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Air Accident Investigation Findings and Recommendations: Aircraft Contaminated Air Events

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Abstract

Over the last two decades, a number of reports have been published by various air accident investigation bureaus (AIB) related to aircraft bleed air contaminated air events. This paper provides a quick review of the key findings, conclusions and recommendations in these reports from nine different countries.

Abbreviations

AAIB	Air Accidents Investigation Branch
AIB	Air accident investigation bureaus
APU	Auxiliary power unit
BFU	German Federal Bureau of Aircraft Accident Investigation
ICAO	International Civil Aviation Organization

Overview

Aviation safety is advanced by reports, investigations and a reported ‘no blame’ culture, however most contaminated air events are never reported. Of those that are reported, most are not investigated by AIBs and investigators often lack subject matter expertise.

The basis for air accident investigations are predicated on the International Civil Aviation Organization

(ICAO) annex 13. As an example of air accident investigation bureaus (AIB) investigation legal basis, the European regulation 996/2010 requires that all accidents and serious incidents be investigated. The safety investigation authority or AIB may decide to additionally investigate incidents *"when they expect to draw safety lessons from them."* The scope of the investigation and procedure to be followed depend on lessons that are expected to be drawn from them for the improvement of aviation safety, especially taking into account the need for the cost-efficient utilization of investigation resources in the European Union.[1]

Under ICAO and the EU regulation 996/2010, an accident includes a person being seriously injured as a result of being in the aircraft. A serious injury includes an injury which is sustained by a person in an accident involving hospitalization for more than 48 hours, commencing within seven days from the date the injury was received or injury to any internal organ. A serious incident is defined as an incident involving circumstances indicating that there was a high probability of an accident. Listed examples of serious incidents include fires and smoke in the passenger compartment, events requiring the emergency use of oxygen by the flight crew (pilots), and flight crew incapacitation in flight.

AIBs differ somewhat in their interpretation of incidents that require investigation. The German BFU for example reports that *"according to the Commission Regulation (EC) 996/2010 and the law relating to the investigation into accidents and incidents associated with the operation of civil aircraft, the BFU can only investigate cases relevant for aviation safety. These include fire or smoke on board, occurrences which force the flight crews to don their oxygen masks and any flight crew incapacitation during the flight. Observation of odours, or smoke, irritations or headaches only becomes part of an investigation if they originate from fire or incapacitation."*[2] Many other investigation reports involve incidents where impairment occurred or a contaminated air event was reported. The extent of the investigation and reports vary widely as expected based upon the regulatory requirements listed above. The AIBs in Australia and Germany have both produced a general overview report on fume events, while a 2004 UK report broadened its review to look at a variety of aircraft reporting fume events.[3–5]

As shown in Table 1, AIB Investigation reports have been produced in 13 different countries. Out of these countries nine of them have made AIB recommendations or similar based on their investigation. The UK AAIB has made 13 recommendations in five different

reports, while Germany has produced five recommendations in two reports and Austria and the UAE have made six and eight recommendations respectively in one report each. A total of 46 differing AIB recommendations have been identified.

Table 1: Air Accident Investigation Bureau Investigations:

AIB investigations: Countries	**Number of AIB recommendations**
Australia	Australia x 7
Austria	Austria x 6
France	
Germany	Germany x 5
Iceland	Iceland x 1
Ireland	Ireland x 1
New Zealand	
Portugal	
Spain	Spain x 1
Sweden	Sweden x 4
Switzerland	
UAE	UAE x 8
UK	UK x 13
Total: 13 Countries	**Total: 46 in 9 countries**

Table 2 provides a breakdown analysis of the different types of recommendations. Nine recommendations relate to airworthiness, maintenance and certification, while eight refer to research on the oils and other bleed air supply contaminants and effects on human health. Seven recommendations relate to the introduction of bleed air supply detection and warning systems. Other areas included amendments to checklists and use of oxygen and protocols for crew and passengers during and post event reporting, among others.

Recommendation	**No.**	**Recommendation**	**No.**
Airworthiness/	9	Research- oils/contaminants and	8

maintenance/certification		effect on health	
Data analysis	3	Develop treatment protocol	1
Reporting	3	Research – identification of oil contaminants in cabin air	1
Education & training	3	Detection/warming systems	7
Checklist/mandatory oxygen(100%) use	5	Filtration	1
Mandatory use of PBE	1	Emergency evacuation/procedures	1
Crew/passenger protocol during/post event	5	Safety risk assessment	2
International database	2		

Table 2: Categorization of Air Accident Investigation Bureau Recommendations

It is however not mandatory for the organizations to whom the recommendations are addressed to undertake the recommended action. The EU regulation for example states *"The safety recommendations resulting from an accident or serious incident investigation or other sources, such as safety studies, should always be considered by the competent authority and, as appropriate, acted upon to ensure adequate prevention of accidents and incidents in civil aviation."* [1]

Several examples of key recommendations include:

1. Sweden: RL 2001:41e R1 – that existing emergency checklists and emergency training programs are complemented regarding immediate steps to be taken when suspicion arises that the cabin air is polluted. The instruction for such occasions shall call for the immediate use of the oxygen mask selected to 100%.[6]

2. UK: Safety Recommendation 2007-002 – It is recommended that the European Union

Aviation Safety Authority (EASA) consider requiring, for all large aeroplanes operating for the purposes of commercial air transport, a system to enable the flight crew to identify rapidly the source of smoke by providing a flight deck warning of smoke or oil mist in the air delivered from each air conditioning unit.[7]

3. Germany: Safety Recommendation 07/2014 – EASA should implement a demonstration of compliance of cabin air quality during type certification of aircraft (CS-25), engines (CS-E) and APU (CS-APU) such that the same requirements apply to all these products and permanent adverse health effects resulting from contaminated cabin air are precluded. Aircraft engine and APU type certification should include direct demonstration of compliance of all substances liable to cause cabin air contamination. Certification should be based on critical values which preclude permanent adverse health effects on passengers and crew.[5]

4. Spain: REC 15/2016 – It is recommended that the International Civil Aviation Organization (ICAO) monitors research and/or studies conducted by organizations representing civil aviation, authorities, industry and academic research institutions to determine the real impact that exposure to contaminated cabin air has on human health and takes actions to improve safety, as necessary.[8]

The same recommendation listed above relating to detection systems was made to the Federal Aviation Administration (FAA) as Safety Recommendation 2007-003.[7] Both recommendations were repeated in a further AAIB investigation report related to a B757 incident as the report stated *"to date the AAIB has not received formal responses to these recommendations."* [9]

A wide variety of key findings and conclusions have been outlined in the AIB reports examined. A few examples are listed below:

- Only fume events involving fire/smoke or those requiring the use of oxygen or pilot incapacitation must be investigated with lesser events not requiring investigation as not effecting safety;
- Fumes in the cabin are not new and are currently the subject of much industry discussion;
- As conditioned air is sourced from engine compressors on turbine engines, it is vulnerable to contamination from engine oil leaks that allow oil to enter the compressor air path;

- This incident and others show that prompt action by the crew in donning oxygen masks at the first signs of adverse symptoms can have significant safety benefits;
- A lot of fume events caused comfort limitations for the occupants but posed no danger;
- Cabin air contaminations during fume events have cause health impairments in occupants and impaired cabin crew in their performance;
- Two pilot impairment occurs;
- Impairment seen as an occupational health and safety (OHS) issue;
- Margin of safety rarely reduced as pilots used oxygen;
- Fumes from engine oils and hydraulic fluids is occurring in the cabin and flight deck on numerous aircraft types;
- Smoke or fumes in the flight deck or passenger cabin present the crew with a potentially hazardous situation, which requires prompt action;
- Inconsistent reporting is thought to have affected the quality of the evidence;
- No means of rapidly ascertaining the source of the fumes/ smoke was available to the crew;
- Smoke protection for passengers is not a requirement on public transport aircraft;
- Maintenance difficulty in identifying the source;
- The regulations put the onus on the system design for clean air, with little requirement placed on the constituents of the lubricating engine oils so as not to be harmful to, or affect, the occupants of aircraft;
- There was a lack of general information available on potential contaminants of the bleed air by engine oil, and their effects on human physiology.

An AIB report on a B757 related to transient oil fumes after take off and adverse effects experienced soon after, stated: *"During the descent, both crew members began to feel disorientated and found that they had to concentrate hard to carry out their normal duties. At this point the commander began to feel 'confused'… The flight crew expressed concern that neither had detected the slow degradation in their performance as this only became fully apparent after they had donned oxygen masks and began to recover."* [10]

Upon careful review, very different patterns of thinking can be seen. As an example:

Sweden: *"The Incident was caused by the pilots becoming temporarily affected by probably polluted cabin air."* [6] In this case oil leakage was identified during ground and air

investigations after the event. The captain subsequently lost his medical certificate to fly due to ill health.

Switzerland: *"The serious incident is attributable to the fact that on approach to Zurich Airport the cockpit filled with fumes which caused a toxic effect, leading to a limited capability of acting of the copilot. These fumes were caused by an oil leak…"* [11] In this case oil leakage was reported during post event investigations.

Germany: Very few cases, affected safety/impairment is an occupational health and safety (OHS)/comfort issue.[5]

Other factors leading to difficulty in post flight investigations include:

- Significant under-reporting.
- No contaminated air detection systems are available, despite CS/FAR 25.1309c requirement.
- Very low levels of oil leakage can lead to fumes.
- Levels identified in cabin air quality investigations are consistently low. However safe limits do not apply to the aircraft environment.
- It is very difficult to confirm low level oil leakage by currently available maintenance procedures.

In summary, the above AIB investigation reports have significant implications for flight safety as well as occupational and public health. The problem of contaminated air is definitely under-recognized. Specialist expertise for AIB investigations is required and investigations should look at the broader picture and if necessary, gather perishable evidence, look at operational, maintenance and human data and take into account all factors relevant to contaminated air exposures.

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