Investigation of aircraft contaminated air supplies

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Bleed air contamination history

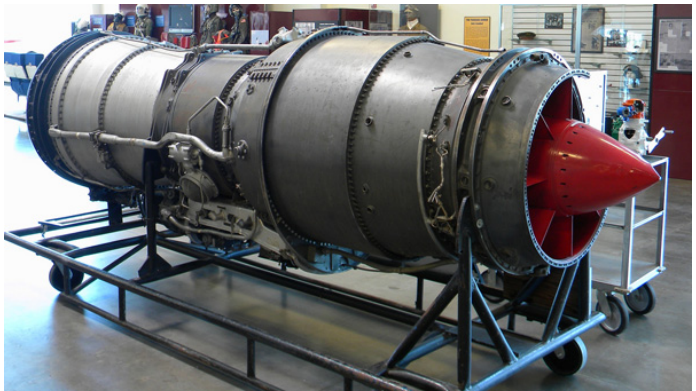
- Bleed air contamination – 1950s /military
- Sourced to oil fumes
- Linked with adverse effects
- Heated oil studies – Significantly increased toxicity with temps above 600^{o}F (260^{o}C)
- Turbo compressors used except for Caravelle
- Bleed air used to reduce costs & considered safe?

1952/53 – J57 Engine

B-52 and the F-100 – Bleed Air

The J57 (JT3) Engine was the first Pratt & Whitney-designed turbojet.

Early use of MIL-L-7808 Synthetic oil
Type I or 3 centistoke jet oils



15 May 1954

WILLIAM J. VAN EVERY
1st Lt, USAF

"At approximately 1530 hours on 15 May 1954, I was flying aircraft number 52-1436, an RB-57A, in a three (3) plane formation from Shaw Air Force Base, South Carolina. Approximately 40 minutes after take-off while flying over an overcast at 7000 feet,

I experienced blurred vision, became nauseated and experienced considerable dizziness.

I recall no strange or unpleasant odors, nor did I taste anything out of the ordinary. I did feel a definite dryness of mouth and throat.

This condition lasted possibly a minute or two. As I became more aware of the situation or nearly to the passing out point I recall dropping back from the formation and opening the clear vision window and unhooking the oxygen mask. Fresh air from this open window seemed to relieve the unpleasant conditions I felt."

Ref: Loomis T, Krop S. MLSR No. 61 - Cabin Air Contamination In RB-57A Aircraft. Maryland: Army Chemical Center, 1955.

Various issues to consider

- Flight safety/impairment
- Under-reporting
- Design/certification
- Lack of awareness
- No detection systems
- Occupational/public health
- Science

AIB investigations

Bleed air supply contamination

- Numerous reports
- 20 key recommendations and findings
- 8 bureaus of air safety

- Mid 1990s – 2016
- 8 countries, 2 continents

Refer: Loraine T. Air Accident Investigation Findings and Recommendations. Presentation at International Aircraft Cabin Air Conference, Imperial College London. 19-20 September, 2017: https://www.aircraftcabinair.com/films

ICAO Annex 13 and EU Reg 996/2010

- Serious incident: Annex 1 ✔
  - Events requiring emergency use of oxygen by pilots
  - Pilot incapacitation
- Accident:✔
  - Serious injury
  - Hospitalization > 48 hrs (commence within 7 days)
  - Injury to internal organ
- Investigate incidents if safety lessons could be drawn. ? **(Eu Reg 996/2010)**

Other factors

Limitations…

- Most contaminated air events are never reported
- Of those reported most are never investigated by air accident investigation teams
- Of those investigated, investigators often lack the resources or subject matter expertise

Key findings/recommendations 1/2

- Lesser impairments from fumes (other than from fire/smoke) requiring oxygen use by pilot or pilot incapacitation − not investigated as not effecting safety ?
- Subtle impairment/lack of awareness of hazardous situation & need for prompt action
- Pilots not using O2/emergency checklist
- Pilot's well-being and judgment can be affected by exposure to engine oil fumes
- 2 pilot impairment occurs
- Lack of reporting/detection systems

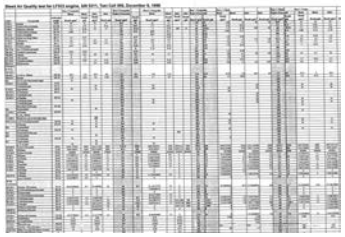
Key findings/recommendations 2/2

- Maintenance difficulty in identifying source
- Fumes not new/numerous aircraft types
- Regulations focus on design but ignore toxic levels of contamination, effect on people
- International actions should identify real impact on human health
- Certification does not cover all contaminants
- Margin of safety rarely reduced – (BFU 2014)
- Impairment seen as OHS issue – (BFU 2014)

Key recommendations -

- 2001:  Suspicion of unhealthful cabin air – Pilots to use of oxygen masks selected to 100% oxygen
- 2007/2009:  Detection system for smoke/ oil mist
- 2014:  EASA demonstrate certification & compliance (airframe/engine/APU) that CAQ does not lead to permanent health effects

Different thinking



Incident caused by the pilots becoming temporarily affected by **probably** polluted cabin air. (measurements undertaken after)

Very few cases safety affected/Impairment is an **OHS/comfort issue**

Serious Incident due to oil fumes causing a **toxic effect** and limited capability of pilot

Overall

- Significant implications
- Under-recognized
- Specialist expertise required
- Investigations should:
  - Look at broad picture & if necessary…
    - Gather perishable evidence
    - Look at operational, maintenance & human data
    - Take into account all factors relevant to contaminated air exposures

Other factors: Difficulties in investigation

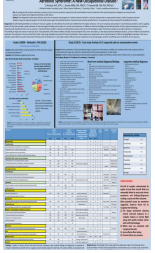
- Under-reporting is significant – EASA, FAA, Michaelis, Bae…
- No detection systems
- Very low levels of oils cause fumes
- Levels found in CAQ investigations - Low, but safe levels do not apply to aircraft environment
- Very difficult to confirm leakage by maintenance techniques

Flight Safety

AAIB Bulletin: 7/2007 G-CPET – October 2006 – B757

- During the descent, both crew members began to feel disorientated and found that they had to concentrate hard to carry out their normal duties. At this point the commander began to feel ‘confused’.

- The flight crew expressed concern that neither had detected the slow degradation in their performance as this only became fully apparent after they had donned oxygen masks and began to recover.



Flight Safety

- BAe 146 study*: Immediate/ST effects = 44%
- 15 incidents study*:
  - Impairment = 93% (73% involved pilots)
  - 33% - full or partial incapacitation of 2 pilots
  - 87% - positive oil identification

Other – Crew impairment rates

- CAA MORs: 2006-2011 – 30%
- BFU – 27%
- Michaelis (PhD, 2010) – 32%

* Michaelis S, Burdon J, Howard CV. Aerotoxic Syndrome: A New 16. Occupational Disease? Public Health Panorama 2017; 3: 141-356.
http://www.euro.who.int/__data/assets/pdf_file/0019/341533/5_OriginalResearch_AerotoxicSyndrom_ENG.pdf

Other factors: Design

- Oil leaks at low-levels in normal operations
- All dynamic seals leak
- Oil fumes NOT limited to failure or over servicing scenarios
- Low level leakage increases with changing pressure/ temps/speed…
- Oil & other fluids associated (MSDS…) with hazards/ impairment − Cannot meet design requirements*

* Michaelis, S. (2016) 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, Cranfield. Available from: http://www.susanmichaelis.com/caq.html

* Michaelis S, Morton J (2017) 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

Other factors: Science

- Oils and Hydraulic fluids
- Pyrolysed complex mixture − Cannot define toxicity*
- Hazardous substances: EU Classification reg. 1272/2008
- In line with MSDSs/chemicals databases
- Chronic low level exposures + acute events:
  - More susceptible
  - Diffuse pattern
  - Ultrafine particles/OPs/complex mixture

*Exxon Mobil to T Elwood MP,UK; 2013

*European Chemicals Agency − TCP review, 2016

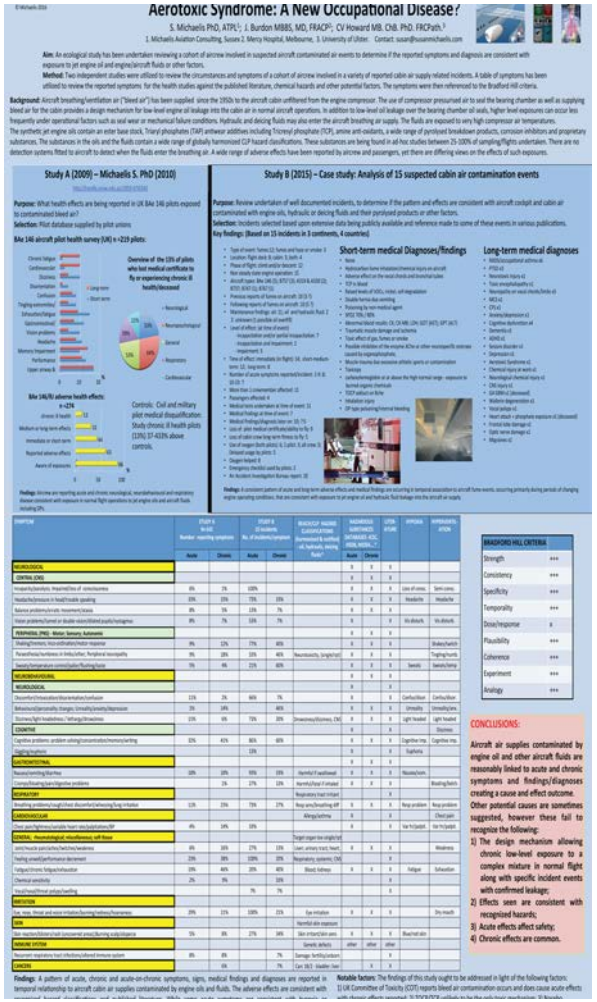
*Howard et al. 2017 & 2018

Other factors: Science

- Michaelis et al. (2017)
  - 2 studies show consistent diffuse pattern: primarily neurological/respiratory − Aerotoxic Syndrome
- Howard et al. (2017)
  - Acute on chronic effects − Aerotoxic Syndrome
- Howard et al. (2018)
  - Ultrafine particles generated − Increase toxicity
- Terry et al. (2012)
  - Repeat low level OP exposures cause non cholinergic effects
- Axelrad et al. (2003)
  - Increased susceptibility with repeat low-level OP exposures
- Cherry et al. (2002)
  - Individual susceptibility to OPs − highly variable

Other factors: Health

Aircraft air supplies contaminated by engine oil and other aircraft fluids are reasonably linked to acute and chronic symptoms and findings/diagnoses creating a cause and effect outcome.



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Limitations

- Current studies addressing high level acute exposures only
- Occupational exposure limits… do not apply to aircraft environment
- Cannot determine toxicity/effects of complex heated mixtures without proper studies
- Low level background exposure or transient fume events not taken adequately into account
- Most events are fumes/not smoke
- Oil leakage below permissible consumption rate not considered as hazardous by many
- Impairment not given adequate attention

Solutions - general

- Bleed air filtration – DHL – Pall Aerospace
- Bleed air sensors & flight deck warning
- Bleed free designs
- Advanced seal/engine designs
- Less toxic oils
- Better maintenance practices
- Improved reporting & analysis of data
- Greater understanding of physiological effects to chronic low-level exposures
- Improved checklists/O2 use if air suspected to be contaminated
- Review of compliance
- Effective medical protocol/disease recognition
- Training & education – ICAO Guidance > GCARS

Recommendations: AIBs

- Broader perspective required for CAQ – not limited to pilot incapacitation/emergency use of O2…
- O2 used if contaminated air suspected
- Better appreciation that all engines leak oil in normal operation & implications - design factor
- Call for mitigating initiatives
- Call for better reporting/education/maintenance practices…
- Detailed analysis of contaminated air events using specialist expertise