



## Project 002 Ambient Conditions Corrections for Nonvolatile Particulate Matter Emissions Measurements

Missouri University of Science and Technology, Aerodyne Research Inc., and Honeywell

### Project Lead Investigator

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### University Participants

#### Missouri University of Science and Technology (MS&T)

- PI: Philip D. Whitefield, Chancellor's Professor of Chemistry
- FAA Award Number: 13-C-AJFE-MST, Amendments 002, 003, 005, 008, 010, and 012
- Period of Performance: September 18, 2014, to October 31, 2022
- Task: Collect nonvolatile particulate matter (nvPM) data in a combustor rig to assess ambient effects on nvPM emissions

### Project Funding Level

PROJECT	FUNDING	MATCHING	SOURCE
13-C-AJFE-MST-002	\$1,288,836.34	\$1,288,836.34	EMPA LETTER
	\$284,613.66	\$284,613.66	TRANSPORT CANADA
13-C-AJFE-MST-003	\$500,000.00	\$500,000.00	EMPA LETTER
13-C-AJFE-MST-005	\$500,000.00	\$500,000.00	EMPA LETTER
13-C-AJFE-MST-008	\$579,234.00	\$579,234.00	EMPA LETTER
13-C-AJFE-MST-010	\$725,500.00	\$725,500.00	EMPA LETTER
13-C-AJFE-MST-012	\$1,217,221.00	\$1,217,221.00	EMPA LETTER

### Investigation Team

- Professor Philip Whitefield, Missouri University of Science and Technology
- Steven Achterberg, research technician, Missouri University of Science and Technology
- Max Trueblood, research technician, Missouri University of Science and Technology
- Dr. Richard Miake-Lye, subcontractor, Aerodyne Research, Inc.
- Rudy Dudebout, subcontractor, Honeywell Aerospace
- Paul Yankowich, subcontractor, Honeywell Aerospace

### Project Overview

During this reporting period, the MS&T/Aerodyne team collaborated with Honeywell to collect nvPM data for a combustor rig to assess ambient effects on nvPM emissions.

## Task 1 – Collect nvPM Data in a Combustor Rig to Assess Ambient Effects on nvPM Emissions

Missouri University of Science and Technology

### Objectives

nvPM emissions from aircraft engines are affected by changing inlet conditions. A combustor rig test provides the most flexibility for quantifying the impact of changing conditions on nvPM emissions and developing methods for use in inventory modeling. The MS&T/Aerodyne team has worked with Honeywell to conduct combustor rig tests, collect nvPM mass and number emissions data, and to perform data analysis to determine nvPM ambient corrections.

### Research Approach

- Define and assemble a standardized nvPM measurement system that will include the same Mobile Measurement System (MMS) that was used to sample nvPM from 25 Honeywell HTF7350 production engines in 2017
- Design and fabricate the nvPM emission rakes and combustor rig adaptive hardware required to enable nvPM and gaseous emissions data to be acquired from Honeywell's existing HTF7000 Combustor Test Rig
- Perform four combustor rig tests with Jet A and three alternative fuels
- Vary combustor test conditions (derived from engine cycle performance analysis, covering a range of engine ambient inlet conditions on the ground and at altitude) and measure nvPM emissions
- Analyze data to inform performance-based nvPM emissions modeling for all altitudes

### Milestones

A rig test matrix has been devised and executed for exclusively burning jet A. Preliminary data analysis has been performed during this reporting period. An outstanding dataset has been acquired albeit under the constraints of the ongoing pandemic protocol restrictions. It was not possible to deploy the entire North American Reference System (NARS) due to travel restrictions associated with the pandemic protocol; however, critical nvPM size measurement capabilities (Cambustion DMS500) were deployed, and their operation was monitored remotely, thus yielding a synchronized size dataset. Analysis of the size data is underway.

### Major Accomplishments

- Honeywell and the MS&T/Aerodyne team have assembled two standardized nvPM emissions measurement systems.
- Honeywell has completed the design and fabrication of rakes and adaptive rig hardware required to enable nvPM emissions measurements in the HTF7000 Combustor Test Rig.
- Honeywell has completed the initial set-up of the sampling system and performed the shake-down test.
- Honeywell found some hardware interferences in the shake-down tests, and the necessary corrections have been made. During the pandemic delay, the calibrations required for the Honeywell and NARS nvPM measurement systems expired. Thus, these instruments have undergone recalibration.
- Specifically, data for six different temperature points ranging from idle to 100% thrust with associated variations in corrected flow, fuel air ratio, and pressures were studied with Jet A as the candidate fuel. Facility pressure limitations resulted in a pressure limit of approximately one half of the 100% landing and take-off full-engine pressure. The reported mass-based emissions index (Elm) and noise- based emissions index (Ein) data were corrected for thermophoretic loss. A typical data example is given in Figure 1.

### Publications

An informational paper was provided to the Emissions Characterization Task Group of Emissions Technical Working Group 3 (WG3-7) in the 12<sup>th</sup> cycle of the Committee on Aviation Environmental Protection (CAEP/12) on September 20–24, 2021.

### Outreach Efforts

Results were presented at the 7<sup>th</sup> meeting of the Emissions technical Working group 3 (WG3-7) in the 12<sup>th</sup> cycle of the Committee on aviation environmental protection (CAEP/12) on September 20-24

### Awards

None

### Student Involvement

No graduate students were employed in this task; however, three undergraduate research assistants (Christian Hurst, Nicholas Altese, and Susan Donaldson) were employed in pretest activities, including individual component testing and calibration and data reduction and interpretation. This work was halted during Covid restrictions.

### Plans for Next Period

- Re-install and perform a shake-down test of the nvPM combustor rig measurement system with rig in the test cell
- Conduct a rig test with Jet A and three sustainable aviation fuel (SAF) blends (Phase II)

## EFFECT OF PRESSURE & CORRECTED FLOW

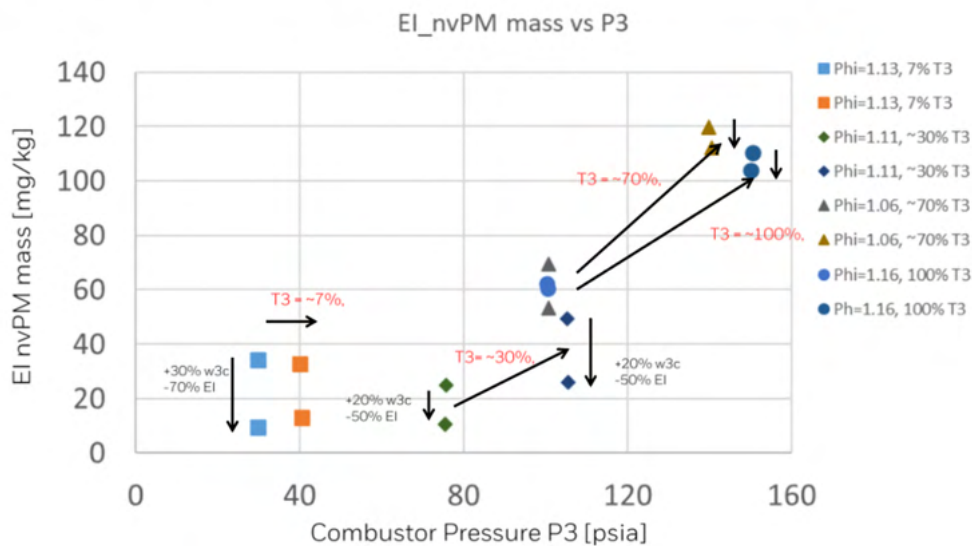


Figure 1. Example of typical data from a preliminary analysis of the test matrix results.