Quality Assurance Project Plan for The Development of A Commercial Aircraft Hazardous Air Pollutants Emission Inventory Methodology

Prepared for the:
Environmental Protection Agency
and the
Federal Aviation Administration

Prepared by:
KB Environmental Sciences, Inc.

In Coordination with:
Aerodyne Research, Inc.

March 31, 2008

APPROVAL SHEET

This sheet documents the approval of the leaders for this Quality Assurance Project Plan (QAPP). This QAPP was prepared for the purpose of documenting the procedures to develop a methodology to estimate hazardous air pollutant (HAP) emissions from commercial aircraft.

Title: Quality Assurance Project Plan for the Development of a Commercial Aircraft Hazardous Air Pollutants Emission Inventory Methodology

Federal Aviation Administration:

Date: 01 APRIL 08

Ralph Iovinelli - Operations Research Analyst
Office of Environment and Energy, AEE-300 Emissions Division
Washington, D.C.

Date: 4/1/08

Dr. Mohan Gupta – Operations Research Analyst
Office of Environment and Energy, AEE-300 Emissions Division
Washington, D.C.

Environmental Protection Agency:

Bryan Manning

Date: 4/8/08

Bryan Manning – Mechanical Engineer
Office of Transportation and Air Quality, Assessment and Standards Division
Ann Arbor, Michigan

Ruth Schenk

Date: 4/9/2008

Ruth Schenk – Quality Assurance Manager
Office of Transportation and Air Quality
Ann Arbor, Michigan

Aerodyne Research, Inc:

Richard Miake-Lye

Date: April 4, 2008

Rick Miake-Lye – Vice President
Center for Aero-Thermodynamics

KB Environmental Sciences, Inc.:

B. Carrol Bryant

Date: 3-31-08

Carrol Bryant - President

Table of Contents

List of Tables

1.0 Introduction

For over 20 years, the mobile source hazardous air pollutant (HAPs) speciation profile that has been applied to all commercial aircraft engines was based on a single measurement campaign from a single engine, as documented in the Environmental Protection Agency's (EPA's) SPECIATE Database version 4.0.[1,2] Recent field campaigns have generated new publicly-available datasets that include HAPs emissions data from various modern commercial aircraft engines. Because there is more recent data available, the Federal Aviation Administration (FAA) and the EPA agree that the purpose of this project is to:

- Evaluate all available datasets to determine if the HAPs speciation profile currently used for commercial aircraft engines should be revised.

If the evaluation results in the consensus that the speciation profile should be revised, the objectives of this project are to:

- Develop a revised speciation profile.

- Develop a methodology to incorporate data from future field campaigns that generate more HAPs-related datasets.

- Review, and revise if necessary, the factors used to convert aircraft-related total unburned hydrocarbons (THC) to volatile organic compounds (VOC) and total organic gases (TOG).

In addition to the public availability of the final HAPs-related data, it is the FAA's intent that if a revised speciation profile is developed, the profile, the methodology used to calculate air toxic emissions inventories, and any resultant conversion factors will be incorporated in to the Emission and Dispersion Modeling System (EDMS).

The evaluation of project objectives will be a collaborative effort of the project participants. Over the past several months, Aerodyne Research, Inc.[3] (Aerodyne) has evaluated the secondary data discussed in Section 2.0 of this QAPP. The results of the evaluation indicate that, regardless of ambient conditions, type of fuel, power setting, and type of engine, there is a "fingerprint" of emitted HAPs in aircraft exhaust. Aerodyne will present the participants in this project with a working paper which will include, but not be limited to, correlation plots and comparisons of current speciation data to the datasets described in Section 2.0 of this Quality Assurance Project Plan (QAPP).

[1] http://www.epa.gov/ttn/chief/software/speciate/index.html
[2] In this document, the term hazardous air pollutant (HAP) is synonymous with toxic air pollutant (TAP) and toxic air contaminant (TAC).
[3] The Center for Aero-Thermodynamics of Aerodyne Research Inc. is active in a wide variety of research efforts including advanced diagnostic measurement techniques for engine emission characterization.

This QAPP outlines the procedures that will used to ensure that the products that result from this project are of the type, and quality required by the EPA, the FAA, and end users. This QAPP was developed following guidance from the American National Standards Institute (ANSI)/American Society for Quality (ASQ) ANSI/ASQ E4-2004 document entitled *Quality Systems for Environmental Data and Technology Programs*. The guidance in the ANCI/ASQ document applies to the collection, generation, compilation, analysis, and use of environmental data[4]. Additional guidance/reference material included the EPA's documents entitled *QAPP Requirements for Secondary Data Research Projects*[5] and *Quality Manual for Environmental Programs*[6]. These EPA documents provide example guidance that was used in the preparation of this QAPP and requirements for quality assurance (QA) and quality control (QC) activities.

Notably, the environmental data discussed in this QAPP was collected for purposes other than what the data was intended to be used for (secondary use of data). The sources of the secondary data are identified in Section 2.0 of this QAPP.

1.1 Project Description

Given the current "state-of-the-science" with respect to air toxic emissions from aircraft engines, the EPA and FAA are co-developing a methodology to quantify HAPs emissions from commercial aircraft in a consistent manner; particularly when applied to aircraft air toxic emissions inventories. The intent of the EPA and the FAA is to develop a mutually-agreeable methodology to estimate the types and amounts of HAPs emitted from commercial aircraft engines.[7] The methodology should be:

- Nationally consistent,
- Supported by scientific data,
- Representative of today's commercial aircraft fleet, and
- "Living" to reflect the state-of-the-science as new data becomes available.

1.2 Project Organization and Responsibilities

The FAA and EPA are co-leaders for this effort:

[4] Environmental data is defined as any measurement or information that describes environmental processes, location, or conditions; ecological or health effects and consequences; or the performance of environmental technology.
[5] http://www.epa.gov/quality/qs-docs/found-data-rqts.pdf
[6] http://www.epa.gov/quality/qs-docs/5360.pdf
[7] The technical HAPs methodology guidance needs to also consider how piston, turboprop, and general aviation turbofan/turbojet engines should be addressed.

FAA: Ralph Iovinelli
Operations Research Analyst
Office of Environment and Energy
AEE-300 - Emissions Division
800 Independence Avenue, S.W.
Washington, DC 20591
Telephone: (202) 267-3566 Fax: (202) 267-5594
ralph.iovinelli@faa.gov

EPA: Bryan Manning
Mechanical Engineer
Office of Transportation and Air Quality
Assessment and Standards Division
2000 Traverwood
Ann Arbor, Michigan 48105
Telephone (734) 214-4832 Fax: (734) 214-4816
manning.bryan@epa.gov

In addition to the co-leaders, the following agencies/individuals participated in developing this QAPP and providing their collective and individual input through the process of developing the aircraft HAPs emission inventory methodology. The responsibilities of these agencies/companies with respect to this project are also described below:

1.2.1 FAA

FAA is the primary sponsor of this project and is responsible for overseeing the work, ensuring it is completed in a timely manner, and coordinating with other appropriate governmental agencies. In addition to Ralph Iovinelli, one of the co-leaders of this project, the following FAA staff participated in this effort.

- Mohan Gupta – mohan.l.gupta@faa.gov
- Carl Ma – carl.ma@faa.gov
- Ed McQueen – edward.mcqueen@faa.gov

1.2.2 EPA

EPA will provide advice and consultation, including review of draft work plans from FAA's contractors, analytical results, and other work products. EPA will also provide expertise to assist in the preparation of the HAPs speciation profile. In addition to Bryan Manning, one of the co-leaders of this project, the following EPA staff participated in this effort.

- Rich Cook – cook.rich@epa.gov
- Kent Helmer – helmer.kent@epa.gov
- Ken Petche – petche.ken@epa.gov
- Rich Wilcox – wilcox.rich@epa.gov
- Kathryn Sergeant – sargeant.kathryn@epa.gov
- John Kinsey – kinsey.john@epa.gov
- Marion Hoyer – hoyer.marion@epa.gov
- Laurel Driver – driver.laurel@epa.gov
- Suzanne King – king.suzanne@epa.gov
- Ruth Schenk – schenk.ruth@epa.gov

1.2.3 Aerodyne

Aerodyne will provide the primary data review, with an emphasis on recent engine measurement campaigns and how that data compares to previously collected data. Advice and recommendations will be offered on application of this data to verify and/or update speciation profiles. Aerodyne, with assistance from KBE, will also rank the data used in this project (using the criteria described in Section 3.0 – Quality of Secondary Data) and assist KBE in preparing this QAPP.

- Rick Miake-Lye – rick@aerodyne.com

1.2.4 KBE

KBE is responsible for preparing the QAPP and the project report in coordination with Aerodyne in order to capture the data analyses, assumptions, and process changes throughout the development of the HAPs speciation profile and inventory methodology.

- Carrol Bryant – cbryant@kbenv.com
- Mike Kenney – mkenney@kbenv.com
- Mike Ratte – mratte@kbenv.com

1.2.5 CARB

CARB will provide advice and consultation, including review of draft work plans from FAA's contractors, analytical results, and other work products.

- Dale Shimp – dshimp@arb.ca.gov
- Steve Church – schurch@arb.ca.gov
- Steve Francis – sfrancis@arb.ca.gov

2.0 Sources of Secondary Data

The EPA and FAA agree that the commercial aircraft air toxics emission inventory methodology should use the best data, information, and techniques available and that the results provided by the emission inventory should be representative of today's commercial aircraft fleet. This section briefly describes the existing and future datasets that are/will be available for this effort.

The datasets include results from historical testing funded by the U.S. Air Force (referred to in this QAPP as the "Spicer" and "Gerstle" datasets), and the more recent measurement campaigns sponsored by the National Aeronautics and Space Administration (NASA) – Experiment to Characterize Aircraft Volatile Aerosol and Trace Species Emissions (EXCAVATE) – and the NASA, EPA, and Department of Defense (DoD) collaboratively sponsored Aircraft Particle Emissions Experiment (APEX).

The following sources will be identified in any project deliverable in which they are used.

2.1 Spicer (1984-1989)

The Spicer dataset includes HAPs data from the U.S. Air Force Engineering and Services Center from tests performed from 1984 through 1989. One of the purposes of the tests was to obtain a detailed analysis of the composition of the gaseous hydrocarbon (HC) species emitted in gas turbine engine exhaust.

This dataset contains test data for five military turbofan aircraft engines that have civilian variants and one engine that was in military use at that time but was also used on civilian aircraft. The engines tested by Spicer are listed in **Table 1**. As shown, with the exception of the J79 engine, and when considering engine families where specific engine models are not provided in the documentation, the engines tested are currently in use in the U.S. fleet of aircraft. However, the engines conservatively represent only six percent of the engines used on the current fleet.

The Spicer testing was performed both outdoors and in engine test cells and test methods consisted of sampling rakes. During the tests, the engines were fueled with JP-4, JP-5, and JP-8.

Notably, EPA's repository for speciation profiles, SPECIATE, currently includes data from the Spicer dataset. The SPECIATE data (Profile Number 1098-Aircraft Landing/Takeoff (LTO) – Commercial) is currently used to estimate air toxic emissions for commercial aircraft. Notably, the SPECIATE data reflects composite test results for Spicer's tests for the CFM-56 engine at settings of idle, 30 percent, and 80 percent thrust that were performed with JP-5 fuel.[8]

[8] SPECIATE references the following as the source of the Spicer data: Spicer, C. W., et al., Battelle Columbus Laboratories, Composition and Photochemical Reactivity of Turbine Engine Exhaust, Report No. ESL-TR-84-28, Prepared for Air Force Engineering and Services Center (RDVS), Tyndall AFB, FL, September 1984.

Table 1
Spicer Dataset

Engine Model Tested	Engine Manufacturer	Military Aircraft Used On	Number of Engines[a]	Type of Aircraft	Max Thrust Engine (lbs)[a]	Fuel Used in Testing	Testing Method	Civilian Variant or Designation	% of Current U.S. Commercial Aircraft Fleet
TF-39-1C[a]	General Electric	C-5 Galaxy	4	Transport	41,000	JP-4, JP-5, shale derived fuel meeting JP-8 specifications	Outdoors, sampling rake (behind the engine), gas analyzer	CF6-6	0.3
CFM-56-3	CFM International	B-1B Lancer	4	Bomber	20,000	JP-4, JP-5, shale derived fuel meeting JP-8 specifications	Outdoors, sampling rake (behind the engine), gas analyzer	CFM-56-3	3.2
TF-41-A2	Allison	Vought A-7D Corsair II	1	Support	14,500	JP-4	Indoor test cell, Idle, 30%, 75%, and 100%	Rolls Royce Spey	1.7
TF33-P3	Pratt & Whitney	B-52 Stratofortress	8	Bomber	17,000	JP-4	Indoor test cell, Idle, 30%, 75%, and 100%	JT3D	0.3
TF33-P7	Pratt & Whitney	C-141 Starlifter	4	Cargo/Air Transport/ Refueling	20,250	JP-4	Indoor test cell, Idle, 30%, 75%, and 100%		
J79	General Electric	F-104 Starfighter	1	Multirole	10,000 w/o afterburner	JP-4	Indoor test cell, Idle, 30%, 75%, and 100%	CJ805	0.0
Total									5.5[b]

[a] The TF-39 has essentially the same core engine as the CF6-6 (DC10). However, the tested TF-39 was not equipped with emission abatement features.
[b] A conservatively high estimate because some percentages assume engine families, not specific engine models.

2.2 Gerstle (1997-2002)

From 1997 through 2002, the Air Force's Institute for Environment, Safety and Occupational Risk Analysis tested, characterized, and evaluated the exhaust emissions (including HAPs) of several military aircraft turbofan engines with civilian variants. The data from this effort is referred to as the Gerstle dataset. The Gerstle tests were performed using aircraft engine test cells and JP-8 fuel.

A list of the tested military turbofan engines and their civilian variants is provided in **Table 2**. Notably, the F108-CF-100 engine is the military version of the CFM-56 engine, a newer model of the engine tested by Spicer. Two turbojet, one turboprop, and one turboshaft engine tested by Gerstle also have civilian variants. These engines are also listed in Table 2.

When considering the tested engine models, and engine families where the specific engine model is not provided in test documentation, the turbofan engines in the Gerstle dataset represent approximately eight percent of the current fleet of commercial aircraft with the turbojets and turboshaft engines representing approximately two and one percent of the fleet, respectively (the tested turboprop engine is no longer in use). In total, the engines tested by Gerstle represent less than 11 percent of the engines used on the current U.S. fleet of aircraft.

2.3 EXCAVATE (2002)

The NASA-sponsored testing referred to as EXCAVATE was performed in January of 2002. A civilian B757 aircraft equipped with RB211-535-E4 engines was tested during ground-based operations for the purpose of evaluating the production of aerosols and aerosol precursors as a function of engine power, fuel composition, and plume age. The tests were performed on aircraft-mounted engines using gas sampling probes and the fuel used in the testing was JP-5 (with three different sulfur concentrations, 810 parts per million (ppm), 1,050 ppm, and 1,820 ppm). Less than one percent of the current U.S. aircraft fleet operates with the RB211-535-E4 engine and only 5.5 percent of the B757's are equipped with this engine.

2.4 APEX

As previously stated, APEX was the collaborative research effort of NASA, EPA, DoD, and the FAA. The main objective of the APEX research was to characterize both gaseous and particulate emissions to advance the understanding of emissions from commercial aircraft engines. Participants in the APEX project examined the effects of engine thrust on emissions, simulated emissions at airports, and the effects of varying fuel composition.

Table 2
Gerstle Dataset

Engine Model Tested	Engine Manufacturer	Aircraft Used In Testing	Number of Engines	Type of Aircraft[a]	Max Thrust/ Engine (lbs)[a]	Fuel Used in Testing	Testing Method	Civilian Variant or Designation	% of Current U.S. Commercial Aircraft Fleet
Turbofans									
F108-CF-100[a]	CFM International	KC-135R	4	Aerial refueling/ airlift	21,634	JP-8	Test Cell. 3-1 hr tests	CFM-56-2A-2	<0.1
F117-PW-100	Pratt & Whitney	C-17 Globemaster II	4	Cargo/ troop transport	40,440	JP-8	Test Cell. 3-1 hr tests	PW2037	1.3
TF33-P-102	Pratt & Whitney	C/EC/RC-135E Stratotanker	4	Cargo/ troop transport	18,010	JP-8	Test Cell. 3-1 hr tests	JT3D-7	<0.1
TF33-P-7/7A	Pratt & Whitney	C-141 Starlifter	4	Cargo/ troop transport	20,250	JP-8	Test Cell. 3-1 hr tests		
TF34-GE-100A	General Electric	A-10A/B Thunderbolt II	2	Close air support	9,065	JP-8	Test Cell. 3-1 hr tests	CF34	6.1
TF39-GE-1C	General Electric	C-5 Galaxy	4	Outsize cargo transport	43,000	JP-8	Test Cell. 3-1 hr tests	CF6	0.3
Turbojets									
J69-T-25	Continental	T-37 Tweet	2	Trainer	1,025	JP-8	Test Cell. 3-1 hr tests	Marbore II – Model 352	0.0
J85-GE-5A	General Electric	T-38 Talon	2	Advanced jet pilot trainer	2,050 (2,900 w/afterburner)	JP-8	Test Cell. 3-1 hr tests	CJ610	1.8
Turboprop									
T56-A-7	Allison	C-130 Hercules	4	Global airlift	4,200	JP-8	Test Cell. 3-1 hr tests	T501-D	0.0
Turboshaft									
T700-GE-700	General Electric	UH60A,UH60G	2	Helicopter	NA	JP-8	Test Cell. 3-1 hr tests	CT7-2	0.8
Total									10.5[b]

[a] The F108-CF-100 is the military designation for the CFM56-2A-2 engine.
[b] A conservatively high estimate because some percentages assume engine families, not specific engine models.

Notably, the APEX testing resulted in the most extensive set of gaseous and particulate emissions data from in-service commercial engines. **Table 3** summarizes data for the APEX1, APEX2, and APEX3 datasets. Notably, the aircraft engines tested for the APEX campaign only represent approximately six percent of the engines in use on the current aircraft fleet.

2.4.1 APEX1 (2004)

The first APEX testing (APEX1) was conducted in April of 2004 at Edwards Air Force Base in California. A NASA-owned DC-8 aircraft equipped with CFM-56-2C1 engines was tested. The testing was performed using sampling rakes (1 meter, 10 meters, and 30 meters downstream) and the sampling was performed at various engine thrust settings (4, 5.5, 7, 15, 30, 40, 60, 65, 70, 85, and 100 percent). A proton transfer reaction mass spectrometer (PTR-MS) was used to measure the concentrations of selected VOCs along with time-integrated sampling using vacuum canisters and 2,4 dinitrophenylhydrazine media. Three fuel variants were used in the testing—JP-8 as the baseline, JP-8 with additives (representing a high sulfur fuel), and Jet-A with a high aromatic hydrocarbon content (22 percent).

A report discussing the APEX1 testing was published in 2006. An executive summary and a general description of the project are followed by detailed appendices describing the measurement approaches and complete listings of the data obtained. This comprehensive report is available on-line at http://particles.grc.nasa.gov. Notably, data generated by EPA during the APEX1 measurement program will be included in a final report that is currently in preparation. However, prepublication release of EPA's data was authorized for the purpose of this FAA/EPA effort.

2.4.2 APEX2 (2005)

APEX2 testing was conducted in August 2005 in Oakland, California. The objectives of the testing were to develop emission factors for particulate matter 10 microns or less in diameter (PM_{10}), to develop chemical source profiles for typical in-use aircraft engines (CFM56 engines on B737 aircraft), to determine the effect of fuel properties and engine operating conditions on PM_{10} emissions, and to evaluate the relationship between smoke numbers (SN) and mass emission rates.

Exhaust plumes were sampled at 30, or 50 meters behind the engines using time-integrated samples (i.e., filters, polyurethane foam plugs, vacuum canisters, and 2,4 dinitrophenylhydrazine media) and continuous instruments as in APEX 1. Jet A was used in the APEX2 testing. Unlike APEX1, the effect of fuel composition was not varied explicitly, although plane-to-plane fuel variations were monitored.

A report summarizing the APEX2 tests has been prepared. It is anticipated to be released as a CARB report. The data that was generated by EPA during APEX2 will be included in a report that is currently in preparation. However, prepublication release of the data was authorized for the purpose of this FAA/EPA effort.

Table 3
APEX Dataset

Dataset	Engine Model Tested	Engine Manufacturer	Aircraft Type	Number of Engines	Max Thrust/ Engine (lbs)[a]	Fuel Used in Testing	Testing Method	% of Current U.S. Commercial Aircraft Fleet
APEX1	CFM56-2C1 (Turbofan)	CFM International	DC-8	4	22,000	JP-8, JP-8 with additives, and Jet-A	Single-point (multiple locations)	0.3
APEX2	CFM56-7B22 (Turbofan)	CFM International	B737-700	2	24,000	Jet-A	Single-point (multiple locations)	0.4
	CFM56-3B1(Turbofan)	CFM International	B737-300	2	22,000	Jet-A	Single-point (multiple locations)	0.3
APEX3	CJ610-8A[b] (Turbojet)	General Electric	Learjet	2	2,950	Jet-A	Single-point (multiple locations),	1.0
	PW4158 (Turbofan)	Pratt & Whitney	A300-622R	2	59,000	Jet-A	Single-point (multiple locations)	0.2
	RB211-535E4-B (Turbofan)	Rolls Royce	B757-324	2	43,100	Jet-A	Single-point (multiple locations)	0.8
	AE3007-A1E (Turbofan)	Rolls Royce USA/Allison	ERJ145-XL	2	8,110	Jet-A	Single-point (multiple locations)	0.4
	AE3007-A1P (Turbofan)	Rolls Royce USA/Allison	ERJ145-ER	2	7,580	Jet-A	Single-point (multiple locations)	0.7
	CFM56-3B1 (Turbofan)	CFM International[c]	B737-300	2	20,000	Jet-A	Single-point (multiple locations)	1.7
Total								5.5 [a]

[a] The CFM56-2C1 is assumed only once in the total.
[b] Derived from the military J85 turbojet engine (data for the J85 are included in the Gerstle dataset).

2.4.3 APEX3 (2005)

APEX3 testing was conducted in October and November of 2005 in Cleveland, Ohio.

The objectives of the testing were to develop emission factors for PM_{10}, to develop chemical source profiles for a broader range of typical in-use aircraft engines, to determine the effect of fuel properties and engine operating conditions on PM_{10} emissions, and to evaluate the relationship between smoke numbers (SN) and mass emission rates. Engines measured in APEX3 spanned a range from a small business jet, through a modern regional turbofan, single-aisle transport turbofan, to a large high bypass ratio turbo fan, representing five different engine types, some measuring more than one example.

Exhaust plumes were sampled at 15, 30, or 43 meters behind the engines using time-integrated samples (i.e., filters, polyurethane foam plugs, vacuum canisters, and 2,4 dinitrophenylhydrazine media) and continuous instruments as in APEX1 and JETS/APEX2.

Jet-A was used in the APEX3 testing and the effect of fuel composition was not varied explicitly, although plane-to-plane fuel variations were monitored. A report summarizing the APEX3 testing/results will be prepared upon completion of the chemical analyses. As for APEX1 and APEX2, data generated by EPA will be included in a report that is currently in preparation. However, EPA authorized the data to be released prepublication for the purpose of this FAA/EPA effort.

2.5 Summary

For ease in assimilating the information, **Table 4** summarizes the types of commercial aircraft engines (and assumed civilian variants for the military aircraft engines) that were tested during the six measurement campaigns (Spicer, Gerstle, EXCAVATE, APEX1, APEX2, and APEX3). As shown, approximately 15 percent of the current U.S. aircraft fleet operates with the tested turbofan engines, approximately two percent of the fleet operates with the tested turbojet engines, and approximately one percent of the fleet operates with the tested turboshaft engines (the tested turboprop engine is not in current use).

3.0 Quality of Secondary Data

EPA is preparing a QAPP for a project that will update the SPECIATE database (SPECIATE 4.0-Quality Management Plan (QMP)/Quality Assurance Project Plan (QAPP)). The SPECIATE QAPP describes the criteria that will be used to rate the EPA's updated speciation profiles. The commercial aircraft engine speciation profile developed through this effort will also update the SPECIATE database. As such, the rating criteria will be the same as the rating criteria defined in the final SPECIATE QAPP.

Table 4
Dataset Summary

Type of Engine	Civilian Engine Family	Tested Engine Model	Civilian Variant (if applicable)	Max Thrust (lbs)	Dataset	Fuel Used in Testing	Test Method	% Current U.S. Commercial Aircraft Fleet
Turbofan	AE3007	AE3007-A1E	--	8,110	APEX3	Jet-A	Single point (multiple locations)	0.4
		AE3007-A1P	--	7,580	APEX3	Jet-A	Single point (multiple locations)	0.7
	TF-39	TF-39-1C	CF6-6	41,000	Spicer	JP-4, JP-5, shale derived fuel meeting JP-8 specifications	Outdoors, sampling rake, gas analyzer	0.3
	CFM-56	CFM-56-3	--	20,000	Spicer	JP-4, JP-5, shale derived fuel meeting JP-8 specifications	Outdoors, sampling rake, gas analyzer	3.2
		F108-CF-100 (CFM-56-2A-2)	--	21,634	Gerstle	JP-8	Test cell	
		CFM56-2C1	--	22,000	APEX1	JP8, JP-8 with additives, and Jet-A	Single-point (multiple locations)	
		CFM56-2C1	--	22,000	APEX2	Jet-A	Single-point (multiple locations)	
		CFM56-7B24	--	24,000	APEX2	Jet-A	Single-point (multiple locations)	
		CFM56-3-B1	--	20,000	APEX3	Jet-A	Single-point (multiple locations)	
	Rolls Royce Spey	TF-41-A2	Rolls Royce Spey	14,500	Spicer	JP-4	Indoor, test cell	1.7
	JT3D	TF33-P3	JT3D	17,000	Spicer	JP-4	Indoor, test cell	0.3
		TF33-P7	JT3D	20,250	Spicer	JP-4	Indoor, test cell	
		TF33-P102	JT3D-7	18,010	Gerstle	JP-8	Test cell. 3-1 hr tests	
		TF33-P-7/7A	JT3D-7	20,250	Gerstle	JP-8	Test cell. 3-1 hr tests	
	CJ805	J79	CJ805	10,000[a]	Spicer	JP-4	Indoor, test cell	0.0
	PW2000	F117-PW-100	PW2037	40,440	Gerstle	JP-8	Test cell. 3–1 hr tests	1.3
	CF34	T34-GE-100A	CF34	9,065	Gerstle	JP-8	Test cell. 3–1 hr tests	6.1
	CF6	TF39-GE-1C	CF6	43,000	Gerstle	JP-8	Test cell. 3–1 hr tests	0.3

Table 4
Dataset Summary (Continued)

Type of Engine	Civilian Engine Family	Tested Engine Model	Civilian Variant (if applicable)	Max Thrust (lbs)	Dataset	Fuel Used in Testing	Test Method	% Current U.S. Aircraft Fleet
Turbofan (continued)	RB211	RB211-535-E4	--	40,100	EXCAVATE	JP-5 (varying sulfur content)	Sampling probes	0.8
		RB211-535-E4	--	43,100	APEX3	Jet-A	Single point (multiple locations)	
	PW4000	PW4158	--	59,000	APEX3	Jet-A	Single point (multiple locations)	0.2
Turbojet	Marbore II	J69-T-25	Marbore II – Model 352	1,025	Gerstle	JP-8	Test Cell. 3-1 hr tests	0.0
	CJ610	J85-GE-5A	CJ610	2,050	Gerstle	JP-8	Test Cell. 3-1hr tests	1.8
		CJ610-8A	--	2,950	APEX3	Jet-A	Single point (multiple locations)	
Turboprop	T501	T56-A-7	T501-D	4,200	Gerstle	JP-8	Test Cell. 3-1 hr tests	0.0
Turboshaft	CT7	T700-GE-700	CT7-2	NA	Gerstle	JP-8	Test Cell. 3-1 hr test	0.8
Total								17.9[b]

[a] J79 thrust without afterburner.
[b] A conservatively high estimate because percentages assume engine families, not specific engine models.

4.0 Data Reduction and Data Validation

A comparison of the test results used to evaluate the speciation of HAPs from commercial engines in the more recent work reinforces the earlier speciation results obtained by Spicer for the CFM56-3 engine. Therefore, with revisions due to a few adjustments for contributions of currently included compounds and additions of a large number of small concentration species, it is recommended that the current data in the SPECIATE database be used as a base from which the HAP emission inventories for commercial aircraft engines are prepared. The few compounds requiring adjustment are phenol and butyraldehyde(butanal)/crotonaldehyde. Additionally, methanol and a large number of species present at low concentration (each less or much less than a percent total mass fraction) were quantified during recent measurements and were not measured in the Spicer campaign. These compounds will be added to SPECIATE database to be included as part of the commercial aircraft engine profile. The revised species profile decreases the unidentified species mass fraction from around 34 percent (original Spicer estimate) to 23 percent (current) of the total organic mass.

A spreadsheet has been developed that will provide the base data and calculations that will be used to develop the revised SPECIATE profile. This spreadsheet will be provided to the agencies/individuals participating in the development of this QAPP. As stated in Section 5.0 (Documentation and Records) of this QAPP, the FAA will be the owner of the spreadsheet and will provide a webpage on which the final version and supporting documentation will be posted.

5.0 Documentation and Records

The FAA will draft, circulate, and file all agendas and minutes of meetings/conference calls. The FAA will also maintain a file of all reference material used to produce this QAPP and presented/discussed in meetings/conference calls.

Aerodyne, with assistance from KBE will develop an electronic (spreadsheet) format dataset that will include the test data that will be evaluated for this project. FAA will be the owner of the dataset and the Final Report. The electronic dataset will include note sheets that will document the calculations and/or graphs that are used to produce the commercial HAPs speciation profile(s)

The FAA will provide a webpage on which the final version of the spreadsheet (if developed) and supporting documentation (at a minimum, the Final Report), will be posted.

6.0 Reports/Deliverables

If it is determined that the commercial aircraft engine HAPs speciation profile should be updated, the deliverable products for this project will include a Final Report based on the activities conducted for the project. The Final Report will include, but not be limited to, documentation of the calculations and equations that were used to develop the revised speciation profile, a plan to integrate future data in to the profile, and the revised THC-VOC-TOG conversion factors (including the methodology and calculations used to develop the conversion factors).

.

References

Aerodyne Research Inc. (Miake-Lye, R.) Advancing the Understanding of Aviation's Global Impacts. November 2005.

ANSI/ASQ. Quality Systems for Environmental Data and Technology Programs. 2004.

BACK database. April 2005.

EPA, QAPP Requirements for Secondary Data Research Projects. July 1, 1999: http://www.epa.gov/quality/qs-docs/found-data-qapp-rqts.pdf.

EPA, Documentation for the 1996 Base Year National Toxics Inventory for Aircraft Sources. June 2, 2000.

EPA (Helmer, K.). FAA-OTAQ Quality System Overview. PowerPoint presentation: June 11, 2007 telecon.

EPA (Kinsey, J.) Preliminary Data from the Aircraft Particle Emissions Experiments 2 and 3 (APEX-2 and APEX-3). Powerpoint presentation: June 11 2007 telecon.

FAA, Air Quality Procedures For Civilian Airports & Air Force Bases, April 1997.

FAA, Select Resource Materials and Annotated Bibliography on the Topic of Hazardous Air Pollutants (HAPs) Associated with Aircraft, Airports, and Aviation. July 1, 2003.

FAA (Iovinelli, R. and Gupta, M.) A National Framework for Estimation of Aircraft HAPs Emission Inventory to be Used in NEPA Studies. PowerPoint presentation to: EPA OTAQ Office – Ann Arbor, Michigan. March 29, 2007.

NASA (Chowen C. Wey, ed.) Aviation Particle Emissions Workshop. NASA/CP--2004-213398, 2004.

NASA. Experiment to Characterize Aircraft Volatile Aerosol and Trace-Species Emissions (EXCAVATE). August 2005. NASA.

Shumway, L.A. Trace Element and Polycyclic Aromatic Hydrocarbon Analysis of Jet Engine Fuels: Jet A, JP-5, JP-8. December, 2000.

Spicer, et al. Chemical Composition and Photochemical Reactivity of Exhaust from Aircraft Turbine Engines. Annales Geophysicae 12, 944-955. 1994.

USAF (Spicer, C.W. et al.) Composition and Photochemical Reactivity of Turbine Engine Exhaust (Report No. ESL-TR-84-28). September, 1984.

USAF (Spicer, C.W. et al.). Aircraft Emissions Characterization: TF33-P3, TF33-P7, and J79 (Smokeless) Engines (Report No. AD-A-197864/2/XAB). August, 1987.

USAF (Spicer, C.W. et al.). Aircraft Emissions Characterization, TF41-A2, TF30-P103, and TF30-P109 engines (Report No. ESL-TR-87-27). . December 1987.

USAF (Spicer, C.W. et al.). Aircraft Emissions Characterization (Report No. ESL-TR-87-63. 1988.

USAF (Spicer, C.W. et al.) Aircraft Emissions Characterization of F101 and F110 Engines (Report No. ESL-TR-89-13). March 1990.

USAF (Gerstle, T., et al.) Aircraft Engine and Auxiliary Power Unit Emissions Testing: Vol. 1, Executive Summary (Report No. IERA-RS-BR-TR-1999-006-Vol 1). March 1999.

USAF (Gerstle, T., et al.) Aircraft Engine and Auxiliary Power Unit Emissions Testing: Vol. 2, Detailed Sampling Approach and Results (Report No. IERA-RS-BR-TR-1999-006-Vol 2). March 1999.

USAF (Gerstle, T., et al.) Aircraft Engine and Auxiliary Power Unit Emissions Testing: Vol. 3, Particulate Matter Results (Report No. IERA-RS-BR-TR-1999-006-Vol 3). March 1999.

USAF (Gerstle, T., et al.) Aircraft Engine and Auxiliary Power Unit Emissions Testing: Final Report Addendum F119-PW-100 Engine Emissions Testing Report (Report No. A669404). June 2002.