

Investigation Report

Identification

Type of Occurrence:	Incident
Date:	2 January 2015
Location:	Near Hamburg
Aircraft:	Airplane
Manufacturer / Model:	Airbus / A 321
Injuries to Persons:	None
Damage:	Aircraft not damaged
Other Damage:	None
State File Number:	BFU15-0006-PX

Factual Information

History of the Flight

The airplane departed Frankfurt Main Airport at 07:43 hrs¹ for a flight to Hamburg. The Pilot in Command (PIC) was the Pilot Flying (PF), the co-pilot the Pilot Monitoring (PM). During climb the senior cabin crew member informed the PIC that at the doors² unpleasant smell was noticeable.³ The smell was described as "scharfer

¹ All times local, unless otherwise stated.

² During a later conducted interview it was stated that there had been smell in the entire cabin.

³ This and the following information regarding the course of the flight are based on the analysis of the CVR and FDR recordings and the statements of the crew.

Geruch (fierce smell)" like "verbrannter Staub (burnt dust)". But it did not smell like "Käsefüße (smelly feet)". The PIC justified the smell with the long time period the airplane had had between flights and the "erhöhte[n] Luftfeuchtigkeit (the high humidity)".⁴ The PIC mentioned then that he too had noticed the smell as well and described it as "Öl (oil)" and "TCP".⁵ The Cockpit Voice Recorder (CVR) did not record any other reports concerning smell.

At 0823:50 hrs during the approach to Hamburg the PIC said: "Jetzt riecht's wieder (now it smells again)". He made the connection with the airplane just having entered clouds. The co-pilot described the smell "mehr wie so Käsefüße (more like smelly feet)", whereas the PIC used the term "oil smell". The PIC switched off "das einser Bleed (the one bleed)"⁶ and "crossbleed on"⁷. Approximately 30 seconds after the smell had started the two pilots began to complain about its intensification. They expressed this with drastic words. Now the smell was described as "beißend (caustic)". Since the switching off of the bleed air of Engine #1 did not reduce the intensity of the smell, at 0824:50 hrs the bleed air system was changed so that the cabin air was supplied by engine No 1 only. This configuration did not reduce the smell either. At 0825:16 hrs the co-pilot suggested they don their oxygen masks. The PIC confirmed this and two seconds later the two pilots donned their oxygen masks. The CVR recorded several deep breaths followed by a brief conversation about the quality of the communication while using oxygen masks and the PICs instructions to configure the airplane for landing. Then the co-pilot informed the air traffic control unit that smell had occurred and the pilots donned their oxygen masks and therefore unusual "sound" would be heard. He also stated that they would not require any further assistance and it was a normal approach. Then the procedures for landing and communications with the air traffic control unit were conducted.

At 0828:40 hrs the co-pilot asked the PIC how he was doing. The PIC answered: "Also mir geht's sehr, sehr gut, hab keine Problem im Moment (I feel very, very good, I do not have any problems right now)". He also said that prior to touch-down the smell had been caustic and he had had a short moment of light-headedness. The co-pilot replied that he had felt prickling.

4 According to the CVR recording the PIC said that the airplane at that time was entering clouds.

5 TCP: Tri-Cresyl-Phosphate. The data sheet of the Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (GESTIS-Stoffdatenbank) describes ToCP as scentless liquid.

6 Bleed-Air-System

7 The FDR recorded the ECS configuration. Refer to the chapter Flight Recorder.

When the PIC informed the air traffic control unit about the number of occupants on board the airplane he made an error in summation but recognised it right away and corrected the number.

When passing 1,000 ft AGL during the approach the FDR recorded the following parameters, among others.

Deviation LOC ⁸ :	0.00039 ddm ⁹ (equals	0.00 DOT ¹⁰)
Deviation G/S ¹¹ :	-0.00391 ddm (equals	-0.01 DOT)
Rate of descent:	720 ft/min	
Airspeed:	151 CAS ¹²	

Landing gears were extended and the flaps lever was in position FULL. The function Autothrust was in Speed-Mach-Mode and deactivated at this altitude. During the approach the landing checklist was completed and the wind conditions discussed. At 0831 hrs the airplane landed on runway 23. The FDR recordings showed that touch-down occurred with a speed of 131 CAS. Hereby at most the following accelerations were reached: n_y : 0.07/-0.12 g, n_z : 1.29 g.

When the co-pilot read back the APRON¹³ frequency he mixed up two digits. The air traffic control unit pointed it out to the co-pilot whereupon he read back the correct frequency.

The fire brigade accompanied the airplane until it reached Gate 15. Shortly before Gate 15 was reached the Auxiliary Power Unit (APU) was switched on. The CVR recordings showed that when the flight crew arrived at the gate they made jokes about their appearances wearing oxygen masks. After they had switched off the engines they removed the oxygen masks.

After the landing the pilots talked intensely about the prevailing wind conditions and the therefore necessary challenging control technique. The PIC expressed how impressed he had been how the changing wind conditions had forced him to react quickly with his control inputs.

⁸ LOC: Localizer

⁹ ddm: Difference in the depth of modulation

¹⁰ DOT: Indication in the cockpit

¹¹ G/S: Glideslope

¹² CAS: Computed-Airspeed

¹³ Apron movement control by the airport operator

To the fire brigade the PIC said that they had donned their oxygen masks as precautionary action.

The pilots stated that they had not completed any checklist to identify the source of the smell because they wanted to focus on the landing. There was no information that passengers had noticed the smell.

Personnel Information

Pilot in Command

Age:	44
Sex:	Male
Licence:	ATPL (A)
Last issued:	20 June 2014
Ratings:	A320
	PIC/IR (both valid until 30 April 2015)
Medical certificate:	Class 1 (valid until 5 July 2014)
Limitations or restrictions:	RXO ¹⁴ , TML ¹⁵
Total flying experience:	12,330 hours

Co-Pilot

Age:	32
Sex:	Male
Licence:	ATPL (A)
Last issued:	15 November 2011
Valid until:	15 November 2016
Ratings:	A318/319/320/321
	COP/IR (both valid until 31 December 2015)
Medical certificate:	Class 1 (valid until 20 April 2015)
Limitations or restrictions:	None

¹⁴ Specialist ophthalmological examinations

¹⁵ Restriction of the period of validity of the medical certificate

Aircraft Information

Manufacturer:	Airbus
Type:	A321-131
Manufacturer's Serial Number:	0518
Year of manufacture:	1995
Maximum Take-Off Mass (MTOM):	83,000 kg
State of registry:	Germany
Total airframe hours:	47,481 hours
Cycles:	37,055

Engine:

Manufacturer:	International Aero Engines AG (IAE)
Type:	V2530-A5
Serial number:	Left: V10139 / Right: V10071

The aircraft type A321 is a twin-engine low-wing aircraft. The aircraft had a German certificate of registration. The Airworthiness Review Certificate (ARC) was valid until 17 September 2015.

The maintenance documentation (TechLog) showed an entry on 29 December 2014 as R-Module (Ramp Inspection) (Jobcard A1014320, Issued SEP14), which was the last maintenance action prior to the flight on 2 January 2014.

The operator provided the list of lubrication consumption depicted in Appendix 4. Also provided were the maintenance records of this airplane which showed that prior to 2 January 2015 a smell occurrence had been recorded on 15 September 2014 (entry in the TechLog T7535519).

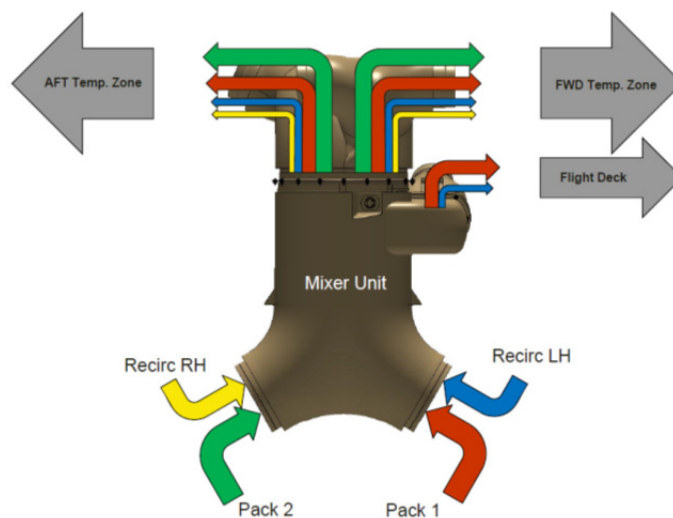
On 29 December 2014 the airplane had last been de-iced. Afterwards it had performed four flights.

Environmental Control System

In normal operation the Environmental Control System (ECS) is supplied with engine bleed air from both engines. As an alternative the supply can be provided by the APU

or a ground power unit. The bleed air is first fed to two air cycle machines (Pack), where air pressure and air temperature are reduced, and then to the mixer unit. In the mixer unit this air and the recirculating air from the cabin are mixed. Depending on the desired temperature hot air is added to this mixture before it is fed to the cockpit and the front and aft cabin areas.

The air for the cockpit is a mixture of the air from pack #1 and the recirculating air from the left cabin area.

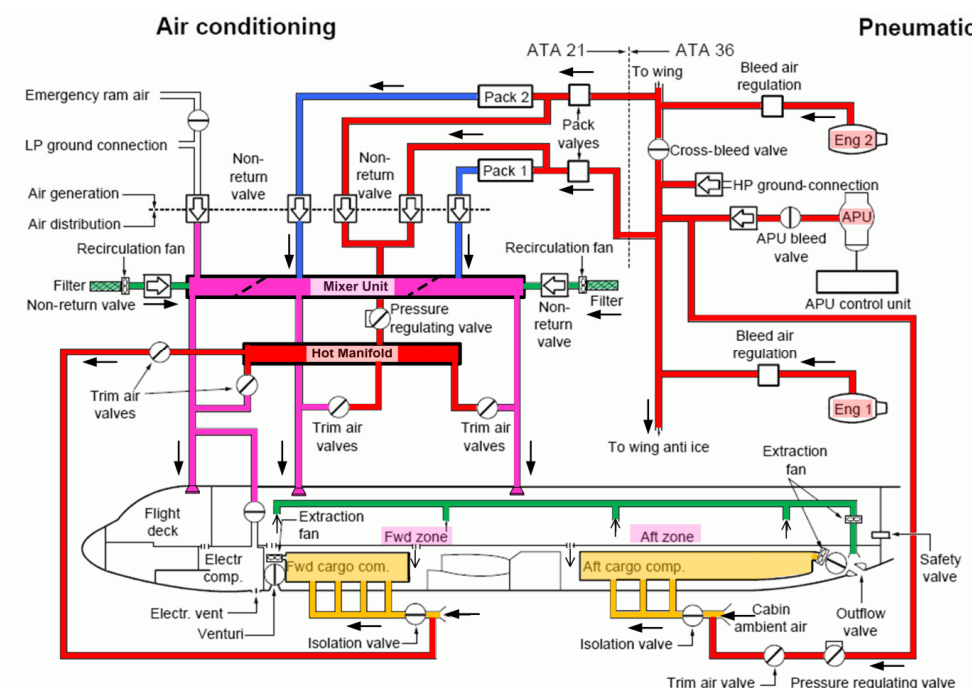


Simplified schema of the mixer unit

Source: Airbus

Recirc RH and Recirc LH describe the source of the recirculating air (right and left fuselage side)

The air pressure within the airplane is controlled by the amount of air drained from the cabin.



Environmental control system - general diagram

Source: Airbus/BFU

Meteorological Information

According to the aviation routine weather report (METAR) of Hamburg Airport of 0750 hrs the following weather conditions prevailed:

Wind:	240°, 19 kt, gusts 29 kt
Visibility:	6,000 m
Special weather phenomena:	Rain, drizzle
Clouds:	1-2 octas at 300 ft, 5-7 octas at 700 ft
Temperature:	7°C
Dewpoint:	6°C
Air Pressure:	1,011 hPa
Temporary change:	Wind 240°, 20 kt, gusts 35 kt Visibility 4,000 m

The air traffic control unit advised the flight crew of the surface wind being 250° with 21 kt, gusts 32 kt.

Aids to Navigation

For the approach to runway 23 in accordance with Instrument Flight Rules (IFR) the Instrument Landing System (ILS) was available as precision approach procedure.

Radio Communications

Radio transmissions with the air traffic control unit responsible were conducted in English.

Aerodrome Information

Hamburg Airport (EDDH) is an International Airport. It has two runways - 05/23 and 15/33, respectively.

Flight Recorder

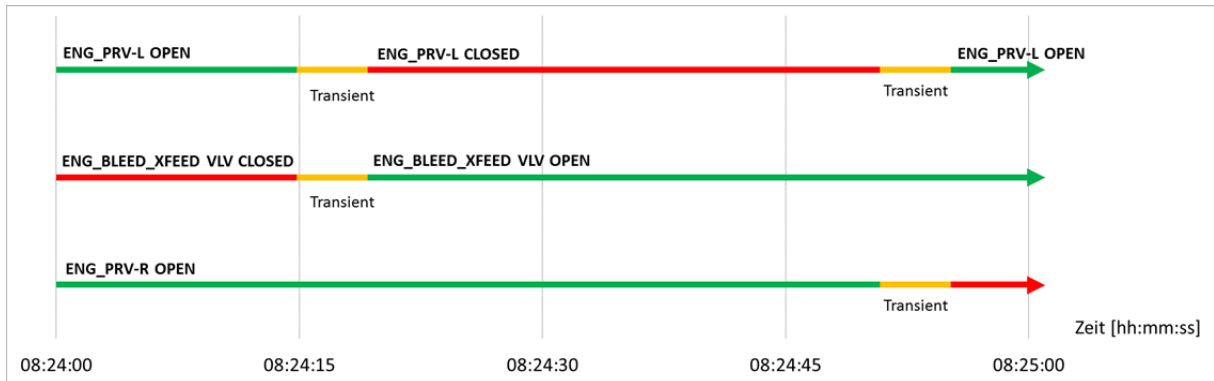
The airplane was equipped with a Fairchild F 1000 Flight Data Recorder (FDR) and an L-3 Communications Corporation FA 2100 CVR. The BFU read out the data of both recorders. The read-outs were used as basis for this report.

The relative times of the CVR data were synchronised with the recorded time of the FDR data. The first time the parameter Manual Radio Transmission Key (VHF-Button) was recorded after landing served as synchronisation point.

During the four previous landings (touch-down time +/- 2 s) the FDR recorded the following maximum values for the acceleration in the three aircraft axes ($n_{x,y,z}$):

n_x : -0.16 g, n_y : -0.07 / 0.09 g, n_z : 1.39 g

The FDR parameters ENG_PRV-L, ENG_PRV-R, and ENG_BLEED_XFEED VLV indicated the positions of the bleed and cross bleed valves. The position of the valves did not change any more until the landing.



Depiction of the FDR parameters ENG_PRV-L, ENG_PRV-R and ENG_BLEED_XFEED VLV

Source: BFU

Findings on the aircraft

The maintenance organisation of the operator compiled an action order after the smell had occurred. Among other things, it included checking both engines for leakages, replacement of filters, and checking the air inlet of the APU for contaminations. The maintenance documentation (TechLog) showed that no leakages or contaminations were found.

The measurement device Aerotracer was used during a high power run up. This was done before the filters were replaced. Nine different combinations (engine thrust, ECS setting and air sources) were checked. During the measurement the following indications occurred:

Substance: „GLYCOL OLD“

Concentration: „?“

No Engine Oil indications were generated.

The BFU provided the manufacturer of the Aerotracer with the raw data of the air quality measurements, with the aim to gather more information about possibly measured substances, which normally are not indicated.

The results of the measurement on 3 January 2015 were confirmed. In addition, the data showed that Acetone (max. 0.527 ppm¹⁶) and once Ammonia (max. 1.106 ppm) were detected.

¹⁶ ppm: parts per million

In accordance with the operational flight plan landing mass of the aircraft was 59,900 kg.

Medical and Pathological Information

The BFU sent questionnaires to the pilots and the four flight attendants in order to estimate their physical impairments and their intensity. The two pilots and three flight attendants answered as follows:

Description of the symptoms according to the BFU questionnaire	Persons describing these symptoms
1) Irritation (e.g. eyes, nose, throat) - but no impairments	PIC, one flight attendant
2) Indisposition (e.g. headache, nausea) - but no impairments	PIC, three flight attendants
3) Able to perform duties with little difficulty but with reduced efficiency	Co-pilot, one flight attendant
4) Able to perform duties with some difficulty and/or mistakes	PIC
5) Able to perform duties but with great difficulties	
6) Unable to perform any duties	one flight attendant ¹⁷

The PIC listed the following symptoms in a report the next day: Prickling in the fingers, light-headedness, scratchy throat, and indisposition. In another report written two weeks later he listed the following additional symptoms: Hot flashes, slight dizziness, and significant prickling in the fingers up to the carpus. During an interview conducted by the BFU three weeks after the occurrence the PIC stated that he had felt the prickling in his fingers even after the flight.

The co-pilot stated that all symptoms had disappeared after he had donned the oxygen mask and he had felt fit and highly productive.

¹⁷ This flight attendant had also indicated level 2.

Concerning the statement on the CVR recording that he had told the fire brigade the masks had been donned as precautionary action, the PIC added he had done so to reassure them.

The statement on the CVR that he felt very well again he had made to induce confidence in the co-pilot.

Both, the PIC and the co-pilot stated that they had been fit during the flight before the smell occurred and did not have any impairment. The day prior to the flight they had slept long and felt rested. Five days prior to the flight the PIC had conducted his last flight; for the co-pilot it had been two days.

Both pilots viewed the errors (wrong number of occupants on board and wrong read back of the frequency), which had occurred in the flight phase with the oxygen masks, as normal. They could also have happened during any other flight.

On 2 January 2015 blood samples were taken from both pilots. The BFU was provided with the test results of these samples (Appendix 5). The laboratory stated there were no irregularities. The test results of a urine sample, taken at the day of the occurrence, from one of the flight crew members had also been provided. Analysis showed 1.34 µg/l Di-Phenylphosphate (reference value: 5 µg/l).

A report of the cabin crew stated that the cabin crew also noticed the smell during the approach. It was described as "starken Geruch (strong smell)" like "nach alten Socken (like old socks)". The report did not contain any evidence of incapacitation of any member of the cabin crew.

There was no evidence that passengers had had any health problems.

Fire

There was no evidence of fire.

Organisations and their Procedures

The Operations Manual Part A (OM-A) of the operator lists the criteria for a stabilised approach:

LATEST AT 1000 ft:

LOC & G/S: +/-1 DOT

Rate of Descent max 1000 fpm (may be exceeded brief in gusty conditions)

Airspeed -5/+10 from Target Speed (-----“-----)
Landing Configuration
Adequate Power

The Operations Manual Part-B/QRH of the operator includes a checklist SMOKE/FUMES/AVNCS SMOKE (Appendix 6).

Additional Information

Air Quality Measurement Device

The manufacturer of the air quality measurement device Aerotracer stated that the device can detect and identify volatile substances, such as adhesives, hydraulic fluid or lubricants, commonly used materials in aircraft. It was developed for the trouble shooting after fume events.

The manufacturer also stated that the indication "GLYCOL OLD" is activated when ethylene glycol (principal component of de-icing fluids) is detected.

Assessment of the Toxicological Pathway

The BFU has charged the Institut für Arbeits-, Sozial- und Umweltmedizin der Universitätsmedizin Göttingen (ASUM-UMG, University Medical Centre Göttingen) to assess the course of the flight and the impairments the pilots had described. In the past few years in the context of occupational medical assessment, the institute had become a contact point for aircraft crew members involved in fume events. Human biomonitoring had been established at the institute, but the crew members of this flight had not participated.

Based on the information provided by the BFU regarding this case and another similar one, and their own knowledge and experiences the experts of the ASUM-UMG analysed and assessed the actions of the flight crew regarding their impairment. The result was presented in a report, together with a description of the toxicological pathway:

The symptoms described in the recorded conversations are consistent with those symptomatologies of other cabin air incidents [Abou-Donia et al., 2013; Heutelbeck et al., 2016]. They can be explained, among other things, by the occurrence of Volatile Organic Compounds (VOC) in the cockpit / cabin air.

VOCs comprise seven compound classes: Alkane, aromatics, terpene, chlorinated hydrocarbon, ester, aldehyde, and ketone, and others [Seifert, 1999]. Many of these compounds are ingredients in lubricants or hydraulic fluids (before or after pyrolysis), kerosene, and de-icing fluids used in aviation [Ritchie, 2003; Mair et al., 2015, Rosenberger et al., 2016]. [...]

The described symptomatology is consistent with the impact of VOC. Because of the described clouding of consciousness¹⁸ and the appearance of "verwaschene Sprache (slurred speech)" of a pilot here the neurotoxic effect of VOC is paramount.

The observed fast effect, e.g. on the central nervous system, and the quick disappearance as soon as the exposure ended or was interrupted, is characteristic for VOC. Limitation of performance under exposure is surely present.

Supplementary to the toxicological statement regarding possible intoxication, the ASUM-UMG toxicologist wrote:

Regarding the provided conversation transcriptions and the occurrence of exposure the pilots do not report any of the indicator symptoms of an organophosphate intoxication. As explained in the toxicological statement the symptomatology described in both cases are consistent with the impact of VOC. In the present cases, the impact of organophosphate cannot safely be ruled out, but due to the currently available information it is rather unlikely.

Regarding the concentration of VOC, which result in physiological symptoms, he remarks:

In relation to the symptomatology in your case the following concentration-effect-relationships described in literature [Seifert, 1999] can be applied:

0.20 - 3.0 mg VOC/m³ Irritation or impairment of well-being possible

3.0 - 25 mg VOC/m³ Exposure results in an effect; headache possible

> 25 mg VOC/m³ Headache. Other neuro-toxic effects except headache possible.

¹⁸ Note: The PIC described his impairment as "Benommenheit (light-headedness)". Clouding of consciousness: State of reduced alertness and limited perception. Clinical symptoms: The Patient can open his eyes spontaneously or through pain stimulation and/or obey requests. Verbal expression is possible. The patient is not oriented in regard to person, place, and time. Source: Neurochirurgie, Handbuch für die Weiterbildung und interdisziplinäres Nachschlagewerk; Hrsg. Moskopp, Wassmann; Schattauer Verlag 2005.

The toxicologist could not narrow down which of the seven classes of VOC could be assumed to have been the cause for the symptoms of the crew members.

General Examinations of the Institut für Arbeits-, Sozial-, und Umweltmedizin der Universitätsmedizin Göttingen

The ASUM-UMG was charged by the association of the statutory accident insurance to conduct examinations of crew members, who have been involved in other flights, where fume events have occurred. The resulting expert opinions listed the different existing VOCs in blood and urine samples¹⁹. The BFU was provided with results of individual samples. Ten different VOCs were determined:

2-Butanone (blood/urine)	n-Octane (blood)
Isopropanol (blood/urine)	n-Decane (blood)
2-Methylpentane (blood/urine)	2-Heptanone (blood/urine)
n-Hexane (blood/urine)	Toluol (blood/urine)
n-Heptane (blood)	Acetone (blood/urine)

The BFU was not provided with a detailed description of the preparation, storage, and analysis routines and the applied validation and quality assurance standards.

No crew member of the occurrence flight was examined at the ASUM-UMG.

Assessment of the Pilots' Impairment

The BFU asked the Kriminaltechnische Institut des Bundeskriminalamtes (BKA, Federal Criminal Police Office) to assess the CVR recordings regarding any signs of possible intoxication or stress present in the voices. The result showed that the persons involved did not suffer from impaired consciousness during the occurrence. There are no irregularities regarding voice, language, and manner of speaking, which would indicate abnormal stress in the speaker.

In addition, the BFU asked three airline transport pilots, who are familiar with flight safety issues, to assess the CVR recordings. None of these pilots could determine any noteworthy impairment in speech or actions.

Further Information Regarding the Cabin Air Quality in Transport Aircraft

In 2014 the BFU published the Study of Reported Occurrences in Conjunction with Cabin Air Quality in Transport Aircraft (BFU 803.1-14 / 07.05.2014). In this study 663

¹⁹ Determined using Headspace Gas Chromatography / Mass Spectrometry

reported occurrences between 2006 and 2013 were analysed. Subsequently, the BFU has issued four safety recommendations.

https://www.bfu-web.de/DE/Publikationen/Statistiken/Tabellen-Studien/Tab2014/Studie_Fume_Events_2014.html?nn=223308

In 2015 the International Civil Aviation Organization (ICAO) published Circular 344-AN/202, Guidelines on Education, Training and Reporting Practices related to Fume Events.

In March 2017, the European Aviation Safety Agency (EASA) published the study Preliminary Cabin Air Quality Measurement Campaign, which addressed the identification and quantification of substance classes present in the cabin air of transport aircraft. For the study, several flights with different aircraft types were conducted, where air samples were taken, which were tested for VOC individual substances, TCP and aldehyde. Already during the flight the total amount of VOC, CO, CO₂, O₂, the air density, the air pressure, and the temperature were measured. The limit values, which are defined in Germany for rooms inside public buildings, were not exceeded in any of the measurements. The authors think it unlikely that such low substance concentrations can be detected/are detectable with the currently used bioanalytical procedures.

The BFU was provided with measurement data of cabin air of a flight, where a fume event occurred, where the same measurement equipment was used as in the flights for the EASA study. The analysis of these measurements showed that the concentration of individual substance classes was similarly low as was determined during the EASA study.

Information from the Aircraft Manufacturer

The aircraft manufacturer answered the questions of the BFU as to which of the above-mentioned pollutants could be released through materials or operating fluids used in aircraft. The condensed statement is:

Due to the high number of existing VOCs and the limited information in the safety data sheets it was not possible for the aircraft manufacturer to name all possible sources (components, working procedures, etc.), where VOCs could be released. A search in the database revealed 450 entries for compounds which contain one or more of the 10 VOCs the ASUM-UMG has determined. During the manufacturing process of the airplane these are mainly used for bonding, surface coating, corrosion protection, and cleaning. There is no indication that they are used during aircraft

operation. Kerosene contains some of the compounds mentioned above to a smaller or larger extent, since it mainly consists of a mixture of hydrocarbons (C9 to C16). Kerosene does no longer contain large amounts of Hexane.

In summary, the aircraft manufacturer answered the question, which pollutants could be created in contaminated bleed air, as follows:

There is no conclusive database of thermal breakdown products which covers all possible contamination and temperature scenarios. Bleed air, as normal air, contains about 21% oxygen. Therefore, only oxidised products such as aldehyde and acids should be the result of thermal degradation. There is only one study (ASHRAE Research Project Report 1306-RP), which reports that during thermal degradation of engine oil aliphatic hydrocarbons are created. For safety reasons the thermal degradation was carried out under nitrogen atmosphere and therefore is not representative for bleed air contaminations.

The aircraft manufacturer referred to the published data of the ASHRAE 1262 RP study which concludes that, with few exceptions, the concentrations of the majority of VOCs found in the aircraft cabin were equivalent or lower than those in buildings.

Analysis

The smell event in the airplane was characterised by the fact that the two pilots simultaneously noticed an intense and unpleasant smell. Immediately afterwards they both noticed symptoms and performance impairments. The flight attendants also experienced impairments.

The BFU investigation aimed at assessment of the flight safety hazard due to the symptoms of the flight crew through cabin air contamination. The source of the smell should be determined.

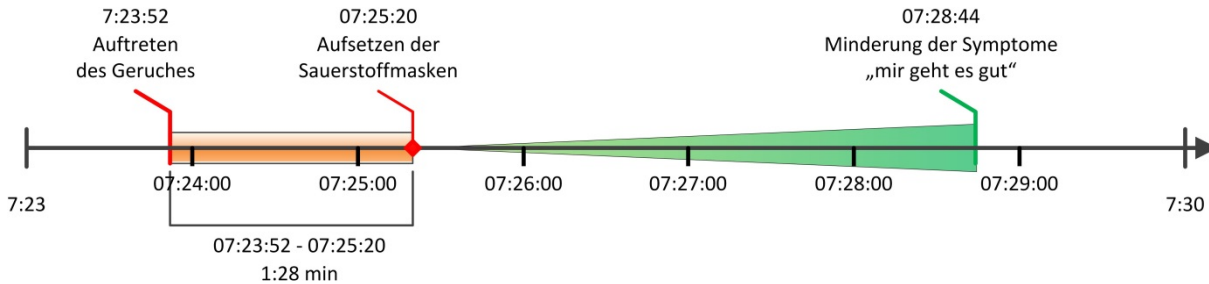
Flight Operations/Flight Crew Action

For the assessment of the flight crew's actions the BFU had the data of the CVR and FDR and the statements of the crew available.

The CVR recordings show that the smell was immediately associated with engine lubricant. It is possible that this is connected with the assumption expressed during climb that it must be "Öl (oil)" or "TCP".

The PIC then initiated actions to clear the smell by changing the bleed air supply. Since the flight crew assumed bleed air supply contamination these actions are considered correct.

Because the smell could not be eliminated and the pilots associated their health impairments with it, donning their oxygen masks was a logical action. Immediately after donning their oxygen masks the pilot had perceived improvement of their symptoms. The BFU is of the opinion that the flight crew had taken the correct action to eliminate the symptoms. This is also true considering the fact that flying under oxygen masks causes impairments for the conduct of the flight (e.g. impeded communication).



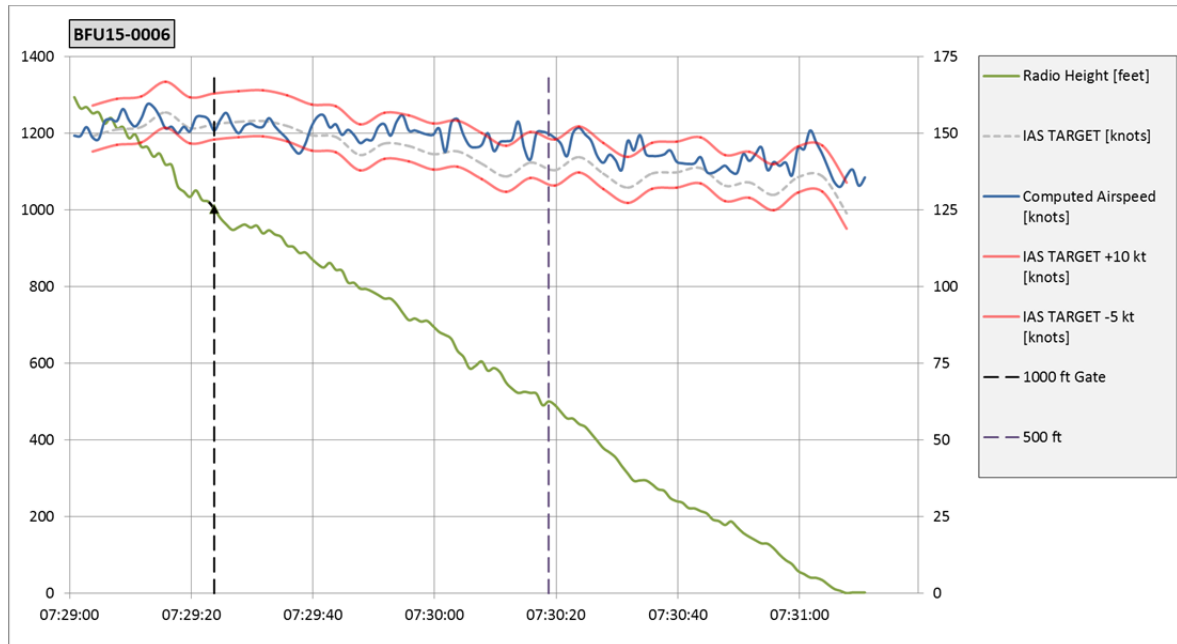
Chronological sequence of the occurrence

Source: BFU

Then the flight crew completed the landing checklist. Based on the landing mass, the reported wind conditions and the configuration of the aircraft target approach speed (IAS-TARGET)²⁰ was 153 kt at a flight altitude of 1,000 ft AGL²¹. While passing this altitude the speed was adhered to with the tolerances permitted in the OM-A. Neither the vertical and lateral ILS deviations nor the allowable maximum sink rate were exceeded. Thus, the criteria for a stabilised approach were adhered to. The analysis of the airspeed shows that the pilot was able to fly the aircraft during the approach within the tolerances.

²⁰ IAS TARGET = Max [VAPP, (VAPP + CURRENT HEADWIND - TWR HEADWIND)]

²¹ AGL: Above Ground Level



Analysis of the airspeed during the approach

Source: BFU

The recorded acceleration values during the landing were low and comparable to other landings with this airplane. The course of the flight shows that the flight crew was able to accurately control the airplane even while wearing oxygen masks and dealing with the difficult wind conditions during the landing.

The flight crew did not use any checklist to identify the source of the smell, because according to their statements they wanted to focus on the landing. The use of the SMOKE/FUMES/AVNCS SMOKE checklist would not have given the flight crew any effective guidance, because it is geared towards identification and isolation of any possible source of smoke in the airplane. Therefore it is not suited to determine and eliminate the various causes for smells.

A differentiated examination of smells is necessary, because on the one hand they can indicate some malfunction within the airplane (e.g. fire) and on the other hand can be a normal event during the operation of an aircraft.

The fact that the flight crew associated the smells with the entry in to clouds, but also with the odourless TCP shows that they had an unclear and biased conception about their causes. The BFU is of the opinion that it is necessary that crews are trained regarding the many causes of smells, their classification, and the possibly resulting hazards.

Therefore, the aircraft manufacturer should issue operating instructions for actions to be taken during fume events. The operators of aircraft should inform their crews of the development of smells and their risk assessment.

Technical Examination

The examination of the airplane did not reveal any findings, which would have explained the smell event. However, the technical examination was limited to the assumption that the smell had been caused by contaminated bleed air. Other possibilities were not taken into account. The BFU is of the opinion that there are different sources for smell development in airplanes. These are not solely limited to contaminated bleed air. These can also be substances, which are already on board and released during normal operation or malfunction (BFU Study 803.1-14, pages 49 ff and ICAO Circular 344-AN/202, Item 2.3.2).

Trouble shooting geared solely towards contaminated bleed air reduced the possibility to determine the source of the smell. The maintenance actions conducted prior to the flight do not explain the smell event.

Aircraft Maintenance and Measurement with the Air Quality Measurement Device

The measurement with the air quality measurement device was conducted prior to the trouble shooting proper. This ensured that possible contaminations of the bleed air supply system and the filters were not removed and thus the measurement results not distorted. Nevertheless, this measurement only reproduced the condition as it was during the ground test run, sometime after the smell event itself. Due to the fact that at that time no indication "Engine Oil" was generated, does not rule out entirely that the air had been contaminated by engine oil during the previous flight. But because no abnormal amounts of lubricant consumption occurred during the flight it can be ruled out that a major amount of engine oil ended up in the bleed air. The subsequent engine check did not reveal any oil leakages. The BFU does not have assured evidence available, which amounts of engine oil in the bleed air only cause smell and which already health impairments (BFU Study 803.1-14 / 07.05.2014 / Safety Recommendation 05/2014).

The BFU cannot fully explain why the air quality measurement device has generated the indication "GLYCOL OLD/?", even though on that day the airplane had not been de-iced. There is a possibility that de-icing fluid residue from previous de-icing procedures was present in the ECS. The technical examination of the airplane did

not reveal any liquid residue in the examined part of the bleed air system. It is possible that very small amounts had remained undetected in the ECS, which then caused the indication. However, it is then not understandable why the smell did not occur during the previous flights and why small amounts should have triggered these symptoms. It can also not be explained why the smell only developed during certain flight phases.

There is also no explanation as to why the indications Acetone and Ammonia occurred. Due to the description of the smell and the measured extremely low concentration it is unlikely that the substances were involved in the smell event. It was also not possible to draw conclusions as to the concentration of these substances at the time of the smell event during the flight.

Determination of Causes during the Flight and Distribution of the Air in the Airplane

The cockpit and cabin crews noticed the smell. No local sources, such as oven and defective component, could be identified. Therefore, it is very probable that the ECS supplied the cabin with the smell.

Due to the complex distribution of air from the two bleed air sources and the recirculating air into the cockpit and cabin (refer to page 6 simplified schema of the mixer unit) it is impossible to determine in normal operation, from which part of the bleed air system the contamination is transported to the interior of the airplane.

Only when the ECS is exclusively supplied with bleed air from one engine is it possible to determine the source of the bleed air contamination.

This was tried to accomplish by shutting off bleed air supply of engine #1 and opening the cross bleed valve (and therefore supply of both packs from engine #2). Due to the high air transfer rate (54 h^{-1}) a high amount of air was replaced in the cockpit in the 30 seconds this configuration was maintained. This should have resulted in a reduction of smell intensity. The flight crew did not notice this, however. This could indicate bleed air engine #2 contaminations. However, ECS contamination (flow direction after the cross bleed valve) or the trim air could have caused the persisting smell.

The unreliable olfactory human perception could be another reason for the continuing perception of the smell, which should not be ignored.

The BFU is of the opinion that since none of these reasons can be ruled out it cannot be determined whether the smell was caused by engine #1 bleed air contamination.

The subsequent change of the packs' air supply (supply of the packs exclusively from engine #1) did not achieve any result because immediately afterwards the pilots donned their oxygen masks.

Aircraft Manufacturer Statements

The aircraft manufacturer told the BFU that VOC occur with various products, which are used in aircraft production. They also confirmed that VOC can occur in cabin air if the bleed air is contaminated with them. According to the results of the studies the concentration of VOC, created through thermal degradation, in the cabin air is so low that the target values for air quality of interior rooms were not exceeded. Based on these statements the BFU does not understand, how a contamination of the cabin air with VOC via the ECS could have occurred, which then caused the symptoms of the crew.

Crew Impairments

Flight Crew:

According to their statements the flight crew did not have any health impairments until the smell occurrence at 0823:50 hrs. The CVR recordings showed that the pilots did not talk about any health impairments up until they donned their oxygen masks. Sometime afterwards both pilots said that they had observed symptoms before. These were described differently. The PIC talked about a short sense of light-headedness, the co-pilot had felt prickling. The CVR did not contain any other information regarding symptoms.

According to the PIC's estimation, which he had arrived at immediately after he had donned his oxygen mask, "normale (normal)" landing was possible. At no time was a Pan Pan or Mayday call considered, which indicates that the pilots did not assess the situation as dangerous. The PIC said 3:24 minutes after donning the oxygen masks that he now felt "sehr, sehr gut (very, very good)". The conversation of the crew at the gate also showed that the smell event and the noticed symptoms did not play any role anymore, because they did not speak of the event. The crew was still very impressed by the control inputs that had been necessary due to the prevailing wind conditions. Neither their actions nor their speech indicated that the pilots had been impaired by the smell event.

At a later date, one day and two weeks after the occurrence, during a self-assessment, the PIC broadened the symptomatology. He listed hot flashes, scratchy throat, slight dizziness, light-headedness, and prickling in the fingers. On the questionnaire he indicated level 4²². The BFU could not understand why the PIC assessed problems in performing tasks, because the objective data does not show any performance impairments on his part. The analysis of the occurrence became complicated by the escalating description of the impairments, since the multiple symptomatology does not allow a correlation with a defined toxicological-physiological reaction (refer to Toxicological Assessment).

The co-pilot's descriptions of his symptoms are more uniformly. The observation recorded on the CVR of prickling was later repeated by him during the interviews. The objective data does not show any indication of performance impairment of the co-pilot. The BFU is of the opinion that the sporadic occurrence of small mistakes (erroneous addition of the occupants on board and reading back of the frequency) is no evidence of reduced performance.

The BFU is of the opinion that the symptoms the pilots observed may have influenced their performance, but were at no time so pronounced that they jeopardised the performance of tasks.

Cabin Crew

The cabin crew indicated different levels of impairments in their questionnaires. Mainly level 2 was indicated.²³ One cabin crew member stated that he/she was not able to perform tasks. The BFU does not understand this because the cabin crew report does not contain the incapacitation of a cabin crew member. The report of the PIC does not contain any such indication either, nor was it recorded on the CVR.

The cabin crew members were also exposed to the smell. Their impairments were similar to those of the pilots before they donned their oxygen masks. Their symptomatology did not worsen even though they did not don any oxygen masks.

Toxicological Assessment

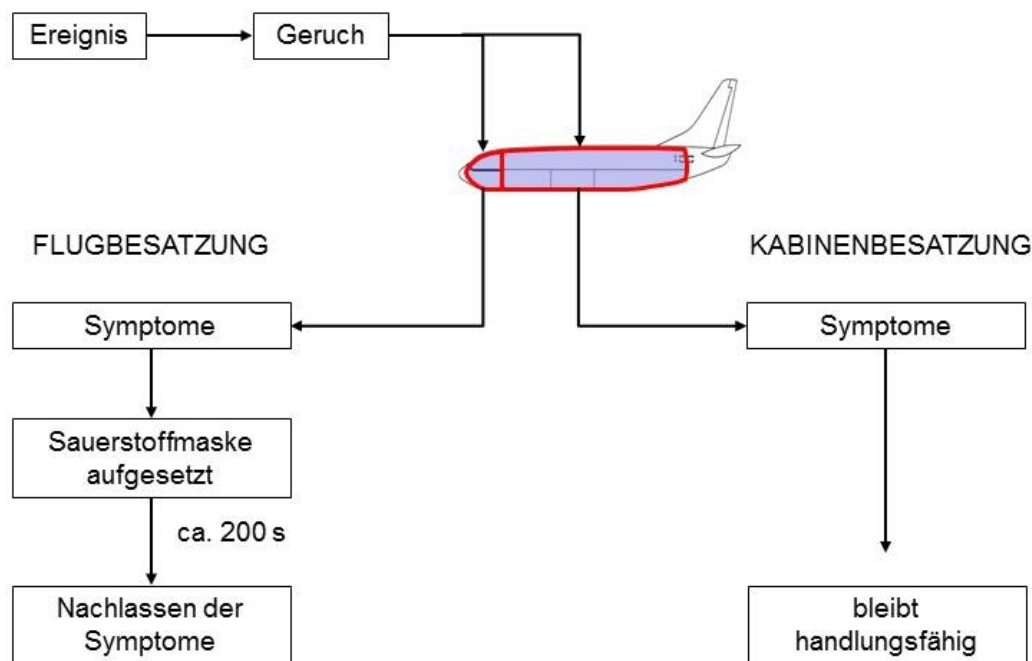
²² Level 4: To perform tasks, but with some difficulties and/or minor errors

²³ Level 2: Indisposition (e.g. headaches, nausea) - but no impairment

On board the airplane an event occurred which resulted in strong smell.

Subsequently, the crew members observed symptoms. The pilots donned their oxygen masks, which significantly reduced the symptoms.

It was not possible for the BFU to determine, which substances in the cabin air had caused the smell and how the symptoms, the crew members had described, could have occurred. This event was characterised by the rapid occurrence of symptoms, but also by their rapid disappearance after a short oxygen dose.



Schematic sequence of the smell event

Source: BFU

The toxicological statement of the ASUM-UMG indicated that the occurrence of VOC in the cabin air caused the smell and the symptomatology of the crew. Seven classes of VOC were indicated. The toxicologist could not narrow them down. The assumption of the toxicologist²⁴ that VOC could have caused the contamination of the cabin air, is for the BFU only insofar understandable as that the rapid appearance of symptoms associated with VOC under exposure and their rapid disappearance after the termination of the exposure corresponds with the course of this event.

²⁴ The clouding of consciousness the toxicologist had assumed in his expert opinion did not occur

It was not possible to unambiguously clarify, which concentration of VOC in the cabin air would have been necessary to cause the described symptoms. In the expert opinion, the reference table for the appearance of health symptoms during TVOC²⁵-Exposure (Seifert, 1999) used, describes more severe symptoms at concentrations of $>25 \text{ mg/m}^3$. Based on the statement of the aircraft manufacturer and other measurement results, the BFU has available, a TVOC exposure of this magnitude through addition to the cabin air is not comprehensible. Furthermore, the study used for the expert opinion describes exposure times of up to 0245 hrs. Therefore, neither the considered TVOC concentrations nor the exposure time correspond with the known characteristics of this cabin air event.

The other investigation results could not support the explanation of the toxicologist, i.e. the existence of VOC in the cabin air as cause of the symptoms, or they were not suited for the proof of existence. The medical examination of the crew (blood and urine samples) was, in this case, not suitable because it was not geared toward the verification of VOC. Even if the VOC verification were positive, e.g. through human biomonitoring, the resulting individual health consequences, as well as the underlying biological pathways, are presently not defined. Besides the occupational medical examination at the Institut für Arbeits-, Sozial- und Umweltmedizin der Universitätsmedizin Göttingen there is no other examination methodology geared to aircraft cabin air contamination.²⁶

The measurements with the air quality device cannot be used for the verification of the toxicologist's assumption, because they were conducted after the occurrence. It is possible that de-icing fluid residue could have allowed the generation of VOC during thermal degradation. The entry of larger amounts of de-icing fluid into the ECS is very unlikely, because the airplane had already conducted four flights since the last de-icing procedure, and no smell event had been reported.

The technical examination did not reveal any defects or contaminations at the airplane, which could have explained the existence of VOC in the cabin air. The information from the aircraft manufacturer did not provide any explanation for the assumed existence of VOC in noxious concentrations in the cabin air.

The BFU is of the opinion that because the cause for the smell could not be identified analysis of the occurrence was difficult. Therefore, based on the technical analysis it

²⁵ TVOC: total volatile organic compounds

²⁶ At the time of the compilation of this report

is not possible to assess if and in which concentration the assumed VOC or other pollutants were present during this flight.

Even though it cannot be ruled out that VOC caused the observed symptoms, it is not plausible in regard to the necessary concentrations in the cabin air. The toxicological statement of the ASUM-UMG assessed the presence of organophosphates (e.g. TCP) as cause for the symptoms as unlikely. It was also not possible to determine other contaminations as cause. The diversity of the described symptoms can physiologically not be explained by a single underlying biological pathway. It is therefore not possible to state a cause for the symptoms of the crew.

Taking into consideration the statement of the aircraft manufacturer, the EASA study, and the measurement results of cabin air during other fume events, the BFU cannot comprehend that contaminated cabin air could trigger the kind of symptoms the pilots noticed.

Hence, after the smell occurred other, possibly psychological reactions, must have triggered the symptoms or acted as catalyst.

Use of the Oxygen Masks

According to the initial report to the BFU the pilots had stated that the use of the oxygen masks had been necessary. This fact met the example list for Serious Incidents in the appendix of the Regulation (EC) 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.

It was not possible during the investigation to determine the cause of the smell. Therefore, it is not clear if and to what extent pollutants hazardous to health were present in the cabin air. They were, however, not present in a concentration, which would have triggered a high accident probability.

The BFU cannot assess with absolute certainty how the state of health of the pilots would have developed, if they had not donned their oxygen masks. Based on the result of the analysis it is very likely that even without use of the oxygen masks the impairment would not have led to incapacitation. The objective data of the course of the flight or the speech analysis of the BKA do not indicate any performance

impairments of the flight crew, neither before nor after use of the oxygen masks²⁷. The cabin crew was exposed to a similar cabin air quality and able to perform tasks even though they were not given any oxygen. There were no incapacitated passengers. This allows the conclusion that the pilots in the cockpit would have remained capable of acting without the use of oxygen masks. Therefore, according to the Regulation (EC) 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, there was no high probability of an accident.

This assessment does not question that donning the oxygen masks, by taking the related disadvantages into account, improved the condition of the crew and was therefore an appropriate action. The BFU investigation could not determine unambiguously which mode of action triggered the improvement.

²⁷ After alternating switching off of the bleed air supply, the entire aircraft cabin was supplied by just one bleed aid source.

Conclusions

Findings:

Strong smells occurred during the flight. The cause for the smells could not be determined.

After the smells had occurred the crew experienced symptoms.

The flight crew was able to perform their tasks before and after donning their oxygen masks.

Donning their oxygen masks was a suitable action to reduce their symptoms.

It was a stabilised approach.

The flight crew's ability to act was not influenced in a way that would have jeopardised the safe conduct of the flight. There was no high probability of an accident.

The requirements for the classification as Serious Incident were not met.

The propagation of VOC in the cabin air in a concentration causing health impairments could not be verified.

The influence of organophosphates (e.g. as TCP) as trigger for these symptoms has to be considered as unlikely.

There were no medical findings suggesting possible intoxication of the crew members. The methodology to test the blood was not suited to detect intoxication with the substances under suspicion.

There were no technical findings, which could indicate the cause of the smell.

There is no checklist for crews how to deal with smell events.

Cause:

During the flight a smell event and symptoms occurred, which caused the flight crew to don their oxygen masks.

It could not be conclusively clarified if and what contaminations caused the smell and which connection there might be with the symptoms.

Safety Recommendation

Safety Recommendation No. 04/2018

The Bundesverband der Deutschen Luftverkehrswirtschaft e.V. (BDL, German Aviation Association) should coordinate the activities of the operators organised in the association that the crews are provided with relevant information regarding the existence, possible causes, and effects of fume events in aircraft cabins and are trained accordingly.

The BDL should organise an exchange and coordination process of the operators organised in the association regarding the content and course of action in order to achieve harmonised implementation.

Secured findings from research and development are to be used. The ICAO document "Circular 344-AN/202, Guidelines on Education, Training and Reporting Practices related to Fume Events" should serve as the basic principle.

The Directorate General Mobility and Transport of the European Commission, in cooperation with EASA, has initiated a project investigating cabin air quality (FACTS). The BFU therefore refrains from issuing further safety recommendations.

Investigator in charge: Thomas Karge

Assistance: Dr. Thomas Harendza

Braunschweig 29. March 2018

Appendices

1. Air exchange rate in the A321 cabin
2. Possible influences which may result in impairments, observations and limitations in the aircraft cabin
3. Smell source examples
4. Consumption of lubricants in engines
5. Laboratory test results
6. Checklist SMOKE/FUMES/AVNCS SMOKE

Appendix 1

AIR FLOW RATES¹⁾ AND VOLUMES: A321

A321	Volume		2 Packs <i>NORM</i>		2 Packs <i>ECON</i>		1 Pack (Failure Case)	
Cockpit	9 m ³	Fresh Air flow [kg/s]	0.084		0.067		0.050	
		Recirc. Air flow [kg/s]	0.064		0.066		0.069	
		Fresh Air Exchange Rate [1/h]	38.3		30.6		22.8	
		Total Air Exchange Rate [1/h] ²⁾	67.3		60.7		54.0	
Cabin	155 m ^{3 3)}	Fresh Air flow [kg/s]	0.871		0.697		0.522	
		Recirc. Air flow [kg/s]	0.659		0.686		0.712	
		Recirc. Flow Ratio [%]	43		50		58	
		Fresh Air Exchange Rate [1/h]	22.9		18.3		13.7	
		Total Air Exchange Rate [1/h]	40.3		36.4		32.5	
		Number of Occupants ⁶⁾	199+6		140+6 ⁴⁾		199+6	
		Fresh Air per Occupant [l/s]/[cfm]	4.81	10.21	5.41 ⁴⁾	11.46 ⁴⁾	2.89	6.12
		Total Air per Occupant [l/s]/[cfm]	8.46	17.94	10.74 ⁴⁾	22.76 ⁴⁾	6.83	14.47
Cargo	FWD: 25,4 m ³	Total Flow [kg/s]	0,145 ⁵⁾		0,145 ⁵⁾		0,145 ⁵⁾	
	AFT/Bulk: 32,6 m ³	Total Flow [kg/s]	0,132 ⁵⁾		0,132 ⁵⁾		0,132 ⁵⁾	

1) All values apply to cruise at FL 390 and 24°C cabin/cargo temperature

2) Total Air flow = Fresh Air flow + Recirculated Air Flow

3) Furnished Cabin Volume: Crown Area, Hatracks, Passengers, Seats, Stowages, Lavatories and Galleys are considered as not

4) Recommended Limit for FCOM 3.03.06

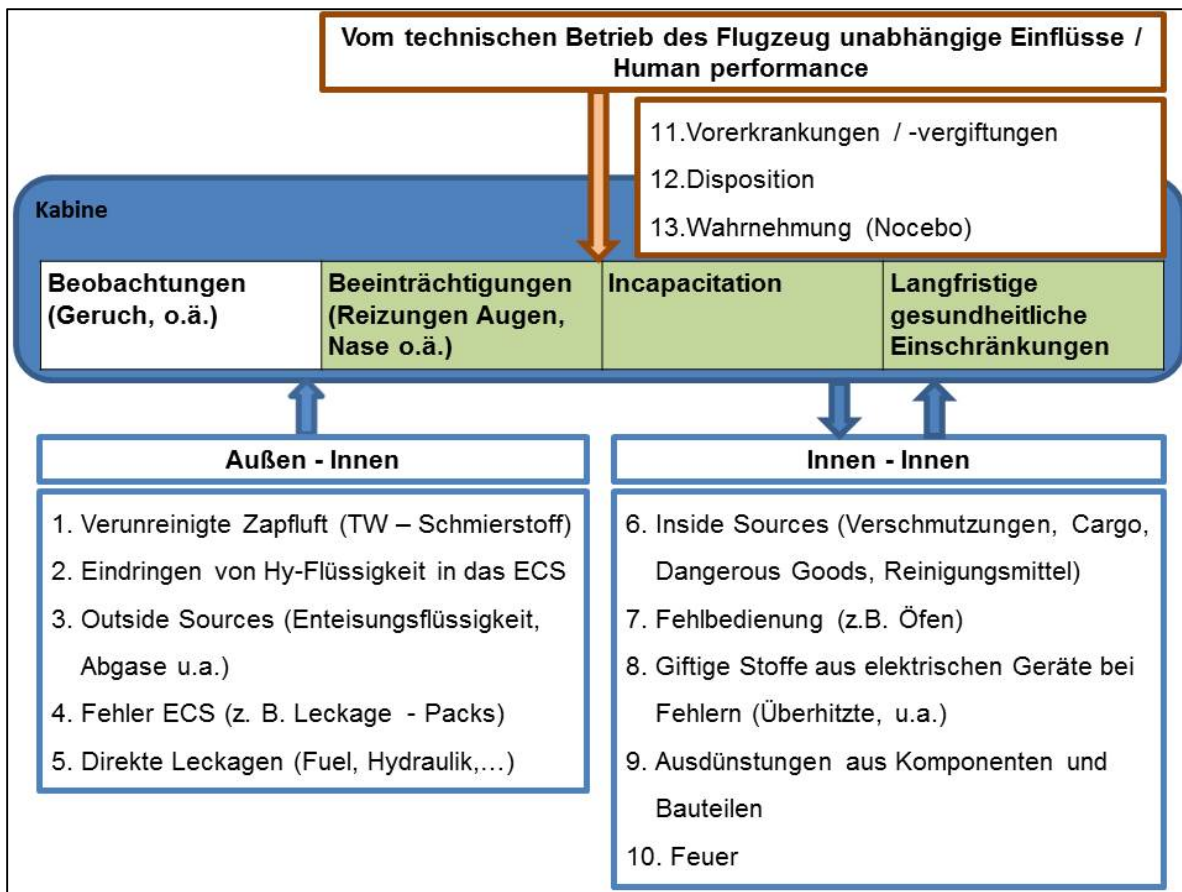
5) Cargo ventilation/heating (standard option)

6) Standard layout

Air exchange rate in the A321 cabin

Source: Airbus

Appendix 2



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

Appendix 3

Potential contaminants in the ventilation supply air:

- De-icing and/or anti-icing fluid
- Electrical faults
- Engine compressor wash
- Engine oil
- Exhaust (aircraft or ground vehicles)
- Fuel
- Hydraulic fluid
- Recirculation fan failure

Items in the cabin and/or flight deck that can be sources of fumes:

- Carry-on baggage
- Cleaning products
- Disinfectants
- Disinfectants
- Food items
- Galley equipment
- Lavatories

Smell source examples

Source: (ICAO Circular 344-AN/202)

Appendix 4

Consumption Estimates from 07.07.2014 to 05.03.2015						
Acrog	Engine Des (V10329)	Refill Amount, qts	Consumption, qts/h	Smoothed, qts/h	Aircraft Hours	THST Refill
	1	3.17	0.0532	0.0532	45644.03	08.07.2014 02:35
	1	0		0.0532	45656.03	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
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	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	0		0.0532	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	0		0.0532	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	0		0.0532	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304	0.07	45696.4	18.07.2014 06:55
	1	2.11	0.0304			

Consumption of lubricants in engines

Source: Operator

Consumption Entries from 01.01.2015 to 29.06.2015 (2015, 42000.18)						
Acereg	Engine Pos (V10139)	Refill Amount, qts	Consumption, qts/h	Smoothed, qts/h	Aircraft Hours	TSMT Refill
1	1	0	0.147	0.0	4747.32	02.01.2015 21:00
1	1	2.11	0.084	0.02	4758.46	29.01.2015 04:30
1	1	0	0.084	0.02	4759.75	31.01.2015 00:10
1	1	0.85	0.021	0.02	4761	04.02.2015 21:15
1	1	1.74	0.065	0.02	4762.9	06.02.2015 00:10
1	1	1.9	0.064	0.04	4771.81	22.02.2015 21:15
1	1	0	0	0.04	4778.9	02.03.2015 17:50
1	1	2.11	0.157	0.03	4788.95	11.03.2015 01:00
1	1	2.85	0.049	0.04	4790.88	29.03.2015 21:00
1	1	0	0.049	0.04	4792.48	06.04.2015 21:00
1	1	0	0.028	0.04	4807.89	16.04.2015 18:05
1	1	4.23	0.046	0.05	4812.14	24.04.2015 21:15
1	1	0.23	0.03	0.05	4825.07	15.05.2015 21:00
1	1	3.7	0.008	0.05	4831.85	22.05.2015 20:15
1	1	2.11	0.0335	0.05	4837.82	31.05.2015 21:30
1	1	1.06	0.029	0.15	4841.28	10.06.2015 20:35
1	1	2.01	0.0307	0.12	4852.68	18.06.2015 07:40
1	1	0	0.031	0.1	4854.48	29.06.2015 21:00
1	1	4.23	0.031	0.1	4862.48	29.06.2015 21:00
Consumption Entries from 01.01.2015 to 29.06.2015 (2015, 42000.18)						
Acereg	Engine Pos (V10071)	Refill Amount, qts	Consumption, qts/h	Smoothed, qts/h	Aircraft Hours	TSMT Refill
1	1	0	0.083	0.1	4747.32	02.01.2015 21:00
1	1	2.11	0.084	0.1	4758.46	29.01.2015 04:30
1	1	0	0.084	0.1	4759.75	31.01.2015 00:10
1	1	2.64	0.065	0.09	4761	04.02.2015 21:15
1	1	4.76	0.091	0.09	4762.9	06.02.2015 00:10
1	1	3.17	0.062	0.08	4771.81	22.02.2015 21:15
1	1	3.2	0.078	0.08	4778.9	02.03.2015 17:50
1	1	5.71	0.11	0.08	4788.95	11.03.2015 01:00
1	1	3.17	0.0614	0.09	4790.88	29.03.2015 21:00
1	1	0	0.0614	0.08	4792.48	06.04.2015 21:00
1	1	0	0.043	0.08	4807.89	16.04.2015 18:05
1	1	6.34	0.0969	0.08	4812.14	24.04.2015 21:15
1	1	3.7	0.027	0.08	4825.07	15.05.2015 21:00
1	1	6.34	0.1214	0.08	4831.85	22.05.2015 20:15
1	1	3.7	0.1798	0.1	4837.82	31.05.2015 21:30
1	1	4.23	0.0972	0.09	4837.82	31.05.2015 21:30
1	1	1.06	0.0309	0.18	4841.28	10.06.2015 20:35
1	1	8.03	0.1228	0.17	4852.68	18.06.2015 07:40
1	1	0	0.1021	0.17	4854.48	29.06.2015 21:00
1	1	8.45	0.1021	0.15	4862.48	29.06.2015 21:00
Consumption Entries from 01.01.2012 to 29.06.2015 (2015, 42000.18)						
Acereg	Refill Amount, qts	Consumption, qts/h	Smoothed, qts/h	Aircraft Hours	TSMT Refill	
1	0	0.0	0.0	03.01.2015 21:00	02.01.2015 21:00	
1	0	0.0	0.0	29.01.2015 04:30	29.01.2015 04:30	
1	0	0.0	0.0	31.01.2015 00:10	31.01.2015 00:10	
1	0.33	0.0013	9.0E-4	2223	04.02.2015 21:15	
1	0	0.0	9.0E-4	0	06.02.2015 00:10	
1	0	0.0	9.0E-4	0	22.02.2015 21:15	
1	0	0.0	9.0E-4	0	02.03.2015 17:50	
1	0	0.0	9.0E-4	0	11.03.2015 01:00	
1	0	0.0	9.0E-4	0	29.03.2015 21:00	
1	0	0.0	9.0E-4	0	06.04.2015 21:00	
1	0	0.0	9.0E-4	0	16.04.2015 18:05	
1	1.48	0.0056	0.0021	2485.9773	24.04.2015 21:15	
1	0	0.0	0.0021	0	15.05.2015 21:00	
1	0	0.0	0.0021	0	19.05.2015 20:05	
1	0	0.0	0.0021	0	22.05.2015 20:15	
1	0	0.0	0.0021	0	31.05.2015 21:30	
1	0	0.0	0.0021	0	10.06.2015 20:35	
1	0	0.0	0.0021	0	18.06.2015 07:40	
1	0	0.0	0.0021	0	29.06.2015 21:00	

Consumption of lubricants in engines

Source: Operator

Appendix 5

02.01.2015

Entlassungsbericht - ambulant

BGA

unbekanntes Vollblut

	Referenz	Einheit	02.01.2015 10:45
FiO2 / O2-Beatmung	21.0	%	
Patiententemperatur	37.0	°C	
pO2		mmHg	
pCO2		mmHg	
pH		mm	
Aktuelles Bikarbonat		mmol/l	
Aktueller Basenexzess	-2.0*3.0	mmol/l	
O2-Sättigung		%	
Hämoglobin gesamt	14.0 - 17.5	g/dl	
Hämatokrit	36 - 48	%	
Carboxyhämoglobin	0.5*1.5	%	
Methämoglobin	*<1.5	%	
Natrium	135 - 145	mmol/l	
Kalium	3.5 - 5.0	mmol/l	
ionisiertes Calcium	1.15 - 1.29	mmol/l	
Chlorid	99 - 111	mmol/l	
Glukose	70*105	mg/dl	
Laktat	0.5*2.2	mmol/l	
Bilirubin gesamt	*<1.2	mg/dl	
pO2 (Temperatur korrigiert)		mmHg	
pCO2 (Temperatur korrigiert)		mmHg	
pH (Temperatur korrigiert)		mm	

Hämatologie

Hämatologie EDTA-Blut

	Referenz	Einheit	02.01.2015 10:49
Hämoglobin KC	14.0 - 17.5	g/dl	
Erythrozyten	4.50 - 5.90	Mrd/ml	
Hämatokrit	36 - 48	%	
MCV	80.0 - 94.0	fl	
MCH	26.0 - 34.0	pg	
MCHC	31.5 - 37.0	g/dl	
EVB	11.5*14.5	%	
Leukozyten (Leuk)	3.8 - 11.0	Mrd/l	
Thrombozyten (Thro)	150 - 400	Mrd/l	

Klinische Chemie

Plasma

	Referenz	Einheit	02.01.2015 10:49
Harnstoff (Hn)	9 - 21	mg/dl	
Kreatinin (Krea)	0.6 - 1.2	mg/dl	
ASAT (GOT)	10 - 50	U/l	
ALAT (GPT)	10 - 50	U/l	
CK gesamt	- 173	U/l	
C-reaktives Protein (CRP)	- 5	mg/l	

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Universitätsklinikum Hamburg-Eppendorf
Körperschaft des öffentlichen Rechts
Gerichtsstand: Hamburg
USt-ID-Nr.: DE218618948

Seite 2/3

Laboratory test results

Source: Pilot/BFU

Appendix 6

SMOKE/FUMES/AVNCS SMOKE		REMOVAL OF SMOKE/FUMES	
IF PERCEPTIBLE SMOKE APPLY IMMEDIATELY:		EMER EXIT LIGHT..... ON	
• IF REQUIRED:		• If fuel vapors:..... ON	
CREW OXY MASKS..... USE 100% EMERG		CAB FANS..... OFF	
BLOWER..... OVRD		PACK 1-2..... OFF	
EXTRACT..... OVRD		• If no fuel vapors:..... OFF	
CAB FANS..... OFF		CAB FANS..... OFF	
A320 (at ex. A/C) - A/CU - A/CW		LOG FLOW..... HI	
GALLEY..... OFF		10 000 FT MEA-MORA	
END		DESCENT (FL 100, or MEA-MORA, or minimum	
A320 (at ex. A/C) - A/CU - A/CW		obstacle clearance altitude)..... INITIATE	
GALY & CAB..... OFF		ATC..... NOTIFY	
END		SMOKE/FUMES/AVNCS SMOKE PROC. CONTINUE	
SIGN..... ESTABLISH		While descending, continue applying the	
CKPT CAB COM.....		appropriate steps of the SMOKE/FUMES/	
• IF SMOKE SOURCE IMMEDIATELY OBVIOUS,		AVNCS SMOKE procedure depending on the	
ACCESSIBLE AND EXTINGUISHABLE:		suspected smoke source:	
FAULTY EGP..... ISOLATE		• At FL 100, or MEA-MORA:	
• IF SMOKE SOURCE NOT IMMEDIATELY		APU MASTER SW (if in ELEC EMER CONFIG)	
ISOLATED:		PACKS 1-2..... OFF	
DIVERSION..... INITIATE		MODE SEL..... MAN	
DESCENT.....		MAIN AIS CTL..... FULL UP	
Descent to FL 100, or MEA-MORA, or		RAM AIR INLET..... OFF	
minimum obstacle clearance altitude		APU MASTER SW..... OFF	
• AT ANY TIME of the procedure, if SMOKE/		• If smoke persists, open CKPT window:	
FUMES becomes the GREATEST THREAT:		MAX SPEED..... 200 KT	
REMOVAL OF SMOKE/FUMES..... CONSIDER		COCKPIT DOOR..... OPEN	
ELEC EMER CONFIG.....		HEADSETS..... ON	
Refer to the end of the procedure to Set		PM COCKPIT WINDOW..... OPEN	
ELEC EMER CONFIG.		• When window is open:	
• At ANY TIME of the procedure, if situation		NON AFFECTED PACK(s)..... ON	
becomes UNMANAGEABLE:		VISUAL WARNINGS (noisy CKPT)..... MONITOR	
IMMEDIATE LANDING..... CONSIDER		SMOKE/FUMES/AVNCS SMOKE	
AIR COND SMOKE-CAB EQUIPMENT SMOKE		PROC..... CONTINUE	
• IF AIR COND SMOKE SUSPECTED:		• IF SMOKE SOURCE CAN NOT BE	
APU BLEED..... OFF		DETERMINED AND STILL CONTINUES OR	
BLOWER..... AUTO		AVNCS/ELECTRICAL SMOKE SUSPECTED:	
EXTRACT..... AUTO		ELEC EMER CONFIG..... CONSIDER	
A320 (at ex. A/C) - A/CU - A/CW		• IF SMOKE DISAPPEARS WITHIN 5 MINUTES:	
CARGO AFT SOL VALVE..... OFF		NORMAL VENTILATION..... RESTORE	
END		TO SET ELEC EMER CONFIG	
PACK 1..... OFF		EMER ELEC GEN 1 LINE..... OFF	
• If smoke continues:		EMER ELEC PWR..... MAN ON	
PACK 1..... ON		• WHEN EMER GEN AVAILABLE:	
PACK 2..... OFF		EMER ELEC GEN 1 LINE..... OFF	
• If smoke still continues:		GEN 2..... OFF	
PACK 2..... ON		ELEC EMER CONFIG	
BLOWER..... OVRD		APPLY ECAM PROCEDURE, BUT DO NOT	
EXTRACT..... OVRD		RESET GEN, EVEN IF REQUESTED BY ECAM.	
REMOVAL OF SMOKE/FUMES..... CONSIDER		• AT 3 min OR 2 000 ft AAL BEFORE LANDING:	
• IF CAB EQUIPMENT SMOKE SUSPECTED:		EMER ELEC GEN 1 LINE..... ON	
• If smoke continues:		• WHEN A/C IS STOPPED:	
EMER EXIT LIGHT..... ON		ALL GEN..... OFF	
BUSTIE..... OFF			
GEN 2..... OFF			
SMOKE DISAPATON..... CHECK			
FAULTY EGP..... SEARCH/ISOLATE			
• If smoke still continues or if faulty			
equipment confirmed isolated:			
GEN 2..... ON			
BUSTIE..... AUTO			
• If faulty equipment not confirmed			
Isolated, before L/G extension:			
GEN 2..... ON			
BUSTIE..... AUTO			
REMOVAL OF SMOKE/FUMES..... CONSIDER			
UNDETERMINED/AVNCS/ELECTRICAL SMOKE			

Checklist SMOKE/FUMES/AVNCS SMOKE

Source: Aircraft operator

This investigation 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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