



AEROSPACE INFORMATION REPORT

AIR1539™**REV. C**

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Superseding AIR1539B

(R) Environmental Control System Contamination

RATIONALE

AIR1539C references have been updated and design considerations provided for relevant atmospheric and ground air supply contaminants. Gaseous atmospheric contaminants that affect ECS and fuel tank inerting systems are also discussed.

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1. SCOPE

This SAE Aerospace Information Report (AIR) includes a discussion of liquid and particulate contaminants which enter the aircraft through the environmental control system (ECS). Gaseous contaminants such as ozone, fuel vapors, sulphates, etc. are also covered in this AIR. This publication is concerned with contamination sources which interface with ECS and fuel tank inerting systems, and the effects of this contamination on equipment. Methods of control will be limited to the equipment and interfacing ducting which normally falls within the responsibility of the ECS designer.

1.1 Purpose

The purpose of this AIR is to categorize sources of ECS contaminants, define the effects of these contaminants on equipment, and outline design features that can be used to control contamination in aircraft systems.

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 +1 724-776-4970 (outside USA), www.sae.org.

AIR910	Ozone in High Altitude Aircraft
AIR4766	Air Quality for Commercial Aircraft Cabins
AIR4766/1	Air Quality for Commercial Aircraft Cabin Particulate Contaminants
AIR4766/2	Airborne Chemicals in Aircraft Cabins
AIR7521	Measurement Data and Reference Values for Compounds Potentially Found in Aircraft Engine Bleed Air

2.1.2 FAA Publications

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

AC 120-38. [1980]. Transport Category Airplanes Cabin Ozone Concentrations.

2.1.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49.221.89990.1000, www.easa.europa.eu.

CS-E. Engines.

2.1.4 ASHRAE Publications

Available from ASHRAE Headquarters, 1791 Tullie Circle, NE, Atlanta GA 30329, Tel: 800-527-4723 (U.S. and Canada only) or 404-636-8400, www.ashrae.org.

ASHRAE Handbook. [1977]. Fundamentals.

ASHRAE TRP 959. [2001]. "Determine Aircraft Supply Air Contaminants in the Engine Bleed Air Supply System of Commercial Aircraft." Energen Report Number AS20151.

2.1.5 Other Applicable Publications

ARINC 600-20. "Air Transport Avionics Equipment Interfaces." ARINC Industry Activities, an SAE ITC Program. Available from <https://www.aviation-ia.com/products/600-20-air-transport-avionics-equipment-interfaces-2>.

Bhangar, S., and Nazaroff, W.W. [2013]. "Atmospheric ozone levels encountered by commercial aircraft on transatlantic routes." Environ. Res. Lett. 8: 014006 (7pp). DOI:10.1088/1748-9326/8/1/014006. Online supplementary data available from <https://iopscience.iop.org/article/10.1088/1748-9326/8/1/014006/pdf>.

Caravan, R.L., Khan, A.A.H., Zador, J., Sheps, L., et al. [2018]. "The reaction of hydroxyl and methylperoxy radical is not a major source of atmospheric methanol." Nature Communications, Nature 9:4343. <https://www.nature.com/ncomms/>. DOI:10.1028/s41467-018-06716-z.

Cheng, M.D. [2013]. "Classification of volatile engine particles." Aerosol and Air Quality Research. 13:1411:1422. DOI:10.4209/aaqr.2013.01.0011.

Cooper, O.R., Parrish, D.D., Ziemke, J., Balashov, N.V., et al. [2014]. "Global distribution and trends of tropospheric ozone: An observation-based review." Elementa: Science of the Anthropocene, 2:000029, DOI:12952/journal.elementa.000029.

Fairlie, D., Jacob, D., and Park, R., [2006]. "The impact of transpacific transport of mineral dust in the United States." Atmospheric Environment, Manuscript #ATMENV-D-06-00482R1, NASA Langley Research Center.

Harrison, J.J., Chipperfield, M.P., Boone, C.D., Dhomse, S.S., et al. [2016]. "Satellite observations of stratospheric hydrogen fluoride and comparisons with SLIMCAT calculations." Atmospheric Chemistry and Physics 16: 10501-10519. <https://www.atmos-chem-phys.net/16/10501/2016/>. DOI:10.5194/acp-16-10501-2016.

Lamarque, et al. [2007]. "Role of hydrogen sulfide in a Permian-Triassic boundary ozone collapse." Geophysical Research Letters, 34: L02801.

Lockheed-Georgia Company. "Report, 46-1327 C-130 Contamination Investigation."

Minschwaner, K., Manney, G.L., Livesey, N.J., et al. [2010]. "The photochemistry of carbon monoxide in the stratosphere and mesosphere evaluated from observations by the Microwave Limb Sounder on the Aura satellite." Journal of Geophysical Research. 115(D13). DOI:10.1029/2009JD012654.

Mohapatra, S.C. [2006]. "An Overview of Liquid Coolants for Electronics Cooling." Electronics Cooling. Retrieved from <https://www.electronics-cooling.com/2006/05/an-overview-of-liquid-coolants-for-electronics-cooling/>.

NASA Ozone Watch. [2018]. "Images, data, and information for atmospheric ozone." Goddard Space Flight Center. Retrieved from <https://ozonewatch.gsfc.nasa.gov/facts/SH.html>.

NASA Technical Memorandum 81671. [1981]. "Ozone Contamination in Aircraft Cabins: Results from GASP Data and Analyses."

NASA Technical Memorandum 82742. FAA-EE-83-12. [1984]. "Tabulations of Ambient Ozone Data Obtained by GASP Airlines; March 1975 to July 1979."

Parker. [1970]. "Air Pollution at Heathrow Airport." London Dept. of Trade and Industry, Herts, England.

Robins, C.S. [1968]. "737 Air Conditioning Engine Bleed Air Contamination." Boeing Company.

Robins, C.S. [1969] "737 Engine Bleed Air Contamination Analysis for UAL." Boeing Company.

Russell. [2015]. "Layers of Earth's Atmosphere." <https://scied.ucar.edu/atmosphere-layers>.

Snow, J.A., Heikes, B., Schen, H., O'Sullivan, D.W., et al. [2007]. "Hydrogen peroxide, methyl hydroperoxide, and formaldehyde over North America and the North Atlantic." Journal of Geophysical Research Atmospheres. https://www.researchgate.net/publication/228367677_Hydrogen_peroxide_methyl_hydroperoxide_and_formaldehyde_over_North_America_and_the_North_Atlantic. DOI:10.1029/2006JD007746.

Speidel et al. [2007]. "Sulfur dioxide measurements in the lower, middle, and upper troposphere: Deployment of an aircraft-based chemical ionization mass spectrometer with permanent in-flight calibration," Atmospheric Environment, 41:2427-2437.

Tereszchuk, K.A. et al. [2013]. "Observations of peroxyacetyl nitrate (PAN) in the upper troposphere by the Atmospheric Chemistry Experiment-Fourier Transform Spectrometer (ACE-FTS)." Atmospheric Chemistry and Physics. 13:5601-5613. <https://www.atmos-chem-phys.net/13/5601/2013/>. DOI:10.5194/acp-13-5601-2013.

Tetra Tech. [2013]. "Final Report: LAX Air Quality and Source Apportionment Study." Volume 1. Executive Summary. Los Angeles World Airports Environmental Services Divisions. <https://www.lawa.org/lawa-environment/lax/lax-air-quality-and-source-apportionment-study>.

Umezawa, T., Baker, A.K., Oram, D., Sauvage, C., et al. [2014]. "Methylene chloride in the upper troposphere observed by the CARIBIC passenger aircraft observatory: Large-scale distributions and Asian summer monsoon outflow." J. Geophys. Res. Atmos., 119:5542-5558. DOI:10.1002/2013JD021396.

United States Air Force Scientific Advisory Board. [2012]. "Report on Aircraft Oxygen Generation." SAB-TR-11-04. https://www.airforcemag.com/PDF/DocumentFile/Documents/2012/AFSAB_Oxygen_020112.pdf.

Von Clarmann, T. [2013]. Chlorine in the stratosphere. Atmosfera (2013). 26(3):415-458.

Worden, J.R., Turner, A.J., Bloom, A.A., Kulawik, S.S., et al. [2015]. "Quantifying lower tropospheric methane concentrations using near-IR and thermal IR satellite measurements: comparison to the GEOS-Chem model." Atmospheric Measurement Techniques. Discuss. 8:3851-3882. https://www.researchgate.net/publication/276088518_Quantifying_lower_tropospheric_methane_concentrations_using_near-IR_and_thermal_IR_satellite_measurements_comparison_to_the_GEOS-Chem_model.

2.2 Definitions

AEROSOL: A suspension in a gaseous medium of solid particles, liquid particles, or solid and liquid particles having a negligible falling velocity (ISO 7708, 1995).

BLEED AIR: As used in this document, air from outdoor origin entering cabin after having been processed through an engine compressor, turbo compressor, or shaft-driven compressors.

2.3 Acronyms and Abbreviations

µm Micron/Micrometer

AC FAA or EASA Advisory Circular

ACM Air Cycle Machine

APU Auxiliary Power Unit

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

CFC-11 Pentachlorofluoroethane

CH ₃ Cl	Methylene Chloride, Dichloromethane
CH ₃ OOH	Methyl Hydroperoxide
CH ₄	Methane
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
ECS	Environmental Control System
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration (USA)
H ₂ S	Hydrogen Sulfide
HCN	Hydrogen Cyanide
HF	Hydrogen Fluoride
hPa	Hectopascal (Pressure)
ICAO	International Civil Aviation Organization
ISO	International Standard Organization
mm Hg	Millimeters of Mercury (Pressure)
NASA	National Aeronautics and Space Administration
NO	Nitric Oxide
NO _y	Nitrogen Oxides
O ₃	Ozone
PAN	Peroxyacetylnitrate
ppbV	Parts per Billion in Volume
ppmV	Parts per Million in Volume
pptV	Parts per Trillion in Volume
SO ₂	Sulfur Dioxide

3. TYPES AND SOURCES OF CONTAMINATION

Two types of contamination are of concern to ECS design. Particulate contaminants include sand and dust, metal, and carbonaceous material. Refer to AIR4766/1 for a more in-depth discussion on particulate contaminants in aircraft ECS systems. Chemical contaminants may be generated within aircraft components or be present in the operating environment, and potentially can be introduced into the cabin through the ECS. Refer to AIR4766/2 for a more in-depth discussion regarding gaseous contaminants that may be present within the bleed air supply and in recirculated cabin air.

3.1 Sources of Chemical Contamination

3.1.1 Tropospheric and Stratospheric Contaminants

The troposphere is the lowest layer of our atmosphere (Figure 1) as depicted by Russell [2015]. Starting at ground level, it extends upward to about 10 km (6.2 miles or about 33000 feet) above sea level. Tropospheric gaseous contaminants are in the operating aircraft envelope at cruise altitudes. The next atmospheric layer is called the stratosphere. The stratosphere extends from the top of the troposphere to about 50 km (31 miles) above the ground. The ozone layer is within the stratosphere. Atmospheric temperature gets warmer as you go higher in the stratosphere (Russell, [2015]).

Several recent studies provide information that is valuable for aircraft designers to understand potential long-term exposure effects of atmospheric gaseous contaminants.

- Methanol is present at 1 to 15 ppbV in continental boundary layer and 0.1 to 1 ppbV in remote troposphere (Figure 2), per Caravan et al. [2018].
- Tropospheric levels of sulfur dioxide are in the parts per trillion range (pptV). NO, NO_y, and SO₂ are greater in contrails, but still in ppbV and pptV levels and are depicted by Speidel et al. in their Figure 8 (Speidel et al. [2007]).
- Measured levels of sulfur dioxide are in the pptV range and are depicted by Speidel et al. in their Figure 5 (Speidel et al. [2007]).
- Carbon monoxide production occurs from methane oxidation reactions and dissociation of CO₂ in the atmosphere (Minschwaner et al. [2010]). CO range is in the ppbV level (Minschwaner et al. [2010]).
- Chlorinated hydrocarbons from volcanic eruptions and solid rocket fuels do not survive transport to the stratosphere and are washed out in the troposphere (Figure 3) (Von Clarmann. [2013]).
- Hydrogen sulfide emission simulations estimate 10 pptV emissions of H₂S with emissions measured for the study. Tropospheric levels of H₂S may increase to 140 ppbV with elevated surface emission levels. The measurements of Lamarque et al. [2007] are presented in Figure 4.
- Ozone is present seasonally in certain regions of the troposphere. Section 3.1 of AIR910 provides additional detailed information on atmospheric ozone levels. Figures 5 (NASA Ozone Watch. [2018]), 6 (Bhangar and Nazarov. [2013]), and 7 (Cooper et al. [2014]) provide further information on the levels and variability of ozone concentrations.

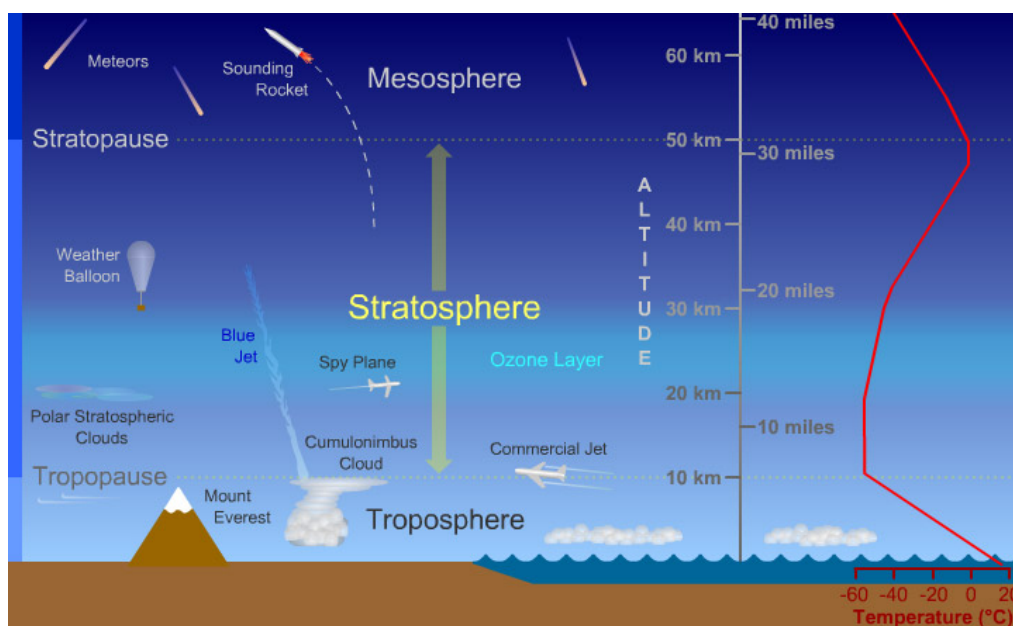


Figure 1 - Atmospheric layers

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