01-31	1.003247	2025-07-11	1.022672
SWA03	674519	709779	2024-01-31	1.020786	2025-08-05	1.035674
SWA03	674539	680689	2024-01-31	0.990884	2025-07-11	0.987341
SWA03	674559	680699	2024-01-31	1.001104	2025-07-11	0.994866
Swema 03+	674949	N/A	2023-04-26	0.994153	2025-07-14	0.953299
Swema 03+	674899	N/A	2023-04-26	1.016170	2025-07-15	0.974294
Swema 03+	674929	N/A	2023-04-25	1.016157	2025-07-14	1.018504
Swema 03+	674939	N/A	2023-04-25	1.000523	2025-07-15	0.962208
Swema 03+	674989	N/A	2023-04-26	1.015883	2025-08-05	0.994634
Swema 03+	674969	N/A	N/A	N/A	2025-07-14	0.961906

Airflow Station: Duct Mounted Station

Each Dwyer FLST-8x8 duct mounted airflow measurement station utilizes an airflow averaging element generating a velocity pressure signal similar to a pitot tube. It has an accuracy of ±2% of actual flow. The airflow rate is calculated as follows:

$$Q = A \cdot C \cdot \sqrt{\frac{P_v}{\rho}}$$

where Q is the airflow rate (ft^3/min), A is the duct area (ft^2), C is constant at 1096.7, P_v is the velocity pressure (in w.c.), and ρ is the density of air (lb/ft^3) based on supply air temperature and barometric pressure.

Airflow Station: Velocity Pressure Sensor

The velocity pressure for each airflow station is measured with an Omega PX653-0.1D5V differential pressure (dP) transducer. The specifications for this unit are listed below.

Parameter	Value
Linearity	0.125 Pa
Hysteresis	0.005 Pa
Repeatability	0.013 Pa
Compensated Temperature Range	2 to 57°C
Thermal effects: Zero	0.007 Pa/°C
Thermal effects: Span	0.027% reading/°C
Response time	250 ms

Particle Measurement: UPAS

Ultrasonic Personal Air Sampler (UPAS) v2.1+ is a portable, self-powered device that weighs 250 g. It consists of multiple components in a package slightly larger and heavier than a cell-phone (128mm x 70mm x 23mm, 0.2 kg). The components include:

- Sensirion SPS30 to measure particulate matter (PM) concentration.
- Sensirion SCD41 to measure carbon dioxide concentration.
- Bosch BME280 to measure temperature, humidity and pressure.
- Silicon Labs Si1133-AA00-GMR to measure light intensity.
- 24 W-h Li-Ion battery
- Also equipped but not used include a sample filter, flow rate, pressure differential, pump, GPS, and accelerometers.

UPAS: Sensirion SPS30

The Sensirion SPS30 particulate matter (PM) unit uses a fan to draw air through the unit where a laser scattering method is used to measure the particulate concentration.

Parameter	Conditions	Value
Number concentration size range	PM0.5	0.3 to 0.5 µm
	PM1.0	0.3 to 1.0 µm
	PM2.5	0.3 to 2.5 µm
Number concentration precision for the above	0 to 1000 #/cm^3	±100 #/cm^3
	1000 to 3000 #/cm^3	±10 % m.v.
Long-term number concentration precision limit drift	0 to 1000 #/cm^3	±12.5 #/cm^3/year
	1000 to 3000 #/cm^3	±1.25% m.v./year
Additional precision limit drift	Temperature delta to 25°C	±0.5% m.v./°C

Source: Sensirion SPS30 Datasheet, accessed December 23rd, 2025

UPAS: Sensirion SCD41

The Sensirion SCD41 is a photoacoustic NDIR sensor complete with a built-in SHT4x humidity and temperature sensor for signal compensation.

Parameter	Conditions	Value
CO_2 measurement accuracy	400 to 1000 ppm	±(50 ppm + 2.5% of reading)
	1000 to 2000 ppm	±(50 ppm + 3% of reading)
	2000 to 5000 ppm	±(50 ppm + 5% of reading)
CO_2 repeatability	Typical	±10 ppm
CO_2 response time	Typical	60 s
Humidity accuracy	15 to 35°C, 20% to 65% RH	±6% RH
Humidity response time	Typical	90 s
Temperature accuracy	15 to 35°C	±0.8°C
Temperature response time	Typical	120 s

Source: Sensirion SCD41 Datasheet, accessed December 23rd, 2025

UPAS: Bosch BME280

The Bosch BME280 is a sensor module packaged in a compact package. Temperature readings tend to read higher due to internal heat from other components within the UPAS sensor.

Sensor	Parameter	Conditions	Value
Temperature	Operating Range		-40 to 85°C
	Absolute accuracy	0 to 65°C	±0.5°C
Humidity	Response time	0% to 90% RH	1 s
	Accuracy	20% to 80% RH	±3% RH
	Long term stability	10% to 90% at 25°C	0.5% RH/year
Pressure	Operating range	0 to 65°C	300 to 1100 hPa
	Temperature coefficient of offset	25 to 75°C, 900 hPa	±1.5 Pa/K
	Accuracy	300 to 1100 hPa, 0 to 65°C	±1.0 hPa
	Long term stability	300 to 1100 hPa, 0 to 65°C	±1.0 hPa/year

Source: Bosch BME280 Datasheet, accessed December 23rd, 2025

UPAS: Silicon Labs Si1133-AA00-GMR

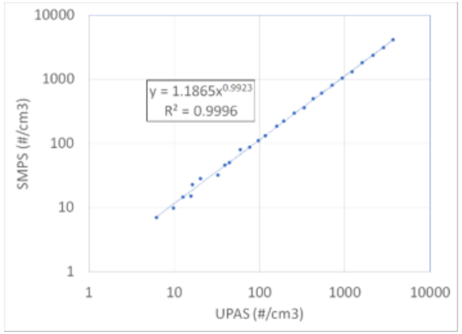
The Silicon Labs light sensor is a low-power, reflective-based, infrared proximity, ultraviolent (UV) index, and ambient light sensor. It is used only to synchronize the time of all UPAS sensors by cycling the lights in the environment.

UPAS: Calibration

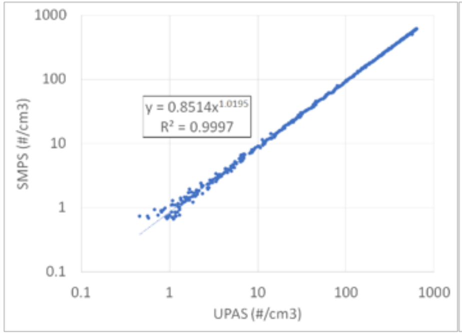
All UPAS sensors were placed in a sealed tote measuring about 1 meter cubed. In separate runs, aerosols or carbon dioxide was introduced into the tote with the same injection equipment described in chapter 6 (Methodology: Injection Systems). Using small 100mm fans, the aerosols or carbon dioxode were suspended and allowed to decay over time with dilution while the UPAS sensors recorded the particle concentrations or tracer gas concentrations. The background particulate concentrations were recorded with the SMPS and APS equipment. The background carbon dioxide concentration was measured with a CAI (California Analytical Instruments) NDIR (Non-Dispersive Infrared) system.

UPAS: Calibration (cont’d)

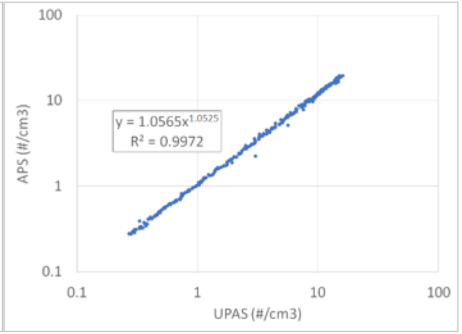
The results for one of the UPAS sensors is shown below for the three particle size bins and the carbon dioxide concentration. The calibration was repeated for all sensors and has been applied to the data.



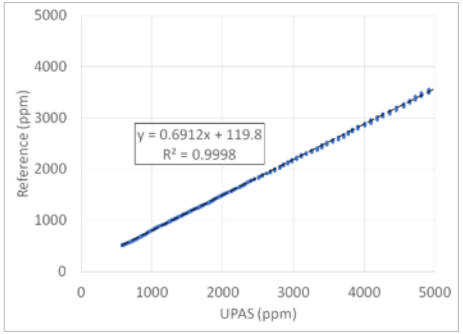
0.3 µm to 0.5 µm



0.5 µm to 1.0 µm



1.0 µm to 2.5 µm



Carbon Dioxide (ppm)

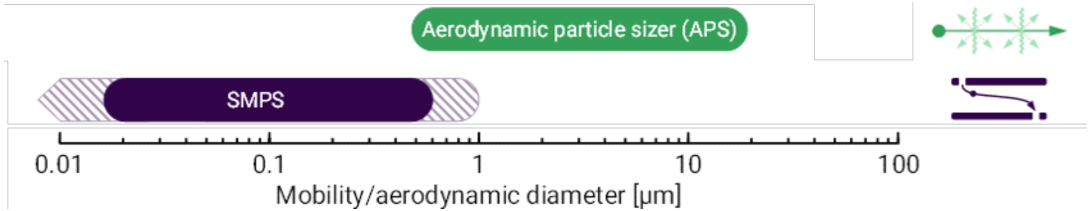
Particle Measurement: Benchtop Systems

TSI 3938 Scanning Mobility Particle Sizer (SMPS) consists of a 3082 electrostatic classifier equipped with a 3081A long differential mobility analyzer (DMA). The output of the 3082 classifier is connected to a 3752 condensation particle counter (CPC), which allows the system to count smaller particles from 10 to 700 nm.

TSI 3321 Aerodynamic Particle Sizer (APS) provides high-resolution, real-time aerodynamic measurements of larger particles from 500 nm to 20 µm.

Particle Measurement: Benchtop Systems (cont'd)

The SMPS and APS are used in parallel to characterize both submicron and supermicron particle size regimes.



Combined, the system takes a few minutes to characterize the aerosol distribution for the release of particles into the test chamber or jet bridge.

Particle Generation: Topas ATM-222L Atomizer

The generator can be operated via a pneumatic coupling plug by compressed air. The operational airflow is controlled via the pressure drop over the nozzle for the purpose of a reproducible and long-term stable aerosol generation. The table provides the general specifications for this unit.

Parameter	Value
Setting Range	0 to 6000 hPa
Aerosol flow rate	50 to 250 L/hr
Particle production rate	4.0×10^6 to 1.4×10^{10} #/s
Particle size range	0.01 to 2 µm

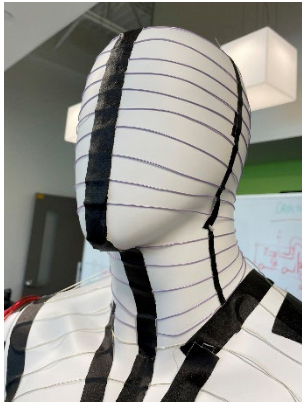
Source: ATM 222 Aerosol Generator website, accessed January 6th, 2026.

Particle Generation: Tekceleo P&S-360 Atomizer

The P&S 360 nebulizer utilizes an amplified vibrating mesh technology to provide efficient, stable and precise flowrate control, down to increments of 10 µL/min. The technology ensures that the droplet size is calibrated with a very low-variance Gaussian distribution, resulting in narrow dispersity nebulization that enhances the accuracy and repeatability of the aerosol generation. The robust design of the P&S 360 nebulizer is suitable for continuous use and provides consistent results over extended periods. It is compatible with a wide range of liquids, including suspensions and solutions.

Manikin: Male

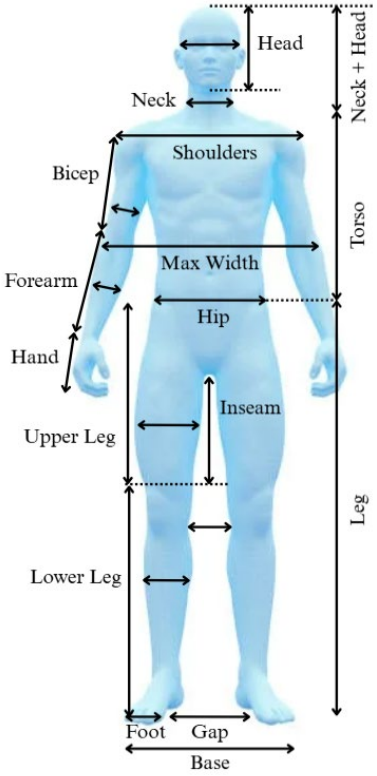
Eight (8) fiberglass manikins representing a 99th percentile male were purchased. Each manikin was fitted with nichrome or nickel-chromium wiring to create 16 segments that have their heat output individually controlled for a maximum combined output of 300W.

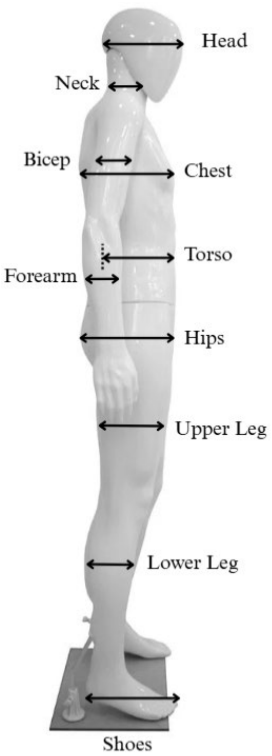


Manikin: Male Dimensions

Front View	inch	cm
Base	14.8	37.5
Bicep Length	12.0	30.5
Bicep Width	4.3	11.0
Foot Width	26.7	10.5
Forearm Length	11.0	27.9
Forearm Width	3.7	9.5
Gap Base	7.9	20.0
Gap Knee	5.5	14.0
Hand Length	6.0	15.2
Head Length	8.0	20.3
Head Width	6.3	16
Height	77.5	196.8
Hip Width	15.0	38.1
Inseam	13.8	35.0
Leg Length from Hip	40.0	101.6
Lower Leg Length	20.9	53.0
Lower Leg Width	4.1	10.5

Front View	inch	cm
Max Width	24.0	61.0
Neck + Head Length	11.5	29.2
Shoulder Width	21.5	54.6
Torso Length	26.0	66.0
Upper Leg Length	18.9	48.0
Upper Leg Width at Knee	4.5	11.5
Upper Leg Width Groin	6.9	17.5
Bicep Depth	4.5	11.5
Chest Depth	10.0	25.4
Forearm Depth	3.7	9.5
Head Depth	8.0	20.3
Hips Depth	10.5	26.7
Lower Leg Depth	4.3	13
Shoe Length	12.0	30.5
Torso Depth	7.0	17.8
Upper Leg Depth	3.7	21.0





Manikin: Male Heat Capacity

Thermal manikins were used to mimic human shape and heat profiles using a wire-wrap resistive heating element.

16 powered zones covering the entire body with a total maximum power output of 300 W. Each zone is individually set. The power was set to 80% of capacity to mimic a higher metabolic rate due to walking and carrying their belongings.

Zone	Location	Max Power (W)
1	Head/Neck	28.0
2	Chest	13.5
3	Back	13.5
4	Abdomen/Buttocks	41.0
5	Left Upper Arm	41.0
6	Right Upper Arm	41.0
7	Left Lower Arm	6.9
8	Right Lower Arm	6.9
9	Left Hand	5.0
10	Right Hand	5.0
11	Left Thigh	41.0
12	Right Thigh	41.0
13	Left Calf	41.0
14	Right Calf	41.0
15	Left Foot	5.0
16	Right Foot	5.0

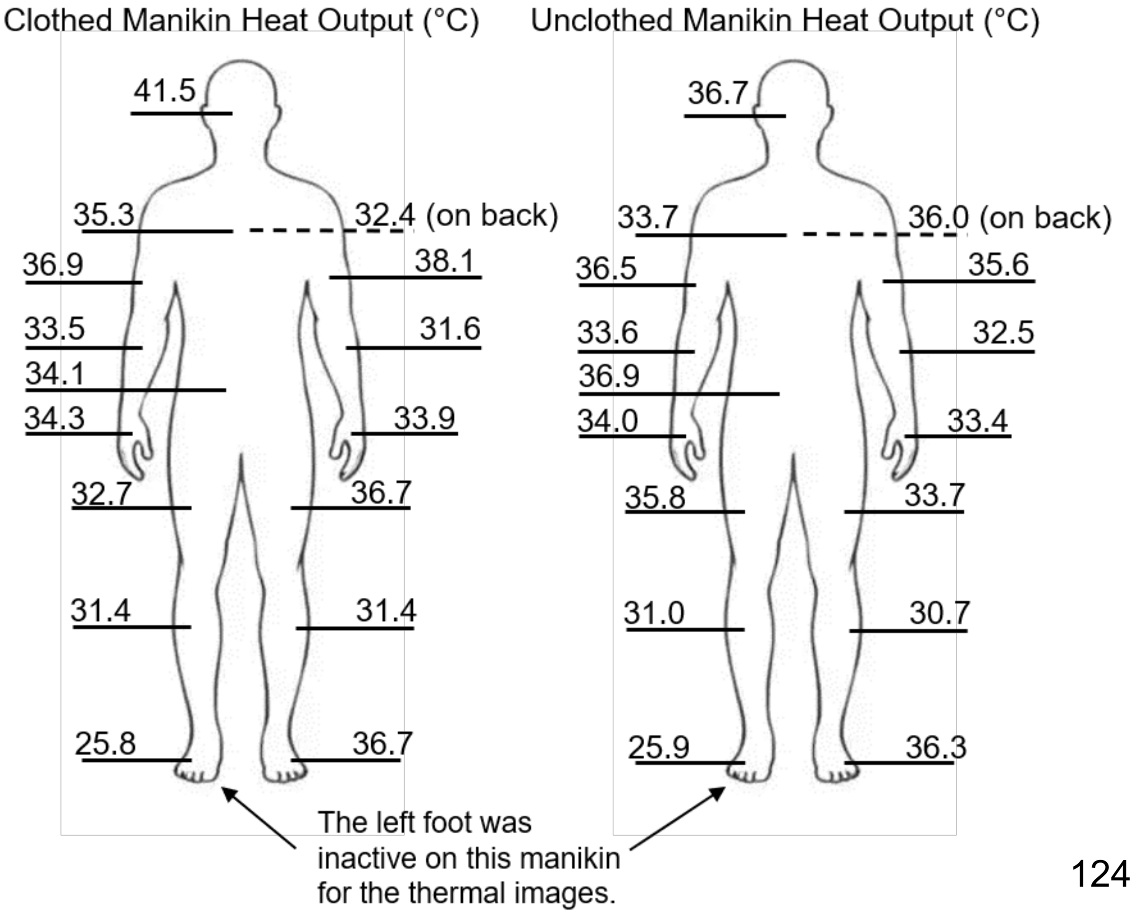
Manikin: Male Thermal Profile

Top picture shows sedentary standing male researcher (right) standing next to the heated and clothed manikin. The manikin is set to 80% power with settings used during experimentation. Both had similar clothing ensembles. The manikin has a higher heat output as it was set to a higher metabolic heat output.

Bottom photo shows the same heated manikin but without clothing.

Manikin: Male Thermal Heat Profile

The surface temperature of each segment for one manikin was measured with a thermocouple temporarily attached between the heating wires.



Manikin: Box

One (1) box measuring 1708mm x 203mm x 406mm (67.25” x 8” x 16”) was constructed out of metal ducting that was painted black. It consists of a surface mounted heater applied to the inside surface. The power output was set to 240W to replicate the same heat output of the male manikin. The picture on the right shows the box (right) next to 1823mm (72”) tall person for comparison.

10. Data: Storage Structure

Storage Structure Data Overview

This chapter provides an overview of how the data is stored in the Phase 2 Jet-Bridge Ventilation Dataset (https://doi.org/10.21949/qqdx-gh59).

Data Folder Structure

Folder Name	Description
<Root>	Root folder holding the folders that follow below.
Templates	Bridge wall boundary coordinates.
CSV	Data files in spreadsheet format.
TXT	Same data as those in the CSV folder except arranged to produce time lapse contour plots.
Averages	Average of TXT data by parameter (CO_2, Light, P, PM0.5, PM1.0, PM2.5, T_{db}, T_{dp}, T, and V) for each repetition when the conditions were at quasi-steady state conditions.
Summary	Average data by parameter for all reps in a series.
HVAC	Temperature, flow, and pressure of conditioned air supplied to the airport or bridge environments.
Periods	Contains files that list the start time and length of data used to calculate the statistics in the files stored under the Averages and Summary folder.

Files in the Root Folder

File	Description
README.pdf	This file
Data Dictionary.csv	Abbreviated version of this section that is suitable for the National Transportation Library (NTL).

Filename Structure for Templates Folder

Three sets of files that provide the wall boundary conditions for the jet bridges used to collect data. It can be applied to the corresponding data set found in the FOLDERNAME folder. They use the same data format identified later in the “Data Structure” slides under this section.

Filename	Used with data sets starting with
Boundary - FOLDERNAME - SWEMA.txt	S01 to S10
Boundary - FOLDERNAME - UPAS.txt	P and G
Boundary - FOLDERNAME - Airport.txt	S11 only

Filename Structure for CSV, TXT & HVAC Folders (1/2)

TEST TYPE

G	Tracer Gas
P	Particle
S	Air Speed

JET BRIDGE CONFIGURATION

01	Empty, downstream dose outlet placed at 40 ft
02	Same as 01 with manikin placed at 42 ft facing downstream
03	Same as 01 with manikin placed at 37 ft facing downstream
04	Same as 01 with manikin placed at 34 ft facing downstream
05	Same as 04 with three additional manikins placed 6 ft apart downstream
06	Same as 04 with six additional manikins placed 3 ft apart downstream
07	Empty, upstream dose outlet placed at 42 ft
08	Same as 07 with manikin placed at 40 ft facing upstream
09	Same as 01 with manikin placed at 31 ft facing downstream
10	Same as 01 with box placed at 31 ft
11	Airport bridge

TEST SETUP (see next slide)

STATION # (see next slide)

FLOW CONDTION (see next slide)

REP # (see next slide)

FILE TYPE (see next slide)

Filename Structure for CSV, TXT & HVAC Folders (2/2)

TEST TYPE (see previous slide)

JET BRIDGE CONFIGURATION (see previous slide)

TEST SETUP

A	Adiabatic conditions
B	Heat added or removed through walls, manikin, box, or heater.
xC	x is A or B. Same as A or B except supply air temperature is colder.
xH	x is A or B. Same as A or B except supply air temperature is warmer.
AExx	Sensor sensitivity test with sensors at station xx and lower.
AX	Special case with different supply air temperature with each rep.
C	Same as A but with nozzle reduced from 0.43” to 0.25” inner diameter.
D	Same as A except with sub-µm atomizer only (Topas ATM-222L).
E	Same as A except with super-µm atomizer only (Tekceleo P&S360).

STATION #

xx	Cross-section at z = xx
CL	Center-plane section

FLOW CONDITION

HN	High exhaust fan speed. Neutral bridge air pressure.
HP	High exhaust fan speed. Positive bridge air pressure.
LN	Low exhaust fan speed. Neutral bridge air pressure
LP	Low exhaust fan speed. Positive bridge air pressure.

REP #

FILE TYPE

csv	Spreadsheet format
txt	Block data format
hva	HVAC data

Filename Structure for Averages & Summary Folders

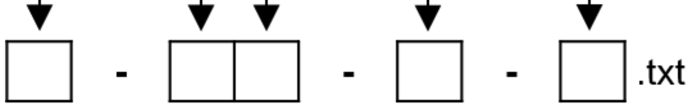
VARIABLE	
V	Air Speed (m/s)
T	Dry-bulb temperature for SWEMA only (°C)
Tdb	Dry-bulb temperature for UPAS only (°C)
Tdp	Dew point temperature (°C)
Light	Light level (lux)
P	Barometric pressure of the air (hPa)
PM0.5	Particle concentration <= 0.5 µm (#/cm^3)
PM1.0	Particle concentration > 0.5 µm and <= 1.0 µm (#/cm^3)
PM2.5	Particle concentration > 1.0 µm and <= 2.5 µm (#/cm^3)
CO2	Concentration of carbon dioxide gas in air (ppm)

TEST TYPE (same as before)

JET BRIDGE CONFIGURATION (same as before)

TEST SETUP (same as before)

REP #	
Any number	Average of a single rep.
Letter	Average of a specific set of reps. Refer to data summary sheets for details.
Omitted	Average of all averaged reps.



Filename Structure for HVAC Folder

This folder contains HVAC data for the lab and airport bridges. The table below explains the file structure and the data they contain

Filename	Description
G*, P*, and S*	Temporal HVAC data for each experiment with the same file names located in the other folders.
XXX-CATR.csv	Averaged HVAC for each data file above Ventilation measurements for all lab jet bridge air speed, particle, and tracer gas measurements.
XXX-Airport-01.csv	Indoor and outdoor environmental measurements for an undisclosed airport gate and bridge for the month of December 2024. Building pressure is unavailable.
XXX-Airport-02.csv	Indoor and outdoor environmental measurements for an undisclosed airport gate and bridge for the month of March and April 2025. PCA data is unavailable.

Filename Structure for Periods Folder

The air speed data was collected only when the HVAC system reached steady-state conditions at the desired conditions. Thus, all of the air speed data was averaged.

Given the dynamic nature of particle and tracer gas research, only the quasi-steady state section is averaged for each repetition. The files contain the times as to when the data for each station or entire bridge was determined to be at quasi-steady state.

Filename	Used with
Sets-UPAS.txt	For an individual station in a single rep.
Series-UPAS.txt	For all stations in a single rep.

Data Structure for Processed Folder

Cartesian coordinates of where the sensor was located.

UPAS serial number for files starting with G or P. Swema probe number for files starting with S.

Header that describes the data that follows below.

Time is the Epoch Unix Timestamp, which is the number of seconds that have passed since January 1st, 1970 at 00:00:00 Coordinated Universal Time (UTC).

Data for the given time for the variables defined in the header. Please note that not all of the columns are shown.

X (in)	13.668	13.668	13.668	13.
Y (in)	12.89	12.89	12.89	1
Z (in)	120	120	120	
UPAS	52	52	52	
Time (sec)	Light (lux)	Tdb (°C)	Tdp (°C)	P (hPa
1747428198	0	23.6	8	9
1747428199	0	23.6	8	9
1747428200	0	23.6	8	9
1747428201	0	23.6	8	9

Data Structure for Temporal Folder

TITLE is the filename without the extension.

VARIABLES define the variable structure used throughout the file.

ZONE is a header that describes the data for a given relative measurement time. Relative time is listed as seconds under SOLUTIONTIME.

The data is organized as a 2D matrix. Each row corresponds to each variable identified under VARIABLES. Each column is the data collected at a location in space.

```
TITLE="G01-BC-1-16"
VARIABLES="X (m)", "Y (m)", "Z (m)", "Light (lux)", "Tdb (°
(ppm)"
ZONE SOLUTIONTIME=0, DATAPACKING=BLOCK, I=4, J=2, K=1
0.35 0.35 0.35 0.35 1.04 1.04 1.04 1.04
0.72 1.33 1.94 2.55 0.72 1.33 1.94 2.55
4.88 4.88 4.88 4.88 4.88 4.88 4.88 4.88
0 0 0 0 0 0 0 0
24.0 24.4 25.5 25.3 24.5 24.9 25.4 25.9
6.5 7.4 8.4 7.4 7.7 9.6 9.3 10.9
987.90 987.90 987.90 987.50 987.80 988.00 987.80 987.60
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
0 0 0 0 0 0 2 0
```

Data Structure for Averages Folder

TITLE is the filename without the extension except the units are included at the end.

VARIABLES define the variable structure used throughout the file.

ZONE is a header that describes the data for each station.

The data is organized as a 2D matrix. Each row corresponds to each variable identified under VARIABLES. Each column is the data collected at a location in space for a station.

```
TITLE="CO2-G01-BC-1 (ppm)"
VARIABLES="X (m)", "Y (m)", "Z (m)", "Mean", "dMean",
"Median", "dMedian", "StdDev"

ZONE I=4, J=2, K=1 F=BLOCK
0.35 0.35 0.35 0.35 1.04 1.04 1.04 1.04
0.57 1.18 1.79 2.40 0.57 1.18 1.79 2.40
3.05 3.05 3.05 3.05 3.05 3.05 3.05 3.05
43.428 52.363 49.873 40.371 53.499 62.022 81.623 122.295
-19.756 -10.821 -13.312 -22.813 -9.686 -1.163 18.439 59.111
48.000 55.000 52.000 45.000 65.000 70.000 95.000 136.000
-22.750 -15.750 -18.750 -25.750 -5.750 -0.750 24.250 65.250
23.729 27.082 32.873 28.838 26.921 29.830 40.219 51.819
```

Data Structure for Summary Folder

TITLE is the filename without the extension except the units are included at the end.

VARIABLES define the variable structure used throughout the file.

ZONE is a header that describes the data for each station.

The data is organized as a 2D matrix. Each row corresponds to each variable identified under VARIABLES. Each column is the data collected at a location in space for a station.

```
TITLE="CO2-G01-BC (ppm)"
VARIABLES="X (m)", "Y (m)", "Z (m)", "Mean", "Std Dev
(Mean)", "Median", "StdDev (Median)"

ZONE I=4, J=2, K=1 F=BLOCK
0.350 0.350 0.350 0.350 1.040 1.040 1.040 1.040
0.570 1.180 1.790 2.400 0.570 1.180 1.790 2.400
3.050 3.050 3.050 3.050 3.050 3.050 3.050 3.050
40.484 48.081 43.635 30.218 50.435 50.484 62.707 117.002
2.804 3.661 5.596 7.333 3.079 10.186 13.380 4.223
45.333 52.667 48.333 29.667 57.000 53.000 70.000 134.667
1.886 5.558 6.650 11.585 6.164 15.253 17.795 3.399
```

Data Structure for HVAC Folder: Airport Data (1/2)

The airport data contains indoor and outdoor environmental data for an undisclosed operational airport. The table on the next slide lists the variables.

Data Structure for HVAC Folder: Airport Data (2/2)

Col	Variable	Units	Description
1	Time	sec	Epoch Time
2	A/C	See right	Aircraft Present? (1 = yes, 2 = no)
3	A/C #	#	Aircraft Record #
4	Tdb.a.Gate	°C	Ambient Air Dry-Bulb Temperature at Gate
5	Tdp.a.Gate	°C	Ambient Air Dew Point Temperature at Gate
6	Tdb.PCA.SA	°C	PCA Supply Air Dry Bulb Temperature
7	Tdp.PCA.SA	°C	PCA Supply Air Dew Point Temperature
8	Tdb.Bubble	°C	Bridge Air Dry Bulb Temperature at Aircraft
9	Tdp.Bubble	°C	Bridge Air Dew Point Temperature at Aircraft
10	Tdb.Gate	°C	Bridge Air Dry Bulb Temperature at Gate Doors
11	HVAC Mode	See right	Gate HVAC Mode (2=normal, 1=parial setback, 0=full setback)
12	S.SA.Fan	%	Gate Supply Air Fan Speed (%)
13	S.RA.Fan	%	Gate Return Air Fan Speed (%)
14	Tdb.Gate.SA	°C	Gate Supply Air Dry Bulb Temperature
15	Tdb.Gate.RA	°C	Gate Return Air Dry Bulb Temperature
16	Tdp.Gate.RA	°C	Gate Return Air Dew Point Temperature
17	Tdb.Gate	°C	Gate Space Air Dry Bulb Temperature
18	dP	Pa	Building Pressure Relative to outside

Col	Variable	Units	Description
19	P	hPa	Pressure (Weather Station)
20	Tdb.a.WS	°C	Ambient Air Dry-Bulb Temperature (Weather Station)
21	Tdp.a.WS	°C	Ambient Dew Point (Weather Station)
22	G.A	kJ/m^2	Solar Radiation (Weather Station)
23	V.ave	kph	Wind Speed (Weather Station)
24	V.peak	kph	Wind Gust (Weather Station)
25	V.angle	°	Wind Direction (Weather Station)

Data Structure for HVAC Folder: CATR Data (1/2)

The CATR data contains environmental data for the air delivered to the jet-bridge. The data is averaged over 5 minutes with the start time set to the start of when the Processed and Temporal data was averaged to create the Averages data files.

Data Structure for HVAC Folder: CATR Data (2/2)

Col	Variable	Units	Description
1	Series	None	Summary data file name for which the data applies.
2	Sets	None	Averages data file name for which the data applies
3	Start	sec	Epoch Time for the start of the average.
4	End	sec	Epoch Time for the end of the average.
5	P	hPa	Barometric pressure of the air
6	Tdb.SA	°C	Supply Temperature Dry Bulb
7	Tdp.SA	°C	Supply Temperature Dew Point
8	Tdb.Lab	°C	Exterior Temperature Dry Bulb
9	Tdp.Lab	°C	Exterior Temperature Dew Point
10	dP	Pa	Pressure difference between bridge and lab (Positive indicates bridge air has a higher pressure)
11	Q.FS1	lps	Flow station for top connection
12	Q.FS2	lps	Flow station for middle connection
13	Q.FS3	lps	Flow station for bottom connection
14	Q.FS	lps	Sum of all three flow stations

Data Structure for Periods Folder

Both files have the format shown in the table below. The Sets data file is what was used to produce the files located in the Averages folder.

Variable	Description
Sets or Series	File name of Sets (located in the Processed or Temporal folders) or Series (located in the Averages folder)
Relative Start Time (sec)	Time at which the data was determined to be at quasi-steady state conditions.
Length (sec)	Length of time at which the data remained at quasi-steady state conditions.

Summary Report Structure

Filename or title as found in the <u>Processed</u> and <u>Temporal</u> folders.

Date(s) of the experiment.

Test type is <u>Air Speed</u>, <u>Particle</u>, or <u>Tracer Gas</u>.

Bridge configuration as defined in test configuration section.

Target temperature differential across the walls of the jet bridge.

Exhaust fan setting (high or low).

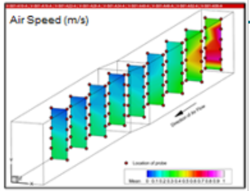
Target pressure differential across the walls of the jet bridge.

Number of repetitions used to create the composite display at the lower right.

S01-A[Station #]-[Rep #]

Date	2025-03-28 to 2025-04-01
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Positive
Repetitions	3 (1, 2, and 3)
Purpose	Establish baseline flow patterns along the length of the empty jet bridge.
Description	• Air speed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the upper supply air inlet diffuser, using a 6x2 array of hot sphere anemometers. • Measurements were made at 9 consecutive stations, for five minutes each. • Data points were collected at 4 Hz.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	728	6	25.8	-2.7	9.8
2	720	6	26.5	-3.4	11.6
3	727	6	25.4	-2.5	9.7
Ave	725	6	25.9	-2.9	10.4



HVAC summary data taken from the <u>HVAC summary.csv</u> file.

Composite display of the test type parameter – air speed in this example – of all data described on this sheet. More data is available in the processed and temporal folders. Each data set will have its unique set of data that may be different from other data sets.

General description of how the data was gathered for this sheet.

Reason why the data was gathered.

Summary Report Structure: HVAC Table

Each line represents the averaged HVAC measurements for each repetition. The Periods data file was used to produce these tables. **Bold text** represents the averages all of values above to the top or to the next bold line.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	T_{db} (°C) ΔT_{bridge}	T_{dp} (°C) Bridge
1	728	6	25.8	-2.7	9.8
2	720	6	26.5	-3.4	11.6
3	727	6	25.4	-2.5	9.7
Ave	**725**	**6**	**25.9**	**-2.9**	**10.4**

Flow is the total airflow into the bridge at STP conditions.

Differential pressure between the bridge and the lab. Positive values indicate the bridge air wants to leak out of the bridge.

T_{db} is the dry bulb temperature. Lab is the air surrounding the bridge. ΔT_{bridge} is the temperature differential between the bridge air and the lab air. Positive values means the bridge air is warmer than the lab air.

T_{dp} is the dew-point temperature of the air inside the bridge.

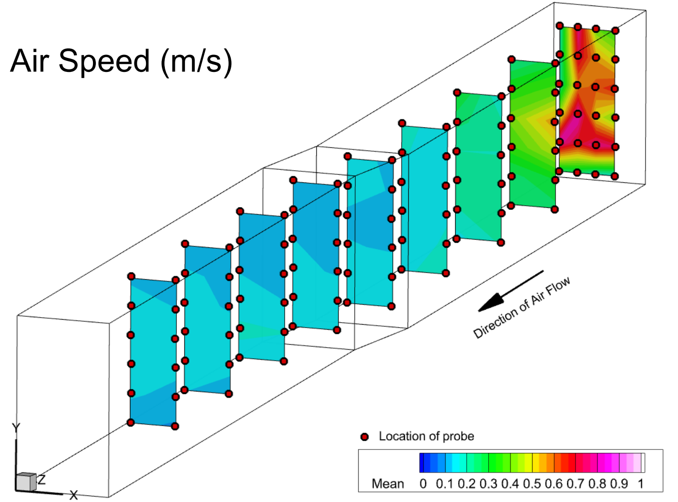
11.a. Data Summary: Air Speed

S01-A-[Station #]-HN-[Rep #]

Date	2025-04-11 to -15, and -18 to -22
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	6 (1 through 6) for stations 10 and 40 3 (1, 2, and 3) for all other stations
Purpose	Establish baseline flow patterns along the length of the empty jet bridge.
Description	• Air speed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. • Measurements were made at 8 consecutive stations, for five minutes each. • Data points were collected at 3 Hz.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	529	0.2	23.3	0.0	10.2
2	527	0.3	23.3	-0.1	9.7
3	525	0.3	23.7	-0.1	10.3
4	520	0.4	23.3	0.0	8.8
5	520	0.3	24.1	-0.1	9.7
6	523	0.3	23.4	0.0	7.9

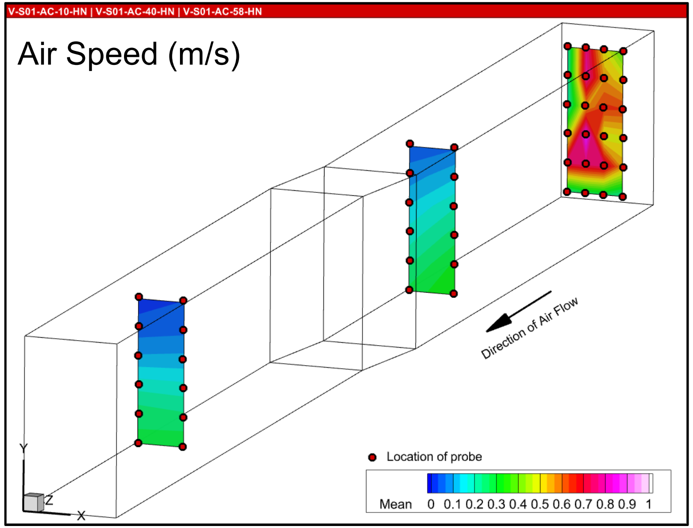
V-S01-A-10-HN | V-S01-A-16-HN | V-S01-A-22-HN | V-S01-A-28-HN | V-S01-A-34-HN | V-S01-A-40-HN | V-S01-A-46-HN | V-S01-A-52-HN | V-S01-A



S01-AC-[Station #]-HN-[Rep #]

Date	2025-04-11 to -14
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	-3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the effect of varying temperature differential between supply air entering the jet bridge and the temperature of the air in the lab space around the jet bridge.
Description	• Airspeed and temperature measurements are taken only at 10 ft, 40 ft, and 58 ft (separately) using a 6×2 array of hot sphere anemometers. • Average values are based on five minutes of 3 Hz data.

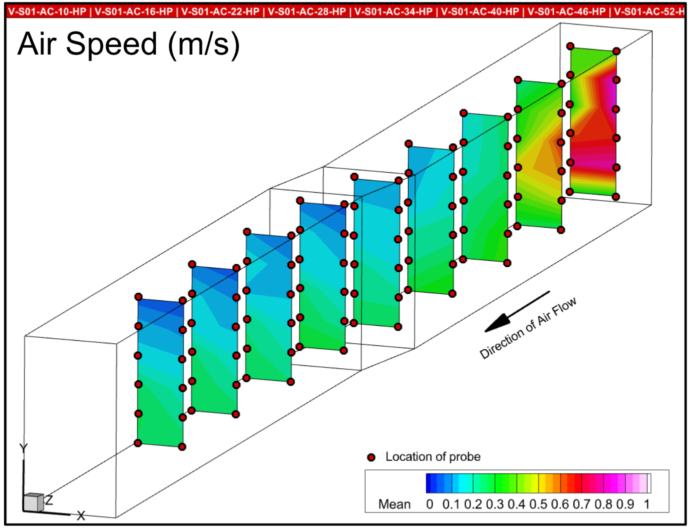
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	534	0.2	23.3	-3.0	9.8
2	532	0.2	23.5	-3.2	9.8
3	534	0.2	23.1	-3.0	9.0
AVE	**534**	**0.2**	**23.3**	**-3.1**	**9.5**



S01-AC-[Station #]-HP-[Rep #]

Date	2025-03-28 to 2025-04-01
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	-3°C
Exhaust Setting	High
Bridge Pressure	Positive
Repetitions	3 (1, 2, and 3)
Purpose	Establish baseline flow patterns along the length of the empty jet bridge.
Description	• Air speed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the upper supply air inlet diffuser, using a 6x2 array of hot sphere anemometers. • Measurements were made at 9 consecutive stations, for five minutes each. • Data points were collected at 4 Hz. • All data was averaged under summary data set A.

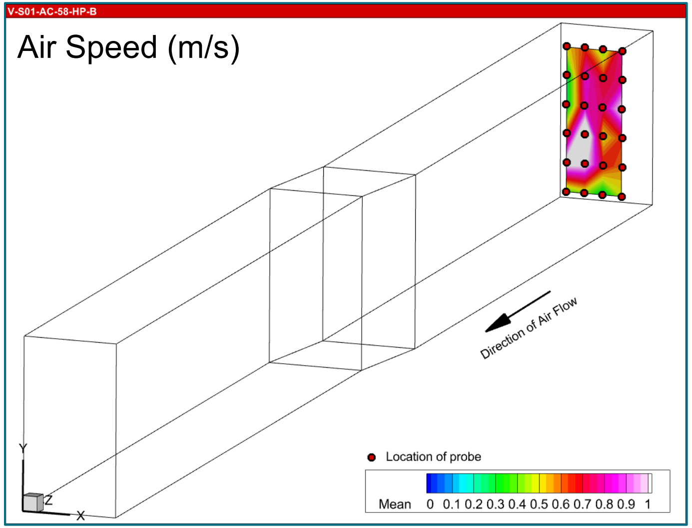
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	728	6.2	25.8	-2.7	9.8
2	720	6.2	26.5	-3.4	11.6
3	727	6.2	25.4	-2.5	9.7
AVE	**725**	**6.2**	**25.9**	**-2.8**	**10.3**



S01-AC-58-HP-[Rep #]

Date	2025-03-26
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	-3°C
Exhaust Setting	High
Bridge Pressure	Positive
Sets (S)	2 (1 = outer columns of 6 and 2 = inner columns of 6)
Repetitions (R)	3 (4, 5, and 6)
Purpose	Characterize the airflow boundary conditions at the inlet diffuser.
Description	• Airspeed and temperature measurements are taken only at 58.3 ft (1 foot away from diffuser) using a 6×4 array of hot sphere anemometers, measured in two halves. • Average values are based on five minutes of 4 Hz data. • All data was averaged under summary data set B.

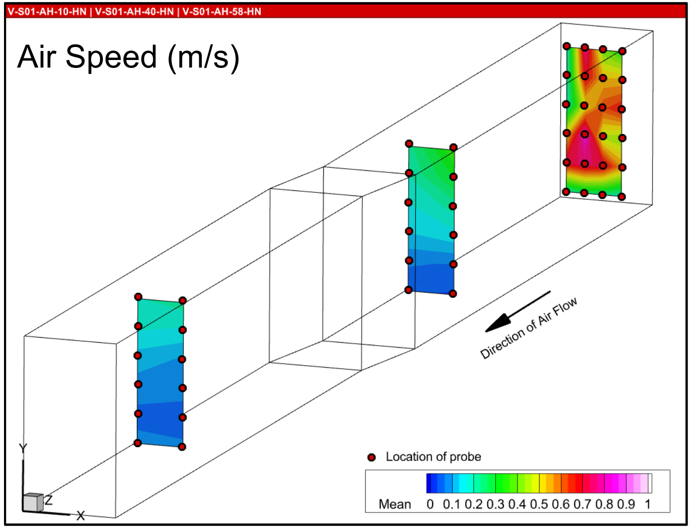
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
4	738	6.2	25.2	-2.2	9.0
5	738	6.2	25.5	-2.5	8.2
6	737	6.2	25.4	-2.4	8.8
AVE	**738**	**6.2**	**25.4**	**-2.4**	**8.7**



S01-AH-[Station #]-HN-[Rep #]

Date	2025-04-11 to -14
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	+3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the effect of varying temperature differential between supply air entering the jet bridge and the temperature of the air in the lab space around the jet bridge.
Description	• Airspeed and temperature measurements are taken only at 10 ft and 40 ft (separately) using a 6×2 array of hot sphere anemometers. • Airspeed and temperature measurements are taken at 58.3 ft using a 6×4 array of hot sphere anemometers, measured in two halves. • Average values are based on five minutes of 3 Hz data.

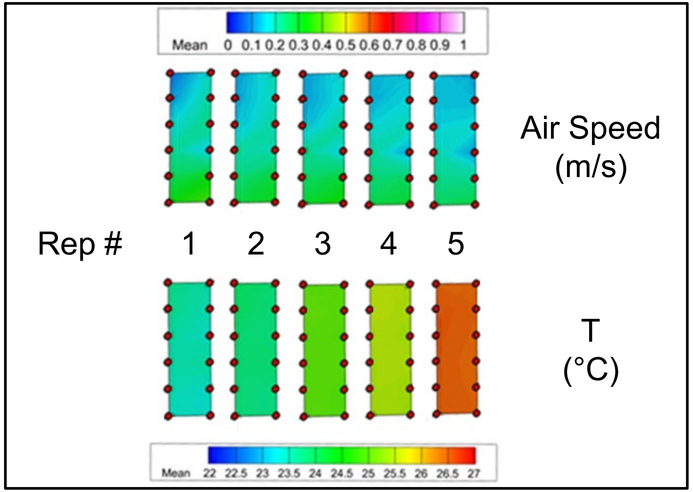
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	524	0.3	23.6	3.0	10.0
2	525	0.2	23.6	2.7	9.9
3	529	0.2	23.3	2.9	9.1
AVE	**526**	**0.2**	**23.5**	**2.9**	**9.7**



S01-AX-40-HP-[Rep #]

Date	2025-04-01
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	Increasing Supply Temperature
Exhaust Setting	High
Bridge Pressure	Positive
Repetitions	1 each (1, 2, …5 for 24°C, 25°C, … 28°C)
Purpose	Observe the airflow pattern at 40 ft at five different supply temperatures.
Description	• Airspeed and temperature measurements were taken only at 40 ft using a 6×2 array of hot sphere anemometers. Supply air temperature was increased in 1° increments from 24 to 28 °C. • Average values are based on five minutes of 4 Hz data.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	722	6.2	26.0	-2.5	8.9
2	723	6.2	26.2	-1.2	8.6
3	721	6.2	26.2	-0.5	8.4
4	718	6.2	26.5	0.3	8.4
5	720	6.2	26.6	1.2	10.9

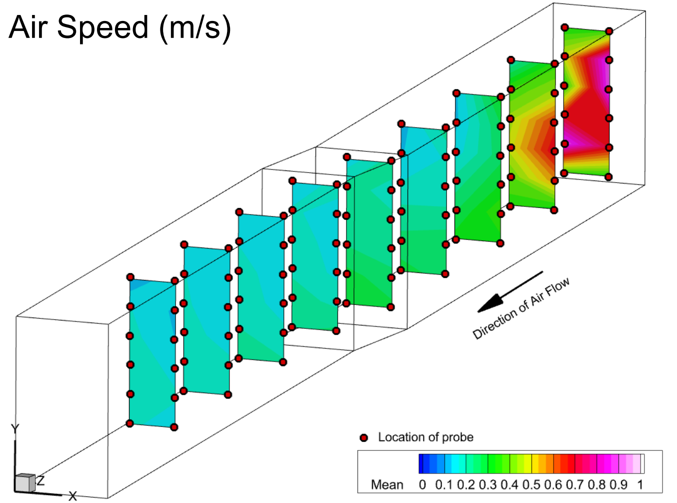


S04-A-[Station #]-HP-[Rep #]

Date	2025-04-02
Test Type	Air Speed
Configuration	4 (Unheated manikin at 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Positive
Repetitions	3 (1, 2, and 3) except station 52, which has 1 rep
Purpose	Observe the impact of a single manikin on the jet bridge airflow profile.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. A single manikin was placed at 34 ft, six feet downstream from the dosing nozzle. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	730	6.2	23.2	-0.4	8.9
2	730	6.2	23.3	-0.5	8.8
3	729	6.2	23.3	-0.6	9.5
AVE	**730**	**6.2**	**23.3**	**-0.5**	**9.1**

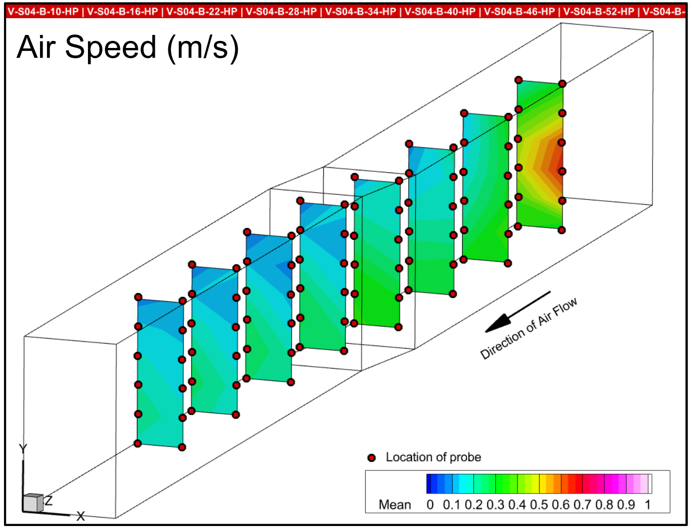
V-S04-A-10-HP | V-S04-A-16-HP | V-S04-A-22-HP | V-S04-A-28-HP | V-S04-A-34-HP | V-S04-A-40-HP | V-S04-A-46-HP | V-S04-A-52-HP | V-S04-A-



S04-B-[Station #]-HP-[Rep #]

Date	2025-04-02
Test Type	Air Speed
Configuration	4 (Heated manikin at 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Positive
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a single manikin on the jet bridge airflow profile.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. A single manikin was placed at 34 ft, six feet downstream from the dosing nozzle. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

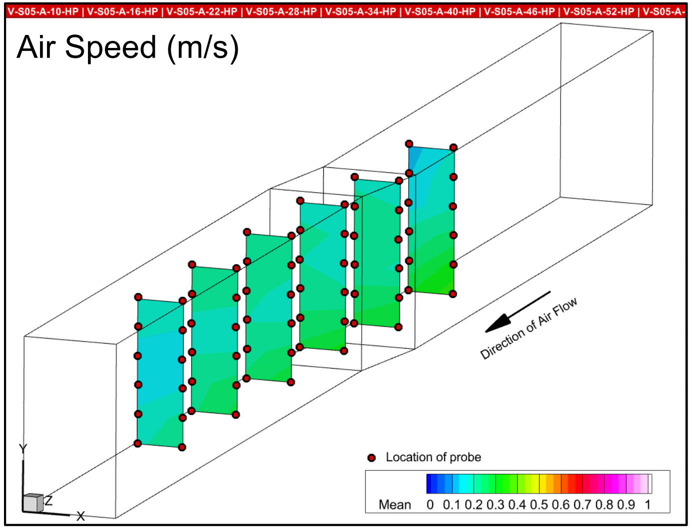
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	730	6.2	23.9	-0.2	8.7
2	727	6.2	23.8	-0.3	8.4
3	729	6.2	23.7	0.1	8.6
AVE	**729**	**6.2**	**23.8**	**-0.1**	**8.6**



S05-A-[Station #]-HP-[Rep #]

Date	2025-04-08
Test Type	Air Speed
Configuration	5 (Four unheated manikins at 16, 22, 28, and 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Positive
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a four manikins on the jet bridge airflow profile.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Four manikins were placed at 6 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

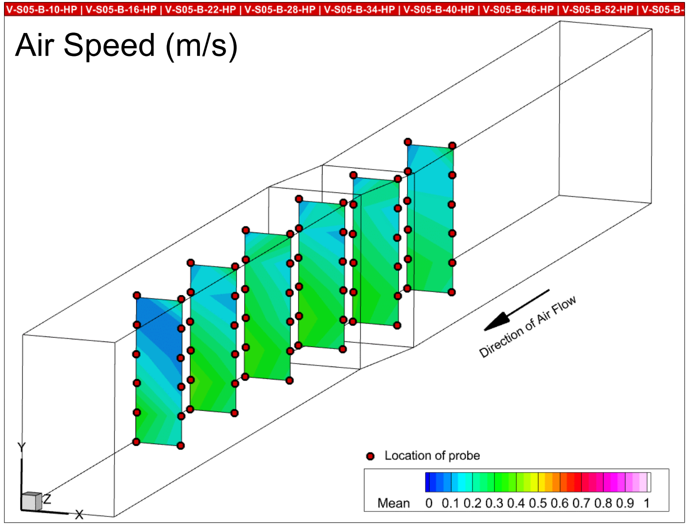
Rep #	**Flow (lps)**	**dP (Pa)**	**T_{db} (°C)**		**T_{dp} (°C)**
			Lab	**ΔT_{bridge}**	**Bridge**
1	729	6.2	22.9	0.2	9.6
2	728	6.2	23.2	-0.2	9.9
3	728	6.2	23.3	-0.4	10.2
AVE	**728**	**6.2**	**23.1**	**-0.1**	**9.9**



S05-B-[Station #]-HP-[Rep #]

Date	2025-04-10
Test Type	Air Speed
Configuration	5 (Four heated manikins at 16, 22, 28, and 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Positive
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a four heated manikins on the jet bridge airflow profile.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Four manikins were placed at 6 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

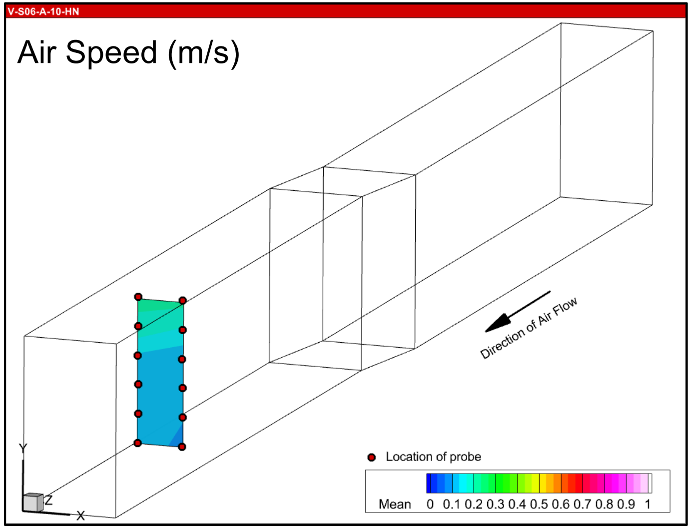
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	729	6.2	23.6	-0.6	9.9
2	728	6.2	23.7	-0.6	10.0
3	728	6.2	23.7	-0.6	10.0
AVE	**728**	**6.2**	**23.7**	**-0.6**	**10.0**



S06-A-10-HN-[Rep #]

Date	2025-04-15 to -17
Test Type	Air Speed
Configuration	6 (Seven unheated manikins at 16, 19, 22, …, 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a seven unheated manikins on the jet bridge airflow profile downstream.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Seven manikins were placed at 3 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

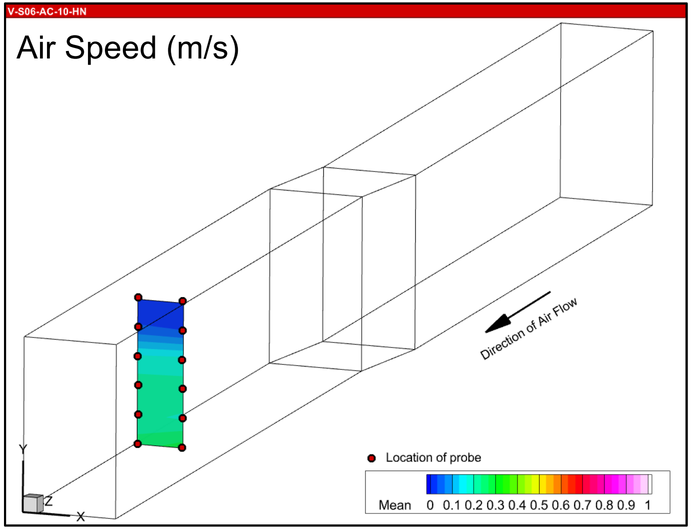
Rep #	**Flow (lps)**	**dP (Pa)**	**T_{db} (°C)**		**T_{dp} (°C)**
			Lab	**ΔT_{bridge}**	**Bridge**
1	522	0.2	24.2	0.1	10.4
2	521	0.3	24.4	0.0	10.3
3	534	0.2	22.4	-0.1	6.8
AVE	**526**	**0.2**	**23.7**	**0.0**	**9.2**



S06-AC-10-HN-[Rep #]

Date	2025-04-15 to -17
Test Type	Air Speed
Configuration	6 (Seven unheated manikins at 16, 19, 22, …, 34 ft)
Target ΔT	-3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a seven unheated manikins on the jet bridge airflow profile downstream.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Seven manikins were placed at 3 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

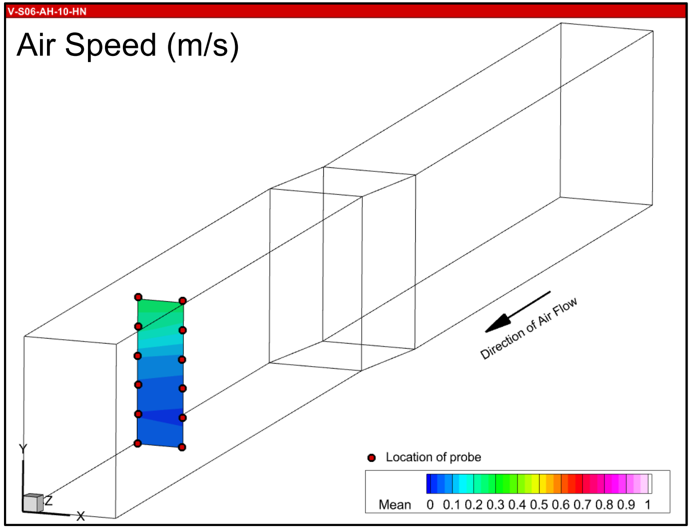
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	T_{db} (°C) ΔT_{bridge}	T_{dp} (°C) Bridge
1	523	0.2	24.2	-3.2	10.3
2	532	0.2	22.9	-3.0	11.2
3	537	0.2	22.8	-2.9	11.6
AVE	**531**	**0.2**	**23.3**	**-3.0**	**11.0**



S06-AH-10-HN-[Rep #]

Date	2025-04-15 to -17
Test Type	Air Speed
Configuration	6 (Seven unheated manikins at 16, 19, 22, …, 34 ft)
Target ΔT	+3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a seven unheated manikins on the jet bridge airflow profile downstream.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Seven manikins were placed at 3 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

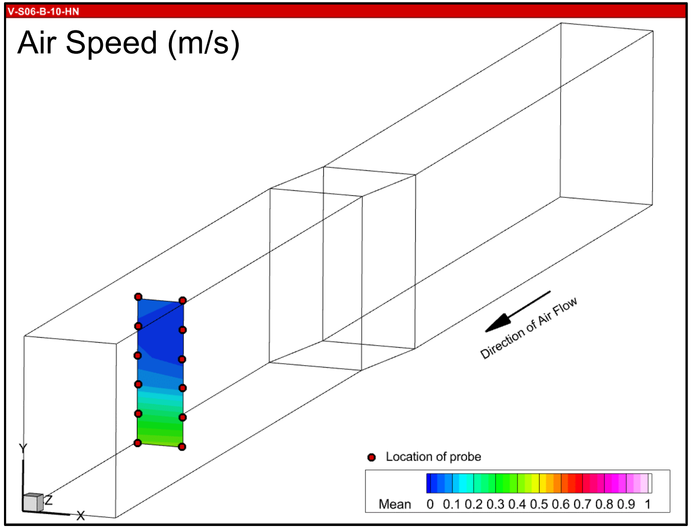
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	521	0.3	23.6	2.9	11.4
2	522	0.3	23.3	3.1	11.7
3	520	0.4	23.0	2.9	10.6
AVE	**521**	**0.3**	**23.3**	**3.0**	**11.2**



S06-B-10-HN-[Rep #]

Date	2025-04-17
Test Type	Air Speed
Configuration	6 (Seven heated manikins at 16, 19, 22, …, 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a seven heated manikins on the jet bridge airflow profile downstream.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Seven manikins were placed at 3 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

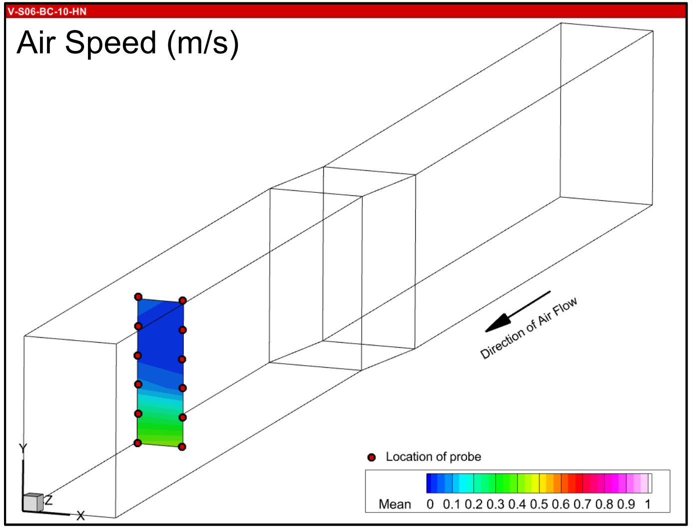
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	528	0.2	23.7	-0.1	12.2
2	520	0.3	24.4	0.1	13.1
3	517	0.4	25.2	0.0	9.2
AVE	**522**	**0.3**	**24.4**	**0.0**	**11.5**



S06-BC-10-HN-[Rep #]

Date	2025-04-17
Test Type	Air Speed
Configuration	6 (Seven heated manikins at 16, 19, 22, …, 34 ft)
Target ΔT	-3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a seven heated manikins on the jet bridge airflow profile downstream.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Seven manikins were placed at 3 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

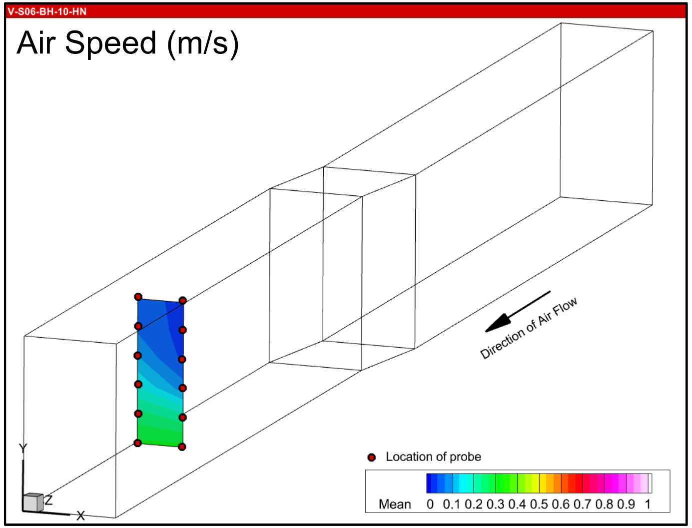
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	521	0.4	24.2	-3.0	12.5
2	523	0.4	24.9	-2.9	9.1
3	526	0.3	24.9	-2.8	9.1
AVE	**523**	**0.4**	**24.7**	**-2.9**	**10.2**



S06-BH-10-HN-[Rep #]

Date	2025-04-17
Test Type	Air Speed
Configuration	6 (Seven heated manikins at 16, 19, 22, …, 34 ft)
Target ΔT	+3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the impact of a seven heated manikins on the jet bridge airflow profile downstream.
Description	• Airspeed and temperature measurements are taken every six feet, from 10 ft away from the exhaust air outlet, to the 52 ft mark, using a 6×2 array of hot sphere anemometers. Seven manikins were placed at 3 ft intervals, starting at 16 ft. • Manikin facing downstream. • Average values are based on five minutes of 4 Hz data.

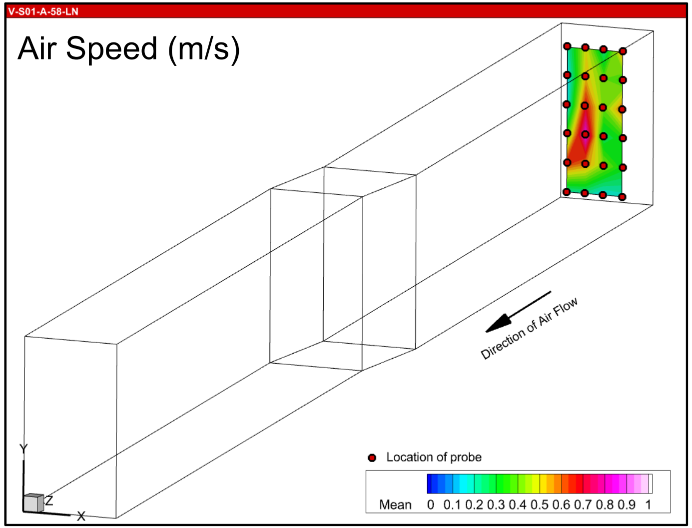
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	522	0.3	23.9	2.9	12.6
2	510	0.4	25.0	3.0	9.2
3	510	0.5	25.0	3.0	9.4
AVE	**514**	**0.4**	**24.6**	**3.0**	**10.4**



S01-A-58-LN-[Rep #]

Date	2025-03-14
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	Low
Bridge Pressure	Neutral
Sets (S)	2 (1 = outer columns of 6 and 2 = inner columns of 6)
Repetitions (R)	3 (1, 2, and 3)
Purpose	Characterize the airflow boundary conditions at the inlet diffuser.
Description	• Airspeed and temperature measurements are taken only at 58.3 ft (1 foot away from diffuser) using a 6×4 array of hot sphere anemometers, measured in two halves. • Average values are based on five minutes of 4 Hz data.

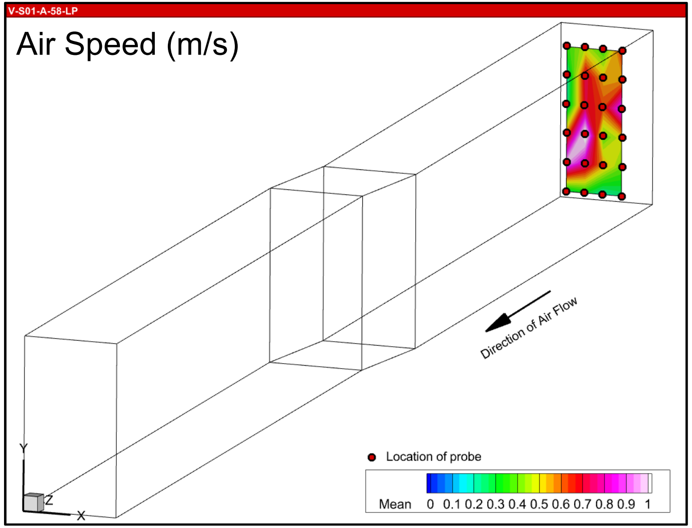
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	408	0.3	----	----	----
2	407	0.3	----	----	----
3	413	0.2	----	----	----
AVE	**410**	**0.3**	**----**	**----**	**----**



S01-A-58-LP-[Rep #]

Date	2025-03-24 to -25
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	Low
Bridge Pressure	Positive
Sets (S)	2 (1 = outer columns of 6 and 2 = inner columns of 6)
Repetitions (R)	3 (1, 2, and 3)
Purpose	Characterize the airflow boundary conditions at the inlet diffuser.
Description	• Airspeed and temperature measurements are taken only at 58.3 ft (1 foot away from diffuser) using a 6×4 array of hot sphere anemometers, measured in two halves. • Average values are based on five minutes of 4 Hz data.

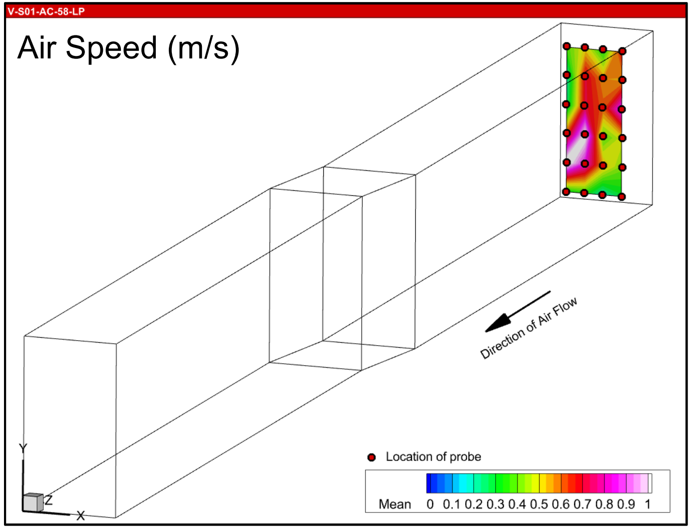
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	565	6.2	----	----	----
2	566	6.2	----	----	----
3	566	6.2	----	----	----
AVE	**566**	**6.2**	**----**	**----**	**----**



S01-AC-58-LP-[Rep #]

Date	2025-03-26
Test Type	Air Speed
Configuration	1 (Empty Jet Bridge)
Target ΔT	-3°C
Exhaust Setting	Low
Bridge Pressure	Positive
Sets (S)	2 (1 = outer columns of 6 and 2 = inner columns of 6)
Repetitions (R)	3 (1, 2, and 3)
Purpose	Characterize the airflow boundary conditions at the inlet diffuser.
Description	• Airspeed and temperature measurements are taken only at 58.3 ft (1 foot away from diffuser) using a 6×4 array of hot sphere anemometers, measured in two halves. • Average values are based on five minutes of 4 Hz data.

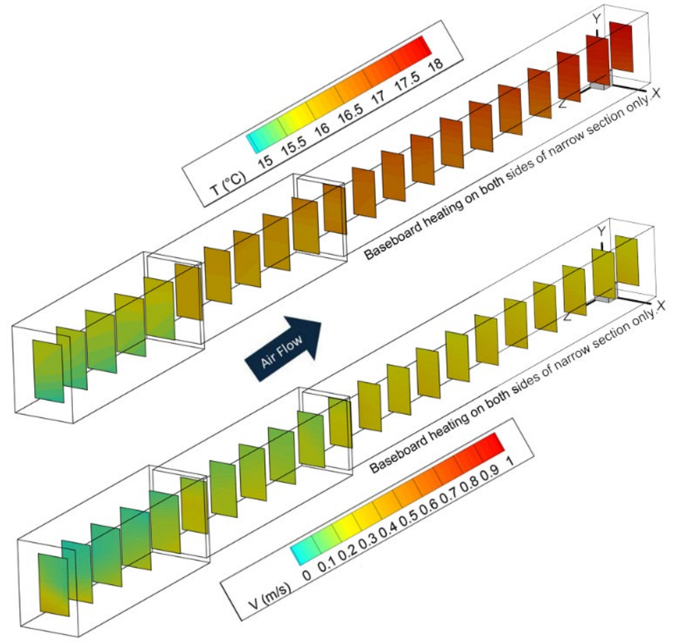
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	590	6.2	25.3	-2.4	8.2
2	592	6.2	25.4	-2.5	8.9
3	592	6.2	25.5	-2.7	8.6
AVE	**591**	**6.2**	**25.4**	**-2.5**	**8.6**



S11-BH-[Station #]-ZZ-1

Date	2024-08-13
Test Type	Air Speed
Configuration	11 (Operational Jet Bridge)
Target ΔT	N/A
Exhaust Setting	N/A
Bridge Pressure	N/A
Stations	21 (z = 1, 5, 10, 15 … 95, 99)
Repetitions	1
Purpose	Document the airflow and temperature conditions inside an operational bridge.
Description	• Bridge configured for boarding. Airport and rotunda doors were open. • Bridge was cooling down during measurements due to reverse airflow from unconditioned outside air. • Each measurement was collected simultaneously with six Swema probes for each X-Y slice. • Measurements were started at top of Section B1 and worked upstream (i.e. towards the aircraft).

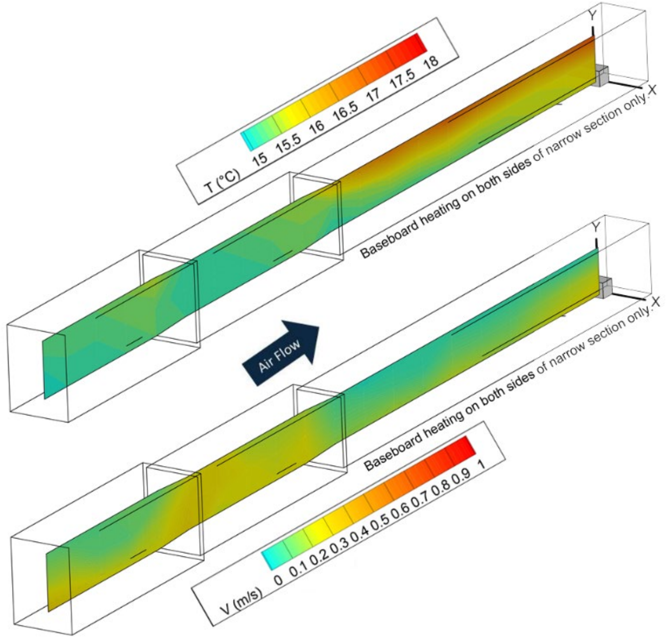
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	ΔT_{bridge}	T_{dp} (°C) Bridge
-----	-----	----	----	----	----



S11-BH-CL-ZZ-1

Date	2024-08-13
Test Type	Air Speed
Configuration	11 (Operational Jet Bridge)
Target ΔT	N/A
Exhaust Setting	N/A
Bridge Pressure	N/A
Stations	1 (but measured with 3 probes at a time)
Repetitions	1
Purpose	Document the airflow and temperature conditions inside an operational bridge.
Description	• Bridge configured for boarding. Airport and rotunda doors were open. • Bridge temperature was stable. • Each measurement was collected simultaneously with three Swema probes at each point on x-axis. • Measurements were started at top of Section B1 and worked upstream (i.e. towards the aircraft).

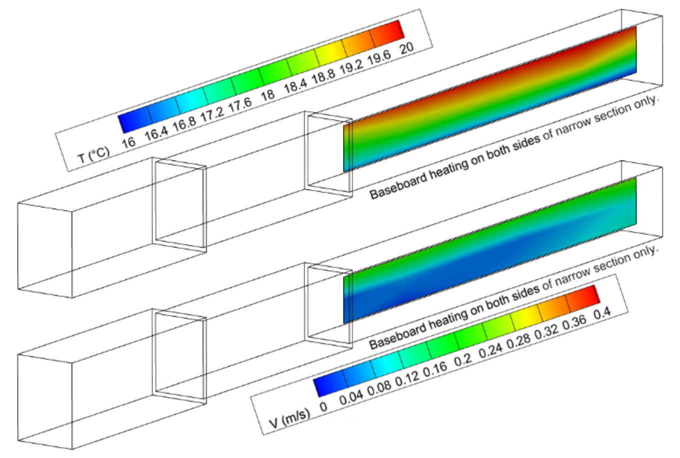
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	ΔT_{bridge}	T_{dp} (°C) Bridge
-----	-----	----	----	----	----



S11-BH-CL-ZZ-2

Date	2024-08-13
Test Type	Air Speed
Configuration	11 (Operational Jet Bridge)
Target ΔT	N/A
Exhaust Setting	N/A
Bridge Pressure	N/A
Stations	1 (but measured with 3 probes at a time)
Repetitions	1
Purpose	Document the airflow and temperature conditions inside an operational bridge.
Description	• Bridge configured for boarding. Airport doors were closed. Rotunda doors were left open. • Bridge temperature was stable with very little flow. • Each measurement was collected simultaneously with three Swema probes at each point on x-axis. • Measurements were started at top of Section B1 and worked upstream (i.e. towards the aircraft).

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
-----	-----	----	----	----	----

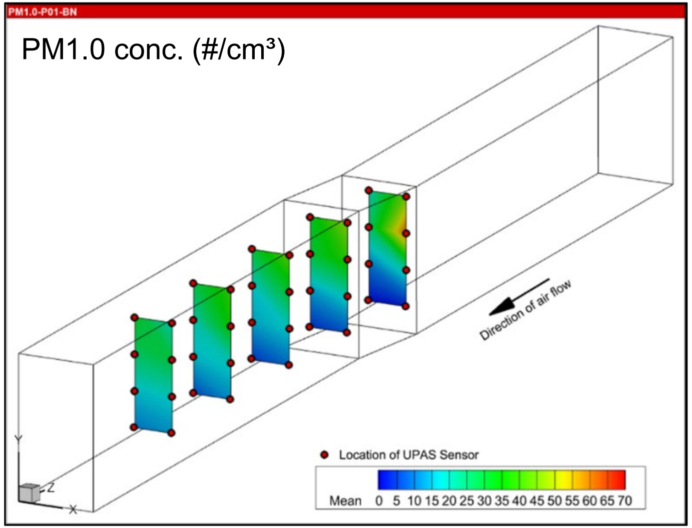


11.b. Data Summary: Particle

P01-A-[Station #]-HN-[Rep #]

Date	2025-05-02
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Establish baseline particle dispersion patterns along the length of the empty jet bridge with five stations at once.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data. • All data was averaged under summary data set A.

Rep #	**Flow (lps)**	**dP (Pa)**	**T_{db} (°C)**		**T_{dp} (°C)**
			Lab	**ΔT_{bridge}**	**Bridge**
1	534	0.2	23.4	0.1	3.1
2	535	0.2	23.6	-0.2	2.8
3	533	0.2	23.5	-0.1	2.2
ALL	**534**	**0.2**	**23.5**	**-0.1**	**2.7**

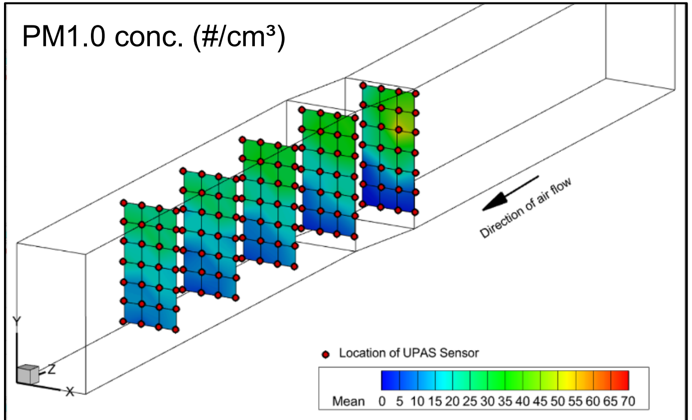


P01-A-[Station #]-HN-[Rep #] (cont.)

Date	2025-05-26
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	6 (4, 5, 6, 7, 8, and 9 partial with only station 34)
Purpose	Establish baseline particle dispersion patterns along the length of the empty jet bridge.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using a single 7×4 array of 28 UPAS sensors per station, moved sequentially upstream. • Average values are based on five minutes of 1 Hz data. • All data was averaged under summary data set B.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
4	534	0.2	23.6	0.0	6.8
5	533	0.2	23.6	-0.1	6.9
6	532	0.2	23.7	-0.1	6.9
7	537	0.2	23.3	0.0	6.4
8	536	0.2	23.3	0.0	6.5
9	539	0.2	23.3	0.1	6.3
ALL	**535**	**0.2**	**23.5**	**0.0**	**6.6**

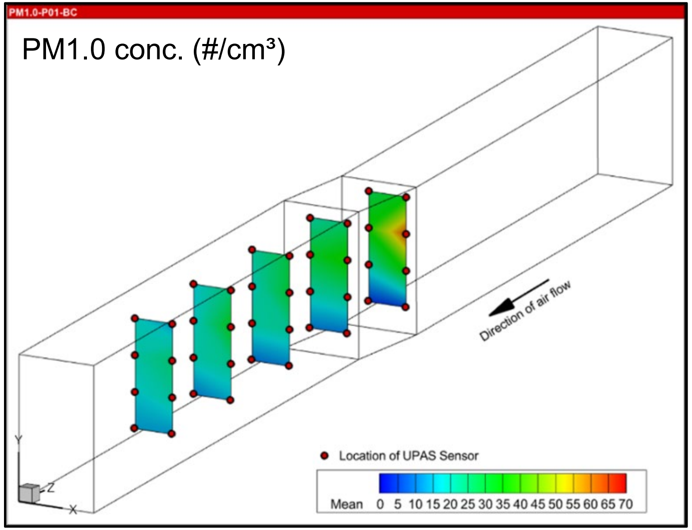
PM1.0 conc. (#/cm³)



P01-AC-[Station #]-HN-[Rep #]

Date	2025-05-02
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	-3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Establish baseline particle dispersion patterns along the length of the empty jet bridge with five stations at once.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

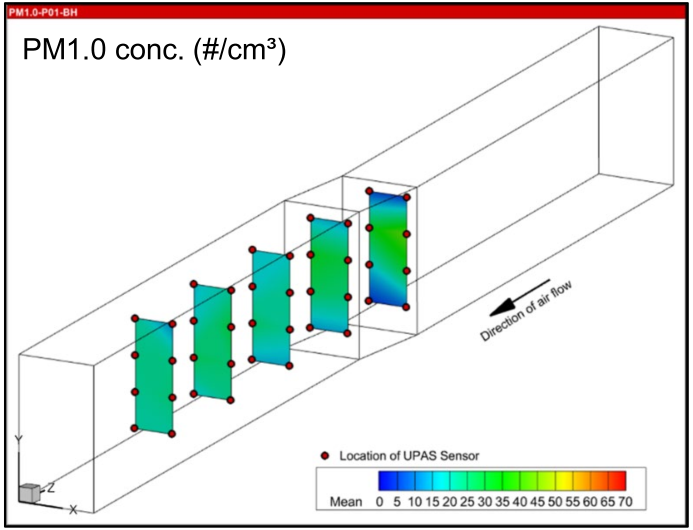
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	535	0.2	23.4	-2.7	-2.4
2	538	0.2	23.5	-3.0	-2.5
3	536	0.2	23.6	-3.1	-2.2
ALL	**536**	**0.2**	**23.5**	**-2.9**	**-2.4**



P01-AH-[Station #]-HN-[Rep #]

Date	2025-05-02
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	+3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Establish baseline particle dispersion patterns along the length of the empty jet bridge with five stations at once.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

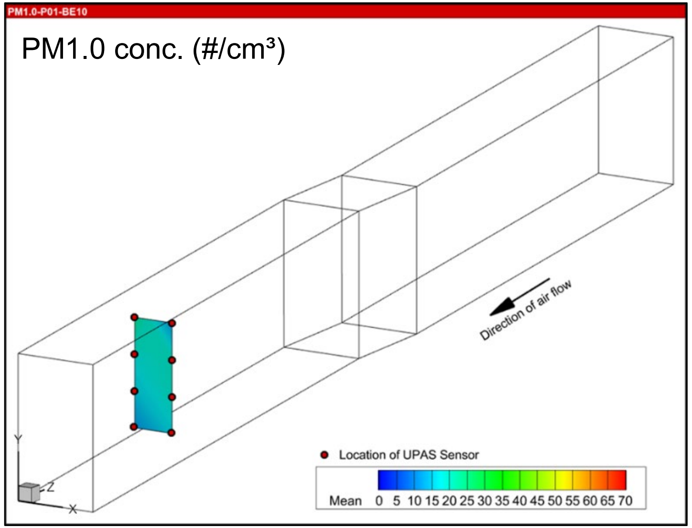
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	531	0.2	24.0	2.7	-0.6
2	530	0.2	23.9	2.8	-1.6
3	530	0.2	23.9	2.9	-2.1
ALL	**530**	**0.2**	**23.9**	**2.8**	**-1.4**



P01-AE10-[Station #]-HN-[Rep #]

Date	2025-05-13
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

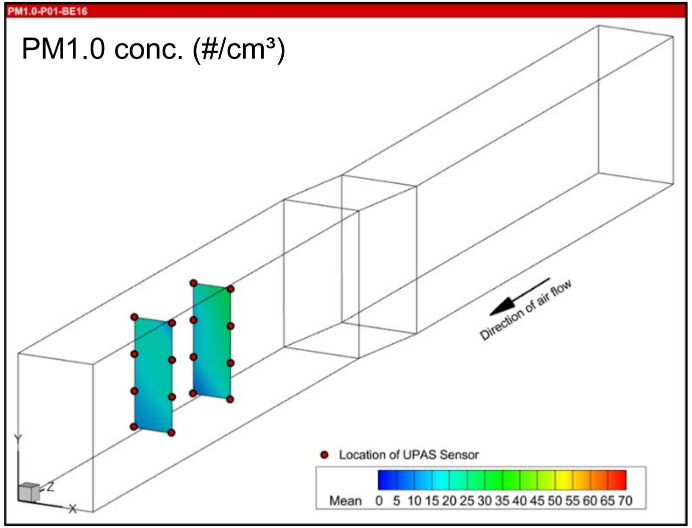
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	555	0.2	23.4	0.0	10.4
2	558	0.1	23.4	0.1	10.3
3	559	0.1	23.5	0.0	10.7
ALL	**557**	**0.1**	**23.4**	**0.0**	**10.5**



P01-AE16-[Station #]-HN-[Rep #]

Date	2025-05-13
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

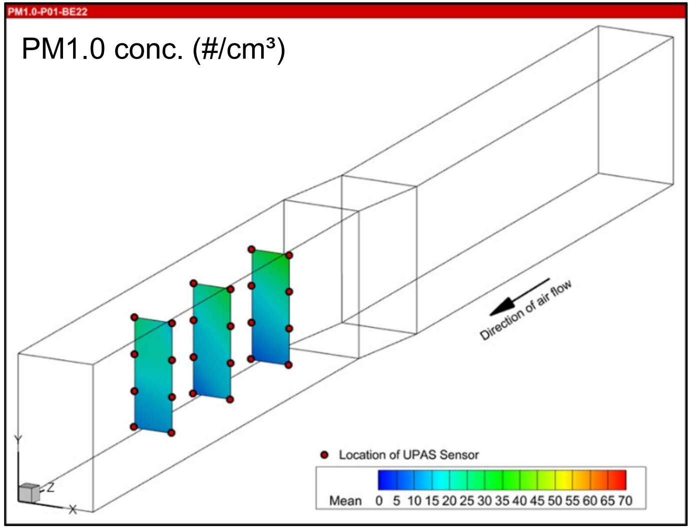
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	555	0.2	23.6	-0.2	10.4
2	556	0.2	23.6	-0.1	10.5
3	558	0.1	23.5	0.0	10.4
ALL	**556**	**0.2**	**23.6**	**-0.1**	**10.4**



P01-AE22-[Station #]-HN-[Rep #]

Date	2025-05-13
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

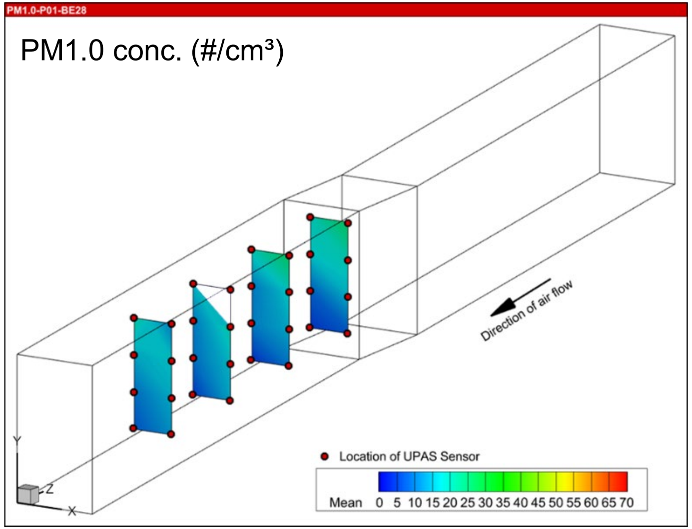
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	556	0.2	23.4	0.0	10.3
2	555	0.2	23.2	0.2	10.3
3	557	0.1	23.3	0.1	10.4
ALL	**556**	**0.2**	**23.3**	**0.1**	**10.3**



P01-AE28-[Station #]-HN-[Rep #]

Date	2025-05-13
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

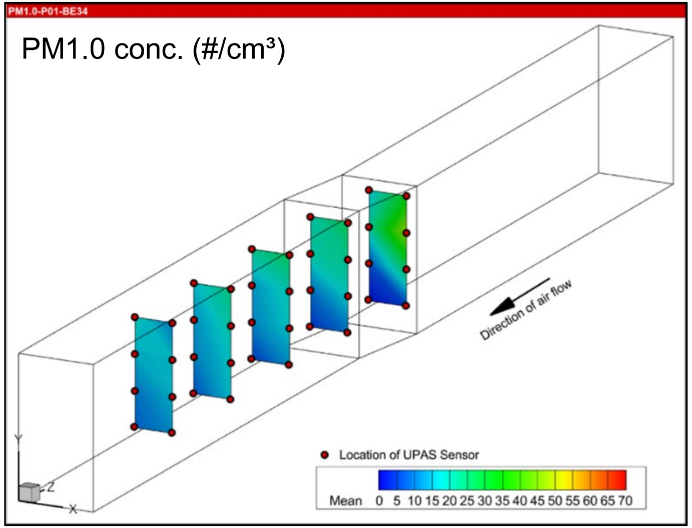
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	557	0.2	23.3	0.1	10.1
2	557	0.2	23.2	0.2	10.1
3	559	0.1	23.4	-0.1	10.2
ALL	**558**	**0.2**	**23.3**	**0.1**	**10.1**



P01-AE34-[Station #]-HN-[Rep #]

Date	2025-05-13
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

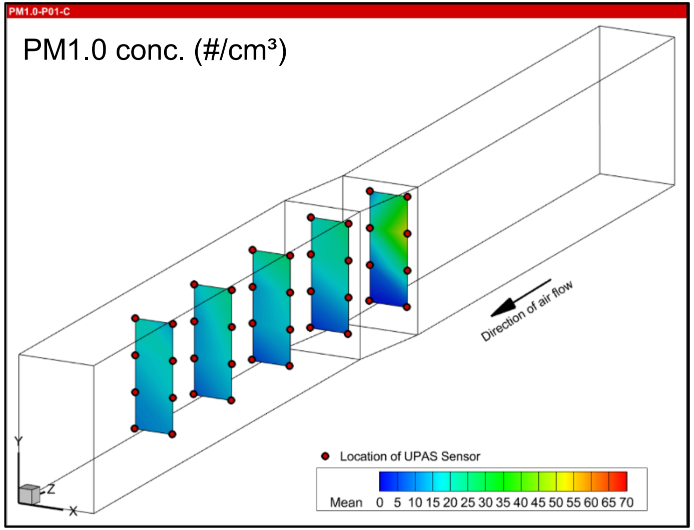
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	558	0.1	23.2	0.2	9.9
2	560	0.1	23.4	0.0	10.0
3	558	0.2	23.3	0.1	10.2
ALL	**559**	**0.1**	**23.3**	**0.1**	**10.0**



P01-C-[Station #]-HN-[Rep #]

Date	2025-05-14
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect of increasing dosing plume velocity by installing a smaller dosing nozzle.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • The dosing nozzle is reduced in size from 0.43” to 0.25” inner diameter to increase the plume velocity at the nozzle exit from 1.05 m/s to 3.11 m/s. • Average values are based on five minutes of 1 Hz data.

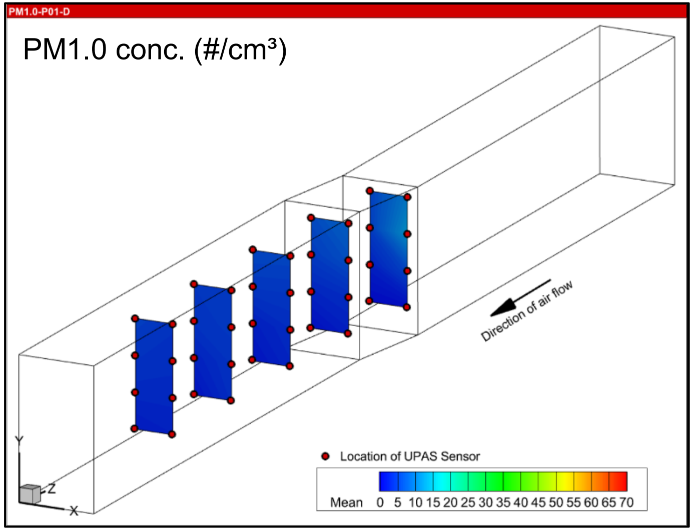
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	533	0.2	22.7	0.1	9.1
2	534	0.2	22.5	0.1	9.0
3	535	0.2	22.5	0.3	9.0
ALL	**534**	**0.2**	**22.6**	**0.2**	**9.0**



P01-D-[Station #]-HN-[Rep #]

Date	2025-05-13
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	1 except for station #10, which has 2 reps
Purpose	Evaluate the particle size produced by the sub-μm atomizer only (Topas ATM-222L).
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

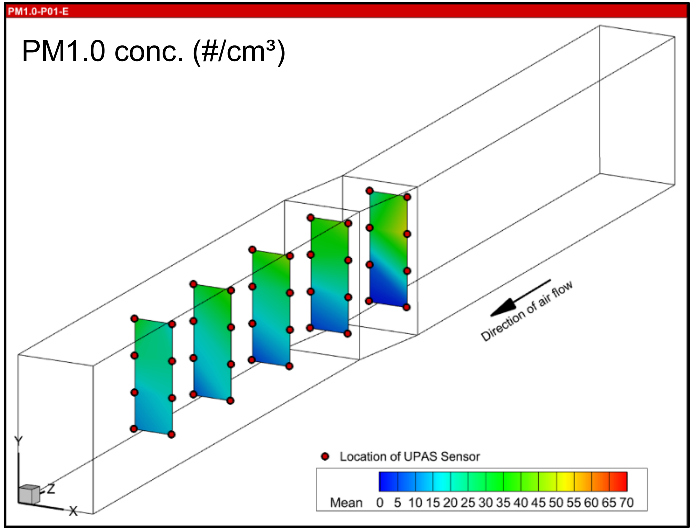
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	556	0	23.7	-0.6	8.8
2	556	0	23.7	-0.6	8.8
ALL	**556**	**0**	**23.7**	**-0.6**	**8.8**



P01-E-[Station #]-HN-[Rep #]

Date	2025-05-13
Test Type	Particle
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	1 except for station #10, which has 2 reps
Purpose	Evaluate the particle size produced by the super-μm atomizer only (Tekceleo P&S360).
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

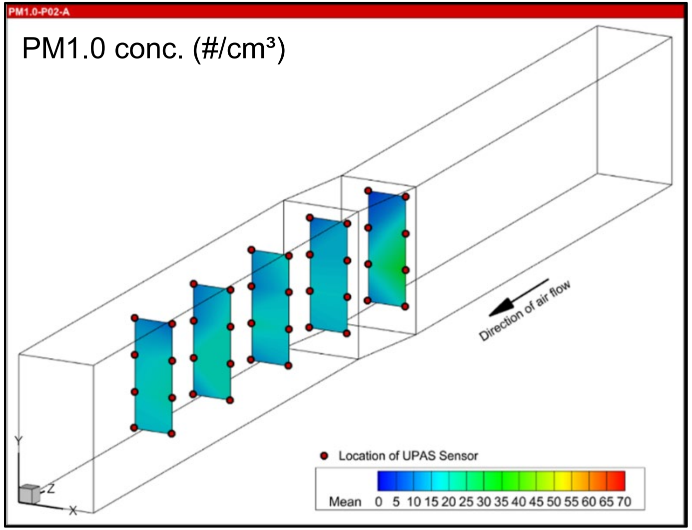
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	558	0.2	23.6	-0.2	9.8
2	559	0.2	23.7	-0.2	9.8
ALL	**559**	**0.2**	**23.7**	**-0.2**	**9.8**



P02-A-[Station #]-HN-[Rep #]

Date	2025-05-06
Test Type	Particle
Configuration	2 (Manikin upstream of dosing nozzle at 42 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect of a unheated manikin behind the dosing nozzle on particle dispersion.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single manikin was placed at 42 ft. • Average values are based on five minutes of 1 Hz data.

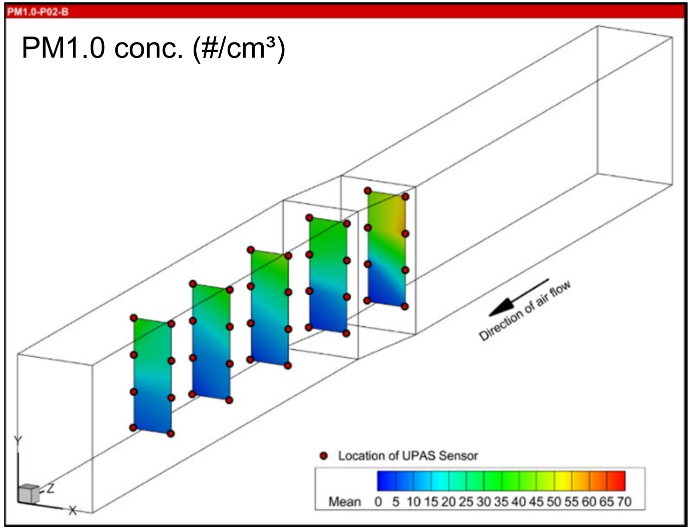
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	536	0.2	22.6	-0.2	8.7
2	535	0.2	22.6	-0.4	8.7
3	536	0.1	22.7	0.1	8.7
ALL	**536**	**0.2**	**22.6**	**-0.2**	**8.7**



P02-B-[Station #]-HN-[Rep #]

Date	2025-05-06
Test Type	Particle
Configuration	2 (Manikin upstream of dosing nozzle at 42 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect of a heated manikin behind the dosing nozzle on particle dispersion.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single manikin was placed at 42 ft. • Average values are based on five minutes of 1 Hz data.

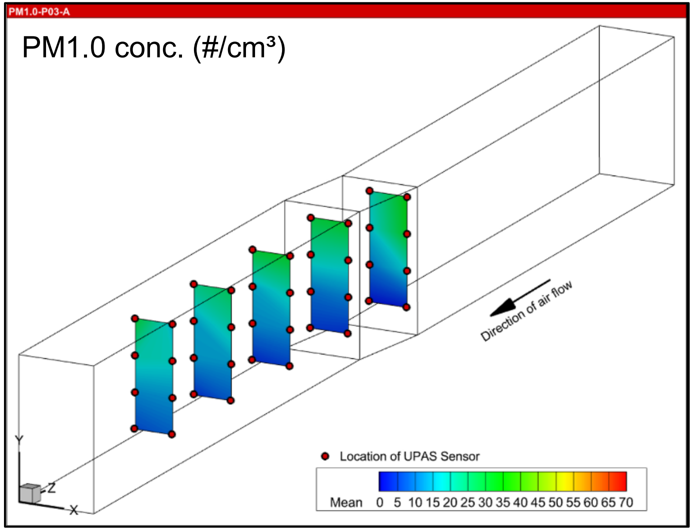
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	ΔT_{bridge}	T_{dp} (°C) Bridge
1	534	0.2	22.7	0.1	8.8
2	535	0.2	22.7	0.2	8.9
3	534	0.2	22.6	-0.1	9.1
ALL	**534**	**0.2**	**22.7**	**0.1**	**8.9**



P03-A-[Station #]-HN-[Rep #]

Date	2025-05-06
Test Type	Particle
Configuration	3 (Manikin downstream of dosing nozzle at 37 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect of a unheated manikin forward the dosing nozzle on particle dispersion.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single manikin was placed at 37 ft. • Average values are based on five minutes of 1 Hz data.

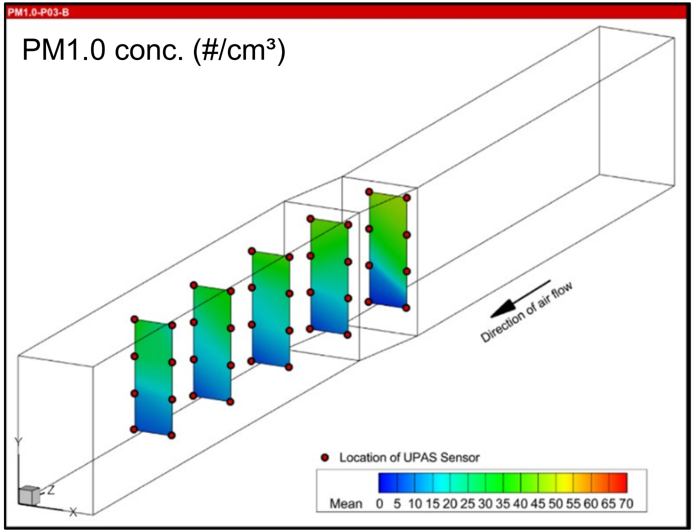
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	537	0.2	22.0	-0.1	1.2
2	538	0.2	22.0	0.0	5.6
3	539	0.2	22.1	0.3	2.6
ALL	**538**	**0.2**	**22.0**	**0.1**	**3.1**



P03-B-[Station #]-HN-[Rep #]

Date	2025-05-06
Test Type	Particle
Configuration	3 (Manikin downstream of dosing nozzle at 37 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect of a heated manikin forward the dosing nozzle on particle dispersion.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single manikin was placed at 37 ft. • Average values are based on five minutes of 1 Hz data.

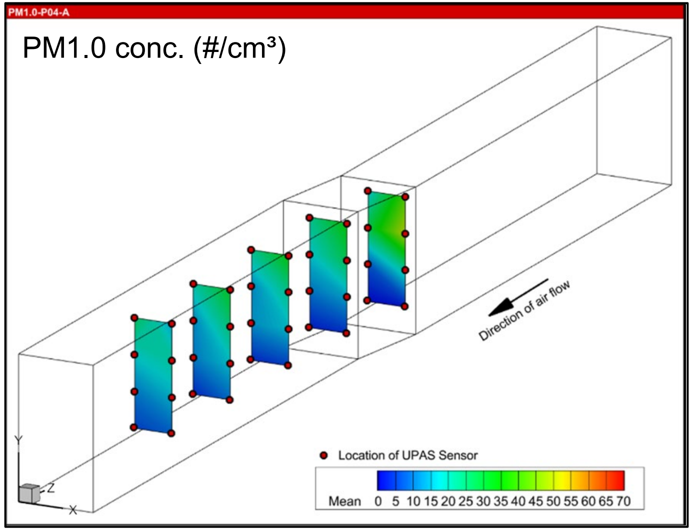
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	T_{db} (°C) ΔT_{bridge}	T_{dp} (°C) Bridge
1	535	0.2	22.6	-0.3	9.2
2	533	0.2	22.6	-0.3	9.3
3	535	0.1	22.5	0.2	9.3
ALL	**534**	**0.2**	**22.6**	**-0.1**	**9.3**



P04-A-[Station #]-HN-[Rep #]

Date	2025-05-07
Test Type	Particle
Configuration	4 (Manikin downstream of dosing nozzle at 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect of a unheated manikin further forward the dosing nozzle on particle dispersion.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single unheated manikin was placed at 34 ft. • Average values are based on five minutes of 1 Hz data.

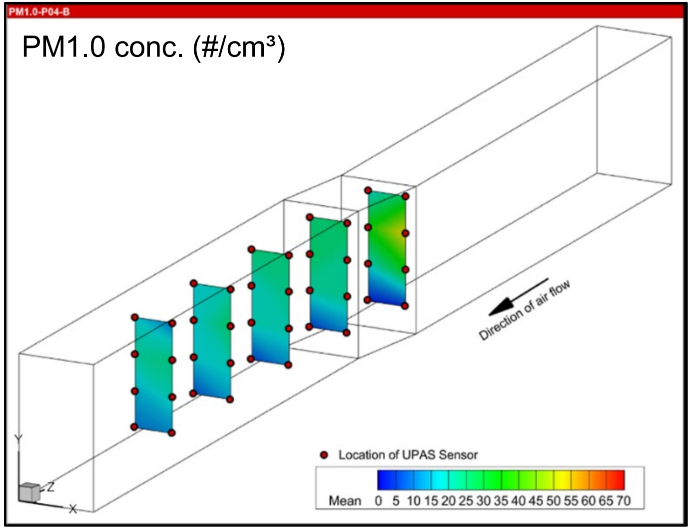
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	ΔT_{bridge}	T_{dp} (°C) Bridge
1	532	0.2	23.0	0.1	8.7
2	531	0.2	23.0	0.1	8.7
3	533	0.2	22.9	0.2	8.7
ALL	**532**	**0.2**	**23.0**	**0.1**	**8.7**



P04-B-[Station #]-HN-[Rep #]

Date	2025-05-07
Test Type	Particle
Configuration	4 (Manikin downstream of dosing nozzle at 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect of a heated manikin further forward the dosing nozzle on particle dispersion.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single heated manikin was placed at 34 ft. • Average values are based on five minutes of 1 Hz data.

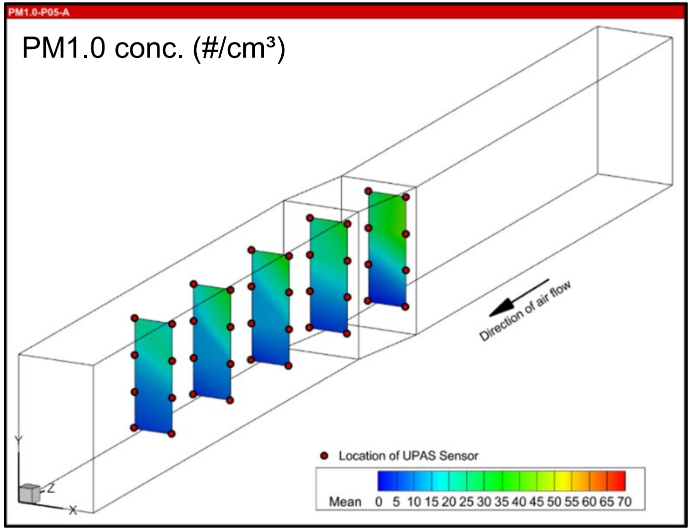
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	536	0.1	23.2	-0.1	8.7
2	530	0.2	23.2	-0.1	8.7
3	534	0.2	23.1	-0.1	8.7
ALL	**533**	**0.2**	**23.2**	**-0.1**	**8.7**



P05-A-[Station #]-HN-[Rep #]

Date	2025-05-07
Test Type	Particle
Configuration	5 (Four manikins downstream of dosing nozzle)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect on particle dispersion of four unheated manikins spaced 6 ft apart, with the first manikin placed 6 ft downstream from aerosol release.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Unheated manikins were placed at 16, 22, 28, and 34 ft. • Average values are based on five minutes of 1 Hz data.

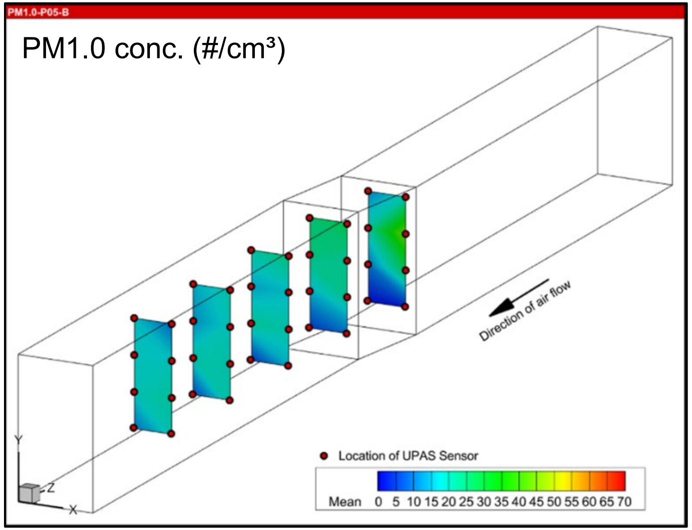
Rep #	**Flow (lps)**	**dP (Pa)**	**T_{db} (°C)**		**T_{dp} (°C)**
			Lab	**ΔT_{bridge}**	**Bridge**
1	532	0.2	22.7	0.3	8.3
2	533	0.2	22.8	0.2	8.3
3	534	0.2	23.0	-0.1	8.3
ALL	**533**	**0.2**	**22.8**	**0.1**	**8.3**



P05-B-[Station #]-HN-[Rep #]

Date	2025-05-07
Test Type	Particle
Configuration	5 (Four manikins downstream of dosing nozzle)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect on particle dispersion of four heated manikins spaced 6 ft apart, with the first manikin placed 6 ft downstream from aerosol release.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Heated manikins were placed at 16, 22, 28, and 34 ft. • Average values are based on five minutes of 1 Hz data.

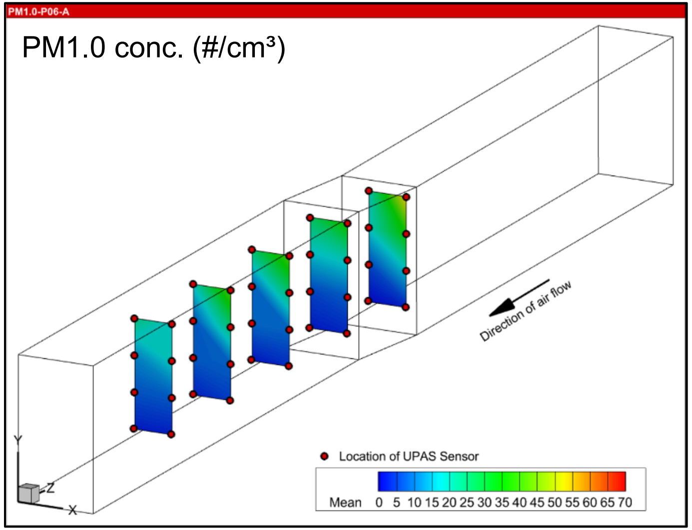
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	531	0.2	22.9	0.1	8.3
2	536	0.2	22.8	0.2	8.4
3	534	0.2	23.3	-0.3	8.5
ALL	**534**	**0.2**	**23.0**	**0.0**	**8.4**



P06-A-[Station #]-HN-[Rep #]

Date	2025-05-12
Test Type	Particle
Configuration	6 (Seven manikins downstream of dosing nozzle)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect on particle dispersion of seven unheated manikins spaced 3 ft apart, with the first manikin placed 6 ft downstream from aerosol release.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Unheated manikins were placed at 16, 19, 22, 25, 28, 31, and 34 ft. • Average values are based on five minutes of 1 Hz data.

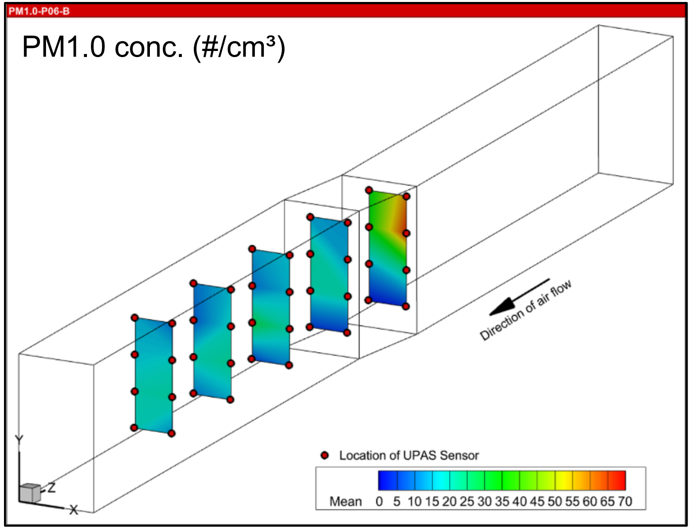
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	ΔT_{bridge}	T_{dp} (°C) Bridge
1	540	0.1	22.8	0.0	7.7
2	538	0.2	22.8	0.0	8.2
3	540	0.1	22.8	-0.1	8.5
ALL	**539**	**0.1**	**22.8**	**0.0**	**8.1**



P06-B-[Station #]-HN-[Rep #]

Date	2025-05-12
Test Type	Particle
Configuration	6 (Seven manikins downstream of dosing nozzle)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect on particle dispersion of seven heated manikins spaced 3 ft apart, with the first manikin placed 6 ft downstream from aerosol release.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Heated manikins were placed at 16, 19, 22, 25, 28, 31, and 34 ft. • Average values are based on five minutes of 1 Hz data.

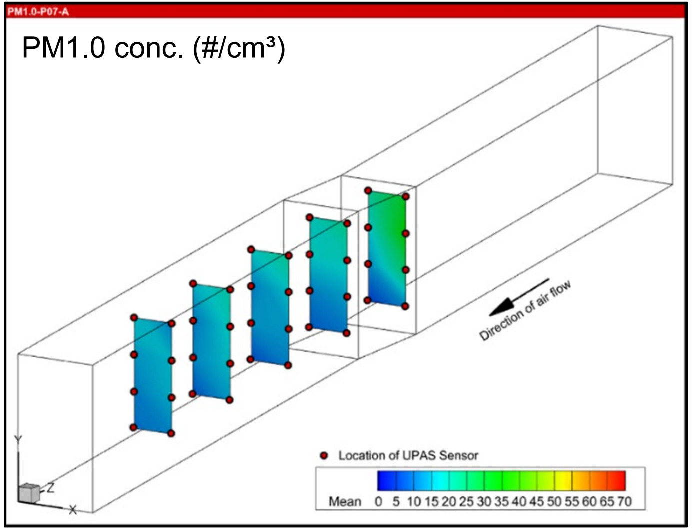
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	ΔT_{bridge}	T_{dp} (°C) Bridge
1	539	0.1	23.0	-0.1	10.5
2	535	0.2	23.1	-0.2	10.6
3	537	0.2	23.0	-0.1	10.8
ALL	**537**	**0.2**	**23.0**	**-0.1**	**10.8**



P07-A-[Station #]-HN-[Rep #]

Date	2025-05-14
Test Type	Particle
Configuration	7 (Empty bridge with dosing nozzle facing upstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the effect on particle dispersion of orienting the dosing nozzle against the flow of air moving through the empty jet bridge.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	534	0.2	22.8	0.0	9.8
2	536	0.2	22.8	0.0	9.9
3	536	0.2	22.8	0.0	9.8
ALL	**536**	**0.2**	**22.8**	**0.0**	**9.8**

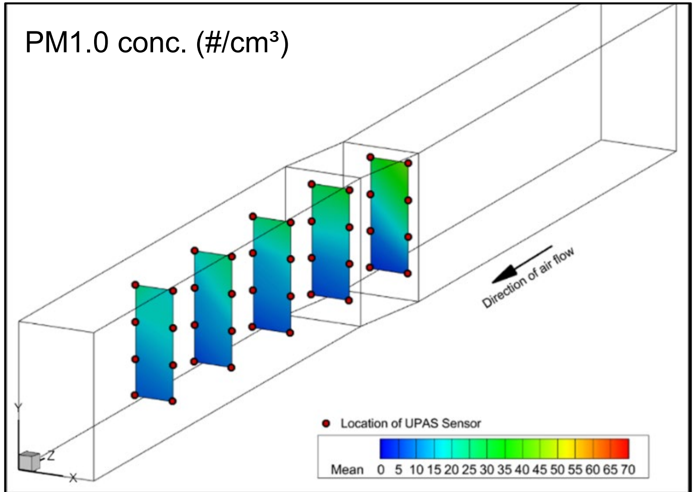


P08-A-[Station #]-HN-[Rep #]

Date	2025-05-14
Test Type	Particle
Configuration	8 (Manikin at 40 ft with dosing nozzle facing upstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	4 (1, 2, 3, and 4)
Purpose	Evaluate the effect on particle dispersion of orienting the dosing nozzle against the flow of air moving through the jet bridge with one manikin.
Description	• Particle concentration is measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	534	0.2	22.9	-0.1	10.0
2	535	0.2	23.0	-0.1	10.1
3	537	0.2	22.8	0.1	10.1
4	536	0.1	22.8	0.0	10.1
ALL	**535**	**0.2**	**22.9**	**0.0**	**10.1**

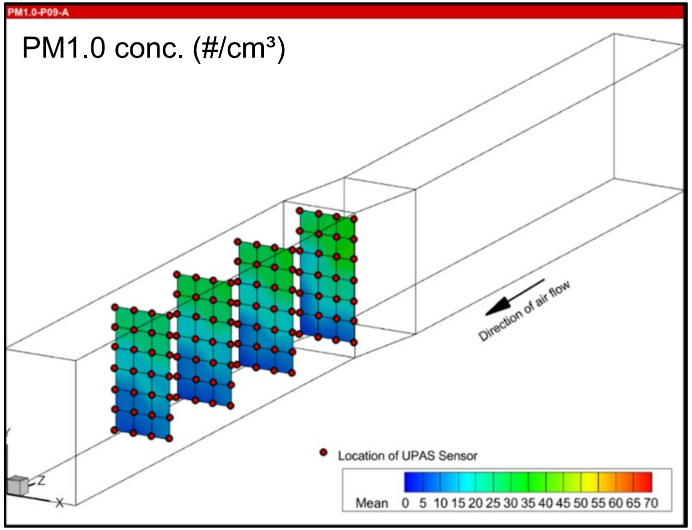
PM1.0 conc. (#/cm³)



P09-A-[Station #]-HN-[Rep #]

Date	2025-05-27
Test Type	Particle
Configuration	9 (Manikin at 31 ft with nozzle pointed downstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	To be evaluated alongside P10-A, to compare the results obtained when a human is represented by a manikin (P09) or a box of similar dimensions (P10).
Description	• Particle concentration is measured every six feet, from 10 ft to 28 ft (4 stations) using a single 7×4 array of UPAS devices, moved sequentially upstream. • A unheated manikin was placed at 31 ft, facing downstream. • Average values are based on five minutes of 1 Hz data.

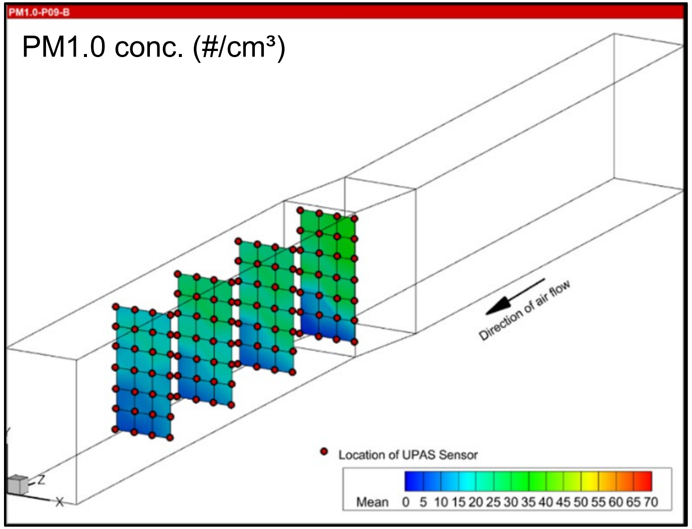
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	536	0.2	22.6	0.6	5.8
2	536	0.2	22.3	0.9	5.8
3	537	0.2	22.1	0.9	5.6
ALL	**537**	**0.2**	**22.4**	**0.8**	**5.7**



P09-B-[Station #]-HN-[Rep #]

Date	2025-05-27
Test Type	Particle
Configuration	9 (Manikin at 31 ft with nozzle pointed downstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	To be evaluated alongside P10-A, to compare the results obtained when a human is represented by a manikin (P09) or a box of similar dimensions (P10).
Description	• Particle concentration is measured every six feet, from 10 ft to 28 ft (4 stations) using a single 7×4 array of UPAS devices, moved sequentially upstream. • A heated manikin was placed at 31 ft, facing downstream. • Average values are based on five minutes of 1 Hz data.

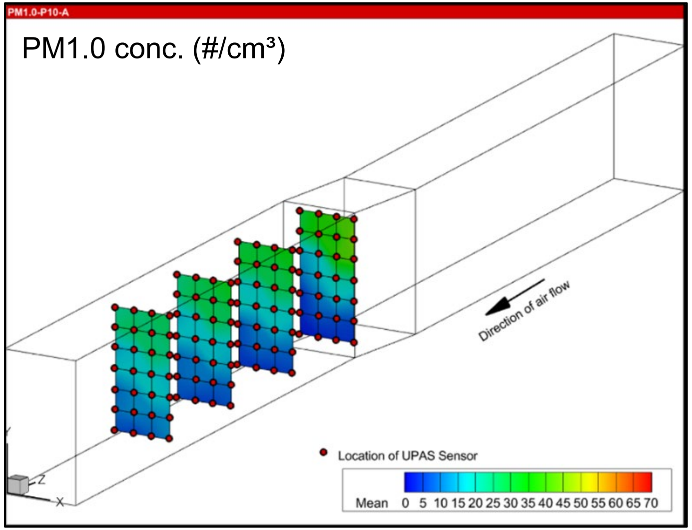
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	538	0.2	23.4	-0.1	6.0
2	536	0.2	23.3	0.0	6.0
3	536	0.2	23.3	0.0	6.0
ALL	**537**	**0.2**	**23.3**	**0.0**	**6.0**



P10-A-[Station #]-HN-[Rep #]

Date	2025-05-27 to -28
Test Type	Particle
Configuration	10 (Box at 31 ft with nozzle pointed downstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	To be evaluated alongside P10-A, to compare the results obtained when a human is represented by a manikin (P09) or a box of similar dimensions (P10).
Description	• Particle concentration is measured every six feet, from 10 ft to 28 ft (4 stations) using a single 7×4 array of UPAS devices, moved sequentially upstream. • A unheated box was placed at 31 ft, facing downstream. • Average values are based on five minutes of 1 Hz data.

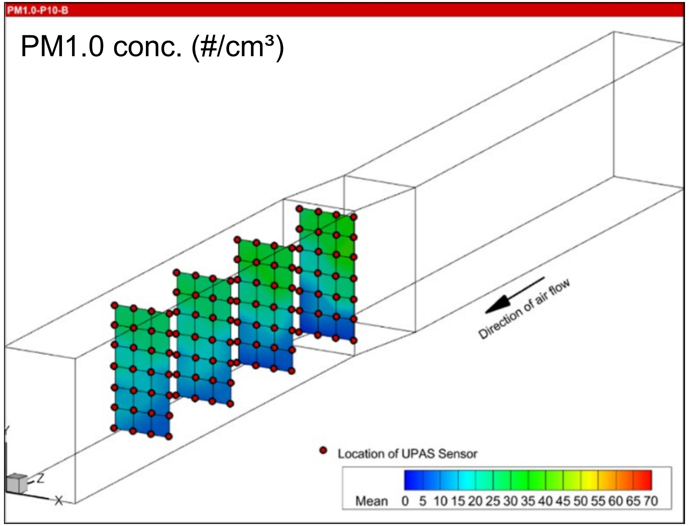
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	537	0.2	23.3	0.1	6.3
2	536	0.2	23.3	0.1	6.3
3	536	0.2	23.3	0.0	6.3
ALL	**536**	**0.2**	**23.3**	**0.1**	**6.3**



P10-B-[Station #]-HN-[Rep #]

Date	2025-05-28
Test Type	Particle
Configuration	10 (Box at 31 ft with nozzle pointed downstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	To be evaluated alongside P10-A, to compare the results obtained when a human is represented by a manikin (P09) or a box of similar dimensions (P10).
Description	• Particle concentration is measured every six feet, from 10 ft to 28 ft (4 stations) using a single 7×4 array of UPAS devices, moved sequentially upstream. • A heated box was placed at 31 ft, facing downstream. • Average values are based on five minutes of 1 Hz data.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	537	0.2	23.2	0.1	6.6
2	537	0.2	23.2	0.0	6.7
3	536	0.2	23.2	0.1	6.7
ALL	**537**	**0.2**	**23.2**	**0.1**	**6.7**

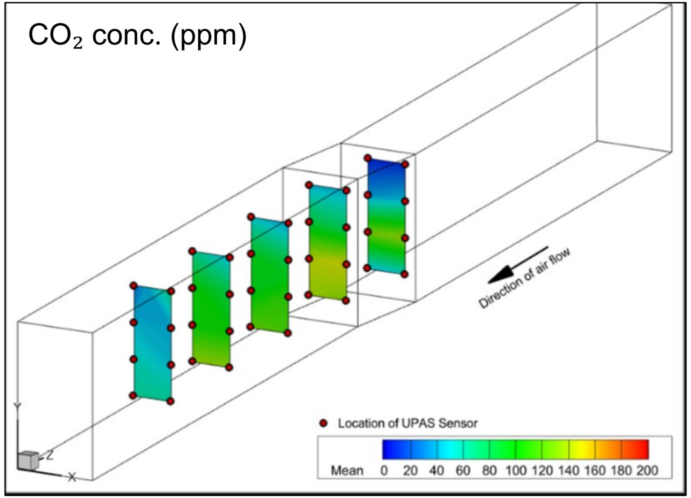


11.c. Data Summary: Tracer Gas

G01-A-[Station #]-HN-[Rep #]

Date	2025-05-16
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	4 (1, 2, 3, and 4)
Purpose	Observe the effect of varying temperature differential between supply air and the external lab temperature as tracer gas is dosed into the jet bridge.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

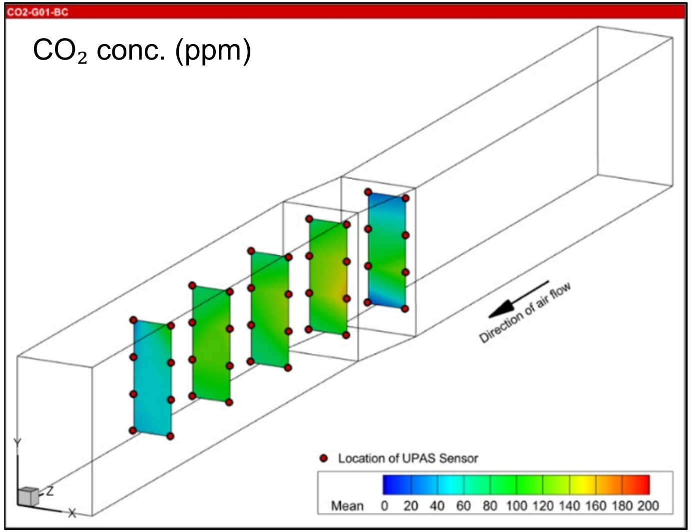
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	534	0.2	22.6	-0.2	9.9
2	531	0.2	22.5	-0.1	9.8
3	531	0.2	22.4	0.0	9.6
4	532	0.2	22.4	-0.1	9.6
ALL	**532**	**0.2**	**22.5**	**-0.1**	**9.7**



G01-AC-[Station #]-HN-[Rep #]

Date	2025-05-16
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	-3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the effect of varying temperature differential between supply air and the external lab temperature as tracer gas is dosed into the jet bridge.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

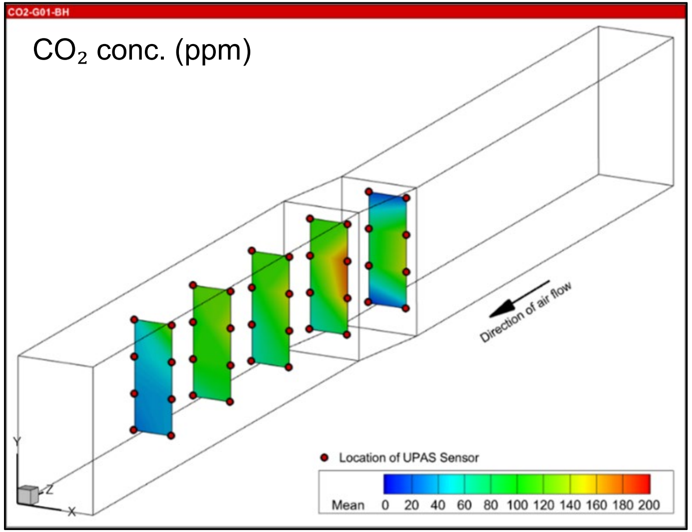
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	533	0.2	22.5	-3.2	9.4
2	536	0.2	22.6	-3.3	9.6
3	535	0.2	22.4	-3.1	9.7
ALL	**535**	**0.2**	**22.5**	**-3.2**	**9.6**



G01-AH-[Station #]-HN-[Rep #]

Date	2025-05-16
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	+3°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Observe the effect of varying temperature differential between supply air and the external lab temperature as tracer gas is dosed into the jet bridge.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

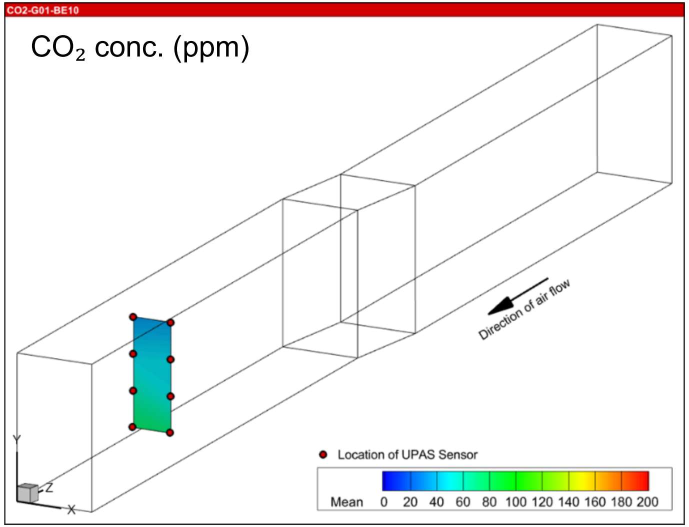
Rep #	**Flow (lps)**	**dP (Pa)**	**T_{db} (°C)**		**T_{dp} (°C)**
			Lab	**ΔT_{bridge}**	**Bridge**
1	532	0.2	22.5	2.9	9.3
2	530	0.2	22.6	2.9	9.4
3	528	0.2	22.6	2.8	9.4
ALL	**530**	**0.2**	**22.6**	**2.9**	**9.4**



G01-AE10-[Station #]-HN-[Rep #]

Date	2025-05-21
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

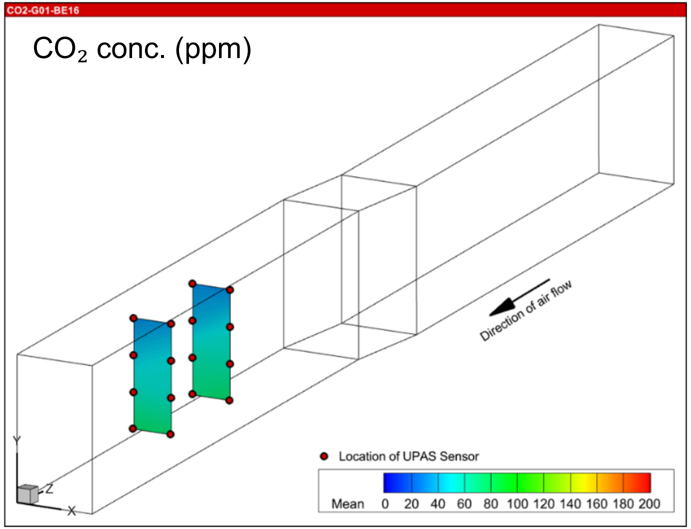
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	535	0.2	22.4	0.3	6.9
2	533	0.2	22.5	0.2	6.9
3	537	0.2	22.4	0.3	7.0
ALL	**535**	**0.2**	**22.4**	**0.3**	**6.9**



G01-AE16-[Station #]-HN-[Rep #]

Date	2025-05-21
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

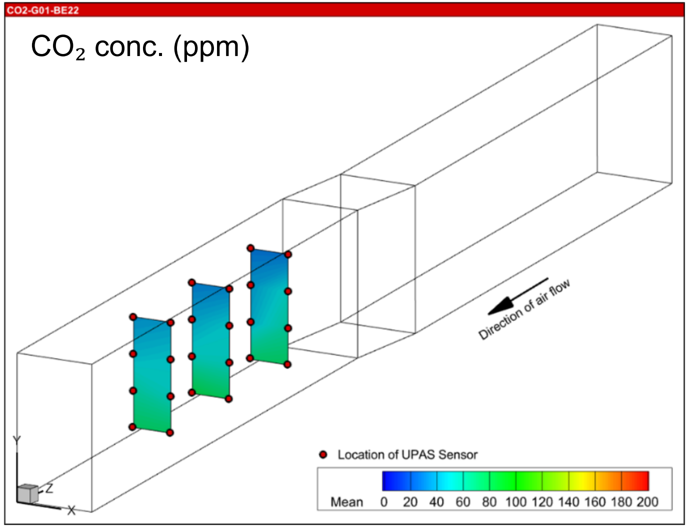
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	536	0.2	22.6	0.1	7.0
2	535	0.2	22.4	0.3	6.9
3	534	0.2	22.5	0.2	6.9
ALL	**535**	**0.2**	**22.5**	**0.2**	**6.9**



G01-AE22-[Station #]-HN-[Rep #]

Date	2025-05-21
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

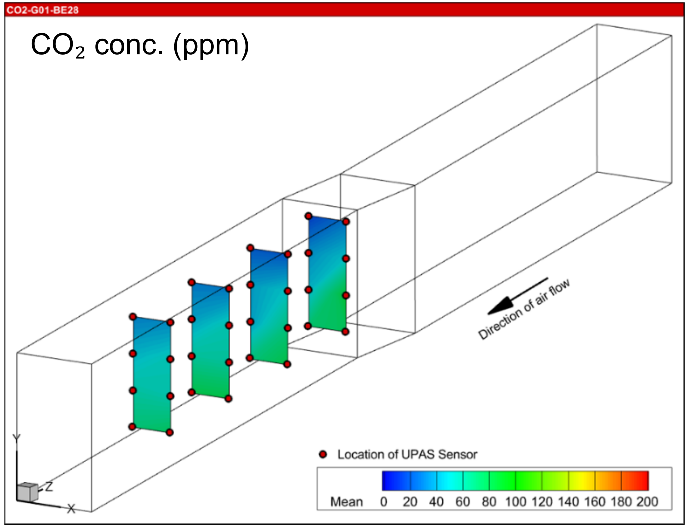
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	528	0.3	22.4	0.2	6.9
2	536	0.2	22.6	0.1	6.9
3	532	0.2	22.5	0.2	6.9
ALL	**532**	**0.2**	**22.5**	**0.2**	**6.9**



G01-AE28-[Station #]-HN-[Rep #]

Date	2025-05-21
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

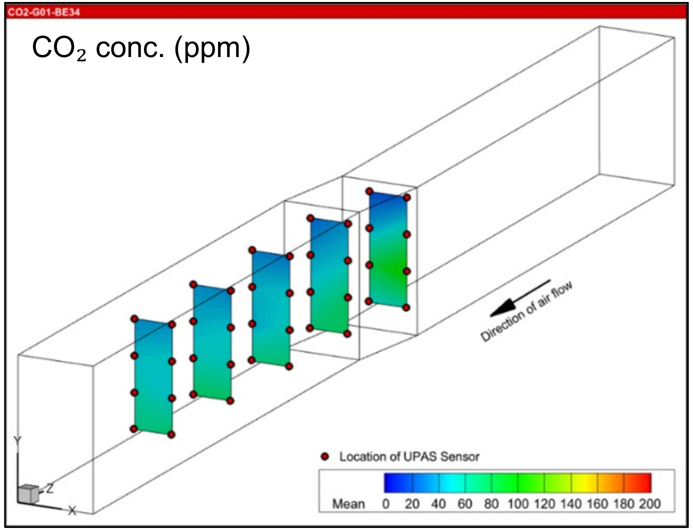
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C) Lab	ΔT_{bridge}	T_{dp} (°C) Bridge
1	534	0.2	22.5	0.1	6.9
2	534	0.2	22.4	0.2	6.9
3	537	0.2	22.4	0.2	6.9
ALL	**535**	**0.2**	**22.4**	**0.2**	**6.9**



G01-AE34-[Station #]-HN-[Rep #]

Date	2025-05-21
Test Type	Tracer Gas
Configuration	1 (Empty Jet Bridge)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Evaluate the impact of the upstream physical measurement apparatus on downstream measurements.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. Next, the 4x2 array that is furthest upstream is removed and the test is performed again with the new upstream station. This is repeated until only the 10 ft station remains. • Average values are based on five minutes of 1 Hz data.

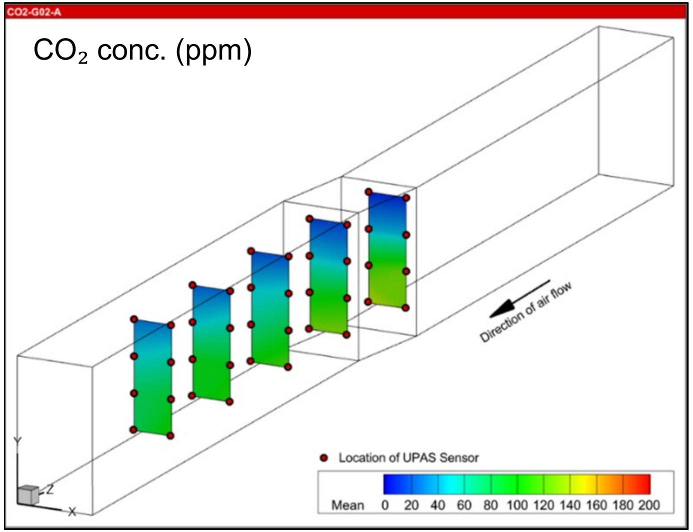
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	535	0.2	22.5	0.2	6.9
2	533	0.2	22.4	0.3	7.0
3	535	0.2	22.5	0.2	7.0
ALL	**534**	**0.2**	**22.5**	**0.2**	**7.0**



G02-A-[Station #]-HN-[Rep #]

Date	2025-05-20
Test Type	Tracer Gas
Configuration	2 (Manikin upstream of dosing nozzle at 42 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P02-A. Evaluate the effect of a unheated manikin behind the dosing nozzle on particle dispersion.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

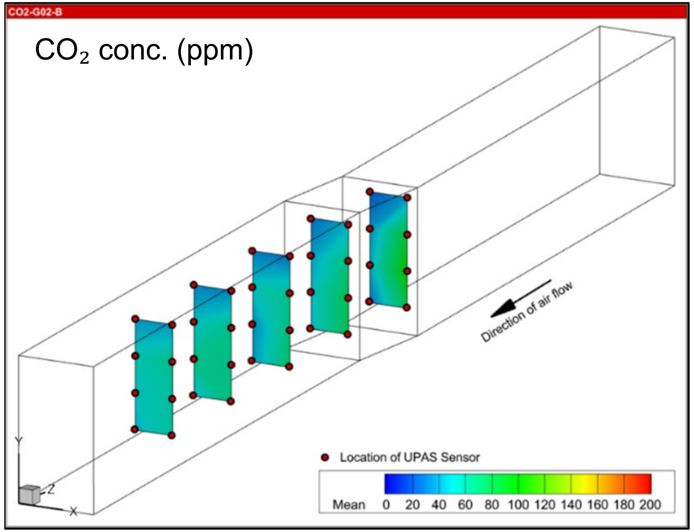
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	528	0.3	25.1	0.1	9.0
2	530	0.2	25.3	0.0	9.7
3	531	0.2	25.3	-0.2	10.3
ALL	**530**	**0.2**	**25.2**	**0.0**	**9.7**



G02-B-[Station #]-HN-[Rep #]

Date	2025-05-20
Test Type	Tracer Gas
Configuration	2 (Manikin upstream of dosing nozzle at 42 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P02-B. Evaluate the effect of a heated manikin behind the dosing nozzle on particle dispersion.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

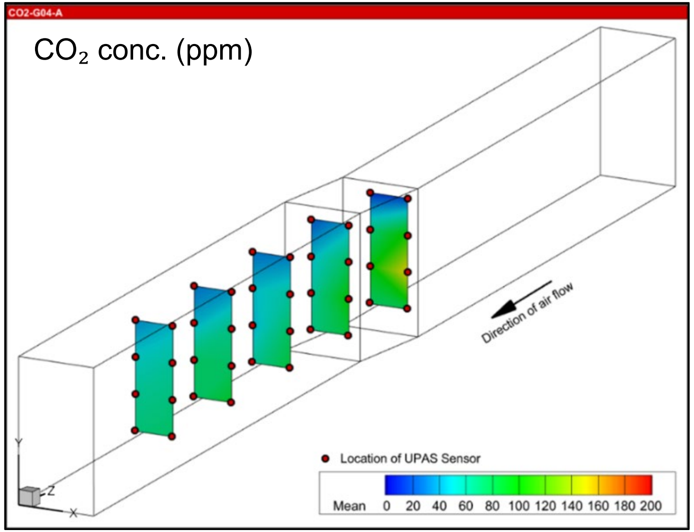
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	530	0.2	26.2	0.0	13.3
2	528	0.2	26.3	-0.1	13.4
3	527	0.2	26.3	0.0	13.5
ALL	**529**	**0.2**	**26.3**	**0.0**	**13.4**



G04-A-[Station #]-HN-[Rep #]

Date	2025-05-20
Test Type	Tracer Gas
Configuration	4 (Manikin downstream of dosing nozzle at 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P04-A. Evaluate the effect of a unheated manikin behind the dosing nozzle on particle dispersion.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single unheated manikin was placed at 34 ft. • Average values are based on five minutes of 1 Hz data.

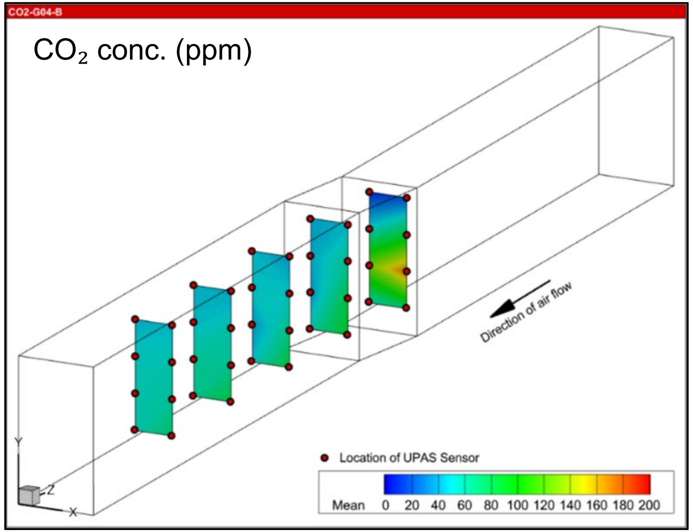
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	534	0.2	25.4	-0.1	11.1
2	531	0.2	25.4	0.0	11.1
3	528	0.3	25.5	0.0	11.3
ALL	**531**	**0.2**	**25.4**	**0.0**	**11.2**



G04-B-[Station #]-HN-[Rep #]

Date	2025-05-20
Test Type	Tracer Gas
Configuration	4 (Manikin downstream of dosing nozzle at 34 ft)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P04-B. Evaluate the effect of a heated manikin behind the dosing nozzle on particle dispersion.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • A single heated manikin was placed at 34 ft. • Average values are based on five minutes of 1 Hz data.

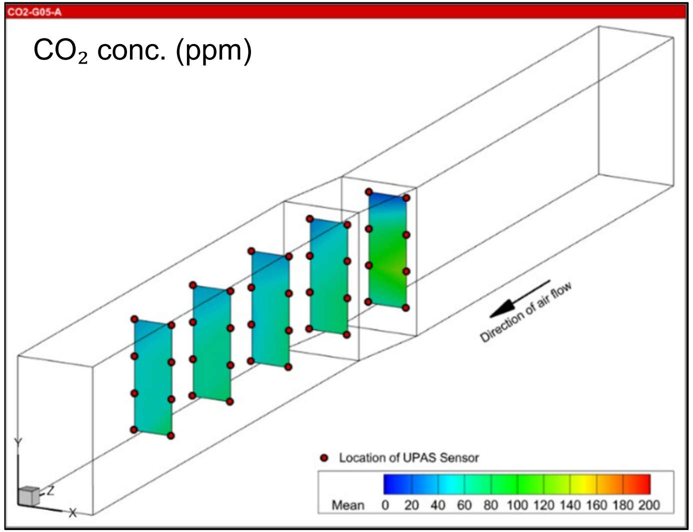
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	528	0.3	26.1	0.2	12.9
2	533	0.2	26.0	-0.1	13.3
3	536	0.2	26.1	0.0	13.2
ALL	**532**	**0.2**	**26.1**	**0.0**	**13.1**



G05-A-[Station #]-HN-[Rep #]

Date	2025-05-21
Test Type	Tracer Gas
Configuration	5 (Four manikins downstream of dosing nozzle)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P05-A. Evaluate the effect of four unheated manikins behind the dosing nozzle on particle dispersion.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Unheated manikins were placed at 16, 22, 28, and 34 ft. • Average values are based on five minutes of 1 Hz data.

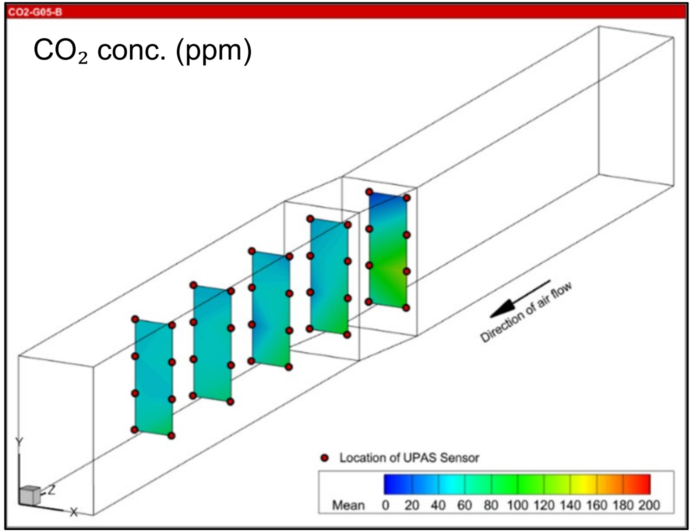
Rep #	**Flow (lps)**	**dP (Pa)**	**T_{db} (°C)**		**T_{dp} (°C)**
			Lab	**ΔT_{bridge}**	**Bridge**
1	534	0.2	21.6	0.1	6.3
2	534	0.2	21.6	0.1	6.3
3	537	0.2	21.8	0.0	6.5
ALL	**535**	**0.2**	**21.7**	**0.1**	**6.4**



G05-B-[Station #]-HN-[Rep #]

Date	2025-05-21
Test Type	Tracer Gas
Configuration	5 (Four manikins downstream of dosing nozzle)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P05-B. Evaluate the effect of four heated manikins behind the dosing nozzle on particle dispersion.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Heated manikins were placed at 16, 22, 28, and 34 ft. • Average values are based on five minutes of 1 Hz data.

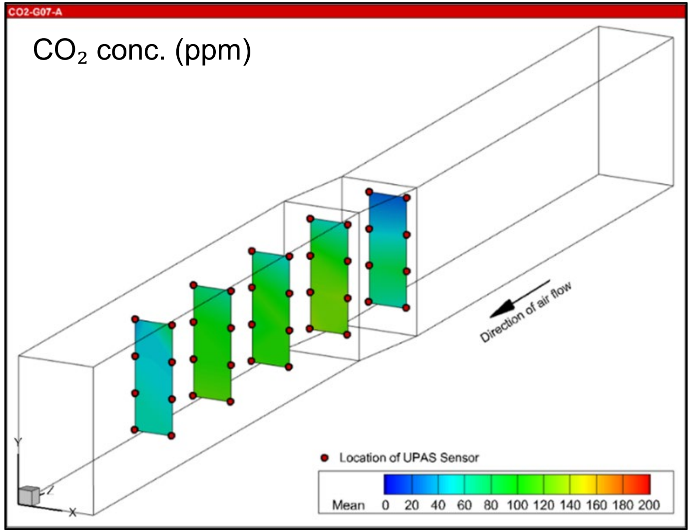
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	535	0.2	22.5	0.2	6.9
2	533	0.2	22.8	-0.1	6.9
3	533	0.2	22.9	0.0	7.0
ALL	**534**	**0.2**	**22.7**	**0.0**	**6.9**



G07-A-[Station #]-HN-[Rep #]

Date	2025-05-16
Test Type	Tracer Gas
Configuration	7 (Empty bridge with dosing nozzle facing upstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P07-A.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

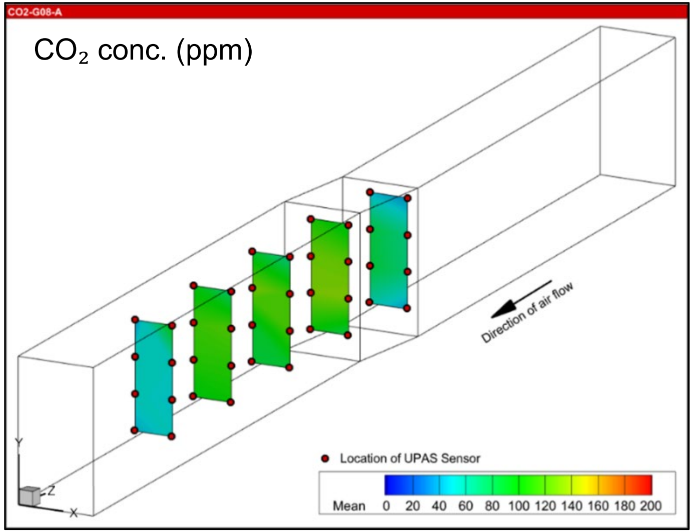
Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	533	0.2	22.6	-0.2	9.3
2	533	0.2	22.6	-0.2	9.5
3	533	0.2	22.3	0.1	9.6
ALL	**533**	**0.2**	**22.5**	**-0.1**	**9.5**



G08-A-[Station #]-HN-[Rep #]

Date	2025-05-16
Test Type	Tracer Gas
Configuration	8 (Manikin at 40 ft with dosing nozzle facing upstream)
Target ΔT	0°C
Exhaust Setting	High
Bridge Pressure	Neutral
Repetitions	3 (1, 2, and 3)
Purpose	Compare with results from particle test P08-A.
Description	• CO_2 concentrations above ambient conditions are measured every six feet, from 10 ft to 34 ft (5 stations) using five 4×2 arrays of UPAS devices. • Average values are based on five minutes of 1 Hz data.

Rep #	Flow (lps)	dP (Pa)	T_{db} (°C)		T_{dp} (°C)
			Lab	ΔT_{bridge}	Bridge
1	527	0.3	22.6	-0.1	9.8
2	534	0.2	22.8	-0.3	9.7
3	531	0.2	22.5	0.0	9.5
ALL	**531**	**0.2**	**22.6**	**-0.1**	**9.7**



11.d. Data Summary: Airport

Airport Building HVAC Data

The airport building HVAC data presented in chapter 4 with the methodology described in chapter 7 is saved under two files under the HVAC folder. The times are reported as Epoch Timestamp. Chapter 7 describes the data by column ID number.

File	Start Time (sec)	End Time (sec)
XXX-Airport-01.csv	1733029200	1735707000
XXX-Airport-02.csv	1742257800	1746016200

12. Discussion

Discussion Overview

This section continues the discussion from section 3 (Model Validation Plan) with recommendations as to how each hypothesis can be tested with the data presented in the previous chapter.

Ventilation Configuration (and Relative Body Motion)

Ventilation Configuration (and Relative Body Motion) Overview

Research Question:

Does the jet bridge ventilation configuration have a large impact on agent exposure and propagation of communicable disease in a jet bridge?

Item	Hypothesis to be tested
1.a	The spatial particle distribution will be independent of jet bridge total airflow rate.
1.b	The spatial particle distribution will be independent of jet bridge airflow direction.

Ventilation Variables

Independent
- Airflow rate
- Airflow direction

Dependent
- Air speed distribution throughout the bridge
- Spatial particle distribution downstream of plume

Control (for all sets)
- Fixed relative humidity (40%)
- Fixed airflow direction (downhill)

Ventilation Summary

No particle data was collected to support answering this research question due to time and budgetary constraints. All particle and tracer gas data were collected at the same airflow rate and direction. All air speed data were collected in the same direction.

However, there are two sets of air speed sets with the same configuration as shown below in the two tables. For each set, different air speeds were used that limits intercomparison of the data but it may be used to test the computational fluid dynamics model.

Comparison Set #1	Airflow Rate (lps)
S01-AC-[Station #]-HN-[All Reps]	532 to 534
S01-AC-[Station #]-HP-[All Reps]	720 to 728
S01-AC-58-LP-[All Reps]	576 to 581

Comparison Set #2	Airflow Rate (lps)
S01-A-[Station #]-HN-[All Reps]	525 to 529
S01-A-58-LN-[All Reps]	407 to 413
S01-A-58-LP-[All Reps]	563 to 625

Aerosol Source

Aerosol Source Overview

Research Question:

Does the aerosol source momentum and composition have a large impact or change on agent exposure and propagation of a communicable disease in an aviation jet bridge?

Item	Hypothesis to be tested
2.a	The spatial particle distribution will be independent of plume velocity.
2.b	The spatial particle distribution will be independent of plume direction.
2.c	The relative spatial particle distribution will be independent of aerosol particle concentration.
2.d	The spatial particle distribution will be independent of particle size.
2.e	The spatial particle distribution will be independent of plume shape.
2.f	The spatial particle distribution will be independent of plume composition.

Aerosol Variables

Independent
- Plume velocity: two (1 and 3 m/s)
- Plume direction: two directions (upstream and downstream)
- Particle size: three size bins (0.3 to 0.5μm, 0.5 to 1.0μm, and 1.0 to 2.5μm)
- Plume composition: two (NaCl particles or CO_2 gas)

Dependent
- Spatial particle distribution downstream of plume measured with UPAS sensor array.

Control: Except where mentioned, the control variables shall be
- All adiabatic conditions
- Particle concentration (high signal-to-noise)
- Plume shape (mouth breathing)
- Supply air temperature = Lab temp ±0.2°C
- Relative humidity = 40% (target)
- airflow rate ≈ 1130 cfm
- Fixed airflow direction = downhill
- Balanced pressure between jet bridge and lab

Hypothesis 2.a (Plume velocity)

Only one comparison set of two data sets will be used to test this hypothesis. The independent variables will be the spatial particle distribution downstream of plume, measured across three size bins.

Comparison set #1	Description
P01-C-[Station #]-HN-[All Reps]	0.25” nozzle size producing 3.1 m/s plume speed
P01-A-[Station #]-HN-[Rep #1 to 3]	0.43” nozzle size producing 1.1 m/s plume speed

Hypothesis 2.b (Plume direction)

Two comparison sets of two data sets each will be used to test this hypothesis. The independent variables will be the spatial particle distribution downstream of plume, measured across three size bins.

Comparison set #1	Description
P07-A-[Station #]-HN-[All Reps]	Empty bridge, upstream nozzle
P01-A-[Station #]-HN-[Rep #1 to 3]	Empty bridge, downstream nozzle

Comparison set #2	Description
P08-A-[Station #]-HN-[All Reps]	Manikin at 40 ft, upstream nozzle
P02-A-[Station #]-HN-[All Reps]	Manikin at 40 ft, downstream nozzle

Hypothesis 2.c (Particle concentration)

No data was collected with the intention of testing this hypothesis. However, each particle data set shows the particle concentration increasing to quasi-steady state conditions and then decaying as the particle injection is turned off. It may be possible to analyze these transit conditions in support of testing this hypothesis.

Hypothesis 2.d (Particle size)

Any particle data set with multiple stations could be used. The particle concentration ratios between the different particle size bins remain the same as the sampling planes move further away from the source. The table below suggests a few data sets that should be given consideration as they do not involve thermal effects or obstructions.

Data Sets	Description
P01-A-[Station #]-HN-[Rep #4 to 9]	Detailed 4x7 grid across five planes measured one at a time in consecutive runs with near identical conditions with the only change being the position of the sensors.
P01-D-[Station #]-HN-[Rep #] P01-E-[Station #]-HN-[Rep #]	The sub-micron and super-micron concentrations were produced separately for comparison.
P07-A-[Station #]-HN-[Rep #]	Empty bridge with dosing nozzle facing upstream.

Hypothesis 2.e (Plume shape)

No data was explicitly collected in support of testing this hypothesis. However, the two different nozzle sizes would create different plume shapes (see hypothesis 2.a) as would directing the plume into and with the jet bridge airflow (see hypothesis 2.b).

Hypothesis 2.f (Plume Composition)

Several sets can be compared against each other, ideally in adiabatic conditions and without any obstructions to avoid mixing conditions that will confound the comparison. The list below shows each pair by replacing [x] with a G or P to the start of the set. The independent variables will be the spatial particle distribution or gas concentrations downstream of plume.

Comparison sets	Description
[x]01-A-[Station #]-HN-[Rep #1 to 3]	Empty bridge, downstream dose.
[x]07-A-[Station #]-HN-[Rep #1 to 3]	Empty bridge, upstream dose.

Thermal Effects

Thermal Effects Overview

Research Question:

Does heat convection significantly influence large scale airflow patterns?

Item	Hypothesis to be tested
3.a	The air speed distributions will be independent of manikin temperature.
3.b	The air speed will be independent of supply air temperature.
3.c	Particle spatial distributions will be independent of manikin temperature.
3.d	Particle spatial distributions will be independent of supply air temperature.

Thermal Effects Variables

Independent
- Manikin temperature (on and off)
- Supply air temperature (20°C, 23°C, and 26°C)

Dependent
- Air speed distribution throughout the bridge
- Spatial particle distribution downstream of plume

Control (for all sets)
- Fixed relative humidity (40%)
- Fixed airflow direction (downhill)
- Additional controls are test specific (see next slides)

Hypothesis 3.a (Air speed and manikin temperature)

Three comparison sets consisting of two data sets each will be used to test this hypothesis. The independent variable will be the air speed average and turbulence intensity measured at each plane.

Comparison set #1	Description
S04-A-[Station #]-HP-[Rep #]	One manikin, unheated
S04-B-[Station #]-HP-[Rep #]	One manikin, heated

Comparison set #2	Description
S05-A-[Station #]-HP-[Rep #]	Four manikins, unheated
S05-B-[Station #]-HP-[Rep #]	Four manikins, heated

Comparison set #3	Description
S06-A-10-HN-[Rep #]	Seven manikins, unheated
S06-B-10-HN-[Rep #]	Seven manikins, heated

Hypothesis 3.b (Air speed and supply temperature)

Two comparison sets consisting of three data sets each will be used to test this hypothesis. The independent variable will be the air speed average and turbulence intensity measured at each plane.

Comparison set #1	Description
S01-A-[Station #]-HN-[Rep #]	Adiabatic conditions
S01-AC-[Station #]-HN-[Rep #]	Air supply -3°C relative to the lab
S01-AH-[Station #]-HN-[Rep #]	Air supply +3°C relative to the lab

Empty bridge

Comparison set #2	Description
S06-A-10-HN-[Rep #]	Adiabatic conditions
S06-AC-10-HN-[Rep #]	Air supply -3°C relative to the lab
S06-AH-10-HN-[Rep #]	Air supply +3°C relative to the lab

Seven unheated manikins

Hypothesis 3.c (Particles and manikin temperature)

Five comparison sets consisting of two data sets each will be used to test this hypothesis. The independent variables will be the spatial particle distribution downstream of plume.

Comparison set #1	Description
P04-A-[Station #]-HP-[All Reps]	1 manikin, unheated
P04-B-[Station #]-HP-[All Reps]	1 manikin, heated

Comparison set #2	Description
P09-A-[Station #]-HP-[All Reps]	1 manikin, unheated
P09-B-[Station #]-HP-[All Reps]	1 manikin, heated

Comparison set #3	Description
P10-A-[Station #]-HP-[All Reps]	1 manikin, unheated
P10-B-[Station #]-HP-[All Reps]	1 manikin, heated

Comparison set #4	Description
P05-A-[Station #]-HP-[All Reps]	4 manikins, unheated
P05-B-[Station #]-HP-[All Reps]	4 manikins, heated

Comparison set #5	Description
P06-A-10-HN-[All Reps]	7 manikins, unheated
P06-B-10-HN-[All Reps]	7 manikins, heated

Hypothesis 3.d (Particles and supply temperature)

One comparison set consisting of three data sets each will be used to test this hypothesis. The independent variables will be the spatial particle distribution downstream of plume.

Comparison set #1	Description
P01-A-[Station #]-HN-[All Reps]	Adiabatic conditions
P01-AC-[Station #]-HN-[All Reps]	Air supply -3°C relative to the lab
P01-AH-[Station #]-HN-[All Reps]	Air supply +3°C relative to the lab

Empty bridge

Human Occupancy

Human Occupancy Overview

Research Question:

Do bodies and obstructive volumes in environment cause significant changes in the large-scale airflow and pathogen dispersion patterns as determine the aerosol distribution through the jet bridge?

Item	Hypothesis to be tested
4.a	The air speed distributions will be independent to the presence of 99th percentile manikins
4.b	The air speed distributions will be independent to the presence of a rectangular manikin to emulate a 50th percentile person.
4.c	The particle size concentrations will be independent to the presence of 99th percentile manikins.
4.d	The particle size concentrations will be independent to the presence of a rectangular manikin to emulate a 50th percentile person.
4.e	The particle size concentration will be independent to the change in airflow direction (or relative change due to walking speed)

Human Occupancy Variables

Independent
- Position of manikin relative to the plume source

Dependent
- Air speed distribution throughout the bridge
- Spatial particle distribution downstream of plume

Control (for all sets)
- Fixed air supply temperature
- Fixed relative humidity
- Fixed airflow direction
- Fixed airflow rate

Hypothesis 4.a (Manikin effect on air speed)

Four data sets will be used to test this hypothesis, with some adjustments to the data before they can be compared as the airflow rates were different. See table below for details. The independent variable will be the air speed average and turbulence intensity measured at each plane.

Data Set	Description	airflow (lps)
S01-A-[Station #]-HN-[All Reps]	Empty bridge	525 to 529
S04-A-[Station #]-HP-[All Reps]	One manikin	729 to 730
S05-A-[Station #]-HP-[All Reps]	Four manikins	728 to 729
S06-A-10-HN-[All Reps]	Seven manikins	521 to 534

Hypothesis 4.b (Smaller manikin effect on air speed)

No air speed data was collected to support testing this hypothesis.

Hypothesis 4.c (Manikin effect on particles)

Eight data sets will be used to test this hypothesis. Unlike hypothesis 4.a, all of the data was collected with the same airflow rates. The independent variables will be the spatial particle distribution downstream of plume.

Data Set	Description
P01-A-[Station #]-HN-[Rep #1 to 3]	Empty bridge
P02-A-[Station #]-HN-[All Reps] P03-A-[Station #]-HN-[All Reps] P04-A-[Station #]-HN-[All Reps] P08-A-[Station #]-HN-[All Reps] P09-A-[Station #]-HN-[All Reps]	One manikin
P05-A-[Station #]-HN-[All Reps]	Four manikins
P06-A-[Station #]-HN-[All Reps]	Seven manikins

Hypothesis 4.d (Manikin size on particles)

Two comparison sets consisting of two data sets each will be used to test this hypothesis. The independent variables will be the spatial particle distribution downstream of plume.

Comparison set #1	Description
P09-A-[Station #]-HN-[All Reps]	99^{th} percentile manikin, unheated
P10-A-[Station #]-HN-[All Reps]	50^{th} percentile box, unheated

Comparison set #2	Description
P09-B-[Station #]-HN-[All Reps]	99^{th} percentile manikin, heated
P10-B-[Station #]-HN-[All Reps]	50^{th} percentile box, heated

Hypothesis 4.e (airflow direction on particles)

One comparison set consisting of two data sets will be used to test this hypothesis. The independent variables will be the spatial particle distribution downstream of plume.

Comparison set #1	Description
P02-A-[Station #]-HN-[All Reps]	Manikin and nozzle facing downstream
P08-A-[Station #]-HN-[All Reps]	Manikin and nozzle facing upstream

Grid Resolution

Grid Resolution Overview

Research Questions:

Does the number of measurement apparatus significantly influence large scale airflow patterns? Do coarse grid measurements taken simultaneously correlate with fine grid measurements taken sequentially? How do multiple planes of sensors affect the jet bridge plug airflow?

Item	Hypothesis to be tested
5.a	Air speed distributions will be independent of the number of air speed sensors.
5.b	Particle spatial distributions will be independent of the number of particle sensors.
5.c	Air speed distributions will agree with CFD results.
5.d	Particle spatial distributions will agree with CFD results.

Grid Resolution Variables

Independent
- Planes of air velocity measurements
- Planes of particle concentration measurements

Dependent
- Air speed distribution throughout the bridge
- Spatial particle distribution downstream of plume

Control (for all sets)
- Fix air supply temperature.
- Fixed relative humidity.
- Fixed airflow direction.
- Additional controls are test specific.

Hypothesis 5.a (# of sensors on air speed)

For all air speed data sets, only one plane was measured at a time given the number of sensors that were available to the project. Thus, there are no sensors upstream of the velocity measurements.

However, there were two different air velocity grid density (12 vs 24) that were measured to show the level of detail that may be missed. The table shows the data for these two sets.

Data Set	Description
P01-A-[Station #]-HN-[Rep #1 to 3]	Measured at inlet with two columns of 6 sensors.
P01-A-[Station #]-HN-[Rep #4 to 9]	Measured at inlet with four columns of 6 sensors.

Hypothesis 5.b (# of sensors on particles)

Five data sets will be used to test this hypothesis. The independent variables will be the spatial particle distribution downstream of plume.

Data Set	Description
P01-AE10-[Station #]-HN-[Rep #]	Empty bridge with only one plane measured
P01-AE16-[Station #]-HN-[Rep #]	Empty bridge with two planes measured
P01-AE22-[Station #]-HN-[Rep #]	Empty bridge with three planes measured
P01-AE28-[Station #]-HN-[Rep #]	Empty bridge with four planes measured
P01-AE34-[Station #]-HN-[Rep #]	Empty bridge with five planes measured

Hypothesis 5.c (Experimental vs CFD for air speed)

All data sets starting with the letter S are available to test this hypothesis. The table below provides recommended data sets that could be evaluated first as they have the same airflow rates for all sets on each row of the table.

Inlet Boundary Condition	Downstream Measurements
S01-A-58-HN-[All Reps]	S01-A-[Station #]-HN-[Rep #]
S01-A-58-HN-[All Reps]	S06-[A or B]-10-HN-[Rep #]
S01-AC-58-HP-[Rep #]	S01-AC-[Station #]-HP-[Rep #]

Hypothesis 5.d (Experimental vs CFD for particles)

All data sets starting with the letter P are available to test this hypothesis. The data set P01-A-[Station #]-HN-[Rep #4 to 9] is the only set available that used a high density layout (4x7), while the rest used a low density layout (2x4). The upstream particle counts were clean as HEPA filters were used to ensure little-to-no background particles were present for each experiment.

13. Next Steps

Next Steps Overview

Next work will take place in a fuselage of a Boeing 737-200, using a tracer gas to evaluate the movement of air through the cabin. This will continue during three in-flight tests on Boeing Max 8 aircraft to document the effective ventilation rate inside the aircraft along with the cabin airflow supply rates.

After the flights, we expect to continue air speed, particulate, and tracer gas measurements inside the Boeing 737-200 aircraft to document the effects of different cabin and airflow configurations. Automated aerosol delivery systems will be explored for more elaborate experiments on contagious disease transmission on moving platforms to simulate passenger movement.

The data presented in this report, followed by the planned measurements inside the fuselage, will be used by the Modeling and Simulation Software Team to validate the disease transmission models that will be used to help airlines develop risk controls to protect their crew and passengers.

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