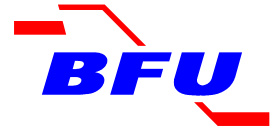


Bundesstelle für
Flugunfalluntersuchung



German Federal Bureau of
Aircraft Accident Investigation

Study of Reported Occurrences in Conjunction with Cabin Air Quality in Transport Aircraft



This study was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FIUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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Abbreviations

AFM	Airplane Flight Manual
AMC	Acceptable Means of Compliance
APU	Auxiliary Power Unit
APU Bleed	APU Bleed
ASU	Air Starter Unit
BfR	Bundesinstitut für Risikoanalyse (Federal Institute for Risk Assessment)
BFU	Bundesstelle für Flugunfalluntersuchung (German Federal Bureau of Aircraft Accident Investigation)
Bleed	Bleed air
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur (Federal Ministry for Transport and Digital Infrastructure)
CK	Creatine kinase
CO	Carbon monoxide
CO ₂	Carbon dioxide
CS-25	Certification Specifications for Large Aeroplanes
CS-APU	Certification Specification for APU
CS-E	Certification Specification for Engines
CVR	Cockpit Voice Recorder
DIN	Deutsche Norm (German Institute for Standardisation)
EASA	European Aviation Safety Agency
ECCAIRS	European Co-ordination Centre for Accident and Incident Reporting Systems
ECS	Environmental Control System
EN	European Standard
EU	European Union
FAA	Federal Aviation Administration

FAR	Federal Aviation Regulation
FDR	Flight Data Recorder
FL	Flight Level
FIUUG	Flugunfalluntersuchung Gesetz (Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft)
ft	Scale unit: foot, feet
hPa	Scale unit: Hectopascal
ICAO	International Civil Aviation Organization
ICD	International Statistical Classification of Diseases and Related Health Problems
LBA	Luftfahrt-Bundesamt
LuftVO	Air Traffic Order
MIL	US Military Standard
SAE	Society of Automotive Engineers
T/O	Take-off
TCP	Tricresylphosphate

Synopsis

Over the last few years, the German Federal Bureau of Aircraft Accident Investigation (BFU) has received an increased number of reports of so-called fume events¹. These kinds of events include smell, smoke or vapour inside the airplane and health impairments of occupants of transport aircraft. In addition, this topic is increasingly discussed among flight crew, occupational unions, the media and in political committees.

The study is based on the Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation. Taken into account were 845 accidents, serious incidents, and incidents, which have been reported to the BFU between 2006 and 2013.

A conjunction with cabin air could be determined in 663 reports. In 180 reports health impairments were described although a conjunction with cabin air quality could not be determined.

In 460 of the 663 reported fume events smell development and in 188 cases smoke development was reported. In 15 cases there was neither smell nor smoke but there were certain health impairments which may possibly have a conjunction with a fume event.

For this study, the BFU has divided the reported occurrences into the following categories:

- Fume events affecting flight safety
- Fume events possibly affecting the occupational safety of crew members
- Fume events affecting the comfort of aircraft occupants
- Fume events and possible long-term effects on aircraft occupants

The data analysis for this study showed that the criteria for a serious incident were met by some of the fume events, because the cockpit crew decided to don their oxygen masks, or one pilot was partially incapacitated. In very few cases the safety margin was reduced such that a high accident probability - in terms of the legal definition - existed.

¹ Subsequently referred to as fume event

There were clear indications of health impairments in terms of occupational health for flight and cabin crew. Individual reports indicated health impairments of passengers.

The BFU is of the opinion that compared to all reports a significant number affected the comfort of passengers only. These are reports which describe, for example, unpleasant but harmless smells.

In 10 of all fume events reported to the BFU, the reporting person reported long-term health impairments at a later date. All these incidents were fume events where either oil smell or "smell like old socks" were reported. In eight of these 10 cases the BFU learned that the reporting person is being medically treated.

With the current means and methods available for air accident investigation, it is not possible to investigate incidents which date back a while. The BFU is of the opinion that the principles of clinical toxicology would have to be applied to clarify a possible long-term effect of fume events.

The fume events taken into account in this study showed that no significant reduction of flight safety occurred. The study shows that fume events occur and can result in health impairments. With the methods of air accident investigation, the BFU cannot assess the possible long-term effects of fume events.

The German Federal Bureau of Aircraft Accident Investigation has issued four safety recommendations. They refer to:

- An improved identification and avoidance actions of cabin air contamination possibly hazardous to health.
- A standardised reporting procedure
- Improvement of the demonstration of compliance of cabin air quality during the certification process of transport aircraft
- Assessment of a possible conjunction between long-term health impairments and fume events by a qualified institution.

1. Initial Situation

1.1 Aim of the Study

For the last several years, flight crew, occupational unions, media, and political committees have increasingly been discussing fume events. The number of reports of such events the BFU receives has also increased. Fume events are occurrences which include smell, smoke or vapour inside the airplane and health impairments of occupants of transport aircraft.

By the investigation of the reported events with the available methods for the investigation of accidents and serious incidents the BFU encounters limits. On the one hand it is the high number of reports and on the other the possibilities to gather verifiable facts in a timely fashion are limited. The processing of these events has shown that in many of these cases access to data and evidence of possible technical malfunctions of aircraft systems and the compilation and assessment of medical data is either very limited or not possible at all.

Based on the received reports and the findings of investigation activities, it is the experience of the BFU that these fume events necessitate a differentiated examination. The spectrum regarding the importance and severity of the events ranges from harmless smells or slight smoke development to impairment due to eye or nose irritations, to impairment of the capability to act of flight crew (incapacitation) to the point of possible long-term impairment.

Based on this, the BFU decided to examine the topic in the scope of a study. The study is based on the Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and it summarises and analyses events which had been reported to and investigated by the BFU.

Aim of the study is:

- To describe the reports received by the BFU
- To explain the classification (accident, serious incident, incident)
- To describe individual cases based on the factual information
- To assess events in regard to
 - Relevance for flight safety
 - Occupational and environmental medical aspects
 - Comfort aspects
 - Possibly long-term health impairment
- To examine whether the cabin pressure control system and environmental control system play a part.
- To describe possible malfunctions of the cabin pressure control system and cabin climate control
- To identify possible safety deficits
- To explain the limitations of BFU investigation options

1.2 Task and Function of the BFU

The German Federal Bureau of Aircraft Accident Investigation (BFU) is subordinated to the Federal Ministry of Transport and Digital Infrastructure (BMVI). The BFU is responsible for the investigation of civil aircraft accidents and serious incidents within Germany and the identification of the cause.

The legal basis for the BFU is: Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, the Law Relating to the Investigation into Accidents and Incidents Associated with the Operation of Civil Aircraft (FIUUG) of 26 August 1998, and, regarding the notification of air accidents and incidents, Para 5 of the Air Traffic Order (LuftVO).

According to Regulation (EU) No 996/2010 Article 1 and FIUUG Para 3 the sole purpose of an investigation is the prevention of future accidents and incidents. It is not the purpose of this activity to assign blame or liability or to establish claims.

The regulations contain the following definitions:

Accident:

Means an occurrence associated with the operation of an aircraft which, [...] takes place between the time any person boards the aircraft with the intention of flight until such time as such persons have disembarked [...], in which:

1. a person is fatally or seriously injured as a result of:

- being in the aircraft, or,*
- direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or,*
- direct exposure to jet blast,*

except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew

or

2. the aircraft sustains damage or structural failure

- which adversely affects the structural strength, performance or flight characteristics of the aircraft, and*
- would normally require major repair or replacement of the affected component,*

except for engine failure or damage, when the damage is limited to a single engine (including its cowlings or accessories), to propellers, wing tips, antennas, [...] tyres, brakes, wheels, fairings, [...] or minor damages [...] resulting from hail or bird strike [...]; or

3. the aircraft is missing or is completely inaccessible

Serious Incident:

Means an incident involving circumstances indicating that there was a high probability of an accident [...].

Incident (FIUUG):

Means an occurrence, other than an accident, associate with the operation of an aircraft which affects or could affect the safety of operation.

Fatal Injury:

Means an injury which is sustained by a person in an accident and which results in his/her death directly in the accident or within 30 days of the date of the accident.

Serious Injury:

Means an injury which is sustained by a person in an accident and which involves one of the following:

- 1. hospitalisation for more than 48 hours, commencing within 7 days from the date the injury was received*
- 2. a fracture of any bone (except simple fractures of fingers, toes, or nose)*
- 3. lacerations which cause severe haemorrhage, nerve, muscle or tendon damage*
- 4. injury to any internal organ*
- 5. second and third degree burns, or any burns affecting more than 5% of the body surface*
- 6. verified exposure to infectious substances or harmful radiation.*

According to Regulation (EU) No 996/2010 Article 5 and FIUUG Para 3 accidents and serious incidents are subject to investigation by BFU. FIUUG Para 3 Subpara 4 allows the investigation of incidents if the BFU expects important findings for flight safety.

The sole objective of all investigations by the BFU is the prevention of future accidents.

In accordance with FIUUG Para 18 the BFU publishes an investigation report which, in its form, is appropriate to the kind and severity of the occurrence. In respect of the anonymity of the persons involved in the accident or incident, the report will supply information about the details of the course of the accident/incident, the aircraft involved, the external circumstances, the results of investigation actions and expertise, adverse effects on the investigations and the reasons, the evaluation of all results and the determination of the causes or the probable causes of the accident or incident.

If appropriate, the report will contain safety recommendations in accordance with Para 19 FIUUG.

Accidents and incidents for which the investigation results are not of special importance to flight safety, will be closed with a summary investigation report in accordance with Para 18 (4) (5) FIUUG. The summary report will only supply information about the aircraft involved in the accident or incident and the history of the flight.

In accordance with Regulation (EU) No 996/2010 Article 17 the BFU may issue safety recommendations on the basis of studies or analysis of a series of investigations or any other activities.

The methods of the BFU are to determine facts concerning a specific occurrence, which are then analysed. The analysis determines the cause.

Part of determining the facts is finding answers to the following questions:

- What has happened?
- Who has taken which actions on what basis (manuals, procedures)?
- Which role played the airplane or the airplane's systems?
- Which role played conditions such as weather, air traffic service providers, airports, etc.?

During the analysis of the facts, the actions of persons involved and the functionality of technical systems are assessed. Key aspects are the following questions:

- Why have errors occurred?
- Were the stipulated procedures sufficient?
- Has a technical system, such as the airplane, systems, etc., functioned as designed?
- Was the system sufficiently fault-tolerant?
- Were the requirements for development, manufacture and type certification of the airplane sufficient?

The regular mode of operation of an investigation authority is also applied to fume events. During the classification process of an occurrence as accident, serious incident or incident it is determined which impairments the flight crew, the cabin crew and the passengers have suffered.

If there are verifiable facts, it is determined whether the system, regulating the pressurized cabin and the cabin climate, has functioned properly and how and why the air was contaminated.

During the analysis comparison with the stipulations is made:

- Certification Specifications for the airplane (e.g. CS-25)
- Supplemental material for the type certification process
- Standards and norms

1.3 Occurrence Reporting

Based on the national Air Traffic Order (LuftVO) and the Regulation (EU) No 996/2010 air accidents and incidents associated with the operation of aircraft are reported to the BFU.

Reports in accordance with Para 5 Air Traffic Order (LuftVO)

According to Para 5 of the Air Traffic Order (LuftVO)² the pilot in command has to immediately report to the BFU accidents and serious incidents associated with the operation of civilian aircraft. If he cannot do so, another crew member has to report accidents or, if no one can do so, the operator.

This shall also apply to accidents and serious incidents outside Germany involving German or foreign aircraft which, at the time of the incident, are operated by German air carriers based on an operator agreement.

As soon as an accident or a serious incident becomes known, the aviation supervision offices, the Flugleiter (a person required by German regulation at uncontrolled aerodromes to provide aerodrome information service to pilots), and the air navigation services units are under obligation to inform the German Federal Bureau of Aircraft Accident Investigation (BFU) without delay.

The requirement to file reports to the Luftfahrt-Bundesamt (German civil aviation authority, LBA) as well as other aeronautical authorities in keeping with other provisions or requirements shall remain unaffected. For example, reports of safety-relevant incidents in accordance with Para 5b of the Air Traffic Order (LuftVO).

Reports in accordance with Regulation (EU) No 996/2010

² Complete regulation text: Para 5 Air Traffic Order (LuftVO)

According to Article 9 of Regulation (EU) No 996/2010 any person involved in the occurrence of an accident or serious incident shall notify without delay the competent safety investigation authority of the State of Occurrence thereof.

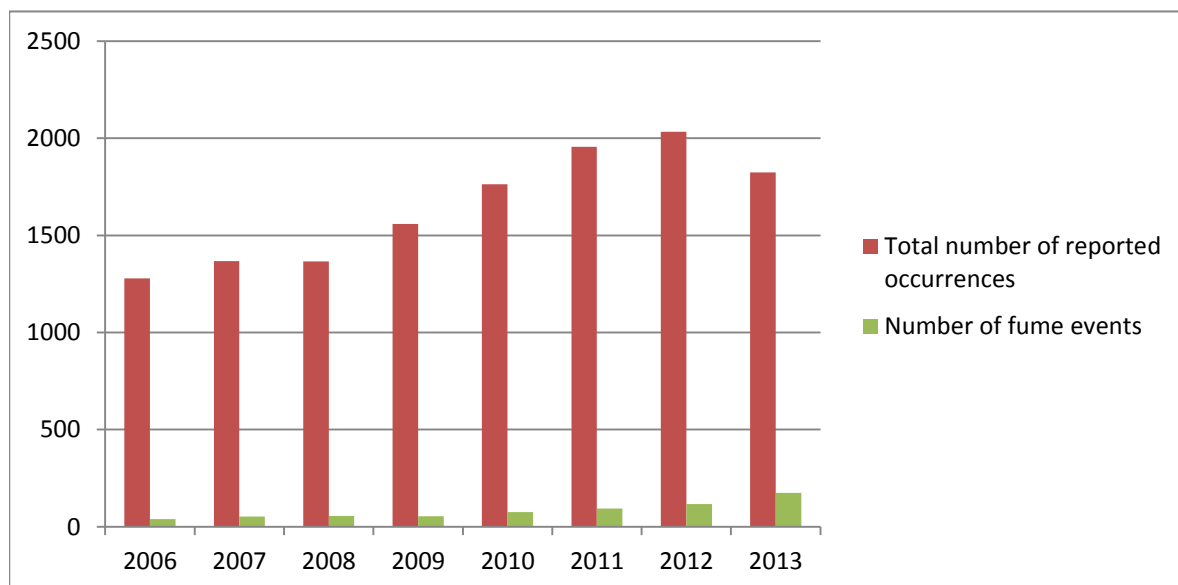
Article 2 (11) of the Regulation (EU) No 996/2010 defines: "person involved"³ means [...], a member of the crew, [...].

1.3.1 Reported Occurrences (2006 to 2013)

Given the above-mentioned definitions and reporting obligations, a total of 12,829 occurrences have been reported to the BFU between 2006 and 2013. Categories:

- 2,259 Accidents (all aircraft)
- 362 Serious incidents (transport aircraft)
- 10,208 Non-reportable incidents

These reports include all BFU activities. They also include national and international occurrences and those of the General Aviation.



Fume events compared to total number of reported occurrences

³ Complete regulation text: Article 2 (11) EU Regulation No 996/2010

1.3.2 Occurrences taken into Consideration (2006 to 2013)

This study took occurrences into consideration which were related to:

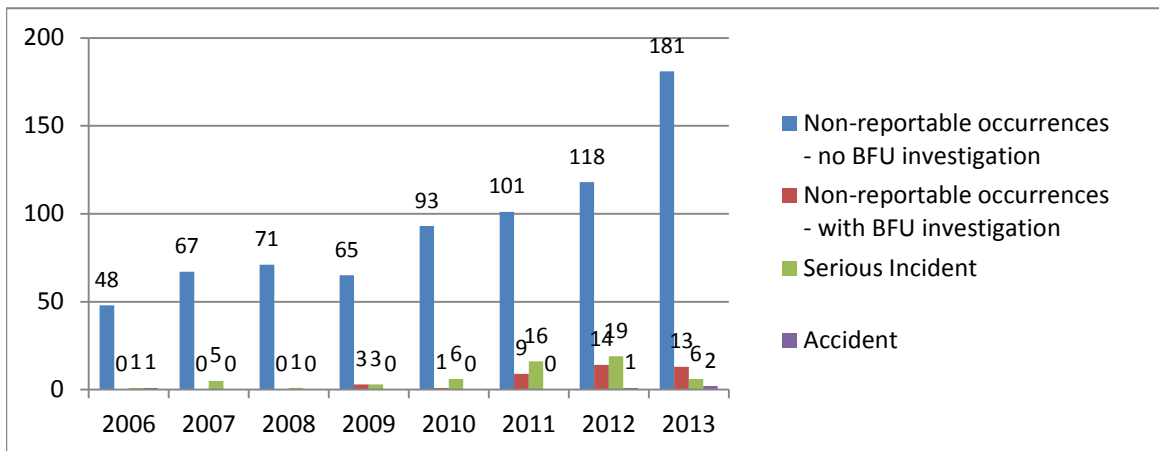
- Smoke
- Smell
- Specific symptoms of aircraft occupants

Cases which only had an indirect conjunction with fume events were also considered. Such as:

- After engine start-up a fire occurred in an AN 12 in Leipzig, and an accident with a Falcon 20 with massive smoke development after a pyrotechnical signal had been triggered in the cabin
- Fire
- Steam in the cockpit
- Metallic smell and sparking coming from the air condition shortly after take-off

Given the consideration mentioned above, between 2006 and 2013, the BFU received 845 occurrences involving transport aircraft. Four of these occurrences were classified as accidents and 57 as serious incidents. In the same time period, 784 non-reportable occurrences were reported. The BFU has initiated an investigation in 40 of these cases, because, based on Para 3 Subpara 4 FIUUG, important insights for the explanation of accidents and serious incidents could be expected.

These events occurred between 2006 and 2013 and were classified as follows:



Categories of reports between 2003 and 2013 included in the study

A total of 845 reports are included in this study; 663 of them were connected to cabin air quality. In 180 reports, health impairments were described although there could not be a conjunction with cabin air quality. In one case a fire occurred in an airplane at the apron and in another there were flying sparks and smell development due to a defective fan.

1.3.3 Reports of Fume Events

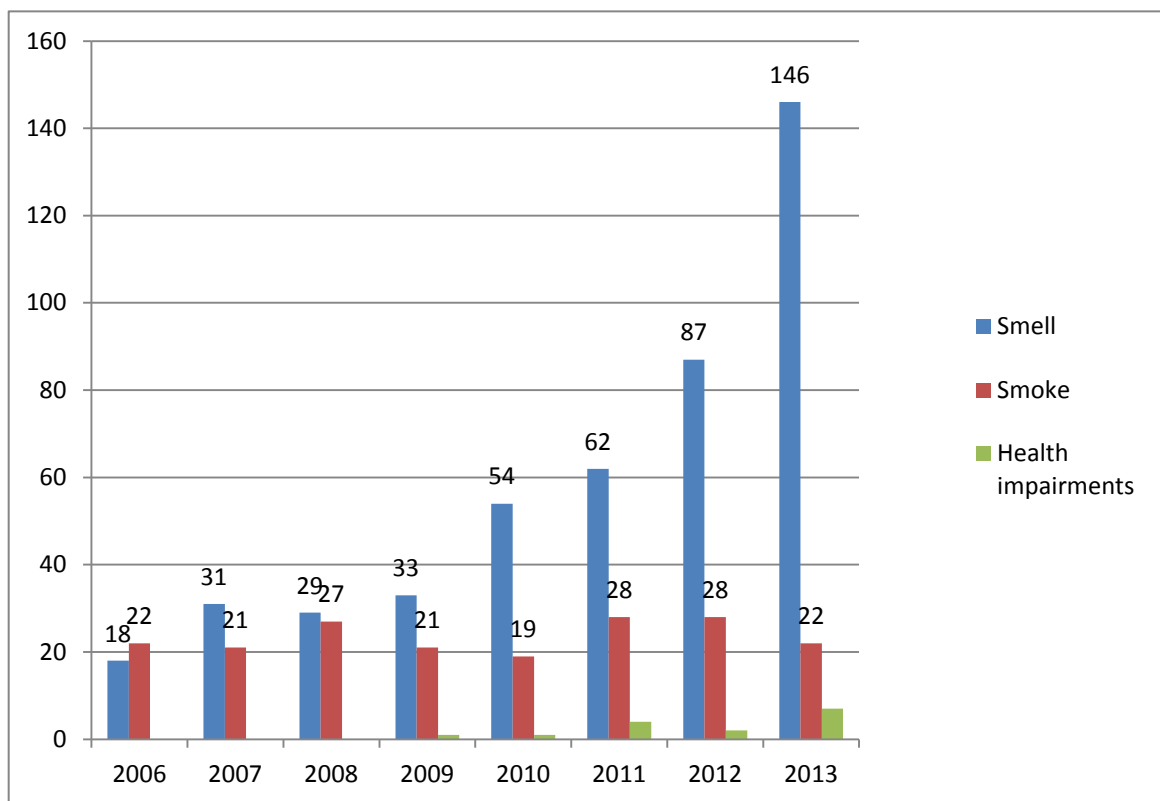
ICAO Annex 13, Regulation (EU) No 996/2010 or the FIUUG do not have legal definitions for fume events. In this study the BFU subsumes occurrences under the phrase fume events where there was smoke or smell in the cockpit or cabin. In addition, occurrences without smoke or smell were taken into consideration if certain symptoms such as indisposition, headaches, light-headedness, tremor, etc. occurred.

Not taken into consideration were symptoms, injuries or illnesses which could verifiably or clearly not be linked to contaminated cabin air. For example, passenger illness or crew incapacitation due to heart attack, stroke, gastro-intestinal disease, etc.

In accordance with the legal definitions in ICAO Annex 13, Regulation (EU) No 996/2010 and the FIUUG, the BFU categorises occurrences as accident or serious incident or incident. The decision diagram (Appendix 5.1) depicts the BFU internal decision making process for the classification and the request for necessary supporting documents.

A total of 663 fume events were reported during the period under review. In 460 of them smell and in 188 smoke was reported. In 15 cases there was neither smell nor smoke but there were certain health impairments which may possibly have a conjunction with a fume event.

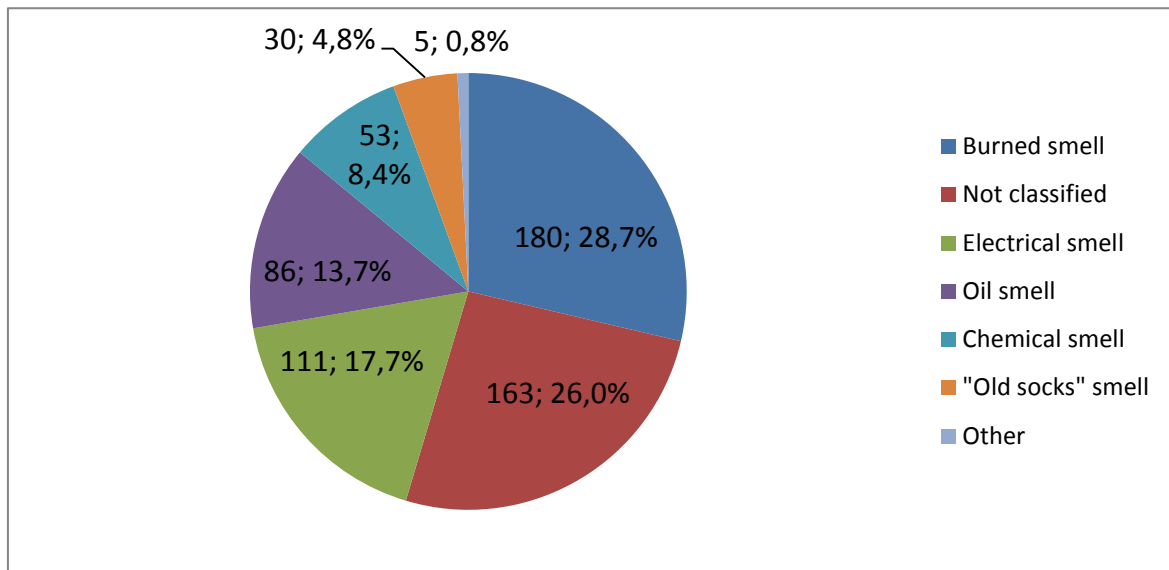
The break-down of the reports classified as fume events reported between 2006 and 2013:



Reports with smell, smoke, health impairments

Description of Smoke and Smell

Smoke and smell had occurred in 648 cases. In 628 cases the description of the smell was more elaborate.

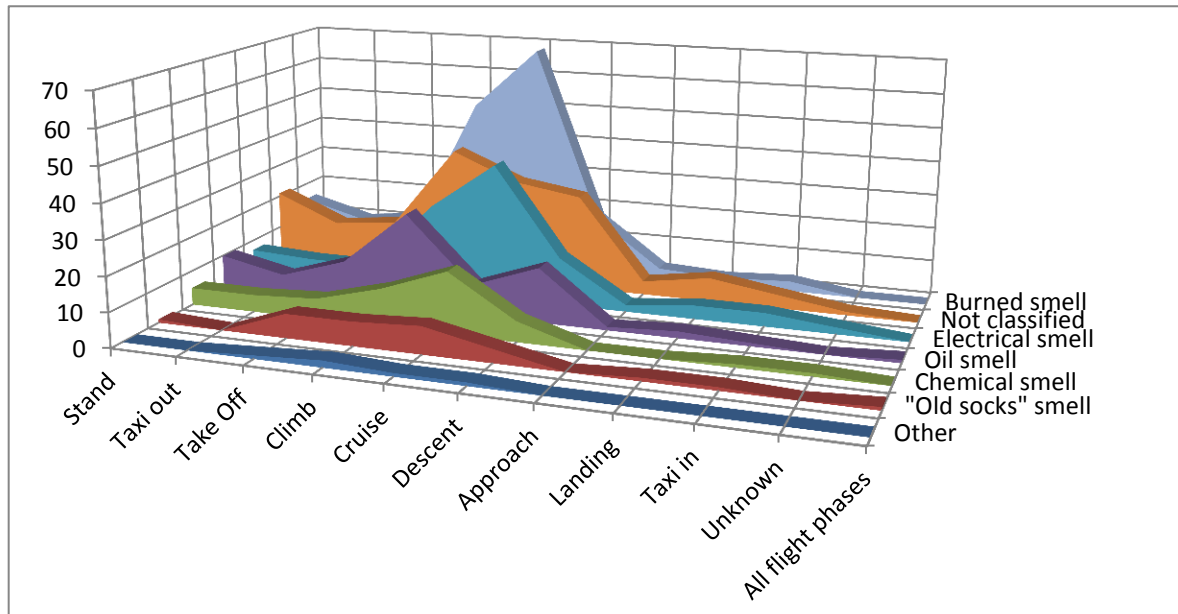


Descriptions of the smells in the reports

Descriptions of Smoke and Smell Associated with Certain Flight Phases

In 624 fume event reports a flight phase was associated with the occurrence of smell or smoke. In two reports all flight phases were listed. 163 of the events occurred during climb and 175 of them in cruise flight. 86 occurrences were linked to a descent. Ten events occurred during the approach and 16 during the landing. 40 events occurred while taxiing prior to take-off and 14 occurred while taxiing after landing. 59 each occurred while standing and during take-off.

The break down for the time period 2006 - 2013 was:

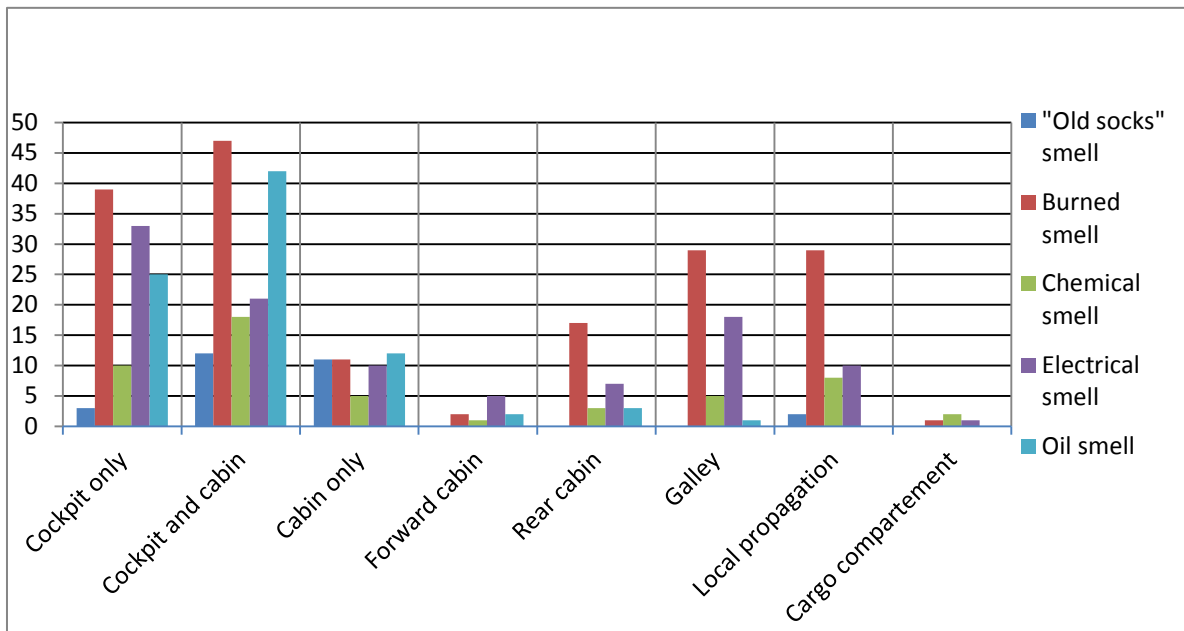


Smell and smoke development associated with flight phases

Sources of Smoke and Smell

A total of 445 statements answered the question of the source of the smell: 140 the cockpit and cabin, 110 cockpit only, 53 galley, 49 cabin only, 10 front cabin, and 30 aft cabin. Four stated the cargo compartment as source and 49 said propagation was "local".

In some reports several persons had been in different areas of the airplane. In these cases the information relating to the larger propagation of smoke or smell was taken into consideration.



Smoke and smell associated with their sources

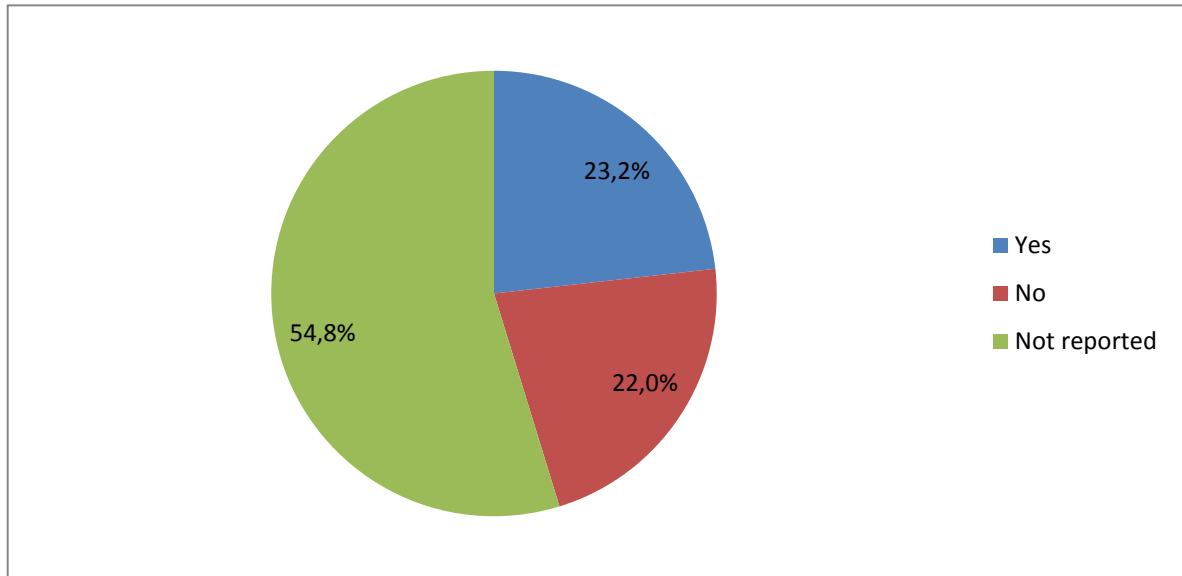
Multiple Reports of Fume Events Involving Individual Airplanes

Between 2006 and 2013, a total of 462 different airplanes were involved. Based on the registration one airplane had a total of 12 reports, one with 8, four with 5, eleven with 4, 30 with 3, 67 with two and 349 with one report each. In seven reports the registration was not given.

Of the 462 airplanes, 357 had German and 105 foreign registrations.

Use of Oxygen Masks

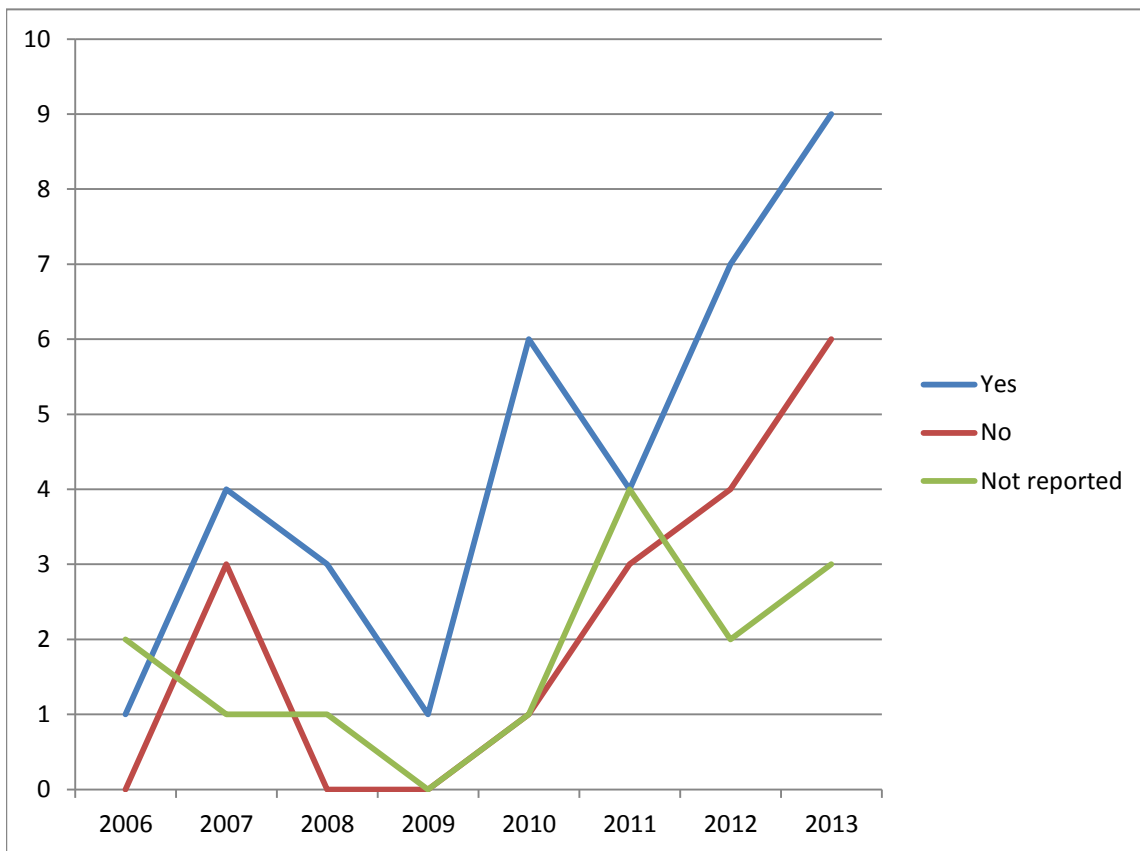
The 663 reports (between 2006 and 2013) were analysed in regard to the flight crew donning their oxygen masks. The results are: in 154 cases the masks were donned and in 146 they were not. In 363 cases the reports did not include any information regarding oxygen masks. Break down in percent:



Analysis of the reports regarding the use of oxygen masks in the cockpit

Use of Oxygen Masks Due to Health Impairments

One or both pilots donned their oxygen masks in 35 cases due to health impairments. The reports of 17 events stated that the oxygen masks were not donned. In 14 fume events where health impairments of pilots had been reported, the BFU does not have any information, whether the pilots donned their oxygen masks.

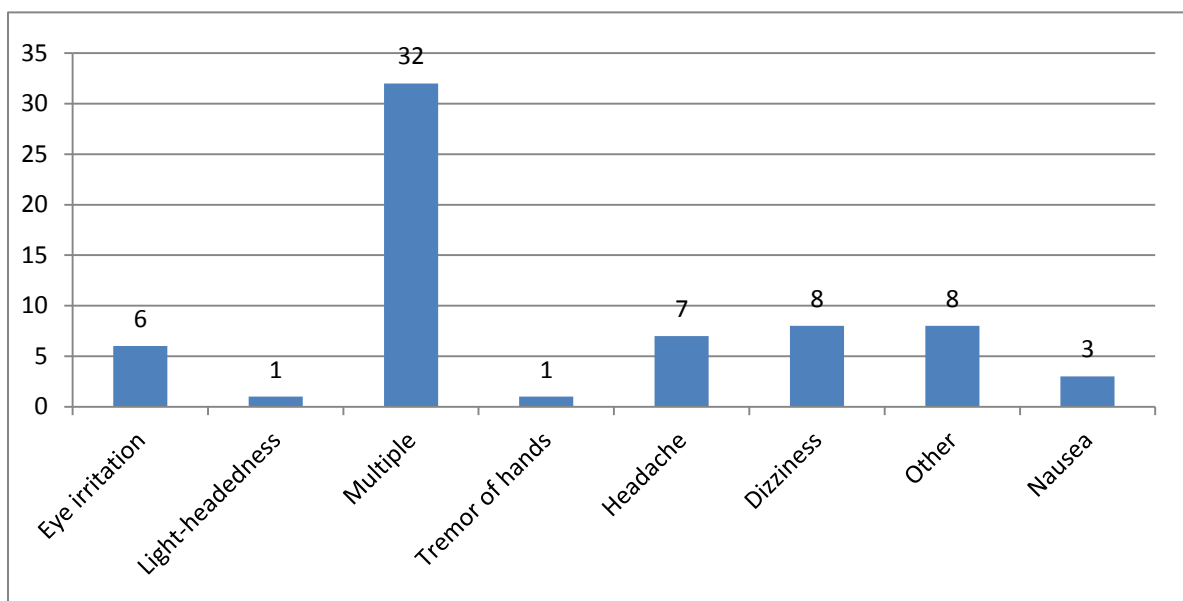


Number of cases where oxygen masks were worn in the cockpit due to health impairments

After the BFU had assessed the facts, it had become apparent that in six cases donning the oxygen masks had been imperative (accident or serious incident).

Health Impairments of Pilots

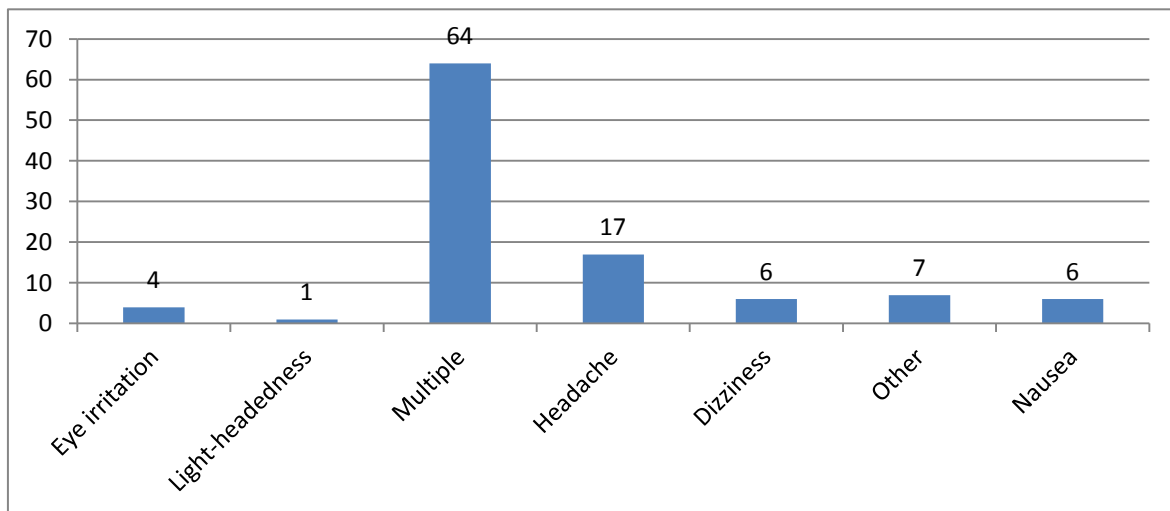
The health impairments of pilots described in 66 reports were: Eye irritation, light-headedness, tremor, headaches, dizziness and nausea. Cases where several of the above-mentioned impairments were reported were subsumed under multiple impairments. Impairments which were not specified were subsumed under "other". The break down was:



Description of the health impairments of pilots

Health Impairments of Cabin Crew

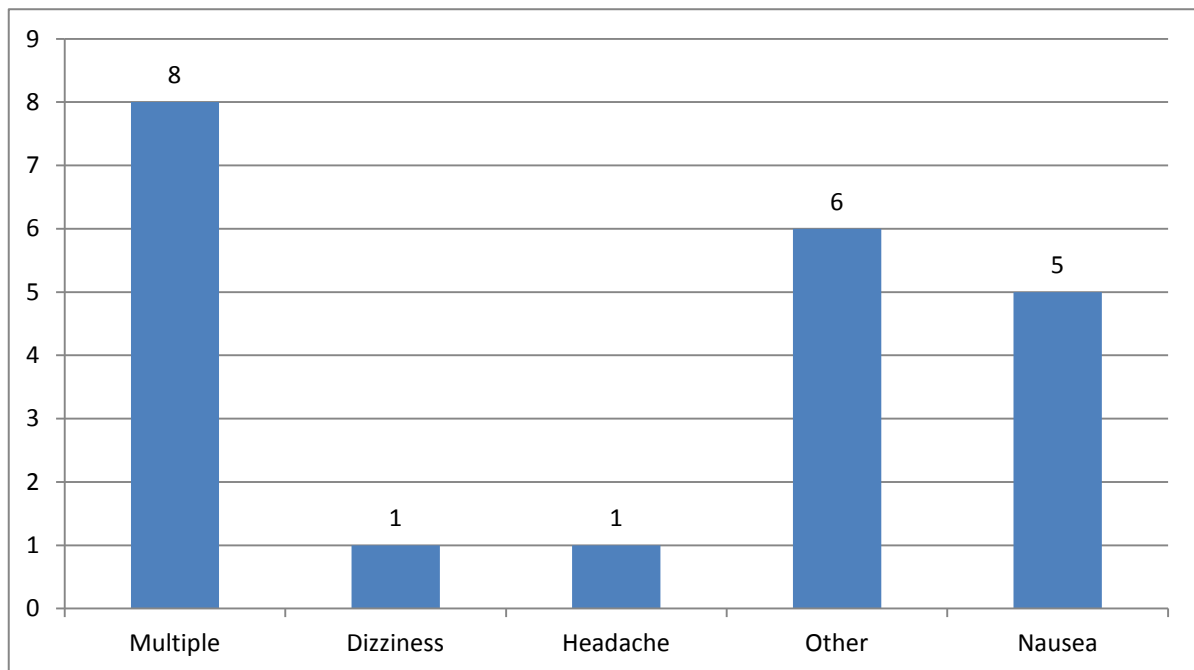
The health impairments described by 105 cabin crew were: Eye irritation, light-headedness, headaches, dizziness and nausea. Cases where several of the above-mentioned impairments were reported were subsumed under multiple impairments. Impairments which were not specified were subsumed under "other". The break down was:



Description of the health impairments of cabin crew

Health Impairments of Passengers

The 21 passengers described their health impairments as: Headaches, dizziness, and nausea. Cases where several of the above-mentioned impairments were reported were subsumed under multiple impairments. Impairments which were not specified were subsumed under "other". The break down was:



Description of the health impairments of passengers

Technical Causes

With some fume event reports technical causes were transmitted. If an investigation was initiated the BFU scrutinised these technical causes. In any other cases the content of the reports was adopted.

System	Number	Examples
APU	24	Oil, de-icing fluid
Avionics	13	Fan
Fire	9	
ECS	23	Fan
Electrical systems	33	Fan, other components
Electrical system of the cabin	21	Lights
external contamination	11	Dry ice, cigarettes, luggage
Coffee machine	11	Contamination / defect
ovens	24	Contaminations of foreign objects
System error	9	Leakages of hydraulic and fuel lines
Import of technical compounds	8	Glue, de-icing fluid
Engine	13	
Engine - washing	11	
Engine - oil overfill	3	
Engine - bird strike	10	
Other	5	Cannot be correlated to one of the above-mentioned groups
Not determined	42	
Unknown	386	
None	3	

Transmitted technical causes

Source: BFU

1.3.4 Accidents

Accident Involving a Dassault Falcon 20

During cruise flight, a fire in the cabin of the airplane developed because a pyrotechnical emergency signal had inadvertently been triggered. The crew decided to conduct an emergency landing at Kiel-Holtenau Airport. During the landing roll the aircraft overshoot runway 08 and came to rest on the adjacent slope.

The flight attendant sustained severe injuries, the other five occupants suffered minor injuries.

Accident Involving an Avions de Transport Régional ATR 72-500

The Pilot in Command (PIC) stated, one of the flight attendants reported smoke and a burnt plastic smell in the cabin. The flight crew stated, that as they completed the Emergency Checklist Smoke an "explosion" occurred in the right engine. Immediately afterwards the fire warning for engine No 2 was illuminated in the cockpit. The cockpit crew shut down engine No 2 and 10 seconds after the warning had been triggered, the first fire extinguisher bottle was emptied. After the extinguishing agent had been released the fire warning ceased.

The pilots stabilised the aircraft in single-engine operation, declared emergency, and returned to Munich.

During the landing on runway 26L the airplane veered left off the runway and came to rest approximately 300 m south of the runway.

Five persons sustained minor injuries and the airplane was severely damaged.

The investigation by the BFU is still in progress.

Accident Involving an Antonov / AN-12 BK

At 0201 hrs, prior to the take-off in Leipzig for a flight to Mineralye Vody, Russia, the Auxiliary Power Unit (APU) was started after engine start-up clearance had been received. After the APU was running, engine No 1, outer left, was started. Once engine No 1 had reached idle speed the start-up for engine No 4, outer right, was begun. During the start-up of engine No 4 the crew heard a dull bang. The co-pilot, who monitors the APU instruments during engine start-up, had observed rotary

speed oscillations and a temperature rise. Shortly afterwards, the APU fire warning indication illuminated. The crew shut off the two already running engines and triggered the APU fire extinguisher system.

The fire destroyed the airplane. Persons were not injured.

The investigation by the BFU is still in progress.

Accident Involving a Boeing 757

The airplane was on a flight from Hamburg, Germany, to Gran Canaria, Spain. During the landing in Las Palmas, Spain, severe smell development in the airplane occurred. The co-pilot donned his oxygen mask because he noticed symptoms. Three cabin crew members also felt severely affected. The subsequent landing occurred without incident. During the preparations for the return flight and prior to boarding, an engine run-up was conducted during which the cabin crew should be at their stations. As the APU was switched on the cabin crew once again noticed the smell. Due to their symptoms two flight attendants and the co-pilot were taken to a hospital. One crew member entered inpatient health care for further diagnosis and treatment after returning to Hamburg.

The Spanish accident investigation authority classified the occurrence as accident due to the inpatient health care of more than 48 hours. The investigation is still in progress.

1.3.5 Examples of Serious Incidents

Serious Incident Involving an A319

Synopsis:

On a flight from Vienna, Austria, to Köln-Bonn, Germany, both pilots noticed an intense and abnormal smell while turning on to the base leg. During intercept of the extended runway centre line for a landing on runway 14L, both pilots noticed a significant adverse effect on their physical and cognitive performance. They donned their oxygen masks and declared emergency. After the landing, both pilots received medical treatment. The co-pilot's CK Creatine Kinase blood level was unusually high.

Investigation:

The investigation by the BFU has confirmed that in the cockpit area a massive smell development occurred; source and propagation could not be determined.

Serious Incident Involving a Boeing 737-700

Synopsis:

Strong smell occurred in the cabin during "turn-around" on the ground and cruise flight.

Later, three crew members could function only to a limited extent.

Investigation:

The crew described the occurrence during an interview as follows:

Prior to take-off at London Gatwick Airport intense smell developed which the crew described as "toxic smelling". Since at that time the APU was supplying the airplane's environmental control system with power the crew suspected it to be the source of the smell. Because the smell seemed to decrease during taxi the flight crew decided to take off and fly back to Nuremberg.

During cruise flight the smell (intense, unpleasant, acrid) appeared again in the cabin. The pilot in command inspected the cabin to get an impression of the intensity of the smell, which, at that time, was not very intense but clearly noticeable. Flight attendants complained of prickling in their limbs, weakness in their legs, strong headaches, dizziness, problems with their concentration, burning eyes, and difficulties swallowing. On his way back to the cockpit, the pilot in command noticed unexpected physiological symptoms: he felt drunk, had weak knees, a headache, his hands shook and felt numb, he felt a strong fatigue, he could no longer concentrate, his left hand and lower arm turned yellow and felt anaemic and cold.

Both pilots decided to continue the flight to Nuremberg and not deviate to Frankfurt because the traffic there was very heavy and there were only 18 minutes left before they would start descent to Nuremberg.

Even though the smell was not noticeable in the cockpit, the pilot decided to don his oxygen mask from time to time because he would suddenly feel very tired and lacked concentration during the descent. The co-pilot did not complain of symptoms, did not don his oxygen mask, and landed the airplane at the arrival aerodrome.

After the landing, the entire crew went to the Aeromedical Center of the airport to receive medical examination and have blood samples taken.

The pilot in command stated that the blood tests of all five crew members showed positive values in the so-called Nebraska Test.

The uniform shirt of one crew member was tested for Tricresyl phosphate. A laboratory determined a TCP value of 93.1 ng/l.

After the flight, two crew members were unfit to work for one week, one for more than one month. Another crew member had a similar experience 11 days later with the same airplane. He subsequently fell ill, became unfit to fly and work. He was diagnosed with "liver insufficiency due to intoxication".

The operator stated that the technical inspection of the airplane did not result in any indications for the source of the smell. On the day after the incident, the interior of the airplane was analysed using an Aerotracer, but did not result in any indication of harmful substances in the air. In addition, the maintenance actions stipulated by the manufacturer after smell had occurred were conducted and the insulation, lavatories and boilers were inspected. One boiler was replaced due to electrical smell.

The operator stated that one day later another smell event with the same airplane was reported. This time the auxiliary power unit was in use. The subsequent technical inspection revealed oil deposits in the load compressor of the APU.

Serious Incident Involving a Boeing 757-200

During the initial climb the crew noticed chemical smell. Once the pilots experienced headaches, they donned their oxygen masks. During cruise flight they removed their masks and continued the flight as planned.

The day after, the airplane was inspected by the operator's maintenance organisation. Oil residues were found in both engines in the area of the spinners and the anti-ice tubes.

Serious Incident Involving an Embraer 190

Synopsis:

Shortly after take-off a strong smell, which was described as "sweaty feet" was noticed in the cabin. Afterwards, some passengers and flight attendants complained of sudden headaches. After the co-pilot had been in the cabin for a short period of time and then also complained of a sudden headache and donned his oxygen mask, the pilot in command decided to check on the situation himself. Shortly afterwards, he too felt indisposed. The two pilots declared emergency and conducted a precautionary landing in Linz, Austria, while wearing oxygen masks.

All five crew members went to a hospital to receive medical examination. Two crew members did not feel fit to work after the incident.

The operator stated that the subsequent technical inspection did not reveal any irregularities.

Serious Incident Involving a Boeing 757-300

During take-off run at approximately 130 kt at Frankfurt/Main Airport the crew noticed a pungent smell. Due to the speed take-off was not aborted. During climb the smell also occurred in the cabin. The pilots decided to return to Frankfurt after both had noticed prickling in their limbs and gums. Both donned their oxygen masks. The approach and the overweight landing occurred without incident.

After the landing, the fire brigade checked the airplane on the taxiway. The air in the aircraft interior was checked also but resulted in no findings. The maintenance organisation inspected the aircraft and determined that the oil reservoir of the right engine was overfilled by two Quarts.

Since cabin crew members had also experienced symptoms such as headaches, grey haze in front of their eyes, and/or prickling in hand and teeth, all nine crew members sought medical treatment in the airport hospital where urine and blood samples were taken. The BFU did not receive any results.

Serious Incident Involving a Boeing 737-800

The airplane took-off from Hanover Airport for a flight to Köln-Bonn and a later leg to Gaziantep, Turkey. Six crew members and 196 passengers were aboard the airplane.

During climb after take-off in Hanover smell was noticed in the cabin. The pilot in command was informed accordingly. The flight was continued in Flight Level (FL) 200 cleared as cruising altitude. The pilot in command described the flight as free of incidents.

During touch-down the senior cabin crew member noticed increased smoke development at one of the over-wing emergency exits. However, it was difficult for her to differentiate between smoke, steam and vapour. She described the smell as acrid and foul, among others, which "had hit her lungs".

Nine seconds after touch-down - at approximately 100 kt - the pilot in command noticed black smoke entering the cockpit via the fresh air intakes and turned both air-conditioning packs off. Subsequently, he noticed a decrease in smoke. The co-pilot noticed the beginning "greyish" smoke development after touch-down and the decrease after the air-conditioning packs had been shut off. Both air-conditioning packs were shut off 47 seconds after touch-down. During taxiing the co-pilot opened the cockpit window on his side so that the remaining smoke or gas, respectively, could leave the cockpit.

In the cabin, the senior cabin crew member experienced arising "extreme unrest" among the passengers some of which got up and were "shouting". Above the seats A and C in row 13 the panels for the oxygen masks were pounded open so that the masks fell out. The pilot in command taxied the airplane to the assigned parking position D9 and the passengers disembarked via the stairs.

Eleven persons sustained minor injuries.

It was determined that the hydraulic oil was overfilled and a valve had malfunctioned.

The investigation by the BFU is still in progress.

1.3.6 Examples of Non-Reportable Incidents the BFU Investigates (Incidents)

Note:

These examples were chosen to show the different types of reports and event descriptions.

Incident Involving an Airbus A 330-200

Synopsis:

Shortly after take-off, smoke in combination with unpleasant smell developed in the cockpit and the front part of the cabin. It decreased during the flight and intensified again during the approach.

The crew complained of headaches, coughing, hoarseness, problems with concentration, dizziness, problems swallowing and slight numbness in the finger tips.

Investigation:

Once the investigation was initiated the interview revealed the following:

On a flight from New York to Berlin, vapour developed in combination with burnt oil smell during climb and descent. Both pilots felt slight dizziness and their fingertips felt numb. All cabin crew members in the front part of the cabin experienced strong headaches, nausea, dizziness, sore throats, problems swallowing, problems with concentration and finding words. In the aft part of the cabin the smell was noticeable also but less intense. The passengers did not complain. The crew described the behaviour of the passengers as "unusually quiet". Because the smell had become less intense once cruise level was reached, the pilots decided to continue the flight. As 7,000 ft were passed during the approach, the strong smell occurred again and remained until the landing.

After the landing, the entire crew went to a hospital to receive medical examination. Blood and urine samples of all crew members were tested. According to the diagnostic procedures, the values were inconspicuous.

On the subsequent days, all crew members complained about having sore throats. One crew member was in hospital for 48 hours and 45 minutes after the incident and another crew member had been unfit to work for nine days. Three crew members stated that they experience symptoms even today. These include slight headaches,

high blood pressure and limited physical performance. Two cabin crew members stated that they did not have any persisting symptoms. The BFU does not have the statements of two other cabin crew members.

After the incident the airplane was flown as ferry flight from Berlin to Düsseldorf for maintenance work. The two pilots on the ferry flight did not use bleed air from engine No 1. After an extensive visual inspection of the right engine they decided to just use the bleed air of that engine and of the APU. During the ferry flight there was no unusual smell in the airplane.

The operator stated that the incident was caused by bearing seal deterioration in the front bearing compartment. It is probable that engine oil has entered the aircraft interior via the bleed air. The operator stated the engine was technically sound but as precautionary action it was changed.

The BFU has classified this occurrence as incident because the hospital time of 48 hours and 45 minutes was largely due to diagnostic procedures.

Serious Incident Involving an A319

The incident described below, occurred a total of three times. A Para 5 Air Traffic Order report was filed after the second event.

Report of 15 October 20xx:

2. Fume Event (1. on 9 October) with the same airplane.

Investigation:

On enquiry by the BFU investigator on duty, the operator stated, in both incidents there had been no health impairments and the incident had been reported to the Luftfahrt-Bundesamt (LBA) in accordance with Para 5b of the Air Traffic Order (LuftVO).

After the third event with the same airplane, the operator reported to the BFU that one crew member had sought medical treatment immediately after the event. The blood test revealed a Methaemoglobin level of 22% which should be below 1% according to the medical doctor. Based on a classification pattern, the physician described the increased level as "moderate impairment". This and other crew members had described the following symptoms: eye irritation, nausea, prickling in finger tips, and light-headedness.

The operator initiated a technical inspection of the airplane which revealed traces of hydraulic oil on the right side of the aft fuselage. Using an Aerotracer the cabin air was tested for contamination but revealed no findings. During a maintenance flight there were neither symptoms nor abnormal values.

In the following days, the BFU received Para 5 Air Traffic Order reports from four crew members with different detailed descriptions of the incident. All reported a strong chemically sweet smell. Symptoms were described as light-headedness, imbalance, reduced motor function, and headaches.

Approximately four weeks after the occurrence, the BFU sent the questionnaire cabin air to five crew members. The five replies showed that during the first fume event, headaches and slight dizziness had occurred but not any severe symptoms. One crew member had a blood test done. The examination results were normal.

In regard to the fume event which had taken place two days later, the BFU sent the questionnaire about three weeks later to five crew members. The BFU received one answer which contained the symptom eye irritation. Other symptoms were not described.

The third fume event involving the same airplane occurred 13 days after the first. The BFU sent out five questionnaires and received three answers. They stated that neither smell nor noticeable smoke had occurred. Three crew members reported eye and nose irritations and indisposition. One crew member stated that he had had slight difficulties to perform his tasks. One flight crew member's blood test result showed a Methaemoglobin value of 22%. A follow-up blood test a few days later resulted in a normal value. The crew member in question told the BFU about eight weeks after the occurrence that he no longer had any health impairments.

1.3.7 Examples of Non-Reportable Incidents the BFU does not Investigate (Incidents)

Note:

These examples were chosen to show the different types of reports and event descriptions.

Non-Reportable Incident Involving a Boeing 737-800

Report:

Suspicious smell in cockpit.

Shortly after T/O suspicious smell was noticed by the cockpit crew for about 1 min. Then it disappeared for the rest of the flight.

Non-reportable Incident Involving an A320

On 14 October 20xx, the BFU received the Para 5 Air Traffic Order report regarding the fume event of 3 October 20xx.

Report:

"Determination of smell of oil and old socks."

The initial report did not contain any information which would have justified the initiation of an investigation by the BFU.

On 13 October 20xx, a crew member told the BFU that on 10 October 20xx he had sought medical treatment and had received the diagnosis "*Toxic effect of other not closer defined substances*" (ICD-10: T658). Since then he is unfit to fly and work.

The crew member described the course of events as follows:

On the day of the incident, the out-going cabin crew informed the in-coming crew of the flight from Berlin-Tegel to Frankfurt / Main that during the approach a smell of "oil and old socks" had occurred; it had especially been noticed on positions 2 and 3. The purser could not determine this smell after taking over the airplane. During the subsequent four domestic flights, he only noticed a metallic taste in his mouth and a smell which he associated with engine exhaust.

During the night after the flights, he woke and felt his entire skin prickling uncomfortably. His limbs felt numb. In the hope his symptoms would soon disappear he reported for duty the next day for a two-day tour. The next night, his symptoms returned and he also experienced pressure in his lungs in combination with laboured breathing. During the next day, he suffered from tinnitus in his left ear whose intensity varied. In addition, the muscles in his fingers, upper thighs and eye lids would twitch sporadically. After he had finished this rotation flight, his symptoms were gastrointestinal problems, continuous fatigue, and lacking concentration and lasted the entire four days he was off duty.

In accordance with Regulation (EU) No 996/2010 and the FIUUG the BFU classified this case as non-reportable incident. The BFU cannot assess a possible causal connection between the fume event and the illness.

Non-reportable Incident Involving an A380

Excerpt from the report of a cabin crew member:

Shortly after take-off in Frankfurt, several flight attendants noticed an unusual smell in the cabin (it could be described as "chemically sweaty feet"). I informed the cockpit crew about the smell. [...⁴] Maintenance advised to cut engine No 3 off from the bleed air - prior to take-off it had been cleaned and it is assumed that dirt residue is the cause. This action seemed to take care of the problem. During the landing in San Francisco the smell occurred again and the cockpit crew said that engine No 3 does not supply the cabin with air. The cockpit crew believed that engine No 3 was not the problem, that there must be another reason for the smell. The pilot in command asked maintenance about the neurotoxic substance TCP and enquired whether it could be the cause. Maintenance negated this. After the landing in San Francisco the pilot in command said the reason for the smell had not been engine No 3 as maintenance had said but rather a problem during which TCP had leaked.

Additional Information:

Several weeks after the occurrence, the BFU received the information that the affected flight attendant had become chronically ill and unfit to work.

Several medical results from different physicians were provided which attest to neurological findings and chronic fatigue. The blood test report of a physician specialising in occupational, social and environmental medicine, determined a value for Diphenylphosphate (U) which was three times as high as the reference value.

In accordance with Regulation (EU) No 996/2010 and the FIUUG the BFU classified this case as non-reportable incident. The BFU cannot assess a possible causal connection between the fume event and the illness.

⁴ Text not relevant for the course of events.

Non-Reportable Incident Involving a Boeing 737-800

Report:

During engine start-up, the crew smelled smoke without smoke emission. They asked the Tower to send the fire brigade.

When the fire brigade arrived there was no smell. Maintenance conducted a technical inspection.

Non-reportable Incident Involving a Bombardier DHC-8-402

Report:

During the de-icing process at the parking position, smoke developed in cockpit and cabin. The airplane was evacuated.

Aboard the airplane were 71 passengers and four crew members; three persons sustained minor injuries.

On enquiry by the BFU:

The enquiry with the operator and the fire brigade revealed that the APU had been switched on during the de-icing procedure, because there was no ground power unit. During the de-icing process, anti-ice agent entered cockpit and cabin via the air condition. The pilot in command decided to evacuate the passengers via the stairs. During the evacuation, two passengers sustained minor injuries.

Non-Reportable Incident Involving a Boeing 757-300

Report:

During the flight the crew smelled smoke (smoulder) in the area of the front galley, the source of which could not be determined. The flight crew decided to deviate to Munich and during the final approach until the parking position was reached, the crew wore their oxygen masks.

On enquiry by the BFU:

The fire brigade inspected the airplane with an infrared camera and identified a charred floor socket next to a door. Wearing the oxygen masks was a precautionary action.

Non-reportable Incident Involving an A319

Report:

First flight of the day for the crew and the airplane. Temperature about +8°C, no de-icing prior to the flight. The airplane is docked at a finger and the passengers are not yet aboard. The cabin crew is preparing the cabin. The flight crew is in the cockpit and turns the APU Bleed On. After about 15 seconds, the purserette enters the cockpit and reports smell in the cabin. I leave the cockpit to investigate. Entering the cabin I do not smell anything special. The two flight attendants are in the aft part of the airplane. I am going toward the middle of the airplane and both flight attendants report chlorine smell and that both of them had slight symptoms. Now I smell something unusual, too, but cannot define it as chlorine smell. At the same time, I feel very slight skin prickling. I return to the cockpit and turn the APU Bleed Off. The first officer and I go into the finger. The cabin crew is waiting there already. All of them reported congruently that all had smelled chlorine and experienced slight light-headedness. One flight attendant complained his eyes were watering. Inside the finger none of us has any symptoms. In the cockpit, the first officer did not smell anything or had any symptoms. I stop boarding and contact MCC.

After 10 minutes two technicians arrive. They turn the APU bleed on again, increase the temperature. Both do not smell anything unusual. They suggest setting the APU inop. The APU bleed is turned off again. Everyone, the technicians and the entire crew, meet in the galley to discuss the situation. I once again turn the APU Bleed On. Back in the galley, the cabin crew once again complains of smell and light-headedness. I do not smell anything, but have again a slight prickling in my body. The first officer and the two technicians do not feel anything unusual. I turn the APU Bleed Off and decide that we will not fly with this airplane. I once again ask the crew about their state of health. All of them feel well, have no symptoms, and are glad that this airplane is not going to be used. Crewing assigns a new flight to us.

I make entries into the WOB and turn the airplane off. Once we arrived at the new airplane, I enquire one more time how the crew is feeling. One flight attendant complains of slight indisposition and light pain in her neck. We decide that she will leave this tour and I inform Crewing. We prepare the airplane for departure. Unfortunately I only now remember the Fume Kit. We all meet in the front cabin area. I present the Fume Kit and read the first page. I have printed out excerpts of the Kit and distribute them. I emphasise that a consultation is optional and encourage

everyone that if in doubt he/she should choose this path. One flight attendant says she will do it. All other crew members do not want to exercise this option and want to do the flight.

[...]

The subsequent flight proceeded without incident. During the flight and afterwards I enquire about the state of health. All three of us are fine and we do not feel anything unusual.

Back at home, I try to contact the other two crew members so I can enquire about their state of health. One flight attendant reports that she had gone to the hospital emergency room as suggested in the Fume Kit. The examination did not result in any findings. The pain in her neck had disappeared during the afternoon and now she is fine. I reached the other flight attendant only the next morning. She told me, that she did not have any symptoms and was fine.

[...]

Note by BFU:

This report was chosen to explain the situation and the course of action of a flight crew during a fume event.

1.3.8 Facts for the Decision Making Process and the Investigation

Decision Making

As with all incident reports and investigations the BFU needs factual information regarding fume events for the decision making process and the classification as accident or serious incident. If the initial incident report does not contain sufficient information, the BFU investigator on duty will gather the necessary additional information so that the director of the BFU can classify the incident and decide whether or not an investigation will commence.

If an investigation will commence, an investigator in charge will be assigned. The investigator in charge will determine content and extent of the investigation and gathers additional facts.

Generally, the following facts are required for the decision making process concerning fume events:

- Were persons aboard the airplane severely injured
- Was there pilot incapacitation
- Were the oxygen masks donned and was doing so imperative
- Was there fire aboard

With the initiation of an investigation additional descriptions and information are required: course of the flight, course of the incident, was the planned flight aborted or continued, smoke or smell development, health impairment, and minor injuries.

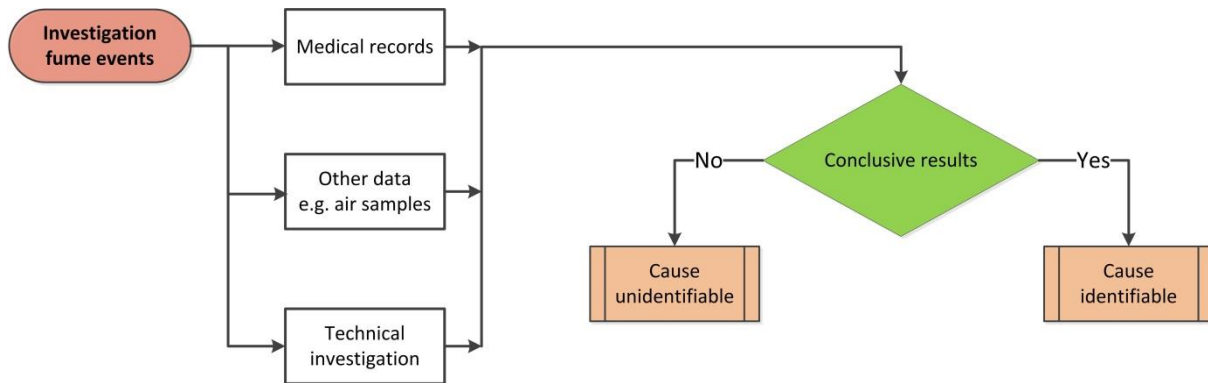
Appendix 5.1 depicts the decision making process.

In the third quarter of 2013, the BFU introduced a questionnaire, which is send to persons involved by the investigator on duty, if there are indications of health impairments. The legal basis for such questions is the Regulation (EU) No 996/2010 and the FIUUG. The BFU normally receives the necessary addresses, e-mail addresses or telephone numbers through the operator based on the above-mentioned legal foundation.

Investigation

Depending on the case, additional information is necessary:

- Medical data
 - Data from First Aid
 - Physician's reports and hospital records
 - Laboratory results
- Other data
- Data concerning cabin air at the time of the incident (generally there are none)
- Results of technical inspections of the airplane
- Subjective data (interviews)
- Objective data (CVR, FDR)
- General information (as is the case in any other accident or serious incident)

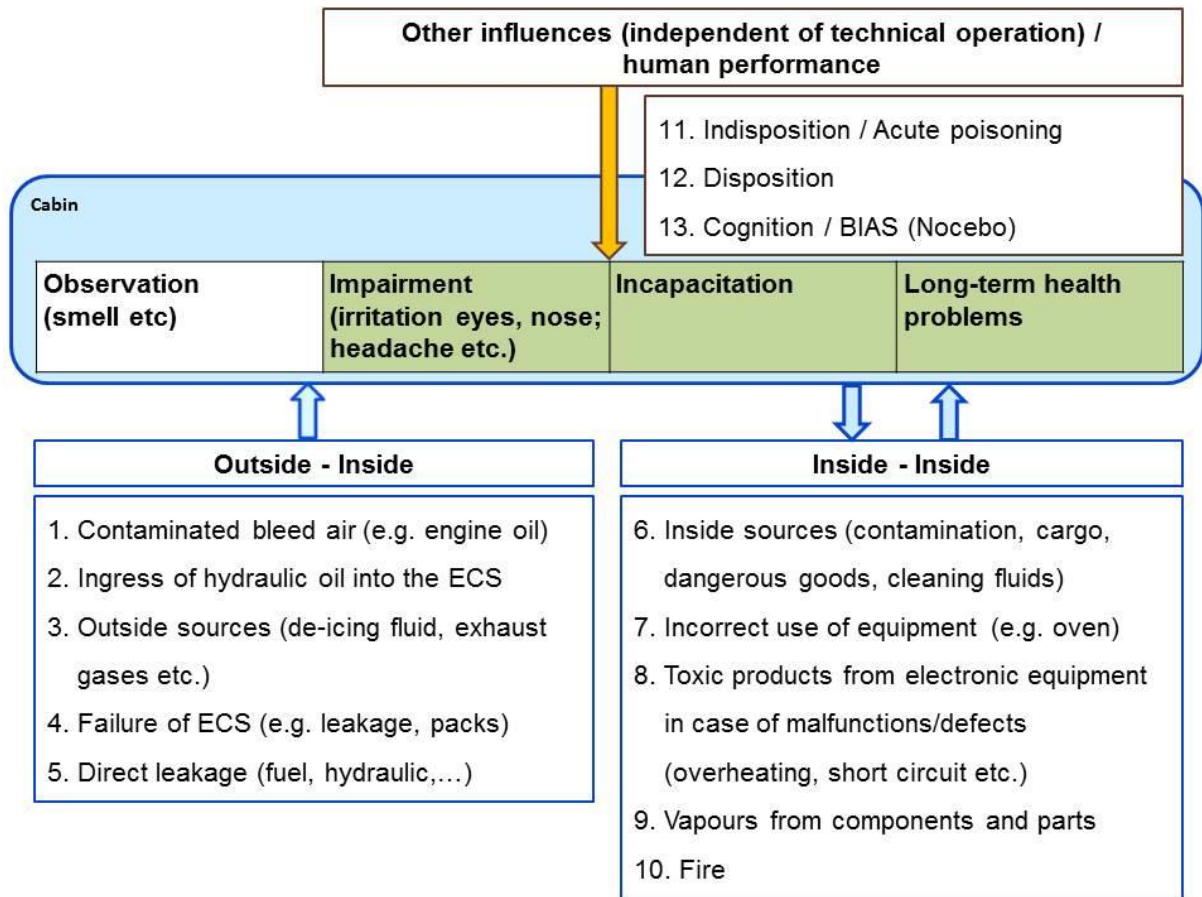


Process description: Investigation of fume events

Source: BFU

When dealing with fume events the question arises: Which influences have led to the incident? Influences could be:

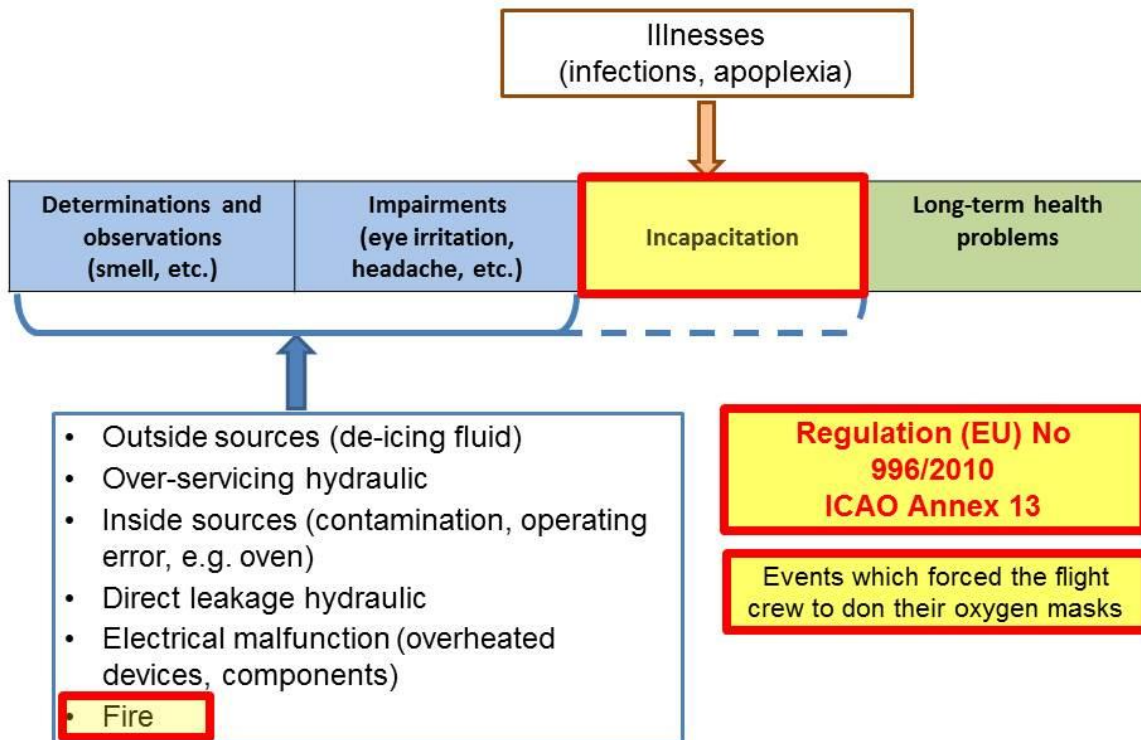
- Impairment due to contamination with a source outside the aircraft cabin (Graph: Positions 1 to 5)
- Impairment due to contamination with a source inside the aircraft cabin (Graph: Positions 6 to 10)
- Impairment which depends on the technical operation of the airplane (Human Performance, Graph: Positions 11 to 13)



Possible influences which may result in impairments, observations and limitations in the cabin Source: BFU

Examination of these influences may lead to classification as

- Occurrence, other than accidents or serious incident in accordance with ICAO Annex 13, Regulation (EU) No 996/2010 and the FIUUG (field with red border)
- Incident (blue fields)
- Long-term health impairments (green fields)



Classification of possible influences

Source: BFU

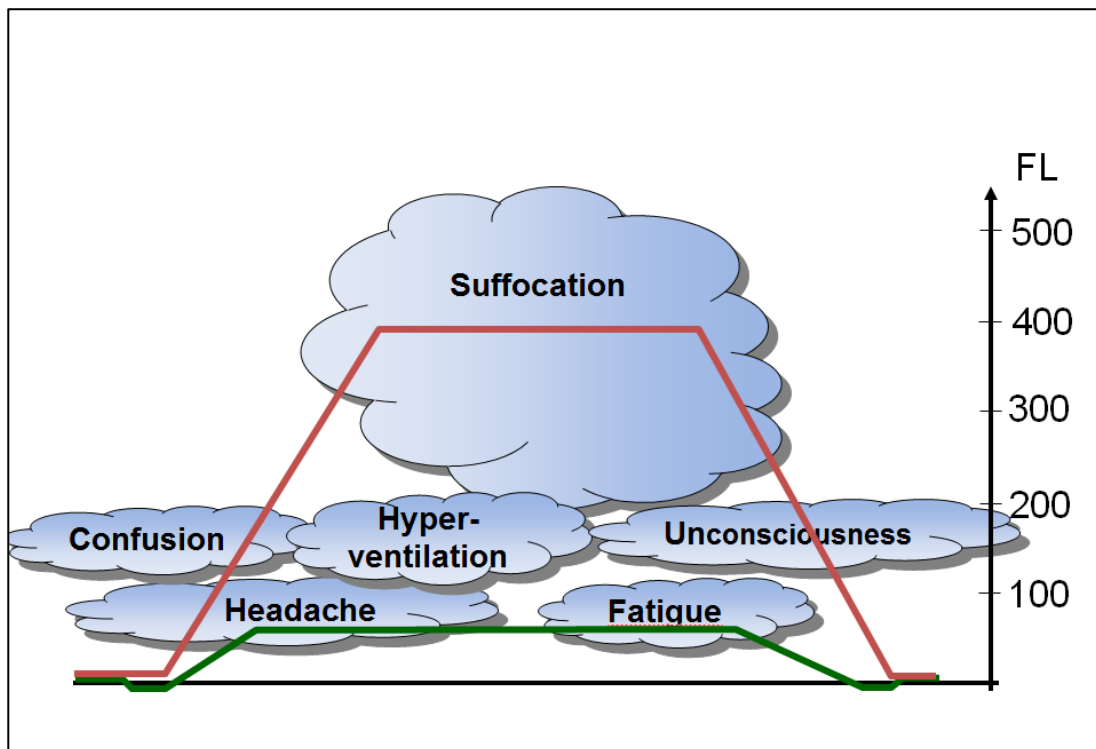
1.4. System Description Cabin Pressure Control and Environmental Control

1.4.1 Environmental Conditions during Cruise Flight

Generally, transport aircraft are in 30,000 ft (about 9,000 m) to 40,000 ft (about 12,000 m) during cruise flight. In these altitudes, the temperatures are between -45°C and -55°C. Barometric air pressure and air density are only about a fourth of that close to the ground.

These environmental conditions make it necessary for transport aircraft to have technical systems, which prepare the kind of air, human beings need once the airplane has reached the critical altitude.

The pressurized cabin, among other things, establishes environmental conditions the occupants find acceptable. In transport aircraft this is so configured that the pressure does not fall below approximately 750 hPa. This pressure in the fuselage is equal to the atmospheric pressure in 8,000 ft (approximately 2,440 m). For most human beings, it is comfortably possible to be in such an altitude. Some people may have symptoms such as headaches or tiredness.



Effects of lack of oxygen in relation to the altitude

Source: BFU

1.4.2 Climate Conditions in the Pressurized Cabin

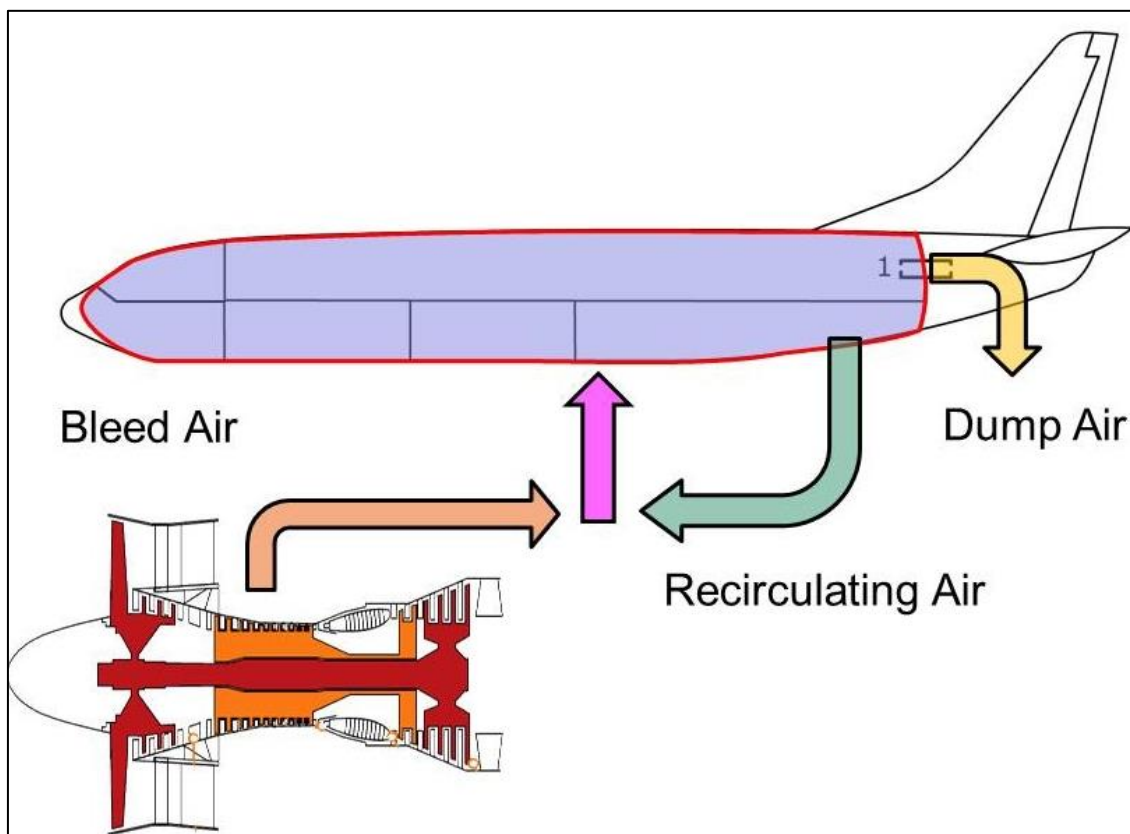
In order to provide the passengers with sufficient oxygen and remove the used air, continued air exchange is necessary. During cruise flight, the air supply has to have a temperature which is comfortable for the occupants. Generally, the air in the cabin of transport aircraft is heated to about 20°C and re-cycled about 15 times per hour. Due to the low ambient air temperature, the air humidity is also low. The relative air humidity inside the pressurized cabin during cruise flight is very low (5 to 20%), because of the process to increase temperature and pressure. Essentially, the relative humidity depends on the vapour concentration the persons aboard emit. At a

humidity of more than 20%, condenser water forms on windows and structural components of the fuselage, because of the low outside air temperature.

1.4.3 Environmental Control System

The Environmental Control System (ECS) of a transport aircraft controls pressure, temperature, and air re-cycling of the pressurized cabin.

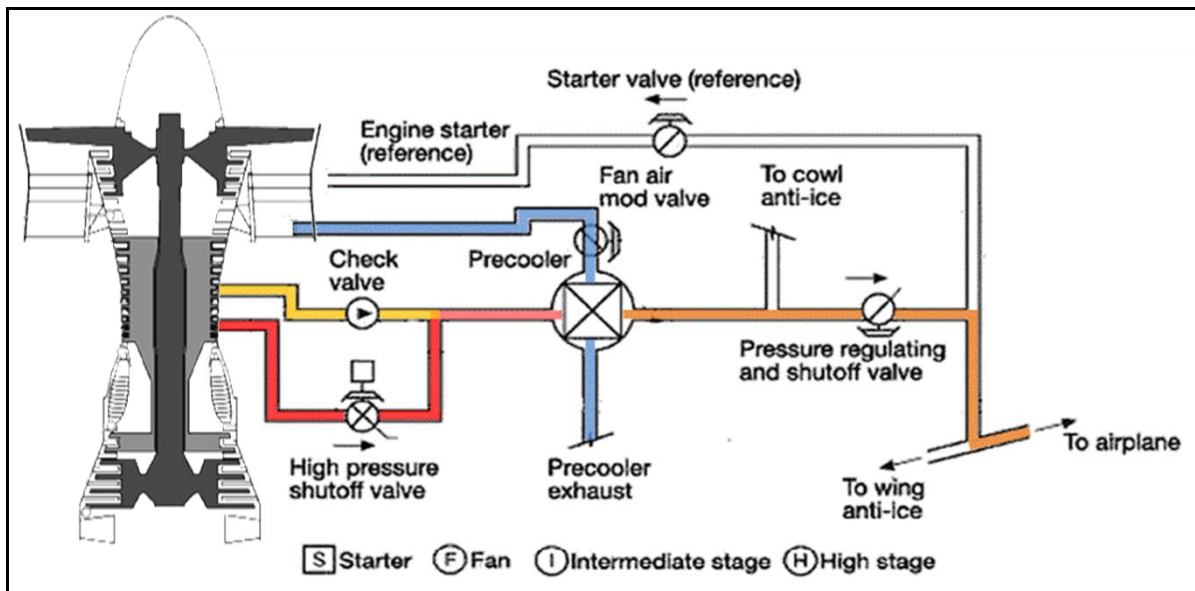
The EC systems of almost all transport aircraft currently in service are supplied by bleed air. It has a temperature of approximately 200°C and a pressure of about 3,100 hPa (45 psi). The air condition reduces temperature and pressure to appropriate values, before the bleed air is mixed with cabin air, and blown back into the cabin. The cabin air pressure is controlled by outflow valves.



Simplified display of an EC system

1.4.4 Bleed Air System

The bleed air for the EC system is usually provided by the engines. Depending on the engine revolutions per minute, the bleed air is either taken from the high or low pressure compressor. The air from the low pressure compressor has a temperature of approximately 280°C and a pressure of up to about 5,860 hPa (85 psi). The air from the high pressure compressor has a temperature of approximately 420°C and a pressure of up to about 13,790 hPa (200 psi). The temperature of the air from the engine pressure compressors is cooled to about 200°C and the pressure is reduced to about 3,100 hPa (45 psi), before it is fed to the consumers. Depending on the aircraft type, the bleed air system not only supplies the EC system with pressurized air, but also the engine starter, the anti-ice, hydraulic, fresh water, and fuel systems.



Simplified display of an engine bleed air system

In addition, and also depending on the aircraft type, the pressurized air for the bleed air system can be supplied by an Auxiliary Power Unit (APU).

1.4.5 Malfunctions

Due to malfunctions in the EC system, the pressure or the temperature in the pressurized cabin can be too high or too low. An automatic alarm warns the flight crew if the pressure is too high or too low. By applying prescribed procedures, the

crew can regulate the pressure. If the temperature is too high or too low, the crew does not get an automatic warning, but has to rely on their own perception.

The different systems, which are supplied with bleed air, are connected with the bleed air system such that flow-back of the different fluids (hydraulic oil, fuel, water) is prevented. Generally, check valves prevent the flow-back.

1.5 Demonstration of Compliance during Type Certification

Civil aviation authorities certify aircraft types on the basis of design and certification regulations. The European Aviation Safety Agency (EASA) issues certificates for transport aircraft in accordance with Certification Specifications CS 25. The Federal Aviation Administration (FAA) applies similar certification principles. These regulations and additional implementation rules describe the minimum requirements for the type certification of transport aircraft. If the manufacturer has made a complete demonstration of compliance with the certification specification, the certification authority issues a type certificate.

In most transport aircraft types, the cabin air is supplied by engine bleed air or the APU and the EC system processes and distributes it. The purity of the cabin air is determined by the functionality of these systems (normal operation and in case of malfunctions). Certification specifications define their requirements.

1.5.1 Structure of the Certification Specifications

Certification specifications are subject to continuous updating so that they reflect the state of technical knowledge and provide appropriate safety requirements. At the beginning of a project, the respective amendment of the certification specification is determined and is changed only if there are major changes. Therefore, an airplane currently in use is usually not certified in accordance with the newest requirements.

The following description refers to an amendment status of the respective certification specifications valid in Europe in September 2013.

The Basic Regulation No 216/2008 stipulates the essential requirements for the construction of airplanes. Based on the Basic Regulation certification specifications for individual products are decreed. Relevant are:

- CS-25 for transport aircraft
- CS-E for engines
- CS-APU for APUs.

In the USA harmonised regulations, so-called FARs, exist. The Acceptable Means of Compliance (AMC) give information on how the individual chapters of the certification specifications can be met. In addition, standard specifications (DIN, EN, SAE, MIL, etc.) are consulted to meet certification specifications.

1.5.2 Cabin Air Quality Requirements in Accordance with CS-25

CS-25.831, CS-25.832 and CS-25.1309 are relevant for cabin air purity. CS-25.831 and CS-25.832 stipulate special requirements for the EC system. EASA stated that these have to be applied for the construction of the airplane and not the engines. Regarding the cabin air, it is stipulated that it has to be free of harmful or hazardous concentrations of vapours and gases.

CS-25.1309 has to be applied for all systems and the engine installation, except for the engine itself, i.e. also for the EC system.

It stipulates allowable failure probabilities for systems in relation to their criticality. EASA stated that the consideration of cabin air contamination is part of the compliance demonstration of the ECS (CS 25.1309). Health impairments of flight crew (without limitations to the capacity to act) would be classified as Major.

Figure 2: Relationship Between Probability and Severity of Failure Condition

Effect on Aeroplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
Effect on Occupants excluding Flight Crew	Inconvenience	Physical discomfort	Physical distress, possibly including injuries	Serious or fatal injury to a small number of passengers or cabin crew	Multiple fatalities
Effect on Flight Crew	No effect on flight crew	Slight increase in workload	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatalities or incapacitation
Allowable Qualitative Probability	No Probability Requirement	<---Probable--->	<---Remote--->	Extremely <-----> Remote	Extremely Improbable
Allowable Quantitative Probability: Average Probability per Flight Hour on the Order of:	No Probability Requirement	<-----> <10 ⁻³ Note 1	<-----> <10 ⁻⁵	<-----> <10 ⁻⁷	<10 ⁻⁹
Classification of Failure Conditions	No Safety Effect	<-----Minor----->	<-----Major----->	<--Hazardous-->	Catastrophic
Note 1: A numerical probability range is provided here as a reference. The applicant is not required to perform a quantitative analysis, nor substantiate by such an analysis, that this numerical criteria has been met for Minor Failure Conditions. Current transport category aeroplane products are regarded as meeting this standard simply by using current commonly-accepted industry practice.					

Correlation between occurrence probability and the severity of the malfunction

Source: EASA

For the installation of the engines, Subpart E Powerplant has to be applied. CS-25.901 stipulates, among other things, that the installation has to meet the requirements of the engine manufacturer or the type certificate holder. In accordance with CS-E20, the engine manufacturer has the obligation to stipulate these requirements.

Engine requirements

The engine manufacturer is obligated, in accordance with CS-E20, to document all requirements for the installation (critical values, interface definitions, etc.). Acceptable Means of Compliance (AMC) E 30 lists the minimum requirements. The requirements for bleed air quality are not included.

CS-E 510 stipulates that a safety analysis has to be done. The respective AMC E 501 stipulates that cabin air contamination has to be considered.

CS-E 690 lists the requirements for the bleed air system if it is used for the airplane's environmental control system. All malfunctions which may have an effect on cabin air purity shall be analysed.

APU requirements

CS-APU 20 stipulates, similar to CS-E, that the requirements for the installation have to be provided in the form of a manual. CS-APU 210 stipulates that a safety analysis regarding bleed air purity has to be conducted. As criteria, the capability to act of the crew or passengers is listed.

Additional requirements

EASA stated on enquiry by the BFU, that other determinations and critical values are listed in standards and national employment regulations, among others, (e.g. ARP4418, UK Health & Safety Executive occupational exposure limits).

The BFU has sent a questionnaire to EASA and received their statement:

During the certification process of a transport aircraft in accordance with CS-25 (especially in regard to the above-mentioned chapters) CO and CO₂ concentrations are considered.

Other substances were only examined during the certification of the engine and the APU.

There was no reason to consider, for example, hydraulic fluid as cause for cabin air contaminations.

By use of procedures (in accordance with the airplane flight manual) other hazards for crew and passengers could be prevented if cabin air contamination occurs.

Long-lasting physiological impairments are not part of CS 25 or CS 25.831 b) and CS-25.1309. These considerations should be carried out by medical health organisations and EASA would then incorporate their results.

During the certification process of engines and APUs, malfunctions of the oil systems, wear of rubstrips, and leakages of the fuel system are considered. This is mainly accomplished by analysis.

SAE ARP4418 and MIL-E-005007E contain compounds and substances and their critical values which have to be considered. The critical values in the ARP4418 are applied for normal operation. For malfunctions other critical values are applied, e.g. the ones from the UK Health & Safety Executive.

Long-term physiological impairments are not part of CS-E.

1.6 Fume Events in Europe

The European Coordination Centre for Aircraft Incident Reporting System (ECCAIRS) records accidents, serious incidents and incidents of the European safety investigation authorities (in Germany the BFU) and of the civil aviation authorities responsible for recording safety incidents.

At the time of the compilation of this study, the following occurrences of other European States which were described as fume events had been recorded for the time period 2010 to 2013:

	Accidents	Serious incidents	Incidents
Finland			5
France			89
Great Britain (UK)	3	1	108
Ireland			4
Iceland			7
Latvia			2
Lithuania			1
Luxembourg			7
The Netherlands			68
Norway			11
Austria		1	
Portugal		2	14
Romania		7	
Sweden		1	1
Hungary		1	

Fume Events in ECCAIRS database

Source: ECCAIRS

Note: These records only take into consideration the closed investigations of fume events (between 2010 and 2013).

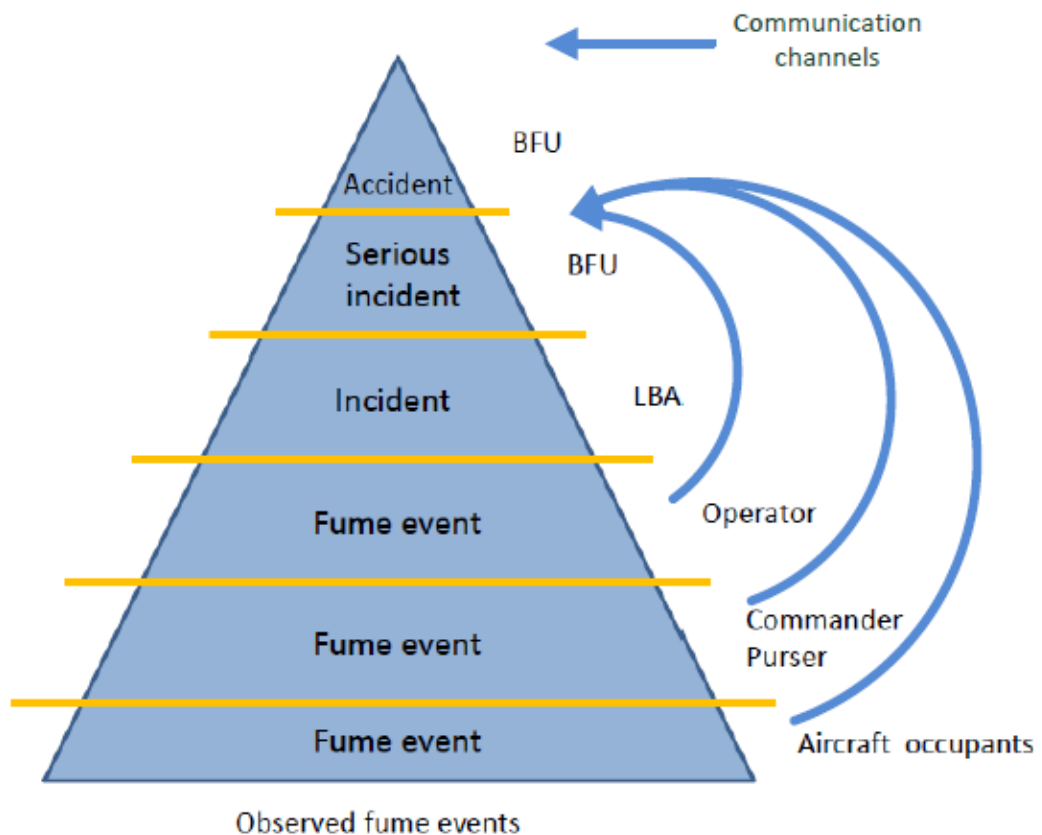
2. Analysis

The BFU decided to publish this study in accordance with Regulation (EU) No 996/2010 because, over the last years, the reports concerning possibly contaminated cabin air have increased, as have the public and political discussions. With the usual investigation methods and means applied to accidents and serious incidents, a causal connection of possibly contaminated cabin air and the medical symptoms aircraft occupants perceived could not be established or only to a limited extent. Based on the BFU's scope of work, the main question was, whether the reported and described incidents negatively affected flight safety. This differentiation had become necessary, because of the broad expectations the public, reporting persons, who might also be affected, and operators had on investigation results.

The investigation of individual incidents was not possible with the currently available and appropriate means. Therefore, all reported incidents between 2006 and 2013 were taken into consideration. Key aspects were the analysis of the reports, the verification regarding the air quality in aircraft cabins during the type certification process, and the technical concept for the processing and distribution of cabin air in transport aircraft.

2.1 Fume Event Reports

Flight and cabin crew or passengers, who notice smells, smoke, or experience health impairments, report these via stipulated reporting channels. In general, the communications channel is: purser, pilot in command, the responsible departments of the operator and, if applicable, the responsible authorities. Depending on the severity and importance of an incident only the operator will receive the information or if the criteria for a Para 5b of the Air Traffic Order (LuftVO) report are met the Luftfahrt-Bundesamt is notified. In case of an accident or serious incident in accordance with Para 5 Air Traffic Order (LuftVO) the BFU is informed. This explains why the operators may have knowledge of more incidents than the responsible authorities.



It also explains why not all incidents, which crew members or passengers notice, are reported to the BFU. This also makes clear, why the operator or the LBA may not have knowledge of all the reports the BFU has received.

Noticeable is the increasing number of reports in conjunction with possibly contaminated cabin air. In 2006, the BFU received 40 reports, in the following years there were about 60; in 2011 there were 94, in 2012 there were 117, and in 2013 there were 175 reports. These numbers demonstrate the increased sensibility where cabin air is concerned. In the period under consideration, the number of reports the BFU received per year has more than quadrupled. Therefore the conclusion can be drawn that the sensitivity for the issue has increased.

Not only do these numbers indicate the increased sensitivity regarding this issue, but also the problem identifying severity and importance of fume events. There is a high number of smell situations in airplanes which cause "alarm" in airplane crew but are not connected to any symptoms which would justify the classification as serious

incident. The BFU is of the opinion, that a multitude of reports are generated, because clear indications or indicators for reportable fume events do not exist.

The content of some of the reports indicates an heightened sensitivity. Some reports lead to the conclusion that they had been reported to the BFU as precautionary action to avoid the disadvantages of verification in the future. It should be considered that the exclusive aim of the BFU is to prevent future accidents and not the settlement of claims or the assertion of other interests.

The implementation of the questionnaires cabin air (initial and follow-up) in the third quarter 2013 shall provoke, that not only the gathering of factual information is standardised but some data from the initial report can be specified and put into perspective.

The BFU is of the opinion, that the increase in reported fume events is due to the heightened sensitivity of flight crew members, the non-existent standardised reporting procedure and the obligation to report to different addressees as stipulated by different EU Regulations.

It must also be taken into account that the term "fume event" is neither described nor defined in any aeronautical regulation.

The increase in fume events is also due to the fact that in accordance with Regulation (EU) 996/2010 involved persons report to the BFU, not just pilots in command or operators, as stipulated in Para 5 of Air Traffic Order (LuftVO). Therefore, the circle of persons entitled to report has become wider. The extensive discussion of cabin air in different internet forums may also have added to the propensity to report.

The reporting channel described above, from the time an event was noticed in the airplane, until the report to the BFU, was not to suggest that only operators can report to authorities. Para 5 of Air Traffic Order (LuftVO) and Regulation (EU) No 996/2010 stipulate that individuals and function owners can submit reports directly. The BFU is of the opinion that factual and objective information is important.

2.2 Fume Event Classification

The BFU classifies fume events, as any other reported incident, in accordance with the legal definitions of the Regulation (EU) No 996/2010 and the FIUUG.

One of the BFU core activities is the investigation of accidents and serious incidents and these are investigated with the pertinent priority. When investigating a serious incident the events which pose a high risk for a potential accident are in the main focus. For example, if a serious incident occurred because there was a fire aboard it has a high priority. An incident where there was smell because of burnt leftover food in one of the ovens has a lower priority.

2.2.1 Classification as Accident

A fume event is classified as accident if someone sustained severe injury or the aircraft was severely damaged. Besides injuries, as described in the definitions (Chapter 1.2), hospitalisation of more than 48 hours within 7 days of the occurrence is a criterion for an accident. For each individual case, there has to be causality between injury and the occurrence. This proof would also have to be provided for possible long-term effects.

The emergency landing of a Falcon 20 at Kiel-Holtenau Airport had become necessary because a pyrotechnical emergency signal had been triggered in the cabin. The injuries were caused by burns, burnt gas intoxication, and the impact. The flight crew could protect themselves by donning their oxygen masks.

The described fume event involving an ATR72 at Munich Airport had been attributed to engine damage with oil smell. But subsequently, during the landing with one engine inoperative the engine structure was severely damaged. Neither crew members nor passengers reported any symptoms, or health impairments.

The accident involving an AN12 at Leipzig Airport occurred in combination with a fire shortly after engine or APU start-up. Therefore it was not an incident where persons aboard an airplane inhaled possibly contaminated air.

The three accidents listed above are not typical fume events during which aircraft occupants may experience health impairments due to fume of unknown origin.

The ongoing investigation by the Spanish investigation authority involving a Boeing B757 at Las Palmas Airport was classified as accident, because one flight attendant was treated in hospital for more than 48 hours within 7 days of the incident due to prolonged health problems. The BFU could not analyse this incident because, at the time this study was published, the Spanish investigation authority had not provided the final conclusions.

The BFU came to the conclusion that the examination of the above-mentioned accidents, except maybe for the one in Spain, could not provide any clear information in regard to typical fume events.

2.2.2 Classification as Serious Incident

Between 2006 and 2013, the BFU received reports of 663 fume events of which 29 events were classified as serious incidents, because at least one criteria was met:

- Fire or smoke aboard the airplane was determined
- The flight crew was forced to don their oxygen masks
- Crew member suffered from incapacitation

The BFU came to the conclusion, that in four cases it was absolutely necessary for the flight crew to don their oxygen masks to ensure a safe conduct of the flight.

The other 25 serious incidents received this classification, because severe smoke development with suspicion of fire, smoke development in combination with oil leakage, or complex technical problems was reported. In addition to the above-mentioned descriptions, flight crew reported health problems. In some cases an investigation was only feasible to a limited extent, because malfunctions could not be reproduced or proof was not or no longer possible. During some investigations it was determined that Flight Data Recorders (FDR) and Cockpit Voice Recorders (CVR) have proven flight operations processes after the occurrence of a fume event and shown the dynamic of the events. There were only marginal indications regarding technical malfunctions or possible leakages in aircraft or engine systems.

At the time this study was compiled, neither medical records were available nor could a technical cause be identified in 12 serious incident cases. This explains the complex problems with verification and reproducibility of fume events. These are the reasons why some investigations are still on-going.

The investigation of 11 serious incidents, which occurred in the period under consideration, has been closed. Two investigations revealed oil leakages in the APU or the hydraulic system.

Five serious incidents were caused by smoke development in combination with electric or electronic systems.

Based on the incidents described above, the BFU came to the conclusion that fume events are often not verifiable in regard to the technical cause and are not only caused by oil leakages.

Not all fume events, classified as serious incidents, have resulted in health impairments, either on the day of the incident or the following days. In 15 cases there were no health impairments or they were not reported. In 14 cases health impairments such as headaches, dizziness, etc. were reported.

The analysis of the fume events, classified as serious incidents, has shown significant uncertainty of flight crew regarding possible health hazards. In 11 cases crew members sought medical treatment either on the day of the incident or later. The BFU did not receive any information regarding medical treatment in 14 cases. In four cases it was confirmed that there was no medical treatment.

The BFU did not receive any medical findings in seven cases. The Regulation (EU) No 996/2010 gives the BFU the legal basis to receive medical records. In most cases the BFU does not receive responses (medical records) to their enquiries. It is possible that the persons involved do not have positive findings available or they deliberately were not forwarded to investigation authorities.

In one case, the so-called Nebraska blood test showed a positive result. The BFU did not receive any details.

By investigating the serious incidents, the BFU has not determined any indications of TOCP or any other poisonous compound except for the one case of a positive Nebraska blood test.

The investigation of fume events, classified as serious incidents, revealed to the BFU:

- Limited investigation options cause significant verification difficulties regarding possibly contaminated cabin air
- Verification problems in regard to health impairments in connection with medical findings
- Impairments of flight and cabin crew and passengers have indeed occurred
- As far as possible, flight-safety relevant situations were prevented due to the timely use of oxygen masks by the pilots

The closed investigations, and even the still ongoing ones, show that there is no relevant flight safety problem.

In 28 cases, the criteria for serious incidents were met without there being a conjunction with a fume event. In 26 cases, members of the flight crew were either partially or entirely incapacitated. Reasons were mentioned which can also occur outside of flight duty (e.g. heart attack, food poisoning, etc.). The numbers show, that in general, the remaining flight crew member still capable to act, can carry out the tasks of the crew member who has become incapacitated.

2.2.3 Classification as Incident

38 reported occurrences, which were no-reportable incidents, were classified as incidents.

The BFU has recorded these 38 cases in ECCAIRS and investigated them as far as possible. At the time of the compilation of this study, nine of these incidents had been closed.

In five of these closed cases, neither the operator nor the BFU could determine any technical cause. In one case, oxygen shortage occurred in the cabin. Dry ice in the cargo compartment caused smoke development in another case.

Based on these closed investigations, the BFU could not determine any possible causes for the fume events.

The 29 still ongoing investigations of incidents are almost all events with smoke and smell developments. In seven cases, oil smell and in six "smell like old socks" were reported. In the cases where oil smell was reported, engine oil leakages were identified in two cases. In one case, an APU valve was damaged. In the "old socks" cases, an oil overfill was identified once. In the other cases there were no indications as to a possible cause.

Aircraft occupants complained of headaches and other health impairments in 26 incident cases.

In 22 cases there was medical treatment or diagnostics; in 16 of these cases the BFU did not receive any results. The BFU received medical records and the following values were noticeable:

- In two cases Methaemoglobin was more than 20% (reference value 1%).

- In two cases the laboratory test results assessed COHb as positive.
- In one case the laboratory test result showed for one person a CO value of 7% and for one person of 12%; both were assessed positive.

The numbers mentioned above show that

- Fume events with health impairments do occur
- Verification means and options (e.g. blood tests) are not always available to the BFU
- There are no standardised procedures for reporting and verification (blood tests)
- In these cases flight safety was not affected

In view of the findings of this study that the fume events did not cause a dangerous reduction of flight safety, an extension of the investigation of these incidents is not justified.

2.3 Analysis of the Reported Incidents and Investigation Results

Based on the reports and investigation results, the BFU has divided the fume events into four categories:

- Fume events affecting flight safety
- Fume events possibly affecting the occupational safety of crew members
- Fume events affecting the comfort of aircraft occupants
- Fume events and possible long-term effects on aircraft occupants

2.3.1 Fume Events Affecting Flight Safety

The data analysis for this study showed that the criteria for a serious incident were met by some of the fume events because the cockpit crew decided to don their oxygen masks or one pilot was partially incapacitated. In very few cases the safety margin was reduced such that a high accident probability - in terms of the legal definition - existed.

In retrospect, it is difficult to assess whether donning the oxygen masks was absolutely necessary. The decision of the crew in case of doubt to don their oxygen masks was correct and it is rather speculative to make statements regarding the result of a flight had the crew not worn their oxygen masks.

During the serious incident involving an Airbus A319 on approach to Köln, both pilots were physically and psychologically impaired to act. It was possible to continue a stable and safe approach because the pilots wore their oxygen masks. The BFU is of the opinion that in this case the oxygen masks were undoubtedly necessary.

The BFU analysis also showed that during fume events the cockpit crew were limited in their capability to perform. There was no fume event, however, where a pilot became completely incapable of action. Again it is rather theoretical to make statements regarding the result of a flight had the crew not worn their oxygen masks.

In accordance with Regulation (EU) No 996/2010 in combination with Regulation (EU) No 859/2008, it is not necessarily a serious incident if a cabin crew member becomes incapacitated.

The definition of severe injuries in accordance with Regulation (EU) No 996/2010 applies for cabin crew and passengers. The analysis of the fume events of the period under consideration has not revealed one case where the conjunction between the fume event and a severe injury was verifiable, except for the event in Spain.

The reported long-term impairments or illnesses are discussed under 2.3.4.

2.3.2 Fume Events Possibly Affecting the Occupational Safety of Crew Members

In 142 cases of the 663 fume events reported to the BFU between 2006 and 2013 health impairments are mentioned. These health impairments were reported by persons involved or other persons stipulated by Regulation (EU) No 996/2010 and Para 5 of the Air Traffic Order or are the results of interviews and investigations by the BFU. Reported were eye irritations, light-headedness, tremor, headaches, dizziness or a combination thereof (multiple).

The study shows that fume events with health impairments of aircraft occupants did occur. Even though the BFU could not identify any significant flight safety aspects and there are only a few reports by passengers, there are clear indications of impairments of flight and cabin crew and passengers.

Especially cabin crew who not only work in the cabin, but are responsible for passenger safety should be protected against hazards in the workplace. The cabin crew does not have oxygen masks available like the flight crew does in the cockpit.

Provision of oxygen masks for cabin crew would not completely solve the potential problem. The passengers still would not be taken care of and the cabin crew would also have to be able to perform their safety tasks in emergency situations.

The analysis also showed that objectification of fume events is absolutely necessary. There were reports of fume events which had been submitted to the BFU to prevent disadvantages in case of an injured event. Some reports were rather emotional and did not contain many facts. The BFU is of the opinion that especially cabin personnel need information on how and when to report fume events.

In summary, the BFU comes to the conclusion that possible health impairments in conjunction with fume events were determined which had, however, no flight safety relevance.

2.3.3 Fume Events Affecting the Comfort of Aircraft Occupants

Of the 663 reported events, 596 were non-reportable. In these cases smells were reported. In 485 of these cases no health impairments of the occupants occurred. This means the majority of the events was disagreeable but harmless. These can be associated with the "comfort zone".

The graph in chapter 2.1 indicates that compared to the BFU numbers, the number of perceived fume events could be considerably higher. The number of cases within the operators or at the Luftfahrt-Bundeamt could be higher as well. The BFU understands that there is a high number of reports which are only reported because passenger comfort is important.

The BFU is of the opinion that this fact justifies a standardised reporting system which includes criteria for an initial classification. Fume events which are only reported because of comfort needs of passengers are only important for operators to improve their product.

2.3.4 Fume Events and Possible Long-Term Effects

In 10 of all fume events reported to the BFU, the reporting person reported long-term health impairments at a later date. One case (Spain) was classified as accident and one other as serious incident. One event was classified as incident with investigation by the BFU and seven others as incidents without investigation by the BFU.

All these incidents were fume events where either oil smell or "old socks" were reported. In eight cases the BFU learned that the reporting person was receiving medical treatment.

In five cases the BFU had medical records. These included blood test results and different medical records. Some results were ICD coded. Others were initial examination findings and general diagnostic findings. In almost all cases where the BFU has medical records serious illnesses or disease patterns are described.

The reports to the BFU stated that one illness had developed as a result of a fume event. There usually was a chronological connection with an already known fume event even though the report of a person involved was submitted at a later date.

A classification of these incidents as accident in accordance with Regulation (EU) No 996/2010 was not possible, because the legal definition of a serious injury does not include long-term illnesses or illnesses which occur later. In addition, a causal connection between the illness and the described fume event would have to be established.

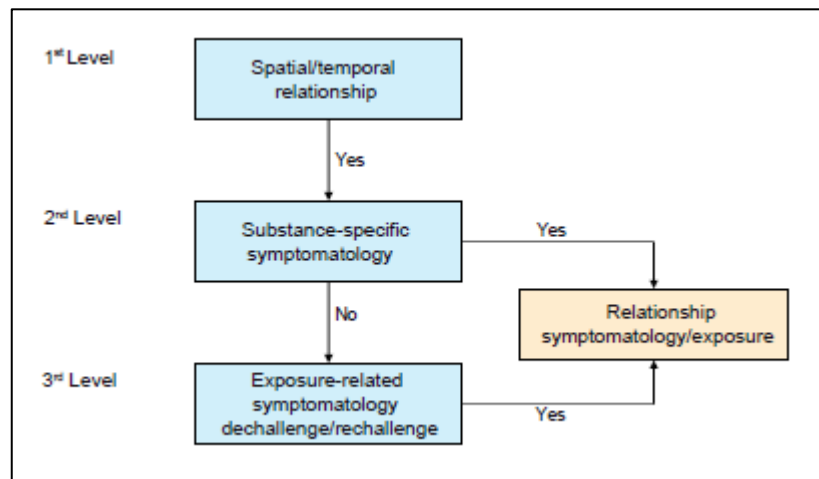
The mode of operation of the BFU, as well as any other air accident investigation authority world-wide, is such that due to a concrete occurrence, facts are determined which allow assessment of the cause.

With the current means and methods available for air accident investigation, it is not possible to investigate incidents which date back a while.

The BFU is of the opinion that the principles of clinical toxicology would have to be applied to clarify a possible long-term effect of fume events. The Bundesinstitut für Risikobewertung (BfR, Federal Institute for Risk Assessment) uses this method to assess illness caused by poisoning. The institute has described this method in Cases of Poisoning Reported by Physicians⁵.

⁵ Cases of Poisoning Reported by Physicians in 2010
Poison and Product Documentation Centre at the Federal Institute for
Risk Assessment – 17th Report (2010)

The institute uses a three-level model to assess poisoning. The assessment efforts are reduced to three single levels which are logically interconnected. The description of the model:



The Three-Level Model

Source: BfR

Level 1:

Is there a justifiable temporal and spatial association between the exposure and the occurrence of health impairment?

Level 2:

Are the manifestations known from other case reports, or can they be explained by the mechanisms of action?

Level 3:

Is there an association between symptomatology and exposure, i.e. are the signs and symptoms temporally associated with dechallenge (symptomatology subsiding after termination of exposure) or rechallenge (symptomatology aggravating on re-exposure)?

The assessment of exposure and health disorders is supported by two BfR matrix models: one to determine the degree of probability of exposure and another to assess the causal relationship between health disorders or manifestations and exposure.

Degree of probability of exposure		Estimation		Measurements			
		Contact with substance		Extracorporeal		Intracorporeal	
		Source(s)	Potential exposure	Single value	Representative measurements	Single value	Exceeding of limit values
No	None	+	-	-	-	-	-
Yes	Possible/cannot be reliably excluded	+	+	+	-	-	-
	Probable	+	+	+	+	+	-
	Confirmed	+	+	+	+	+	+
?	Cannot be assessed	E.g. insufficient data, state of knowledge					

Matrix to assess the degree of probability of exposure to a substance

Source: BfR

Relationship exposure/symptomatology		Plausible exposure to a substance	Partially specific symptoms	Specific symptoms	Specific laboratory analysis	Other diagnosis
No	None	-	-	-	-	+
Yes	Possible/cannot be reliably excluded	+	+	-	-	+
	Probable	+	+	+	-	-
	Confirmed	+	+	+	+	-
?	Cannot be assessed	E.g. insufficient data, state of knowledge				

Matrix to assess the causal relationship between health disorders and exposure Source: BfR

One important element in the search for information is the toxicological history (case history).

The BfR case history comprises seven parts:

1. *Elucidation of current complaints with special reference to the temporal development of the patient's condition;*
2. *Previous diseases and medical examinations;*
3. *Differential diagnostic considerations;*

4. *Medical history provided by persons other than the patient (sometimes referred to as heteroanamnesis);*
5. *Family history;*
6. *Social history;*
7. *Travelling history.*

According to the BfR, for a toxicological history, a number of other factors are of particular importance. These include:

1. *The routes of exposure (oral, dermal, inhalational, etc.);*
2. *The dose and rate of exposure (acute / chronic);*
3. *The toxicant(s) that has/have caused the health impairment; and*
4. *The spatial and temporal relationship between the toxicant(s) involved and the manifestations observed.*

According to the BfR, an accurate and plausible toxicological assessment of the health impairments observed should be preceded by elucidation of the special toxicological data.

The BFU can neither rule out nor confirm that there is a causal connection in the respective cases. The BFU identified the need for clarification. The health of cockpit and cabin personnel and passengers shall not be jeopardised through illnesses triggered by malfunctioning systems aboard an airplane.

The BFU could not discern if illnesses were caused by fume events. The BFU could not verify whether illnesses, which arise later, can be connected to a fume event or could be explained by latent pollution of the cabin air. This analysis has shown that the BFU cannot answer this question with their options and means, neither now nor in the future.

The BFU research showed that the term aerotoxic syndrome deals with possible health impairments which may be caused by air contaminations in the cabin and cockpit of airplanes. At this time, the term is neither medically nor scientifically defined. The current scientific discussion assumes a contamination of the air for passenger cabin and cockpit with partially pyrolyzed oil. Due to existing system leakages fumes may leak out which consist of a complex mixture of:

Tricresylphosphate and its isomers (TCP)

N-phenyl-L-Naphthylamine (PAN)

Carbon monoxide (CO).

One of the possibly toxic agents playing a keynote in the discussion is the ortho-isomer of TCP which may cause peripheral neuropathy. Typical symptoms as after-effects of such fumes are acute breathing disorders and central neurological symptoms.

The analysis of the fume events for this study revealed, the BFU does not have verification of noteworthy cabin air contamination by the ortho-isomer TCP or by any other poisonous substance. Some publications describe minimal concentrations, which cannot even be measured. The BFU is of the opinion that even if these occur the problem is the non-existent or insufficiently standardised critical values.

A technical system recording routinely the composition and possible contamination of the cabin air in real time does not exist and is not mandatory in airplanes.

2.3.5 Technical Causes

Not in all cases were causes found or reported, this fact has to be considered when analysing the technical causes. The reported causes for smells show that smells aboard a transport aircraft can have different causes. The main sources are engines/APU, electrical equipment (in general or in the cabin) and the galleys (ovens, coffee machines). By nature, the EC system plays a decisive role during fume events. Smells were also reported in conjunction with de-icing fluid contamination.

Therefore, the assumption is confirmed that contaminations can enter the cabin from the outside, or they originate from inside caused by airplane systems, the equipment, or cargo/luggage. In many cases, the cause for the smell could be eliminated by deactivating the system or subsystem.

Some other reported causes for the smells do not originate with the operation of the airplane but could occur in the normal course of life, e.g. burnt food, use of glue.

With some of the other reported causes, the health hazard cannot be assessed because of the variety of possible chemical compounds and their conversion products. The BFU cannot assess if the reported oil overfills, because of the small amounts, could cause health impairments beside the odour nuisance.

It is highly likely that a technical malfunction in an airplane system would have been identified and documented. This has to be taken into account when analysing the relatively high number of not determined or unknown causes. It is likely that in the majority of these cases there was no reproducible technical malfunction.

2.4 Certification Specifications and Demonstration of Compliance

2.4.1 Comparison of Certification Specifications

Engines or APU and airplane systems work together to supply the cabin with air.

Comparing the requirements for the airplane (CS-25.831, CS-25.1309), for the engines (CS-E 510, CS-E 690) and for the APU (CS-APU 210) showed the following differences:

Aircraft:

CS 25.831 Ventilation

(b) Crew and passenger compartment air must be free from harmful or hazardous concentrations of gases or vapours.

Engine:

AMC E 510 Safety analysis

(d) Hazardous Engine Effects

(iv) Toxic products.

CS-E 510 (g)(2)(ii) concerns generation and delivery of toxic products caused by abnormal Engine operation sufficient to incapacitate the crew or passengers during the flight.

CS-E 690

(1) Tests to determine the purity of the air supply must be made.

(2) An analysis of defects which could affect the purity of the bleed air must be prepared and where necessary the defects must be simulated and tests, as agreed by the Agency, must be made to establish the degree of contamination which is likely to occur.

APU:

CS-APU 210 Safety Analysis, (g), (2)(ii) Concentration of toxic products in the APU bleed air for the cabin sufficient to incapacitate crew or passengers;

The BFU deliberated whether harmonisation of the requirements of the demonstration of compliance for the airplane, the engines and the APU would improve cabin air quality.

For the certification of an airplane (CS-25) it is stipulated that the cabin air is free of gases or vapours in any harmful or hazardous concentration. This means that the substances can be in the cabin but shall not exceed a certain concentration. This is common procedure and establishes a relationship with critical values (MAK, NIOSH, etc.). The requirement "harmful concentration" establishes a relationship with health impairments of airplane occupants without directly affecting the capability to act. EASA is of the opinion that the requirements of CS-25.831 are only applicable for concentrations of CO and CO₂ but not for other substances. The demonstration of compliance in accordance with this interpretation of CS-25.831 cannot ensure that cabin air is not contaminated with other substances. If this requirement would be applied to all other possibly toxic substances this would constitute a comprehensive demonstration of compliance in regard to cabin air purity.

CS-25.1309 allows for a comprehensive analysis of cabin air systems in case of malfunctions. This certification specification does not only consider "normal operation" but also the failure of components and systems.

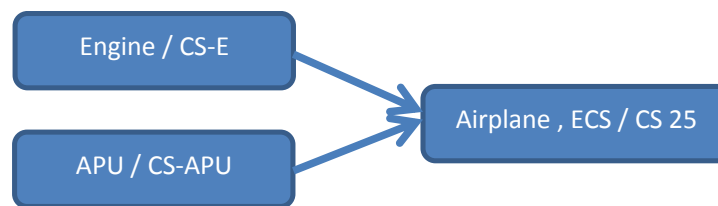
In regard to the demonstration of compliance in accordance with CS-25.1309, EASA classifies the impairment of the capability to act (without incapacitation) as "Major". The BFU estimates that this classification is justified in regard to the described impairments of airplane occupants (flight crew, cabin crew and passengers) (see Table in Chapter 1.5.2). This also means, however, that these events, with a certain frequency of occurrence, are accepted ("Major" equals a probability of $< 10^{-5}$ per flight hour). The social acceptance of this value cannot be assessed in this study.

A complete consideration of all systems, of the toxic products used, and the possible concentrations of these substances in case of malfunction would be a requirement for the complete demonstration of cabin air purity, if demonstration of compliance is done in accordance with CS-25.1309.

The aim of the engine and APU certification specifications is that crew and passengers do not become incapable to act (Incapacitation). A failure analysis which only takes into consideration health impairments (not incapacitation) is not required. This requirement does not eliminate the hazard of occupants sustaining health impairments through cabin air.

Engine certification specifications require air purity. This is a general requirement and does not describe which aim shall be achieved in regard to cabin air. The term "purity" does not include whether the requirement is to eliminate smells, harmful concentrations of substances or the hazard of impairing crew capability to act.

The APU, the engines, and the airplane systems play an equal part in the supply of cabin air. Therefore, the requirements of the individual certification specifications should be comparable.



Cooperation of CS-E, CS-APU and CS-25

The CS-E and the CS-APU list a safety analysis which is comparable to CS-25.1309. As described above the objectives differ:

CS-APU (and AMC):

"Hazardous APU Effects" - "incapacitate the crew or passengers"

CS-E (and AMC):

"Hazardous Engine Effects" - "incapacitate the crew or passengers" and

"Major Engine Effects" - "degrade crew performance"

CS-25 and AMC):

EASA stated that a classification in Major, Hazardous and Catastrophic occurs.

The term "Hazardous" is comparable in all three certification specifications and establishes a direct relationship with the term "Incapacitation".

The CS-APU does not mention "Major Effects" and the CS-E does only name it in regard to the effects on the crew. This makes it obvious that cases where health

impairments (without incapacitation) in conjunction with cabin air quality were reported are not covered by the demonstration of compliance. In accordance with the matrix of CS-25.1309 this would, in general, be classified as minor or major failure condition. CS-E 690 uses the general term "purity" and does not indicate a clear aim.

The BFU does not understand that the CS-25 mentions harmful concentrations (CS-25.831) whereas the CS-E and the CS-APU essentially only eliminate the incapability to act. The BFU is of the opinion that "harmful concentration" should be interpreted solely to mean that health impairments (including long-term) through contaminated cabin air should be eliminated.

EASA stated that chronic health impairments are not addressed in the CS-25 and are not considered during type certification. These considerations should be carried out by medical health organisations and EASA would then incorporate their results. The BFU is of the opinion that a product which has received a type certificate by EASA should be designed in a way that neither crew nor passengers are harmed or become chronically ill.

2.4.2 Supervision of the Type Certification (Application of Critical Values) Detection Methods

One finding was that during demonstration of compliance in accordance with CS-25, CS-E, and CS-APU, only a limited number of substances are considered.

In regard to CS-25.831, EASA only checks the cabin air contamination with CO and CO₂. For the BFU it has not become clear, how demonstration of compliance in accordance with CS-25.1309 in regard to cabin air contamination occurs. EASA stated that hydraulic fluids as sources for contaminations are not considered. In a lot of airplanes, the bleed air system and the EC system are connected with other systems, and in case of malfunctions, they may feed substances into the EC system, e.g. hydraulic oil. The BFU is of the opinion, that during type certification it should be considered which substances can be fed into the cabin air when different systems are working together (normal operation and during malfunctions). The concentrations of these substances should not exceed the critical values for health impairments.

The BFU does not understand how the extensive requirements of CS-25.831 and CS-25.1309 could be met if the certification authority did not conduct a consideration of all substances used.

The certification of engines and APUs rests on the descriptions in the SAE APR 4418. SAE APR4418 lists nine substances and their critical values. These substances are viewed as markers. Other contaminations brought in through the engines are not listed. It is assumed the concentrations of these unlisted substances are within acceptable limits if the critical values of the above-mentioned markers are met. The BFU questions whether the described procedure for determination of the concentrations of nine markers is sufficient. Several publications (CAA Safety Regulation Group Cabin Air Quality 2004/04, SAE AIR4766, NASA Spacecraft Maximum Allowable Concentrations for Airborne Contaminants) describe significantly more and diverse substances in cabin air. DIN EN 4618 lists a total of 19 marker substances. The SAE AIR 4766 lists 21 substances and their critical values which can be present in cabin air.

Based on the descriptions by EASA, the BFU comes to the conclusion that the extent of the demonstration of compliance is not sufficient since not all substances used are considered. There should be a consideration of all substances used (oils, hydraulic fluids, de-icing fluids, etc.) including their ingredients, decay products and critical values for all airplane types. Possible malfunctions should also be included. The critical values should take into consideration health impairment and, if appropriate, the capability to act of the crew.

2.5 Technical Design of the Environmental Control System

Due to the flight profile of a transport aircraft, cabin pressure, temperature and air exchange have to be controlled by a technical system. This means the air is always technically treated. In general, the quality of the conditioned air must be safe for human beings.

Even though this requirement is basically met by the certification specifications, it has to be taken into account, that it is technically recycled air and cabin air quality can be compromised by system malfunctions.

One of the described serious incidents has shown which effect a defective valve can have. Under certain circumstances, hydraulic fluid from an associated system could enter the bleed air system and then the EC system. In individual cases it has happened that hydraulic fluid enters the EC system.

The engine bleed air can be contaminated by engine oil if leakages inside the engine occur. Depending on the operating phase of the engine compressor the temperature

is very high and can cause pyrolysis of oil ingredients. The oil and pyrolysis products can then enter the EC system.

Through the engine and APU compressor intakes any environmental substance can enter the bleed air and then the EC system. On the ground these are mostly exhaust fumes and de-icing fluids.

The BFU is of the opinion, that the analysis of the fume events and the reported incidents alone does not justify design changes of the bleed air system and the EC system. The study did not identify any major flight safety problems which would almost have caused an accident. There were no occupants who had sustained severe injuries which would then have resulted in the classification as accident (in accordance with aeronautical regulations).

Incidents did occur where a flight crew donned their oxygen masks due to smell and/or smoke development to ensure clean, breathable air. In retrospect, there were incidents where wearing oxygen masks was precautionary and there were others where wearing them was necessary.

The descriptions in the reports of headaches, indisposition, burning eyes, dizziness, etc. in conjunction with smell and oil vapours are indications for malfunctions in the bleed air and EC systems. The BFU is of the opinion, that even though a causal connection could not be verified, improvements in regard to occupational medical care are necessary.

The BFU is of the opinion, that the certification authorities, EASA and FAA, have the option to improve the demonstration of compliance in regard to cabin air quality the airplane and engine manufacturers have to comply with.

The BFU is also of the opinion, that possible contaminations could be analysed and, if appropriate, filter systems could be developed to maintain cabin air quality even during system or component malfunction.

As discussed under 2.3.4, the BFU could not assess a possible causal connection between a fume event and long-term health impairments. If another institution can identify a connection, a filter system to protect crew members and passengers might be an approach to solving the problem.

The BFU is of the opinion that turning away from the concept of using bleed air is neither realistic nor justifiable. Refitting every airplane in service is neither technically nor economically imaginable.

The BFU is of the opinion, however, that in the long run other concepts for the cabin air supply are possible.

2.6 Analysis of the Statements and the Medical Records

Statements and Information for the Decision-Making Process

After a fume event has been reported, the BFU collects additional information important for the decision making process. This information often arrives with delay and the content is subjective, therefore, it is difficult to initiate a timely and proper investigation. The reporting operator often cannot answer questions regarding health impairments and enquiries with the persons involved become necessary. It is often not possible to get in contact with the person involved in a timely fashion. Experience has shown that the affected crew members are either already at home, still with the physician, in hospital or are flying again. Even for the question whether oxygen masks were donned a direct contact with the flight crew is necessary. The classification of the event depends on the answer.

Even if the cockpit voice recorder could be seized, it usually contains only information regarding the course of the flight, crew coordination in the cockpit and with the cabin crew. In general, fume events last only a short time and the flight is often continued. If this happens the recording capacity of the CVR is exceeded. Flight data recorders are usually not very helpful, because parameters which would verify fume events are rarely recorded or do not exist.

Because fume events are usually short-term incidents occurring during a flight, the airplane is inspected by technical personnel and returned to service. For economic reasons it is rarely justified to seize an airplane for investigation purposes if it is at all possible because sometimes events are reported with delay. Nevertheless it is important for the decision making process and the initial classification to have early contact with the responsible technician.

The implementation of the questionnaires cabin air (Appendices 5.2 and 5.3) for crew members has proved valuable. The questionnaires help to standardise information content and flow.

Factual Information for the Investigation

In addition to the initial interview by the investigator it is very important to receive medical records. In accordance with Regulation (EU) No 996/2010, the BFU has the right to receive medical data and can provide the commensurate protection, but many persons concerned are sceptical and reluctant to send data and medical records to authorities. In general, it is important that the investigator in charge and the person concerned establish contact and mutual trust before data and medical records are passed on.

Persons involved often give their consent for the use of medical data and promise to send the medical records and test results but never do.

The content of test results and medical records shows the missing standardisation. Often physicians have no information which parameters are important in case of a fume event. In many cases either a blood count or complete blood count is made. The persons involved make unclear statements, e.g. I had a fume event, or I have inhaled TCP. These result in medical examinations and blood tests which do not suffice for the investigation of fume events. Here, too, would standardisation improve the situation. Neither the BFU nor other safety investigation authorities can make suggestions in this regard.

Currently, the BFU does no longer mention the so-called Nebraska Test. The missing standardisation renders this test useless.

The BFU experience has shown that medical records are not very meaningful for the investigation of a fume event. In most cases there is no differentiation between secured, unsecured, or exclusion diagnosis. It is rarely documented when there were no symptoms. If a person concerned says to a physician he/she sustained burnt gas intoxication or inhaled TCP this is often documented as diagnosis without further specification.

If flight and cabin crew and operators want to contribute to the investigation of fume events, the BFU suggests standardisation in this regard also.

2.7 Scope and Limits of the Investigation by BFU

The BFU is the responsible authority for the investigation of accidents and serious incidents, but for the investigation of fume events the options are limited. The BFU

has stated that based on legal requirements the investigation of an incident not classified as accident or serious incident can only be an exception.

The mode of operation of the BFU, as well as any other safety investigation authority, is such that due to a concrete occurrence, facts are determined which allow assessment of the cause. This means, the causal connection between the fume event and the health impairment has to be established.

Even though the BFU does not question these illnesses, the causality cannot be determined with the current methods and means of air accident investigation.

To determine the causality it would be necessary to preserve the cabin air at the time of the event so that it can be examined as to its properties and contaminations. Part of the investigation is verifiable medical diagnoses. Inspections of the airplane and the engines are also necessary.

So far, the BFU could not establish the causality of a fume event as described above.

2.8 Operational Aspects and Defences

The BFU acts on the assumption that fume events and undesirable cabin air contaminations occur. For the protection of airplane occupants, cabin air contaminations should be avoided. But they cannot be entirely ruled out because air condition is necessary. A flight crew should be especially protected. They shall not be impaired in their physical and psychological capacity to act.

The oxygen masks for flight crew are an essential safety measure if air condition and distribution is malfunctioning.

If smell develops in the cockpit and flight crew feel any health impairment, they should decide to don their oxygen masks right away. The airplane manufacturers or the operators have stipulated procedures for the use and handling of oxygen masks during smoke and smell events. These procedures should be trained regularly.

During a fume event, the oxygen mask is an important safety factor because it provides a clean, odourless environment with safe breathable air. The psychological effect to have an insulated and clean environment for breathing can improve the situation.

The analysis of the reports and some individual cases show that a flight crew can prevent a flight-safety relevant situation by the immediate use of oxygen masks after a fume event.

3. Conclusions

The study took into consideration reported and investigated fume events. 663 fume events occurred between 2006 and 2013, in 460 cases smell and in 188 cases smoke developed. Health impairments occurred in 15 cases. The BFU comes to the following conclusions:

- Fume events did occur and have resulted in contaminated cabin air.
- In some fume events the formal requirements for a serious incident were met because the flight crew either donned their oxygen masks or one pilot suffered from partial incapacitation.
- In very few cases the safety margin was reduced to a point where a high accident probability - in terms of the legal definition - existed.
- There were marginal flight safety restrictions, because the flight crew donned their oxygen masks.
- Cabin air contaminations during fume events have caused health impairments in occupants and impaired cabin crew in their performance.
- A lot of reported fume events caused comfort limitations for the occupants but posed no danger.
- A verification of cabin air contamination with toxic substances (e.g. TCP/TOCP) was not possible with the fume events the BFU investigated.
- EASA requires different demonstrations of compliance for airplanes (CS-25), for engines (CS-E) and for the APU (CS-APU) during the type certification process.
- Not all substances which may cause cabin air contamination are directly demonstrated with the demonstration of compliance during type, engine and APU certification.
- There is no standardised reporting and recording system for fume events.
- The BFU detected insecurity among the flight and cabin crew regarding the reporting of fume events.

4. Safety Recommendations

Safety Recommendation No 05/2014

The German Aerospace Industries Association (Bundesverband der Deutschen Luft- und Raumfahrtindustrie e.V. (BDLI)), in cooperation with its member aircraft and engine manufacturers, should initiate a project for scientific research by an independent institute into the potentially hazardous aircraft cabin air contamination and assess their physiological effect on aircraft occupants.

Based on these investigation results, actions for the avoidance, if appropriate, or a sensor system for the detection of specific air contaminations should be developed, which identifies relevant substances and their concentrations so that during so-called fume events the harmless smells can be distinguished from the harmful events.

Safety Recommendation No 06/2014

The German Aviation Association (Bundesverband der Deutschen Luftverkehrswirtschaft, BDL) complement their existing standardisation of the procedures for fume events so that reports in accordance with Article 9 of Regulation (EU) No 996/2010 and Para 5 of the Air Traffic Order to the German Federal Bureau of Air Accident Investigation include such information and data as required for proper classification of the event. Standardised information to be reported per Para 5 h) and j) of the Air Traffic Order (LuftVO) should focus on the following:

- Impairment of the flight crew's capacity to act
- Pilots donned their oxygen masks (as a necessary / precautionary measure / description of the imminent danger)
- Negative effects on occupants
- Number of persons affected
- Duration, intensity, and nature of smell or fume (description of the smell or fume, visibility restriction, colour, source, etc.)

A standardised compilation system should document information (technical investigations, information regarding cargo and passengers) or initiate their incorporation by a respective procedure (medical examinations) which would allow

the company to conduct an analysis and, if appropriate, can be made available to the BFU, should an investigation be initiated.

Safety Recommendation No 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.

Safety Recommendation No 08/2014

The European Aviation Safety Agency (EASA) should launch a research project to have an independent institute, e.g. institute of aerospace medicine or a medical university, study and assess the potential causal connection between transport aircraft cabin air contamination and chronic illnesses.

5. Appendices

Appendix 5.1

Decision making process for the classification as accident or serious incident

Appendix 5.2

Questionnaire cabin air (initial)

Appendix 5.3

Questionnaire cabin air (follow-up)

Investigator in charge:

Johann Reuss

Assistance:

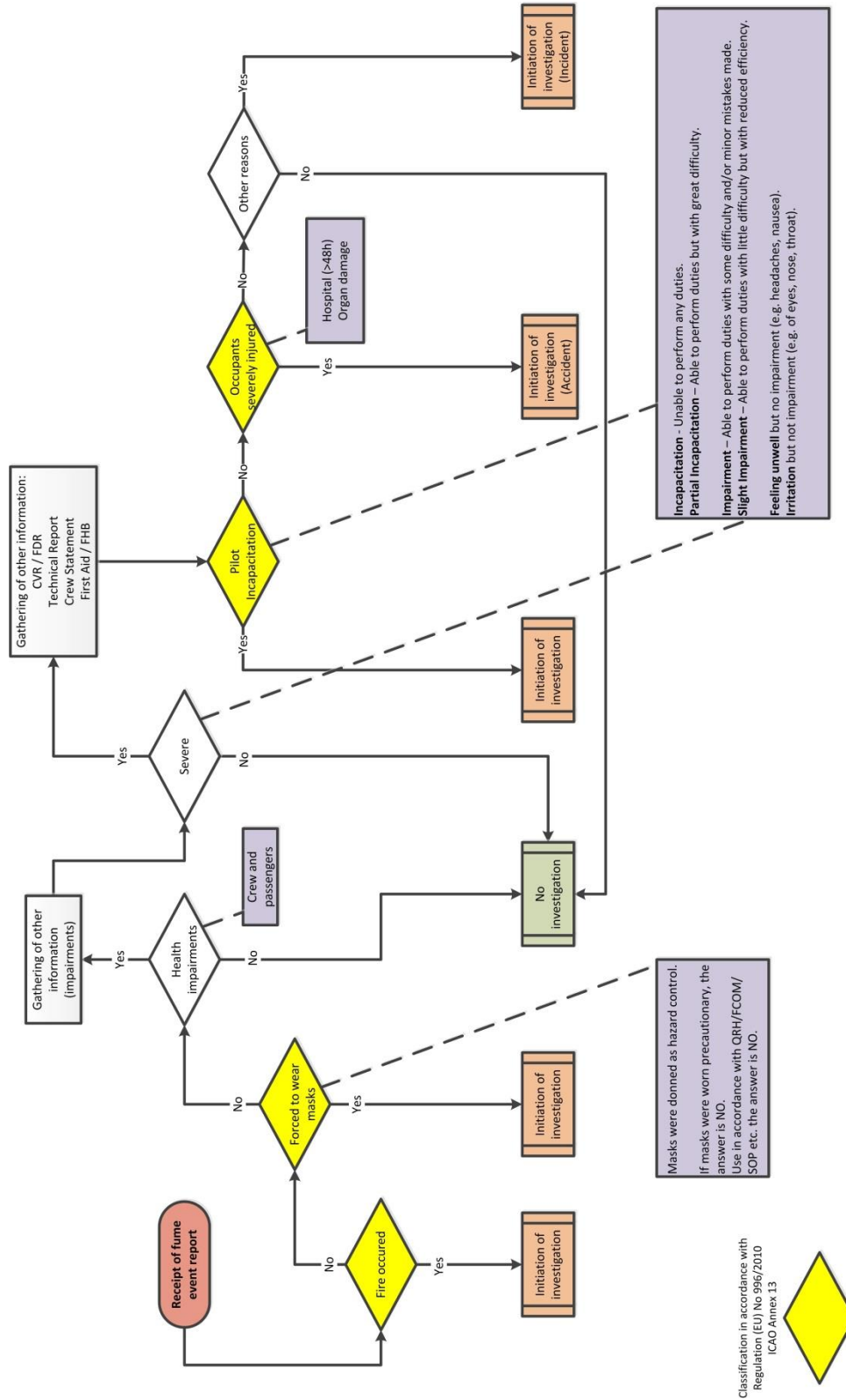
Jens Friedemann

Thomas Karge

Thomas Kostrzewa

Braunschweig, 07/05/2014

Appendix 5.1



German Federal Bureau of Aircraft Accident Investigation

Bundesstelle für Flugunfalluntersuchung



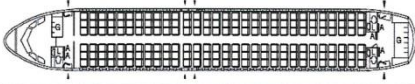
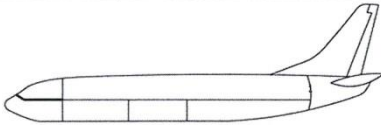
Questionnaire Cabin Air (Initial Interview)

BFU Reg.:

Please complete this questionnaire and return it to the BFU within 24 hours.

Fax-No.: +49 531 3548-246

E-Mail: ops@bfu-web.de

Date of Flight:		Departure Aerodrome:		Arrival Aerodrome:	
Flight No:		Registration:		Aircraft Type:	
Name:			Functions Aboard:		
1. What was observed (smoke and/or smell)? The word smoke also stands for steam or fog.					
<input type="checkbox"/> Smoke		<input type="checkbox"/> Smell		<input type="checkbox"/> Both	
Additional Descriptions:					
Where there other observations (indication, sounds, malfunctions, etc.)?					
2. Who has made these observations?					
<input type="checkbox"/> Captain		<input type="checkbox"/> Co-Pilot		<input type="checkbox"/> Cabin Crew	
<input type="checkbox"/> Pax					
3. In which area of the airplane were these observations made?					
Flight Deck		Cabin		Cargo Compartment	
<input type="checkbox"/> Cockpit		<input type="checkbox"/> Upper Deck		<input type="checkbox"/> FWD	
<input type="checkbox"/> Cockpit Crew Rest		<input type="checkbox"/> Main Deck		<input type="checkbox"/> AFT	
<input type="checkbox"/> E&E Compartment		<input type="checkbox"/> Lower Deck		<input type="checkbox"/> Bulk	
Other:					
					
4. What did you and/or the crew do immediately prior to the first observation?					
5. In which flight phase did the observation occur?					
<input type="checkbox"/> Take Off		<input type="checkbox"/> Climb		<input type="checkbox"/> Cruise / FL: _____	
<input type="checkbox"/> Descent		<input type="checkbox"/> Approach		<input type="checkbox"/> APU Use	
<input type="checkbox"/> Landing		<input type="checkbox"/> Taxi			
Additional Information (Aircraft configuration, Packs, Bleed):					
6. Which checklist was applied?					

Appendix 5.2

BFU Questionnaire Cabin Air (Initial Interview)

7. How intense and what characteristic did the smell/smoke have? How long did it last?		
Minutes:	<input type="checkbox"/> Increasing	<input type="checkbox"/> Decreasing
Description of the smell:		
Additional description of the smoke:		
Opacity:	Colour:	Location (above/below):
Additional Information:		
8. Did you experience any impairments? Which and how intense were they?		
1) Irritation (e.g. eyes, nose, throat) - but no impairments	<input type="checkbox"/>	
2) Feeling unwell (e.g. headache, nausea) - but no impairments	<input type="checkbox"/>	
3) Able to perform duties with little difficulty but with reduced efficiency	<input type="checkbox"/>	
4) Able to perform duties with some difficulty and/or mistakes	<input type="checkbox"/>	
5) Able to perform duties but with great difficulties	<input type="checkbox"/>	
6) Unable to perform any duties	<input type="checkbox"/>	
Additional Information:		
9. How many persons were affected?		
Crew:	Passengers:	
10. Did you or other crew members don an oxygen mask?		
<input type="checkbox"/> Yes	<input type="checkbox"/> No	
11. Why did your or other crew members don oxygen masks?		
<input type="checkbox"/> Precautionary	<input type="checkbox"/> Necessary, because: <input type="checkbox"/> Procedure (QRH etc.) and/or <input type="checkbox"/> Immediate Hazards	
If there were "immediate hazards" please describe:		
12. Will you have a medical examination done?		
<input type="checkbox"/> Yes	<input type="checkbox"/> No	
When:	Where:	
13. Will you pass on the results of the medical examination to the BFU?		
<input type="checkbox"/> Yes	<input type="checkbox"/> No	
14. Cargo (Dangerous Goods List, carry-on luggage, etc.)		
City / Date:	Contact Data (E-Mail, Cell Phone, etc.):	

Bundesstelle für Flugunfalluntersuchung

German Federal Bureau of Aircraft Accident Investigation


Questionnaire Cabin Air (Follow-up)

 BFU Reg.:

Flight Date:	From:	To:
Flight No:	Registration:	Aircraft Type:
Name:		Function:
1. Which medical examinations were conducted after the flight? Please list when, where, to what extent and aim.		
A:		
<input type="checkbox"/> Diagnostics <input type="checkbox"/> Therapy		
B:		
<input type="checkbox"/> Diagnostics <input type="checkbox"/> Therapy		
C:		
<input type="checkbox"/> Diagnostics <input type="checkbox"/> Therapy		
2. Where you given a diagnosis? If yes, which?		
3. Were blood and/or urine samples taken?		
<input type="checkbox"/> Blood		<input type="checkbox"/> Urine
4. Do you know the laboratory results?		
<input type="checkbox"/> Yes		<input type="checkbox"/> No
Note: Please attach copies of the laboratory test results.		

Appendix 5.3

BFU-Questionnaire Cabin Air (Follow-up)

5. Were you unfit to work after the event?	
<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes how long? Why were you unfit to work?	
6. Were you unfit to fly after the event?	
<input type="checkbox"/> Yes	<input type="checkbox"/> No
If yes how long? Why were you unfit to fly?	
8. Do you still experience symptoms? If yes, what are they?	
9. Do you receive medical treatment for these symptoms?	
<input type="checkbox"/> Yes	<input type="checkbox"/> No
10. Additional information you want to give the BFU:	
City/Date:	Contact Data (E-Mail, Phone No, etc.):