On behalf of the Global Cabin Air Quality Executive: GCAQE

Notice of Proposed Amendment 2018-05

Regular update of CS-25 -RMT.0673

Introduction - Rationale:

The certification standards and AMC related to CS 25.831 and ventilation air supply are not specific enough to ensure adequate air quality for crew or passengers. The use of the bleed air system fails to meet the certification requirements for clean breathing air.

Problem description:

The certification standard proposed requires that:

1) The *"system must be designed to provide a sufficient amount of uncontaminated air to enable the crew members to perform their duties without undue discomfort or fatigue and to provide reasonable passenger comfort."* CS/FAR 25.831a
2) *"Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapours."* CS/FAR 25.831b

There are several problems that should be addressed:

A. The ventilation systems utilised in current bleed air aircraft are sourced generally from the engines or APU. The use of the pressurised air from the compressor will in all cases provide low level leakage of oil from the bearing chamber back into the secondary air, including the main core airflow in the compressor, from where the ventilation air is sourced. This occurs as oil seals are not an absolute design and will allow low level leakage past the seals in normal operations, in addition to the less frequent higher levels of leakage in failure or certain operational conditions. **[**1–5**]**

B. Ultrafine particles are generated from oils exposed to high temperatures such as those in compressors and the oil system**.** [4] *"Oil contamination in the compressor will result in a fog of very fine droplets in the bleed air under most operating conditions"*, including *"with very low contamination rates….. development of sensors for detecting oil contamination in aircraft bleed air should focus on ultrafine particle detection and sensing of low contamination levels may require sensitivity to extreme ultrafine particles 10 nanometers and smaller."* [6]

C. The ventilation and air purity requirements are not specific enough to ensure suitable quality of the ventilation air supply. No guidance is given & various AMC used (e.g: SAE ARP 4418) are used to quantify the concentrations of selected markers for engine/APU generated bleed air contaminants at steady state conditions only in ground level test beds and does not look at health effects.

D. The focus under the standards for ventilation air supply is placed on incapacitation, while ignoring to a great degree impairment and discomfort, degraded performance and reduced efficiency.

E. Sufficient amount of uncontaminated air provides the potential for people to focus on the ventilation flow rate, while ignoring the need to provide air that does not impair/ cause undue discomfort, harm /hazardous conditions or degraded efficiency etc.

F. The requirement to provide air free of harmful or hazardous gases and vapours is often interpreted to refer to CO, CO_2 and O_3 only, yet it ought refer more clearly that this means all substances.

G. The design certification requirements and AMC for the engines/APU require that major failure conditions do not occur more than 10^{-5}/engine flight hour or APU operating hour. The airframe requirements and AMC require that major effects are remote, less than 1 x 10^{-5}/flight hour (fh) - > 1 x 10^{-7}/fh. Major effects include those that *“impair crew efficiency”* or cause discomfort to flight crew or physical distress to cabin crew or passengers. The use of the bleed air system that enables and guarantees low level oil emissions in normal flight is associated with impairment, degraded crew efficiency and is considered harmful and hazardous. This is increasingly acknowledged directly or indirectly. [1,4,7–20]

H. CS 25.831 a) and b) cannot be met using the bleed air system. *“The use of the bleed air system to supply the regulatory required air quality standards is not being met or being enforced as required.”* [1,2]

I. Occupational exposure limits and similar threshold limits will not protect against harmful and hazardous conditions from the ventilation supply air. This is widely acknowledged. [4,12,21,22] Harmful and hazardous effects, degraded efficiency and impairment are occurring with repeat (chronic) low level exposure to these fluids/substances and the complex thermally degraded mixtures they create. [4,10,23–25]

J. Aircraft using a bleedless architecture will not meet the air quality standards when the outside air is contaminated by jet engine oils and hydraulic and deicing fluids, such as on the ground or in flight when the outside air contains these substances.

K. There are at present no sensors installed to provide the flight crew with a warning that the air is contaminated. This is required under CS 1309c as the use of the bleed air system and a bleedless system when contaminated by outside air (air other than recirculated) containing the oils and fluids does not meet the required air quality standard of not causing degraded efficiency/ impairment and harm/hazardous conditions.

These concerns are recognized increasingly widely elsewhere. A Few examples include:
German BFU [26]

- *"Engine certification specifications require air purity. This is a general requirement and does not describe which aim shall be achieved in regard to cabin air. The term "purity"* *does not include whether the requirement is to eliminate smells, harmful concentrations of substances or the hazard of impairing crew capability to act."*

- *"The BFU is of the opinion that "harmful concentration" should be interpreted solely to mean that health impairments (including long-term) through contaminated cabin air should be eliminated."*
- *"The BFU is of the opinion that a product which has received a type certificate by EASA should be designed in a way that neither crew nor passengers are harmed or become chronically ill."*
- *"During demonstration of compliance in accordance with CS 25, CS E and CS APU, only a limited number of substances are considered."*
- *"For the BFU, it has not become clear, how demonstration of compliance in accordance with CS 25.1309 in regard to cabin air contamination occurs."*
- *"The BFU does not understand how the extensive requirements of CS 25.831 and CS 25.1309 could be met if the certification authority did not conduct a consideration of all substances used."*
- SR No. 07/2014 *"EASA should implement a demonstration of compliance during type certification of aircraft (CS-25), engines (CS-E) and APU (CS-APU) such that the same requirements apply to all these products and permanent adverse health effects resulting from contaminated cabin air are precluded. Aircraft engine and APU type certification should include direct demonstration of compliance of all substances liable to cause cabin air contamination. Certification should be based on critical values which preclude permanent adverse health effects on passengers and crew."*

AAIB: Safety recommendation 2007-002: *"It is recommended that the EASA consider requiring, for all large aeroplanes operating for the purposes of commercial air transport, a system to enable the flight crew to identify rapidly the source of smoke by providing a flight deck warning of smoke or oil mist in the air delivered from each air conditioning unit."* [[27,28]] Six similar calls for sensors and warning detection systems have been called for by this and additional aircraft investigation bureaus.

Austria: GZ. BMVIT-86.069/0002- IV/BAV/UUB/LF/2016
EASA: SE/SUB/LF/9/2016 *"The installation of technical monitoring options such as sensors which determine the composition, or possible contamination of the cabin air, which routinely record the air in real-time and alert pilots in time, coupled with appropriate filtering systems, should be mandatory for aircraft using bleed air from the cabin air power engines."*

Changes required:

CS 25.831 requires very extensive consideration. The standard as it is is no longer suitable for aircraft air supply systems to ensure people remain free of harm, hazards, impairment or degraded performance/efficiency. There are no detection systems to advise crew when the air is contaminated. The same applies to the standards and AMC related to engine and APU generated air supply contamination.

Specific text in the interim should be amended to include the intent of the following points.

- At least one meaningful marker per contaminant is required to meet CS-25 25.831 a) and b) both on the ground and in flight in real time. Minimum contaminants to be covered are engine oil, hydraulic oil and de-icing fluid. Levels selected must use the best available technology to determine when the air contains such marker compounds at the lowest possible concentration. A warning system must be supplied to the flight deck.

- Part a) should be amended *"to enable the crew members to perform their duties without undue discomfort, impairment or fatigue and without degraded crew performance or efficiency, and to provide passenger comfort with clean air supplied that does not cause adverse effects."*
- Part b) should be amended to *"Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases, vapours and pyrolysed mixtures, including those that cause adverse effects."*
- A clear paragraph on AMC how sufficiently uncontaminated ventilation air supply can be demonstrated must be included.
- If the ventilation air supply cannot be guaranteed to be free of gasses, vapours and mixtures, an alternative system must be introduced or air cleaning technology must be implemented.

Susan Michaelis PhD, MSc, ATPL
For GCAQE
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REFERENCES

1. Michaelis S. *Implementation Of The Requirements For The Provision Of Clean Air In Crew And Passenger Compartments Using The Aircraft Bleed Air System.* (MSc thesis) Cranfield University http://www.susanmichaelis.com/caq.html (2016).

2. Michaelis S. Aircraft clean air requirements using bleed air systems. *Engineering* 2018; 10: 142–172. http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=83906

3. Michaelis S, Morton J. Mechanisms of Oil Leakage into the Cabin Air Supply & the Regulatory Implications. In: *International Aircraft Cabin Air Conference, Imperial College London, 19-20 September 2017*https://www.aircraftcabinair.com/films (2017).

4. Howard CV, Johnson DW, Morton J, et al. Is a Cumulative Exposure to a Background Aerosol of Nanoparticles Part of the Causal Mechanism of Aerotoxic Syndrome ? *Nanomedicine Nanosci Res*; 139. 2018. DOI: 10.29011/JNAN-139. https://gavinpublishers.com/journals/artical_in_press/nanomedicine-and-nanoscience-research-ISSN-2577-1477#

5. Michaelis S. Bearing chamber sealing and the use of aircraft bleed air. In: *Published and Presented at BHR Group's 24th International Conference on Fluid Sealing, 7 – 8 March 2018; Manchester, UK*. 2018. http://www.susanmichaelis.com/pdf/24th%20Int%20Fluids%20sealing%20conference_2018_%20Michaelis_Bearing%20chamber%20sealing.pdf

6. Jones B, Roth J, Hosni M et al. The Nature of Particulates in Aircraft Bleed Air Resulting from Oil Contamination. LV-17-C046. In: *2017 ASHRAE Winter Conference—Papers*. Kansas State University, 2017.

7. Chaturvedi A. *DOT/FAA/AM-09/8. Aerospace Toxicology: An Overview*. Oklahoma City: Federal Aviation Administration, CAMI, 2009.

8. Harrison R, Murawski J, Mcneely E et al. OHRCA: Exposure To Aircraft Bleed Air Contaminants Among Airline Workers - A Guide For Health Care providorshttp://www.ohrca.org/medical-protocols-for-crews-exposed-to-engine-oil-fumes-on-aircraft/ (2009).

9. Michaelis S. *Health and Flight Safety Implications from Exposure to Contaminated Air in Aircraft*. (PhD Thesis) UNSW, Sydney http://handle.unsw.edu.au/1959.4/50342 (2010).

10. Michaelis S, Burdon J, Howard C. Aerotoxic Syndrome : a New Occupational Disease ? *Public Heal Panor* 2017; 3: 198–211. http://www.euro.who.int/en/publications/public-health-panorama/journal-issues/volume-3,-issue-2,-june-2017

11. Winder C, Balouet J-C. The toxicity of commercial jet oils. *Environ Res* 2002; 89: 146–164.

12. Winder C. Hazardous Chemicals on Jet Aircraft : Jet Oils and Aerotoxic Sydrome. *Curr Top Toxicol* 2006; 3: 65–88.

13. European Commission. Regulation (Ec) No 1272/2008 Of The European Parliament And Of The Council Of 16 December 2008 On Classification, Labelling And Packaging Of Substances And Mixtures (CLP) http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database (2009).

14. United Nations. GLOBALLY HARMONIZED SYSTEM OF CLASSIFICATION AND LABELLING OF CHEMICALS (GHS) - 4th ed. New York and Geneva, 2011

15. Eastman. *Oil can Label: Eastman 2197*. 2017.

16. ExxonMobil. Material Safety Data Sheet: Mobil Jet Oil II. *ExxonMobil MSDS* http://www.msds.exxonmobil.com/IntApps/psims/psims.aspx (2016).

17. Boeing. *Boeing MSDS No. 138541. Material Safety Data Sheet- MIL-PRF-23699*. Rev 08/09/2007. Seattle: Boeing, 2007.

18. ICSC. International Programme On Chemical Safetyhttp://www.who.int/ipcs/publications/icsc/en/ (2016).

19. Guerzoni F. *Presentation to SAE E34 Propulsion Lubricants Conference Cardiff, 1999. The Debate Over Aircraft Cabin Air Quality And Health: Implications For Aviation Turbine Lubricants*. Shell Global Solutions, 1999.

20. Peitsch D. Developments In Modern Aero-Engines To Minimize The Impact Of Bleed Air. In: *Air Quality In Passenger Aircraft - Royal Aeronautical Society, London, 16-17 October 2003*. London: Rolls-Royce Deutschland http://projects.bre.co.uk/envdiv/cabinairconference/presentations/Dieter_Peitsch.pdf (2003).

21. ACGIH. *TLVs and BEIs - Threshold Limit Values For Chemical Substances And Physical Agents*. Cincinnati: American Conference of Governmental Industrial Hygienists, 2015.

22. Michaelis S. *The Inapplicability of Exposure Standards*http://www.susanmichaelis.com/caq.html (2014).

23. Howard C, Michaelis S, Watterson A. The Aetiology of ' Aerotoxic Syndrome ' - A Toxico- Pathological Viewpoint. *Open Acc J Toxicol* 2017; 1: 1–3. https://juniperpublishers.com/oajt/pdf/OAJT.MS.ID.555575.pdf

24. Terry AJ. Functional Consequences of Repeated Organophosphate Exposure: Potential Non-Cholinergic Mechanisms. *Pharmacol Ther NIH Public Access* 2012; 134: 355–365.

25. Naughton SX, Hernandez CM, Beck WD, et al. Repeated exposures to diisopropylfluorophosphate result in structural disruptions of myelinated axons and persistent impairments of axonal transport in the brains of rats. *Toxicology* 2018; 406–407: 92–103.

26. BFU. *BFU 803.1-14. Study Of Reported Occurrences In Conjunction With Cabin Air Quality In Transport Aircraft*. Braunschweig: Bundesstelle für Flugunfalluntersuchung, 2014.

27. AAIB. *AAIB Bulletin: 4/2007 G-JECE EW/C2005/08/10*. Aldershot: Air Accidents Investigation Branch, 2007.

28. AAIB. *EW/C2006/10/08. AAIB Bulletin: 6/2009 G-BYAO*. Aldershot: Air Accidents Investigation Branch, 2009.