

AIRCRAFT AIR SUPPLY CONTAMINATION

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SUMMARY AND RECOMMENDATIONS

IFALPA POLICY RECOMMENDATIONS

The aviation industry recognises that the problem of air supply contamination occurs, through service bulletins, defect statistics reports and other sources. IFALPA is concerned that the rates of occurrence of incidents are higher than the aviation industry admits, and for some models of plane are significant. IFALPA supports full reporting and follow up investigations in accordance with all Regulatory requirements as well as medical investigations for those exposed.

As indicated by manufacturer information and industry documentation, materials used in aviation such as jet oils and hydraulic fluids are hazardous and contain toxic ingredients. If such fluids leak into the cabin, toxic exposures are possible. IFALPA is concerned about such exposure events, and supports industry, Government and inter Government initiatives to reduce such incidents.

IFALPA regards the presence of symptoms commonly associated with exposure to airborne contaminants in crew and passengers as a flight safety and health issue.

Corrective actions regarding air supply contamination involving design, operational and maintenance procedures are few, with there being a clear need to review all aspects so as to reduce the intensity and frequency of future exposures.

IFALPA is also concerned that the health implications both short and long-term, following exposure to contaminants being reported by crew and passengers must be properly addressed.

For the reasons above, IFALPA policy recommendations are:

- All aircraft air supply contamination occurrences to be regarded as flight safety & health issue
- All aircraft air supply contamination occurrences to be seen as aircraft defect with all regulatory requirements to be adhered to including: defect report & occurrence Incident report
- All aircraft air supply contamination occurrences involving smoke and or fumes require the use of the emergency/abnormal checklist for smoke or fire & the crew to don oxygen masks at 100%
- Adoption of specific in flight fume/odour occurrence report listing crew effects, aircraft defect and log number, linked to ongoing health examinations
- IFALPA to urge National Regulatory Authorities to review all aspects of air contamination by oil lubricants and hydraulics and applicable Regulations and subsequent actions to ensure all are met
- IFALPA urges that suitable research is to be undertaken investigating: exposure to all air supply contaminants during abnormal oil/ hydraulic and other fluid leakages in aircraft environment, with multiple acute and long term low dose exposures, occupational health and safety aspects on short and long-term basis, medical testing to be undertaken.
- Precaution & prevention principle to be considered for air supply contamination
- IFALPA urges Regulator's to work with industry to reduce the occurrence of exposure events
- IFALPA is urged to provide member organisations with overview of exposure to air supply abnormal leakages.

AIRCRAFT AIR SUPPLY CONTAMINATION

Introduction

Aircraft materials such as oil lubricants and hydraulic and de icing fluids while usually retained in the engines and equipment to which they have been added, sometimes find their way into cabin air supply through abnormal events such as oil leaks, seal and bearing failures as well as fluid ingestion by engines and APU's. Crew and passenger exposure to such events via the aircraft bleed air supply as evidenced from defect, incident and fume reports is a growing concern and medical concern for crews and passengers.

This paper aims to raise the awareness of some of the issues surrounding these abnormal aircraft contamination events with the objective of developing strategies to be undertaken by IFALPA and industry.

Issues with regard to incidents of contamination of Cabin air

While concerns of the toxicity risks of cabin air contamination by hydraulics and lubricants extend back to at least 1953,¹ actual reports of crew inhalation exposure to synthetic lubricating oil go back to at least 1977.²

While reporting of fume exposure incidents is mandatory under defect and incident reporting systems there is evidence that these are not being utilised as required with little intervention from aviation regulators. The Australian Senate Inquiry into cabin air quality noted "... strong evidence of a tendency of pilots to under-report incidents".³ Additionally it can be seen that there are strong discrepancies in the number of fume/ odour reports acknowledged by the regulatory authorities as well as those reports being passed from the operator to the Regulator.

Appendix 1 lists some of the known fume and or smoke incidents/events and crew issues related to oil, hydraulic and other aircraft fluid contaminants from the following sources:

- CAA - Civil Aviation Authority, UK MOR (Mandatory Occurrence Reports) and general information provided
- CASA - Civil Aviation Safety Authority, Australia
- International Air Safety Investigators Bureaus
- Australian BAe 146 aircraft technical log defects - mandatory
- Australian BAe 146 odour Occurrence reports - discretionary
- AFA - American Flight Attendant Association - fume occurrence reports - discretionary
- International research
- Union surveys
- Industry documentation - service bulletins, service Information leaflets, engineering releases etc.
- Military reports
- Pilot medical certificates
- Air crew public submissions to Inquiries into aircraft cabin air quality

While the UK CAA has advised that air contamination from smoke or gas leaking into aircraft cabin air is rare at approximately one event per 22,000 flights (128 incidents out of 2.85million flights in 10 years to 1999), the DTLR recently advised that smoke/odours/fumes reports on UK aircraft numbered 81 in 1996 and rose to 156 in 1999 and 124 reports to November 2000.⁴ The CAA Mandatory Occurrence reports list 50 reports of smoke and fumes related to aircraft contaminants from 1989 to mid 2001 for the

BAe 146 and 31 such reports for the B757 from 1997 to 2001. These types of inconsistencies are common in this data.

CASA lists 20 defect reports on its web site related to smoke and/or fume contamination and related issues for the BAe 146 from 1996 to 2001.⁵ The Australian Transport Safety Bureau lists 18 incidents of oil fumes for the BAe 146 from 1991 to 2001 with a total of 35 oil fume incidents on jet aircraft in the same period.^{3,6} During the same period, Ansett Australia acknowledged (mandatory) aircraft technical log defect reports of fume-odour occurrences every 66 flights BAe 146 flights in 1992 (418 reports), decreasing to one in every 131 flights in 1999 to June 30 (168 reports),⁷ based on a fleet of 13 aircraft.³ At the same time there were over 700 BAe 146 discretionary odour occurrence reports from 1991-2000.³

The number of reports received by the Regulators and Aviation Safety Investigation Bureaus appears to be increasing, which may in part be due to increased awareness of the requirement to report fume and odour occurrences from the cabin air supply.

While the ATSB took two years to produce the occurrence report on a 1997 BAe 146 incident,⁸ the Swedish Investigation Board and UK AAIB still have not produced reports into serious BAe 146 incidents in November, 1999 and November 2000 respectively.

Another very important source of information indicating the existence of the problem is industry supplied service bulletins, service information letters and engineering releases. While this information has not been readily available and was not supplied to the recent Australian Senate Inquiry looking specifically at the issue of air quality issue of the BAe 146 aircraft, it demonstrates that bleed air contamination and oil leaking into the air supply and related issues has been an issue since at least 1984, continuing through to 2001. This information may be available from the aircraft, engine and APU manufacturer and should cover ATA sections including ATA 21, 36, 49, 53, 71, 72, 75 and 79.

Additionally, there is a considerable amount of data available from independent research as well as union surveys reporting crew health problems associated with aircraft air contamination. This data has been available since at least 1983 with a growing number of more recent surveys showing very similar symptoms.

Based on various sources, it is estimated that at least eighteen pilots in four counties have either lost their medical certificates, had long-term time off work or are currently off work with problems connected to air contamination. Publicly available information is difficult to collect; many affected individuals are reluctant to provide information and maybe unaware where to provide such information six pilots and six flight attendants are publicly referenced in the Australian inquiry into air quality on the BAe 146 regarding health effects experienced. In one case all three flight attendants off a 1994 BAe 146 flight resigned due to illness.³

Issues with regard to air supply contamination

While oil lubricants, hydraulic fluids, de-icing fluids and jet fuel should be retained in the engines and equipment to which they have been added, they are known to find their way into the aircraft cabin air supply where crew and passengers are located. Exposures may be either short-term intense or long-term low level.

Sources of exposures include:⁹

- Ingestion of exhaust from other aircraft or recirculation from the aircraft itself on ground
- Hydraulic fluid leaks can introduce contamination into APU inlet in certain aircraft
- Excessive use of lubricants
- Oil and hydraulic fluid ingestion

- Internal contamination by synthetic lubricating oil- during use of engines/APU
- Contamination downstream of source of oil leaks –residual contamination
- Pack burns
- Engine combustion products

Other information indicates further sources of exposure

- Leaking oil seals associated with bearings of jet engines^{10 11, 12, 13}
- Exposure to thermally degraded oil and it's by-products¹⁴
- Exposure to engine components such as seals/bearings that have worn down into respirable particles containing toxic elements such as nickel, beryllium and copper entering bleed air.¹⁴

Some industry recognition of the sources go back many years and include the some of the following sources shown in Appendix 2.

Issues regarding toxicity of aircraft materials

The aviation industry has a specific need for specialised materials. These can be hazardous. Appendix 3 covers these issues in more detail, but covers:

- oils and hydraulic fluids used in airplane engines are toxic, and specific ingredients of oils are irritating, sensitising, neurotoxic and carcinogenic.¹⁴
- Information provided by oil manufacturers to airplane manufacturers understates the toxicity of their oil products, and this has been accepted uncritically by airplane manufacturers and airline operators and is used by them in a manner that understates risk.
- Specifically, publicly available information on the ingredients of the widely used synthetic commercial engine oil Mobil Jet Oil II:
 - discloses hazard information on one neurotoxic isomer of tricresyl phosphate (TOCP);
 - does not disclose information on the other five neurotoxic isomers, which are up to ten times more toxic and present in concentrations thousands of times higher than TOCP;
 - identifies the ingredient Phenyl-alpha-naphthylamine without disclosing it is a sensitiser.
- If oil leaks out of engines, this contamination may be in the form of unchanged oil, degraded oil from long use in the engine, combusted oil or pyrolised oil. If hydraulic fluids leak from where they are contained, this contamination may be in the form of unchanged fluid or degraded fluid from long use in the aircraft.¹⁵ This contamination may be in the form of gases, vapours, mists and particulate matter.
- Prominent components of the types of contaminants reaching the cabin include: carbon monoxide, volatile organic compounds, organophosphate compounds, toxic combustion and pyrolysis products, and so forth. A number of these are associated with neurological and neuropsychological symptoms of toxicity.¹⁶
- Contrary to attitudes in the aviation industry, a leak of an aviation fluid into a passenger cabin is not a “normal condition”. It should be regarded as an abnormal condition¹⁷, and treated accordingly.
- All studies that have been carried out to measure atmospheric contamination in airplanes by engine oil leaks or hydraulic fluids are sufficiently flawed on methodological inadequacies to render their conclusions invalid.¹⁸

- If oils leak out of engines or hydraulic fluid is ingested into bleed air and is passed to the flight deck and passenger cabin, exposed crew and passengers do not have access to appropriate information that can advise them as to hazard, risk or control of exposure. Additionally exposure may occur to contaminants that can affect crew and passenger health and safety.¹⁹
- The use of exposure standards such as threshold limit values to conclude that exposures are acceptable is inapplicable in certain situations in the aviation industry. TLVs should not be applied at altitude,²⁰ or in situations where the possibility of escape to fresh air is lacking.²¹ Acceptability criteria for chemical exposures at altitude must consider the interaction of reduced oxygen, skin exposure to mists, and interactions with other contaminant exposures.^{20,21}
- The design and operation of an aircraft ventilation system is much more complex than for a ground based system due to the need to control air pressure in the cabin.²²

Issues regarding health problems

- **Symptoms:** A full list of signs and symptoms is shown in Appendix 4.^{23, 24}
 - Symptoms from single or short-term exposure include symptoms of: irritation of eyes, nose and upper airways, neurotoxicity, neurobehavioural, gastrointestinal, respiratory and cardiovascular.
 - Symptoms of long-term exposure or residual symptoms of exposure events include all the symptoms noted in short-term exposures as well as skin problems, hair loss, immunosuppression, chemical sensitivity, general symptoms of fatigue, exhaustion, muscle weakness and pain. Some symptoms occur immediately or soon after exposure including some of the irritant, gastric, nervous and respiratory effects, while others such as nervous system impairment, immunosuppression and chemical sensitivity can develop months after exposure has ceased.
 - Short term transient effects can become long-term if exposure is sustained.
 - Crew are exposed more frequently than passengers and consideration must be given to cumulative and chronic exposures⁹
 - Symptoms of exposure reported by crew appear consistent with the toxicity of some of the ingredients of the oils- including hydrocarbon neurotoxicity from exposure to organic chemicals, sensitivity from exposure to a sensitizer, COPIND from organophosphate exposure, or long-term low level toxicity from carbon monoxide exposure.^{10,14}
 - Symptom severity may depend –
 - on contaminants present
 - intensity, duration and frequency of exposure
 - toxicity of compounds (influenced by humidity, decreased oxygen concentration and contaminants such as carbon monoxide)
 - individual susceptibility (including genetic and immunological factors)
 - Clinical testing was rarely undertaken on flight crew immediately after exposure to fumes.³ When such testing was provided, it was inadequate, inappropriate or limited, for example, it may have been masked by in flight oxygen treatment, or carried out too late in an absence of baseline testing, or after half-life data indicated that contaminants had been excreted. It became apparent that specific tests to assess exposure or effects were not necessarily available or used.

- Appropriate testing needs to be determined based upon current information and full range of exposure contaminants, without industry or corporate affiliation bias²⁵

- **Separation of aviation safety from occupational health**

- The aviation industry has gone to great lengths to state that cabin air contamination from oil and hydraulics is purely an OHS issue and absolutely not a safety issue.

“...there is absolutely no doubt in our mind that there is a general health issue here. The number of people who have symptoms indicates that there is a general issue... it is very clear that there is an issue that needs to be addressed. Our assertion is that it is a health and safety issue, it is not a safety issue”¹¹

“I think it is fairly clear that we are not in a position as the Civil Aviation Safety Authority, to recognise there is a significant aviation safety authority issue here, but we do recognise and have had concerns from the outset about other issues, particularly health issues”²⁶

“... potentially two issues... immediate safety of flight issue....the second issue is the general quality of air issue which tends to be a long-term occupational health and safety matter.”²⁷

- Separation of health and safety is an outmoded concept.²⁸ The Australian senate Inquiry took the view that numerous regulations required crew to be in a fit state for flight and therefore acknowledged the regulatory link between crew health and air safety.³
- OHS issue accepted/safety denied
- In one case the connection between health and safety was acknowledged by an airline operator as well as denied

“...oil fumes are detected in minute quantities by the human nose and short-term effects while medically not harmful can cause irritation of the nose, throat, eyes and can cause headaches. These effects can be very distracting and in some circumstances cause a flight safety hazard”²⁹

“...it appears that the issue of air quality....is... a public health issue rather than an aviation safety matter”³⁰

- Safety aspects have been partly denied due use of oxygen in emergency checklists and isolation of the contaminated air system. This does not take into account that most checklists cover the use of oxygen only in cases of smoke rather than smoke and/or fumes, crews may not realise intoxication is occurring, downstream contamination may have already occurred, and full identification of source may not always occur.

When an oil leak occurs from an engine or APU is repaired, the system downstream must also be thoroughly cleaned to eliminate unintentional introduction of contaminants into the cabin...There is no effective way to adequately clean bleed ducts in situ once they have become contaminated with oil breakdown products. Adequate cleaning requires removal of ductwork to wash out oil products.⁹

“What engine is it coming from, what pack is it coming from? There was no way of telling because there was no way to isolate it.....”¹²

- **Short-term symptoms accepted**

- In 1998, Ansett Australia convened panel of “experts” to look at the air quality issue. The panel (and therefore, Ansett) accepted that
 - certain short-term symptoms sometimes associated with BAe 146 odours are substantiated,^{3, 31, 32} for example, irritation of the upper airway mucous membranes headaches, nausea, lethargy, minor shortness of breath and light headedness.³²

- disorientation and discomfort were not uncommon⁷ (*therefore acknowledged*)
- **Aerotoxic syndrome**
 - Symptoms reported by individuals associated with air crew exposure during ground operations and at altitude to atmospheric contaminants from oil lubricants and other aircraft fluids include a consistent symptomology of irritancy, chemical sensitivity and neurotoxicity. The syndrome termed aerotoxic syndrome may be reversible following brief exposures, but pictures are emerging of a chronic syndrome following significant exposures.^{3,23,24}
 - The Australian Senate Inquiry³ noted that contamination of the cabin aircraft air on the BAe 146 aircraft appeared to have led to short-term and medium term health problems and possibly long-term for a number of crew with further research necessary, although the Senate committee had problems in definition of the words medium term, which viewed as being up to ten years.³³

Issues relating to Civil Aviation Authorities and Regulations

There are specific regulations under the FAR's, CAR's, JAR's relating to defect reporting, major defect reporting, fitness for duty, incident reporting and airworthiness standards. These must all be met, however there is clear evidence that this is not occurring.

- The Australian senate Inquiry noted that with regard to cabin air contamination there was strong evidence of under-reporting and that the contamination of aircraft cabin air conflicted with requirements of at least several Civil Aviation Regulations.³
 - **Airworthiness standards - Transport Category Aircraft – Ventilation FAR/JAR 25.831.** The airworthiness standard for aircraft ventilation, FAR 25.831 was introduced in 1965 with the JAR 25.831 based on the FAR introduced some time after. The FAR/JAR includes:
 - a) each crew compartment must have enough fresh air (but not less than 10 cubic feet per minute per crewmember) to enable crewmembers to perform their duties without undue discomfort or fatigue
 - b) Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapors.
- It appears that part a) of the regulation is effectively ignored while part b) is seen by regulators and industry to review CO, CO₂ and O₃ while the regulation is not limited to only these contaminants.
- Aviation regulatory authorities have not seen the issue of air contamination by oils, hydraulic fluids and other contaminants as an aviation safety issue and have labelled the problem as an OHS issue and therefore not their concern,²⁶ despite the effects that have been evidenced in flight with effects on crew performance and therefore air safety. Some of the issues involved are:
 - Air contamination seen as health and safety problem rather than flight safety and therefore not a regulatory issue.
 - Regulator acknowledges air quality issues outside it's area of expertise.
 - Regulator's rely upon information provided by airlines/industry.
 - Regulator's inadequate and limited interpretation of ventilation airworthiness requirements in FAR/ JAR 25.831.
 - Regulator's failure to acknowledge existence of FAR 25.831a and only concerned with CO₂, CO and O₃.

- Regulator's failure to enforce aviation regulations with regard to defect reporting, incident reporting, maintenance, medical and other regulations connected to air contamination events and failure to fully investigate, with heavy reliance upon industry.
- Repeat air contamination defects not being seen as possible certification issue: reliance by Regulator's on initial certification data (with extremely limited review of air supply issue) rather than continuing certification requirements of meeting FAR/JAR 25.
- Regulator's failure to recognise under-reporting of air contamination events, as well as level of actual reporting.
- Regulator's failure to mandate selected service bulletins and raise airworthiness directives on air contamination defects affecting flight safety
- Regulator's failure to look at aircraft type history of air contamination when reviewing current issues.
- Complete failure by Regulatory Aviation Medical Departments to see oil/hydraulics contamination as an issue affecting aviation safety and crew health short and or long-term (despite known problems and failure of pilot medical certificates)

Oil contamination is design/airworthiness issue as well as maintenance

There appears to be complete industry acceptance that while air is drawn from engines, air contamination will continue, despite modifications. The problems must be seen as a design /certification and airworthiness issue rather than simply as a maintenance problem that will occur. The following demonstrate the acceptance of a continuing design problem.

"The air supply is protected from contamination by seals, which achieve maximum efficiency during steady state operation. However, they may be less efficient during transients (engine acceleration or deceleration) or whilst engine is still achieving an optimum operating temperature. Improvements in seal design continue to increase efficiency, and when available, modifications are provided for the engines and APU".³⁴

"...the modifications are really around the reliability of the seals and making sure that they do not fail as frequently. So they are improvements to reliability, rather than improving the quality of the sealing.....we all acknowledge..... that the modifications will not solve the problem completely. They are to reduce the number of events and that is what is important".¹¹

Industry recent actions

While many in the industry have repeatedly stated that oil and other contamination of the air supply system is not a safety issue and purely a health/comfort issue a number of actions have occurred recently including:

- The Australian ATSB⁸ flagged a possible safety deficiency as well as need to review long-term health effects:

The introduction of fumes and odours into the cabin environment following an engine defect constitutes a possible safety deficiency that should be addressed by the regulatory authority, in accordance with its statutory responsibility to monitor the continued airworthiness of aircraft. The implications of long-term exposure to cabin air contamination for the health of passengers and crew requires further examination, together with the development and implementation of suitable counter-measures. The competent authority to co-ordinate such activities is the regulatory authority.
- Two CAA Flight Operations Department Communications (FODCOM) covering Incapacitation Procedures and use of oxygen masks³⁵ noting the possibility of toxic fumes entering air supply from engines/air conditioning systems. Procedures including use of oxygen by both flight crew at 100% and the need for cabin crew to take an active part in monitoring the flight crew in such circumstances are detailed.

- Airworthiness Directive mandating BAe SB21-150 in at least UK, Australia and Canada regarding air contamination due possible oil leakage into the air supply and crew impairment on the BAe 146.³⁶ Despite industry insistence that oil contamination/air quality is not a safety problem, an AD is issued when the regulator considers an unsafe condition exists, is likely to exist or develop.
- BAe SB 21-150-recognition that oil leaks/fumes are to be seen as flight safety hazard³⁷

“in the past oil leaks and cabin/ flight deck smells and fumes may have come to be regarded as a nuisance rather than a potential flight safety issue....Whilst investigations are carried out.....oil leaks and cabin flight deck smells must be regarded as a potential threat to flight safety not just a nuisance.”
- AAIB recommendations 2001-4/ 5/ 6 and 7, 2001-47- covering contamination of air supply by oil from engines/APU and other hazardous substances to be avoided / thorough research program to cover full range of contaminants/ review of contaminant effects on health / additional operational information during air supply contamination including necessity for all flight crew to use O2 at 100% and need for cabin crew to monitor flight crew in such circumstances
- Airworthiness Directives have been issued for the MD80 series aircraft and Rolls Royce engines used on EMB 135/145 aircraft due hydraulic fluid leakages and smoke/in flight shut down due bearing failure respectively³⁸
- Interim Air Safety recommendation Swissair 111 - TSB of Canada - recognition that within the aviation industry there has been belief that odours are often a ‘non event’ diminishing concern about minor odours. Recommendations made that when odour/smoke is from an unknown source occurs, a decision to initiate a diversion and potential emergency landing must be made quickly.
- BAe All Operator Message - abnormal and emergency checklist have been amended to include the addition of the word fumes to titles of relevant smoke drills.³⁹

International Inquiries and actions

A number of International inquiries have taken place into cabin air and health aboard aircraft, with

- SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT RELATIONS COMMITTEE. *Report on Air Safety and Cabin Air Quality in the BAe 146 Aircraft.* Parliament of Australia, Canberra, October, 2000.(see Appendix 5 for recommendations)
- House of Lords select Committee on science and Technology - Air travel and health, 15 November 2000 – Finding that concerns about risk to health from exposure to TOCP were unsubstantiated due to the lack of confirmed cases of TOCP poisoning. This was based upon Dr. Virginia Murray’s evidence that the London poisons Information Centre records and a literature search revealed no cases or inquiries about TOCP in relation to aircraft as well as oil and engine manufacturer evidence given.⁴⁰

“We have had remarkably few enquiries from airlines about adverse health effects that have come to us from occupational exposures. I am not convinced that the data is being collected...I believe perhaps more work should be done to try and identify where the hazards exist.....no case data has been found about any enquiry relating to exposure to tricresylphosphate. All the information provided...comes from a literature search”⁴¹

- UK DETR
 - Stage 1- A consultation on the possible effects on health, comfort and safety of aircraft cabin environments, January, 2001
 - Stage 2- Health in aircraft cabins, June 2001- Limited to selected peer reviewed articles while terming much evidence anecdotal and semi anecdotal and to be discarded.

- National Academy of Science- Air Quality in Passenger Cabins of Commercial Aircraft- due 11/01
- European Parliament/Cranfield study⁴² -Environmental and health impact on aviation, March 2001- the section on 'Voc's and other pollutants consisted of stating that the House of Lords had found no concerns and incorrectly stated an Ansett Australia aircraft had been involved in a serious incident with defects remedied. This in fact was not Ansett, rather *Occurrence Report 9702276*⁸ and from evidence provided to the Australian Senate Inquiry and ongoing actions is clearly a more complex issue.
- US Congress Bill- '*Aircraft Clean Air Act of 2001*⁴³ – Bill provides for certain monitoring of aircraft air quality with additional requirement for air carriers to produce certain mechanical and maintenance records

Conclusions

The paper presents information that indicates that the presence of contaminants in flight decks and passenger cabins of commercial jet aircraft constitutes an air safety, occupational health and passenger health problem:

- Incidents involving leaks or engine oil and other aircraft materials into the passenger cabin of aircraft occur. The rates of occurrence of incidents are higher than the aviation industry admits, and for some models of plane are significant.
- Aviation materials such as jet oils and hydraulic fluids are hazardous and contain toxic ingredients. If such fluids leak into the air supply, cabin and flight deck, toxic exposures are possible.
- Leaks of oil and other fluids into aircraft may be of a nuisance type, but where they affect the health and performance of crew, or the health of passengers, this breaches airworthiness standards and other regulations. Evidence suggests that the numbers of such incidents is not few.
- Available studies for monitoring of exposures are limited in the information they provide. The studies use selective information, tend not to be applicable to abnormal leak events and in many cases use problematic sampling and analysis methodologies.
- Attempts by the industry to minimise this issue, such as acceptance of under-reporting of incidents, inadequate recognition of the extent of the problems, inadequate adherence/interpretation of the regulations, inadequate monitoring, inappropriate use of exposure standards and care provided to crew reporting problems, have enabled this problem to continue.
- A syndrome of symptoms is emerging, called aerotoxic syndrome, suggesting these exposures are common and a sufficiently large enough group of affected individuals exists.

Where contaminants impair the performance or affect the ability of pilots to fly planes, as has been reported in a number of reports, this is a major safety problem. Where contaminants cause undue discomfort or even transient health effects in staff and passengers, this is a breach of FAR 25.831 and other regulations.

Until recently, the approach of the aviation industry to deal with this problem has been to deny that it exists. In this, they have been supported by aviation regulatory agencies, who do not appear to enforce many of the provisions of aviation safety legislation that impact on air quality. In recent years, some limited attempts have been made to address these issues. The industry must continue to address all of the issues, and fix a problem that at least one national government recognises as a serious problem.³

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14/2001, August 2001.

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37 British Aerospace Service Bulletin 21-150 "Air conditioning- To inspect engine oil seals, APU and ECS
jet pump and air conditioning pack for signs of oil contamination , 20 March 2001

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abnormal and emergency checklist-Smoke and fumes, 14 February, 2001

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bin/query/z?c107:S.1019:](http://thomas.loc.gov/cgi-bin/query/z?c107:S.1019))

Appendix 1: Data on Incidents of Cabin Air Contamination

- UK CAA- 1989-1999 –128 incidents (2,850,000 flights) of smoke or gas fume leaks into cabins – 1:22000 flights
B757- 21 Bae 146- 17 A320- 20
- UK CAA¹ - smoke/odours/fumes into UK aircraft- 1996-81 1999-156 2000-124+
- UK CAA Mandatory occurrence reports (MOR)- smoke&/or fume
(oil, hydraulic ,deicing, fuel, aircon, other potentially related)
-B757 1997-2001 –31 defect reports (4 in 1997 /14 part 2001)
-BAe 146 1989-1999 25 defect reports 2000-2001- 25 defect reports

<u>Date</u>	<u>A/C Type</u>	<u>Location</u>	<u>Occ Num</u>
21.01.1999	BAE146		199900440
<u>Flt Phase</u>	<u>Location Info</u>		
CRUISE			
<u>Occ Classification</u>	<u>Event(s)</u>		
Occurrences	Other Occurrence		

Other Occurrence: Flight deck crew incapacitation - possibly due to fumes on flight deck. During cruise at FL240, P2 reported blurred vision, tingling in fingertips and a lack of concentration and requested that P1 assumes control. P1 noted that P2's face was white with lips discoloured and pupils dilated. Pressure checked satisfactory but P1 ordered P2 to use oxygen, then almost immediately P1 felt light-headed with tingling in fingertips. "Smoke in cockpit" drill and high speed descent initiated - ATC informed. Nr1 cabin crew member called to flight deck and reported no smells or fumes in cabin but an almost imperceptible smell on flight deck. Cabin monitored for remainder of flight with no problems noted and with only faintest decreasing smell on flight deck. A/c landed safely with no further incident and flight deck crew were taken to hospital as a precaution. See also 99/02108. Initial report from manufacturer suggested that the most probable cause of the incapacitation was due to the use of dry ice. The Medical and Dangerous Goods Officers 'are sceptical of the above cause' and further consider that the ingress of mineral oil fumes is also unlikely; this is also supported by a research paper from the Dept of Health Care and Epidemiology - University of British Columbia. The operator is no longer using the particular brand of dry ice and has revised his procedures with regard to the stowage of chilled containers immediately adjacent to the flight deck. It seems that there is no conclusive evidence as to the cause of this incident. CAA Closure: Hazard adequately controlled by existing procedures.

<u>Date</u>	<u>A/C Type</u>	<u>Location</u>	<u>Occ Num</u>
05.11.2000	BAE146		200008340
<u>Flt Phase</u>	<u>Location Info</u>		
FLIGHT			
<u>Occ Classification</u>	<u>Event(s)</u>		
Serious Incidents	Smoke / Fumes (not engine) Crew Illness / Incapacitation A/c Technical Occurrence		

SERIOUS INCIDENT: P2 incapacitated by noxious fumes. P1 performance also impaired. Passengers and positioning crew reported oily/petrol smell in rear cabin after take-off which soon dissipated. 20mins prior to landing, P1 left the flight deck to go to the toilet. P2 did likewise on P1's return. 5mins later, P1 felt nauseous and had difficulty concentrating. Simultaneously, P2 became unwell with highly dilated pupils. P2 required assistance applying oxygen mask, his hands were trembling and he had difficulty communicating. P1 then noticed his depth of vision was impaired. Autopilot remained selected for landing which P1 managed to control despite nausea increasing. Both flight crew hospitalised on arrival. Mandatory Service Bulletin 21-150 (issued 20/3/2001) refers. Subject to AAIB Field investigation. See also 2000/08697, 2000/07724 and 2000/08834.

<u>Date</u>	<u>A/C Type</u>	<u>Location</u>	<u>Occ Num</u>
07.07.2001	BAE146	En Route	200104931
<u>Flt Phase</u>	<u>Location Info</u>		
FLIGHT			
<u>Occ Classification</u>	<u>Event(s)</u>		
Occurrences	Smoke / Fumes (not engine)		

A/c Equipment / System Malfunction
Crew Illness / Incapacitation
Ramp Incident

Smell from air conditioning on numerous sectors. P1 felt effects of fumes. Air conditioning system contaminated when engine oil levels overfilled.

During second sector, P1 felt increasingly unwell with headache and with difficulty concentrating. After end of duty time, P1 was quite unwell and slept for over 12 hours (which was unusual). Symptoms returned during 4 sectors flown in the same a/c next day. Preliminary discussion with engineers revealed that engine oil levels had been overfilled at an outstation and air conditioning packs had become contaminated. Reporter comments that this is not the first time P1 has suffered ill effects after flying.

<u>Date</u>	<u>A/C Type</u>	<u>Location</u>	<u>Occ Num</u>
25.10.2000	B757	Admis	200007913
<u>Flt Phase</u>	<u>Location Info</u>		
CLIMB			
<u>Occ Classification</u>	<u>Event(s)</u>		
Occurrences	Smoke / Fumes (not engine) Crew Illness / Incapacitation Diversion /Return Engine Malfunction		

Fumes on flight deck and in cabin. Recurring fault.

After take-off thrust was set, a strong smell likened to "burning rotten socks" was apparent on flight deck. During climb, smell was still evident on flight deck but not as intense and was also reported from pax cabin where it was strongest forward. A/c levelled at FL330 and each pilot in turn breathed 100% oxygen for 1 minute because they both felt light headed. A/c diverted to Luton and on shut down, both pilots still felt light headed and also shaky. Reporter confirms that similar incident had been reported on previous sector. See also 2000/08363 and other occurrences contained therein.

<u>Date</u>	<u>A/C Type</u>	<u>Location</u>	<u>Occ Num</u>
07.11.2000	B757		200008363
<u>Flt Phase</u>	<u>Location Info</u>		
CRUISE			
<u>Occ Classification</u>	<u>Event(s)</u>		
Serious Incidents	Smoke / Fumes (not engine) Crew Illness / Incapacitation		

SERIOUS INCIDENT: Oily metallic smell evident on flight deck. Flight crew partially incapacitated, numerous ATC calls missed.

Subject AAIB Field Investigation: Oily metallic smell had also been evident during previous sector. On this occasion, numerous ATC calls were missed, prompting ATC to ask a/c if everything was all right. P1 then forgot to slow a/c during approach until reminded to do so at 3.7d. Crew unaware that they were becoming partially incapacitated. Recurred 11.11.2000, strong smell on flight deck after engine start and throughout the flight. As P1 developed significant headache in and after the flight and an inability to concentrate, he withdrew from the remaining duty. See also 1997/05805,1998/02188, 1999/01967, 1999/06912, 2000/04381, 2000/07913, 2000/09253, 2001/00510, 2001/00984, 2001/01653, 2001/02217, 2001/02325, 2001/02454, 2001/02487, 2001/02727, 2001/02756, 2001/03044, 2001/03076, 2001/03267, 2001/03277, 2001/03661 and 2001/03786.

<u>Date</u>	<u>A/C Type</u>	<u>Location</u>	<u>Occ Num</u>
25.01.2001	B757	London-Heathrow - LHR	200100510
<u>Flt Phase</u>	<u>Location Info</u>		
PARKED			
<u>Occ Classification</u>	<u>Event(s)</u>		
Occurrences	Smoke / Fumes (not engine) Engine Malfunction Crew Illness / Incapacitation		

A/c refused for service due ongoing history of toxic fumes on flight deck.

On arrival on a/c, flight crew noted Tech Log open defect regarding strong smell of oil during various flight phases on last few sectors. Reporter confirms that previous history showed same toxic fumes on 1 Jun 2000, 23 Dec 2000 (when LH pack was rendered inoperative and a/c released for service) and also 20 Jan 2001 (when both flight crew felt unwell and LH pack suspected/selected off, then isolated for next

flight). During first sector 25 Jan 2001, defect was allegedly cleared for further report with suspect intermittent oil see page from nr1 engine. See also 2000/08363 and other occurrences contained therein (including 2001/02487 involving same a/c).

<u>Date</u>	<u>A/C Type</u>	<u>Location</u>	<u>Occ Num</u>
09.03.2001	B757	En Route	200101653
<u>Flt Phase</u>		<u>Location Info</u>	
CLIMB			
<u>Occ Classification</u>		<u>Event(s)</u>	
Occurrences		Smoke / Fumes (not engine)	
		Engine Malfunction	
		Emergency Descent	
		Crew Illness / Incapacitation	

Metallic/oily smell on flight deck. Both flight crew affected by irritation to mouth/nasal passages and headache.

Smell evident during majority of flight, but only on flight deck. Due to pungency of smell and irritation caused to both flight crew, decision taken to descend from FL390 to FL350, but when there was no change, further descent to FL310 was carried out in preparation for actioning QRH smoke/fire drill. Flight deck door then opened and smell/irritation dissipated which precluded QRH action. Oily deposits wiped off flight deck displays and sample passed to engineering for investigation and analysis. Fault recurred 5 Apr 2001 (2001/02325 refers). See also 2000/08363 and other related occurrences contained therein.

- Australian CASA web site defects² 1996-2001- Bae 146 ALF502R5/ 507 cabin air contamination and related- 20 +
 - **LYC ALF502R5 COMPRESSOR SEAL WORN 01/0876**
No3 engine leaking oil from bleed band area. Fumes entering cabin through air conditioning system. Investigation found No1 bearing seal and face plate assembly worn.
 - **LYC ALF502R5 TURBINE SEAL LEAKING 01/0874**
No1 engine No9 bearing seal leaking. Suspect fumes entering cabin and causing crew problems.
 - **LYC ALF502R5 COMPRESSOR SEAL WORN -00/0349**
No1 engine No1 carbon seal severely worn. Contaminated bleed air entered cockpit causing problems with flight crew.
- Australian Transport Safety Bureau (ATSB)- incidents- oil fumes 1991-11/99 –22 (Jet) incident reports- (10 x BAe 146)³
11/99- 5/01- 13 incident reports- (8 x BAe 146)⁴
selected ATSB published occurrences
 - <http://www.basi.gov.au/occurs/ob199702276.htm>
 - <http://www.basi.gov.au/occurs/ob200000176.htm>
 - Occurrence Brief 200002431 Bae 146 –300 30/4/00 Perth, Western Australia
<http://www.basi.gov.au/occurs/ob200002431.htm>

The co-pilot reported that during the BAe 146 handover, the previous crew stated that the aircraft had an air-conditioning contamination problem and that it appeared to emanate from the No. 2 air-conditioning pack. On entering the aircraft the co-pilot noted that only the No. 2 pack was operating and the ambient air was contaminated. The crew switched off the No. 2 pack until the engines were started and the aircraft had taxied to the runway holding point.

After take-off, the co-pilot reported that he began to feel nauseous and had developed a headache. After discussing the problem with the aircraft captain, he donned an oxygen mask and gradually felt better. During the flight, a flight attendant entered the cockpit and reported a soreness of the head, and that she felt nauseous.....

- Several International investigations have been completed or underway

-Swedish investigation bureau- airlines BAe 146 incident 11/99 (not completed)
 -UK AAIB- British European Bae 146 incident Occ 200008340 11/00 (not completed)
 - <http://www.irlgov.ie/tec/aaiu/1998Reports/1998-010.htm>

- Ansett Australia BAe 146 aircraft tech log defects/ fume-odour occurrences^{5 6}
- -1992 418 defect reports 1: 66 Bae 146 flights
 -1999 (to June30) 168 defect reports 1:131 Bae 146 flights
- Several incidents are reported in the Australian senate Inquiry into cabin air contamination including:⁶

As we were preparing to land in Brisbane I experienced a feeling like drunkenness and I had difficulty lining up the aircraft for landing. I did not tell my first officer how I was feeling and did not hand over to him because I was not aware of the extent of my incapacity.

When switching air supplies from the APU to the engine air supplies, we got this odour in the Cabin - I call it the dirty sock smell. I have smelled it numerous times in the past. I might add that most of the time, and I have smelled it in the past, it has never bothered me - it is just uncomfortable. ... a very short time later, about a minute later, I felt just a slight light-headedness coming about, so what I did was I took the oxygen mask. I did not actually properly don it; I just took it and held it up to my face ... What happened, as I pretty much expected it would, was that the symptoms of this sort of light-headedness went away pretty much straightaway. ... The flight progressed. ... The smell went away. the light-headedness thing sort of came back again and a very, very dull headache transpired, so I started breathing the oxygen again. Lo and behold, it started to go away and, as the flight progressed and once again I was not breathing oxygen the whole time - it went away and then it started coming back again. And then later I just had very dry scratchy eyes, a sore throat, that sort of thing, a taste in my mouth, and the only way I could describe it is it tastes like it smells. ... on descent at the lower altitudes going into Melbourne, I then became aware that with the points of light, ... there was some blurring in my long-distance vision. Once again it was not major. We landed without incident ... It was not until that point, in walking across the ramp at Melbourne, that I realised that I had a slight disorientation. I do not really know how to describe it - not staggering, falling over drunk, but it was very obvious that there was something wrong, that there was a minor incapacitation, ... I have had exposure to these fumes before; it had never bothered me, and now it bothered me. ...

- Australian BAe 146 odour occurrence reports (discretionary- Flight attendants and Pilots)- 1991-2000- 700+ reports^{6, 7}
- US AFA – 1997 Review undertaken of 760 incidents involving 900 flight attendants
- A 1983 study of 89 US Air force flights involving smoke and fumes in the cockpit between 1970 and 1980 detailed 42 symptoms of dizziness and light headedness, 32 of irritated eyes and mucous membranes, 31 of nausea and vomiting, 23 of disorientation, confusion and performance decrement, 22 of headaches and others including visual acuity, paresthesias, chest pain, respiratory distress, cough and 4 cases of loss of consciousness. The source was traced to oil and hydraulic fluid in 23 and 4 cases respectively.⁸
- 1988 RAAF report⁹ notes that
“RAAF has reported many instances of strongly odourous vapours entering the air conditioning system of several C-130 aircraft...escalated considerably in last 12 months... given rise to concern for long-term health of flight crews and in the short-term, operational safety problems which may result from incapacitation of pilots and crew....Operational restrictions were being imposed on aircraft in order to limit the extent to which flight crews were exposed to fumes.”
- A 1998 Canadian BAe 146 review- 112 individuals report symptoms over 4 month period on 5 BAe 146 aircraft with 35 sectors each aircraft. 29 individuals reported headaches 27 and 48 reported burning eyes and throat respectively, with 16 reporting disorientation and other symptoms including tingling and numbness , light headedness, nausea, chest pains, breathing problems requiring oxygen.¹⁰
- Australian Federation of Air Pilots review of BAe 146 flight crew-1999. Crew report increase in symptoms when on duty on BAe 146 ranging from sometimes and often experienced, to long-term symptoms including headaches, light headedness, irritation, disorientation, memory impairment and concentration difficulties, fatigue and weakness, respiratory difficulties, numbness, balance difficulties, nausea and chemical intolerances.¹¹

- Crew health survey in preparation at the University of New South Wales. Of 50 respondents (BAe146) 28% were male and 72% female with flight crew comprising 32% of respondents. A wide range of symptoms both in flight/short-term(96%) as well as long-term (76%) were reported including eye irritation at 77%, breathing problems at 63%, nausea and vomiting at 59%, intense headache at 83% , tingling at 41% and sensitivity to chemicals at 73%.
- 7 case studies of Flight and cabin crew all experiencing short term in flight contaminated air exposure/ill effects as well as longer term ill health involving loss of pilot medicals and careers.¹²
- Service bulletins/service Information leaflets / All Operator letters or messages / engineering releases / aircraft maintenance manuals / special program letters and other aircraft documentation regarding oil/ hydraulic fluid and other contamination may be available. ATA sections of relevance will generally include 21, 36, 49, 53, 71, 72, 75 and 79

In the case of the BAe 146, service bulletins and service information leaflets relating to air contamination are numerous and go back to at least 1984 and continue in 2001, relating in many cases specifically to air contamination and oil leakage and related matters into the air supply. Additional data is also available from the engine and APU manufacturer. e.g.

- BAe SIL 21/7 Dec 84 – “oil contamination of Air Conditioning System”
- BAe SIL 21/45- cabin air quality trouble shooting advice and relevant modifications
- SB 49-5-35040G 24/10/84 Title – APU-Power plant-Introduce an improved Compressor inlet duct seal (Garrett Change13) Reason-Inadequate sealing between APU accessory drive gearbox oil sump and compressor inlet duct, and between top and bottom halves of inlet duct, allows fumes to be sucked from the bay area through the APU and into passenger cabin.
- BAe **SB 21-150 20/3/01** Title-**Air conditioning- Inspect engine oil seals, APU and ECS jet pump and air conditioning pack for signs of oil Contamination** Reason-Incidents reported of impaired performance of flight crew. Possible inhalation of oil and or breakdown products leaking from engines or APU and contaminating ECS. Cabin/ flight deck smells to be regarded potential threat to flight safety
- Flight crew medical Certificates- BAe 146 crew in Australia and UK have been refused pilot medical certificates with several claims of Loss of Licence being processed. Other BAe146 and B757 and A320 pilots have medically retired.

This list is not exhaustive

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- ² CASA - Civil Aviation Safety Authority – Service Difficulty Reports www.casa.gov.au
- ³ ATSB- Evidence to the Senate Inquiry into Air Safety – BAe 146 Cabin Air Quality
- ⁴ SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT RELATIONS COMMITTEE - HANSARD 31May, 2001
- ⁵ ANSETT AUSTRALIA. Evidence to the Senate Inquiry into Air Safety – BAe 146 Cabin Air Quality, ‘BAe 146 return to work program- flight attendant information kit’- 28 February 2000
- ⁶ SENATE RURAL AND REGIONAL AFFAIRS AND TRANSPORT RELATIONS COMMITTEE. Report on Air Safety and Cabin Air Quality in the BAe 146 Aircraft. Parliament of Australia, Canberra, October, 2000.
- ⁷ Flight Attendant Assoc. of Australia. Evidence to Senate Inquiry into Air Safety- Bae 146 cabin Air Quality, September 1999, September,2000
- ⁸ RAYMAN R.B., McNAUGHTON G.B. Smoke/fumes in the cockpit. Aviation, Space and Environmental Medicine, August 1983, pp 738 - 740
- ⁹ KELSO AG, CHARLESWORTH JM, Contamination of Environmental Control Systems in Hercules Aircraft, Australian Department of Defence MRL-R-1116, April, 1988.
- ¹⁰ VAN NETTEN, C. Air quality and health effects associated with the operation of the BAe 146 - 200 aircraft. Applied Occupational and Environmental Hygiene **13**: 733 - 739, 1998.
- ¹¹ Australian Federation of Air Pilots, Crew health survey, December 1998

- ¹² WINDER, C., BALOUET, J.-C. Symptoms of irritation and toxicity in aircrew as a result of exposure to airborne chemicals in aircraft. *Journal of Occupational Health and Safety – Australian and New Zealand* **17**: Nov 2001.

Appendix 2: Industry Recognition of Cabin Air Contamination

- 1953 - Aeromedical Association - toxicity risks of cabin air contaminants of hydraulics and lubricants¹
- 1981 - Society of Automotive Engineers (SAE) Aerospace Information report² - Sources of vaporous contamination:

Engine compressor bearings upstream of the bleed ports are the most likely sources of lube oil entry in the engine air system and thence into the bleed system contaminating the cabin/cockpit air conditioning systems. Although precautions are taken in the design of the bearings to preclude oil leakage into the compressor air passage, failure conditions can result in the introduction of oil into the air stream. At temperatures above 320 degrees Celsius, this oil can break down into irritating and toxic compounds.

- 1983 - Mobil Oil memo - Mobil Jet oil II³

If cabin air becomes contaminated with any lubricant and/ or its decomposition products, in sufficient quantities, some degree of discomfort due to eye nose and throat irritation could be experienced. Problems like these can be generally traced to improper design, improper maintenance or malfunctioning of the aircraft.

1983- FAA Report⁴-

A malfunctioning seal.... Could allow oil to enter the turbine's compressor section, which is the source of bleed air.

- 1983 - Study undertaken of 89 incidents of smoke/fumes in US Air Force aircraft in period from 1970-1980 of which 23 and 4 of the 65 (41%) identified sources were attributed to oil lubricants and hydraulic fluids respectively with all toxic substances identified having acute and long-term effects.⁵
- 1983 – NTSB study of turbine oil by-product contamination of cabin ECS system⁶ -
there are certain instances in which chronic or repeated exposure may sensitise a person to certain chemicals so that later concentrations in the ppb may later illicit an acute hypersensitivity type reaction
- 1984 - Service Information leaflet 21/7⁷ -
Oil contamination of Air Conditioning System- advice offered should oil contamination of the air conditioning system be experienced
- 1987 - Service Bulletin SB 36-13 24/4/87⁸ -
Title- Pneumatics- APU Air Supply-Introduce Catalytic Converter in APU bleed air supply. Reason: APU oil leakage has caused contamination of bleed air, resulting in odour problems in passenger compartment and ECS component contamination
- 1991 - Allied Signal Aerospace memorandum⁹ -
Several BAe 146 aircraft are having reports of objectionable odors described as 'dirty socks' or musty. Very little work has been done in the aviation industry to pinpoint the chemical compounds causing such odours ... the odor appears to be coming from breakdown products of the oil, either through incomplete combustion on the catalytic converter, or by chemical or biological reaction occurring in the Environmental control System of the aircraft.
- 1998 - A Canadian study into air quality and health effects on the BAe 146-200 aircraft¹⁰ -
air quality complaints... traced to leaky oil seals associated with bearings 1 and 9 of the jet engines.
- 1998 - Ansett External Panel of Specialists - Consensus statement¹¹ –
the panel accepts that the short-term symptoms associated with odours that have been reported on the BAe 146 and other types are substantiated. These odours have been generally linked with inadequate ventilation together with aircraft system defects.

- 1999 - British Aerospace¹² -

Reports of cabin air odours have been received from time to time and have predominantly been determined to be due to minor systems failures such as leaks from oil seals on the aircraft engines or APU

- 1999 - Ansett Australia¹³ -

the source of the odours has been identified as predominantly Mobil Jet Oil II leaking past oil seals in the engines and /or Auxiliary Power Unit into the air conditioning system

This list is illustrative only, and not meant to be exhaustive.

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1

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3 MOBIL OIL CORPORATION, Environmental Affairs and Toxicology Department New York, 24/1/83 – Correspondence, Mobil Jet Oil II.

4 Crane R. Sanders D., Inhalation Toxicology- Evaluation of thermal degradation products from aircraft and automobile engine oils, aircraft hydraulic fluid and mineral oil- FAA report AM- 83-12, April 1983

5 RAYMAN R.B., MCNAUGHTON G.B. Smoke/fumes in the cockpit. Aviation, Space and Environmental Medicine, August 1983, pp 738 - 740

6 WIZNIAK, E.P. Special Investigation - An Evaluation of the Potential for Turbine Oil by - product Contamination of an Aircraft's Cabin Environmental System. National Transportation Safety Board, 25 April 1983.

7 BRITISH AEROSPACE. Service Information leaflet, SIL 21/7: Oil contamination of Air Conditioning System, British Aerospace, Hatfield UK, December, 1984.

8 BRITISH AEROSPACE. Service Bulletin, SB 36 - 13, Hatfield, UK, April 1987. Allied Signal Aerospace, memorandum : results of Air quality testing for Dan - Air London, 22 July 1991.

9 ALLIED SIGNAL AEROSPACE. –Results of Air Quality Testing for Dan-Air London , 22 July 1991

10 VAN NETTEN, C. Air quality and health effects associated with the operation of the BAe 146 - 200 aircraft. Applied Occupational and Environmental Hygiene **13**: 733 - 739, 1998.

11 ANSETT AUSTRALIA. Consensus Statement, External Panel of Specialists, BAe 146 Odour Occurrences, Brisbane, 25 March 1998.

12 British Aerospace. Evidence to SENATE INQUIRY INTO Air Safety-BAe 146 Cabin Air Quality , September 2000

13 Ansett Evidence to SENATE INQUIRY INTO Air Safety- BAe 146 Cabin Air Quality November, 1999

Appendix 3: Issues regarding toxicity of aircraft materials

• Chemicals used in Aircraft Materials

- Materials used in the operation of aircraft may contain hazardous ingredients
- The toxicity of specific ingredients, include irritants, sensitisers, neurotoxicants, carcinogens and so on.¹
- At least one jet oil (Mobil Jet Oil II, claimed to have a 49% market share) contains at least two hazardous ingredients.^{2, 3, 4}
 - TCP, or Tricresyl phosphate (CAS No 1330-78-5) containing 3% with mono, di and tri 'ortho' isomers.⁵ In product safety information, the manufacturer only discloses one of the six ortho-cresyl containing TCP isomers (TOCP).⁶ Later information discloses that, at 0.005 ppb, TOCP is present at a concentration over six hundred and fourteen thousand times less than all ortho-cresyl isomers.^{5,7} 'Ortho-cresyl' phosphates are known to be neurotoxic^{8,9} and have been identified in bulk oil samples.¹⁰
 - PAN - Phenyl-alpha-naphthylamine (CAS No 90-30-2) containing 1%. PAN is a skin sensitiser¹¹ and includes impurities such as 2-Naphthylamine (a known carcinogen)¹², n-phenyl-2-naphthylamine and 1-naphthylamine.
- Manufacturers admit a reluctance to replace toxic additives (for example, TCP) that work well in critical applications for safety reasons despite recognition of toxicity.⁷
- The neurotoxic potential of the ortho-cresyl isomers of TCP, notably TOCP, has been known for many years¹³ with much research and industry data focussing on the toxicity of TOCP.¹⁴
- It has been known for more than forty years that other ortho-cresyl isomers such as the MOCP and DOCP are ten and five times more toxic than TOCP.^{2,8,9,14}
- The TCP in Mobil Jet Oil II contains other ortho-cresyl isomers in addition to the Tri ortho isomer and in larger quantities as advised recently by Mobil to Australian Senate Inquiry Mono-ortho cresyl phosphate (MOCP) is in TCP at 3070 ppm and Di-ortho cresyl phosphate (DOCP) is in TCP at 6 ppm while TOCP is at 5 ppb (or 0.005 ppm).⁵
- The jet oil manufacturer only discloses ingredient concentration for TOCP. By combining the ingredient concentrations of the various ortho-cresyl containing isomers with their relative toxicities, the practice of disclosing information on TOCP alone underestimates the toxicity of the OCP ingredients by a factor of over 6,000,000.² This is the information the aviation industry is given by product manufacturers and acts on in its own aviation safety activities.
- There is no direct information on absorption through the inhalation route for TCP.¹⁴
- A new jet oil has been introduced, Mobil Jet Oil 291. It has lower levels of TCP, but is not phosphate free. The TCP contains less than 1 ppb TOCP, 1.1 ppm DOCP and 1760 ppm MOCP, about half the toxicity when compared to Mobil Jet Oil II.²

- Higher molecular weight hydrocarbons can be cause of 'dirty socks' odours. SVOC's, include TCP isomers and may generate 'foul odours'.¹⁵
*'Semivolatile products of incomplete combustion...typically have very objectionable odors'*¹⁶
- Concern exists over the potential for TMPE and TCP to cause the highly neurotoxic TMPP and the difficulty in demonstrating its presence. (Exxon 2380 banned by US navy due high potential for formation of TMPP)¹⁷
- Hydraulic fluids are known to contain high levels of phosphates including Tributyl phosphate (TBP) in Skydrol LD4 at 50-70%.

- Toxicology of organophosphates**

- OP effect on esterases and neurotoxic esterases are well known. An intermediate syndrome was described in 1987.¹⁸
- Signs of poisoning are usually foreshadowed by a range of symptoms including, salivation, lacrimation, visual impairment, nausea and vomiting, abdominal pains, cramps, parasympathomimetic effects on heart and circulation, fasciculations and muscle twitches.¹⁹
- Signs of low level intoxication include headache, vertigo, general weakness, drowsiness, lethargy, difficulty in concentration, slurred speech, confusion, emotional liability.²⁰
- Chronic exposure to OP's has been associated with a range of neurological and neuropsychological effects.^{21 22 23 24 25} Chronic organophosphate neuropsychological disorder (COPIND) lists neurological and neuropsychological symptoms including: headaches, mental fatigue, depression, reduced concentration and impaired vigilance, reduced information processing and psychomotor speed and memory deficit.²⁶
- COPIND may be seen after single or short-term exposures leading to signs of toxicity²² or long-term low level repeated exposure with (often) no apparent signs of exposure.²⁴
- The National Toxicology Bibliographic database for TCP includes acute and chronic hazards and notes toxicity by inhalation and skin absorption as well as listing numerous symptoms -

"Acute/chronic hazards: This compound is toxic by inhalation, ingestion or absorption through the skin. It is an irritant of the skin and eyes...mucous membranes and respiratory tract. When heated to decomposition it emits toxic fumes of phosphorous oxides ..."

"Symptoms: Symptoms of exposure include irritation of the skin, eyes, flaccid paralysis ..., motor activity changes and muscle weakness. It may cause respiratory tract and mucous membrane irritation... serious damage of the nervous and digestive systems and muscular pain... gastrointestinal upset...soreness, aching, numbness, headache, vertigo, ... parasthesias, decrease of strength in arms and legs ... vomiting ... diarrhoea and abdominal pain..."

- Chevron Hydraulic fluid A MSDS lists the following:**

IMMEDIATE HEALTH EFFECTS

EYE: Not expected to cause prolonged or significant eye irritation.

SKIN: Contact with the skin causes irritation. Not expected to be harmful to internal organs if absorbed through the skin.....

INGESTION: Because of its low viscosity, this material can directly enter the lungs, if swallowed, or if subsequently vomited. Once in the lungs it is very difficult to remove and can cause severe injury or death.

INHALATION: Excessive or prolonged breathing of this material may

cause central nervous system effects. Contains a petroleum-based mineral oil. May cause respiratory irritation or other pulmonary effects following prolonged or repeated inhalation of oil mist at airborne levels above the recommended mineral oil mist exposure limit.

SIGNS AND SYMPTOMS OF EXPOSURE: Skin irritation: may include pain, reddening, swelling, and blistering. Central nervous system effects may include headache, dizziness, nausea, vomiting, weakness, loss of coordination, blurred vision, drowsiness, confusion, or disorientation. At extreme exposures, central nervous system effects may include respiratory depression, tremors or convulsions, loss of consciousness, coma or death.

CARCINOGENICITY: Can cause cancer in laboratory animals, but is not considered to be a human carcinogen

- **MSDS, Labels and other product manufacturer information**

- MSDS's present varied information and may not be available to aircrew. In some cases these products are classified by the manufacturer as being not harmful/hazardous when classification criteria indicate otherwise.^{3,4} It appears that these assessments are made by the manufacturer based on it's own testing.^{27,5}
- Mobil advises MJO2 not hazardous as product tested as a whole⁶ when priority should be given to hazardous substances³ list and practical experience such as the health effects of the substance on exposed persons should be taken into account.⁴
- Mobil Jet Oil II MSDS advises symptoms of overexposure not expected to occur under normal conditions of use –

Effects of Overexposure: *This product is not expected to cause these effects under normal conditions of use and appropriate personal hygiene practices. This product contains TCP. Overexposure to TCP by swallowing, prolonged or repeated breathing of oil mist, or prolonged or repeated skin contact may produce: nervous system disorders, including gastrointestinal disturbances, numbness, muscular cramps, weakness and paralysis....*

First aid measures include: skin contact- wash contact areas with water,.. remove contaminated clothing... inhalation exposure remove from further exposure. If respiratory irritation, dizziness or nausea or unconsciousness occurs, seek immediate medical assistance... Exposure controls ... respiratory protective equipment should be used if ventilation is inadequate and breathing of excessive concentrations of vapours or mists is likely or prolonged or repeated skin contact is likely. If prolonged or repeated skin contact is likely oil impervious gloves should be worn... Note to Physicians this product is not expected to produce these effects under normal conditions of use and appropriate personal hygiene. This product contains TCP which can cause symptoms associated with cholinesterase inhibition.....neurotoxicity.... Under normal conditions of use this product is unlikely to produce neurotoxic effects by dermal or inhalation exposure...

- Mobil Jet Oil II MSDS and current oil can label advise prolonged or repeated breathing of oil mist, or prolonged or repeated skin contact may produce nervous system disorders -

Prior to 1998

<p>Warning! Contains Tricresyl Phosphate. Produces paralysis if taken internally. Do not use as medicine or food product. Wash thoroughly after handling.</p>

After 1998

WARNING!
Contains Tricresyl Phosphate.
Swallowing this product can cause nervous system disorders, including paralysis.
Prolonged or repeated breathing of oil mist, or prolonged or repeated skin contact can cause nervous system defects.

PRECAUTIONS:
Never swallow. Wash hands after handling and before eating. Never use in or around food. Avoid prolonged or repeated overexposure to skin or lungs.

FIRST AID:
If swallowed, seek immediate medical attention. If medical attention is delayed, induce vomiting. In case of contact, wash skin with soap and water. Remove contaminated clothing.

FOR INDUSTRIAL USE ONLY
Not intended or suitable for use in or around a household or dwelling. Never use empty container to carry water or food. Do not cut or weld on empty container.
(In thirteen languages) When using do not eat, drink or smoke. After contact with skin, was immediately with plenty of soap and water.

- **Abnormal Conditions**

Exposure to oil and hydraulic contamination through the aircraft air supply is **not a normal condition**

- Mobil warnings and information to industry refers to their jet oil product as being not toxic under normal conditions of use.
- Mobil do not consider accidental exposure to oil vapours in an aircraft cabin to be “normal use”. However levels reached according to Mobil research are safe.⁵
- Testing done under normal conditions - BAe advises that “every test which has been done has failed to detect the presence of any of these chemicals in the cabin in normal operations.”²⁸

- **Other Issues that can impact on exposure to jet oils and other contaminants**

- **Altitude:** Aircraft passenger cabins are pressurised to 2400 m.
 - The change in pressure causes a decrease in absolute oxygen concentration. People may begin to become hypoxic at such pressures, in some cases with having higher respiratory rates and therefore higher exposure.²
 - The lowering in oxygen may increase the toxicity of other contaminants, such as carbon monoxide.
 - effects of cabin pressurisation and humidity and other onboard factors and the possible interactions between them have not been studied adequately.¹⁵
- **Exposures to Gases, Vapours and Particulates:**
 - Inhalation exposures include gases and vapours as well as particulates (fumes, smoke, mists) that may be in proportionately greater concentrations than for gases and vapours. Oil has a low vapour pressure, and therefore any haze, mist or smoke will be of an aerosol/mist form. The presence of oil mist on surfaces will also present a residual vapour problem.^{2,29}

- Most engine oil leaks would be in particulate form such as an aerosol or mist by poorly volatile chemicals that would coalesce onto surfaces presenting a skin hazard.
- Therefore, inhalation and skin exposure may occur with ingestion improbable.¹
- Consideration should be given to exposure to combustion/pyrolysis products.²
- **Testing/monitoring**
 - Testing has not occurred during abnormal leak events³⁰
 - *“Investigations into suspected incidents are...retrospective...little evidence about the composition of the air when the problem occurred”*³¹
 - *“during the testing period, there were no specific ‘smell’ incidents”- (TCP was found)*³²
 - *“the...reported measurements were conducted under normal operating conditions. No unusual or episodic conditions were noted”*³³
 - *“these scientists examining the aeroplanes- although they obviously have not been on board during a real event- have actually chosen those aeroplanes”*²⁸
 - Industry testing limited and not on problem aircraft types looking at abnormal operations, while information is applied to say aircraft air is acceptable.
 - Data indicating concerns often selectively used or misinterpreted by industry to indicate acceptable outcome (e.g. see Appendix 1 Mandatory Occurrence Report Occ **199900440**)^{10,28}
 - Inadequate sample collection methods to measure for all toxic contaminants
 - many tests carried out on ground
 - collection of contaminated air into container for subsequent analysis underrates problem as mist particles settle on walls of container, leaving only small amounts of vapour to be analysed at a later date
 - numerous studies have looked at very limited range of contaminants and other detected contaminants remain unidentified
 - Semi-volatile organic compounds are not detected by traditional volatile organic compounds methods, were not collected during revenue flight and were not analysed using analytical technologies with appropriate extraction efficiency for OP's.¹⁶
 - Inappropriate use of exposure standards and inappropriate application of information/data.
- **TCP has been detected on aircraft** TCP has been found in aircraft on several occasions: Testing took place on ground during pack burns and there were no smell incidents during testing.
 - During Pack Burn on a Southern Australia BAe 146 and Ansett BAe 146^{32,34}
 - RAAF C-130 - TCP identified in traces of turbine oil found in air filter bags³⁵
- **Exposure Standards:** Exposures standards represent concentrations of individual chemical substances to which nearly all workers may be exposed without effect.³⁶ Several issues that must be taken into considerations include:

- Exposure standards apply to single chemicals.
- Exposure standards only consider inhalation and ignore skin exposure - (TCP is known to be a significant skin absorber³⁷).
- Exposure standards are established at NTP conditions (25°C; 760 mm Hg) and must be modified for application at altitude or where skin exposure is possible, or for multiple exposures).
- The majority of currently detected compounds do not have exposure standards.^{15,36} This does not imply that these products are safe or non hazardous.³⁶ Of the 10 isomers of TCP, only TOCP has an exposure standard while other included isomers are known to be more toxic.
- There is no system of permissible exposure standards that applies to aircraft, and the use of conventional (sea level equivalent) values is improper. The quotes¹⁶ below demonstrate some of the problems with application of exposure standards at altitude.

“Contaminants may be below recommended levels in currently recognized safety limits such as those published by ACGIH, NIOSH, NASA, but still may not meet customer expectations with respect to odours.

“In addition extenuating circumstance on board aircraft (including low humidity and reduced cabin pressure) have not been studied to the extent that a new standard can be proposed that incorporates these factors.

“Currently the best available standards developed by cognizant authorities are those that apply to spacecraft and workplace environments.... there is no agreement on a toxicological standard among aviation toxicologists to apply to aircraft at this time.....

“NASA SMAC’s were developed for healthy astronauts and cannot be applied to the general population who may not be in as good physical condition....

“ACGIH TLV’s were developed for the average worker at or near sea-level pressure in relatively good health.

“Flight crew are working in conditions where atmospheric pressure is reduced.....the user may evaluate the data using standards that he feels most appropriate for his application.

“Contaminant levels may be well below recommended levels in currently accepted safety standards-yet generate complaints, because they act in synergy with other contaminants or because some standards may be outdated and not have incorporated more recent scientific and medical evidence. In addition, extenuating circumstances on board aircraft (including humidity and cabin pressure) have not been studied to the extent that a new standard can be proposed - that incorporates these factors or identifies interactions between factors.”¹⁵

- **Pack burns** –operators exposed to levels of hydrocarbons approaching exposure limits with exposure continuing for some time after completion of the procedure.¹⁵ Recommendation to cease regular pack burns.¹⁵
- **Recirc mode** – recirc mode recommended due improved humidity levels and reduction in organic contaminants.¹⁵

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Appendix 4: Aerotoxic Syndrome

Symptoms from single or short-term exposures include ^{1,2,3}

- neurotoxic symptoms: blurred or tunnel vision, nystagmus, disorientation, shaking and tremors, loss of balance and vertigo, seizures, loss of consciousness, parathesias;
- neuropsychological symptoms: memory impairment, headache, light-headedness, dizziness, confusion and feeling intoxicated;
- gastro-intestinal symptoms: nausea, vomiting;
- respiratory symptoms: cough, breathing difficulties (shortness of breath), tightness in chest, respiratory failure requiring oxygen;
- cardiovascular symptoms: increased heart rate and palpitations;
- irritation of eyes, nose and upper airways.

Neurotoxicity is a major flight safety concern, especially where exposures are intense.

Symptoms from long term exposure

Symptoms from long term low-level exposure or residual symptoms from exposure events include:

- neurotoxic symptoms: numbness (fingers, lips, limbs), parathesias;
- neuropsychological symptoms: memory impairment, forgetfulness, lack of co-ordination, severe headaches, dizziness, sleep disorders;
- gastro-intestinal symptoms: salivation, nausea, vomiting, diarrhoea;
- respiratory symptoms: breathing difficulties (shortness of breath), tightness in chest, respiratory failure, susceptibility to upper respiratory tract infections;
- cardiovascular symptoms: chest pain, increased heart rate and palpitations;
- skin symptoms: skin itching, rashes, skin blisters (on uncovered body parts), hair loss;
- irritation of eyes, nose and upper airways;
- sensitivity: signs of immunosuppression, chemical sensitivity leading to acquired or multiple chemical sensitivity
- general: weakness and fatigue (leading to chronic fatigue), exhaustion, hot flashes, joint pain, muscle weakness and pain.

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Appendix 5- Australian Senate Inquiry into Air Safety- BAe 146 Cabin Air Quality – October 2000 -Recommendations

Recommendations of the Senate Report

Recommendation 1

- (a) The Committee recommends that CASA should reassess matters recommended for further action by the BASI/ATSB incident report (No. 199702276) concerning the incident on 10 July 1997 involving Captain Kolver.
- (b) The Committee also recommends that CASA reassess its requirements for monitoring the operations and cabin and cockpit air quality of the BAe 146 aircraft operating in Australia and, where necessary, introduce regulations under the *Civil Aviation Act 1988* specifying:
 - a specific national standard for checking and monitoring the engine seals and air quality in all passenger commercial jet aircraft;
 - maintenance procedures (including specific maintenance procedures for ageing aircraft);
 - specific, appropriate maintenance and operational procedures for the BAe 146 which pay particular attention to the need to ensure aircraft are withdrawn from operational flying and serviced to ensure any operating faults resulting in oil leaks, fumes or smoke are immediately repaired;
 - that incident reports should now be specifically designed so as to reflect the history of the cabin air problem that has been encountered on the BAe 146;
 - sources of contamination in the cabin and cockpit environment in the BAe 146 be identified and further evaluated using appropriate sampling and analytical technology for the contaminants which, for example, might result from the burning of lubricating oil used in the BAe 146 engines;
 - companies operating BAe 146 and other passenger commercial jet aircraft in Australia provide CASA with specific reports on the results of monitoring these matters within an appropriate timeframe, whether quarterly or six-monthly, in order that CASA can assess the operations of the aircraft; and
 - air quality monitoring and compulsory reporting guidelines for all passenger jet aircraft operators.

Recommendation 2

The Committee recommends that CASA adopt the modification to aircraft air circulation systems proposal for the BAe 146 aircraft by the aircraft's manufacturer as compulsory for all BAe 146 operating in Australia and that this be achieved by preparation and issue by CASA of an appropriate form of maintenance direction under the Civil Aviation Regulations.

The Committee also recommends that registration of BAe 146 aircraft operating in Australia be reviewed, and that renewal of Air Operating Certificates and registration of the BAe 146 be subject to completion of those recommended modifications as a condition for continued registration of the aircraft.

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 4

That the issue of cabin air quality be reviewed by the National Occupational Health and Safety Commission with a view to including aerotoxic syndrome in appropriate codes as a matter of reference for future Workers Compensation and other insurance cases.

Recommendation 5

The Committee recommends that the Minister for Transport request the Strategic Research Development Committee of the National Health and Medical Research Council to set up and undertake an appropriate research program on the effect of exposure to aircraft cabin air on air crew and passengers. The Committee also recommends that the Minister advise the Parliament on the form and duration of, such a program as part of the Government response to this report.

Recommendation 6

While the Committee is aware that the cases referred to are a matter of state jurisdiction, the Committee recommends that the Minister for Transport, in co-operation with appropriate State Ministers, appoint an experienced, retired judicial officer or eminent person who is appropriately qualified to conduct a review of unsuccessful or inordinately delayed

employees' compensation cases, pilots' loss of license insurance, personal income protection, and with-held superannuation/other insurance claims made for personal injury and loss of employment as a result of ill health claimed to result from exposure to fumes on the BAe 146 and other aircraft. That person should be asked to report to the Minister on any conclusions they reach and whether those cases were dealt with according to requirements and appropriate standards of procedural fairness.

The Committee also recommends that the Minister table the conclusions and any recommendations it makes in the Parliament.

Recommendation 7

The Committee recommends that the Minister for Employment, Workplace Relations and Small Business, as the Minister responsible for national issues affecting occupational health and safety authorise a review of the use of Mobil Jet Oil II and that the National Industrial Chemicals Notification and Assessment Scheme be requested to conduct this review.

The Committee also recommends that the potentially hazardous chemical components of Mobil Jet Oil II be referred to NICNAS as a priority for review and assessment.

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.