2019 INTERNATIONAL AIRCRAFT CABIN AIR CONFERENCE

CONFERENCE PROCEEDINGS

Presentations of the 2019 International Aircraft Cabin Air Conference
17-18 September 2019
Imperial College London
CONFERENCE PROCEEDINGS
Presentations

2019 International Aircraft Cabin Air Conference
17-18 September 2019, Imperial College London

London: Global Cabin Air Quality Executive (GCAQE)
2019
Introduction

The International Aircraft Cabin Air Conferences are developing into a series of conferences organized every two years. The conferences are mapping the business, regulatory and technical solutions to aircraft cabin air contamination.

The conferences in 2017 and 2019 provided networking opportunities for those seeking to understand the subject of contaminated air, the flight safety implications, the latest scientific and medical evidence investigating the contaminated air debate and the solutions available to airlines and aircraft operators. The two conferences held so far have been the most in-depth conferences ever on the topic of aircraft cabin air contamination.

By way of expert global independent and industry speakers, the Aircraft Cabin Air Conferences seek to achieve the following key objectives:

- Provide a historical overview of the contaminated air issue and its causes.
- Map out the flight safety aspects of contaminated air through case studies, discussion and air accident investigation findings.
- Disseminate the latest medical and scientific theories and findings on the health aspects of exposure to contaminated air.
- Give guidance of the regulatory aspects of cabin air quality.
- Examine the latest development towards bleed air filtration, contaminated air warning sensor systems and other potential solutions.
- Provide an opportunity for networking and sharing good practice to facilitate better inter-agency working.

Please refer to the Conference Programme 2019 (https://doi.org/10.5281/zenodo.4554737) for additional information not repeated here:

- Sponsors and Supporters
- Welcome by the Conference Director, Captain Tristan Loraine
- Contaminated Cabin Air Key Timeline 1930 – 2019
- Agenda
- Introduction to the GCAQE
- Bleed Air Simplified
- Conference Speakers
In total 30 presentations were given at the 2019 International Aircraft Cabin Air Conference (ACA 2019). This document contains the 25 presentations provided by the authors. It combines the presentations into one PDF for further dissemination and archiving.

Single presentations can be retrieved for reading and can be quoted conveniently also by their individual Digital Object Identifier (DOI). They are listed on the Conference Proceedings Homepage: https://zenodo.org/communities/aircraftcabinair. The DOI of each presentation is given in the Table of Contents.

Citation of Proceedings (ISO 690):

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Independent citation of an individual article (ISO 690):
LASTNAME, FirstName, 2019. ArticleTitle. Presented at the 2019 International Aircraft Cabin Air Conference (Imperial College London, 17-18 September 2019). Available from: https://doi.org/10.5281/zenodo...

29 filmed presentations of the Aircraft Cabin Air Conference 2019 are available at https://vimeo.com/ondemand/aca2019 for purchase. A trailer can be played and gives an impression of the two conferences.

The presentations were formatted by the authors. They are given here in alphabetical order by author last name.

Neither the conference organizers nor the editors or publishers can be held responsible for inaccuracies or errors in any included presentation.

Dieter Scholz
<table>
<thead>
<tr>
<th>Authors</th>
<th>Title</th>
<th>DOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tony Cable</td>
<td>A Brief Background - An Air Accident Investigator's Perspective</td>
<td><a href="https://doi.org/10.5281/zenodo.4464436">https://doi.org/10.5281/zenodo.4464436</a></td>
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<tr>
<td>Judy Cullinane</td>
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</tr>
<tr>
<td>Marcus Diamond</td>
<td>Cabin Air Sampling of Organophosphates during Fume Events in Australia</td>
<td><a href="https://doi.org/10.5281/zenodo.4464851">https://doi.org/10.5281/zenodo.4464851</a></td>
</tr>
<tr>
<td>Daniel Dumalin</td>
<td>Aircraft Cabin Air – Neurotoxicity</td>
<td><a href="https://doi.org/10.5281/zenodo.4464526">https://doi.org/10.5281/zenodo.4464526</a></td>
</tr>
</tbody>
</table>
Richard Hansen:
Suspected Air Quality Problems on Board - Experiences & Actions
https://doi.org/10.5281/zenodo.4464536

Vyvyan Howard:
Why the Brain Is the Most Vulnerable Target Organ in Chronic Organo-Phosphate Exposure
https://doi.org/10.5281/zenodo.4464541

Byron Jones:
Bleed Air Contamination Detection
https://doi.org/10.5281/zenodo.4464547

Victor Leung:
Deoxo(TM) Ozone and Ozone/VOC Converters: Essential for Cabin Clean Air
https://doi.org/10.5281/zenodo.4464555

Margaret of Mar:
GCAQE Closing Speech
https://doi.org/10.5281/zenodo.4501505

Nick McHugh:
Contaminated Cabin Air: A Flight Safety Issue
https://doi.org/10.5281/zenodo.4464561

Susan Michaelis:
The Regulatory Implications of Bleed Air Supply Contamination
https://doi.org/10.5281/zenodo.4474513

David Michaels:
The Triumph of Doubt: Dark Money and the Science of Deception
https://doi.org/10.5281/zenodo.4464573

Rick Mlcak:
Monitoring Cabin Air Quality on Commercial Aircraft
https://doi.org/10.5281/zenodo.4464581

Ricardo Pavia:
Dealing with Cabin Odor Events
https://doi.org/10.5281/zenodo.4464585
Jordi Roig:
Respiratory Disease Caused by Aerotoxic Syndrome: A Case Series
https://doi.org/10.5281/zenodo.4464591

Dieter Scholz:
Cabin Air Contamination – A Summary of Engineering Arguments
https://doi.org/10.5281/zenodo.4450241

Moira Somers:
A GP's Perspective on Fume Events over 20 Years
https://doi.org/10.5281/zenodo.4464599

David Stein:
Collaborative Development of an Aircraft Fresh Air Filtration System
https://doi.org/10.5281/zenodo.4464609

Terry Tetley:
Health Effects of Air Pollution
https://doi.org/10.5281/zenodo.4464629

Antti Tuori:
IFALPA Position on Cabin Fume Events
https://doi.org/10.5281/zenodo.4464637
Fume events on aircraft: “How often?”

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Industrial Hygienist
Air Safety, Health and Security Department
Association of Flight Attendants-CWA, AFL-CIO

Aircraft Cabin Air Conference 2019
Imperial College London
Sept. 18, 2019
Study: ‘Toxic Air Events’ Happening On More Flights Than FAA Reports

By Susie Steimle  September 24, 2018 at 11:44 pm  Filed Under: Air Safety, airplane travel, Alaska Airlines, FAA, fume event, Strange Odor, Toxic Air
If something negative doesn’t happen very often, then it’s easy to justify not doing anything about it, especially if the consequences of it happening can be downplayed and dismissed.

(Little or no data = little or no problem)
What events must be reported?

- Service Difficulty Reporting regulation 14CFR121.703
  - Requires US airlines to report each “failure, malfunction, or defect” that causes “smoke, vapor, toxic or noxious fumes” to accumulate/circulate during flight (wheels up) or, technically, on the ground IF the airline is of the “opinion” that flight safety could have been “endangered”
  - Excludes events that are reported at the gate, during taxi out, after landing (UNLESS the airline deems that flight safety could have been compromised)
  - Excludes “NFF” – such as slow internal leak, worn but not failed seal, overservicing
https://av-info.faa.gov/sdrx/Query.aspx
More reporting rules in US

• Mechanical Interruption Reporting regulation 14CFR121.705
  – Each “interruption to a scheduled flight,” diversion, tail swap, etc. caused by known or suspected mechanical difficulties or malfunctions not required to be reported under SDR rule
  – So this could include fumes on the ground that caused cancelation, diversion, etc. even if a mechanical difficulty was only suspected...

• Hard to tally/track because there is no central database (the Certificate Management Office for each airline maintains them), and they are only kept for one year.
FAA Accident and Incident Data System (AIDS) which contains incident records “gathered from several sources” including incidents reported on FAA Accident and Incident Reporting Form (8020-23), that is mandatory, per FAA Order 8020.11D (2018)

https://www.asias.faa.gov/apex/f?p=100:12:::NO:::
FAA Form 8020-23: Accident/Incident Report Form

- Incidents must be reported -- “An occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operation.” (FAA Order 8020.11D, 2018)

Excerpt from reporting form:

- The FAA guidance to its inspectors on how to meet this incident reporting order lists various incident types; NMAC, PD
4) Unidentified Flying Object (UFO). If any FAA employee receives a report of a UFO, the individual making the report should be referred to the nearest scientific establishment or institution of higher learning that has expressed interest in such reports. If concern is expressed that life or property might be endangered, refer the individual to the local police department.” (FAA Order 8900.1, Vol. 7, Ch.1, 7-36(C)(4))

http://fsims.faa.gov/wdocs/8900.1/v07%20investigation/chapter%202001/07_001_002_chg_54c.htm
One answer to “how often”

- On Feb. 14, 2012, US Congress passed this law:

FAA MODERNIZATION AND REFORM ACT OF 2012

SEC. 917. RESEARCH AND DEVELOPMENT OF EQUIPMENT TO CLEAN AND MONITOR THE ENGINE AND APU BLEED AIR SUPPLIED ON PRESSURIZED AIRCRAFT.

(a) In General. -- Not later than 60 days after the date of enactment of this Act, the Administrator, to the extent practicable, shall implement a research program for the identification or development of appropriate and effective air cleaning technology and sensor technology for the engine and auxiliary power unit bleed air supplied to the passenger cabin and flight deck of a pressurized aircraft.
REPORT TO CONGRESS

FAA MODERNIZATION AND REFORM ACT OF 2012

SECTION 917
RESEARCH AND DEVELOPMENT OF EQUIPMENT TO CLEAN AND
MONITOR THE ENGINE AND AUXILIARY POWER UNIT (APU) BLEED AIR
SUPPLIED ON PRESSURIZED AIRCRAFT

Data Search:

Reported events considered in this assessment were collected through the Service Difficulty Reporting System (SDRS), National Transportation Safety Board (NTSB), FAA Accident Incident System (AIDS), and the FAA Voluntary Disclosure Reporting Program (VDRP). Each of these data sources was searched, using a text mining concept (including the terms: fume, odor, smell, smoke, and bleed air), for air carrier events of cabin air contamination by hydraulic or oil particulates.

A total of 69 events over a ten year period between 2002 through 2011 were found and reviewed. None of these reported events involved known injuries, fatalities, or damage as defined by 49 CFR Part 830\(^1\). These events are summarized as follows:

- Events involving oil contamination, 18.
- Events involving hydraulic oil contamination, 0.
- Events involving other contamination (smoke, fumes, other unknown), 51.
Summary of that FAA “report”

18 oil/hydraulic fume events per 104.9 million flights

= 0.00000017 or $1.7 \times 10^{-7}$ events per flight

Or 1 event per 5.8 million flights

The FAA conducted a safety database assessment of airliner cabin air quality events involving Part 121 commercial airline operators. The results of the analysis indicate an extremely low occurrence involving bleed air contamination from engine oil or hydraulic fluid. While there

As shown by the search summary, the occurrence of oil or hydraulic based contamination of bleed air is extremely low. In formulating the annual aviation safety research portfolio, the FAA evaluates the relative risk of aviation safety hazards and the potential for safety improvement. The FAA will continue to consider cabin safety risk and sponsor research in this area appropriate to the risk level.
If something negative doesn’t happen very often, then it’s easy to justify not doing anything about it, especially if the consequences of it happening can be downplayed and dismissed.

(Little or no data = little or no problem)
Facts are stubborn, but statistics are more pliable.

- Mark Twain
  Writer
Under the Freedom of Information Act (FOIA), Title 5 U.S.C. 552, I am requesting a copy of reports of smoke and fumes in the cabin/flight deck that the FAA received from US carriers from Jan. 1, 2002 through Dec. 31, 2011. Please include reports that contain one or more of the following search terms: fume, odor, smell, smoke, bleed air.
FAA response to FOIA request

- By law, FAA must make an initial response to FOIA request within 20 business days.
- I received my first response after 83 business days.
- 383 business days after my initial request, including resubmitting it, making phone calls and sending countless emails...
AID & SDR Data Extract

WARNING: The AID and SDR records provided on the enclosed CD-Rom are only accurate as of the day that the CD-Rom was made. Release of information from this CD-Rom after the date of production may involve the release of records that are inaccurate or invalid.
10 years of fume event data

- That CD listed **15,885 SDR records**, each of which contained one or more of these words: fume, odor, smell, smoke, bleed air; also, 365 AIDS reports

- Focusing on the SDRs, I excluded 3,448 SDRs that did not involve fumes/smoke/haze in the cabin/flight deck...

- I reviewed the remaining 12,437 SDRs and sorted each into the groups on the next slide, according to defined criteria. An expert mechanic and a pilot helped me with the 586 reports I wasn’t sure about, general questions...

- Data on next slide has undergone “first pass” review and classification, subject to review. Please do not cite (yet).
<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
<th>% reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>4,531</td>
<td>36%</td>
</tr>
<tr>
<td><strong>Bleed source (but specifics not defined)</strong></td>
<td>1,799</td>
<td>14%</td>
</tr>
<tr>
<td>Oil</td>
<td>1,336</td>
<td>11%</td>
</tr>
<tr>
<td>Fan</td>
<td>1,027</td>
<td>8.3%</td>
</tr>
<tr>
<td>Fuel</td>
<td>635</td>
<td>5.1%</td>
</tr>
<tr>
<td>Oven</td>
<td>387</td>
<td>3.1%</td>
</tr>
<tr>
<td><strong>Hydraulic fluid</strong></td>
<td>168</td>
<td>1.4%</td>
</tr>
<tr>
<td>Deicing fluid</td>
<td>137</td>
<td>1.1%</td>
</tr>
<tr>
<td>Duct (blown, disconnected, clogged)</td>
<td>106</td>
<td>0.9%</td>
</tr>
<tr>
<td>Battery</td>
<td>73</td>
<td>0.6%</td>
</tr>
<tr>
<td>Bird strike</td>
<td>42</td>
<td>0.3%</td>
</tr>
<tr>
<td>Engine wash</td>
<td>40</td>
<td>0.3%</td>
</tr>
<tr>
<td><strong>Other, defined but not listed (mostly packs)</strong></td>
<td>1,019</td>
<td>8.2%</td>
</tr>
<tr>
<td><strong>Source UNKNOWN or too vague to classify</strong></td>
<td>1,193</td>
<td>10%</td>
</tr>
<tr>
<td>Category description</td>
<td>N reports</td>
<td>% total</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>Confirmed/consistent with oil fumes in supply air</td>
<td>1,336</td>
<td>11%</td>
</tr>
<tr>
<td>Contaminated bleed source (specifics not defined)</td>
<td>1,799</td>
<td>14%</td>
</tr>
<tr>
<td>Other (mostly defective/failed pack issues)</td>
<td>1,019</td>
<td>8.2%</td>
</tr>
<tr>
<td>Unknown (fault not found or insufficient details)</td>
<td>1,193</td>
<td>10%</td>
</tr>
</tbody>
</table>

1. APU auto shutdown with smoke in cabin. Found threads stripped at the gearbox housing oil outlet port. This condition lead to an external oil leak. The oil was then drawn into the inlet thus causing the smoke in cabin. Borescope of the power section revealed diffuser vane erosion and hot section deterioration. Replaced APU.

2. During climb, the left aft smoke detector sounded and flight attendants reported odor in the cabin. Flight crew returned to departure airport. Maintenance replaced coalescer socks and performed a pack burnout. APU on MEL.

3. FLT 5745 - HSV-CLT - Returned to field due to smoke in the cabin with pack operation. Maintenance troubleshoot and isolated the right, causing the smoke. Maintenance replaced the right pack. Operation checks good. The aircraft was returned to service. (M)

4. During climb through 15,000 ft, the crew reported the odor of smoke in the cabin and flight deck. The aircraft returned to IAH and landed without incident where maintenance inspected the aircraft. Engine runs were performed operating the pressurization, air conditioning, and bleed systems and the odor could not be duplicated. The aircraft was test flown satisfactorily with no odor of smoke in the cabin or flight deck.

5. Diversion due to odor in aft cabin. MX in progress.
More findings

• The source of at least 10% of these fume events was unknown/undefined, and another 14%+ were consistent with a bleed source but not defined. Data shows:
  
  – ...that FAA should add some more standardized questions on the SDR form that airlines submit, in order to more clearly define the causes.
  
  – ...airlines struggle to define the sources of fumes and would benefit from reliable sensors that can, at a minimum, distinguish oil, hydraulic, and fuel, and also electrical (incl. fans), if there are suitable marker compounds.

• FAA should not make up numbers to justify inaction to Congress and should not take 383 business days to respond to a simple data request.

**FLIGHT 2140, LGA-BOS - STRONG ODOR DIRTY SOCK SMELL ON CLIMB. MAINTENANCE ACCOMPLISHED JOB CARD 43L00021001. NO DEFINITIVE ODOR PRESENT. REPLACED RECIRC FILTERS AS PRECAUTION PER AMM 21-24-02. PAN APU FOR 45 MINS WITH PACKS.**
Characterization of the frequency and nature of bleed air contamination events in commercial aircraft

M. Shehadi, B. Jones, M. Hosni
Mechanical and Nuclear Engineering Department,
Kansas State University, Manhattan, KS, USA

Abstract Contamination of the bleed air used to pressurize and ventilate aircraft cabins is of concern due to the potential health and safety hazards for passengers and crew. Databases from the Federal Aviation Administration, NASA, and other sources were examined in detail to determine the frequency of bleed air contamination incidents. The frequency was examined on an aircraft level, with data for 6 years (2007-12) of reported incidents. The average incident rate for all aircraft reported in this study is 0.2 incidents per 1000 flights, which is closer to the lower end of estimated range of 0.09-3.9 incidents per 1000 flights cited previously. However, the highest frequency model in this study was 0.8 incidents per 1000 flights. As long as the underreporting is more or less uniform, there should be no large relative impact in terms of the comparisons between aircraft models. It is entirely possible that underreporting could vary considerably from airline to airline due to reporting policies and other factors.
Another answer to “how often”, based mostly on FAA data

• Researchers found that US airlines reported 5.4 bleed air events fleet-wide per day (on average, over six years, from 2007-12) (Shehadi et al., 2016).

• If you take the “5.4 per day” documented over those six years and apply it to the 10 years, the number of fume events during the 10 years will be closer to 20,000 (not 18).
Oil and hydraulic fumes: How often?

• 2016 – published research paper
• FAA databases: 2007-12
• 1 event per 5,000 flights

• 2013 - FAA report to Congress
• Claimed FAA databases: 2002-11
• 1 event per 5.8 million flights
• “extremely low occurrence”
Facts are stubborn, but statistics are more pliable.

--U.S. Federal Aviation Admin.
Are any of these data comprehensive?

The 69 events represent the actual values obtained from this specific data search. While this data search may not represent all engine and APU bleed air contamination events in Part 121 operations, it does provide an accurate accounting of these events during the period from 2002 through 2011, on a search of the terms “fume, odor, smell, smoke, and bleed air.”

-FAA, August 2013 report to Congress

• Undoubtedly, these data are only a subset of the airline-reported fume events in the US.
  • “Fume, odor, smell, smoke, and bleed air” are not the only search terms for fume events.
  • The reporting rules are very limited in scope.
  • There is evidence that airlines underreport.
In summary:

• GLOBALLY, there are no national aviation fume event reporting systems for crews/passengers, despite decades of recommendations to create one.

• In the US, the “service difficulty reporting” regulation excludes ground-based fume events and “NFF” fume events, guaranteeing that the number of reported fume events will be significantly downplayed.

• There is evidence that US airlines significantly underreport (even reportable) fume events to all three databases.
Recommended action

1. SDR language needs to change:

Sec. 121.703

Service difficulty reports.

(a) Each certificate holder shall report the occurrence or detection of each failure, malfunction, or defect concerning—

(1) An aircraft component that causes accumulation or circulation of smoke, vapor, or toxic or noxious fumes in the crew compartment or passenger cabin during flight operation;

(b) For the purpose of this section during flight operation means the period from the moment the aircraft leaves the surface of the earth on takeoff until it touches down on landing, any person boards the aircraft with the intention of either flight or maintenance work and until such time as all such persons have disembarked.

And airlines should actually be held accountable to follow this regulation.
Recommended action:

2. Mandate that airlines train crew and maintenance workers to recognize, respond to, and report fumes, per ICAO Circular 344-AN/202

- Prompt recognition and response will mitigate exposure to fumes
- Reliable reporting essential to defining and addressing the problem
- Does not require any technology or changes to the aircraft; common sense
Recommended action:

3. Airlines need to be more discriminating customers

- Absent aviation regulators actually doing their job, airlines need to be more discriminating customers. Airlines need to create demand for non-bleed systems and bleed air filters/sensors by telling manufacturers that they want to buy them. (This is starting...)
In closing...

• Late 2014, I filed another FOIA request with the FAA, asking for a copy of the 69 fume event reports (and especially the 18 oil fume reports) that they told Congress about, plus documentation for how those reports were selected.

• And this time, after only 47 biz days and a few pestering emails, I received this response...
Dear Ms. Anderson:

This letter responds to your FOIA request dated December 3, 2014, concerning an AVS report to congress where the Federal Aviation Administration reported that it identified a total of 69 smoke/fume event reports found in its SDRS database over a 10-year period.

Your request was forwarded to multiple offices in the FAA to include the Office of the Associate Administrator for Aviation Safety (AVS). A records search was conducted in this office, but we did not locate any records or files pertaining to your specific request. Please be aware that your request was forwarded to the Office of Accident Investigation and Prevention, which prepared the referenced report. You will receive a separate response from that office.
Fume events on aircraft
Cabin Air Safety Act of 2019

A BILL

To improve the safety of the air supply on commercial aircraft, and for other purposes.

1. Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

2. SECTION 1. SHORT TITLE.

3. This Act may be cited as the “Cabin Air Safety Act of 2019”.

Introduced April 10, 2019
Questions?

Judith Anderson, MSc CIH
Industrial Hygienist
Air Safety, Health, & Security Dept.
AFA-CWA, AFL-CIO
judith@AFAnet.org – (001) 206-932-6237
AN APPROACH TO THE INVESTIGATION OF
SYMPTOMATIC PERSONS AFTER EXPOSURE TO
AIRCRAFT FUME EVENTS

Jonathan Burdon MBBS, MD, FRACP, FCCP
S. Michaelis, V. Howard, L. Budnik, A. Heutelbeck, X. Baur,
J. Roig, L. Coxon, J. Midavaine, H. Petersen, G. Hageman,
C.L. Soskolne, D. Gee, C. Furlong

For DiMoPEx COST-Action and Collegium Ramazzini working groups on Cabin Air Quality

Aircraft Cabin Air Conference 2019
Background and Overview

• Term ‘Aerotoxic Syndrome’ - Not accepted by some
• Aerospace industry does not like term
• Not all present with same symptoms
• Aircraft related illness suggested (CASA EPAAQ 2012)
• For now term reasonable & justifiable
Background - Guidelines

• Some past Guidelines – none comprehensive
• Acknowledged that Guidelines will vary
• Comprehensive Guidelines
  • Consensus view of international experts
  • Nearing completion
  • Synopsis presented today
• Pocket Guidelines planned
Scope of Presentation

• We are addressing
  • Bleed air contaminants/substances
    • Oils, hydraulic, de-icing fluids

• Not other pollutants
  • Pesticides
  • Infections
Technical Matters

• Medical need for understanding background of FE

• Outside air used to flush cabin & assist with pressurisation

• Pyrolysed oil in bleed air (design) - not Boeing 787 Dreamliner
  • No engine ‘bleed’ air filtration

• Good data assists in medical investigation/management

• Air exchange rates > than other indoor sites (sealed buildings)
Time of Presentation / Injury

- Time of presentation with illness after FE important
  - In-Flight
  - Immediate Post Flight
  - Late / Subsequent
- Most report symptoms in-flight or immediately after
- Fume event / Smoke / Long-term low dose exposure (months / years)
- Industry set standards – PROTECT MOST - NOT EVERYONE !
Time of Presentation / Injury

• Industry set standards

   PROTECT MOST - NOT EVERYONE!

• Set for ground level

• Not applicable to cabin environment
   • Altitude / complex pyrolysed mixtures
Presenting Symptoms

• Presenting symptoms - described elsewhere

• May involve all organ systems

• Duration
  • Hours, days, weeks, months
  • Sometimes, full recovery never occurs
### Table 2  Aerotoxic syndrome: short- and long-term symptoms

<table>
<thead>
<tr>
<th>Short term exposure</th>
<th>Long term exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neurotoxic symptoms: blurred or tunnel vision, nystagmus, disorientation, shaking and tremors, loss of balance and vertigo, seizures, loss of consciousness, parathesias;</td>
<td>Neurotoxic symptoms: numbness (fingers, lips, limbs), parathesias;</td>
</tr>
<tr>
<td>Neuropsychological or Psychotoxic symptoms: memory impairment, headache, light-headedness, dizziness, confusion and feeling intoxicated;</td>
<td>Neuropsychological or Psychotoxic symptoms: memory impairment forgetfulness, lack of coordination, severe headaches, dizziness balance, sleep disorders;</td>
</tr>
<tr>
<td>Gastro-intestinal symptoms: nausea, vomiting;</td>
<td>Gastro-intestinal symptoms: salivation, nausea, vomiting, diarrhoea;</td>
</tr>
<tr>
<td>Respiratory symptoms: cough, breathing difficulties (shortness of breath), tightness in chest, respiratory failure requiring oxygen;</td>
<td>Respiratory symptoms: breathing difficulties (shortness of breath), tightness in chest, respiratory failure, susceptibility to upper respiratory tract infections;</td>
</tr>
<tr>
<td>Cardiovascular symptoms: increased heart rate and palpitations;</td>
<td>Cardiovascular symptoms: chest pain, increased heart rate and palpitations;</td>
</tr>
<tr>
<td>Skin symptoms: skin itching and rashes, skin blisters (on uncovered body parts), hair loss;</td>
<td></td>
</tr>
<tr>
<td>Irritation of eyes, nose and upper airways.</td>
<td>Irritation of eyes, nose and upper airways;</td>
</tr>
<tr>
<td>Sensitivity: signs of immunosuppression, chemical sensitivity leading to acquired or multiple chemical sensitivity</td>
<td></td>
</tr>
<tr>
<td>General: weakness and fatigue (leading to chronic fatigue), exhaustion, hot flashes, joint pain, muscle weakness and pain.</td>
<td></td>
</tr>
</tbody>
</table>

Winder et al 2005
In-Flight Investigation of Fume Event: Environmental

Record

• Type of aircraft
• When did event occur (stage of flight)?
• Where in the aircraft?
• What happened (smell, fumes, smoke)?
• How long did the event continue?
• Describe type of smell
• Who and how many (x out of y) affected?
• Record air quality monitor recordings (if available)
Medical Investigation of Fume Event: In-Flight

- Detailed careful history of FE including severity
- Record
  - Previous FE exposure and frequency, length of service
  - Symptoms and progression of symptoms
  - Observations of others
  - Any treatment given/used
  - Oxygen use (when/duration) including flow rate
  - Unusual behaviour
  - Pre-existing medical conditions
  - Trained medical personnel may record more
  - Treatment given
Medical Investigation of FE: Post Flight

• Medical, occupational and FE event history as before

• Will be more detailed – doctors involved!

• History of career flying time

• Detailed clinical examination
  • All organ systems
  • Emphasis on presenting complaints, neurological and respiratory systems
  • Mental and cognitive state important

• Special investigations - appropriate for presenting complaints
Medical Investigation of FE: Post Flight

• Special Investigations
  • Collect blood as soon as possible (record time from exposure)
  • Cholinesterases (record collection time) – activity assay v Mass spec
  • Routine biochemistry, haematology, muscle enzymes
  • Others, as clinically indicated
  • Carboxyhaemoglobin - HbCO (within 2 hrs post flight, maximum 4 hrs)
  • Methaemoglobin
  • Collection time should be recorded as well as time from exposure.
Medical Investigation of FE: Ongoing Biomonitoring

- After immediate post flight assessment
  - Investigations based on clinical indication
  - Commonly blood and urine
  - Noting need for repeat cholinesterase measurements
  - Unlikely pre-exposure levels measured
  - Measure again at week 1, 4, 12 weeks or symptom stability
  - Number agents / VOCs causing symptoms – probably not just TCP
  - Ongoing biomonitoring allows toxicological assessment relative to symptoms
Medical Investigation of FE: Ongoing Investigations

• Investigations based on clinical indication

• In particular
  • Neuronal and glial autoantibodies – indicate neuronal injury and gliosis
  • Detailed lung function testing may be needed to detect respiratory injury
  • Neurological defects – MRI scans, MRI/PET scans more sensitive
  • Neurobehavioural – Tests include Coding test (Processing speed), Problem solving, Learning, Memory, Sleep studies and others
  • Malignancy – Emerging reports of some cancers
Medical Investigation of FE: Emerging Areas

• Long recognised that fine particulates affect health

• Underscores issue of air quality standards

• Low level recurrent exposures may be cumulative in effect

• More recently ultrafine (nanoparticles) noted more toxic
Conclusions

• Preparation of medical protocol publication
• Long journey by many
• Some previous Guidelines and Protocols
• None as comprehensive as present
• Consensus document - Internationally expert authors
• Pocket Booklet being prepared for Guidance (What to do) for
  • In-Flight event
  • Medical personnel
• Be patient – we are almost there !
Cabin Air Contamination

An Accident Investigator’s Perspective
My Background

▪ Tony Cable:
  • UK AAIB:
    • Accident Investigator for 32 years, until 2009, concentrating on Engineering aspects.
  • AFTA:
    • Advisor on analysing technical failures for 20 years.
  • Specialisations:
    • Investigation.
    • Making effective Safety Recommendations.
ICAO Annex 13

- Annex 13:
  - Standards & Recommended Practices:
    - For inquiries into aircraft accidents and incidents with international involvements.
- Many accident investigation bodies operate under regulations that generally reflect Annex 13.

ICAO – UN International Civil Aviation Organisation

In the following the term “accident Investigation body” refers to official governmental investigation bodies
Accidents & Incidents – Annex 13

▪ ‘Accident’ definition:
  • An event where the result is:
    • Serious injury (defined), and/or
    • Significant aircraft damage (certain exclusions).

▪ ‘Incident’ definition:
  • An event where:
    • No injury or damage, but safety was, or could be, affected.

In the following the term “Accident” includes an Incident
Serious Incident

▪ Annex 13 definition:
  • ‘Circumstances with a high probability of an accident’:
    • “The difference between an accident and a serious incident lies only in the result”.

▪ Annex 13 lists examples, including:
  • ‘Fires and smoke in the cabin’.
  • ‘Flight crew emergency use of oxygen’.

▪ Pilot impairment would qualify.
Purpose of Investigating

- Annex 13 defines the objective of investigation as:
  - ‘Solely to prevent accidents or incidents.’
  - ‘It is not the purpose to apportion blame or liability.’
Contamination Events

- Frequency of airliner cabin air contamination:
  - Aviation Safety websites suggest to me that there tend to be around 2-3 reported cases/day:
    - Smoke.
    - Fumes/Mist.
    - Odour.

- Result:
  - Generally a flight abort and landing.
    - Possibly with pilot(s) impaired.
    - Certainly costly.
Incident Investigation

Investigation of Incidents:

• Official investigation resources are often limited.
• Most accident investigation bodies only investigate incidents designated as a ‘Serious Incident’.
• The decision to make this designation:
  • Is generally by the responsible accident investigation body.
  • Tends to be subjective.
Air Contamination Investigation

- Irrespective of Annex 13:
  - Possible that many contamination events are not subject to official investigation.
Account of One Event

• “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.”
Sources of Contamination

- Principal possible sources:
  - Electrical system malfunction.
  - Hydraulic system malfunction.
  - Oven overheat.
  - Consumer electronics battery overheat.
  - APU oil.
  - Engine oil.
Cabin Air Source

- Typical source of pressurised conditioned air for an airliner cabin:
  - Air bled from the compressors of the gas turbine engines (and/or from an APU).
Engine Oil Containment

- Engine shaft bearings:
  - Multiple bearings:
    - Contained in bearing chambers inside the engine.
    - Lubricated and cooled by engine oil.

- Separation of oil from bleed air:
  - Labyrinth or carbon seal at each end of the bearing chamber (where penetrated by a rotating shaft).
Seals

- Seal pressurisation:
  - Pressurised air is applied to the outside of the seal.
  - The aim is to regulate the pressures so as to maintain an airflow into the bearing chamber.
  - This should prevent oil escape from the chamber.
  - The pressure must be limited to avoid:
    - Wastage of compressed air.
    - Excessive airflow into the oil system.
Oil Seal Performance

- Seal performance:
  - Generally highly effective at preventing much oil from escaping from bearing chambers.
  - The oil consumption of gas turbine engines typically is normally very low.
  - But – this does not mean that either:
    - Cabin air is free of all oil/oil products.
    - Even small traces of oil in the air is necessarily safe.
Oil Leakage Across a Seal

- Seal leakage control:
  - Control of air pressures within engine compartments aims to maintain the correct pressure gradient across each bearing chamber:
    - Appears to be a complex design issue.
    - It appears that the correct pressures might not be maintained:
      - During variation in the engine power level.
      - If an oil seal malfunctions.
  - Oil could escape into the compressor airflow, producing oil mist in the cabin.
Seal Malfunction

- Malfunctions possibly allowing oil escape into the compressor air (and hence the bleed air):
  - Deterioration of bearing.
  - Damage to oil seal component.
  - Obstruction of oil and/or air pipes in the engine.
  - Inadequate scavenging of oil, allowing it to pool in:
    - Engine
    - APU
    - Air ducts
    - Airconditioning units.
## Safety Recommendations

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Reports Making Recommendation</th>
<th>Number of Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Sweden</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>UK</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Ireland</td>
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<td>1</td>
</tr>
<tr>
<td>Iceland</td>
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<td>1</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
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<td>1</td>
</tr>
<tr>
<td>Austria</td>
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<td>5</td>
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<tr>
<td>UAE</td>
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<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>45</td>
</tr>
</tbody>
</table>
Additional Contamination Investigations

▪ Other contamination events:
  • Investigated, and reported on, by nine national accident investigation bodies.
  • Without Recommendations being made.
<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airworthiness/Maintenance/Certification</td>
<td>9</td>
</tr>
<tr>
<td>Data analysis</td>
<td>3</td>
</tr>
<tr>
<td>Reporting</td>
<td>3</td>
</tr>
<tr>
<td>Education &amp; training</td>
<td>3</td>
</tr>
<tr>
<td>Checklist/mandatory oxygen use, at 100%</td>
<td>5</td>
</tr>
<tr>
<td>Mandatory use of Personal Breathing Equipment</td>
<td>1</td>
</tr>
<tr>
<td>Crew &amp; Passenger protocol during and/or after event</td>
<td>5</td>
</tr>
<tr>
<td>International database</td>
<td>2</td>
</tr>
<tr>
<td>Recommendation</td>
<td>Number</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Research - oils and effect on health</td>
<td>8</td>
</tr>
<tr>
<td>Develop treatment protocol</td>
<td>1</td>
</tr>
<tr>
<td>Research – identify oil contaminants in cabin air</td>
<td>1</td>
</tr>
<tr>
<td>Detection/Warning systems</td>
<td>7</td>
</tr>
<tr>
<td>Filtration</td>
<td>1</td>
</tr>
<tr>
<td>Emergency evacuation procedures</td>
<td>1</td>
</tr>
<tr>
<td>Safety risk assessment</td>
<td>2</td>
</tr>
</tbody>
</table>
Sample Recommendation - 1

- UK AAIB Safety Recommendation 2007-002 (paraphrased):
  
  • ‘It is recommended that the EASA and the FAA consider requiring a system to provide a flight deck warning of smoke or oil mist in the air delivered from each air conditioning unit.’
Sample Recommendation - 2

- Germany BFU - Safety Recommendation 07/2014 (paraphrased):
  
  ‘EASA should implement a demonstration of compliance of cabin air quality during type certification of aircraft, engines and APU such that permanent adverse health effects resulting from contaminated cabin air are precluded.’
Investigation Output

- Output – aimed at preventing recurrence:
  - Published information:
    - From which others can learn.
  - Safety Recommendations:
    - Principal output.
    - Generally addressed to:
      - Airworthiness Regulators.
      - Manufacturers.
      - Operators.
Response to Recommendations

▪ Are Recommendations likely to be effective at preventing recurrence?:
  • Only if the recipients take effective action.

▪ Do recipients tend to take effective action?:
  • Very frequently not, in my experience.
Experience of Recommendations

- In my experience:
  - The aim of many recipients appears to be to avoid taking action:
    - Often apparently on the grounds of cost:
      - but short-term vs much larger potential long-term cost.
  - It seems that large aircraft manufacturers can and do have appreciable influence on their regulator.
Wording of Recommendations

- The wording can influence the effectiveness:
  - Wording along the lines of:
    - “The regulator shall require . . . .“
  - Is much better than:
    - “The regulator shall consider requiring . . . .“
  - The “consider” Recommendation commonly seems to be a waste of time.
“Procedures Not Followed”

A common response to a Recommendation:

- ‘Ground/flight crew didn’t follow correct procedure.’
- ‘This caused the accident.’
- ‘Thus corrective action is not required.’

This ignores the fact that crew might not always follow procedures, because of:

- Accidental omission – an inevitable Human Factor.
- Task overload in a very highly confusing situation.
- Consequent sheer inability to identify the situation, and thus the necessary procedure.
Cabin Air Recommendations

- Known investigations of incidents:
  - 45 Safety Recommendations:
    - From over 15 published reports.
    - Carried out by over 13 investigation bodies.

- Response to Recommendations:
  - Often difficult to assess in detail over an extended period if a Recommendation has prompted action.
  - Information suggests few signs that effective action has been taken on most of the Recommendations.
Accident Recurrence

Investigation experience shows:

- Accidents where a previous similar event(s) did not provide a clear warning are rare.
- Many cases where repeat accident(s) result from lack of effective action on Recommendations.
Current Situation

- It appears that much remains to be done on:
  - Determining the levels of oil products in cabin air:
    - During normal operation.
    - During smoke/fume events.
  - The possible chronic & acute effects of the levels.
  - Means to warn of unacceptable oil levels.
  - Means to prevent oil entering the cabin.

Thank you
Occupational Health Problems among Flight Attendants

Presented by James Cone, MD, MPH
Aircraft Cabin Air Conference
9/18/2019
William Carley, Wall Street Journal 1977:

“Airline crew members and passengers may face a new hazard: ozone sickness, which has apparently struck hundreds of people during recent flights.”
Studies have suggested that flight attendants may experience increased rates of respiratory symptoms, particularly associated with exposures to long-haul flights.

This association is plausible because flight attendants are known to experience exposures to respiratory irritants: Ozone, specific chemicals including hydraulic fluids, engine oils, jet fuel and pesticides, cigarette smoke (prior to ban), and viral infectious diseases.
OFFICIAL PRONOUNCEMENTS AT THE TIME

- J. Donald Collier, Director, Environmental Affairs, Air Transport Association: “The record and experience of over 20 years of jet operations is conspicuously quiet on health problems related to air quality”.

- FAA: “Standards for air quality are satisfactory”.

- John P. Reese, Aerospace Industries Association: “Air quality in aircraft cabins is equal to or better than the air quality in other environments”.
Xenix Corporation: Made ventilation systems for aircraft. Petitioned FAA in 1980’s for aircraft cabin air quality standards. They accused the FAA of “a premeditated effort to stonewall and obstruct the efforts to establish meaningful health and safety standards”.
UC Berkeley/CA Department of Public Health Study – IUFA – Reed (1980)
NIOSH Study – IUFA – Malignant melanoma (1981-82)
APFA Study #1 – Cone and Cameron (1983)
APFA Study #2 – Cone and Cameron (1983-4)
IUFA study – Cone and Earle (1983-4)
AFA study – Reproductive hazards (1994)
CA Department of Public Health-AFA Study – Reynolds and Cone – Breast cancer and malignant melanoma (1999)
Study initiated by IUFA representing American Airlines flight attendants.

Symptoms reported particularly on SFO-HNL turnaround flights.
Symptoms of respiratory distress, sinus congestion, nasal pain, blocked eustacian tubes and nosebleeds are associated with exposure to airborne contaminants while flying.

Specific types of aircraft are associated with increased frequency of symptoms.

Mobil Jet II oil is the cause of the increased symptoms.
Individual flight attendants were examined at the SF General Hospital Occupational Health Clinic.

Questionnaire survey distributed to all flight attendants on the SFO-HNL turnarounds, total of 5 flights each.

Additional group of flight attendants flying turnarounds from LAX-HNL were surveyed.

Investigation into the chemicals contained in Mobil II oil.
Four flight attendants were examined. All identified “dirty socks odor” associated with symptoms. Symptoms sometimes occurred even without the odor, however.

Odor and symptoms were most frequently reported on DC-10-10 aircraft. Odor was strongest in over-wing section and galleys. Also in cockpit.

Odor strongest on taxi, take-off and landing.
“DIRTY SOCKS” ODOR

- Odor more pronounced when Mobil II jet oil was used.
- Odor was reduced when water separator bags were changed.
- American Airlines correspondence indicated that management also suspected Mobil II jet oil to be culprit. They suspected contamination of the Auxiliary Power Unit (APU) door or inlet duct by oil from the #2 engine. Contamination of heat exchangers and insufficient cabin ventilation were also suspected.
POTENTIAL EXPOSURES

- Turbine oils: Mobil Jet II oil is a synthetic oil containing tri-cresyl phosphates: known eye, skin and mucous membrane irritants.

- Hydraulic fluids: Also contained phosphate esters.

- Other potential chemical exposures: NOX, O3, cigarette smoke, formaldehyde, pyrolysis products of engine oils, jet fuel and hydraulic fluid.
Clinical evaluation: Symptoms of nasal burning, headache, eye tearing, nasal discharge, sneezing, sore throat, hoarseness, cough and hearing difficulties after beginning to fly SFO-HNL turnarounds.

Symptoms lasted 1-5 days.
58 questionnaires received from flight attendants on SFO-HNL turnarounds over 3 day period, 8/15/83-8/17/83. Participation rate 100%

Age: 34-44, mean = 37 years.

All were female. 17 were smokers. 42 reported prior allergies.

Unusual odors noted by 14/20 flight attendants working on one particular aircraft, on taxi and descent.

Odors described as “dirty socks”, musty or “petroleum burning”.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>#</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye</td>
<td>38</td>
<td>66</td>
</tr>
<tr>
<td>Nose</td>
<td>35</td>
<td>60</td>
</tr>
<tr>
<td>Sinus</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>Chest</td>
<td>12</td>
<td>21</td>
</tr>
<tr>
<td>Ear</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>Central Nervous System</td>
<td>10</td>
<td>17</td>
</tr>
</tbody>
</table>
Symptoms are caused by one or more air contaminants. At least one of these contaminants is the probable cause of the “Dirty Socks” odor.

Concentrations vary by aircraft type, location within aircraft, and phase of flight.

Mobil II jet oil implicated as a possible causative agent.
PHASE I STUDY RECOMMENDATIONS

- Identification of all likely cabin air contaminants
- Industrial hygiene sampling of likely contaminants during each phase of flight
- Eliminate causes of exposure, improve maintenance procedures, or engineering changes to aircraft: e.g., more frequent changes of water bags, burn out contaminants from A/C systems, clean APU door/inlet, change to different engine oil, increase fresh air flow.
- Respiratory protection for flight attendants in the meantime.
- Medical / Epidemiologic Surveillance of airline crew for symptoms reported.
Meetings with medical department, American Airlines

Expansion of symptom survey to include other bases and airlines using other equipment.

Industrial Hygiene Survey onboard flight, SFO-HNL turnaround, on a DC-10 aircraft. Sampling for O3, NOX, SO2, phosphoric acid esters, organic vapors.
Sampling results: Nitrous oxide detected on 3 segments of the flight, at concentration of 1 ppm. One segment with nitrous oxide also had “dirty socks” odor noted. No other contaminants detected.

A total of 683 questionnaires were received out of 720 distributed (95%)

Age: Mean of 36 years.

88% female.

Allergy history: 36%


68% were non-smokers.

Aircraft: N (%)
- 747 170 (26%)
- DC-10-10 275 (39%)
- DC-10-30 237 (35%)
PHASE II SURVEY RESULTS

- Symptoms: Statistically significant associations seen with type of aircraft and eye, nose, throat and sinus irritation, eye dryness, watery eyes, redness, burning eyes, nose itching, nasal discharge and dryness, and sinus burning, congestion and pressure/pain.

- Shortness of breath, dizziness and lightheadedness associated with type of aircraft.

- Boeing 747 and DC-10-10 both associated with increased risk of symptoms

- Base: Oakland (World Airways) flight attendants had lower risk of symptoms.

- Dirty Socks Odor: Significantly associated with eye, nose and sinus irritation symptoms.
Flight attendants flying DC-10-10 or Boeing 747 aircraft are at significantly higher risk of developing irritant/allergic rhinitis, particularly after exposure to “Dirty Socks” odor.

Symptoms suggest a powerful mucous membrane and respiratory irritant.

Nitrous oxide was measured on one flight. It is a known respiratory irritant. Levels were lower than usually associated with such symptoms.

Prime suspect agents: Vaporization, combustion / pyrolysis products of aircraft fluids, particularly engine oils.
Flight attendants who have developed symptoms of rhinitis or upper respiratory / eye irritation should be removed immediately from further exposure. Make O2, cartridge respirators available.

All air packs should be operating at all times.

Destructive analysis of Mobil II jet oil.

Further study by FAA or others to determine, cause of the problem, and institution of engineering controls to eliminate the source.
1000 members of the Independent Union of Flight Attendants based in SFO and London were surveyed regarding symptoms and exposures, March 1983-April 1984.

Prospective study of peak expiratory flow rates using a miniature hand-held device to measure lung function before, during and after flights.
PHASE III STUDY RESULTS

- A total of 280 questionnaires were returned. (28%).
- Age: Predominantly 40-49 years of age.
- 90% female.
- Chest pain or tightness reported by 65% of participants. Cough 57%; 38% said they usually had symptoms of shortness of breath or chest tightness while flying.
- Equipment: Boeing 747 SP associated most frequently with symptoms (62%).
• 8 out of 20 selected to participate in this phase completed testing.

• 2 of 8 had evidence on PEFR of >20% drop over a 24 hour period. Both were associated with long-haul flights. All 8 had small but measurable drop in mean PEFR comparing pre-flight to post-flight measurements. 7/8 had a statistically-significant drop in PEFR.
Results of our studies of flight attendants in the early 1980’s demonstrated consistent symptoms and some evidence of decreased pulmonary function associated with certain aircraft / flights.

Symptoms are similar to those reported in the study performed in 1978 by CA Department of Public Health.

Contamination of the Auxiliary Power Unit by engine oil was recognized over 35 years ago as a likely cause of symptoms among flight crews.
British Airways Evacuates Smoky Plane

By ILLANA MAGRA

LONDON — The cabin of a British Airways flight filled with what appeared to be smoke as it prepared for landing in Spain on Monday afternoon, prompting the airline to evacuate more than 170 passengers, with three taken to the hospital.

In an emailed statement on Tuesday, the airline acknowledged that its Flight BA122 from Heathrow Airport near London had experienced a technical issue on its landing approach into Valencia, Spain’s third-largest city.

The statement added that three passengers had been taken to a hospital as a precaution and had since been discharged, and that the airline was investigating the details of what had happened.

That came as little comfort to many of those onboard the flight, some of whom posted on social media about their experience.

Most passengers were barely discernible through the white smoke or vapor in a video shared on Twitter by Gayle Fitzpatrick, one of the passengers on the flight.

Neither the crew — some of whom, according to passengers, put on oxygen masks and protective fire gear — nor the airline said anything to the passengers about what happened. Ms. Fitzpatrick, a corporate governance manager at Audit Scotland, said in a message on Tuesday.

“We are still waiting to hear what happened,” she said. “It was very scary.”

Thomas Budd, a lecturer in airport planning and management at Cranfield University in Britain, said potential causes of smoke in a plane cabin included electrical failures, overheating equipment, galley spillages and hot-air leaks from pneumatic ducts.

In this case, the flight was nearing its finish when the plane started descending rapidly, and “a horrible white acid smoke” began to fill the cabin, Ms. Fitzpatrick said.

“Detective was going off,” she added.

There was a smell of metal and chemicals, Lucy Brown, another passenger, said in a message on Tuesday. “We covered our mouths with our clothes,” she said. “We don’t know why oxygen masks didn’t deploy.”

Passengers shouted they couldn’t breathe, she added.

Others were crying and hyperventilating, Ms. Fitzpatrick said, but eventually everyone was evacuated — 175 passengers were onboard, along with six cabin crew members and two pilots. British Airways said — by going down chutes after the crew opened the emergency doors.

Ms. Fitzpatrick said on Tuesday that she was still in shock, adding that both she and her husband still had sore chests.

Ms. Brown, who said that she had to wait seven hours after landing to get her luggage, wrote on Twitter on Monday that the experience was terrifying.

“Felt like a horror film,” she said. “Hopefully we’ll find out what went wrong on the plane soon so it never happens again.”
1. Janet Wei, MD, Chrisandra Shufelt, MD, MS, Eveline Oestreicher Stock, MD, Claire Mills, RDMS, RVT, Shivani Dhawan, MS, Riya Jacob, BASc, Tina Torbati, BS, Galen Cook-Wiens, MS, Neal Benowitz, MD, et al. Vascular aging is accelerated in flight attendants with occupational secondhand smoke exposure. JOEM 2019.


3. McNeeley E. Symptoms related to new flight attendant uniforms. BMC Public Health 2019
Legal Summary

THIS PRESENTATION IS ONLY A SNAPSHOT, OF SOME OF THE LEGAL CASES FROM AROUND THE WORLD, THAT ARE AVAILABLE IN THE PUBLIC ARENA.

IN PROVIDING CASES FROM AROUND THE WORLD, I AM NOT PROVIDING LEGAL ADVICE IN ANY FORM.

ANY OPINIONS EXPRESSED, ARE MY PERSONAL OPINIONS, BASED ON EXPERIENCE AND OR KNOWLEDGE AND NOT THOSE OF OTHERS.

JUDY CULLINANE
Covering Snapshot

- Key Messages
- OHS Tribunals Canada
- British Columbia WCAT From Workers Compensation Appeal Canada
- Labour Court Germany
- Social Court Germany
- Amsterdam Court
- France Court
- Workers Compensation & Appeal Board Pennsylvania USA
- Department of Labor and Industry Pennsylvania USA
- Virginia Court USA
- Latest Fume Events
- Workers Compensation Court Australia
- Australian Senate Inquiry 2000
- Australia Dust Diseases Tribunal
- Workers Compensation Court Australia - Perth
- How did Ansett Australia stop Workcover Claims
- Dismissing Claims
- Discontinued or Filed for Bankruptcy Australia
- Civil Cases Awarded/Settlements
- What Emergency Landing?
- Pilots Loss of License
- Coroners Findings
- Still Going
- Court Trial Dates for 2020
- Common Threads
- Takeaway
- Thank You 😊
Airlines consider operational and financial risk, **but why not the health risk?**

Airlines are not expected to ground fleets, **but they are excepted to maintain - maintenance schedules, act on reports, adhere to regulations - cabin airflow and uphold Occupational Health and Safety.**

Airlines (most airlines) require a full medical assessment, including a chest x-ray – you must have 100% health…to be employed…**so what happened in your working environment…?**

**While industry work to find solutions, please don’t forget the people, who have lost their health and careers through no fault of their own.**
Ms. Martinez was employed by Air Canada as a flight attendant and a member of the flight attendant bargaining unit represented by the Canadian Union of Public Employees (CUPE). On November 29, 2011, she operated flight AC 460 from Toronto to Ottawa aboard an Airbus A319 identified as Fin 277.

According to HSO Pollock, during that flight Ms. Martinez noticed an odour in the cabin which she described as “dirty wet sock smell” to which she attributed nausea and headache. She thus refused to operate the return flight to Toronto (AC 465) on the basis that the odour constituted a danger.

A joint report from the flight deck crew (G. Mongrain and M. Lefebvre) indicates that Captain Mongrain advised the Service Director prior to departure of flight AC 460 of a defect log entry concerning an inoperative Auxiliary Power Unit (APU) valve which would result in no air conditioning from the APU, require the first engine to be started at the gate prior to pushback and a second engine cross bleed start after pushback.

The HSO report indicates that during the pre-flight safety briefing for AC 460, the Service Director advised the cabin crew, including Ms. Martinez, that Fin 277 had a history of a “dirty, wet sock” odour in the cabin.
**Diaz Delgado et al. v. Air Canada**  
**Date:** 2015-08-27  **Case No.:** 2011-38 and 2012-22  **Citation:** 2015 OHSTC 15

**Between:** Francisco Diaz Delgado, Meng Liang and Hadin Blaize, Appellants and Air Canada, Respondent

**Matter:** Appeals under subsection 129(7) of the Canada Labour Code of directions issued by a health and safety officer.

**Decision:** The decisions that a danger does not exist is confirmed.

**Reasons**

1. These cases concern appeals brought under subsection 129(7) of the Canada Labour Code (the Code) by the appellant employees of Air Canada, of decisions that a danger does not exist rendered under subsection 129(4) of the Code by Health and Safety Officers (HSOs) Mary Pollock and Rochelle Blain on March 26, 2012, and July 18, 2011, following their investigations into work refusals by the appellant Air Canada employees Diaz Delgado, Liang and Blaize.

2. Given the commonality of documentary evidence and testimony, **these two appeals were heard together with two other appeals which were brought under subsection 146(1) of the Code by employer Air Canada concerning directions issued under subsection 145(1) of the Code on November 4 and December 23, 2011, by HSO Mary Pollock pursuant to her investigation into work refusals by Air Canada employees Claudia Martinez and Jerome LaPorte (Air Canada appeals).** The circumstances of the latter appeals are very similar to the appeals dealt with in the present decision. A separate decision will deal with these Air Canada appeals.

Appeals under subsection 129(7) of the Canada Labour Code of two decisions rendered by a health and safety officer.

Decision The two decisions are rescinded.

Reasons

1. This decision concerns the redetermination of two appeals brought under subsection 129(7) of the Canada Labour Code (Code) against two decisions that a danger does not exist rendered under subsection 129(4) of the Code.

2. Health and Safety Officer (HSO) Rochelle Blain rendered the first decision that a danger does not exist on July 18, 2011, following an investigation prompted by the work refusal of five of the respondent’s employees. Mr. Francisco Diaz Delgado and Mr. Meng Liang, two of the employees who had filed a work refusal, filed an appeal of HSO Blain’s decision on July 28, 2011.

3. HSO Mary Pollock rendered the second decision that a danger does not exist on March 12, 2012, following an investigation prompted by the work refusal of Ms. Hadin Blaize, another of the respondent’s employee. Ms. Blaize filed an appeal of HSO Pollock’s decision on April 13, 2012.

Decision

[115] For all of the reasons stated above, I conclude that the refusing employees in the present appeals were well founded in claiming danger when they exercised their right to refuse to work. Following redetermination of the decision, I rescind the original decisions of absence of danger rendered by HSOs Pollock and Blain. (Smell, history of reported problems Person suffered accident at work – had the right)

Francisco Diaz Delgado, Meng Liang and Hadin Blaize and Air Canada
Air Canada v. Canadian Union of Public Employees  Date: 2015-08-27. Case No.: 2011-62 and 2012-06 Citation: 2015 OHSTC 14

Matter: Appeal under subsection 146(1) of the Canada Labour Code of directions issued by a health and safety officer.

Decision

- The direction under subsection 125.2(1) of the Code is rescinded.
- The direction under paragraph 125(1)(s) is confirmed.
- The direction under paragraph 125.1(f) of the Code and section 5.4 of the Aviation Occupational Health and Safety Regulations is confirmed.

Reasons

- [1] These cases concern appeals brought under subsection 146(1) of the Canada Labour Code (the Code) of directions issued by Health and Safety Officer (HSO) Mary Pollock on November 4, 2011 and December 23, 2011.

- [2] In both cases, the issuance of these directions was preceded by a finding of “danger” by said HSO at the conclusion of her investigation into the work refusals registered by the two refusing employees. In both instances, the appellant formulated its appeal by stating that it was appealing “the finding of danger” in the directions issued by HSO Pollock. For the purpose of hearing and determination on the merits and given the great facts and circumstances similarity as well as the commonality of documentary evidence and testimony, these two appeals were heard simultaneously with two other appeal cases, those having been brought under subsection 129(7) by employees of the present appellant against the decisions that a danger does not exist rendered pursuant to subsection 129(4) of the Code respectively by Health and Safety Officers Mary Pollock and Rochelle Blain on March 26, 2012 and July 18, 2011. A separate decision will deal with those appeals.
British Columbia WCAT
From Workers Compensation Appeal Canada

Tracey Morey Flight Attendant WCAT Decision Number: WCAT-2006-02748-AD. WCAT Decision Date: June 30, 2006

Original decision

By a claims adjudicator at the Workers’ Compensation Board (Board), disallowing her claim in relation to symptoms experienced during and after her shift as a flight attendant on November 10, 1999. Dissatisfied with the Review Board findings, the worker brings this further appeal.

Under section 239 of the Workers Compensation Act (Act), WCAT is authorized to consider and decide appeals such as this one. Section 254 of the Act gives WCAT the exclusive jurisdiction to inquire into, hear and determine all questions of fact and law which may arise or need to be determined in an appeal.

In WCAT Decision #2006-02747-AD. Both the cited findings, draw on analysis of section 5 of the Act and item #13.00 of RSCM…to show the alleged toxic exposure experienced by the worker was a compensable injury.

“In view of all the evidence, I find the worker did suffer a personal injury on November 10, 1999 which arose out of and in the course of her employment. She was disabled by the initial acute symptoms and by the lingering dizziness and vertigo described in the medical reports here considered.”

Conclusion

For the reasons indicated, the worker’s appeal is allowed and the October 19, 2001 Review Board findings are varied accordingly. At the Review Board level, the worker’s representative requested reimbursement for the medical-legal report from Dr. Chin. This was denied by the Review Board, however I now allow it.
In its judgment, the Labour Court (Sozialgericht) assumes that the applicant was with high certainty a victim of a work injury. The following factors were decisive: Since the fifties of the last century, there has been a large number of cases in which health problems have been reported by aircraft personnel or passengers, without warning odours. After reviewing and evaluating all individual points of view, the Freiburg Court concluded that an accident had occurred.

The applicant has thus become a victim of a work injury.

The First Chamber of the Sozialgerichts Gießen dismissed the action.

- It could not be established that a toxic effect had taken place on the flight. The prerequisite for the determination of an occupational accident is that the insured activity, the harmful effects as well as the illness, because of which compensation is claimed, are proven. On the other hand, the probability of the causal link is sufficient for the recognition of a health disorder as a result of harmful effects.

The full proof is provided if the fact requiring proof is proved with certainty - was lacking.

- The Court did not overlook the fact that numerous aspects of this complex issue, such as the possibility that the occurrence of so-called fume events are related to the procedure for obtaining cabin air, had so far not been clarified or were disputed. However, this does not lead to an easing of the burden of proof or even a reversal of the burden of proof for all subjectively or objectively perceived changes in smell during a flight. This would only be conceivable if a large number of passengers and insured persons were demonstrably ill on such a flight, which was not the case here. It was only certain that an unpleasant smell had been perceived by the plaintiff and other crew members. A chemical (toxic) load was neither secured during the flight nor afterwards.
FREIBURG ARBEITSGERICHT - SOCIAL LAW COURT – Considered

The Chamber has no doubt that on 20.6.2014, the KHigerin - suffered health damage in the form of inhalation trauma and thus an accident at work external effect, namely the inhalation of contaminated cabin air. (Statutory Accident Insurance – Nerve Poison in Cabin Air) Incident worked for Lufthansa AG fume event 9 October 2011

A stewardess has been having considerable health problems which occurred after a flight, due to the fact that poisonous chemicals floated around the aircraft. Together with Oliver Birk of the Stuttgart office of the DGB Rechtsschutz GmbH, she fought at the labour/industrial court Freiburg/Germany to determine the existence of an accident.

After reviewing and evaluating all the individual aspects, the Freiburg Social Court came to the conclusion that an accident had occurred. The applicant has thus become a victim of a workplace injury.

The judgment of the Sozialgericht Freiburg is not yet final. If the employers’ association (BG=Berufsgenossenschaft) appeals to the National Social Court, we will continue to report. (the case number is given at the bottom of the article)


GIESSEN SOCIAL LAW / LABOUR COURT  Germany (worker’s comp) – Dismissed the Action 9 May 2019

Amsterdam Court


Case number C/13/547894 / KG ZA 13-1016 HJ/PV Authority. Date of judgment 18-09-2013 Date of publication 18-09-2013

Areas of law. Civil Justice. Special features - Applications for interim measures

Case Kort geding. Eiser is Pilot for KLM

Decision - The judge in preliminary relief proceedings

5.1. Condemns KLM to commission a research institute, or a researcher, to investigate the presence and concentration of TCPs in the cabin air of its Boeing 737s within fourteen days of the notification of this judgment;

Study was undertaken: TCP identified in 46% of flights at low levels- no fume events identified.

Air France V CHSCT (Health and safety workers committee (2010))

Grand Instance of BOBIGNY - **Order applied to prevent cabin air monitoring**

- In support of its claims, AIR FRANCE submits firstly that there is no justification for any serious risk within the meaning of Article L 4614-12 of the Labor Code.
- AIR FRANCE notes finally that the risk of inhalation of polluted air in cabin is old and known, that it is rare and already taken into account by the employer so that it can not be qualified as a serious risk.
- AIR FRANCE submits, secondly, that the expert measure decided by the CHSCT PNT and PNC is in any case useless.
- The defendants – there was knowledge of 29 incident reports for the first quarter of 2008, company reports 22 reports for the full 2008 year.


Supreme Court of Appeal (2012) - Cour de cassation.
France Court

Easyjet V CHSCT (Health and Safety Workers Committee (2016))

Tribunal de grand Instance de Bobigny (2018)

Order applied to prevent monitoring studies requested by CHSCT

- **Outcome:** annul the decision of the 2016 CHSCT for air monitoring studies.

- **Verdict against CHSCT/ not appealed**

2 pilots in France have lodged an action in the Tribunal de Grand instance (High court). No third party Asking magistrate to investigate if a case can be lodged with the French criminal prosecutor.
Macon Fowler v. US Airways Inc. Dsp: 3630624-1 Filed and Heard in Harrisburg Pennsylvania 17102

Termination and Review Petition Circulated Date: 01/21/2015. Injury Date: 01/16/2010

Decision: 15 Jan 2015 (was delayed due to numerous attempts to resolve through mediation)

Claimants Review Partition Granted in part and the description of his injury in the NCP is amended to include the addition of “reactive airways disease due to inhalation exposure.”

Defendant’s Termination Petition is Granted that the claimant fully revered from his injuries suffered as of January 16, 2010 effective June 17, 2010.

“In the case at bar, very skilled counsel for Employer/Defendant Kimberly A. Zabroski, Esquire “saved” the Employer’s termination petition by, making sure Dr. Greenberg acknowledged that US Airways accepted respiratory irritation due to an episode of exposure as acknowledged on the NCP (Dr. Greenberg’s Dep. at pp. 14-15, 36). Under ’To and Jackson, supra, the Judge believes Dr. Greenberg’s testimony was competent. However, if this case is appealed, the Judge would believe the WCAB may took a second look at this issue, including whether Dr. Greenberg failed to accept the diagnosis of “reactive airway disease.” However, this WCJ believes his testimony meets the legal standard of proving a termination of benefits under Jackson and To.”

https://www.dli.pa.gov/Pages/default.aspx.

I believe Macon Fowler has never fully recovered...not 100%
DAVID HILL v. US AIRWAYS

Appeal Case: A13-0157 Opinion Mailing Date: 04/15/2015

Determination: Affirmed

Opinion from the Workers’ Compensation Appeal Board file. An appeal to the Commonwealth Court of Pennsylvania may be taken by any party aggrieved by the Board’s decision – the denied claim on the basis of an error of law.

Decision

- “Because Dr. Greenberg credibly testified that Claimant fully recovered from his accepted work injury of single acute episode of exposure to non-toxic odour resulting in transient respiratory irritation, and testified that he can return to unrestricted work and requires no further treatment, the WCJ did not err in granting Defendant relief”.

- “However, the WCJ did not accept the Claimant’s evidence regarding the extent of the work-related injury or disability, appeal denied, 563 Pa. 622 757 A.2d 936 (2000) (determining that an employer can meet its burden by presenting unequivocal medical evidence of a claimant’s full recovery)”. 

- “We note that Dr. Harrison even acknowledged that while exposure can cause respiratory problems, there is no evidence that Claimant has reactive airway disease or a chronic problem. As such, the WCJ did not err”.

History of fumes prior to event & after
Fumes entered cabin on return flight - start up, cruise, descent, Oil & Hydraulic fluid identified.

Aviation career 1972 to January 16, 2010 as a Boeing 767 Captain Workers Compensation & Appeal Board Pennsylvania USA denied.
Kamyszek v. Delta Airlines, Inc. et al Federal Civil Lawsuit Virginia Eastern District Court


Christopher Kamyszek, a passenger on board Delta Airlines flight from Salt Lake City to Minneapolis - 16 Dec 2011.

- Seeking USD $5 million compensation for alleged loss of enjoyment of life, ability to earn a living and employment, as well as damages for mental pain and suffering and permanent, debilitating physical injury. He claims he was injured by a fume event on board the aircraft, approximately fifteen minutes after take-off.

- It appears this case is not continuing.

21 May 2015 - So Ordered re 27 Stipulation of Dismissal filed by Christopher Kamyszek. Signed by District Judge Liam O'Grady on 5/21/15. (gwalk.)

30 April 2015 ORDER that the 25 Unopposed Motion to Dismiss Airbus with Prejudice is GRANTED. Signed by District Judge Liam O'Grady on 04/30/15. (pmil.)

28 April 2015 MOTION to Dismiss With Prejudice by Christopher Kamyszek. (Barks, Daniel)
Latest Fume Events…Yes…July and August 2019

- **6 August 2019** British Airways flight to Valencia – smoke filled the cabin – emergency with smoke – 200 evacuated

- **28 July 2019** American Airlines Flight AA728 Philadelphia to London Heathrow – odour “call it a dirty socks smell. We need to turn this around...we are not declaring an emergency...” “Cabin...row 22...” Diverted to Boston.
  - Sick Flight attendants (9) and passengers

- **19 July 2019** British Airways Airbus A380 Flight BA286 San Francisco to London Heathrow – diverted to Vancouver – most crew crew incapacitated

https://www.change.org/p/stop-contaminated-cabin-air-in-aircraft/u/24901209?fbclid=IwAR2Nin-Urdeiwcm236wak9dhD1AEeEFA9heE5OABpAxVOqZ7v-9mxgsXY-Pc
Alysia Chew v Eastwest Airlines Ltd & Ansett Australia Ltd, Compensation Court of New South Wales, (Matter 19652 of NSW), Judgement 28 April 1999

Ms Chew suffered injury January 1992 to 30 October 1993; and Section 47 of the Workers Compensation Act applies and that the applicant as a result of the injury, “is unable without substantial risk of further injury to engage in employment of a certain kind because of the nature of that employment shall be deemed to be incapacitated for her employment at that kind.” pp 12-13.

The basis of Ms Chew’s claim was that between January 1992 and 30 October 1993, when a flight attendant with Eastwest Airlines, she was exposed to fumes, toxic substances and other irritants whilst carrying out duties as a flight attendant on BAe 146 aircraft. Ms Chew also claimed that fumes within the aircraft to which she was exposed contained Mobil Jet Oil II which contained the substance triorthocresyl phosphate (TOCP).
Carter v Ansett Australia Ltd [2000] QDC 049 District Court of Queensland

- June 2000 - **Was granted an extension of time** to 31 August 1999 to commence action – due to material not being available at the time.

Carter v Ansett Aust Ltd [2000] QCA 333  Supreme Court of Queensland

- Appeal No 5414 of 2000 DC No 1227 of 2000

- 18 August 2000 **Successful** in the District Court in extending the period of limitation in an action for damages for personal injuries against the applicant – the applicant sought leave to appeal against the decision – suffered injuries as a result of exposure to toxic chemicals whilst in the employ of Ansett Australia – was exposed to fumes in the cabin of a BAE146-200 aircraft between 1993 and 1994 – where there was a discerned the existence of a causative relationship between the ingestion of the fumes and the symptoms suffered at a time outside the period of limitation – whether that material fact of decisive character relating to the right of action was not within her means of knowledge until 31 August 1999.

- [18] "In our opinion the decision of the learned District Court judge was correct. Moreover we think he reached that decision by correctly applying the provisions of s 30 and s 31 of the Limitation of Actions Act. Accordingly we would refuse leave to appeal with costs”.


- Resigned on medical ground in 1995 as did the three flight attendants on the same flight all requiring oxygen 14 Nov 1994
1992 Incident - Joanne Turner – BAe146 Flight Sydney to Brisbane – thick cloud of smoke - oil leak

*Turner v Eastwest Airlines Limited* [2009]New South Wales Dust Diseases Tribunal 10 (5 May 2009)

**Court of Appeal** – Supreme Court of New South Wales

- In April 2010, The Supreme Court of NSW dismissed an application by East West Airlines for leave to appeal (*"East West Airlines Limited v Turner [2010]," 2010)*.

*East West Airlines Ltd v Turner [2010] HCATrans 238 (3 September 2010)*

- Cabin smells from oil were noted to be an ongoing problem acknowledged by the defendant, with numerous complaints about the cabin air prior to the incident on 4 March 1992, including an entry 10 days prior to the incident stating: "APU AIR NOT FIT FOR HUMAN CONSUMPTION. *Ms Turner was found to have been exposed to Mobil Jet Oil II on 4 March 1992 with the court finding that pyrolysed effects of Mobil Jet Oil II are harmful to the lungs.* As such Ms Turner suffered from a pathological condition to the lungs caused by exposure to the smoke and that condition has continued for more than eighteen years and is expected to be life-long.

The High Court of Australia subsequently dismissed the appeal by East West Airlines in August 2010

Workers Compensation/Civil Perth Australia

Judith Anne Cullinane and Ansett Australia Limited WC93D No 962 of 1998

Flight 6-8 November 1997 BAe146 JJW 3 Days incapacitated

Flight Attendant Pauline Guy on same flight 6-8 November 1998 Workcover claim advised 12 January 1998 excepted “Tiredness, Dizziness, nausea etc due to Environmental Factors

Flew as passenger mid November 1998 on A320, collapsed exiting aircraft-wheelchair. On return flight came off-wheel chair with oxygen. Test Flight Jan 1998 on 737 as passenger, off in a wheelchair with oxygen. (Required oxygen on flight soon after takeoff – tingling extremities, nausea, tiredness, loss of control of limbs

District Court Western Australia No. 4296 of 1998 summons served 6 November 1998.

Judith Anne Cullinane – District Court of Appeal

▷ The Commissioner noted that the Defendant sought to dispute the Plaintiff’s claim on the causation issue, but he adopted the submissions on the “material contribution” being the relevant test, accepting Dr Barnes and Professor Winder, concluding that there was a “real and not remote chance that the exposure to fumes in the workplace caused the plaintiff’s symptoms”. (Limit of claim over threshold – proceeds to District Court)

Decision On the capacity issue, the Commissioner accepted that there was evidence that the Plaintiff may very well never return to work as a flight attendant”.

▷ Court Appeal 25 February 1999 – J Cullinane won and awarded costs

▷ Court Case 2000 Judith Anne Cullinane won the right to review all Ansett Australia and other documents with the defendants claiming “Sensitive information” but this was disapproved with some were in the public domain, some were internet articles, some were duplicates etc.

Nov 2001 – tender as evidence BAe AGREEMENTS $. Settlement at Mediation pre trial July 2002 (10 hour mediation)
How did Ansett Australia stop Workcover Claims

Oct 1995  Ansett Dr Dai Lewis in an email – “Discussion with Dr Patrick Carrol, Consultant adviser to the Queensland Workers Compensation Board confirms that his report to the Board states in his opinion there is not a “Toxic Chemical” involvement her. He is also to talk to Hickson’s treating Specialist, hoping to put him right”.

“…I will continue to try and reverse the certifying Doctors opinions….and continue to provide the analyses to Dr Carrol who by the way will in the end be examining each of our Flight Attendants.”

April 1995  Ansett Lewis email …..”Queensland Workcover confirm they don’t require any further sampling…information…as a result they are denying Flight attendant Workcover claims. “…Less specific test, one simply for oil mists. We could do this but it would only be of use an identifier of trouble and would not in itself prove of any great use in court action….Tedlar Bag”.

Oct 1995  Dr Affleck calls Dr Lewis about 3 crew…”knows him so limited testing to carbon monoxide”… Flight attendants had asked for Cholinesterase

April 1997  Ansett Dr Dai Lewis to Cpt Jenson “…offer ground duties…threat of loss of flying duties worked well before East West was absorbed.”

November 1997 Richard Fox – “Testing Tedlar Bags…..not designed to measure semi volatile compounds…will not detect TCP… Sample taken then tested 3 weeks later…” “Richard Fox report refers to design and to test within 24 hours no more than 72 hours. Method of testing at Ansett allows the potential loss of compounds, meaning…exposure probably greater than reported”. “AGAL analysis is for volatile compounds only. Semi volatile compounds that were collected would still be adhered to the inside of the tedlar bag”. “Many fuel, oil, hydraulic fluid decomposition products fall into the semi volatile category, including triorthocresylphosphate isomers….writes about reference the WHO EHC 110 on Tricresyl phosphate: Triortho cresyl phosphate….mixed o-cresyl isomers”.

(Report from R Fox regarding Judy Cullinane’s flight and flight reports)
March 1998 Consensus – “Independent Panel” ..Westermann, Carroll Rob Loblay and others signed...Dr Dai Lewis drafted the consensus for the BAe146 ...to be signed off by all...March 1998.

The “Independent Panel” were also the Work Cover Doctors !

The consensuses statement was attached to a letter was sent to Flight Attendant and Workers Compensation Doctors

The “Independent Panel” reviewed selected and incorrect reports....” The following R Fox’s report had changes from the draft to the published report.

Air Quality and Comfort Measurement Aboard a Commuter Aircraft and Solutions to improve Perceived Occupant Comfort Levels

Paper ID 8199 Draft a by Richard Fox ...different to the published version. 1998

- ‘Findings from the bleed air contamination monitor indicated that full hydrocarbon clean out of the ECS systems on the three aircraft tested never occurred”....System contamination was not only in the filters, but in other areas of the system as well”. “Air flow...flows in the aisle...head height...generally well below 0.1 meter/second”

- States carbon monoxide never detected in flight...method used summa cannister....which is not designed to detect carbon monoxide. Semi-volatile contaminants were analyzed from samples removed from the aircraft filters. A search referenced against a calibrated standard was made for the isomers of Tricresylphosphate. No isomers of tricresylphosphate were detected. However, Triethylphosphate was detected. Triorthocresylphosphate is of concern since is is considered to be a neurotoxin. (Ansett has crossed out and written “no need to write this”)  

- Unsafe levels of formaldehyde measured during pack burnouts.
Ansett Australia had in its possession...

Dec 84 21/7 British Aerospace Service Information Leaflet — “The following is offered should oil contamination of the air conditioning system be experience.

Jan 24 1983 Mobil Oil Corporation J Aveni — “Mobile Jet Oil has been used for many years by many commercial airlines with no incidents of adverse health affect. Obviously if cabin air becomes contaminated with any lubricant and/or its decomposition products in sufficient quantities, some degree of discomfort due to ye, nose and throat...generally traced to improper design, improper maintenance or malfunction of the aircraft.”

April 92 Dan Air - confirming oil leakage, shaft seal APU and problems for over 1 year.

May 1992 Dr Vasak report 16 in the case of justified medical concern following a continuing inhalation exposure to the contaminated air...some biological tests may be of help (eg: inhibition of cholinesterase in a case of proven exposure of a toxic organophosphate)

1995 Ansett Engineer “...taking up directly with Allied Signal...filtration can only handle day to day leakage”.

Nov 1996 Ansett K Currie to Dr Dai Lewis ‘ latest summary information, lack of approx. 50% of incidents don’t find there way into the logs”.

August 1997 Richard Fox to Ansett Dr Dai Lewis...”Pack Burns didn’t appear to remove all organic matter... in fact TCP is being detected by health and safety measures during and after Pac Burns...levels measured on bleed air contamination monitor during Pack Burn were 4 times greater than we allow in our engine except in our APU facilities...”. R Fox used Suma Cannisters which do not detect TCP but Dr Van Nettan used catalytic converters - detected TCP.

Sept 1997 Ansett Greg Vaugh spoke to Ansett Dai Lewis ‘Spoken to Air BC – 1 case neuro poisoning’ ‘triorthercresyl phosphate (TOCP) – neurotoxic to humans, sufficient evidence, additionally QLD health found TCP.”

December 1997 George Lee report to Dr Lewis...use cryogenic trap...small amount of tricresyl phosphate found...pack burn then...altered a pack burn to 70 C...then not detected.

Jan 2000 Ansett Dr Dai Lewis email to Rod Westermann “...interested in seeing any ...flight attendants...following BAE 146 return to work program...sent via our insurer QBE...interest/ Also mentions pilots and depression...”.
Dismissing Claims

Patricia Forames, et al. v. ST Aerospace Mobile, Inc., Case No. 1111434 (Ala. Sup. Ct.)

Date: August 30, 2013 Court: Alabama Supreme Court

Decision: **affirmed** the Mobile County Circuit Court’s summary judgment dismissal of eleven claims of “Areotoxic Syndrome” exposure by US Airways crew members.

- **B767 (2010) - US AIRWAYS Tail N 251AY** (had suffered fumes over many months)
- First Officer Mick Fowler (June 2010) reported, fatigue, wooziness and grogginess, during a fume event while landing a Boeing 767 – after landing he was taken off the plane on a stretcher to an emergency room.

- **Captain David Hill** medical’s failed - neurological
- 2 Pilots had medical certificates withdrawn by FAA and denied workers comp on appeal
- Cabin Crew workers compensation accepted

- **Captain David Hill – took his own life 2016 (RIP)**

Incident late 1999 - Melissa Dray

- June 2015 - BAe Systems – Western Australia District Court registrar George Kingsley ruled Bae Systems had a case to answer.
- Melissa filed for bankruptcy in Perth...unable to continue against BAe Systems

Welcome Melissa ☺... Melissa is here today and will be speaking later...
Civil Cases: Awarded/Settlements

Filed in 1998 Debra Bradford & 24 other Flight Attendants v Alaska Airlines and others. Alaska Airlines settled with the flight attendants earlier in 2000, agreeing to pay $725,000 without admitting any wrongdoing.


2002 Judith Cullinane v Ansett Australia Limited – BAe146 Incident 6-8 November 1997 Settled out of Court.

2007 Stewarts Law V Excel Airways – Settled ?…: B767/passengers

2011 Terry Williams v Boeing– American Airlines MD-82 Aircraft

Ridgell v. Frontier Airlines, Inc. et al

The plaintiff claims Frontier Airlines has so far refused to acknowledge a dangerous 'fume event' during which the air in the cabin of a flight became contaminated.

Frontier Airlines, Inc.; Airbus S.A.S.; and Airbus Group HQ Inc.

- Alleged “fume events” resulting from the possible defective design and manufacture of the companies’ Airbus fleet of aircraft. Passenger cabin becomes contaminated with “pyrolised compounds”.
- Flight made an emergency landing in Phoenix – Frontier refused to acknowledge the event, with scheduling posted as landing on time in Orlando without incident.
- Lawsuit passengers “experienced physical distress,” including “passing out, choking, coughing and eye irritation”.

The Court denied class certification and the case settled individually but on a confidential basis.
12 November 1999 during a flight between Bromma and Sturup in Sweden - Captain on a BAe 146 operated by Braathen's Malmo Aviation had to use oxygen when effected by fumes. Captain handed over to the First Officer to land the plane.

- Investigation the airline had come to the conclusion that, “the oil leak was the reason for the air in the cabin being made toxic.”

- **Loss of license – Neils Gomer** - Fumes, dizzy, groggy, drunkenness, disorientated

- Numerous more known to be awarded around the world and some known to be denied.
22 June 2015 - Five Crew filed to sue The Boeing Company in the Cook County Circuit Court Illinois – alleging breaches of duty of care “negligent acts or omissions” Incident - Alaska Airlines unscheduled landing in Chicago July 2013.

Due to court early 2020


2019 Unite Union Legal notices served - 51 cases against: (Comprising 4 Pilots, 47 Cabin Crew)

- British Airways.
- EasyJet
- Thomas Cook
- Jet2
- Virgin Atlantic
Westgate (Died 2012)

2015: Regulation 28- Prevent future deaths: airline & CAA - (withdrawn)

2017: Final findings

▶ Accidental death: (accidental) pentobarbital overdose:
▶ Suffering from
▶ Dorsal root ganglioneuropathy affecting spinal nerves and possibly cranial nerves
▶ Myocarditis.....
▶ Depression and anxiety (caused in part by ganglioneuropathy & that condition remained undiagnosed

Bass (Died 2018)

▶ Death by misadventure

"The senior coroner wrote the letter of concern to the chief coroner asking him to advise all coroners of the need for the additional tests in cases where toxic cabin air is a suspected cause of death. Significantly the senior coroner in his letter recognised that exposure to toxic cabin air may lead to a clinical impact on the body."

Court Trial Dates for 2020

**Vashti Escobedo V Boeing** Illinois Circuit Court Cook County Law Division

- Filed Apr 15, 2016 later Vashti Escobedo, Ray C Escobedo and Lara K Lane as Plaintiffs
- 29 Aug 2019 the case was set down for focussed case management for 3 October 2019 at 9:30am

2013. An Alaska Airlines flight took off from Boston for San Diego. The plane had to be diverted to Chicago after all four flight attendants became violently ill. Two passed out.

**Escobedo V Boeing** goes to court – **February 2020 in Chicago** (expected to be 4-5 weeks)

Involves 4 Flight Attendants injured in the same event and a Flight Attendant from a separate event.

**Woods V Boeing** goes to court – **February 2020**

[https://www.bloomberglaw.com/exp_blp/eyJjdHh0IjoiRE9DIiwiaWQiOiJYMVE2TkxDSVU0ODlLCJ1dWlkIjoiTlFycjR6YUFydVptdnBmRigRTBnUT09S0ZlekpzenBJSkpSaEdMc21BeXNRd09liwidi6MSSwGIlZ16jIE1NTUwNzc2MDYmMDAICjzaWciOIJZSHhQODRQVnVWd05jdWfpNXhKVBqK0pISVE9In0=](https://www.bloomberglaw.com/exp_blp/eyJjdHh0IjoiRE9DIiwiaWQiOiJYMVE2TkxDSVU0ODlLCJ1dWlkIjoiTlFycjR6YUFydVptdnBmRigRTBnUT09S0ZlekpzenBJSkpSaEdMc21BeXNRd09liwidi6MSSwGIlZ16jIE1NTUwNzc2MDYmMDAICjzaWciOIJZSHhQODRQVnVWd05jdWfpNXhKVBqK0pISVE9In0=)
Common Threads

**Failure of Cases**
- Couldn’t prove exposure
- Method of testing and or results
- Different countries, courts, rules, regulations
- Prove the fact or threshold of injury
- Lack of understanding

**Success of Cases**
- Precedent set
- Doctors diagnosis with supporting specialist reports
- Evidence of fume event and that others were sick, including passengers
- The wording of the statements, reports
- **A good understanding of the issue and how to explain and argue it……ESSENTIAL**

Turbo Oil 219 Oil can says: “Do not breathe mist or vapor from heated material” (Worth remembering….for Court)
Signed 3 September 1993

“...Pursuant to the Aircraft Purchase Agreements, BAE warranted that relevant parts of the Aircraft (as therein defined) would conform to applicable specifications supplied by BAe and would be free from defects due to defective material and or defective workmanship or defective design on the part of the BAe in accordance with and subject to the terms, conditions and limitations contained in the Aircraft Purchase Agreements”.

"Ansett have EWA have made certain written claims against BAe alleging defective design of the Aircraft resulting in the obnoxious oil and other (the "cabin environment problem") fumes affecting the passenger cabins of some or all of the Aircraft”.

“BAe herby agrees with Ansett and EWA that it shall pay EWA the sum of Australian $750,000"
Eastwest Airlines (Operations) Limited and Ansett Transport industries (Operations) Pty Limited and Allied Signal Incorporated and another with AVCO Corporation

**Agreement 1993** “Allied Signal to provide EWA and Ansett a total Parts and Labour Credit of US$1,235,000 as financial consideration associated with the operation of Allied Signal APUs on the BAe146 aircraft. The applicability of the credit will be limited to APUs and APU parts including kits to convert 85-129(E) APUs to A-129(K) configuration...labour and parts..”.

“After detailed and protracted investigations, it was determined that a source of the smell was oil leakage from Allied Signal APUs which entered the bleed air system through the air conditioning packs”.

- “Credit is to be used against any account receivable due from EWA or Ansett...purchase of APUs and APU parts including kits to convert 85-129(E) APUs to A-129(K)
- (Not dated...has 1993 and not signed by Allied Signal – Signed By Ansett and East West with Common Seal)

**Similar Agreement 1993** with AVCO Corporation claiming engine bleed air problems since the purchase in 1989 until 1993...various deficiencies and inadequacies. Seeking US$150,000 cash and US$100,000 parts credit to be used in full by 31 Dec 1994. (Only signed by Ansett and EWA with Common Seal)

- Both of these remained **unsigned**.
TAKE AWAY

It could happen to you, your loved one, your family or friends. It’s not about money... it's about your health... your career... your lifestyle.

Airlines (most airlines) require a full medical assessment, including a chest x-ray – you must have 100% health... to be employed... so your health should not be degraded by your workplace.

While industry tries to work out a solution, don’t forget the people who have lost their health and careers.

Times up.... billable hours... $$$$$$$$$$$$
Your Legal Bill to Date $182,000..... NEXT Court date..... COST $$$$$$$$$$$.....

What does it matter to a company... it’s tax deductible... it is not out of their own pocket...
Thank you to my late husband Tim Cullinane who supported me when I became ill in November 1997 with my court case and the Australian Senate.

(We met on a flight – Tim passed away with multiple myeloma Dec 2008) (RIP)

Thank you to my son Joel who was 7 when I got sick in November 1997, and who then looked after us both. When we had to sell everything and live in a tent, while I continued to fight the airlines for compensation you never complained.

We regrouped and had to re-enter the workforce. I completed an MBA 2012 and together Joel and I we were admitted into the Queensland Law Courts as Lawyers.

...We made it...I am definitely slower.... And it was and still is a struggle.

Picture – Joel and I – My proudest day.
CABIN AIR QUALITY MONITORING //
Organophosphates sampling during fume events in Australia
The Australian Federation of Air Pilots’ mission:
To represent and promotes the interests of Australian professional flight crew and champions the highest possible standards of aviation safety
WHY SAMPLE?

Dozens of concerned and affected pilots

There are unanswered questions

Unactioned findings from Gov’t reviews & enquiry

Refutable statements in other sampling studies

Adding to the data

Our industry needs to acknowledge the problem and improve
The committee received considerable evidence criticizing aspects of the regulatory regime for the aircraft and focusing on issues that should be taken up by regulators, such as:

- Oil leaks & exposure to oil fumes
- Responses to crew complaints
- Testing procedures for cabin air
- Modification measures necessary to remedy fume contamination

Recommendation 3

The Committee believes that development of an appropriate and accurate test for the presence of any chemical fumes in aircraft cabins is essential. The Committee accordingly recommends that CASA liaise with operators to develop a standardised, compulsory monitoring program which provides for testing cabin aircraft air during fume events.

Recommendation 8

The Committee recommends that CASA assess how quickly fitting appropriate high-grade air filters can be made mandatory for all commercial airliners flying in Australia to minimise any deleterious health effects arising from poor aircraft cabin air on crew and passengers. In view of proposed standards currently under consideration in the United States of America and elsewhere, such a system should ideally be designed to remove at least 99% of particles 0.3 micron or larger from recirculated cabin air.
(b) Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapours ...

(c) There must be provisions made to ensure that the conditions described in para B ... are met after reasonably probable failure or malfunctioning of the ventilating, heating, pressurization or other systems and equipment.
CASA'S VIEW

CASA outlined in a submission its views on air quality on the Bae 146 aircraft. According to the authority:

A team of Australian medical experts reviewed the test methods and results and has declared that there is no contaminant present in the cabin environment that will induce any long term or permanent effects on the passengers or crews.

In particular, at no time was tricresylphosphate (TCP) ever identified in any sample gathered in an Australian aircraft.

Action Recommended:

It is believed the quality of the air to meet certification standards for this type of aircraft should be tested by Gas Liquid Chromatography to determine levels of organophosphates and their interaction with hydrocarbons/volatile organic compounds in the ambient cabin air.
EPAAQ FORMED 2007 //

EPAAQ was unable to reach definitive conclusions saying it is an area of research where “reasonable people’s views can differ”.

CASA considered it wouldn’t propose any major policy or regulatory decisions based on that evidence. It also noted many of the EPAAQ’s recommendations fell outside the ambit of CASA’s functions set out in the *Civil Aviation Act 1988* (Cth)

**Civil Aviation Advisory Publication (CAAP) advises:**
(c) smoke, toxic or noxious fumes inside the aircraft is considered a major defect

**FAA response to 2002 CAQPCCA report acknowledges:**
“FAA rulemaking has not kept pace with public expectation and concern about air quality and does not afford explicit protection from particulate matter and other chemical and biological hazards. No present airplane design fulfills the intent of 25.831 because no airplane design incorporates an air contaminant monitoring system to ensure the air provided is free of hazardous contaminants.”
(Federal Aviation Administration, 2005)
REGULATOR RESPONSES

EPAAQ report, CASA said:
Contamination of aircraft cabin air by bleed air – a review of the evidence (up to September 2009)

The panel’s inability to reach definitive conclusions highlights the fact that this is an area of research where reasonable people’s views can differ. In the circumstances, it would not be prudent for CASA to make major policy and regulatory decisions on the basis of inconclusive evidence.

EASA found:
• a causal relationship between the reported health symptoms and oil/hydraulic fluid contamination has not been established. As there is no conclusive scientific evidence available, the Agency is not able to justify a rulemaking task to change the existing design or certification specifications.
Cranfield University: Are there organophosphates in cabin air?

- In over 95% of the cabin air samples, no detectable amounts or ToCP or TCP were found. **TBP was detected more routinely, but not in the majority of samples.**

EASA study 2017: Final Report Preliminary Cabin Air Quality Measurement Campaign

- Study results indicate that under routine aircraft operations, contaminant level in aircraft cabins are mostly similar to those in residential and office buildings

- In more than 95% of all cabin air samples, no detectable amounts or ToCP or other TCP’s were found.

- In conclusion: “... A continuation of the previous measurement series is also not considered as constructive, since encountering a real TCAC-event, which needs to be investigated in order to answer some of the questions, remains very unlikely ...”

Is this a “pretended” problem?
Do we know the isomers to look for?
SENATE’S FINDINGS - ATTITUDE OF AIRLINES TO STAFF’S REACTIONS TO FUMES

The response to employees showing symptoms of toxicity showed a **lack of understanding of duty of care**.

Information issued to staff on the issue has attempted to **minimize the problem using language of public relations**.

The basic approach to injured staff appears to be **adversarial**.

Staff have been **bullied and have been victimized**.

Workers have been **forced to keep working** in conditions that continue to **aggravate their health, in some cases to permanent incapacity**.

Staff have been **offered demeaning duties**, and genuine attempts at rehabilitation have been lacking.
<table>
<thead>
<tr>
<th>Date</th>
<th>ATSB Reference Number</th>
<th>Category</th>
<th>ATSB Investigation</th>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
<th>State</th>
<th>Aircraft Manufacturer</th>
<th>Model</th>
<th>Operation Type</th>
<th>Operation Sub Type</th>
<th>Airspace Type</th>
<th>Airspace Class</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/02/2018</td>
<td>201800597</td>
<td>Incident</td>
<td>Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Airbus</td>
<td>A320</td>
<td>All Transport High Capacity</td>
<td>Passenger</td>
<td>CTR</td>
<td>C</td>
<td>During pre-flight preparations, fumes were detected in the cockpit and cabin. The engineering inspection did not determine the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>12/04/2018</td>
<td>201801808</td>
<td>Incident</td>
<td>alenam Moosilaneen (AIA)</td>
<td>31° 49.599′ S</td>
<td>116° 1.002′ E</td>
<td>WA</td>
<td>Boeing Company</td>
<td>737</td>
<td>All Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>A</td>
<td>During cruise, the cabin crew observed smoke emanating from the in-flight entertainment screen. Engineers replaced the in-flight entertainment screen.</td>
<td></td>
</tr>
<tr>
<td>12/06/2018</td>
<td>201802812</td>
<td>Incident</td>
<td>near Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>A</td>
<td>During climb, cabin crew detected fumes emanating from an oven.</td>
<td></td>
</tr>
<tr>
<td>12/09/2018</td>
<td>201805646</td>
<td>Incident</td>
<td>alenam Geraldton Aerodrome</td>
<td>28° 47.772′ S</td>
<td>134° 42.45′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>A</td>
<td>During descent, fumes were detected in the cabin. The engineering inspection did not determine the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>12/10/2018</td>
<td>201807271</td>
<td>Incident</td>
<td>Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Embraer-Brasilian De</td>
<td>EMD-120</td>
<td>Air Transport Low Capacity</td>
<td>Passenger</td>
<td>CTR</td>
<td>C</td>
<td>During pre-flight procedures, fumes were detected in the cockpit and cabin. The engineering inspection revealed the left fan pressure regulating shutoff valve was not secure.</td>
<td></td>
</tr>
<tr>
<td>12/10/2018</td>
<td>201807287</td>
<td>Incident</td>
<td>near Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>C</td>
<td>During descent, fumes were detected in the forward Galley. The engineering inspection did not determine the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>12/10/2018</td>
<td>201807904</td>
<td>Incident</td>
<td>near Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>C</td>
<td>During descent, fumes were detected in the cockpit and cabin. The engineering inspection did not determine the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>12/12/2018</td>
<td>201808958</td>
<td>Incident</td>
<td>near West Angeles Airlines</td>
<td>27° 5.1′ S</td>
<td>130° 43.002′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>A</td>
<td>During cruise and again in the next sector, fumes were detected in the cabin. The engineering inspection revealed the left and right hand water separator drain was not secure.</td>
<td></td>
</tr>
<tr>
<td>13/02/2018</td>
<td>201800445</td>
<td>Incident</td>
<td>near Broome Aerodrome</td>
<td>11° 50.882′ S</td>
<td>121° 11.808′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>A</td>
<td>During descent, fumes were detected in the cockpit and cabin. The engineering inspection did not determine the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>13/03/2018</td>
<td>201801168</td>
<td>Incident</td>
<td>Gold Coast Aerodrome</td>
<td>27° 3.87′ S</td>
<td>152° 29.382′ E</td>
<td>QLD</td>
<td>Boeing Company</td>
<td>737</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTR</td>
<td>C</td>
<td>During engine shut-down, fumes were detected in the cockpit and cabin. The engineering inspection did not reveal the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>15/06/2018</td>
<td>201802840</td>
<td>Incident</td>
<td>Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>S.A.B. Aircraft Co.</td>
<td>340</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTR</td>
<td>C</td>
<td>During preparation for flight, fumes were detected in the cabin. The engineering inspection determined the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>15/06/2018</td>
<td>201802835</td>
<td>Incident</td>
<td>near Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>C</td>
<td>During descent, fumes were detected in the cockpit and cabin.</td>
<td></td>
</tr>
<tr>
<td>15/07/2018</td>
<td>201809619</td>
<td>Incident</td>
<td>near Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>C</td>
<td>During descent, fumes were detected in the cockpit and cabin. The engineering inspection did not reveal the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>15/08/2018</td>
<td>201804823</td>
<td>Incident</td>
<td>Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>The Boeing Company</td>
<td>717</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>C</td>
<td>During push back, fumes were detected in the cabin. The source of the fumes was traced to the exhaust air being taken in by engines on start-up and spreading</td>
<td></td>
</tr>
<tr>
<td>15/08/2018</td>
<td>201804547</td>
<td>Incident</td>
<td>near Perth Aerodrome</td>
<td>31° 56.418′ S</td>
<td>116° 15.082′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>C</td>
<td>During descent, fumes were detected in the cabin. The source of the fumes was traced to the exhaust air being taken in by engines on start-up and spreading</td>
<td></td>
</tr>
<tr>
<td>12/10/2018</td>
<td>201807344</td>
<td>Incident</td>
<td>near Darwin Aerodrome</td>
<td>12° 26.882′ S</td>
<td>132° 53.302′ E</td>
<td>NT</td>
<td>Airbus</td>
<td>A320</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>A</td>
<td>During descent, fumes were detected in the cockpit.</td>
<td></td>
</tr>
<tr>
<td>15/10/2018</td>
<td>201807507</td>
<td>Incident</td>
<td>near Broome Aerodrome</td>
<td>17° 58.582′ S</td>
<td>122° 11.668′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>D</td>
<td>During approach, fumes were detected in the cockpit. The engineering inspection did not reveal the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>18/11/2018</td>
<td>201808138</td>
<td>Incident</td>
<td>Avalon Aerodrome</td>
<td>38° 3.37′ S</td>
<td>146° 46.2′ E</td>
<td>VIC</td>
<td>Airbus</td>
<td>A320</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>D</td>
<td>During descent, fumes were detected in the cockpit. The engineering inspection did not reveal the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>12/15/2018</td>
<td>201808135</td>
<td>Incident</td>
<td>Nifty Aerodrome, 135A/135B</td>
<td>22° 38.02′ S</td>
<td>132° 38.88′ E</td>
<td>WA</td>
<td>Fokker Aircraft B.V.</td>
<td>F28</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>D</td>
<td>During descent, fumes were detected in the cockpit. The engineering inspection did not reveal the source of the fumes.</td>
<td></td>
</tr>
<tr>
<td>12/12/2018</td>
<td>201808961</td>
<td>Incident</td>
<td>near Gold Coast Aerodrome</td>
<td>27° 3.87′ S</td>
<td>152° 59.302′ E</td>
<td>QLD</td>
<td>Airbus</td>
<td>A320</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>C</td>
<td>During descent, fumes were detected in the cockpit. The engineering inspection revealed a leak in the APU.</td>
<td></td>
</tr>
<tr>
<td>14/02/2018</td>
<td>201800510</td>
<td>Incident</td>
<td>Condobula Aerodrome, 223A/M</td>
<td>27° 3.87′ S</td>
<td>134° 37.322′ E</td>
<td>WA</td>
<td>Airbus</td>
<td>A320</td>
<td>Air Transport High Capacity</td>
<td>Passenger</td>
<td>CTA</td>
<td>A</td>
<td>During descent, fumes were detected in the cockpit and cabin. The engineering inspection determined the cause of the fumes was the oil pump.</td>
<td></td>
</tr>
</tbody>
</table>
WHY SAMPLE FOR TCP?

Because the engine oil manufacturers appear to report the TCP content of their products unevenly, Professor Chris van Netten of the University of British Columbia analysed the actual TCP content – both total TCPs and the relative amounts of four TCP isomers – in samples of eight aviation engine oils and three aviation hydraulic fluids.

The total TCP content of the eight oils ranged from 2.2 to 5.2% (by weight), and the total TCP content of each hydraulic fluid was zero.

**Tricresyl Phosphate ((TCP) is an indicator of bleed air contamination of aircraft air**

- Highly specific to most jet turbine oils

**To assess risk, need to measure the level of exposure to bleed air components**

- TCP and its isomers are known neurotoxins
- Important indicator of the presence of all other pyrolysis products
TCP ISOMER PATTERNS FROM JET TURBINE OILS //
Short communication

Design of a small personal air monitor and its application in aircraft

Chris van Netten*

School of Population and Public Health, University of British Columbia,
James Mather Building, 5804 Fairview Avenue, Vancouver BC, Canada V6T 1Z3

ARTICLE DATA

Article history:
Received 25 April 2008
Received in revised form 22 July 2008
Accepted 30 July 2008

ABSTRACT

A small air sampling system using standard air filter sampling technology has been used to monitor the air in aircraft. The device is a small ABS constructed cylinder 5 cm in diameter and 9 cm tall and can be operated by non technical individuals at an instant notice. It is completely self contained with a 4 AAA cell power supply, DC motor, a centrifugal fan, and accommodates standard 37 mm filters and backup pads. The monitor is totally enclosed and pre assembled in the laboratory. A 45° twist of the cap switches on the motor and activates the sampling system.
Please fill in this report if you have activated the VN Sampler device within an aircraft cabin/flight deck.

### Name or Sampler #

**107B**

### Approx' monthly crew hours flown

60

### Approx' monthly aircraft cycles flown

37

### Date LCL

2018

### A/C type

NB Jet

### Route or FLT No

X

### A/C Reg

VH -

### Company report reference, e.g. Maint log, safety report

### Time of activation LCL

50 min

### A/C Reg

VH -

### Phase of flight, e.g. GND, Eng start, taxi, climb, cze, disc, app/ldg

Cruise & descent

### Cruise & descent

Bleeds On or Off

On

### APU, On or Off

Off

### Odour comments

Oil, skydrol, fuel, dirty socks, gym bag, electrical etc

### Oil/dry heated dust

Fume comments e.g. visible, haze, not visible etc

Not visible

### Contamination comments

Likely bleed air? IFE/equipment? Ovens? etc

### Likely bleed air or ECS oil contamination

This A/C has exhibited oily odours late on descent recently, including on both sectors today. Not noticed by crew other than the Captain. These mild odours are generally treated as normal. This A/C has had recent fume events involving oil found leaking from the APU. Air sample taken based on reasonable suspicion of the presence of oil in the air conditioning. Request confirmation of oil presence in this sample. Post flight, Capt’ had an aggravated chest & dry cough which persisted through the night. Sampling commenced in cruise....................
Van Netten: Given levels of TBP & TCP in normal flights are usually close to or below our detection limit, almost all samples, except #83, identify a problem.
### STUDIES MEASURING TCP

### Showing maximum total TCP levels detected

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Country / Region</th>
<th>Max. level TCP $\mu$g / m³</th>
<th>Number of samples</th>
<th>number of aircraft</th>
<th>number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denola</td>
<td>2011</td>
<td>Australia</td>
<td>51.3</td>
<td>78</td>
<td>46 individual a/c</td>
<td>9 incidents smoke odour</td>
</tr>
<tr>
<td>Fox (PhD)</td>
<td>2012</td>
<td>US</td>
<td>100</td>
<td>?</td>
<td>Single engine study</td>
<td></td>
</tr>
<tr>
<td>Cranfield</td>
<td>2011</td>
<td>UK</td>
<td>37.7</td>
<td>100</td>
<td>5 a/c types</td>
<td>‘minor' fumes in 25 flights</td>
</tr>
<tr>
<td>Hanhela</td>
<td>2005</td>
<td>Australia</td>
<td>49</td>
<td>80</td>
<td>3 a/c types</td>
<td>no correlation, but some samples taken with canopy open</td>
</tr>
<tr>
<td>Fox / Malmo</td>
<td>1999</td>
<td>Sweden</td>
<td>20.3</td>
<td>1</td>
<td>1</td>
<td>(1) engine test</td>
</tr>
<tr>
<td>AFAP</td>
<td>2018/19</td>
<td>Australia</td>
<td>3.872</td>
<td>19</td>
<td>7 a/c, 1 type</td>
<td>19</td>
</tr>
</tbody>
</table>

300 different substances – cabin and bleed air studies
Pyrolysed oil 127 + (EASA 2017)

**Van Netten:** TCP makes up only 3% of jet turbine oil - the reported values should be multiplied by 33 to obtain exposure to all engine oil components
Sample 119 - This sample shows one of the higher results for TBP and TCP yet there was barely a detectable odour during the sampled flight. None of the cabin crew detected an odour at all and the pilots detected it only mildly.

This aircraft had a leaking hydraulic pressure line, with extensive hydraulic oil evident on the belly of the aircraft, as shown in the images. Note that the aircraft had been cleaned only 2 weeks earlier. Post incident this aircraft was designated for a further wash "at company convenience". On further investigation, engine oil was found to be present in the APU compartment drain and fumes were noted by the engineers when the APU inlet door was opened.

5 days later a significant oil fumes event occurred which involved an air return. No cause was found and it was suggested that the odour may have been due to "smelly passengers". One crew member showed a slightly elevated carboxy haemoglobin level (carbon monoxide) when tested several hours after the event.

This aircraft had also been reported for a strong oily odour on 2 previous recent occasions. After one of the events, engineers assessed the odour to be due to atmospheric ozone in accordance with the Trouble Shooting Manual.

Sample 115 - This sample was taken on reasonable suspicion of a problem due to recent occasional sporadic oily smells. Only one crew member detected a very mild "dusty" or "dry musty" smell during the sampling period. No other crew members detected any odour. This aircraft subsequently had a fumes event 6 weeks later with the crew describing a mild "heated dust-like" odour and then a moderate "sweaty socks" odour. Upon investigation engineers discovered oil leaking from the APU into the APU air intake.
Van Netten: **Sample #114** Significant TBP was detected as well as a trace of TCP. Again, as above, a high acute exposure could have been present during the sampling time.
APU HYDRAULIC OIL INGESTION

<table>
<thead>
<tr>
<th>Sample#</th>
<th>TBP</th>
<th>m-TCP</th>
<th>mmp-TCP</th>
<th>mpp-TCP</th>
<th>p-TCP</th>
<th>Total TCP</th>
<th>Flow rate (Liters/min)</th>
<th>Sampling time (minutes)</th>
<th>Volume (Liters of air)</th>
<th>TCP/m3</th>
<th>TBP/m3</th>
</tr>
</thead>
<tbody>
<tr>
<td>83 SIM</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1</td>
<td>54</td>
<td>54</td>
<td>LOD</td>
<td>383.3</td>
</tr>
<tr>
<td>107 SIM</td>
<td>9.20</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.2</td>
<td>20.00</td>
<td>24</td>
<td>LOD</td>
<td>1085.7</td>
</tr>
<tr>
<td>114 SIM</td>
<td>68.00</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>&lt;LOD</td>
<td>1.19</td>
<td>1.19</td>
<td>1</td>
<td>35</td>
<td>35.00</td>
<td>34.00</td>
<td>563.60</td>
</tr>
<tr>
<td>115 SIM</td>
<td>31.00</td>
<td>&lt;LOD</td>
<td>2.59</td>
<td>2.06</td>
<td>1.23</td>
<td>5.88</td>
<td>1.00</td>
<td>55.00</td>
<td>55.00</td>
<td>106.90</td>
<td>1390.60</td>
</tr>
<tr>
<td>119 SIM</td>
<td>89.00</td>
<td>69.95</td>
<td>126.05</td>
<td>80.12</td>
<td>34.73</td>
<td>247.85</td>
<td>1.00</td>
<td>64.00</td>
<td>64.00</td>
<td>3872.60</td>
<td>1510.20</td>
</tr>
<tr>
<td>125 SIM</td>
<td>74.00</td>
<td>14.55</td>
<td>26.38</td>
<td>15.46</td>
<td>6.41</td>
<td>62.80</td>
<td>1.10</td>
<td>45.00</td>
<td>49.00</td>
<td>1281.60</td>
<td></td>
</tr>
<tr>
<td>161 SIM</td>
<td>5.00</td>
<td>4.86</td>
<td>9.78</td>
<td>6.21</td>
<td>2.93</td>
<td>23.78</td>
<td>1.20</td>
<td>40.00</td>
<td>48.00</td>
<td>495.40</td>
<td></td>
</tr>
</tbody>
</table>

APU hydraulic oil ingestion aligns with detected TBP
APU HYDRAULIC OIL INGESTION
COMMON SYMPTOMS OF ILLNESS //

Single or short-term exposures:

- **Neurotoxic**: blurred or tunnel disorientation, shaking and tremors, loss or seizures, loss of consciousness
- **Psychotoxic**: memory impairment, headache, light-headedness, dizziness, confusion and feeling intoxicated
- **Gastro-intestinal**: nausea, vomiting
- **Respiratory**: cough, breathing difficulties

Long term low-level exposure or residual exposure:

- **Neurotoxic**: numbness (fingers, lips, limbs), parathesias
- **Psychotoxic**: memory impairment, lack of coordination, forgetfulness, severe headaches, dizziness, sleep disorders
- **Gastro-intestinal**: salivation, nausea, vomiting, diarrhea
## RAW DATA SECOND SAMPLE SET

<table>
<thead>
<tr>
<th></th>
<th>ng/filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 102 SIM</td>
<td>TBP 57.15</td>
</tr>
<tr>
<td>Sample 68 SIM</td>
<td>96.30</td>
</tr>
<tr>
<td>Sample 69 SIM</td>
<td>68.08</td>
</tr>
<tr>
<td>Sample 71 SIM</td>
<td>68.87</td>
</tr>
<tr>
<td>Sample 81 SIM</td>
<td>83.17</td>
</tr>
<tr>
<td>Sample 163 SIM</td>
<td>112.84</td>
</tr>
<tr>
<td>Sample 112-1 SIM</td>
<td>165.19</td>
</tr>
<tr>
<td>1-Con(Process control) SIM</td>
<td>51.32</td>
</tr>
<tr>
<td>Blank 1</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Blank 2</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Blank 3</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>Blank 4</td>
<td>&lt;LOD</td>
</tr>
<tr>
<td>LOD</td>
<td>2.08</td>
</tr>
</tbody>
</table>
Hair sampling confirming a presence of chemicals including tri-cresyl phosphate (TOCP) in his system,

I found offered history most compelling and could not exclude the possibility of a syndrome secondary to chronic airborne chemical exposure.

report by Dr proposed a link between exposures derived from his employment and his subsequent symptoms, and concluded with the recommendation that should not fly again in an aircraft in which fume events were possible,

Report: Opinion: Treating doctor correspondence, Serial consultations Enduring and fluctuating symptoms of cough and wheeze, but additional non-specific, systemic symptoms such as malaise and headache. ...there was evidence of tri-cresyl phosphate exposure and organophosphate exposure in specialist pathology sampling..

Although not a generally accepted term,...case is consistent the diagnosis of "aerotoxic syndrome". There are ample grounds to surmise that symptoms are consistent with airborne chemical fumes used in the aviation.

There is evidence that in some cases, symptoms can endure indefinitely. Treatment is supportive.
UFPs: CRANFIELD 2011

No air quality event reported
Aircraft 12 years old

81,000 with strong oil smell on ground when APU selected on

Reapplication of climb power during climb

Introduction of engine bleed air after takeoff
Aircraft 14 years old

97800 after introduction of engine bleed air – full power takeoff

81500 – 1st pack selected on when climb power set after takeoff

Data collection stopped
Captain Marcus Diamond
BSc Melb, ATPL Aus, NZ, PNG
Safety & Technical Manager

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Aircraft Cabin Air – Neurotoxicity

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Lab of Neurophysiology | qEEG – ERP
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Neurophysiology

qEEG – ERP - EP
Neurophysiology

• EEG
Neurophysiology

qEEG

2D Topography

- Theta
- Alpha

3D Source Analysis

- Absolute Power
- Amplitude Asymmetry
- Coherence
- Phase Lag

Event Related Potentials

- P300
  - Pz

- EP
  - Auditory
  - Visual

- CNV
  - Cz
Neurophysiology

- qEEG
  - 2D topography

![Graphs and Topographies](image)

qEEG - Spectral Analysis and 2D Topography
Neurophysiology

- qEEG
  - LORETA 3D Source Analysis

qEEG - Low Resolution Brain Electromagnetic Tomography
Preliminary Results

Total subjects: 30
Neurophysiology

• Subjects
  ▪ 30 (of 100+)
  ▪ Pilots, Flight Attendants
    Frequent Flyers, Ground Crew
  ▪ 25-67 years of age
  ▪ 2-42 years of flying
  ▪ Active or
    Non-active for 6 months – 22 years
Group 1
Total subjects: 25 of 30

Group 1 - Persistent base rhythm
Group 1

Total subjects: 25 of 30

• 2D Topography

![Graph showing absolute and relative power distributions across different frequencies.](image-url)
Group 1
Total subjects: 25 of 30

• LORETA
Group 1
Total subjects: 25 of 30

- qEEG
  - 3D LORETA

Right Hemisphere
Group 2

Total subjects: 4 of 30

Group 2 - Minimal base rhythm
(Group 3)
Total subjects: 1 of 30

Delta
Theta
Alpha
Beta

Absence of base rhythm

2013
2019

2013
2019

2013
2019

2013
2019
Pattern Distribution

Total subjects: 30

- **Group 1**
  - **Prominent** base rhythm
  - R-Post-central, R-Superior Temporal
  - Peak Frequency: 7-12 Hz
  - Pilot, Flight Attendant
    Frequent Flyer, Ground Crew

- **Group 2**
  - **Minimal** base rhythm
  - R-Post-central, R-Superior Temporal
  - Peak Frequency: 9-12 Hz
  - Pilot, Flight Attendant
    Frequent Flyer

- **(Group 3)**
  - Absent base rhythm
  - Frequent Flyer
Connecting the dots
Cognitive (dys)functions

• Functions
  ▪ Sensory integration
  ▪ Attention
  ▪ Executive functions

• Symptoms
  ▪ Hypersensitivity
  ▪ Attention problems
  ▪ Losing train of thought
  ▪ Unable to multitask
  ▪ Trouble following conversations
  ▪ Difficulty remembering steps in a multi-step process
  ▪ Slow processing
Cholinergic System

- **Organophosphates**
  - Bleed Air - Tricresyl phosphate (TCP)
  - Desinsectants
  - Flame Retardants
- **Carbamates**
  - Desinsectants
- **Metals**
  - Aluminum
Cholinergic System

- Acetylcholinesterase (AChE)
Cholinergic System

- Acetylcholinesterase (AChE)
Aerotoxic Signature (AS)?

Organophosphates

Cholinergic System

Symptoms

- Sound and Light hypersensitivity
- Attention problems
- Losing train of thought
- Unable to multitask
- Trouble following conversations
- Difficulty remembering steps in a multi-step process
- Slow processing

qEEG (ERP)

Distribution

AchE, ACh, ChAT, receptors

Drugs

Acetylcholine (ACh), Choline Acetyltransferase (ChAT)
Thank you for your attention

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Making the Safety Case for Aircraft Operators
(Fume Risk in the Cabin/Cockpit)

Cliff Edwards
Independent Aviation Risk Management Consultant (Retd)
Background

• This presentation suggests arguments to aid the management of risks of fume contamination of the cockpit or passenger cabin during operational flights.

• The focus of this paper is commercial aircraft operations.

• Cliff has spent much of his career leading in developing aviation safety systems for aircraft operators.

• He has no specialist skills in aircraft design, or specialist knowledge in fume contamination, but he recognises the risks.
Managing Risk

• Risks exist in life, & largely we manage these,
  – if we know of the risks, and
  – understand how to control the level of risks we face.
• Technically “risk” is a calculated point to predict the probability x severity of the risk effecting the organisation.
• Public transport aircraft operators are required to manage their risks as a corporate responsibility, and this sits with the Accountable Manager.
Managing Risk

• Donald Rumsfelt made famous the statement that there are three classes related to Risks:
  ▪ Known Knowns
  ▪ Known Unknowns, and
  ▪ Unknown Unknowns
• The former as we know these risks should be managed already.
• The latter can’t be effectively managed as they are unimagined.
• The middle group which I believe includes fume contamination is an emerging risk needing to be effectively managed.
• It falls to aircraft operators to demonstrate management of this risk, or potentially face future litigation.
Demonstrating Risk Management

• Risk & Hazard Management is a core requirement of the operator’s required SMS.
• Risk assessments are done using a structured approach, typically a matrix.
• Once risks are assessed, it is a corporate responsibility to demonstrate effective control.
• Risks should be managed effectively to levels of an acceptable level of safety, preferably ALARP (as low as reasonably practicable).
### The Argument for ALARP?

What do we mean by achieving an acceptable level of safety:

- Is ALARP Achievable?
- What is Tolerable?
- What is an acceptable level of safety?

<table>
<thead>
<tr>
<th>The Safety Case &amp; Hazard Analysis</th>
<th>Legal safety level as the Way the lawyers see it Well intentioned safety level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional Requirements</td>
<td>Where we are today safety level</td>
</tr>
<tr>
<td>OPERATION</td>
<td>Tolerability as defined as the minimal level acceptable to the Accountable Manager</td>
</tr>
<tr>
<td>REGULATIONS</td>
<td>OM and MOE Level</td>
</tr>
<tr>
<td></td>
<td>ALS (Acceptable Level of Safety)</td>
</tr>
<tr>
<td></td>
<td>Define the minimum level you must meet</td>
</tr>
<tr>
<td></td>
<td>Baseline Level</td>
</tr>
</tbody>
</table>

**True ALARP**

**GAP**

**Temporal ALARP Level**

**Tolerability Level**
The Operational Safety Case

• The aircraft manufacturers and the regulators appear to be reluctant to aid operators in managing this laterly defined risk, we developed a bowtie hazard analysis and a draft Safety Case that can be used by the operators.

• These documents offer a modelled approach that is not specific to any aircraft type, or aircraft operator.

• However it is relevant to the fume contamination in the cabin and cockpit.

• And its free of charges and consultants!
The Operational Safety Case

- Safety Case includes a generic Risk Assessment.
- Fume contamination is an emerging risk to the aircraft operator in their risk profile, it nonetheless exists.
- As a risk that can impair the health & performance of both flight crews and the operator’s clients it should not continue to be ignored.
The Operational Safety Case

• The level of risk is not the key issue driver but it exists and has caused harm to occupants of pressurised aircraft so it is relevant.

• The aircraft operator’s Accountable Manager is responsible for the management of their risks.

• If not appropriately addressed it will leave aircraft operators exposed to challenges and potential liabilities.
The Hazard Analysis (HA)

- DON’T PANIC!
- This is the total picture
- Let’s break it down to core elements
Core Elements of the HA

- One Hazard (Contaminated Bleed Air)
- One Top Event (Toxic fumes from a/c pressurisation and conditioning systems in cockpit and cabin)
- 6 Primary threats
- 6 Potential consequences of varying significance.
One Hazard

“Fume contaminated air” - is able to enter the cabin and cockpit through the designed-in air management systems.

- This is of course a variable, dependent on the engines’ current condition, design limits and aircraft type.

- Nonetheless, the fumes from superheated oils used in aircraft engines are demonstrably toxic if breathed in sufficient amounts.
One Top Event

Toxic fumes from the aircraft pressurisation and conditioning systems enters into the cockpit & cabin.

- The top event defines the first point of loss of control
- This also is a variable, that is dependent on the engines’ current condition, design limits and aircraft type
- It is not limited to engines having significant oil loss across the seals.
6 Primary Threats

Each threat has differing controls defined in the Hazard Analysis, most of which are not currently in practical use.

- T1-R Inadequate aviation regulatory oversight for air contamination
- T2-R OH&S regulations not applied or enforced for air crew and passengers in relation to air contamination
- T3-R Oils reaching the gas path used at high temperatures where toxins are released
6 Primary Threats

Each threat has differing controls defined in the Hazard Analysis, most of which are not currently in practical use.
6 Consequences

1st consequence

Single extreme event results in incapacitation or death of one or more crew or passengers

6th consequence

Damage to airline/operator reputation through inadequate quality of air which through new technology can be much improved

The consequences range from the single extreme event in decreasing order of severity to damage to reputation
The Identified Risks

The risks may vary in individual operations depending on the means of assessment employed, we used the CS-25 Amdt. 22, 2018 wording and conclude these to be:

**Hazardous:** Failure Conditions, which would reduce the capability of the aeroplane or the **ability of the crew** to cope with adverse operating conditions to the extent that there would be:

(i) A large reduction in safety margins or functional capabilities;
(ii) Physical distress or excessive workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or
(iii) Serious or fatal injury to a relatively small number of the occupants other than the flight crew.
# A Generic Risk Assessment

<table>
<thead>
<tr>
<th>Potential Consequence of a Hazardous Fume</th>
<th>Increasing Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rating</strong></td>
<td><strong>People</strong></td>
</tr>
<tr>
<td>0</td>
<td>No adverse effect</td>
</tr>
<tr>
<td>1</td>
<td>Minor adverse effect (Slight Impairment)</td>
</tr>
<tr>
<td>2</td>
<td>Major adverse effect (Impairment)</td>
</tr>
<tr>
<td>3</td>
<td>Hazardous adverse effect (Significant impairment)</td>
</tr>
<tr>
<td>4</td>
<td>Hazardous adverse effect (Single fatality or serious injury)</td>
</tr>
<tr>
<td>5</td>
<td>Catastrophic Effect</td>
</tr>
</tbody>
</table>

- **A** Extremely improbable < 1x10^-9
- **B** Extremely remote < 1x10^-7
- **C** Remote < 1x10^-5
- **D** Probable < 1x10^-3
- **E** Frequent > 1x10^-3

Integrate risk reduction measures as necessary for intolerable outcomes.

---

**Legend:**
- Slight Impairment
- Impairment
- Significant Impairment
- Serious Injury
- Death

---

**Notes:**
- Incorporate risk reduction measures as appropriate.
- Evaluate outcomes for further risk assessment.

---

**Conclusion:**
- Continuous monitoring and risk mitigation strategies are essential for safety.
Conclusion

- These Risks Exists in your day to day operations.
- This operator-based approach demonstrates the possible threats and controls needed to manage the hazard and avoid the potential consequences.
- **Accountable Managers** need to be able to demonstrate adequate control of this hazardous event.
- Detailed copies of the generic Safety Case could be made available to aircraft operators.

- Are you adequately prepared?
GITTE FURDAL DAMM

- Danish Aviation College 1997
- Aviation Assistance 1998-1999
- Cimber Air 2000-2012
- Jettime 2014-2016
- About Human Factors 2016 - Now
- Human Factors and System Safety 2019 -2020 Lund University
“Human Factors is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance” (Human Factors & Ergonomics Society).
Reykjavik Flight Symposium 2018

Is Resilience a Valuable Skill in Aviation?
WHY DID I NOT KNOW OF THIS?

▸ General knowledge about contaminated cabin air?
▸ Investigations reports methods?
▸ Training and tools provided?
▸ When things become the norm?
▸ Political interests?
From the Flight Crew:

From Investigation Report:

ABOUT HUMAN FACTORS
Hindsight Bias

Richard Cook
The ‘FUSELAGE FIRE OR SMOKE – SMOKE’ checklist in the operator’s FCOM had the following memory items:

- **Oxygen Masks**
  - On + 100%
- **Smoke Goggles**
  - On
- **Mic switch**
  - MASK
- **Hot Mic**
  - OFF
- **Headset**
  - On
- **Recirc Fans**
  - OFF
- **Emergency Lights**
  - ON
- **Passenger Signs**
  - ON
- **Descend**
  - ASAP - Check MSA
- **Land immediately at nearest suitable aport**
8.8

Smoke, Fire or Fumes

Condition: Smoke, fire or fumes occur.

1. Diversion may be needed.
2. Don oxygen masks and set regulators to 100%, as needed.
3. Don smoke goggles, as needed.
4. Establish crew and cabin communications.
5. BUS TRANSFER switch .............. OFF
6. CAB/UTIL switch .................. OFF
7. IFE/PASS SEAT switch ............. OFF
8. RECIRC FAN switches (both) ....... OFF
9. APU BLEED air switch ............. OFF
10. **Anytime** the smoke or fumes become the greatest threat:
    
    >>> Go to the Smoke or Fumes Removal checklist on page 8.16

**Continued on next page**
Use of Oxygen Masks

The 663 reports (between 2006 and 2013) were analysed in regard to the flight crew donning their oxygen masks. The results are: in 154 cases the masks were donned and in 146 they were not. In 363 cases the reports did not include any information regarding oxygen masks. Break down in percent:

- **Yes**: 23.2%
- **No**: 22.0%
- **Not reported**: 54.8%

Analysis of the reports regarding the use of oxygen masks in the cockpit
NUISANCE OR FLIGHT SAFETY?

▸ “In the past, oil leaks and cabin/flight deck odours and fumes may have come to be regarded as a nuisance rather than a potential flight safety issue”
The Local Rationality Principle

“People are doing reasonable things given their point of view and focus of attention; their knowledge of the situation; their objective and the objectives of the larger organisation that they work for. In the end, what they do makes sense to them at that time. You have to assume that nobody comes to work to do a bad job”.

(Sidney Dekker, Field Guide to Understanding Human Error).
The ability to see, hear or become aware of something through our senses, and the way in which something is regarded, understood or interpreted shaped by learning, memory, expectation and attention.
CHALLENGES IN CURRENT THINKING

- Lack of education/training
- Nuisance vs. flight safety
- Tools provided
- The human aspect
Work-as-imagined  Work-as-done

Erik Hollnagel
NORMALISATION OF DEVIANCE

The gradual process through which unacceptable practice or standards become acceptable
Considering the human aspect

“If professionals consider one thing “unjust” it is often this: split-second operational decisions that get evaluated, turned over, examined, picked apart, and analysed for months - by people who were not there when decisions was taken, and whose daily work does not even involve such decisions”

Sidney Dekker, Just Culture.
WHAT TO DO?

▸ Think differently
▸ Educate the practitioners
▸ Incorporate knowledge in training
▸ Encourage inputs from practitioners
▸ Consider the human aspect
“Human Factors is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance” (Human Factors & Ergonomics Society).
THANK YOU FOR YOUR ATTENTION
Suspected air quality problems on board

Experiences & Actions
First serious incident reported in year 2012
Boeing 757 A/C - Registration: TF-ISL

Cabin Crew not able to perform duties due to illness. Aircraft diverted to the nearest airport
• Cabin crews more aware of CAQ after this incident
• Increase in CAQ reports
• New Safety Management System implemented
• Reporting system more accessible and effective
• Employees encouraged to report safety issues
• Flight crew informed about possible causes for discomfort on board
Common description in reported cabin crew illness

Cabin crew illness/dizzy/shortness of breath
CC illness - 2 cc exp headache, nausea, oxy
CC illness – oxy
Cabin crew ill/dizziness
Crew illness/dizziness
CC illness - 4 cc experienced dizziness
CC illness - all cc exp dizzy, headache
CC illness - 1 cc exp nausea, dizzy, oxy
Poor air quality in cabin
Cabin crew illness - oxy, dizzy, nausea, headache
<table>
<thead>
<tr>
<th>Toxic aero syndrome</th>
<th>Hypoxia</th>
<th>Motion Sickness</th>
<th>Hyper ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fatigue</td>
<td>• Changes in skin colour, ranging from blue</td>
<td>• Nausea.</td>
<td>• Dizziness</td>
</tr>
<tr>
<td>• Blurred vision</td>
<td>to cherry red.</td>
<td>• Pale skin.</td>
<td>• Lightheaded</td>
</tr>
<tr>
<td>• Loss of consciousness</td>
<td>• Confusion</td>
<td>• Cold sweats.</td>
<td>• Weakness</td>
</tr>
<tr>
<td>• Dizziness</td>
<td>difficulties in concentration</td>
<td>• Vomiting.</td>
<td>• Confusion</td>
</tr>
<tr>
<td>• Headaches</td>
<td>• Coughing</td>
<td>• Dizziness.</td>
<td>• Fast heart rate</td>
</tr>
<tr>
<td>• Vomiting or nausea</td>
<td>• Fast heart rate.</td>
<td>• Headache.</td>
<td>• Shortness of breath.</td>
</tr>
<tr>
<td>• Irritation to eyes, nose and throat</td>
<td>• Rapid breathing.</td>
<td>• Increased salivation.</td>
<td>• Numbness or tingling in hands or</td>
</tr>
<tr>
<td>• Confusion difficulties in concentration</td>
<td>• Shortness of breath.</td>
<td>• Fatigue.</td>
<td>feet</td>
</tr>
<tr>
<td></td>
<td>• Sweating.</td>
<td></td>
<td>• Anxiety</td>
</tr>
<tr>
<td></td>
<td>• Wheezing.</td>
<td></td>
<td>• Fainting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Sore chest muscles.</td>
</tr>
</tbody>
</table>
Nr of AQR per year 2014-19
Total legs on all aircraft

<table>
<thead>
<tr>
<th>Year</th>
<th>Nr of reports</th>
<th>Per 10,000 legs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>22</td>
<td></td>
</tr>
</tbody>
</table>
Nr of reports per month 2018-19

- January 2018: 2
- February 2018: 2
- March 2018: 3
- April 2018: 3
- May 2018: 10
- June 2018: 5
- July 2018: 4
- August 2018: 8
- September 2018: 11
- October 2018: 2
- November 2018: 2
- December 2018: 0

- January 2019: 2
- February 2019: 1
- March 2019: 5
- April 2019: 3
- May 2019: 10
- June 2019: 5
- July 2019: 4
- August 2019: 8
- September 2019: 2
- October 2019: 2
- November 2019: 0
- December 2019: 0
How many affected by suspected bad air quality 2019
All CC or fewer

- All cc: 6
- '1-3cc: 14
One incident where engine borescope indicated a defect seal on engine shaft to be the cause for oil smell in cabin. The engine in question was replaced.

Reported incidents where defect APU gearbox pressure regulating valve, was presumably the cause for oil smell in cabin.
One incident due to leaking seal on engine shaft

Rolls-Royce RB211 Turbofan

Diffuser  LP Fan  IP Compressors  HP Compressors  Combustor  HP Turbine  IP Turbine  LP Turbines  Nozzle

High Pressure Shaft
Intermediate Pressure Shaft
Low Pressure Shaft
GEARBOX REGULATING VALVE

Identification and Location
The gearbox regulating valve is a normally open, air pressure closed valve.

The gearbox regulating valve is mounted above the de-oil solenoid valve on the front of the gearbox.

The gearbox regulating valve is an LRU.

Purpose
The gearbox regulating valve helps provide and maintain gearbox

If the gearbox regulating valve fails mechanically closed:

• Oil will be pushed through the carbon seals, possible smell
  in cabin, smoke out of exhaust, or oil consumption during
  ground operations

• In-flight operations would be normal

When the gearbox pressure increases, pressure is applied to the
poppet. When the force exceeds pre-load on spring, the poppet
will modulate to relieve all pressure in excess of 4.5 psid above
ambient. Air is vented through the discharge orifice of the sleeve
and the discharge port of the valve.

Maintenance Tip
If the gearbox regulating valve fails mechanically open:

• The APU operates normally during ground operations
Difference between ACS on B767 and B757

ACS Boeing 767

ACS Boeing 757
Guidelines in case of illness of crew members in flight
Illness of Crew Member(s) (in-flight)

Guidelines when a crew member feels unwell and/or ill during flight.

Immediately inform SCCM and Commander of Crew Members condition. Important, regardless of severity of illness

Is the Crew Member able to perform duties??

YES

Observe and monitor health status.

NO

Commence First Aid and contact MedAire
In case of serious illness, use ALERT CALL.

SMS360 Report
All Crew illness shall be reported, regardless of severity.

NO

Is there any suspicion of Air Quality/Odour event?

YES

Treat the symptoms and contact MedAire;
- Administer Oxygen from portable oxygen bottle, until symptoms have subsided.
- Contact MedAire and follow recommendations.
- Continue oxygen treatment if necessary.

The importance of reporting.
For effective and efficient process of investigation and overall management, reporting is vital.
Filling in the CTL, SMS360, Air Quality Report and AJTL is mandatory.

Cabin Technical Log
Suspicion of Air Quality/Odour event shall be logged in CTL.
It is important for concise technical inspection/analysis.
Include:
- Cabin Temperature
- Airflow of vents in galley/cabin
- Smell or Odour
- Other

Air Quality Report
Where?
In Forms-folder in Flight Deck (and Comply-Resources-Air Quality Report)

Who reports?
All Crew Members experiencing symptoms
Commander will place the report in the AJTL
If report is submitted post-flight, attach a copy with SMS360 report.

SMS360
All Crew illness shall be reported, regardless of severity
Where?
https://ice.sms360.net (mywork)

Who reports?
Commander,
SCCM and/or Crew Member involved.

AJTL
Enter „Suspected Air quality event“ in the defects column.

Who Reports?
Commander
Standardized Cabin Air Quality Reporting Form

Based on IATA Guidance for airline health and safety staff on the medical response to Cabin Air Quality Events
ANNEX 1

Standardized Cabin Air Quality Reporting Form

Based on IATA Guidance for airline, health, and文创 staff on the medical response to Cabin Air Quality Events

Section 1: Flight and Reporter Details

Note: For each question, check all that apply. If one answer is dominant for a given question, write an * next to that item.

AC number: AC type: Flight date: 
Tech log # (known): Departure site: 
Reporter name: Employee no.: Email: Phone: 

Form completed by: 
- Flight crew 
- Cabin crew 
- Maintenance 
- Other 

PIC signature (operator discretion) 

Phase(s) of flight:
- Parked (pre-flight) 
- Pushback 
- Engine start 
- Taxi-out 
- Take-off 
- Climb 
- Cruise 
- Descent 
- Approach 
- Take-off 
- Climb 
- Parked (post-flight) 

Estimated duration of incident
__________ (hrs.) ______ (min.) 

Engine power level changes:
- Yes 
- No 
- Unknown 

Knows history of similar conditions on same aircraft?
- Yes 
- No 
- Unknown 

Recent aircraft service history:
- None 
- De-icing or anti-icing 
- Engine/APU oil serviced 
- Other 
- Unknown 

Section 2: Smoke or Fire Information

Note: For each question, check all that apply. If one answer is dominant for a given question, write an * next to that item. 

Evidence of smoke or fire?
- Smoke 
- Fire 
- Neither smoke nor fire 

Type of smoke or fire?
- Localized smoke 
- Generalized smoke 
- Open flame 

Location of smoke or fire:
- Cabin: if cabin specify: 
- Flight deck 
- Lavatory 
- Galley 
- Cargo 

Section 3: Fume Information

Note: For each question, check all that apply. If one answer is dominant for a given question, write an * next to that item.

If fume, describe type:
- Acrid 
- Chemical 
- Decaying 
- Smelly 
- Musty or mouldy 
- Exhaust 
- Electrical 
- Fuel 
- Vomit 
- Other 

Icelandair
Intensity of fumes
- Mild
- Moderate
- Strong
- Nauseating

If fumes in cabin:
- Forward cabin
- Mid cabin
- Aft cabin
- Galley
- Lavatory
- Other:

Apparent location of fumes in cabin/flight deck:
- Air supply system vents
- Cabin item
- Flight deck equipment
- Galley equipment
- Other:
- Unknown

If fumes in flight deck:
- General flight deck area

If fumes in cargo:
- Known source
- Unknown source
- If known, identify:

Potential source of fumes coming from outside the aircraft:
- De-icing or anti-icing underway
- Fueling underway
- Proximity to other aircraft (exhaust)
- Proximity to ground service vehicle exhaust
- Other:

Section 4: Other Observations — All Events
Note: For each question, check all that apply.
- Blocked drain
- Cabin item:
- In-flight entertainment system malfunction
- Galley equipment malfunction
- Air outlets in galleys closed
- Air outlets in galleys open
- Leak or spill
- Lights flickering or malfunction
- Dry-ice being used in galleys
- Irregular equipment noise
- Other:

Air supply source:
- APU
- Engines
- Ground conditioned air unit
- Ground air starter
- Other:

Section 5: Symptoms and Reactions — All Events
Note: For each question, check all that apply.

Symptoms reported?
- Yes; if yes, complete table below
- No
- Unknown

If yes, symptoms reported by:
- Flight crew
- Cabin crew
- Maintenance
- Passenger(s): Seat #
### Symptom/Reported by
- Abnormal taste
- Dizziness
- Fatigue or weakness
- Headache
- Irritated eyes, nose, throat
- Slowed thinking
- Tingling
- Trouble breathing
- Nausea
- Other

### Flight crew | Cabin crew | Maintenance | Passenger(s)
--- | --- | --- | ---

### Comments:

---

### Emergency equipment used?
- Yes: if yes, complete table below
- No

<table>
<thead>
<tr>
<th>Equipment/used by</th>
<th>Flight crew</th>
<th>Cabin crew</th>
<th>Maintenance</th>
<th>Passenger(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen mask</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoke goggles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portable breathing equip.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portable oxygen bottle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire extinguisher</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drop down masks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Medical assistance required?
- None
- Flight crew
- Cabin crew

### Type of medical assistance if applicable:
- On-board only
- Medical advisory service
- Emergency room or clinic
- Other: ________________

### Additional details:

---

---

### Section 6: Maintenance Follow-Up and Information — All Events

Note: If these questions don't apply, Maintenance fault or source identified?  
- Yes
- No

### Impact on operation
- None
- Diversion
- Return to base
- Aircraft change
- Flight cancelled
- Gate delay
- Other: ________________

### Maintenance action(s), if known:

---

---

If needed, provide additional comments:

---
Cabin Air Quality
Phase 1 inspection
Task No: ENG-SYS-2100-001
CAQ flow chart - Line Maintenance procedure

In-flight CAQ Reported by crew Line Maintenance procedure

Is there an AJTL entry stating anything about poor cabin air quality

No → No further action needed

Yes → Did crew complete CAQ report?

No → No action needed. A/C is serviceable

Yes → Perform CAQ phase I inspection as per task ENG-SYSY-2000-001

Yes → Review CAQ report and question operating crew if they noticed any toxic smell/odor, or saw any smoke or fumes

No → Release A/C after CAQ phase I inspection and defer CAQ phase II inspection for 10 calendar days

Yes → Perform CAQ phase II inspection as per task ENG-SYSY-2000-002 before next flight

Continue

If no further CAQ report on A/C in 10 consecutive calendar days, initial report is considered as isolated one time occurrence and CAQ phase II inspection can be canceled

Continue

Make a note any maintenance actions on MC and line shift handover
# Accomplishment Instructions

## Part 1 - Preparation

<table>
<thead>
<tr>
<th>Subtask</th>
<th>Description</th>
<th>Acc. By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Go over the attached flow chart <strong>at the bottom</strong> of this task to determine if either Phase 1, Phase 2, both or neither inspections are required. <strong>NOTE:</strong> If neither task is applicable, N/A the rest of this task and close in Mainteninx.</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Prepare and make sure a man-lift is available for APU access</td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>In Mainteninx, determine how much is left of interval for HEPA filter replacement task 21-004-00-X, record FH left below: FH left: ________ FH <strong>NOTE:</strong> Contact Maintenance Control if unsure how to perform this action.</td>
<td></td>
</tr>
</tbody>
</table>

## Part 2 - HEPA filter

*If the HEPA filters are replaced, make sure they are sealed in a bag and routed to U/S part shelf on KEF Line.*

*Notify Maintenance Control of the location of the HEPA filter so they can be sent for lab analysis.*

**NOTE:** HEPA filters do deliver 100% airflow even though they are 99% clogged!

<table>
<thead>
<tr>
<th>Subtask</th>
<th>Description</th>
<th>Acc. By</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>If HEPA filters are found in US condition or have less than 600 FH remaining, replace the filter i.a.w AMM 21-25-02. Contact Maintenance Control to reset the time of task 21-004-00-X in Mainteninx. <strong>NOTE:</strong> If the HEPA require replacement, N/A all other steps in Part 2.</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>Inspect HEPA filters by removing the AFT bulkhead heating system access panel i.a.w. AMM 25-50-03-004-001.</td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>Use a flashlight for a look at the HEPA filters to determine the condition of the filters.</td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>If the HEPA filters are found dirty, replace i.a.w AMM 21-25-02. Contact Maintenance Control to reset the time of task 21-004-00-X in Mainteninx.</td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td>Replace all cabin and flight compartment zone temperature sensor filters and make sure that the fans are operational i.a.w AMM 21-61-09-209-001.</td>
<td></td>
</tr>
</tbody>
</table>
| 3.2 | Check cabin, lavatories and galleys for any unusual odor, for example:  
+ Food in galley  
+ Urine Smell in lavatories and surrounding area  
+ Electrical Smell in Cabin/Galley  
+ If oil, hydraulic or de-icing odor, fumes found in flight compartment, cabin or galley investigate source |
| 3.3 | Visually inspect FWD and AFT galley ventilation filters for cleanliness, replace if found dirty.  
Check for adequate airflow by using a piece of A4 paper to cover the ventilation grille, see if airflow is adequate to hold the paper in place. |
| 3.4 | Open one passenger PSU (1/3) in each PSU and galley (close after measurement) and check for adequate airflow out of gaspers with velocity meter.  
**NOTE:** Normal airflow over passenger approximately 3-5 m/s  
**NOTE:** Normal airflow in galley approximately 10+ m/s (at least) |
| 3.5 | In the flight compartment, check EICAS STATUS and MAINT page for any ATA 21 (Air Conditioning) or ATA 36 (Pneumatics) related messages. |
| 3.6 | View EICAS ECS page and confirm proper operation of the following valve and temperature values raise/lower with operation of the temperature knob on the P5 overhead panel.  
- This task is similar to AMM 21-51-00-705-104 – Pack/Zone System Health Check  
**NOTE:** On some aircraft zone valve indication will blank in full open position.  
**NOTE:** Valve indication can be seen as “percentage of open”. The values as follows:  
+ 0.0 = Fully Closed  
+ 1.0 (or blank) = Fully Open  
**NOTE:** Temperature indications can be seen as follows:  
+ Full cold, heat decreases towards approx. 17 degrees  
+ Full hot, heat increases towards approx. 30 degrees  
Check the following valves on the EICAS ECS page:  
+ FLT DK pneumatic trim valve  
+ FWD pneumatic trim valve  
+ AFT pneumatic trim valve  
+ Master TRIM VALVE – check for normal open/close travel |
| 3.7 | Operate the air condition packs, walk the cabin aisle (FWD to AFT) and check for any unusual noise from sections of the overhead duct caused by ruptured/unconnected tubes/lines.  
**NOTE:** Normally, in these circumstances a low hissing sound might be audible.  
**NOTE:** Make sure HEPA filter inspection is complete before you do this. |
### Part 4 – Exterior/E&E inspection

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 4.1 | Check RAM air intake door for any obstructions and proper operation as per AMM 21-53-00-735-014 – System Test – Ram Air System  
**NOTE:** If not applicable, it is sufficient to remain in GND MODE. |
| 4.2 | Perform an operational test of the Recirculation System/Fans i.a.w AMM 21-25-00-005-040. |
| 4.3 | Perform BITE test on Cabin Temperature Controllers i.a.w AMM 21-51-00-745-159. |
| 4.4 | Perform BITE test on Cabin Pressure Controller i.a.w AMM 21-31-00-705-085. |
| 4.5 | Perform BITE test on the Yaw Damper Module i.a.w installation test of AMM 22-21-04-424-033. |
| 4.6 | Open engine cowlings and check Engines and APU for any obvious oil and/or hydraulic leaks. |
| 4.7 | Open the air-condition bay and check for any air or fluid leak above or around air-condition packs and intake. |
CORRECTIVE ACTION IN AIR QUALITY ISSUES IN GENERAL

ACTIONS TAKEN regarding Cabin Air Quality
1. ENGINES
   Swapping engines and parts;
   Oil replacement
   (TCP free oil on all B757 and B737 since 2005)

2. ACS
   Air filter exchange;
   Air condition ducts inspection and system cleaning
3. AIR QUALITY TESTING
On ground (Aerotracer) on passenger flights and special flights

Measurements include:

- atmospheric pressure and oxygen ratio
- temperature and humidity
- noise volume
- airspeed and distribution
- microbial and mold testing
- odor test (Aerotracer)
- Other test for: CO (Carbon Monoxide), CO2 (Carbon Dioxide), SO2 (Sulfur Dioxide), O3 (Ozone), VOC.
4. Icelandair’s Medical Officer review:
   • Medical examinations
   • Blood tests from crew members immediately after suspect flights.
   • No findings - All “normal“ results.

5. Investigation from the Icelandic Accident Investigation Committee (RNSA)
   • No findings – All “normal“ results.
On Going Actions - FACTS

Icelandair is participating in the European research project 'FACTS'.

The project is to determine the potential contamination of cockpit and cabin by engine oil.

Several test flights have already been flown.

Validate the Bleed Air Contamination Simulator (BACS).

Furthermore, these test flights are intended to provoke fume events during the flights to be able to capture samples for analysis into the contaminants in the air.
Recommendation

1. Get clear information about what chemical compound shall be looked for (FACTS)

2. Measure equipment on board every aircraft, that can collect samples of these compounds

3. Get clear information on where the hazardous to health limits are for these compounds

4. Total clean air system is promising, and should be tested further.
THANK YOU FOR YOUR ATTENTION
Why the brain is a vulnerable ‘target organ’ to chronic low-dose OP exposure

Prof Vyvyan Howard FRCPath
Centre for Molecular Biosciences
University of Ulster
v.howard:ulster.ac.uk

Aircraft Cabin Air Conference 2019
Critical research questions

• Why are pilots and cabin crew more vulnerable to the effects of ‘fume events’ than the passengers, particularly for neurological sequelae? One would expect the opposite – healthy worker effect.

• What is the effect of continual exposure to a low-dose complex mixture of fugitive turbine engine emissions for individual cumulative exposure times measured in thousands of hours?

• What is the effect continual exposure to an aerosol of combustion nano-particles on the kinetics of TAPS and other pyrolysis chemicals across the blood brain barrier?
Medical attention sought or hospitalisation after fume event

Fumes 88%
Fumes & haze 12%
Oil/hydraulic leaks identified 47%

Aircraft type

Aircrew
Passengers
The basic anatomy and physiology of nerve cells

- **Action potential**
- **Pre-synaptic ("sending") cell**
- **Synapse**
- **Post-synaptic ("receiving") cell**
Structure of a Neuron

cell body
nucleus
dendrite
axon
myelin sheath
Synapses
Axonal transport
Axonal transport
High dose OP exposure scenarios

- OPIDN
- Nerve gas effects
OrganoPhosphate induced Delayed Neuropathy is a HIGH DOSE condition

ESTERASE INHIBITION BY OPs

“Active” target protein

OH

+ ORGANOPHOSPHATE

“Inactive” target protein

If target is NTE and “aging” occurs, OPIDN is induced, which involves increased negative charge at the active site
TOCP can cause OPIDN at acute high doses
Nerve Agents Inhibit ACHE

ACh accumulates and causes over-stimulation of nerves, muscles and glands.
What does acetyl choline do?

**Effects**

- Acetylcholine is a transmitter in two kinds of synapses, meaning nerve agents function in two ways.
  - **Muscarinic receptors:**
    - Smooth muscle
    - Glands
  - **Nicotinic receptors:**
    - Skeletal Muscles
    - Ganglion
However not all adverse effects of OPs are high dose
Functional consequences of repeated organophosphate exposure: Potential non-cholinergic mechanisms

A.V. Terry Jr. *
The purpose of this review is to discuss several non-cholinesterase targets of OPs that might affect such fundamental processes and includes cytoskeletal and motor proteins involved in axonal transport, neurotrophins and their receptors, and mitochondria (especially their morphology and movement in axons).

117 References cited (41 in vivo, 12 in vitro, 15 in silico)
There is now substantial evidence that this canonical (cholinesterase-based) mechanism cannot alone account for the wide variety of adverse consequences of OP exposure that have been described, especially those associated with repeated exposures to levels that produce no overt signs of acute toxicity. These include covalent binding of OPs to tyrosine and lysine residues, which suggests that numerous proteins can be modified by OPs. In addition, the mechanisms of oxidative stress and neuroinflammation and the known OP targets of motor proteins, neuronal cytoskeleton, axonal transport, neurotrophins and mitochondria. This type of exposure has been associated with prolonged impairments in attention, memory, and other domains of cognition, as well as chronic illnesses where these symptoms are manifested (e.g., Gulf War Illness, Alzheimer's disease). Precisely the spectrum of symptoms reported for air crew by Michaelis, Burdon & Howard (2017).
Low dose effects of OPs detailed by Terry

**Table 1**

Non-cholinesterase targets of OPs (at physiologically relevant concentrations).

<table>
<thead>
<tr>
<th>Target</th>
<th>Description/functions</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Papain</td>
<td>Cysteine protease found in lysosomes</td>
<td>Chaiken &amp; Smith, 1969</td>
</tr>
<tr>
<td>Carboxylesterase</td>
<td>Serine hydrolase/enzyme that hydrolyzes carboxyl esters</td>
<td>Su et al., 1971; Chanda et al., 1997</td>
</tr>
<tr>
<td>Adenylyl cyclase</td>
<td>Enzyme that catalyzes the conversion of ATP to cyclic AMP/important in the G protein signaling cascade</td>
<td>Huff et al., 1994; Song et al., 1997; Auman et al., 2000</td>
</tr>
<tr>
<td>Neuropathy target esterase</td>
<td>Phospholipase enzyme important in phospholipid metabolism, neurite outgrowth and process elongation during neuronal differentiation</td>
<td>Lush et al., 1998</td>
</tr>
<tr>
<td>Acylpeptide hydrolase</td>
<td>Serine protease enzyme that catalyzes the removal of N-acylated amino acids from acetylated peptides role in the coordinated protein-degradation</td>
<td>Richards et al., 2000</td>
</tr>
<tr>
<td>M₂ muscarinic receptors</td>
<td>Second messenger coupled acetylcholine autoreceptor</td>
<td>Bomser &amp; Casida, 2001a</td>
</tr>
<tr>
<td>Fatty acid amide hydrolase</td>
<td>Serine hydrolase enzyme that catabolizes a class of bioactive lipids called the fatty acid amides including endocannabinoids (e.g., anandamide)</td>
<td>Quistad et al, 2001</td>
</tr>
<tr>
<td>Cannabinoid CB₁ receptors</td>
<td>G protein-coupled receptors for endocannabinoids/functions not fully understood, but may play roles in neurotransmitter release, synaptic plasticity, pleasure, appetite, memory/concentration, perception of time, pain tolerance, etc.</td>
<td>Quistad et al, 2002</td>
</tr>
<tr>
<td>Albumin</td>
<td>Most abundant transport protein in plasma, also regulates the colloidal osmotic pressure of blood</td>
<td>Peeples et al, 2005</td>
</tr>
<tr>
<td>Transferrin</td>
<td>Glycoprotein that binds and transports iron in the plasma</td>
<td>Grigoryan, Li, Anderson, et al., 2009; Grigoryan, Li, Xue, et al., 2009; Grigoryan, Schopfer, Peeples, et al, 2009</td>
</tr>
<tr>
<td>Kinesin</td>
<td>Motor protein involved in anterograde axonal transport in neurons as well as other cellular functions such as mitosis, meiosis, etc.</td>
<td>Grigoryan, Li, Anderson, et al., 2009; Grigoryan, Li, Xue, et al., 2009; Grigoryan, Schopfer, Peeples, et al, 2009</td>
</tr>
<tr>
<td>ATP synthase</td>
<td>Mitochondrial enzyme responsible for synthesizing ATP from ADP and inorganic phosphate</td>
<td>Grigoryan, Li, Anderson, et al., 2009; Grigoryan, Li, Xue, et al., 2009; Grigoryan, Schopfer, Peeples, et al, 2009</td>
</tr>
<tr>
<td>Tubulin</td>
<td>Globular proteins that form microtubules (i.e., polymers of dimerized tubulin which serve structural roles in the cytoskeleton, support intracellular transport, mitosis, etc.)</td>
<td>Jiang et al., 2010</td>
</tr>
</tbody>
</table>

*a GP-phosphorylation of M2 receptors reported by Bomser and Casida (2001) (using chlorpyrifos oxon) was not observed in experiments where paraoxon or a biotin labeled fluorophosphonate was evaluated (Proskocil et al., 2010).*

- detected anterograde axonal transport deficits associated with the oxon metabolite of chlorpyrifos at 0.1 nM \textit{in vitro}, in cultured embryonic rat neurons, a very low concentration.
Why are UFPs in cabin air of critical importance?

1) CV Howard: nanotoxicology review : University of Ulster
   • UFPs can cross the BBB and chemicals adherent to their surface ‘piggyback’ into the brain. Pharmaceuticals are already being delivered thus. Their continual presence in cabin air will enhance the penetration of neurotoxic substances into the brain.
   • A common feature of all UFPs, irrespective of their composition, is to induce inflammation, predominantly by ROS production.

2) Byron Jones- Kansas State University
   • Oil contamination of bleed air- Fine oil fog: 10-150 nm or below.
   • particulates as a marker of oil contamination in bleed air
   • Sensors to be developed for UFPs 10nm & below

Conclusions

• The basic physiology and anatomy of neurons in the CNS makes the brain particularly vulnerable as a target to damage by OPs at repeated low dose.

• The basic mechanisms – particularly impaired axonal transport - to explain this vulnerability have been published and reviewed in the scientific literature.

• The stance of some stakeholders to only address high dose exposure pathologies, such as OPIDN, ignores that literature and is scientifically unsustainable.

• The presence of an aerosol of UFPs in cabin air will have the effect of increased penetration of the blood brain barrier by UFPs which will be accompanied by any OP molecules adherent to their surfaces.
Bleed Air Contamination Detection

Byron W. Jones
Kansas State University

Aircraft Cabin Air Conference
London 2019
How do we ensure no oil in the bleed air supplied to the cabin? (existing fleet)

Two Options (at least):

• Detect and Isolate
• Clean the Bleed Air
Contamination Detected

Contaminated Air

Left Engine

Right Engine

APU
Contamination Source Isolated

Contamination Source

Left Engine

Right Engine

APU
Source determination easy.

Source determination difficult plus confounding from cabin sources.
Much of the Available Data from VIPR Project
And from Associated FAA-ACER Project
Detection Requirements

Real-time sensing, detect within minutes if not seconds.

As a minimum, detect at levels associated with acute contamination events.

Hopefully, detect at much lower levels.
What Level of Contamination

VIPR: 1200 gr/h oil for ~20 kg/s air flow 17 ppm by mass

ACER: 60 gr/h oil for ~1.5 kg/s air flow 11 ppm by mass

Levels are associated with acute contamination events.

May need to detect at levels at least an order of magnitude less for low level contamination detection, i.e. oil contamination on the order of 1 ppm by mass.
Potential Markers

Carbon Dioxide

Carbon Monoxide

Total Volatile Organic Compounds (TVOC)

Specific VOCs
  Formaldehyde
  Acetaldehyde
  Other?

Specific Semi-Volatile Compounds (SVOC)
  Tricresyl Phosphate (TCP)
  Others?

Particles
  Ultrafine Particles

Other? List is not necessarily comprehensive
Carbon Dioxide

At the levels of oil contamination associated with an acute contamination event, CO$_2$ concentrations will be raised by a few ppm at most.

Given background levels around 400 ppm, CO$_2$ is not sufficiently sensitive to be useful.

Conclusion: No
But may be useful for indicating engine exhaust.
TVOC

VIPR: ~500 ppb rise in TVOC over background with ~17 ppm by mass of oil

Possibly useful at altitude with good sensor for acute contamination event.

Problematic for lower levels of contamination.

Background levels in urban environments limits usefulness on ground.

Sensors available but need to be demonstrated viable for this application.

Conclusion: Maybe
Formaldehyde

VIPR: ~300 ppb rise in formaldehyde over background with 17 ppm by mass oil

Low background levels. Should be effective for acute contamination event.

Possibly useful for low-level contamination.

Sensors available but need to be demonstrated viable for this application.

Possible confounding by engine exhaust on ground.

Conclusion: Promising
Acetaldehyde

VIPR: ~200 ppb rise in acetaldehyde over background with ~17 ppm by mass oil

Low background levels. Should be effective for acute contamination event.

Possibly useful for low-level contamination.

Sensors not as readily available as for formaldehyde.

Possible confounding by engine exhaust on ground.

Conclusion: Promising but formaldehyde probably better.
Other VOCs present but at lower concentrations.

Nothing to indicate they would be better than formaldehyde or acetaldehyde.
Tricresyl Phosphate

VIPR: ~ 1 ppb with 17 ppm by mass oil

No real-time sensors readily available with the necessary detection levels.

Trend is to reduce or eliminate TCP in oil.

Conclusion: No
## Ultrafine Particles

**VIPR (Minimal Ingestion of Engine Exhaust)**

- Ambient: \(~1\times10^4\) particles/cm\(^3\)
- Bleed Air, No Oil: \(~1\times10^3\) particles/cm\(^3\)
- Bleed Air, Oil*: \(~2\times10^7\) particles/cm\(^3\)

**ACER (Significant Ingestion of Engine Exhaust)**

- Ambient, Engine Off: \(~2\times10^4\) particles/cm\(^3\)
- Ambient, Engine On: \(~2\times10^5\) particles/cm\(^3\)
- Bleed Air, No Oil: \(~2\times10^5\) particles/cm\(^3\)
- Bleed Air, Oil*: \(~2\times10^7\) particles/cm\(^3\)

* ~ 17 ppm by mass oil
Ultrafine Particles

Highly sensitive measurement. Certainly able to detect acute contamination event.

Should be able to detect contamination rates below 1 ppm of oil by mass if results scale to lower contamination rates.

Available sensors are expensive and not well suited for aircraft applications.

Conclusion: Very promising if suitable sensors become available.
Need to collect data at lower contamination concentrations to determine ability to detect low level contamination.

What works for oil may not work for hydraulic fluid; need data for hydraulic fluid.

High bleed air temperature key factor in producing VOCs and CO. High rotational speeds key factor in generating ultrafine particles. Need data for low power levels and for APUs. Is in-flight detection sufficient?
Discussion

Real time detection of acute contamination events is feasible. No technological breakthroughs required.

Detection does not have to be perfect to be useful. If we insist on perfect technology, it will never happen.

On-board sensing can be implemented in stages so we can learn as we go.

Recording for maintenance

Displays and warnings in cockpit

You have to take the first step or you never get anywhere.
Questions

Further Discussion
Ultrafine Particles

VIPR Data

Normalized Concentration (dN/dlog(Dp))

Mid-point Diameter (nm)

- Base case - (1200 grams per hr) injection
- ambient 1
- ambient 2
- ambient 3
- ambient 4
Deoxo™ Ozone and Ozone/VOC Converters: Essential for Cabin Clean Air

Victor Leung
Aircraft Cabin Air Conference
London, UK
September 2019
CLEAN AIR SOLUTIONS FOR AVIATION

- Introduction to BASF
- Deoxo™ ozone and ozone/VOC converters
- Converter life-cycle
- Converter maintenance
We create chemistry for a sustainable future.

- We source responsibly
- We produce safely for people and the environment
- We produce efficiently
- We drive sustainable solutions
- We value people and treat them with respect

We are one of the world’s leading companies in reporting on climate protection and sustainable water management

Sales (2018): €62.7B

Employees (2018): 122,404

6 Verbund sites and 355 other production sites
BASF BUSINESS SEGMENTS

Catalysis is one of the core technologies that binds together the business segments within BASF.
# BASF Catalysts Division

## Strategic Business Units

<table>
<thead>
<tr>
<th>Mobile Emissions Catalysts</th>
<th>Chemical Catalysts</th>
<th>Refinery Catalysts</th>
<th>Battery Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions-control catalysts for cars, trucks, motorcycles</td>
<td>Chemical catalysts plus adsorbents</td>
<td>FCC catalysts and additives for oil refining</td>
<td>Current and next-gen battery materials development</td>
</tr>
</tbody>
</table>

**Precious & Base Metal Services**

‘Full-loop’ metals distribution, financial services, recycling

**Clean Air Solutions**

Clean Air Solutions is committed to providing innovative solutions to the most complex emissions control problems for stationary, aerospace and indoor air.
CLEAN AIR SOLUTIONS SERVED INDUSTRIES

Matching chemistry & catalysis to solve sophisticated customer emissions challenges across a broad variety of industries & segments
**BASF PROVIDES AEROSPACE MATERIALS...**

<table>
<thead>
<tr>
<th>Additive Manufacturing</th>
<th>Air Quality Solutions</th>
<th>Cabin Interiors &amp; Seating</th>
<th>Coatings Solutions</th>
<th>Fire Protection</th>
<th>Fuel &amp; Lubricant Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermoplastic &amp; Thermoset Polymers</td>
<td>Ozone &amp; VOC Catalysts</td>
<td>Thermoacoustic Foam</td>
<td>Cleaners</td>
<td>Flame Retardants</td>
<td>Jet Fuel Additives</td>
</tr>
<tr>
<td>Binder Materials</td>
<td>MRO Services</td>
<td>Thermoplastic Polyurethanes</td>
<td>Corrosion Protection</td>
<td>Fire Extinguishing Agents</td>
<td>Lubricant Base Stocks &amp; Additives</td>
</tr>
<tr>
<td>Photoinitiators &amp; Photopolymers</td>
<td></td>
<td>High Temp Thermoplastics</td>
<td>NDT</td>
<td>Fuel Tank Inerting System</td>
<td></td>
</tr>
<tr>
<td>Carbon Glass Minerals</td>
<td></td>
<td>Thermoplastic Prepregs &amp; Panels</td>
<td>Paint Strippers</td>
<td>Slentex High Performance Insulation</td>
<td></td>
</tr>
<tr>
<td>3DP Design and Fabrication Services</td>
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<td></td>
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</tr>
</tbody>
</table>

**Structural Parts**
- Thermoplastic Foam
- Flexible Foam
- Thermoformable Composites

**Pretreatment**
- Sealants
- Sealant Removers

**Fire Protection**
- Flame Retardants
- Fire Extinguishing Agents
- Fuel Tank Inerting System

**Fuel & Lubricant Solutions**
- Jet Fuel Additives
- Lubricant Base Stocks & Additives

**External Parts**
- Jet Fuel Additives
- Lubricant Base Stocks & Additives

---

**...AND TECHNOLOGY FOR CABIN AIR QUALITY**
An A320 can be retrofitted with an ozone converter if it is not factory installed. There is no disruption of existing ductwork and minimal installation time.
If you’ve flown over an ocean within the last 30 years…

…then you’ve likely breathed air that has passed through a BASF ozone converter.

Mandatory ozone equipment on wide-body aircraft
Optional on single-aisle aircraft

A330/A340

Standard equipment on latest regional jets

EJET E2

Enhances premium flight experience on business jets

G650X

Used on certain military aircraft to improve pilot performance

A400M
OPEC oil embargo of 1973-74: higher fuel economies demanded of airplanes require them to fly at higher altitudes (> 27,000 ft ~8.2 km)
Late 1970s – high ozone levels at these altitudes lead to observations of adverse health effects for crew and passengers.

Prolonged exposure to high ozone concentrations has negative health impacts:

- Breathing discomfort
  - Headaches
  - Eye, nose, and throat irritation
- Reduced lung function
  - Chest pains
- Adult onset asthma
FAR 25.832 mandates maximum allowable cabin ozone level of 0.25 ppmv (SLE) at any time and a maximum time weighted average ozone concentration of 0.10 ppmv (SLE) during any 4 hour interval.

Methods of compliance:

- Modification of aircraft – install ozone converter technology
- Limit flight times (< 4 hours) and/or flight altitudes (< 18,000 ft)
- Statistical analysis that shows aircraft effectively meets the requirements by route selection and flight path
- Statistical analysis based on in-flight cabin air measurements for typical flight routes

Note: SLE = Sea Level Equivalent
1983 – First commercial application of ozone converter technology, pioneered by BASF (Engelhard) and field tested on Boeing 747

2000s – Industry development of Fuel Tank Inerting Systems (FTIS) relies on air separation membrane technology, which is protected by dedicated ozone converter.

2004 – BASF (Engelhard) introduces ozone/VOC catalyst technology for aircraft cabin comfort

2010s – BASF Clean Air Solutions technology development: formaldehyde catalyst, low temperature ozone catalyst, CO$_2$ sorbent

BASF HAS RESPONDED TO THE AEROSPACE MARKET FOR OVER 35 YEARS
Ozone decomposes to oxygen across catalyst.

Catalyst is neither consumed nor altered by the chemical reaction.

$2\text{O}_3 \rightarrow 3\text{O}_2$
**What is a catalyst?**

**Active component + washcoat + substrate**

Active component (e.g. precious or base metal) dispersed through a high surface area washcoat applied to a substrate, such as a ceramic honeycomb block or a corrugated metal foil.

Active site (component) for catalysis

Carrier (washcoat) provides high surface area

Substrate

~1 000 000 x magnification
ACTIVE COMPONENT
&
WASHCOAT

MIX

ACTIVE COMPONENT
&
WASHCOAT

SUBSTRATE

COAT

CATALYST CELLS

VISIBLE INLET
CATALYST FACE
[~5,000 cells visible]

400 cells per in²

1.0 inch
[25.4 mm]

Catalyst Cell
~0.05 inch
[~1.3 mm]
**WHAT IS A CONVERTER?**

A Flying, Pressurized Chemical Reactor

Clean Air Solution for Aircraft Cabins

Converters are subject to aircraft industry and customer design qualification requirements:

- Electrical bonding resistance
- Weight
- External leakage
- Proof pressure
- Burst pressure
- Ozone conversion, new
- Ozone conversion, end of life
- Total pressure loss
- Sand and dust
- Fungus resistance
- Salt fog
- Endurance & fatigue
- Interface loads
- Reliability
- High temperature
- Low temperature
- Temperature variation
- Altitude
- Humidity
- Fire & flammability
- Icing
- Operational acceleration
- Operational shocks
- Operational vibration
- Crash safety sustained
- Crash safety shocks
- Windmilling
- Explosion proofness
- Water proofness
- Fluid susceptibility
POTENTIAL SOURCES OF CABIN ODOR

- VOCs [Volatile Organic Compounds] enter the bleed air stream due to
  - Ingestion of other aircraft and/or airport vehicles engine fume exhaust while on ground or taxiing
  - Ingestion of de-icing fluids
  - Hydraulic fluid leaks
  - Engine oil leaks during operation (fume event)
  - Oil coated vent ducts (desorption)

Odor is the most significant memorable environmental variable on an aircraft

Comfort pyramid per Bubb, H. Komfort and Diskomfort. Ergonomie Aktuell Ausgabe 4. 2003
To mitigate cabin odor, BASF developed the ozone/VOC converter

**SAME PHYSICAL ITEM…**

OZONE CONVERTER

\[ 2O_3 \rightarrow 3O_2 \]

OZONE/VOC CONVERTER

\[ 2O_3 \rightarrow 3O_2 \]
\[ VOC + O_2 \rightarrow CO_2 + H_2O \]

**…BUT WITH ADDITIONAL CHEMISTRY**

An ozone converter can be “upgraded” to an ozone/VOC converter with no disruption to existing ductwork, no disruption to ozone conversion rates, and no disruption to existing maintenance service cycles

* - Currently available on Airbus platforms only
BASF and Airbus worked together to demonstrate by test the efficacy of the ozone/VOC converter to mitigate odor in the aircraft cabin.
### Experiments with JP1 Jet Fuel – Summary of Results

<table>
<thead>
<tr>
<th></th>
<th>Odor Intensity (0 to 6)</th>
<th>Hedonic odor tone (-4 to +4)</th>
<th>Acceptability [decipol] (0 to 31)</th>
<th>Panel members perceiving fuel odor [%]</th>
<th>Total HC (FID) [ppm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream</td>
<td>2.6</td>
<td>-0.8</td>
<td>8.7</td>
<td>80</td>
<td>3.0</td>
</tr>
<tr>
<td>Downstream</td>
<td>2.3</td>
<td>-0.8</td>
<td>8.4</td>
<td>77</td>
<td>3.0</td>
</tr>
<tr>
<td>Downstream w/ VOC catalyst</td>
<td>1.5</td>
<td>0.1</td>
<td>3.0</td>
<td>36</td>
<td>2.4</td>
</tr>
</tbody>
</table>

- **40% improvement**
  - Hedonic odor tone is improved; downstream the odor is described as *slight pleasant*, while upstream it is described as a little unpleasant.

- **60% improvement**
  - The number of panel members perceiving a fuel odor is much smaller downstream when the O₃/VOC catalyst is in place.

- **20% improvement**
OZONE/VOC CONVERTER PROVIDES A SPECTRUM OF PERFORMANCE FOR VOC COMPOUNDS

VOC conversion is compound, converter, catalyst, and operating condition specific.
Ozone/VOC v. Ozone Converter Performance

BTEX Hydrocarbon Compound Mixture

Ozone/VOC converter provides significantly greater hydrocarbon conversion than ozone converter.

Performance shown for initial converter performance (0 flight hours).

BTEX = Mixture of benzene, toluene, ethyl benzene, and xylene.
### Deoxo™ Catalyst Benefits

<table>
<thead>
<tr>
<th>Deoxo™ Catalyst Benefits</th>
<th>Ozone Converter</th>
<th>Ozone / VOC Converter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory compliance with cabin air ozone concentration requirements</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lightweight, easy-to-install (retrofit), and superior catalyst life with proven performance</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reduces jet-fuel odor in the cabin, improving cabin comfort</td>
<td>n/a</td>
<td>✓</td>
</tr>
</tbody>
</table>

**ACTIVE COMPONENT**

**WASHCOAT** & **SUBSTRATE**

**CATALYST**

**COMPLIANCE & COMFORT**

**CONVERTER**

25
INSTALLED CONVERTERS ARE ONLY PART OF THE EQUATION … PROPER MAINTENANCE IS ESSENTIAL

- Ozone converters are rotables and must be maintained properly to ensure effective performance and regulatory compliance with cabin air standards
- Poorly or improperly maintained converters do not guarantee continued performance
- As MRO, BASF has the breadth and depth of knowledge to maintain the catalyst performance in a manner that leverages the original design and thereby extends converter useful life
CATALYST CONTAMINANT EXPOSURE IS INTRINSIC TO OZONE (VOC) CONVERTER APPLICATION
Contaminants “Age” The Converter

FRESH

WASHED

AGED

Bleed Air Leaks, Oil, Hydraulic Fluid, De-icing

BASF MRO Service removes contaminants

plugged washcoat pores “trap” active components rendering them “inaccessible”

active components accessible in opened pores

WASHED SUBSTRATE WASHCOAT

ACTIVE COMPONENT

WASHCOAT SUBSTRATE

WASHCOAT SUBSTRATE

Substrate Washcoat Active Component

28
BASF MRO converter [catalyst] service preserves the active component and pore structure of the catalyst.

This preserves the catalyst aging characteristics for reliable, predictable performance.

When washing no longer restores sufficient activity, the converter can be “recored” – the aged catalyst core is replaced with fresh catalyst.

Reference: BASF MRO Service Database (proprietary)
Aircraft X / Airline Y
**COMPARISON OF CONVERTER SERVICE METHODS**

- **Strip & Recoat**
  - Not quite like the original, but close enough?

- **Renew by Deep Pore Cleaning**
  - Preserves catalyst pore structure for enduring value and performance

- **Overcoat with Different Active Component & Washcoat**
  - Paints a different picture but it still fits the original’s frame

BASF MRO
An overcoat changes the catalyst surface and dilutes the investment in clean air technology

DIFFERENT CATALYST SURFACE EQUALS DIFFERENT TECHNOLOGY

Third-Party Servicing:
Overcoat technology
Base metal active component
Dense washcoat constricts access to underlying original catalyst layer

BASF Catalyst
Original technology
Precious metal active component
Porous washcoat for extended service life in application

OVERCOATED CATALYST BECOMES A “DIFFERENT” TECHNOLOGY

BASF Corporation owned image – all rights reserved.
Adding or concentrating active component at catalyst periphery (catalyst-gas interface) improves ozone conversion for fresh catalyst at initial testing but…
…active component added or concentrated at the catalyst periphery (catalyst-gas interface) is more susceptible to performance loss by surface deposition of gas contaminants.
BASF MRO servicing retains original catalyst design, yielding margins to offset sudden and unexpected changes in operating conditions.

- **Performance margin** to offset sudden ozone spikes
- **Contamination margin** to offset unexpected leaks

**MINIMUM ACCEPTABLE PERFORMANCE**

**PERFORMANCE**

**CONTAMINATION**

**MAINTENANCE CYCLE**
**WHY SHOULD YOU CARE WHO SERVICES THE CONVERTER?**

**Because you want operational margins:**

- ✓ There are no ozone sensors in the aircraft cabin to alert a converter performance failure
- ✓ Contamination is not a predictable event
- ✓ Converter maintenance is a pre-scheduled activity (C check)

The risk, and consequence, of converter non-performance is born by the aircraft occupants…
PROPERLY SERVICED, CONVERTERS ARE AN INVESTMENT IN CLEAN AIR THAT RETAINS VALUE OVER THE LIFE OF THE AIRCRAFT

BASF MRO Services

✓ Performance test

✓ Chemical wash to remove contaminants and renew pore structure of catalyst

✓ Converter recore to replace catalyst core within existing structure
THE AIRCRAFT IS YOUR WORKSPACE AND YOU DESERVE QUALITY CABIN AIR
BASF has been involved in aircraft cabin clean air issues for over 35 years; we developed the ozone and ozone/VOC technology in response to market and customer needs.

Having an ozone or ozone/VOC converter installed is only part of the equation; converters must be properly maintained to ensure continued performance.

BASF is very interested in working with all major stakeholders to further develop solutions for ever evolving aircraft cabin air issues.

We’d like to thank you for the opportunity to discuss these issues today; ultimately, each and every one of you is our end use customer.
Countess of Mar

Closing Speech

International

Aircraft Cabin Air Conference 2019

Imperial College London

17/18 September 2019
Ladies and Gentleman Good Afternoon

I am the Countess of Mar and a co-patron for the GCAQE.

I hope you will agree with me that the 30 speakers we have been privileged to listen to over the last 2 days have again clearly shown us that contaminated air on aircraft is very real and the problem must be resolved.

It is 10 years since the distinguished British Air Accident Investigation Department recommended that contaminated-air detection systems be fitted to passenger aircraft. Still no aircraft flies today with any warning systems fitted. It is not only unbelievable but clearly shows us that our aviation regulators are failing to show the leadership, respect and common sense this issue deserves.

It makes sense that a warning system on an aircraft to alert pilots and crew when the air contains hazardous chemicals should be a statutory requirement. Instead Her Majesty’s Government hide behind the cloak of EASA when it comes to decision making.

Two years ago I stood here beside Captain Niels Goner. He and his co-pilot were totally incapacitated due to oil fume
exposure on the descent to Malmo nearly 15 years ago. They were lucky to survive. The harsh reality is that the industry has been negligent in failing to act. Here, I applaud Eastman for the unambiguous labelling of their 2197 synthetic jet engine oil: “Do not breathe mist or vapour from heated product.” Why do not the other manufacturers follow their lead?

Contaminated air is not just a jet engine oil issue. Countless swab tests remind us this is also an issue of exposure to hydraulic fluids.

Hydraulic fluid cans come with a warning such “Suspected of causing cancer”. In doing so manufacturers have made the risks very clear but why has virtually no passenger or crew-member ever seen such warnings?

My interest in toxic chemical exposures, like that of many others, comes from personal experience; one I would much rather not have had.

I was a sheep farmer in the days when the Government mandated dipping sheep in organophosphate sheep dips to remove parasites but, just as happens today with cabin air contamination, people were not warned.
The first I knew of their ability to cause irreversible damage three years after I first fell seriously ill. The effects have been much like those which I hear about in pilots and crew who have been affected. We are told that organophosphates like those found in engine oils and hydraulic fluids used in aviation are not as poisonous as those used in agrichemicals and veterinary medicines but these assertions are simply not credible. I live every day of my life with the consequences of those exposures thirty years ago.

The sheep dippers who first complained of suffering health effects were dismissed in much the same way suffers of asbestosis, smoking or thalidomide and, now, pilots and crew have been dismissed. The dangers of all but contaminated cabin air have now been recognized, albeit after long periods of denial.

I have raised my concerns in the Lords about the adverse effects of organophosphates on human, plant and animal health through oral questions, questions for written answer, debates and correspondence with Ministers. Since I was made aware of the issues of contaminated air in aircraft, I have also asked hundreds of questions about this important
health and flight safety issue and, I hate to say it, I have been consistently fobbed off by Ministers.

I have frequently been told by Government Ministers and the aviation industry that all the chemicals measured in aircraft are below the exposure standard but, for the most prevalent isomers of the organophosphate TCP in engine oils, the meta and para isomers, there are no exposure standards. I also note that in the fine print of many of these countless industry funded reports, it’s clearly stated that there were no reported contaminated air events during the research. Does this mean that there are never any contaminated air events in aircraft or does it make the research pointless? I think of Toyber’s Dictum – “The absence of evidence is not evidence of absence”, or as Professor Andrew Watterson, my favourite public health expert put it many years ago – “If you don’t look, you won’t find.”

The exposure standard debate is an interesting one. We hear that the chemicals crews are exposed to are below the exposure standard yet most of the chemicals have no exposure standard and exposure standards don’t apply to passengers, especially not the unborn or elderly so why this constant denial? To seek to clarify this matter, I asked Her
Majesty’s Government a Parliamentary Question over 10 years ago: It was very clear. What is the exposure standard for the complex mixture of chemicals people are exposed to on an aircraft when they are exposed to oil fumes and the Government reply was equally clear. None.

Yet over ten years later we still hear people claim everything is below these exposure standards that don’t actually exist or apply. This raises an interesting further question: Is the misinformation agenda such as that Prof Michaels discussed this morning, creating confusion deliberately to delay taking effective action or is it simply ignorance? One can only conclude that aviation is another industry that Prof Michaels will be adding to his increasingly list of industries seeking to misinform on some aspects of this debate.

This may seem harsh or negative but its fact. Just like with asbestosis, smoking or thalidomide, those industries also played the corporate denial game rather than fix the problem.

In my 44 years as a member of the House of Lords, I have found that most issues go through several phases. First there is consistent denial that a problem exists. Then, if there is a problem, it has to be the fault of the person complaining for
not reading the label or failing to use the correct engineering solutions. Then the Government offers to sponsor research which, as we know only too well, finds that there is no problem. Eventually the burden of evidence becomes so great that preventative action has to be taken.

Where are we with the contaminated air issue today, 18 September 2019, some 65 years since the problem was first recognised? I would say we are slowly transitioning into the final phase – let’s fix this problem but let’s not necessarily accept or admit that it exists.

The only real solution to this problem lies in the design architecture of the Boeing 787 and not to use ‘bleed air’ at all, I would very much like to applaud some of those who have played a key role in being part of the solution.

I particularly applaud Pall Aerospace for their extensive research & development in seeking to develop a new total cabin air filtration system. I first heard them talk about designing solutions in 2005, so well done them for all their efforts and persistence.

I congratulate those airlines that have shown the leadership to be part of this new phase and to start flight trials of the
new Pall system. Airlines looking to finally install much needed ‘bleed air’ filtration. I have no doubt your marketing teams will soon turn this leadership into increased revenue as competitors lag behind in vision or duty of care to their crews and passengers

I also cheer those pilots and crew whose own careers and health have been adversely affected by contaminated air exposure and who have played a huge part in driving the industry to the much-needed solutions. There are so many of you but Dr Susan Michaelis, who I am proud to call my friend, must be at the very top of that long list.

I would like to highlight the work of the GCAQE, the largest coalition of unions dealing with this issue. They organized this conference and have been the main voice of the workers who experience these issues every day. Their board of 6, under the Chair of Daniel Tandoi, embraces 6 different nationalities, showing the global nature of the problem and those seeking to resolve it.

Finally, I have a message for all airline chief executives and airline board members around the globe. New filtration systems are now available. Every individual passenger and crew-member deserves to breathe clean air on board. I am
yet to meet a shareholder who would disagree, so please, do the right thing, show leadership and bring this 6-decade old problem to an end.

Thank you
Contaminated Cabin Air
A Flight Safety Issue
Nick McHugh
In the Opposite Direction.
Elimination of Engine Bleed Air Contamination, Henry Reddall.
Boeing 727
So What Changed.

- Advances in Aircraft Manufacturing Technology.
- Advances in Engine Seal Technology.
- Advances in Oil Formulation and Production.
- Costs.
- Shareholder Value.
- The Age of Bleed Air.
Overview

History.

Airmanship.

Some Science.

Closer look at the facts.

Conclusions/Recommendations.
Self.

Aircraft.

Environment.

Risk.
Aerotoxic Syndrome.

Cholinergic Syndrome.

Centre for Disease Control.

Similiaraties
Emergency Preparedness and Response

Nerve Agent and Organophosphate Pesticide Poisoning

TOXIC SYNDROME DESCRIPTION

This purpose of this document is to enable health care workers and public health officials to recognize an unknown or suspected exposure to a nerve agent or an organophosphate (OP) pesticide. Nerve agents are chemical warfare agents that have the same mechanism of action as OP organophosphate pesticides (insecticides). They are potent inhibitors of acetylcholinesterase. Inhibition of acetylcholinesterase leads, thereby leading to an accumulation of acetylcholine in the central and peripheral nervous system. Excess acetylcholine produces a predictable muscarinic syndrome consisting of copious respiratory and oral secretions, diarrhea and vomiting, sweating, altered mental status, autonomic instability, and generalized weakness that can progress to paralysis and respiratory arrest.

The amount and route of exposure to the nerve agent or OP pesticide, the type of nerve agent or pesticide, and the premorbid condition of the person exposed will contribute to the time of onset and the severity of illness. For example, inhalation of a nerve agent or an OP pesticide leads to a quicker onset of poisoning with more severe symptoms when compared to the same amount of exposure intravenously.

Signs and symptoms

The following is a more comprehensive list of signs and symptoms that may be encountered in a person exposed to a nerve agent or OP pesticide. Signs and symptoms are not listed in order of presentation or specificity. Also, partial presentations (i.e., absence of some of the following signs/symptoms) do not necessarily imply less severe disease.

Central nervous system signs and symptoms

- Miosis (unilateral or bilateral)
- Headache
- Restlessness
- Convulsions
- Loss of consciousness
- coma

Respiratory signs and symptoms

- Rhinorrhea (profuse watery runny nose)
- Bronchitis (acute bronchitis with secretions)
- Wheezing
- Dyspnea (shortness of breath)
- Diaphoresis (sweating)
- Respiratory acidosis (increased respiratory acidosis) – early/late (increased respiratory acidosis)
- Bradypnea (decreased respiratory rate) – late (decreased respiratory rate)
Environment

Hazards of our own making.

Complex chemical compounds and UFP’s

One chemical at a time/trigger limits

Directly and indirectly, separately and collectively.
Anti wear TCP and complex mixtures of isomers, ester based stock, anti oxidants and other proprietary ingredients.

Oil Change and engine ‘on wing time’.

Vapor-Phase lubricants / High temperatures and the Creation of Aerosol Nanoparticles under Bearing shear stress. (Bearing Squeeze oil.)

Thermal degradation of small volumes of oil, and assured sequelae.
Uncontaminated Ducting
Contaminated Ducting
European Aviation Safety Agency

Certification Specifications

and

Acceptable Means of Compliance

for

Large Aeroplanes

CS-25

Amendment 1.8
12 June 2018

For the date of entry into force of Amendment 1.8, please refer to Decision 2018/1144/EU in the Official Publication of the Agency.

Amendment 1.8
Risk to Operations

- No Detectors for CO², CO or O³

- Crew Incapacitation, and Acute over Chronic Exposure Threshold.

- When is Smoke Not Smoke? Selecting the Correct Checklist.

- Desensitized Smell After 3 Minutes.

- Complexity of Smoke/Fume/Smell Checklists and the Risks Associated with Smoke Evac Procedure.

- Training.

- Land as Soon as Possible Over Oceanic and Large Land Mass.
Recommendations

- Meaningful Steps.
- Reporting.
- Cabin Air Quality Sensors.
- Bleed Free future Aircraft.
- Medical Assessment Protocols
- Enhanced Training (Recognise Characterize, Respond)
- Long term Health effects.
Conclusion

LONG TERM HEALTH

GENERAL FORESEEABILITY OF INJURY OR IMPAIRMENT.

ULTRA FINE PARTICLES AND THE BLOOD BRAIN BARRIER.
Lucius Seneca

Errare humanum est, sed perseverare diabolicum.”

To err is human, but to persist in error is diabolical.
The Regulatory Implications of Bleed Air Supply Contamination

Susan Michaelis PhD, MSc, ATPL

University of Stirling / Michaelis Aviation Consulting

Aircraft Cabin Air Conference
Imperial College London
17-18 September, 2019
Oil Consumption

- Normal consumption
- Operational factors
- Failure conditions
Oil Bearing Chamber

Normal Oil Consumption

- Normal “permissible” oil consumption via:
  - breather/deoiler - vent system
  - past seals → core airflow
  - oil leaks

- Rate of loss affected by various factors
  - style of seal, balance ratio, lubricating regime, operating conditions (speed, temp, pressures), component condition, wear life, distortion...

All dynamic seals are designed to leak
Seals and Bearings / Air Off-Take
Oil Leaks

1. Normal operations
   • All dynamic seals leak very low levels (not absolute design)
     – Rely on pressurised air: seals have a clearance / lubricated surface
   • Increased leakage:
     – Pressure changes (transients) $\rightarrow$ Power air supply config changes
     – Thermal mechanical changes in engine
     – Low internal pressure – e.g. start up, taxiing, descent
     – Oil hydrolysis (reaction with water) and thermal oxidation $\rightarrow$ release of carboxylic acids which can escape from oil system (associated with strong odour “dirty sock”)

2. Operational: e.g. wearing seal; oil overfill

3. Failure conditions: bearing seal failure or component...
Misconceptions About Oil Leakage

1. Higher pressure in gas path than inside bearing chamber – keeps oil in bearing chamber ×
2. Seals only leak when failure occurs ×
3. Reverse pressures to be avoided – prevents leakage ×

"Sealing bearing chambers at near ambient pressure is difficult" (Chupp 2006)
NASA/TM—2006-214341
Recognition of Oil Leakage in Normal Conditions

- Oil replenishment (‘top up’) maintains oil additives (Johnson 2018)
- Oils designed to work in engine, limiting exposure (ExxonMobil, 2018)
- Bleed system pressure fluctuations cause bearing seals to leak allowing oil to migrate into the cabin bleed air (ExxonMobil, 2018)
- “Shaft seals- must function as SEALS - NOT flow restrictors” (Bill, 1991)
- “A zero seal leakage is an oxymoron” (Chupp, 2006)
- Most engines might have a certain low level turbine oil leak rate (permanent oil entries) (EASA 2017)
Two Ways of Addressing This Problem

1. Engineering failure analysis – currently used
   – Analysis, ground flight testing or simulator tests
   – Engineering judgement, previous experience, sound design & test philosophies.

2. Thorough assessment of the system in use in both normal and failure modes.

Do not place reliance on reporting system due acknowledged under-reporting
Method 1 – Brief Outline of Regulations, Standards & AMC

• 25.831- air does not cause undue discomfort, harm.
• 25.1309 & AMC
  – System works as intended
  – Air supply system does not cause impaired crew efficiency/discomfort > 1 in 100,000 flight hours.
• CS-E/APU... Engine/APU & AMC safety analysis
  – Oil... in bleed air does not degrade crew performance
    > 1 in 100,000 engine/APU hours
Method 2 – Assessment of Whole System

• Oil leaks at low levels in normal operations – permissible oil consumption – *see previous*
• Oils and other hazardous substances enter the bleed air – *see next*
Oils Cause Adverse Effects

- Oil MSDS/labels:
- Global chemical hazards system / e.g. EU classification
  *hazardous substances databases
  - *Oils: Damage to unborn/fertility; damage to organs (single repeat exposures): skin, respiratory sensitization; eye, respiratory, skin irritation; harmful in contact with skin; eye damage
  - * Hydraulic/deicing fluids: Above + harmful if inhaled; genetic effects; suspected to cause cancer; drowsiness, dizziness
- Manufacturers recognizes adverse effects, hazards,
  - Shell (1999); Boeing (2007); ExxonMobil (2017), Rolls Royce (2003)...
- Reports (where available) show Acute (short-term) effects/impairment at > ~ 30%
Mobil Jet Oil II

- May cause damage to organs through prolonged or repeated exposure. (Blood, Kidney); suspected to damage fertility;
- Symptoms of acute exposure to decomposition products: headache; nausea; eye nose & throat irritation;
- Not expected under normal conditions of use.

Eastman 2197

- Do not breathe mist or vapor from heated material;
- Inhalation of thermal decomposition products may lead to adverse effects;
Oils Are Hazardous

• “Jet oils do not pose a hazard when used as intended... Mobil jet oils are intended to be used in the lubrication of engine oil systems” - (ExxonMobil 2018)

• “We do not believe that Mobil jet turbine oils pose any significant toxicological risk to individuals accidentally exposed to aerosols or vapors in aircraft cabins. Such exposures are not what we would refer to as "normal use” (Mobil, Australian Senate Inquiry, 1999/2000)

• “Ortho –TCP is a known hazard; but exposure is controlled.” - (ExxonMobil 2018)

• “Oil leaking from an engine entering the customer off-take is “classified as HAZARDOUS”” (Rolls Royce 2003)

• “Oil vapors and coking smells are obnoxious at best and health hazards at worst to the customer” (NASA, 1995)
Where Are We Up To?

Design guarantees low levels of oil in normal operation – all flights

Confirmed by many cabin air quality studies over 20 years+ / swab tests, ducting...

So does this design meet the airworthiness standards?

Let's have a further look ...
Are the Regulations / Standards & AMC Being Met?

25.831 – Ventilation Air

a) There must be a sufficient uncontaminated "fresh" air to enable crew to perform duties without undue discomfort / fatigue

b) Air must be free of harmful / hazardous concentrations of gasses and vapours
Are the Regulations / Standards & AMC Being Met?

25.831 – Ventilation Air

Is there enough uncontaminated air to not cause undue discomfort – NO

Is air free of concentrations of gasses/vapours causing harm – NO

Adverse / harmful effects are expected and being routinely documented
Are the Regulations / Standards & AMC Being Met?

25.1309 & AMC – Equipment Systems ... Design Requirements

• Do the systems and equipment perform intended function under foreseeable operating conditions?
• ‘Major’ failure conditions must be remote* (CS) - *Unlikely to occur in each aircraft during total life, but may occur several times during life of an number of aircraft.
• Impaired crew efficiency / discomfort to pilots must not occur more than 1 per 100,000 flight hours \(10^{-5} - 10^{-7}\) (AMC)

Oil leakage is a ‘probable’ & above or expected condition
Are the Regulations / Standards & AMC Being Met?

25.1309 & AMC – Equipment Systems ... Design requirements

- **NO**: Oil from the engine lubrication system enters the bleed air (not intended purpose) under foreseeable conditions.
- **NO**: Impairment (‘Major’ failure) to crew efficiency is occurring > than 1 in 100,000 flight hours.
- **NO**: Oil leakage into the bleed air supply will occur to all aircraft.

‘Oil leakage is probable’ & **expected condition**

‘Permissible oil consumption’
Are the Regulations / Standards & AMC Being Met?

Engine/APU - CS E-510 / FAR 33.75 & APU & AMC...- Failure/ safety analysis

• Hazardous engine effects must be ‘extremely remote’ occurring less than 1 in 10 million / engine hours \((10^{-7})\) (CS)
  – Includes toxic products in bleed air sufficient to incapacitate crew/pax (CS)

• Major engine effects must be – ‘remote’ occurring less than 1 in 100,000/engine hours \((10^{-5})\) (CS)
  – Toxic products in bleed air sufficient to degrade crew performance (AMC)
  – Toxic products include degradation of oil leaking into compressor airflow (AMC)
Are the Regulations / Standards & AMC Being Met?

CS E 510 & AMC & CS APU 210 & AMC... Failure analysis...

- **NO:** Degraded crew performance (‘Major’ engine/APU effects) due to oil leakage into compressor airflow/bleed air for cabin is occurring at > 1 in 100,000 engine/APU hours

  ‘Oil leakage is probable’ & expected condition

  ‘Permissible oil consumption’
Other Regulations /Standards Not Being Met

• **FAR/CS 25.1309(c)** - Information concerning unsafe system operating conditions must be provided to the crew to enable them to take appropriate corrective action – Warning system

• **Unsafe condition** – events occur more frequently than safety objectives allow that may impair crew efficiency, cause discomfort to occupants...

• **Bleed air purity testing**
Certification - Michaelis MSc (2016)

- Certification: Must show compliance with all requirements
  - No requirement to follow a specific process
  - Interactive process between regulator and manufacturers
- Engine/APU: Focus on ‘hazardous’ engine effects – concentration of toxic products sufficient to incapacitate – Not AMC
- Airframe: No requirement for the air to be pristine free of contaminants (FAA); CO, CO2,O3, enough fresh air...
  - Manufacturers can choose to follow additional standards: e.g. ASHRAE, ASD-STAN (cancelled), SAE guidelines, NIOSH, CDC...

- Process is insufficient to ensure breathing air (bleed air) will not lead to impaired crew efficiency & degraded performance and adverse effects to occupants.
- There is a gap between the bleed air system regulatory process and the supply of clean air in aircraft. (Michaelis, 2016)
- Non binding
- Focus on failure conditions
Where To Next?

• Future designs should be bleed-free;
• Air cleaning technology (filtration, catalytic convertors) to be provided for supply air (bleed and non bleed aircraft);
• Sensors to be fitted;
• Better designs: seals, improved oil reservoir, other design features;
• Improved clean air regulations/standards & compliance;
• Understanding low-level oil leakage occurs in normal operations, not just failure scenarios;
• Better procedures, training, education: crew, maintenance & management;
• Frequency seen in terms of **design**, NOT reporting.
Thank you

Further information:

https://www.SusanMichaelis.com
susan@SusanMichaelis.com
The Triumph of Doubt: Dark Money and the Science of Deception

David Michaels, PhD, MPH
Department of Environmental and Occupational Health
Milken Institute School of Public Health
The George Washington University
Washington, DC USA

Aircraft Cabin Air Conference

September 18, 2019
According to repeated nationwide surveys, More Doctors Smoke CAMELS than any other cigarette!

Doctors in every branch of medicine were asked, "What cigarette do you smoke?" The brand named most was Camel!

You'll enjoy Camel for the same reasons as many doctors today. Camel has no tar, no nicotine, no carbon monoxide, and a flavor unmatched by any other cigarette.

Make this sensible test: smoke only Camel for 30 days and notice how much Camel please your taste. You'll see why so many doctors prefer Camel.

The Doctors' Choice is America's Choice!

For 30 days, test Camel in your "V-Zone" (V for Throat, V for Taste).

NOW...Scientific Evidence on Effects of Smoking!

A medical specialist is making regular bi-monthly examinations of a group of people from various walks of life. 43 percent of this group have smoked Chesterfield for an average of over ten years.

After ten months, the medical specialist reports that he observed... no adverse effect on the nose, throat and sinuses of the group from smoking Chesterfield.

MUCH Milder CHESTERFIELD IS BEST FOR YOU

First and Only Premium Quality Cigarette in Both Regular and King-Size

CONTAINS TOBACCO OF BETTER QUALITY AND HIGHER PRICE THAN ANY OTHER KING-SIZE CIGARETTE
Tobacco’s Campaign to Manufacture Uncertainty

“Doubt is our product, since it is the best means of competing with the ‘body of fact’ that exists in the minds of the general public. It is also the means of establishing controversy.”

-Brown & Williamson Document No. 332506, 1969
Cancer Personality Pattern Is Reported To Begin in Childhood

New evidence of a personality pattern common to male lung cancer patients has been reported by a Scottish psychologist. The pattern begins in childhood and does not appear to be related to smoking habits.

In a previous study, Dr. David M. Klassen of the University of Glasgow and an associate reported that male lung cancer patients have a significantly diminished outlet for emotional discharge. In addition, they said, such patients tend to bottle up or conceal

Verdict: "Unproved"

Lung Specialist Cites 28 Reasons For Doubting Cigarette-Cancer Link

Although much has been written about possible causal relations of cigarette smoking to lung cancer, there is a good deal of evidence which does not fit this hypothesis, according to a California pulmonary specialist. In a review article digested below, he summarizes 28 reasons for his believing that cigarette smoking is not an important etiological agent in lung cancer, and that the real causes are unknown.

Test Results: Smoking Fails To Raise Cholesterol Levels

There has been a virtual flood of literature 'associating' cigarette smoking with lung cancer," according to Dr. Leon B. Hyde, chief of pulmonary disease service, Veterans Administra-
Case Histories

The following pages contain case histories detailing Hill and Knowlton's work on selected environmental, and occupational health issues:

- Siting a Municipal Waste Incinerator
- Vinyl Chloride and Cancer
- Asbestos and Human Health
- Dioxin and Public Health
- Fluorocarbons and Ozone Depletion
- Saccharin and the FDA
- Toxic Wastes Threaten Major Manufacturing Facility
- Groundwater Contamination Harms Company Reputation
Fluorocarbons and Ozone Depletion

Problem/Situation

Scientific allegations that fluorocarbons released from aerosol spray cans were a threat to the earth's ozone layer had become a cause celebre in the media and government. Despite the fact that there was no real scientific proof of the charges, and that it would be years before facts could be assembled, the media fastened on the threat of increased skin cancer and the doomsday aspects of the story. Public concern and fear about the future caused fluorocarbon users to look to alternatives. Hill and Knowlton was asked by Du Pont to help calm fears, get better reporting of the issues, and gain up to two or three years before the government took action to ban fluorocarbons.
The Nobel Prize in Chemistry 1995

"for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone"

Paul J. Crutzen  Mario J. Molina  F. Sherwood Rowland
"The scientific debate remains open. Voters believe that there is no consensus about global warming within the scientific community. Should the public come to believe that the scientific issues are settled, their views about global warming will change accordingly. Therefore, you need to continue to make the lack of scientific certainty a primary issue in the debate…"
Marketing “Product Defense”

ASBESTOS, TOBACCO, PHARMACEUTICALS - WE’RE ALL NEXT!

♦ Scare science
♦ The loss of presumptive innocence
♦ Where will the liability end?

Presented by
Mr. Joseph Huggard
The Weinberg Group LLC
18 June 2003
The Enronization of Science

• Scientists hired to defend products in regulatory and legal arenas

• Their value is their ability to influence regulation and litigation, _not_ to provide valid science

• Produce science of questionable value
Selected Glassdoor Reviews by Product Defense Firm Employees

• “This is a law consulting company, not a science consulting company. Don’t expect to be a ‘scientist.’” [Cardno ChemRisk]

• “Some of the principal scientists have questionable ethics (and have been called out for it).” [Gradient]

• “Sometimes you will be working for the evil do-ers and trying to make it seem like they did nothing wrong.” [Exponent]
FORD SPENT $40 MILLION TO RESHAPE ASBESTOS SCIENCE

Published — February 16, 2016
Updated — Today at 7:01 am EST
THE TRIUMPH OF DOUBT
DARK MONEY AND THE SCIENCE OF DECEPTION
DAVID MICHAELS
Manufactured Uncertainty Threatens Public Health

• Clean Air

• Clean Water

• Lead Exposure to Children
Manufactured Uncertainty Threatens Public Health

• Sugar

• Sugar-Sweetened Beverages

• Alcoholic Beverages
Manufactured Uncertainty Threatens Public Health

- Glyphosate
- Talc
The Work of Mercenary Scientists Hurts the Credibility of All Scientists
2012: The World Health Association/International Agency for Research on Cancer Classifies Diesel Engine Exhaust as Carcinogenic to Humans
Meet the Volkswagen TDI Clean Diesel Family.

This ain’t your daddy’s diesel.

Old Wives’ Tale #6
Diesel is Dirty

Drive cleaner.

Smoke less.
Polo BlueMotion. Only 102g CO₂/km.

Clean Diesel

VW
Hi Stuart and Len,

Any guidance you might be able to give regarding this WHO assertion that diesel is a carcinogen would help us with counter messaging. This would include studies that might contradict the WHO report below. We also have requests in with Ingolstadt.

Best regards,

Brad Stertz
Corporate Communications Manager

Audi of America, Inc.
2200 Ferdinand Porsche Drive
Herndon, VA 20171
United States of America
Office: +1-703-364-7440
Mobile: +1-703-344-1320
Fax: +1-703-364-7076
mailto: brad.stertz@audi.com
http://www.audiusa.com
http://www.audiusanews.com
2013: German Auto Industry Trade Association Signs Contract with Lovelace

AGREEMENT

between the

Europäische Forschungsvereinigung für Umwelt und Gesundheit im Transportsektor e.V. (EUGT)

(European Research Group on Environment an Health in the Transport Sector, registered association)

Fritschestrasse 35
D-10627 Berlin

Herein after 'Research Association'
- abbreviated as 'EUGT' -

and

Lovelace Respiratory Research Institute (LRRI)

2425 Ridgecrest Drive SE
Albuquerque, New Mexico 87108

represented by
Lori Orona
Project management:

Herein after 'Researcher'
AGREEMENT

EUGT shall contribute the amount of $718,572.00 US-$ (in words: seven hundred eighteen thousand five hundred seventy two $) incl. all taxes to the Researcher. Payment shall be effected to the below-mentioned account of LRRI within 14 days after the first invoice.

The contribution will be made in three installments. For this purpose LRRI will submit an invoice for 50% of the sum after this Agreement has become effective, an invoice for 40% upon completion of the in-life portion of the Research, and an invoice for 10% once the final report on the Research becomes available to EUGT. Work will begin once the initial contribution has been received.
4. Confidentiality

The contracting partners obligate themselves to treat as confidential, and to keep secret vis-à-vis outside parties, and further not to exploit, all documents marked as secret as well as all other information made mutually available. The contracting partners are obligated to maintain the same confidentiality during the performance of the work, and for up to five years after its conclusion, with respect to both the research work to be performed and its results.
VOLKSWAGEN
E189 engines were fitted with a “Defeat device”

The software could recognise that the vehicle is being tested by monitoring:

- Speed
- Engine operation
- Air pressure
- The steering wheel position

During tests, the engine ran below normal power and performance - reducing emissions and helping the car pass the test.

Once back on the road, the engines emitted pollutants up to 40 times the permissible limit in the US.

James Liang, “Leader of Diesel Competence”, VW Group of America
James Liang, “Leader of Diesel Competence”, VW Group of America
2015: Lovelace Scientists Realize that VW Rigged the Study

<1% of OTDE in the tunnel. I believe in our car that system was ON by default.

<table>
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<th>Tunnel NO (ppm)</th>
<th>Tunnel NOX (ppm)</th>
<th>Tunnel NO2 (ppm)</th>
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<tr>
<td>OTDE</td>
<td>146.22</td>
<td>169.77</td>
<td>23.49</td>
</tr>
</tbody>
</table>

Yep they were low. This seems crazy
2016: Lovelace scientists desperately try to salvage the study

From: McDonald, Jacob
Sent: Mon 8/29/2016 5:47 PM (GMT-04:00)
To: 'Matthew J Campen'
Cc: 
Bcc: 
Subject: FY14-050_EUGT NHP Diesel Report_23Nov2015

Here are the results in a draft report. The lavage data are garbage because I didn’t realize this until it was too late the guys did the baselines the day before the actual exposure lavages so there was inflammation from the baselines.....

The blood showed nothing by standard clin path as expected.

The analysis on the bronchial brushings was kind of interesting.

I need to publish a paper and basically I will have to throw out the lavage data and then I have three figures....and a bunch of aerosol stuff....so I am trying to see if I can squeeze out something else that may be interesting and says “old diesel bad, new diesel good’ so I can win the nobel prize.
2016: Lovelace scientists submit abstract, with no mention of the VW

2016 Society of Toxicology Annual Meeting
Late-Breaking Abstracts

**ABSTRACT FINAL ID:** 3601  
**Poster Board:** P293

**TITLE:** Exposures to Old Technology Diesel Emissions to Evaluate Biological Response in Non-Human Primates

**AUTHORS (FIRST INITIAL, LAST NAME) & INSTITUTIONS:**  
J. Brower, H. Irshad, M. Doyle-Eisele, Y. Tesfaigzi, J. McDonald. Lovelace Respiratory Research Institute, Albuquerque, NM.

**KEYWORDS:** Exposure, Environmental; Inhalation Toxicology; Lung; Pulmonary or Respiratory System; Diesel

**ABSTRACT BODY:** The adverse health effects of exposure to standard diesel vehicle emissions (DE) are a major concern among urban populations. Studies investigating the biological effects of diesel exposure date back more than 30 years, but combustion technology is constantly improving. We intended to establish a non-human primate model of acute DE exposure in order to test future hypotheses related to exhaust fractionation and comparisons with alternative fuel technologies. This study evaluated the biological responses of female cynomolgus macaques after acute (4 hour) whole body exposure to filtered air (FA) or whole DE. Flows and dilutions in the exposure system were targeted for 200 μg/m³ particulate in the DE atmosphere. The exposure...
What Needs To Change?

• Research must be directed by independent, unconflicted scientists.

• Polluters and producers of hazardous chemicals must pay for the research, but not control it.
What Else Needs To Change?

• Regulate toxic chemicals by class, not one by one.

• Chemicals are not innocent until proven guilty:

End the Presumption of Innocence!
Thank You for Listening
Cabin Air Quality Sensor

Rick Mlcak
GCAQE

Aircraft Cabin Air Conference

September, 2019
CSI – sensing and identifying the odor
How we Finished the 2017 Conference

Available End 2018
Project Timeline

- **2013**: Sensor project launch
- **2014**: First on-aircraft test of prototype sensors
- **2015**: CAOS first flight test
- **2016**: CAOS prototypes start commercial flights
- **2017**: Sensor ground tests 1 and 2, First Pall/Amriner OEM meeting
- **2018**: Validation of discernment of all fluids on-aircraft, Sensor ground tests 3 and 4, Customer UX and design review, PureCabin ground test
- **2019**: BAS is under development and will launch after CAQS

**Solutions take partners: Airlines, OEMs, and Pall.**
Defining the Specification
**Sensor Functionality**

**Detection Limits and Techniques**
- Detect contaminant events at or below human olfaction levels
- Determine whether contaminants are increasing, stable or decreasing
- Identify contaminant sources by their response fingerprint or “smell”

**Event Classification**
- Turbine oil, hydraulic fluid, de-icing fluid, other
- Separate sensor for CO

**Background Levels**
- Detect changes from “normal” indicating need for preventive maintenance or corrective measures
- Identify “dirty” aircraft requiring service

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Identification: Smell vs. Marker Compounds

Odors are identified by concentration ratios

There are over 300 compounds in the smell of an apple*…

GCMS measured chemical concentrations desorbed from cockpit filter

- also key VOCs in strawberries**

Why can’t humans do it?
Technology Recap

Flow controller

Flow rate
Chemo selective layer
Charge time

Analyte in carrier gas
Preconcentrator collects analyte(s) of interest, and “flash desorbs” them when heated

Analyte is collected on resonator surface
Concentration is determined from change in resonant frequency

Signal magnitude is proportional to # molecules collected

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Conditions and Qualities of Aircraft Fluid Contaminants

CONCENTRATIONS IN CABIN:

Total fluids
~1 to 10 mg/m³

Markers
~ 1 to 50 μg/m³

FORM IN CABIN AIR:

→ Mostly primary constituents (little is burned in bleed system)
→ Both aerosols and vapors due to low vapor pressures
→ Aerosols foul electronic noses and VOC sensors
→ Inlet filters (to protect against aerosols) generate residual false positive signals

Sensor must tolerate exposure to lube and hydraulic oils

→ Requires and materials compatibility & fouling mitigation features

<table>
<thead>
<tr>
<th>Quality</th>
<th>Mobil jet oil</th>
<th>Skydrol PE-5</th>
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<tr>
<td>fire point (°C)</td>
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<td>177</td>
</tr>
<tr>
<td>autoignition temp (°C)</td>
<td>404</td>
<td>400</td>
</tr>
</tbody>
</table>

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Oil Vapors & Ultrafine Particles (aerosols) can:

- Coat the surfaces of sensors
  - Affect accuracy
  - Affect Life
- ‘Stick’ to other surfaces
  - Generate false positives

Aircraft background levels are variable and can generate false positives.

- High background levels impacted by
  - Aircraft age
  - Temperature
  - ECS state
Sensor Evolution
Validating Laboratory and Aircraft Test Data

- Developing tests to compare laboratory challenges with actual aircraft environments
- Measuring performance on aircraft while passing contaminants through the ECS
- Comparing CAQS responses to human olfaction

Measuring sensor performance in the laboratory
Constant Validation of Sensor Design Upgrades

- Oil and de-icing fluid are injected into APU inlet and passed through the ECS
- Background levels are measured during the trial
- Event Detection Algorithm identifies increases in contaminant events
  - Performance improved when sampling from ECS duct
- Classification Matrix identifies the contaminant by fluid type
  - 100% Recognition Accuracy of injected challenges
Cabins are a large source of VOCs, from people, food, luggage, cleaning agents, carpets, seats, plastics, etc.
- High background levels are measured with ESC off

ECS supplies clean air to the cabin, *except* during upset conditions:
- System/Mechanical fault introducing aircraft fluids in bleed air
- Polluted outside air at intake
- Faulty de-icing procedures
- Fouled ECS (packs, ducts)

CAQS measures contaminant levels in ECS-supplied air
- Accelerates detection of upset conditions
- Shields sensor from the chemically “noisy” cabin
Aircraft Ground Bleed Air Test & Functional Flight Check

Increasing background level

- Right bleed thru right pack & left bleed thru left pack, max heat
- Left bleed, left pack, normal heat
- Right bleed, left pack, normal heat
- Packs off
- Left pack, max heat
- Right pack, max heat
- Both packs on, normal heat
- Packs off, recirc on, sampling from ECS duct outlet
- Packs off, recirc on, sampling from cabin

Measurement Index
CAQS Mark 1 – Launch MVP
CAQS MK1 Production Version

- Dimensions: 250 mm x 210 mm x 90mm
- Weight: 4.5kg
- Mounting: sensor supplied with tapped holes and installation kit
- Powered by aircraft electrical supply
  - 28VDC, 35W
- Data saved with time-date stamp
- Data transmitted over WiFi to standard devices
Launch Performance

Detection accuracy
- Achieving 100% accuracy (true positive rate) in the laboratory
- Assessing on-aircraft performance in ground & flight tests
- Will assess & optimize service accuracy using in-service performance data

Monitoring “normal” aircraft background levels
- Initial release will record increasing & decreasing chemical background levels
- With in-service performance data we may learn to predict impending issues from changes in background levels

Lifetime, Maintenance & Calibration
- Will be assessed during the early MK1 release
- Will enable Pall to implement a support strategy
User Interface

- Accessible by laptop or tablet through WIFI
- Data downloadable as csv
- Search criteria on file:
  - Serial number, aircraft type and number, data and time
Permanent Aircraft Installation

- OEM and airline support to determine optimal location
- Access through Avionics hatch
Schedule and Launch Plan

- 10 early-release CAQS MK1 available Q1 2020

- 3 to 6 month initial installation and FOC replacement
  - Assessment of:
    - Performance
    - Life
    - Reliability
  - Optimize algorithms using in-service data
  - Upload software upgrades

- Continuing CAQS MK1 Production & Release
  - 2\textsuperscript{nd} batch Q2, 2020
  - 3\textsuperscript{rd} batch Q3, 2020
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Dealing with Cabin Odor Events

Aircraft Cabin Air
International Conference 2019

Ricardo Pavia
TAP M&E Systems Engineering
Topics

1. Pneumatic and Air Conditioning System
2. Cabin Air Quality troubleshooting
   - Causes of Cabin Odors
   - Dealing with a Cabin Odor Event
   - How to identify the Contamination Source?
   - COS Report
   - ECS Decontamination
   - Test and Release to Service
3. Challenges on Cabin Odor Events
1. Pneumatic and Air Conditioning System

Layout

- The air is provided to cabin with a possibility of adding hot air if required

- Mixer Unit receive fresh air from the packs and the recirculation air from cabin

- Air Conditioning Packs are responsible to dehumidify and reduce the air temperature

  - Part of the regulated air is provided to the Air Conditioning Packs

- The air is regulated in pressure and temperature by the pneumatic system

  - Air is bled from Engines or APU in flight
1. Pneumatic and Air Conditioning System

Air Conditioning Pack

❖ Apply a visual inspection for **oil traces** and **oil smell** on pack components

❖ **High complexity** to understand the affected contaminated components

**AOG** – Aircraft On Ground

If contaminated, a complete pack replacement could take **1 day** per each Air Conditioning Pack
2. Cabin Air Quality Troubleshooting

Causes of Cabin Odors

**EXTERNAL Causes**

- Pollens
- Exhaust fumes from other aircrafts
- Pollution
- Cleaning agent residues
- De-icing fluid
- Hydraulic fluid leaks
- Birds
2. Cabin Air Quality Troubleshooting

Causes of Cabin Odors

**INTERNAL Causes**

- Galley equipment (i.e. ovens, coffee makers, etc)
- Toilet fluid spillage, leakage and also unapproved mixing of different disinfectant fluids in the toilet.
- APU or Engine oil leaks into the bleed system that leads to ECS contamination
- Damaged electrical wiring or components
- Spillages within cargo compartments
2. Cabin Air Quality Troubleshooting
Dealing with a Cabin Odor Event

First Step – How to identify the Contamination Source?
- Analyze the Cabin Odor Sheet
- Identify the contamination source

Second Step – ECS Decontamination
- ECS Decontamination if applicable
- Replace the Engine or APU if applicable

Third Step – Test and Release to Service
- Test the ECS on ground for any odor at cabin
- Put the Aircraft back in service for flight
2. Cabin Air Quality Troubleshooting

How to identify the Contamination Source?

- COS report
- Visual and inspection for odor on APU and Engines for oil leakage
- ERU (Engine Run Up) to identify the correct source of odors
- Flight Crew co-operation on troubleshooting (if possible)
- MMEL for troubleshooting proposes (i.e. bleed OFF or ECS OFF)
- Aerotracer (equipment to measure the type of contamination)
- MMEL dispatch for later corrective actions when people, components and slot are not available.

**Difficulty to identify the exact source of contamination**
2. Cabin Air Quality Troubleshooting

COS Report

Importance of COS report filled by Flight Crew

Includes:

- Aircraft Configuration | Pre flight  
- Time of Event
- Pneumatic/Bleed Configuration
- Air Conditioning Configuration
- Description/Type of the Odor
2. Cabin Air Quality Troubleshooting

APU as Contamination Source

- Visual inspection to APU
- Specific Boroscope Inspection on APU
- Inspection and cleaning to APU bleed duct

INOP
2. Cabin Air Quality Troubleshooting

ECS Decontamination

Initiate the AMM Decontamination procedures

Assess the depth of the contamination into the Air Conditioning System

Components replacement and bleed ducts cleaning

High complexity and time to perform the recommended AMM task for Decontamination of the ECS
2. Cabin Air Quality Troubleshooting

Test and Release to Service

**TEST**

- Engine Run Up/APU on Ground
- Different Bleed and Pack configuration for smell identification at Cabin

**RELEASE TO SERVICE**

- No smell identification
- Put the Aircraft back in-service operation for flight
3. Challenges on Cabin Odor Events

- ODOR IDENTIFICATION IS HIGHLY SUBJECTIVE
- ODOR ROOT CAUSE ANALYSIS IS A TIME-CONSUMING PROCESS
- EVIDENCE FOUND IN INSPECTED COMPONENTS CAN LEAD TO SEVERAL INTERPRETATIONS
Our vision LEANER and FASTER troubleshooting for an air FREE of contaminants
Respiratory disease caused by Aerotoxic Syndrome

J. Roig, MD, PhD, FCCP
Pulmonary Department
Clínica Creu Blanca
Barcelona
- Decreased phrenic nerve activity and therefore decreased diaphragm contraction.
- Nausea and vomiting.
  - Stimulation of muscarinic cholinergic receptors can increase gastric acid secretion and risk of aspiration.
- Overstimulation of the skeletal neuromuscular junction causes fasciculation and paralysis.
- Direct effect on medulla/hindbrain.
  - Decreased respiratory drive.
  - Glial cell inflammation.
- Muscarinic cholinergic stimulation leading to bronchospasm and bronchorrhea.
  - Possible increased risk of pneumonia secondary to cholinergic disruption of immune function.
- Increased risk of pancreatitis and ARDS.
- Increased alveolar fluid and increased pulmonary capillary permeability.
  - Alveolar haemorrhage.
  - Increased alveolar protein, neutrophils and inflammatory cytokines.
CASE 1

- 47-year-old male international airline pilot experienced 4 episodes of cabin air fume events, over 2 years during flights on Airbus aircraft
- 2 of them were smell episodes, the others were smoke events of unknown origin
- Difficulties with immediate memory recall and, occasionally, with the fluency of his speech
- Last event: the pilot developed mild cough and shortness of breath that persisted for several weeks.
- Past history: non remarkable; no prior medication; no other epidemiologic hints
• Severe cough, tiny whitish sputum, moderate dyspnea
• Physical exam: bilateral wheezing, $O_2$ saturation 93% (room air); afebrile
• Chest X-ray and CT scan: normal
• Sputum microbiology: negative
• Negative PCR test (Film Array Respiratory Panel 2) of nasopharyngeal secretions for
  Adenovirus, Influenza A & B virus, Parainfluenza, RSV, Rhinovirus/Enterovirus, 
  Chlamydia pneumoniae, Mycoplasma pneumoniae, Bordetella pertussis, 
  Metapneumovirus & Corona virus
CASE 1

- Spirometry: moderate airway obstruction with a strongly positive bronchodilator test. Diffusion capacity for carbon monoxide ($D_{LCO}$) was normal
- Steroids, leukotriene inhibitors, inhaled long acting muscarinic agents (LAMA) and long acting beta-adrenergic agents (LABA) were prescribed
- Respiratory symptoms slowly subsided during the following 6 months; but neurologic complaints even worsened
- At 3-month follow-up a diagnosis of Reactive Airway Dysfunction Syndrome (RADS) related to Aerotoxic Syndrome was done
<table>
<thead>
<tr>
<th>Pulmonary Function Test</th>
<th>Actual</th>
<th>% Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC, L</td>
<td>7.47</td>
<td>91</td>
</tr>
<tr>
<td>RV, L</td>
<td>2.82</td>
<td>111</td>
</tr>
<tr>
<td>FVC, L</td>
<td>5.09</td>
<td>101</td>
</tr>
<tr>
<td>FEV1, L</td>
<td>2.45</td>
<td>63</td>
</tr>
<tr>
<td>FEV1/FVC</td>
<td>48</td>
<td>63</td>
</tr>
<tr>
<td>FEF(_{25-75}), L</td>
<td>0.94</td>
<td>25</td>
</tr>
<tr>
<td>(D_{LCO}), mL/min/mm Hg</td>
<td>25.8</td>
<td>82</td>
</tr>
</tbody>
</table>
CASE 1: long-term follow-up

- Pain radiating down his arms and slight numbness and tingling in fingers
- Formal neurological examination: normal
- Blood tests: normal
  - Negative immunological studies (ACE, RF, ANA, ANCA)
- MRI examination and EMG: normal
- Neuronal injury:
  - Highly positive tests for autoantibodies against myelin basic protein (MBO), neurofilament proteins (NFP), microtubule associated tau proteins, tubulin, MBP and microtubule associated protein-2 (MAP-2)
  - Astrocytic markers brain injury: highly increased levels for autoantibodies against glial fibrillary acidic protein (GFAP) and glial calcium-binding protein S-100B
Reactive Airways Dysfunction Syndrome (RADS)

- Respiratory symptoms after exposure to irritant fume, vapor,...
  - Cough, wheezing, shortness of breath, chest tightness
- Onset < 24 hours of exposure + at least 3 months
- Documented absence of previous respiratory complaints
- Pulmonary function tests: Bronchial hyperreactivity
- Single inhalation of a high concentration or irritating chemicals generated as aerosol or high levels of particulates

but...
Banauch GI et al. Persistent hyperreactivity and reactive airway dysfunction in firefighters at the World Trade Center.

*Am J Respir Crit Care Med* 2003; 168: 54-62

RADS does not require a clinically severe inhalation injury necessitating medical care
Low dose RADS & Low Intensity Chronic Exposure Dysfunction Syndrome

✓ Related to “irritant-induced asthma”
✓ Multiple exposures to low concentrations of irritants
✓ Intensity of exposure is less but may be of greater duration
✓ Onset of symptoms after several hours or days
✓ Chemical and physical nature of the irritating agent
✓ Concentration & simultaneous multiple agents
✓ Risk factors are incompletely characterized
CASE 2

• 34 year-old female international airline flight attendant exposed to a few, repetitive smell oil odors in the cabin of an Airbus 320 during takeoff and landing for 2 weeks

• Past History: unremarkable. No prior medication

• Nonspecific upper respiratory tract irritation, mild but progressive dry cough, and some skin itching

• After a strong odor episode, she developed a skin rash particularly involving both ears and trunk, the cough worsened, and she began to complain about mild dyspnea
CASE 2

- Blood test (few days after the last episode):
  - Serum cholinesterase of 18 U/L (normal value < 14)
  - Eosinophils count: normal
- Rash subsided after a course of steroid therapy but moderate shortness of breath and dry cough on exercise persisted
- Chest x-ray performed at the onset of the disease was normal
  - Two months after the onset physical examination was unremarkable; CT scan was normal
CASE 2: follow-up

- Inhaled therapy (fluticasone furoate plus vilanterol)
  - Respiratory symptoms progressively subsided
  - Withdrawn after 6 months without any relapse

- Recurrent anxiety and emotional instability
- She gave up working as flight attendant
- Mind – body interventions were useful for recovery
Mindfulness

✓ Mental training to cultivate present moment awareness
✓ Meditation practice is the cornerstone of mindfulness

✓ Non pharmacological approach to psychological symptoms related to illness such as anxiety, depression, self blame, catastrophic interpretations...

✓ Mind & body have been useful in many respiratory conditions
The effect of mindfulness meditation on cough reflex sensitivity

Changes in cough reflex sensitivity to citric acid in healthy volunteers for the control, mindfulness intervention and voluntary cough suppression groups. Horizontal lines represent median values and error bars represent the interquartile range.

Young EC. Thorax 2017
CASE 3

- 56-year-old woman, international airline pilot, presented with symptoms of a long-term, unbearable, dry cough + upper respiratory tract irritation, related to exposure to a variety of environmental substances or odors
- Recurrent headaches, relapsing inflammation of eyelids, pains in her legs and shoulders, weakness, and tingling of her fingertips
- Onset of symptoms 9 years previously soon after a fume event on an Airbus A319
- 4 passengers also required medical assistance because of nausea and shortness of breath
CASE 3

- Physical Exam:
  - low BMI
  - skin abnormalities and eyelids irritation
  - dry cough on deep breathing; O₂ saturation 96% (room air)

- Neurological evaluation: unremarkable

- Blood tests: normal. Increase in myelin associated glycoprotein (MAG)

- Previous chest X rays were reported to be normal

- Spirometric values normal but significant bronchodilator response

- D_LCO normal. Interestingly, the breathing of gas mixture (helium) used to perform the diffusion test induced a severe cough episode
CASE 3

• A diagnosis of multiple chemical sensitivity and bronchial hyperreactivity related to Aerotoxic Syndrome was done

• Cough improved with daily inhaled therapy with fluticasone furoate plus vilanterol

• Non-respiratory symptoms persisted on long-term follow-up

• The patient had been forced many years before to cease flying with obvious negative psychological connotations
Multiple Chemical Sensitivity

Idiopathic environmental intolerance (IEI)
✓ Nonspecific symptoms when exposed to low levels of chemicals, biologic or physical agents
✓ Medical societies scepticism: psychiatric disorder?
✓ No consistent objective diagnostic tests to define an illness...
✓ Cough is the most frequently reported respiratory symptom
✓ Psychological approach mandatory: mind & body interventions
✓ Quick Environmental Exposure & Sensitivity Inventory (QUEESI questionnaire): TILT test (Toxicant-induced loss of tolerance)
There are presently 30 UK airline pilots grounded due to toxic air.
Conclusions

➢ Respiratory symptoms rank second to neurological symptoms
➢ Respiratory symptoms have been often neglected since many clinicians are unaware of this condition
➢ Bronchial hyperresponsiveness is the hallmark of involvement
➢ Some cases are consistent with RADS – Irritant induced asthma
➢ Some cases may also be included in the spectrum of MCS / Idiopathic Environmental Intolerance
Cabin Air Contamination –
A Summary of Engineering Arguments

Dieter Scholz
Hamburg University of Applied Sciences

International Aircraft Cabin Air Conference 2019
Imperial College London, 17/18.09.2019
Contents

- Introduction
- Jet Engine Technology
- Aircraft Systems Technology
- Aircraft System Design Principles
- Engine Metals from the Oil into the Body
- Summary (of Engineering Arguments)
- Contact
Introduction
Introduction

**Definition: Fume Event**
In a fume event, the cabin and/or cockpit of an aircraft is filled with fume. Air contamination is due to fluids such as engine oil, hydraulic fluid or anti-icing fluid. A Fume Event includes a Smell Event. Note: Other reasons for fume in the cabin are possible. The term "fume event", however, is generally used as defined here. Definition adapted from (Wikipedia 2019)

**Definition: Smell Event**
A fume event without visible fume or smoke, but with a distinct smell usually described as "dirty socks" from the butyric acid originating from a decomposition of the esters that are the base stock of the synthetic jet engine oil.

**Definition: Cabin Air Contamination Event (CACE)**
In a Cabin Air Contamination Event (CACE) the air in the cabin and/or cockpit of an aircraft is contaminated. Sensation of the contamination can be from vision (fume/smoke), olfaction (smell/odor), a combination of typical symptoms experienced by several passengers and/or or crew or by related measurements of CO, CO2, ozon or other "harmful or hazardous concentrations of gases or vapours" (CS-25.831).
2019-08-22: Hawaiian Airlines, A321neo
Emergency Landing and Evacuation; Smoke on Board

Oakland to Honolulu, Flight HA47, A321neo, N218HA

21:13: Top of Descent: Smoke starts to fill cabin i.e. when thrust setting changed.

21:16: Pilots received a fire warning from the cargo compartment and declared an in-flight emergency.

21:36: Landing. After landing there was "no visible evidence of fire, no visible flames" said Snook. "We have since determined that a seal failed in the aircraft’s left engine" said Da Silva.

Direct (emergency) venting with ram air (independently of bleed air) is possible below 10000 ft, but was not used.
Jet Engine Technology
Jet Engine Technology

Engine Overview

Engine Alliance GP7000

bearing (example)

(Assuntos Militares 2013)
Jet Engine Technology

Engine Bearings

Rolls-Royce Trent 1000

(Ademiyi 2015)
Lubrication and Sealing of Engine Bearings

Normal operation of engine seals:
1. The "drain" discharges oil.
2. The "dry cavity" contains oil.
3. Air and oil leak from bearings into the bleed air.

=> Engines leak small amounts of oil by design!

Based on (Exxon 2017b)
Engine Air and Oil System

Quotes from: Exxon Mobile (2017a): “Jet Engine Oil System – Overview” with remarks:

- "The scavenged oil flow is slightly lower than the supply flow due to normal oil consumption through the deoiler, oil seals, and oil leaks." (Remark: Oil escapes also from the seals)

- "Therefore, a large amount of air is carried by the scavenge oil and must be removed through a de-aerator when entering the tank." (Remark: Seals do not seal but allow large amounts of air to enter the seals. If pressure in the compressor is low compared to pressure in the oil system i.e. low $\Delta p$, oil can escape from the seals.)
Jet Engine Technology

De-aerator – Separating Air and Oil

- Air leaving the de-aerator still contains some oil (sometimes visible on the engine as white smoke).
- Amount of oil depends on the oil separating efficiency of the de-aerator.
- Oil leaving de-aerator determines (almost exclusively) the oil consumption of the engine.
- Oil leaving through engine seals is only a very small portion \( x \) of the engine's oil consumption (1%?).
- Hence: Oil entering cabin depends more on this portion \( x \) then on the absolute engine oil consumption!
Jet Engine Technology

**Engines Longer on Wing**

**Labyrinth-Seal Clearances Increase as Engines Age**

"Labyrinth-seal clearances naturally increase as an engine ages. As this occurs – due to rubbing under vibration, gyroscopic torque, rough landings or any g-load factor, the engine air flow increases, resulting in even higher oil consumption" (Exxon 2016a) and hence leakage into the bleed air.

The figure shows increasing time to first shop visit of CFM56-7B engines. It follows:

During a period of 10 years (2004 to 2014) maintenance practice changed such that engines stay on the wing almost twice as long without shop visit and seal replacement.

![CFM56-7B time to first shop visit (years)](image-url)
Aircraft Systems Technology
Bleed Air Ducts

Potential Sinks for Oil Contamination

Adapted from (AMM B737)
A320 Temperature Control, Pressure Control, Ventilation

- **Bleed air from engine compressor**
- **Recirculation**
  - Fan
  - 50% of bleed air
- **Outflow valve**
  - 50% of outflow
- **Mixing unit**
- **Trimming air valves**
- **Emergency ram air**
- **Pack flow control valve**
- **Packs 1 and 2**
- **Adapted from (A320 FCOM)**

Dieter Scholz: Cabin Air – Engineering Arguments

International Aircraft Cabin Air Conference

18.09.2019, Slide 15
Aircraft Design and Systems Group (AERO)
Aircraft Systems Technology

Cabin Air Ducts

Potential Sinks for Oil Contamination
Cabin Air Ducts

Insufficient / Impossible Duct Cleaning

In the case of heavy contamination, this being assumed when there are visible traces of oil on the internal surface of the ducts, it is necessary to manually clean the affected ducts using rags and an appropriate degreasing agent.

(Airbus 2013)

Aircraft released back into service over night after an (oil based) CACE are not cleaned as instructed by Airbus, because

- ducts cannot be removed from behind the panels in this short time,
- the inside of ducts is not accessible in the first place.
Aircraft Systems Technology

**How Do We Know about Oil in the Cabin?**

**Oil has left traces on its way from the engine to the cabin interior:**

1. Oil traces in **bleed air ducts**
2. Oil traces in **air conditioning ducts**
3. Oil traces in **recirculation filters**
4. Oil traces on **cabin surfaces** (wall panels, seats, ...)
5. Hydro carbon concentrations in the cabin can be **calculated** and agree with measurements

**Evidence** collected in Scholz 2017a and Scholz 2017b summarized here:

1. (GCAQE 2017)
2. (CAA 2004)
3. (Eckels 2014)
4. (Lamb 2012, Solbu 2011)
5. (Scholz 2017a)

\[
\frac{m_{oil,cab}}{V_{cab}} = \frac{\dot{m}_{oil} \times x_{bear,up} \times x_{seal}}{S_{eng} \times n_{eng} \times M_{CR} \times a(h_{CR})} \times \frac{P_{cab} (\mu + 1)}{P_{CR}}
\]
Primary and Secondary Cabin Air Contamination Events (CACE)

Event Mechanism:
- normal leakage
- seal failure
- neg. Δp in bearing chamber
- transients

Primary CACE
- TCP entry > LOD
- Depot

Secondary CACE
- (not understood today)

Based on EASA 2017b

- mechanical stress?
- thermal stress?
- solvents (water, de-icing fluid, ...)?
Dynamic Cabin Air Contamination Calculation Theory

\[
\frac{d}{dt} c_{cab} + a \cdot c_{cab} = b_1 + b_2 \cdot t
\]

It takes about **20 minutes** for a discrete cabin air contamination event (CACE) to be washed out by the air conditioning system ("thinning effect").

Lakies 2019 at HAW Hamburg
Download of project report: https://doi.org/10.15488/4543
Aircraft System Design Principles
Interpretation of CS-25.1309 with respect to Bleed Air from Jet Engines

CS-25 (AMC 1309, 6. Background, b. Fail-Safe Design Concept)

The CS-25 airworthiness standards are based on ... the fail-safe design concept ...
(2) The fail-safe design concept uses the following design principles:

(i) Designed Integrity and Quality including Life Limits, to ensure intended function and prevent failures.
(v) Failure Warning or Indication to provide detection.
(xi) Error-Tolerance that considers adverse effects of foreseeable errors during the aeroplane's design, test, manufacture, operation, and maintenance.

• The probability of CACEs must not be compared with the effect-probability relationship of CS-25.1309 which is for statistical errors.

• Errors of the bleed air-based air conditioning system are well known, permanent and non-statistical.

• The system's error-tolerance (e.g.: two pilots, autopilot, cockpit crew oxygen masks) is compromised, if it has to cope with already known design errors that are not rectified out of negligence.

• In case of bleed air used for cabin ventilation: Known problems need to be rectified!
“Compressor bleed from turbine engines is attractive because of the mechanical simplicity of the system.” However, “oil contamination ... can occur in using compressor bleed air from the main engines.” “Popular opinion regarding the risk of obtaining contaminated air from the engine may preclude its use for transport aircraft, regardless of other reasons.”
Engine Metals from the Oil into the Body
Engine Metals from the Oil into the Body

Used Oil Analysis for Metal Particles

- **Spectrometric Oil Analysis** Program (SOAP) is an analysis of metal particles in the oil.SOAP can be combined with **oil filter inspection** and **magnetic chip detector inspection** which identifies larger metal particles.
- A monitor program helps to identify the condition of the engine:
  - **Catastrophic** failure of mechanical parts usually generate larger metal particles that can be analysed in magnetic chip detectors.
  - **Slow progressing damage** to gears, bearings and spinning bearing races in the engine case is identified with SOAP. Wear particle size is between 1 \( \mu \text{m} \) and 5 \( \mu \text{m} \).
  - **Normal wear** can produce even smaller particles (nano particles).
  - The most important wear metal in the evaluation is iron followed by chromium – both are present in bearings. If the engine case is titanium, increased titanium levels indicate a spinning bearing outer race.
  - Larger metal particles will stay in the engine.

- **Metal micro and nano particles can leave the engine together with the oil into the cabin!**

Partially based on Exxon 2016b
Engine Metals from the Oil into the Body

Metal Particles in Human Fatty Tissue

(Gatti 2019, report written for client)

**Analysis 8 of Table I.** High-magnification image (1228x) and EDS spectrum of 10-micron and 1-micron brighter-looking particles composed of Carbon, Iron, Chromium and Oxygen: a stainless-steel composition. EDS: Energy-Dispersive X-ray Spectroscopy.
Cabin Air Contamination – A Summary of Engineering Arguments

Summary (1)

There is a problem with aircraft air conditioning systems based on bleed air. The evidence:

- Engine bearing seals leak small amounts of oil by design and more so in failure cases.
- Engines are longer under the wing. Therefore seals are worn out more and leak more.

- Oil residue found in bleed ducts, air conditioning ducts, recirculation filters and on cabin surfaces.

- Hydro carbon concentrations in the cabin can be calculated and agree with measurements. Hydro carbons are about two-fold in standard pax A/C cabins compared to B787.
- "dirty socks smell" comes from the base stock of the oil. This smell is an indication for oil products in the cabin.

- Chemicals and certain metals that are common in the workplace are found in employee's.
Cabin Air Contamination – A Summary of Engineering Arguments

Summary (2)

• There is a "thinning effect" that reduces the contamination concentration, but concentration depends also on the source strength and duration. Accordingly, examples show the cabin constantly full of oil smoke.

• ECS uses bleed air. This design should not be used (SAE).
• Certification rules are violated.

• An aircraft once contaminated with oil cannot be cleaned. Ducts and components would need to be replaced.

• Instead of applying a cautionary proactive attitude, those responsible use too much effort to play things down. We need a change of attitude to the cabin air problem! We need to get back to aviations proven principle of caution and safety first.
Cabin Air Contamination – A Summary of Engineering Arguments

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http://CabinAir.ProfScholz.de
Cabin Air Contamination – A Summary of Engineering Arguments

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Adeniyi 2015

Assuntos Militares 2013

Aviation Week 2016
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**EASA 2017a**  
Project partners: Fraunhofer ITEM, Hannover Medical School (MHH), Lufthansa Technik AG / Deutsche Lufthansa AG, Condor Flugdienst GmbH, British Airways

**EASA 2017b**  
Project partners: The Netherlands Organization for Applied Scientific Research (TNO), National Institute for Public Health and the Environment (RIVM), Institute for Environmental Studies (IVM), Institute for Risk Assessment Sciences (IRAS)

**Eckels 2014**  
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**Exxon 2017a**

**Exxon 2017b**

**Gatti 2019**
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Lakies 2019

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**Scholz 2017b**

**Solbu 2011**

**Wikipedia 2019**

All online resources have been accessed on 2019-09-18 or later.
Cabin Air Contamination – A Summary of Engineering Arguments

Quote this document:

See also:
Scholz, Dieter: *Technical Solutions to the Problem of Contaminated Cabin Air*. German Aerospace Congress, Friedrichshafen, Germany, 04.-06.09.2018. – Presentation No. 0270, download from: [http://CabinAir.ProfScholz.de](http://CabinAir.ProfScholz.de)
A GP’s Perspective of Fume Incidents Over 20 Years

Dr Moira Somers
I will reflect briefly on 4 areas

• My experience with over 38 flight crew
• Dr John Snow and Cholera
• The Asbestos Story and
• My experience with workers from the Alcoa Wagerup Refinery
Figure 1: Frequency of Symptoms recorded for 36 Air Crew

- Bladder dysfunction
- Swollen glands
- Rash
- Hair loss
- Reflux
- Blurred vision
- Epistaxis
- Abdominal discomfort/diarrhea
- Altered smell/taste
- Palpitations
- Depression/stress
- Anxiety
- Balance disturbance
- Paresthesia/tingling
- Chemical sensitivity
- Dizziness
- Prolonged recovery
- Breathing difficulties/ chest tightness
- Improve away from fumes
- Headaches
- Sore eyes
- Cognitive dysfunction
- Sore throat
- Nausea
- Lethargy

Number Of Air Crew With Symptom
• Consistent history across aircrew
• Consistent history across aircrew

• Fume incidents often consistent with technical logs
• Consistent history across aircrew

• Fume incidents often consistent with technical logs

• Same aircraft frequently reported as having fume incidents
• Consistent history across aircrew

• Fume incidents often consistent with technical logs

• Same aircraft frequently reported as having fume incidents

• Continuum of exposure
Alternate Diagnoses

• Infection
• Primary anxiety disorder
• Hyperventilation
• PTSD
• Depression
• Dehydration
• Gastro-Oesophageal Reflux Disease

• Mass Psychogenic Illness
• "All in the Head"
• "Just flying"
• Stress
• Bronchitis
• Viral illness
• No diagnosis - fit to fly
• Somatoform disorder
Dr John Snow and Cholera
Dr John Snow and Cholera

• Detailed history is most important

• Just because we don’t understand the exact mechanism or have the appropriate tests doesn’t mean the condition isn’t real or cause serious harm.

• Simple measures can be instituted to prevent harm.

• In time Medicine will gain understanding. All disease is subject to advancing knowledge.
Asbestos
Asbestos

• First diagnosis Asbestosis early 1920’s

• Dr Eric Saint – warning to Government WA re Wittenoom in 1948

• First legal cases 1970’s not successful

• Corporate Veil pierced – CSR held accountable
Alcoa Wagerup Refinery
Alcoa Wagerup Refinery

- Demonstration Corporate Responsibility
- Zeigarnik effect
Reflection Points

Barriers to GPs:

- Time
- Knowledge
- Reluctance to be involved in medicolegal issues
Reflection Points

Barriers to Aircrew:

• Lack of information
• No exposure plan
• Lack of support
• No disease status for Aero Toxic Syndrome
• Multiple Emergency Departments
• Fear of job loss/worker’s compensation
• Multiple inconsistent diagnoses
• No dedicated protocol for assessment
Possible change

• Symptoms surveys prior to and post flight – epidemiological studies
• Information at induction
• Exposure plan
• Assessment/diagnosis/treatment protocols
• Specimens collections for biomarkers/genetic studies
• Corporate/workforce/research/medical collaboration
Fresh Air Filtration
Reaching the Finish Line

David Stein
GCAQE
Aircraft Cabin Air Conference

September, 2019
Cabin air quality control through advanced filtration and sensing.
Project Timeline

Solutions take partners: Airlines, OEMs, and Pall.
Aircraft Integration
Detailed ECS knowledge essential to incorporating additional pressure drop filtration system
OE support on system performance and interactions critical
Pall Clean Air Technology (CAT) filters fresh air provided by the engines or APU before it enters the cabin. To date, work has focused on a solution that requires a filter to be installed directly upstream of the mixing chamber, with an additional high temperature filter to remove particulate and VOC from the trim air.
Based on a typical PAX loading and considering atmospheric conditions at a number of airports worldwide, the air temperature in this location will typically be at or below 32°F with large quantities of free water being produced.

The system has to:

• Be able to manage high levels of free water and icing
• Must not negatively impact the performance of other system components
• Must not negatively affect the cabin heating and cooling performance
• Must meet all the CS-25 certification requirements
Key Design Consideration
Performance Requirements

- Integration in the aircraft (critical to field a solution)
- Meet the ultimate goal of reducing fume events and odors
Odor Events Come with Ultra-fine Particles

Levels at measured at:
- Airport ~ 250,000 particles/cm³
- Indoor air ~ 4,000 particles/cm³
- Major roads ~ 20,000 particles/cm³

ACP Packs ON after take-off
Climb power reapplied after level

Indoor air
Major roads
Airports
MaVE

Decreases UFPs by 90%
Ultrafine particulate (UFPs) – PM0.1
- Often condensates of hydrocarbons
- Elevated UFP levels during fume events

Latest Technology
Filter Membrane
Proven Experience in VOC Removal

VOC Removal Efficiency:
Synthetic vs. Natural Carbon 100 PPM limonene

In-Cabin Performance Dodecane Challenge at 10 ppm Face Velocity 1.1 m/s

Flight Hours / A330

Removal Efficiency / %

Specific Volume of Air Treated / m³ Air per gram Carbon

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A-CAF and MaVE in Combination

A-CAF (Advanced Cabin Air Filters)

Representative MaVE
Validated Simulation Models

Cabin Air Quality Simulation

Through numerous ground tests and simulating fume events we validated our simulation analysis tool to enable optimization of the VOC adsorbent.
Product Performance
Test Capability

Replica of ECS system enables:
- Pressure Testing
- VOC tests
- Water Tests
- Icing Tests
Key Performance Parameters

- Integration in existing aircraft with minimum and acceptable impact on performance of ECS and associated equipment
- Removal of contaminants that could be present in the fresh air supply before they reach the cabin or cockpit
  - Validation in the laboratory
  - In aircraft (film)
- Service life aimed to match existing A-CAF
  - Will be confirmed through service evaluation
Aircraft Ground Test
Because of technological developments related to the products, systems and/or services described herein, the data and procedures are subject to change without notice. Please consult your Pall representative or visit www.pall.com to verify that this information remains valid. Pall Corporation has offices and plants throughout the world. For Pall representatives in your area, please visit our website.

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Health effects of air pollution

Terry Tetley

National Heart and Lung Institute
Imperial College London
Ambient air pollution

London smog 1952:
Increased hospital admissions with >4,000 of premature deaths.
Clean air act 1956 “solved” the problem

TODAY - PM10, PM2.5, gases etc, due to urban traffic, industry, combustion...

DEP: <100nm diameter; high particle number concentration/m$^3$ and /unit mass
• PM2.5 caused 4.2 million deaths/year globally in 2015, compared to 3.5 million in 1990;

• 5th highest ranking mortality risk factor

Deaths associated with fine ambient particulate matter (PM$_{2.5}$):
• Cardiovascular (~48%; ischaemic heart disease and stroke),
• Respiratory conditions (~35%; asthma, chronic obstructive pulmonary disease, cystic fibrosis).
• Lung cancer (~9%)

Particulate air pollution was classified as a carcinogenic agent by the International Agency for Research on Cancer (IARC) in 2013

Respiratory effects of air pollution

Chronic obstructive pulmonary disease - emphysema

SYSTEMIC EFFECTS

COPD

Healthy lungs
Outdoor air pollution exposure
Tobacco smoke

Cough
Infection

Healthy human heart
Plaque with fibrous cap
Cap ruptures
Blood clot forms, blocking artery
Dead heart tissue at site of blockage
Respiratory effect:

- Increased respiratory mortality

- Increased incidence and exacerbation of chronic pulmonary diseases:
  - asthma, chronic obstructive pulmonary disease, cystic fibrosis

- Increased pulmonary infections – compromised, young and elderly

- Increased symptoms: cough, phlegm, wheezing, breathlessness

- Increased lung cancer

- Reduced lung function/growth in childhood which affects adult health
Health effects of air pollution

Respiratory disease – COPD, asthma, infection, lung cancer
Reduced lung growth
Reduced lung function

Type 2 diabetes
Type 1 diabetes
Liver toxicity
Renal disease
Altered bone metabolism

High blood pressure
Endothelial dysfunction
Increased blood clotting
Systemic inflammation
Thrombosis
Atherosclerosis

Strokes
Neurological development
Mental health
Neurodegenerative disorders

Cardiovascular disease – myocardial infarction, cardiac arrhythmia, cardiac failure

Accelerated aging
Autoimmune rheumatic disease

Premature birth
Low birth weight
Reduced/delayed foetal growth
Lower sperm quality, infertility
Preeclampsia

Imperial College London
Respirable PM$_{10}$ and PM$_{2.5}$

PM$_{2.5}$ enters the gas exchange region of the lungs

Ref: http://www.epa.gov/research
Deposition and impact of inhaled PM$_{2.5}$ and PM$_{0.1}$
Structure of the lung
Oxidative stress and IL-6 mediator release from human lung respiratory epithelial cells following 24 hour exposure to DEP/Envirox

25µg/ml

50µg/ml

100µg/ml

Prenatal and early life diesel exhaust exposure disrupts (brain) cortical lamina organization: Evidence for a reelin-regulated pathogenic pathway induced by interleukin-6

Related to AUTISM SPECTRUM DISORDERS (ASD)

Chang YC et al. Brain Behav Immun. 2019 May;78:105-115
Diesel exhaust particles (DEP) activate guinea pig and human airway sensory nerves- involvement in cough?

Introduction of DEP into the airways caused airway nerve activation in a guinea pig model

DEP caused activation of isolated guinea pig and human vagus nerve

The organic soluble component, not the carbon core, caused guinea pig and human afferent vagal nerve activation

Mechanistic link between diesel exhaust particles and respiratory reflexes.


DEP: Diesel exhaust particles; TRPA1: transient receptor potential Ankyrin-1; PAH’s: Polycyclic aromatic hydrocarbons; ROS: Reactive oxygen species.
Effect of intratracheal instillation of DEP and carbon black (CB) on lung inflammation and pulmonary vascular platelet activation (thrombosis) in mice (4h).

Introduce 25 μg DEP or carbon black into lung (4h)

Track and localise labelled platelets

Intratracheal instillation of DEP, but not CB, causes significantly greater vascular pulmonary platelet aggregation in mice in vivo that is slow to resolve

Intratracheal instillation of CB, but not DEP, causes marked pulmonary inflammation in mice

OXFORD STREET II

Respiratory and cardiovascular responses to walking down a traffic-polluted road compared with walking in a traffic-free area in participants aged 60 years and older with chronic lung (COPD) or heart disease (IHD) and age-matched healthy controls: a randomised, crossover study.

Sinha ray et al. Lancet 2018;391(10118):339-349
OXFORD STREET II STUDY
Distribution of black carbon, nitrogen dioxide (NO₂), noise, ultrafine particles, PM₂.₅ and PM₁₀ concentrations, temperature, and relative humidity on the visit days to Oxford Street or to Hyde Park – Sinharay et al. Lancet 2018, 391:339

Box plots with 95% CIs. PM=particulate matter. **p<0·01. ***p<0·001.
OXFORD STREET II STUDY
Odds ratio of getting worse symptoms of cough, sputum, shortness of breath, wheeze, sweat, and total scores for all these symptoms at Oxford Street versus Hyde Park for healthy volunteers and participants with COPD or IHD – Sinharay et al. Lancet 2018, 391:339

COPD=chronic obstructive pulmonary disease.
IHD=ischaemic heart disease.
OXFORD STREET II
Change in FEV$_1$ % of predicted value (A), and FVC % of predicted value (B) from the time 0 and at intervals after the start of the 2 hour walk in Oxford Street or Hyde Park. For healthy volunteers and participants with COPD or IHD

A

Healthy

COPD

IHD

B

FEV$_1$=forced expiratory volume in the first second. FVC=forced vital capacity.

* $p<0.05$, ** $p<0.01$, *** $p<0.001$, comparing Oxford Street with Hyde Park.

+ $p<0.05$, ++ $p<0.01$, +++ $p<0.001$, compared with time point 0.
• Symptoms, including cough and wheeze increased in Oxford Street

• Reduced lung function in COPD subjects was related to levels of NO$_2$, ultrafine PM$_{0.1}$ and fine PM$_{2.5}$ particles.

• Cardiovascular changes, including increased arterial stiffness in Oxford Street, were seen in healthy and COPD subjects and related to NO$_2$ and ultrafine particles.

• Cardiovascular medication prevented the effects of air pollution on (increased) arterial stiffness in subjects with heart disease
Deposition and impact of inhaled PM$_{2.5}$ and PM$_{0.01}$
Inhaled Nanoparticles Accumulate at Sites of Vascular Disease.


- 0.02% of inhaled nanogold (~20nm diameter) excreted in urine by healthy individuals after 2h exposure during exercise.
- Nanogold in human and mouse atherosclerotic plaques after 4h exposure.
Particles reach the interstitial tissues of the lung and can remain there
Uptake and translocation of MWCNTs by human alveolar epithelium

Alveolar epithelial type 1 cells exposed to MWCNTs

70-80% of 300nm CNTs (green) intracellular

2-3% translocate to the basolateral compartment

Rueuraroengsak, Porter, Tetley unpublished
Hopping probe ion conductance microscopy of human respiratory alveolar epithelial cells exposed to carboxyl-modified and amine-modified particles for 4 hours.

Carboxyl-modified NP (-ive)

Amine-modified NP (+ive)

Ruenraroengsak et al. Respiratory epithelial cell cytotoxicity and membrane damage (holes) caused by amine-modified nanoparticles, Nanotoxicology 2012, 6:94-108
Nanoparticle-induced reactive oxygen species (ROS), importance of surface charge and protection by antioxidant treatment.

Rueuraroengsak & Tetley
PFT 2015
Systemic impact of inhaled PM$_{2.5}$ and PM$_{0.1}$
Association between PM$_{2.5}$ and constituents of PM$_{2.5}$ and preterm delivery in California 2000-2006.

*Basu et al. Paed. Perinatal Epidemiology, 2017; 31:424-434*

231,637 births; 23,265 preterm births

50% PTB were 25-34 years old

PM2.5 data from 7 monitor sites, collected every 3$^{rd}$ or 6$^{th}$ day

Related to:
Traffic and biomass combustion

Long term exposure

Hispanic and Asian background

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Overall % change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total PM2.5</td>
<td>+16.4 (13.5-19.5)</td>
</tr>
<tr>
<td>NH$_4^+$</td>
<td>+21.2 (17.1-25.4)</td>
</tr>
<tr>
<td>NO$_3^-$</td>
<td>+18.1 (14.9-21.4)</td>
</tr>
<tr>
<td>Br</td>
<td>+16.7 (13.2-20.3)</td>
</tr>
<tr>
<td>Elem. Carbon</td>
<td>+10.9 (6.3-15.6)</td>
</tr>
<tr>
<td>Zn</td>
<td>+14.4 (10.3-18.6)</td>
</tr>
<tr>
<td>Cl</td>
<td>-8.2 (-10.3 - -6.0)</td>
</tr>
<tr>
<td>Na</td>
<td>-13.2 (-15.2 - -11.3)</td>
</tr>
<tr>
<td>Na$^+$</td>
<td>-11.9 (-14.1 - -9.6)</td>
</tr>
<tr>
<td>V</td>
<td>-19.2 (-25.3 - -12.6)</td>
</tr>
</tbody>
</table>
SUMMARY

• There are significant systemic health effects of ambient air pollution particles

• Size, chemistry and shape matters

• Susceptibility eg age, defence mechanisms, genetics, existing disease all play a part

• Mechanisms involved remain unclear
Health effects of air pollution

Respiratory disease – COPD, asthma, infection, lung cancer

Reduced lung growth
Reduced lung function

Type 2 diabetes
Type 1 diabetes
Liver toxicity
Renal disease
Altered bone metabolism

High blood pressure
Endothelial dysfunction
Increased blood clotting
Systemic inflammation
Thrombosis
Atherosclerosis

Strokes
Neurological development
Mental health
Neurodegenerative disorders

Cardiovascular disease – myocardial infarction, cardiac arhythmia, cardiac failure

Accelerated aging
Autoimmune rheumatic disease

Premature birth
Low birth weight
Reduced/delayed foetal growth
Lower sperm quality, infertility
Preeclampsia
THANK YOU
A review of the possible associations between ambient PM2.5 exposures and the development of Alzheimer's disease.

Maternal exposure to fine particulate air pollution induces epithelial-to-mesenchymal transition resulting in postnatal pulmonary dysfunction mediated by transforming growth factor-β/Smad3 signaling.
Tang W et al. Toxicol Lett. 2017;267:11-20

Triggering Mechanisms and Inflammatory Effects of Combustion Exhaust Particles with Implication for Carcinogenesis.
Øvrevik J, Refsnes M, Låg M, Brinchmann BC, Schwarze PE, Holme JA.
Basic Clin Pharmacol Toxicol. 2017 Sep;121 Suppl 3:55-62

Short-term effects of airport-associated ultrafine particle exposure on lung function and inflammation in adults with asthma.
Habre R, Zhou H, Eckel SP, Enebish T, Fruin S, Bastain T, Rappaport E, Gilliland F.
Environ Int. 2018 Sep;118:48-59
Association between PM$_{2.5}$ and PM$_{2.5}$ Constituents and Preterm Delivery in California, 2000-2006.
Basu R, Pearson D, Ebisu K, Malig B.

Association between fertility rate reduction and pre-gestational exposure to ambient fine particles in the United States, 2003-2011.
Xue T, Zhu T. Environ Int. 2018 Dec;121(Pt 1):955-962

Ambient fine particulate pollution associated with diabetes mellitus among the elderly aged 50 years and older in China.

Exposure to Environmental and Occupational Particulate Air Pollution as a Potential Contributor to Neurodegeneration and Diabetes: A Systematic Review of Epidemiological Research.
Dimakakou E, Johnston HJ, Streftaris G, Cherrie JW.
Alzheimer's disease and alpha-synuclein pathology in the olfactory bulbs of infants, children, teens and adults ≤ 40 years in Metropolitan Mexico City. APOE4 carriers at higher risk of suicide accelerate their olfactory bulb pathology.


Exposure to ambient fine particles and neuropsychiatric symptoms in cognitive disorder: A repeated measure analysis from the CREDOS (Clinical Research Center for Dementia of South Korea) study.

IFALPA Position on Cabin Fume Events
IFALPA represents the international community of air line pilots;
A Federation of nearly 100 National Associations
And over 100,000 Pilot Members
Driven by dedicated volunteers who seek to improve Aviation Safety
The Mission of IFALPA is to promote the highest level of aviation safety worldwide and to be the global advocate of the piloting profession; providing representation, services and support to both our members and the aviation industry.
IFALPA Position & Briefing Leaflet On Cabin Fumes

https://www.ifalpa.org/publications/library/cabin-fumes-2777

https://www.ifalpa.org/publications/library/cabin-fumes-2781
Fume Event – A Safety Issue

► A fume event may result in the incapacitation of crew members and jeopardize flight safety

► Immediate safety concerns resulting from an abnormal situation (fume events) should be differentiated from any potential short and long-term health effects

► Some of the consequences of such leaks are still subject to debate

► Various types of fumes may contaminate the air supply system
The airworthiness design standards FAR 25.831 (U.S.) and CS 25.831 (Europe) contain ventilation specifications.

- “Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapors.”

- However, clean air has not been adequately defined. This condition must be met at initial design certification as well as on an ongoing basis known as ‘continuing airworthiness’.

There are currently no required methods for air sampling after fume events. There is a lack of certification specifications for continued airworthiness once engines have been installed on the aircraft.

Detection systems are also required by FAA & EASA 25.1309(c),

- these requirements have never been enforced regarding bleed air
Crew Action

- Always follow the manufacturer’s and/or operator’s procedures.
- Don oxygen masks
- Establish communication
- Follow the associated emergency procedures
Reporting

- Effective and comprehensive reporting system is required
- A standardized reporting form (ICAO circular 344) is encouraged to be used
- Required reports:
  - mandatory reports, as required by the State of the Operator
  - aircraft technical log
  - smoke and fumes reporting form
Post Event Procedures

► review the in-flight incident including consultation with the flight and cabin crew as soon as practicable

► Determine whether any crewmember felt unwell, and/or whether their performance was adversely affected;

► Require any crewmember who felt unwell, or felt their performance was affected, not to operate as a member of the crew until they have been assessed as fit by a medical practitioner.
  
  ► The medical check should be done as soon as practicable after the fume event.

► Fill in required reports

► Follow the recommendations of your doctor, operator, and pilot association.
Medical Examination After A Fume Event

► So far no uniform protocol on medical checks after fume event have been established. Therefore, only general guidelines on what medical tests should be performed can be given.

► Follow your own operator’s procedure if operator has one.

► Additional tests may be performed as part of ongoing research.

► Some more specific volatile organic compounds tests are under development for fume events, but they are not yet in routine use.
Medical Examination

► Clinical history, physical examination, including neurological evaluation

► Laboratory tests, depending on the clinical situation, that may include, but are not limited to,

► O2-Saturation and arterial blood gas analysis (PaO2, PaCO2, Ph, HCO3-)

► Hemoglobin, methemoglobin, carboxyhemoglobin

► Blood-glucose, lactate, electrolytes

► In case of respiratory problems, spirometry, and lung diffusion capacity test

► Any additional tests deemed necessary by the treating doctor.
Training

- Basic and recurrent training on fume events
- Training according to ICAO Circular 344

A - Sources and types of on-board fumes

B - Odour descriptors to recognize the presence of oil and hydraulic fluid fumes

C – Potential for impairment

D – Procedures to apply during and after fume events

E – Reporting of fume Events
Long Term Health Effects

► Still unclear whether fume events cause long-term health effects
► Minimal seal leakage may occur even in normal operations
  ► This may explain why only some of the crew experience symptoms whilst others remain asymptomatic after a fume event. Those whose “cumulative dose” exceeds a certain threshold may experience symptoms.
  ► Genetic differences in metabolism may play a role in the cumulative effects
► IFALPA awaits further scientific evidence
Maintenance

► Post event maintenance should be carried out in accordance with the Trouble Shooting Manuals and Aircraft Maintenance Manuals (TSM/AMM).
  ► These contain appropriate actions regarding how to proceed after a fume event, including the cleaning of the air conditioning ducts when an oil leak has been identified.

► All maintenance actions shall be clearly documented and visible for the next operating crew.

► Avoid overfilling of engine and APU oil
New Technologies/ Solutions?

- Alternatives to bleed air systems
- Bleed air filtration
- Fume event detection/monitoring
- Reduced toxicity oils
- Separate checklists for fume events
Conclusions & IFALPA Position

- IFALPA is calling for better regulatory enforcement in relation to bleed air contamination.
- Effective and comprehensive reporting of fume events is paramount.
- A comprehensive and uniform medical assessment protocol after a fume event should be developed and implemented.
- Crews should be given basic and recurrent training on fume events.
- More medical/scientific research and results are needed on the long-term health effects of fume events along with clinical and epidemiological correlation.
- IFALPA advocates bleed air free design as an ultimate solution. Meanwhile, filters and detection systems should be improved and installed.
Thank you