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(R) Procedure for Sampling and Measurement of Engine and APU Generated Contaminants in Bleed Air Supplies from Aircraft Engines

RATIONALE

This document is the required 5 year review and revision document. Since the original draft was introduced in 1995 significant changes have transpired in the formation of aircraft cabin air quality specifications and standards. This document reflects the most current standard recommendations for aircraft cabin air quality which have been drafted by ASD-STAN for use within the European States, but also incorporates information from NIOSH recommendation. Acceptable engine generated contaminant limits are inherently lower than allowable cabin contaminant levels, to ensure that contaminant levels are maintained below maximum allowable levels during aircraft operation.

TABLE OF CONTENTS

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1. SCOPE

Aircraft propulsion engine and APU manufacturers shall demonstrate that air provided to the aircraft cabin is of acceptable quality. This ARP provides the basic information required to perform an engine bleed air quality certification test. This document provides the recommended levels and describes the measurement procedures required for the quantification of gaseous and particulate contaminants, which may be present in aircraft engine bleed air.

1.1 Purpose

Recommended techniques for engine sampling and sample transfer are given, together with specific analytical methodology, for each of the contaminants listed in Section 3. Recommendations are also made for an engine test format and for the allowance of ambient air quality on the measured engine contaminant concentration levels. The list and recommended limits of contaminants in Table 1 are considered appropriate for the certification and passenger safety requirements of both civil and military aircraft. If testing is performed on the aircraft, the operator should be aware that other sources of contamination may be present.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AIR1539 Environmental Control System Contamination

ARP1796 Engine Bleed Air Systems for Aircraft

2.1.2 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

See Section 2.1.3

2.1.3 U.S. Code of Federal Regulations

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-0000, www.gpoaccess.gov.

Title 14, CFR Part 23 Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes

Title 14, CFR Part 25 Airworthiness Standards: Transport Category Airplanes

2.1.4 European Aircraft Cabin Air Quality Standards

Available from ASD-STAN, Gulledelle 94-b.5, B-1200, Brussels, Belgium, http://www.aecmastan.org/standards/EngineStandard.asp.

PrEN 4618 Aerospace Series - Aircraft Internal Air Quality Standards, Criteria, and Determination Methods

2.1.5 European Regulations

Available from European Aviation Safety Agency, Postfach 10 12 53, D-50452 Koeln, Germany, Tel: +49-221-8999-000, www.easa.eu.int.

CS-23 Normal, Utility, Aerobatic & Commuter Aeroplanes

CS-25 Large Aeroplanes Certification Standard

CS APU-320 Bleed Air Contamination

CS E-690 Contamination Tests of Bleed Air for Cabin Pressurization or Ventilation

2.1.6 U.S. Department of Defense Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

USAF AFOSH STD 48-8 Controlling Exposures to Hazardous Materials. Replaces AFOSH Standard 161-8.

2.1.7 Occupational Safety and Health Administration Publications

Available from U.S. Department of Labor/OSHA, OSHA Publications, P.O. Box 37535, Washington, DC 20013-7535, Tel: 202-693-1888, www.osha.gov/pls/publications/pubindex.list.

Title 29 CFR 1910 Subpart Z Toxic and Hazardous Substances

2.1.8 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D 5466 Standard Test Method for Determination of Volatile Organic Compounds in Air by Pumped Sorbent Tube and Thermal Desorption

2.1.9 ASHRAE Publications

Available from ASHRAE, 1791 Tullie Circle, N E, Atlanta, GA 30329, Tel: 404-636-8400, www.ashrae.org.

ASHRAE 959RP Determine Aircraft Supply Air Contaminants in the Engine Bleed Air Supply System on Commercial Aircraft, 1999/2000. ASHRAE Insights 2/07/01.

2001 ASHRAE Handbook, Fundamentals, Chapter 12 and Chapter 37, ISBN 1-883413-87-7

2.1.10 NIOSH Publications

Available from U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402 and the National Technical Information Services, Springfield VA 22161, http://www.cdc.gov/niosh/.

NIOSH Manual of Analytical Methods (NMAM), Fourth Edition, Particulates Not Otherwise Regulated, Respirable: Method 0600, Issue 3 dated January 15, 1998

NIOSH Manual of Analytical Methods (NMAM), Fourth Edition Barton, Paul, NIOSH/DPSE, "Chapter G, Aerosol Photometers for Respirable Dust Measurements, pp 63-69

NIOSH Manual of Analytical Methods (NMAM), Fourth Edition Barton, Paul, NIOSH/DPSE "Chapter O, Factors Affecting Aerosol Sampling," pp 184-207

2.1.11 USEPA Publications

USEPA Ambient Monitoring Technology Information Center, contains procedures including EPA TO-11A, TO-13A, TO-15A, http://www.epa.gov/ttn/amtic.

2.2 Definitions

AEROSOLS: A suspension in a gaseous medium of solid particles, liquid particles or solid and liquid particles having a negligible falling velocity (ISO 1995).

BLEED AIR: Air from outside the plane entering the cabin after having been processed through an engine compressor, turbo compressor and/or air conditioning units.

ENGINE GENERATED CONTAMINANTS: Those substances produced directly by the engine, including those formed by thermal degradation within the engine. The compounds listed in Section 4 are representative marker compounds from the various subsets of potential engine-generated contaminants. It is assumed that if levels of marker compounds are within specifications, then levels of all other potential engine-generated contaminants will also be within acceptable levels.

EXPOSURE: Exposure to a chemical is the contact of that chemical with the outer boundary of the human body. The outer boundary of the human body is the skin and the openings into the body such as the mouth, the nostrils and punctures and lesions in the skin (WHO, 1999).

FLAME-IONIZATION DETECTOR (FID): A hydrogen-air diffusion-flame detector, that produces a signal nominally proportional to the mass-flow rate of hydrocarbons entering the flame, and responsive to the number of carbon atoms entering the flame.

PARTS PER MILLION BY VOLUME (ppmV): 10^6 v/V where v = volume of test gas in mixture in liters, and V is volume of the mixture in liters.

SYNTHETIC OIL (LUBRICANT): A mixture of esters of fatty acids with the general empirical formula of $C_xH_yO_z$ and a molecular mass of approximately 600 kg/kmol (or g/gmol).

TIME-WEIGHTED AVERAGE (TWA): As defined by NIOSH or ACGIH: A measured mean concentration of a single toxicant over a given period of time.

THRESHOLD-LIMIT VALUE (TLV): As defined by NIOSH or ACGIH: An acceptable concentration of a single contaminant, where the level is not to be exceeded in an 8 h period.

VOLATILE ORGANIC COMPOUND (VOC) - Two definitions are available:

Based on chemical composition (France) where C + H are present (and where O can replace H, though CH_4, CO and CO_2 are excluded).

Based on vapor pressure > 10 Pa or > 13 Pa (U.S. EPA). The U.S. EPA has published a list of 318 different VOCs.

SEMI VOLATILE ORGANIC COMPOUNDS (SVOCs): Defined as having a lower vapor pressure than VOCs and non-volatile organic compounds, and are characterized by an extremely low vapor pressure of a fraction of a Pa.

2.3 Acronyms and Unit Symbols

AC - Advisory Circular (FAA/EASA)

AFOSH - Air Force Occupational Safety and Health

AIR - Aerospace Information Report (SAE)

APU - Auxiliary Power Unit

ARP - Aerospace Recommended Practice (SAE)

AS - Aerospace Standard (SAE)

ASD-STAN - Aerospace and Defense Industries Association of Europe Standards Organization

ASHRAE - American Society for Heating, Refrigerating and Air-Conditioning Engineers

ASTM - American Society for Testing and Materials

CAS - Chemical Abstract Services

CFR - Code of Federal Regulations

CO - Carbon Monoxide

CO_2 - Carbon Dioxide

CS - Certification Standard

CPC - Condensation Particle Counter

DNPH - acidified 2, 4-dinitrophenylhydrazine

DODSSP - Department of Defense Single Stock Point

EASA - European Aviation Safety Agency

EPA - Environmental Protection Agency

FAA - Federal Aviation Administration (USA)

FAR- Federal Airworthiness Regulations

FR - Federal Register

GC/MS - Gas Chromatography/Mass Spectrometry

HP - High Pressure

hPA - Hecto Pascal

HPLC - High Performance Liquid Chromatography

ISO - International Standard Organization

LP - Low Pressure

LPC - Laser Particle Counter

m - Meter

MEK - Methyl Ethyl Ketone

mg - Milligram

mm Hg - Millimeters of Mercury (Pressure)

NASA - National Aeronautics and Space Administration

NDIR - Non Dispersive Infra Red Spectroscopy

NIOSH - National Institute for Occupational Safety and Health

OSHA - Occupational Safety and Health Administration

Pa - Pascal

ppm - Parts per Million

PTFE - Polytetrafluoroethylene

SAE - Society of Automotive Engineers

SMPS - Scanning Mobility Particle Sizer

STEL - Short Term Exposure Limit

TLV - Threshold Limit Value

TWA - Time Weighted Average

µm - Micron/Micrometer

USAF - United States Air Force

VOC - Volatile Organic Compound

3. RECOMMENDED SPECIFICATION LIMITS OF CONTAMINANTS

3.1 Bleed Air Quality Requirements

Table 1 lists marker compounds for sampling and analysis to demonstrate acceptability of engine generated bleed air, as found in AIR4766. The marker compounds listed in the table include marker compounds for potential contaminants identified in prEN4618.

The compounds in Table 1 and their maximum allowable concentrations are at or below the maximum allowable levels allowed in the following aircraft certification requirements:

- FAA 14CFR Part 25.831.
- CS 25.831
- CFR Title 29, Chapter XVII, Section 1910.1000

TABLE 1 - MARKER COMPOUNDS TO BE SAMPLED AND ANALYZED FOR THE BLEED AIR QUALITY TEST

--CAS No.	Compound and Relationship to Reference Limits	mg/M^3	(ppmV)	14CFR 25.831/ CS 25	Test Technique
75-07-0	Acetaldehyde (prEN4618 limit)	18	10		DNPH-HPLC
107-02-8	Acrolein (prEN4618 limit)	0.5	0.2		DNPH-HPLC
71-43-2	Benzene (prEN4618 limit)	3.2	1.0		GC/MS
124-38-9	Carbon Dioxide (prEN4618 limit)	3650	2000	5000 ppm	NDIR
630-08-0	Carbon monoxide (prEN4618 limit)	17.8	12	50 ppm	NDIR
50-00-0	Formaldehyde (prEN4618 limit)	1.0	0.8		DNPH-HPLC
78-93-3	Methyl Ethyl Ketone (2-Butanone) (prEN4618 limit)	598.5	200		GC/MS
	Particulates not otherwise regulated, Respirable (NIOSH limit)	5.0			Photometer, SMPS, or CPC
108-88-3	Toluene (prEN4618 limit)	153	40		GC/MS

NOTE: prEN4618 and NIOSH limits above are maximum recommended allowable engine-generated concentrations above ambient levels at time of test. User should consult latest version of referenced standard for current limits.

NOTE: FAA Limits are applicable to limits within the aircraft cabin. Engine limits are the delta between measurements of the engine bleed outlet minus the bleed air supply inlet.

4. METHODOLOGY

4.1 Test Format

4.1.1 Engine Test Program

In order to verify that the engine will perform satisfactorily in service, the test shall simulate as closely as possible the service conditions. It is important to measure the bleed air quality at as many stabilized conditions as possible over the engine power range. Due to high engine running costs, it may not be possible to check all conditions, but at least the following stabilized settings shall be tested for all specification requirements:

Propulsion Engines:

a. An idle setting with the high pressure (HP) bleed selected.

b. A condition just before HP to low pressure (LP) bleed switch occurs.

c. A condition just after HP to LP bleed switch occurs.

d. A high-power condition, for example altitude cruise, with LP bleed selected.

Auxiliary Power Units:

Maximum ECS Flow Setting

4.1.2 Engine-Inlet Measurements

A separate sampling for all the contaminants shall be made sequentially or simultaneously on the engine inlet air during the test sequence, to provide information on the ambient contamination levels. In all cases account should be taken of these measured data in the calculation of the engine-generated values. Because of variations in ambient conditions it is essential that measurements and samples be taken as close together as possible during the test.

4.1.3 Data Acquisition

Real-time analyzer data will be recorded by either entry into a data sheet or from a digital data-acquisition system. Engine parameters will be recorded for each operating condition where the inlet and bleed air quality is sampled.

Sampling for trace contaminants will be performed using adsorbent media and evacuated canisters or an equivalent method. These samples will then be extracted and analyzed in a controlled laboratory environment. A variety of analytical methods may be used to evaluate the bleed air quality. These methods are briefly described below:

a. DNPH cartridges - DNPH adsorbent tubes. DNPH is a coating applied to silica gel, which provides a medium to capture aldehydes and convert them to optically active derivatives. EPA Method TO-11A delineates HPLC to perform the analysis of these tubes. Adsorbent cartridges shall contain an ozone-removal bed ahead of the DNPH bed. Cartridges shall be stored in a freezer before use. Cartridges shall be transported for analysis using temperature control such as an ice chest with cooling media. Flow rates through DNPH cartridges can be as high as 2 L/min. An acceptable flow rate for the media being used shall be determined to ensure that the flow rate is controlled by the sampling system, and not by the flow resistance of the sampling media.

b. Summa® canisters or adsorbent media - Evacuated pre-cleaned stainless steel canisters are used for collecting gaseous samples. EPA Method TO-15A plus tentatively identified compounds. This test method determines levels of EPA target compounds using GC/MS.