

AEROSPACE INFORMATION REPORT

AIR4766™

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Air Quality for Commercial Aircraft Cabins

RATIONALE

A great deal of research has been conducted in the past 10 years, and a great deal of study to correlate research findings to improve design and operation of Commercial Aircraft. This Aerospace Information Report is one of the most comprehensive documents available and was created with the input of some of the most respected authorities in the field of Aircraft Cabin Air Quality. This document provides general information on cabin air quality and the other factors affecting the perception of cabin air quality. It also provides extensive references so that the user may further research areas of specific interest. Some figures and tables within this document have come from other sources which have published or soon will publish information related to this topic. Use of these outside sources provides the user of the AIR with a ready reference to what other organizations are doing in this field.

AIR4766 has been reaffirmed to comply with the SAE Five-Year Review policy.

FOREWORD

This document is an overhead document of related Aerospace Information Reports (AIR) related to the various engineering aspects in designing environmental control systems to provide acceptable air quality to commercial aircraft cabins. The total airflow supplied to the cabin is a mixture of outside air and cabin filtered air, or possibly just outside air, and is intended to provide a safe, healthy, and comfortable cabin environment. The cabin air quality may be affected by contaminants from sources internal or external to the airplane systems. Other factors that can affect the perception of the cabin air quality include cabin altitude, thermal environment and relative humidity.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides information on air quality and some of the factors affecting the perception of cabin air quality in commercial aircraft cabin air. Also a typical safety analysis process utilizing a Functional Hazard Assessment approach is discussed.

1.1 Purpose

The purpose of this AIR is to discuss air quality issues and environmental factors in commercial airplanes. This AIR provides general information and references more detailed SAE references regarding on Environmental Control System (ECS), air quality contaminants, cabin pressurization, temperature, and humidity that affect the perception of the cabin environment. A system safety assessment utilizing a Functional Hazard Assessment approach is also included.

The airplane cabin is a unique environment that is low in humidity and pressurized to a cabin altitude of up to 2400 m (8000 ft). Multiple factors affecting our perception of environmental comfort include being subject to continuous noise and vibration, accelerations in multiple directions, and potential exposure to contaminants. The design of the cabin environment system along with the airline maintenance/operations is intended to provide a safe, healthy, and comfortable cabin environment.

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.

ARP85	Air Conditioning Systems for Subsonic Airplanes
ARP89	Aircraft Compartment Automatic Temperature Control Systems
ARP147	Environmental Control Systems Terminology
ARP731	General Requirements for Application of Vapor Cycle Refrigeration Systems for Aircraft
AIR806	Air Conditioning of Aircraft Cargo
AIR860	Aircraft Electrical Heating Systems
AIR910	Ozone in High Altitude Aircraft
ARP926	Fault/Failure Analysis Procedure
AIR1168/7	Aerospace Pressurization System Design
AIR1204	Control of Water Carryover from the Environmental Control System and Condensation on the Structure

ARP1270	Aircraft Cabin Pressurization Control Criteria
AIR1539	Environmental Control System Contamination
AIR1609	Aircraft Humidification
ARP4418	Procedure for Sampling and Measurement of Engine Generated Contaminants in Bleed Air Supplies from Aircraft Engines Under Normal Operating Conditions
ARP4754	Certification Considerations for Highly-Integrated or Complex Aircraft Systems
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
AIR4766/1	Air Quality for Commercial Aircraft Cabin Particulate Contaminants
AIR4766/2	Airborne Chemicals in Aircraft Cabins
AIR5784	A Review of Literature on the Relationship Between Gas Turbine Engine Lubricants and Aircraft Cabin Air Quality

Commercial transports are designed to comply with the Federal Aviation regulations. In addition, the aircraft industry uses a number of other standards to ensure that cabin air quality is acceptable to the public at large as well as cabin and cockpit crew.

2.1.2 FAA Publications

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

Code of Federal Regulations Title 14 part 25, Airworthiness Standards: Transport Category Airplanes

AC20-32B, Carbon Monoxide (CO) Contamination in Aircraft-Detection and Prevention

AC 20-42C, Hand Fire Extinguishers for Use in Aircraft

AC 25-7A, Flight Test Guide for Certification of Transport Category Airplanes

AC 25-9A, Smoke Detection Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures

AC 25-20, Pressurization, Ventilation, and Oxygen Systems Assessment for Subsonic Flight Including High Altitude Operation

AC25-22, Certification of Transport Airplane Mechanical Systems

AC 25-1309, System Design and Analysis

AC-29-2C, Certification of Transport Category Rotorcraft

AC 33-2B, Aircraft Engine Type Certificate Handbook

AC 120-38, Transport Category Airplanes Cabin Ozone Concentrations

2.1.3 U.S. Government Publications

EPA documents are available from the U.S. Environmental Protection Agency, www.epa.gov/nscep/. NASA publications are available from NASA, Documentation, Marshall Space Flight Center, AL 35812, www.nas.nasa.gov. The GAO and OSHA publications can be obtained from the U.S. Government Printing Office, 732 Capitol Street, Washington, DC 20401, www.gpoaccess.gov. Military publications are available through www.e-publishing.af.mil.

AFOSH Standard 48-8 Controlling Exposures to Hazardous Materials is available from on the internet at www.e-publishing.af.mil/shared/media/epubs/AFOSHSTD48-8.pdf

AFP 161-26 (TB MED 265), "Threshold Limit Values of Airborne Contaminants" Departments of the Air Force and Army

Environmental Protection Agency (EPA) National Ambient Air Quality Standards

EPA. 1992. Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990. U.S. Environmental Protection Agency. Office of Research and Development. Washington, DC EPA/600/R-92/047.

GAO Report 04-54, 2004. "Aviation Safety, More Research Needed on the Effects of Air Quality on Airliner Cabin Occupants.

NASA, 1989, Spacecraft Maximum Allowable Concentrations (SMACs).

National Technical Reports Server (NTRS), 1973, "Bioastronautics data book, second edition," Report Number: AD-749887, NASA-SP-3006. Available on the internet at no charge from NTRS.

Occupational Safety and Health Administration (OSHA) Code of Federal Regulations, Title 29, Subpart Z-Toxic and Hazardous Substances.

2.1.4 EASA Publications

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

CS-25, Certification Specifications for Large Aeroplanes

2.2 Other Applicable References

Air Quality in Passenger Aircraft: Providing a Safe and Comfortable Cabin Environment. 2003. International Aviation Conference. Perera, e. Ed. Building Research Establishment (BRE), London

Air Quality Guidelines for Europe, 2nd Edition. 2000. World Health Organization Regional Office for Europe, Copenhagen.

Aircraft Accident Report 1/2004. Report on the incident to BAe 146, G-JEAK during the descent into Birmingham Airport on 5 November 2000. UK Department for Transport air Accidents Investigations Branch. Available on line from AAIB at <http://www.aaib.gov.uk>.

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ASHRAE STD 62-1989, "Ventilation for Acceptable Air Quality", Published by the American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. Atlanta, GA.

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Leaderer, B. P. and Cain, W. S. 1983. Air Quality in Buildings During Smoking and Non-smoking Occupancy. ASHRAE Transactions 89(2B):601-613.

Michaelis, S. Ed., 2007. Aviation Contaminated Air Reference Manual. ISBN 978-0-9555672-0-9. Publisher: Susan Michaelis, DFT Enterprises Ltd. Southwater Business Resource Center, Beeson House, 26 Lintot Square, Southwater, Horsham, West Sussex, England. RH739LA.

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Sulzman, F. M. and Genin, A. M. 1994. Space Biology and Medicine Vol. II: Life Support and Habitability. Joint U.S./Russian Publication AIAA, Washington, D.C., Nauka Press, Moscow.

Threshold Limit Values for Chemical Substances In Workroom Air Adopted by the American Conference of Governmental Industrial Hygienists.

Parliament of the Commonwealth of Australia: Air Safety and Cabin Air Quality in the BAe146 Aircraft. Report by the Senate Rural and Regional Affairs and Transport References Committee. October 2000. ISBN 0-642-71093-7. www.aph.gov.au/senate.

Pedely, J. F. 1995. Ventilation and Indoor Air Quality: Factors That Affect the Results. Presented at the 1995 ASHRAE Winter Meeting, January 28 - February 1, 1995. Chicago, IL.

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Wheeler, A. E. 1993. Better Filtration: A Prescription for Healthier Building. Indoor Air Quality '93. ASHRAE. Atlanta, GA.

2.3 Definitions and Acronyms

ARP147 provides an extensive list of environmental control systems terminology and acronyms. This document is intended to help standardize the meaning of words used in aircraft environmental control system design and analysis.

AAQS: Ambient Air Quality Standards

AC: Advisory Circular

ACGIH: American Conference of Governmental and Industrial Hygienists

ACM: Air Cycle Machine

AFM: Airplane Flight Manual

AIHA: American Industrial Hygiene Association

AIR: Aerospace Information Report

ALTERs: Acceptable short-term exposure ranges

AMJ: Joint Airworthiness Authorities Advisory Material Joint

ARP: Aerospace Recommended Practice

ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers

ASTM: American Society of Testing and Materials

ATSDR: Agency for Toxic Substances and Disease Registry

C: Carcinogen, exposure should be kept to a minimum.

CAA: United Kingdom Civil Aviation Authority, superseded by European Aviation Safety Agency, also, New Zealand Civil Aviation Authority

CO: Carbon Monoxide

CO₂: Carbon Dioxide

CS: European Air Safety Regulations

D: Day

DAPS: Document Automation and Production Services

DNPH: Dinitrophenyl hydrazine

EASA: European Aviation Safety Agency

ECS: Environmental Control System

EPA: Environmental Protection Agency

ETS: Environmental Tobacco Smoke

FAA: United States Federal Aviation Administration

FARs: Federal Aviation Regulations

FHA: Functional Hazard Assessment

GAO: United States General Accounting Office

GC/MS: Gas Chromatography/mass spectroscopy

h: hour

HEPA: High Efficiency Particulate Air Filter

HSDB: hazardous substances data bank

HPLC: High performance Liquid Chromatography

IRIS: Integrated Risk Information System

JAA Joint Airworthiness Authorities, superceded by EASA

LOAELL: lowest observed adverse effect level

MRLs: Minimal Risk Levels

NA: Not applicable

NAAQS: National Ambient Air Quality Standards

NAS: National Academies of Science

NASA: National Aeronautics and Space Administration

NIOSH: United States National Institute of Safety and Health

NOAEL: no observed adverse effect level

NRC: National Research Council

NTRS; National Technical Reports Server

OSHA: Occupational Health and Safety Administration

PELs: Permissible Exposure Limits

PM2.5: Particles less than 2.5 microns in diameter

PM10: Particles less than 10 microns in diameter

PrEN: European Prenormative Standard

Ppb: parts per billion

PPM: parts per million

RfC: Reference Concentration

SMACs: Spacecraft Maximum Allowable Concentrations

SVOCs: Semivolatile organic compounds

TOCP: Tri-ortho-cresyl-phosphate

TLVs: Threshold Limit Values

VCM: Vapor Cycle Machine

VOCs: Volatile organic compounds

WHO: World Health Organization

WK: Week

3. ENVIRONMENTAL CONTROL SYSTEM REQUIREMENTS/ADVISORY CIRCULARS/GUIDELINES

The aircraft must comply with the regulations that are applicable as issued by aviation authorities in order to be certified. The wording of the different nation aviation authorities regulations may not be consistent and so different methods of compliance may be necessary. Other non-aviation regulations, standards or guidelines covering cabin environment, may or may not apply depending on the nations, or whether they apply to indoor versus outdoor environment. In general, occupational exposure limits are different from the general public health standards. There is also the aspect of odor thresholds that are of a subjective nature and up to several orders of magnitude lower than occupational exposure limits. In addition the airplane cabin environment represents a very unique environment that is not similar to the building environment. The non-aviation standards/regulations/guidelines that have been developed can be used as guidance material. ARP4754 entitled "Certification Considerations for Highly-Integrated or Complex Aircraft Systems" provides additional information that the user may wish to refer to for further background on ECS certification considerations.