# BLEEDLESS ENGINE TECHNOLOGY – A CLEAN AIR SOLUTION

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Global Cabin Air Quality Executive

DR SUSAN MICHAELIS, PHD, ATPL

## ELECTRIC & HYBRID AEROSPACE TECHNOLOGY SYMPOSIUM BREMEN 17 & 18 NOVEMBER 2015

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# PRESSURISATION
## What do these columns have in common?

| ? | ? |
|---|---|
| Stratocruiser | Caravelle |
| Constellation | B727, B737 |
| Comet | A300 |
| Convair880/990 | F28, F100… |
| DC8 | ERJ 135…, E-170… |
| VC10 | BAe 146/RJ |
| B707 + B787 (Dreamliner) | A350, A380 |

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# PRESSURISATION
## What do these columns have in common?

| Bleed free | Bleed air |
|---|---|
| Stratocruiser | Caravelle |
| Constellation | B727, B737 → |
| Comet | A300 → |
| Convair880/990 | F28, F100… → |
| DC8 | ERJ 135…, E-170… → |
| VC10 (1962) ↓ | BAe 146/RJ → |
| B787 – Dreamliner (2008) | A350, A380 |

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# Cabin Blower - AiResearch - Garrett



Boeing B-29 Superfortress

First Flew: 1942

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# 1954 – Dash 80 (Boeing 707)


Turbo compressors

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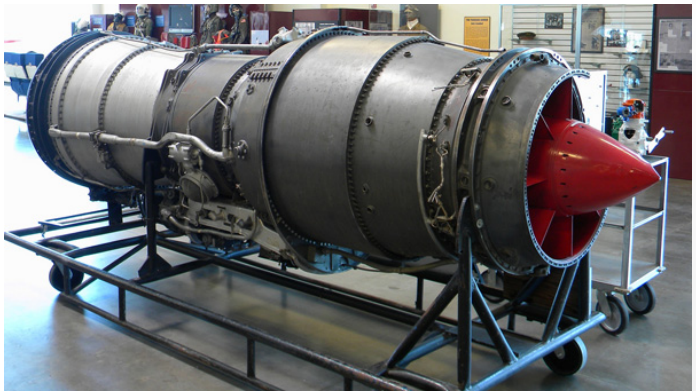
# 1952/53 – J57 Engine


B-52 and the F-100 – Bleed Air


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

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



# 15 January 1954

- Engine Compressor Bleed Air Contamination Study - XC-132 Project - R.W. Maddock – Douglas
- J-57 & T-57 engine contamination problems.
- The paper states the problem was first reported in the flight-testing of the B-52 in 1952.
- “Apparently the occurrence is completely erratic, with no predictable pattern since contamination has occurred at all modes of airplane operation, such as take-off, high altitude cruise, descent and taxi. So far there is no known condition or sequence of conditions, which will reliably reproduce the trouble.”

# 15 May 1954

*"At approximately 1530 hours on 15 May 1954, I was flying aircraft number 52-1436, an RB-57A, in a three (3) plane formation from Shaw Air Force Base, South Carolina. Approximately 40 minutes after take-off while flying over an overcast at 7000 feet, I experienced blurred vision, became nauseated and experienced considerable dizziness. I recall no strange or unpleasant odors, nor did I taste anything out of the ordinary. I did feel a definite dryness of mouth and throat.*
*This condition lasted possibly a minute or two. As I became more aware of the situation or nearly to the passing out point I recall dropping back from the formation and opening the clear vision window and unhooking the oxygen mask. Fresh air from this open window seemed to relieve the unpleasant conditions I felt."*

**WILLIAM J. VAN EVERY**
**1st Lt, USAF**

Loomis, TA and Krop, S. (1955) "Cabin air contamination in RB-57A aircraft - Medical Laboratories Special Report. No. 61," Publication Control No. 5031-61, Chemical Corps. Medical Laboratories, Army Medical Center, Maryland. 1955.

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# October 1955

**Elimination of Engine Bleed Air Contamination**

Henry A. Redall – North American Aviation

Aware of oil contamination issue for last two years – suspect compressor bearing seals main source – different aircraft with basically the same engine have contradicting reports – in-depth look at filter options.

Solutions: "The Separate Compressor As A Solution – This method of eliminating contamination is considered to be the most positive… also the heaviest, most complicated and most expensive."

The contamination in our present airplanes is not toxic.

Dr George Kitzes of the United States Air Force Aero Medical Laboratory been studying the problem since it first presented itself.

# 27 May 1955 - Caravelle (1st Flight)


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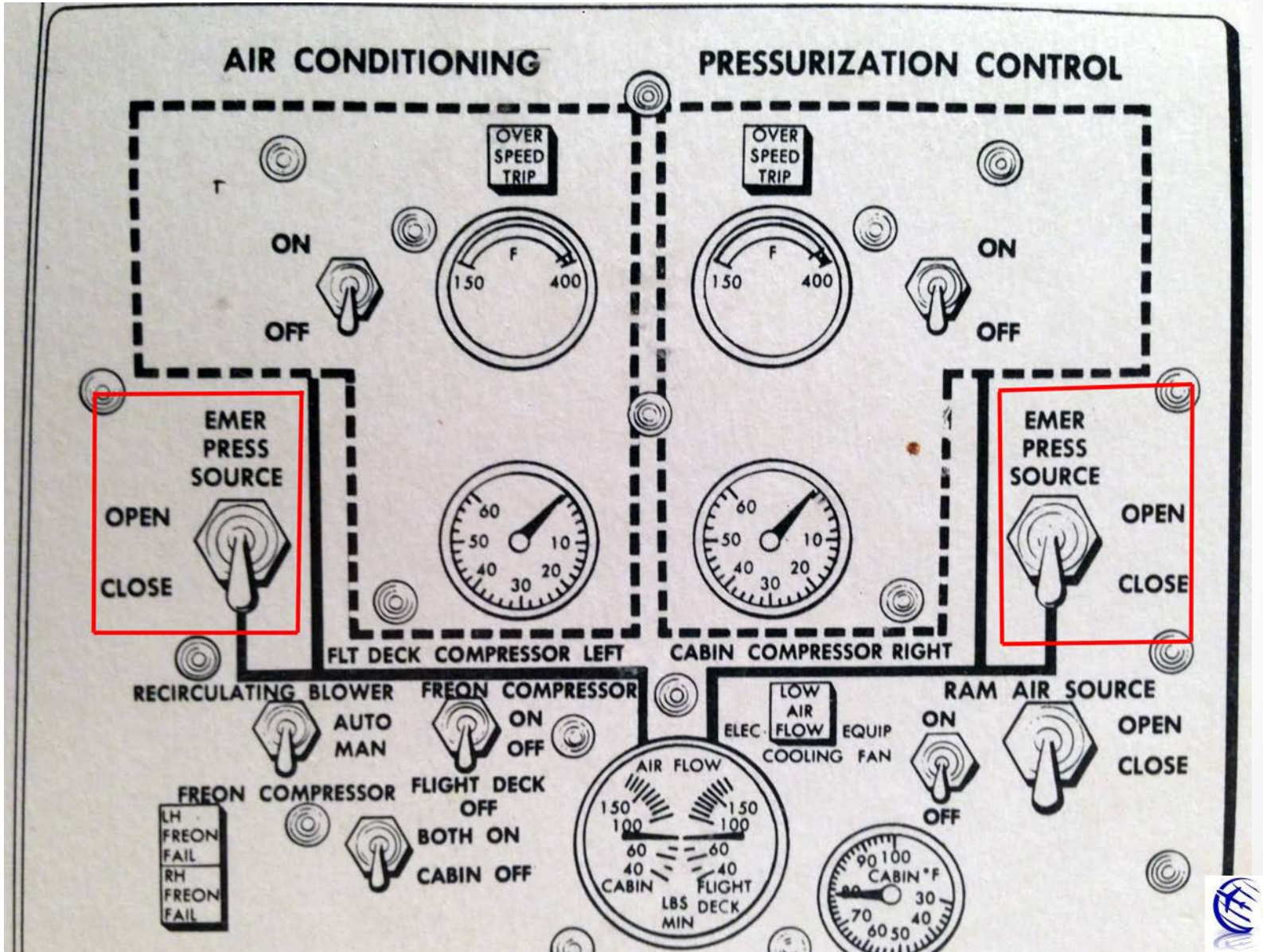
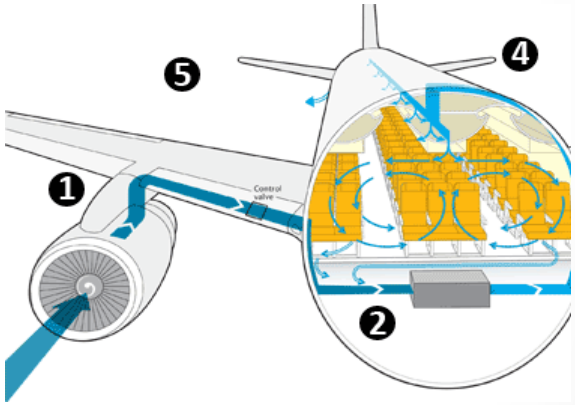
# 1959 - CV 880 – Cabin Compressors



# Chain of events

- SYNTHETIC JET OILS


- BLEED AIR TO SUPPLY BREATHING AIR




- REPORTS

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# YOU HAVE THE REAL SOLUTION

- **MEA (More electric aircraft)**

ENVIRONMENT MICHAEL GUBISCH TOULOUSE

## EU project trials a breath of fresh air

Clean Sky initiative plans bleedless air-conditioning system test on Airbus A320 as part of future narrowbody research

Researchers are planning to flight test bleedless air-conditioning and wing anti-ice demonstrator systems under the EU's Clean Sky environmental initiative in 2015.

The objective is to assess nascent technology for new-generation single-aisle aircraft that could enter service beyond 2020, says Nicolas Bonleux, executive vice-president sales and marketing for Liebherr-Aerospace, the demonstrator equipment supplier.

Airbus opted for a bleed air-based cabin air system on the re-engined A320neo, which is due to enter service in 2015. However, some components will be electrically actuated.

Liebherr is testing an all-electric air-conditioning pack for narrowbody aircraft at its facility in Toulouse, its base for air-management systems manufacturing and its aerospace division.

Bonleux says Liebherr has worked on all-electric cabin air systems for over 10 years and developed demonstrator equipment for the last five.

The manufacturer displayed a turbo compressor at the Farnborough air show in 2012, which would be required on bleedless aircraft to generate pressurised air for the cabin.

The demonstrator systems are likely to be tested on a DLR aircraft

The major challenge for the bleedless architecture is meeting increased demand for electrical power and managing energy consumption across aircraft systems, says Bonleux.

In addition, the test aircraft will be equipped with several different wing ice-protection systems, says Clean Sky, a joint venture between the EU and regional aerospace industry.

It is undecided whether the tests will be conducted on an Airbus-owned A320 or an aircraft provided by programme partners, such as German aerospace research centre DLR, says Clean Sky.

Clean Sky has a number of different work streams designed to deliver breakthrough technologies that reduce aviation's environmental impact. ■

Also Current fleet- Detection systems & Bleed filtration

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# SOLUTION- MEA
# - AVOIDS

- COMPRESSED AIR SUPPLIED TO CABIN AS BREATHING AIR
- SYNTHETIC JET ENGINE OILS
- HAZARDOUS SUBSTANCED INHALED
- EXPOSURES
- FLIGHT SAFETY RISKS
- OIL FUME REPORTS IN CABIN
- REGULATION COMPLIANCE
- ADVERSE HEALTH EFFECTS
- SCIENCE SUPPORTING ADVERSE EFFECTS
- LEGAL CASES
- INTERNATIONAL ACTIONS

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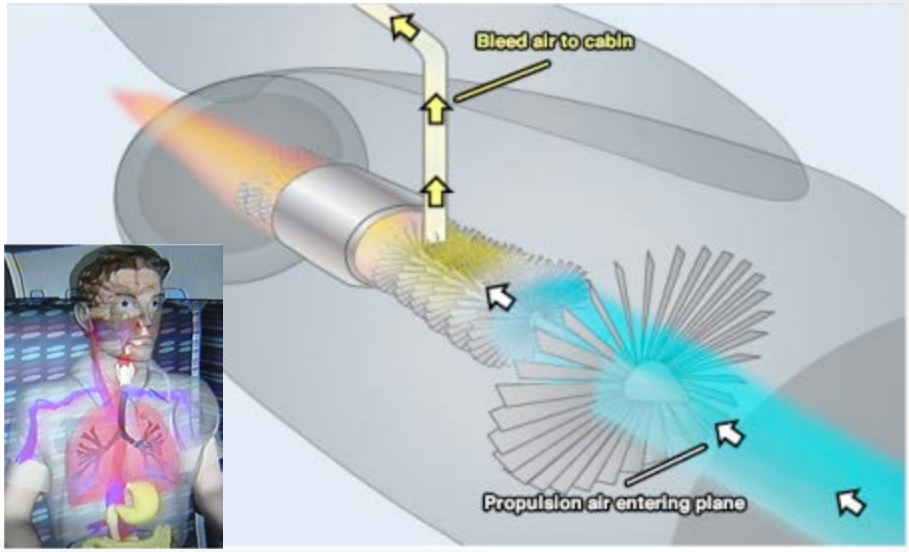
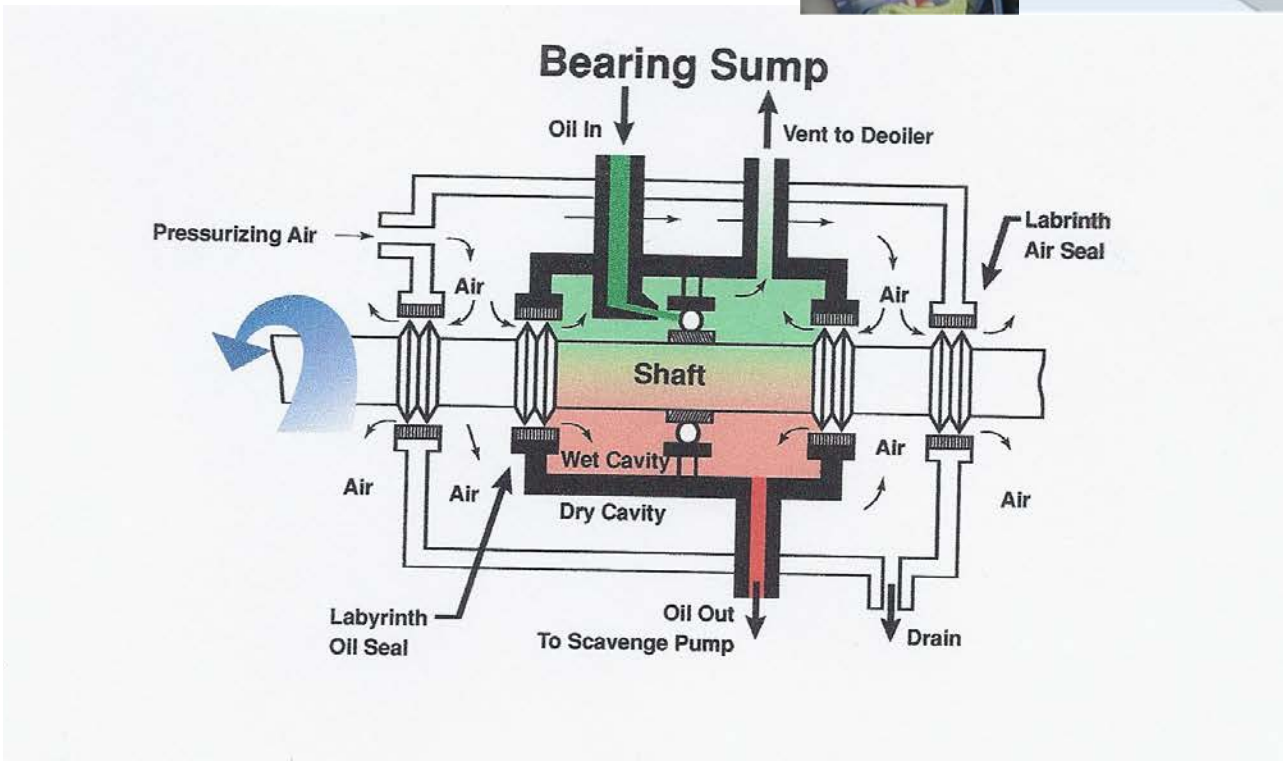
# MEA AVOIDS
## BLEED AIR for cabin





Low level oil leaks as a function of design/operation using bleed air system

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# MEA AVOIDS
# JET ENGINE OILS in cabin air


- Heated synthetic jet engine oils leak into air supply
- Hydraulic & deicing fluids can leak into air supply
- Substances are hazardous & toxic
- E.g: oil contains:
  - Polyol ester base stock (95% of oil) - pyrolysis
  - Organophosphates (OP) – Tricresyl phosphate/Triaryl phosphates – antiwear additives – Known neurotoxins; irritants/sensitization, impair fertility
  - Amines – PAN…. - antioxidants – Irritant/sensitization
  - **Wide range of pyrolysis/decomposition products**

Usually fumes & not visible/ transient/less obvious

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# MEA AVOIDS

# EU/UN HAZARD CLASSIFICATIONS (CLP) – Harmonized & NOTIFIED

**Substances - hazardous under REACH/CLP Regulations**

**Oil , hydraulic, deicing fluids:**

| | |
|---|---|
| ✈ Harmful if swallowed/dermal: | ✈ Eye/skin irritant & ? Respiratory irritant |
| ✈ May (suspected) cause damage fertility or harm the unborn child | ✈ Skin sensitizer |
| ✈ Single exposure & repeated target organ toxicity - nervous system | ✈ Very toxic by inhalation |
| ✈ May cause genetic defects | ✈ May cause allergy/asthma or breathing difficulties if inhaled |
| ✈ May (Suspected) of causing cancer | ✈ May cause drowsiness or dizziness |

TXP – Substance of Very High Concern (SVHC) – REACH

**May cause harm to the unborn/Impair fertility**

# MEA AVOIDS

# EFFECTS – HSDB, ICSC..... (TCPexample)

## TCP- Acute

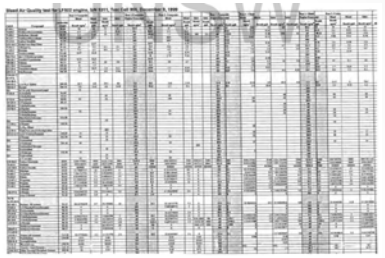
- Irritant of skin, eyes & mucous membranes, respiratory tract
- Gastrointestinal upset – nausea, vomiting…
- Numbness, headache, vertigo,
- paresthesias (tingling) of hands & feet, limbs)
- attack on the peripheral nerves, pyramidal tract
- Cramps, decrease in strength in arms & legs
- Visual disturbances
- Hyperhydrosis (excessive sweating)
- Hypotension
- General fatigue, irritability
- Effects on CNS,PNS

## PAN - Acute

- Blue: lips, fingernails, skin
- Confusion, dizziness, headache , nausea
- Effects on blood- methaemoglobin
- …

# MEA AVOIDS

## EXPOSURES OCCURRING!

TCP & isomers being found in normal flight regularly – 18% - 95% of samples
TXP, TBP etc. also found routinely

# MEA AVOIDS

## REGULATIONS NOT BEING MET

- 25.831 a/b – Ventilation
- CS-E 510 & CS-APU 210 – safety analysis
  - Impairment - $<10^{-5}$ – Toxic products /degrade crew performance
  - Incapacitation - $<10^{-7}$ – Toxic products (leaking oil) cause incapacitation
- CS-E 690 – Bleed air purity testing
- CS-APU 320 –Bleed air contamination
- CS 1309C – warning indication
- AMC 21A.3B 9B - Unsafe condition
- Continuing Airworthiness - **Reg (EC) No 2042/2003**
- **Mandatory reporting -** Regulation (EU) No 376/2014

**OHS Regulations – REACH / CLP Dir** 89/391/EEC …….

**EASA– Not aware of any accidents –** A-NPA (A-NPA) 2009-10 (2011)

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# MEA AVOIDS
# FLIGHT SAFETY RISKS

- **IFALPA/ECA** - When a fume event occurs, cabin air contamination can cause short-term physical effects which compromise flight safety;
- **AAIB** - Crew impairment occurs due to leaking oil and contamination of the air supply; Detection systems required
- **SAE** - Oil fumes can contaminate the air supply with flight safety concerns
- **ExxonMobil** - Signs: Exposure to oil fumes may cause irritation characterized by tears, redness, burning sensation (eyes), redness, swelling or cracking of skin, or burning sensation in the nose, throat and lungs (inhalation).Neurotoxicity may be characterized by dizziness, headache, confusion and intoxication

- **MANY OTHERS**

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# MEA AVOIDS
# REPORTS OF OIL FUMES IN CABIN

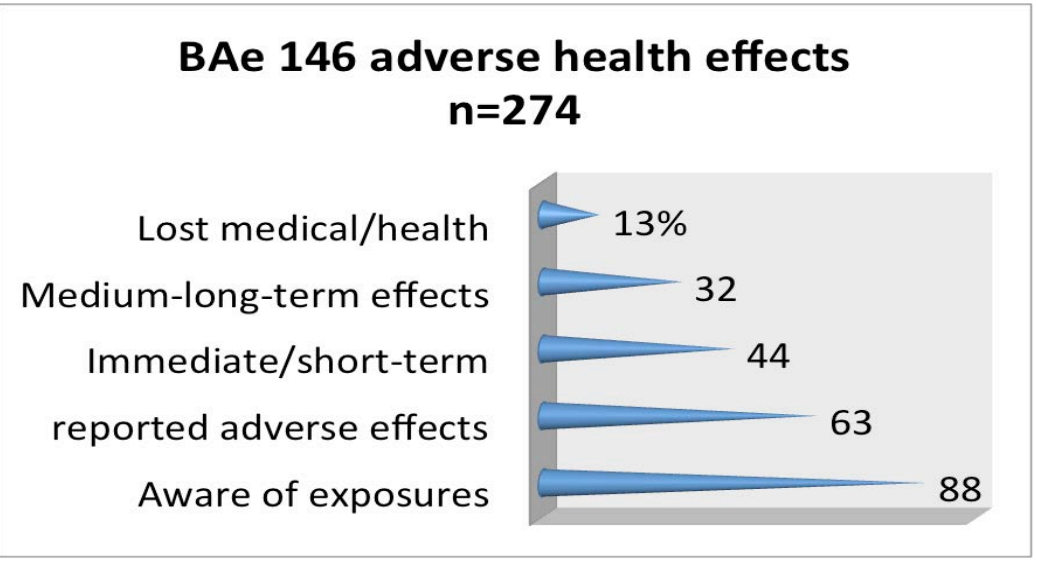
- Records incomplete/ under-reporting is very common;
- Events are NOT rare;
- 32% of contaminated air events; involved crew impairment;
- Oxygen rarely used;
- Airline: Oil fumes reported in 1% of flights at major UK airline;

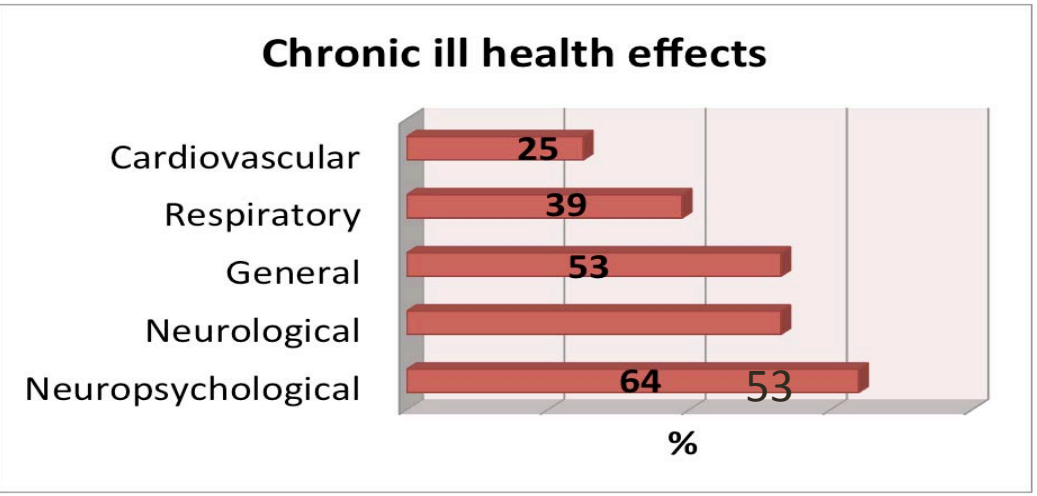
Engineering is often not finding source of fumes with aircraft dispatched with repeat events

Design & operation of oil seal system explains frequency

# MEA AVOIDS
# HEALTH EFFECTS

Chronic ill health
37- 433%
above controls




Aircrew/passengers are reporting: Chronic neurological, respiratory disease consistent with exposure to jet engine oils including OPs

Cancers: Higher than population averages

**Aerotoxic Syndrome** is a valid term

- causative relationship exists
- Published literature -✔

Michaelis S (2010) PhD - Health and Flight Safety Implications from Exposure to Contaminated Air in Aircraft'.

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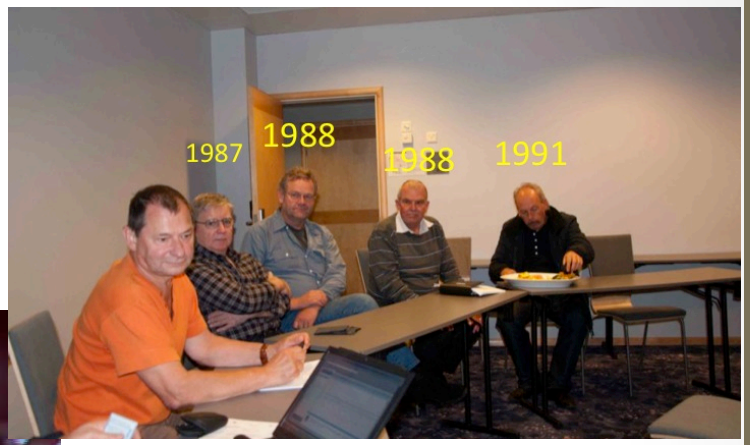
# The people.....



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# MEA AVOIDS
# LEGAL CASES

Court made plane sense with payout for hostie Joanne Turner

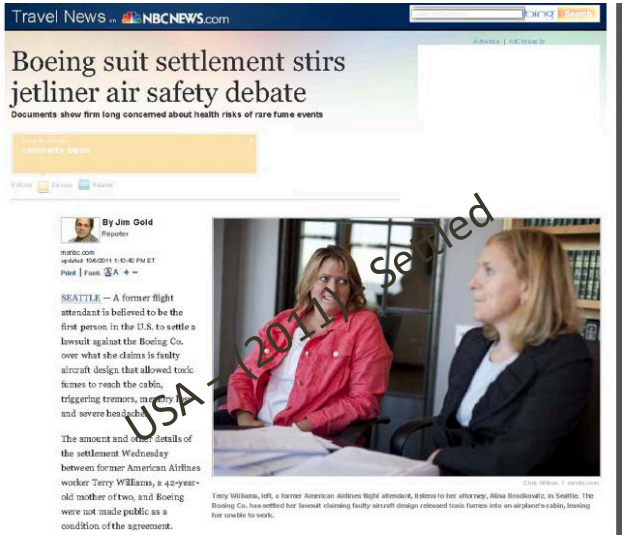
Save this story to read later

BY LISA DAVIES
The Daily Telegraph
Apr 02, 2010
12:00AM

A FORMER Ansett flight attendant will collect almost $140,000 after an historic win in which a court agreed she was dangerously exposed to toxic fumes on a plane almost 10 years ago.

Mother-of-two Joanne Turner was awarded $138,757 by the Dust Diseases Tribunal last year after a decade-long legal battle over

High Court of Australia (2010) WIN



Travel News on NBCNEWS.com

Boeing suit settlement stirs jetliner air safety debate

Documents show firm long concerned about health risks of rare fume events

By Jim Gold
Reporter

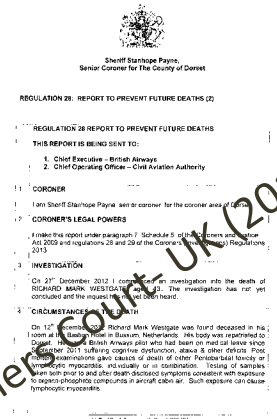
msnbc.com
updated 10/6/2011 1:10:40 PM ET

SEATTLE — A former flight attendant is believed to be the first person in the U.S. to settle a lawsuit against the Boeing Co. over what she claims is faulty aircraft design that allowed toxic fumes to reach the cabin, triggering tremors, memory loss and severe headaches.

The amount and other details of the settlement Wednesday between former American Airlines worker Terry Williams, a 42-year-old mother of two, and Boeing were not made public as a condition of the agreement.

Terry Williams, left, a former American Airlines flight attendant, listens to her attorney, Alisa Brodkowitz, in Seattle. The Boeing Co. has settled her lawsuit claiming faulty aircraft design released toxic fumes into an airplane's cabin, leaving her unable to work.

USA – (2011) settled



Sheriff Stanhope Payne,
Senior Coroner for The County of Dorset

REGULATION 28: REPORT TO PREVENT FUTURE DEATHS (2)

REGULATION 28 REPORT TO PREVENT FUTURE DEATHS

THIS REPORT IS BEING SENT TO:

1. Chief Executive – British Airways
2. Chief Operating Officer – Civil Aviation Authority

CORONER

I am Sheriff Stanhope Payne, senior coroner for the coroner area of Dorset.

CORONER'S LEGAL POWERS

I make this report under paragraph 7, Schedule 5 of the Coroners and Justice Act 2009 and regulations 28 and 29 of the Coroners (Investigations) Regulations 2013.

INVESTIGATION

On 27th December 2012 I commenced an investigation into the death of RICHARD MARK WESTGATE (aged 52). The investigation has not yet concluded and the inquest has not yet been heard.

CIRCUMSTANCES OF THE DEATH

On 12th December 2012 Richard Mark Westgate was found deceased in his room at the Bastion Hotel in Bussum, Netherlands. His body was repatriated to Dorset. He was a British Airways pilot who had been on medical leave since October 2011 suffering cognitive dysfunction, ataxia & other deficits. Post mortem examinations gave causes of death of either Pontobarbital toxicity or lymphocytic myocarditis, individually or in combination. Testing of samples taken both prior to and after death disclosed symptoms consistent with exposure to organo-phosphate compounds in aircraft cabin air. Such exposure can cause lymphocytic myocarditis.

Coroner's Court – UK (2015) x 2

**OTHERS** globally

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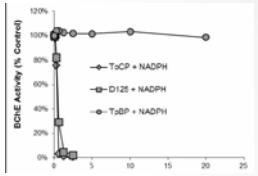
# MEA AVOIDS -
# SCIENCE SUPPORTING EXPOSURE




**Treon 1954 (USAF)** American Industrial Hygiene Association Quarterly. 16: 3, 187-195, 1955 (USAF)

-Toxicity arises from thermal decomposition of oil base stock (95% of oil)

-Oils heated to high temps very much more toxic than at lower temps causing pneumonitis, degenerative changes to liver, brain & kidneys

**Furlong (2012) University Washington** Chemico-Biological Interactions 2012

-TCP formulation (DURAD 125) bioactivates in liver into enzyme inhibitors almost like TOCP that paralysed 50,000 in prohibition

-Other triaryl phosphate isomers (including TPCP) adversely affect normal physiological processes

**Abou-Donia (2013) Duke Univ** J of Toxicology and Environmental Health, Part A, 2013

-Chronic exposure results in neurodegeneration below threshold where neurologic deficits occur.

-Temporal association between exposure and biologic damage

**Hausherr (2014)** Toxicological Sciences

-Low level Exposure to TOCP causes functional neurotoxicity – other isomers being reviewed

**Kojima (2014)** Toxicology

-OPs in oils & hydraulic fluids are endocrine disruptors

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# MEA AVOIDS
# More International Actions

Current

- CEN (European standards) to develop cabin air quality standard
- EASA – Issued new cabin air monitoring study
- EASA – Issued new oil pyrolysis study
- REACH – Undertaking review
- Future Sky – mitigating risk of fire, smoke, fumes
- Bleed free systems being tested-
- SAE – Cabin air related recommended practices being reviewed
- ICAO - oil fumes training/education program –Completed

2000-2014 – over 100 inquiries, standards, regulatory reviews, laws & research projects in 3 continents

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# IN SUMMARY

- Use of engine compressor for heating and pressurisation air started towards end of WW2.
- Complaints of contaminated Bleed Air date back to 1952 with the introduction of 1st generation of synthetic jet engine oils.
- French Caravelle probably forced US to respond.
- Reports increase with arrival of BAe 146 in 1981 and smoking ban on aircraft in late 80s early 90s.
- Boeing 787 only modern bleed free aircraft today.

- YOU HAVE THE WAY FORWARD
- CREW UNIONS & PASSENGERS SUPPORT YOU

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