Audrey MALRAT-DOMENGE, Dieter SCHOLZ

Annexe 5. Comptes rendus des auditions

Les propos tenus lors des différentes auditions et retracés dans les comptes rendus qui suivent relèvent de la seule responsabilité de leurs auteurs et ne sauraient être perçus comme validés ou partagés par l'Anses.

Anses working group

Minutes of the hearing of Pr Scholz on the operation of air conditioning in aircraft cabins and the associated air quality

July 8th, 2021

The aim of this hearing is to gather some information on:

- How ventilation/air conditioning/filtration works in aircraft
- The regulation of ventilation/air conditioning/filtration
- The incidents from the air system in aircraft called "fume events"
- The factors influencing the chemical contamination of the cabins according to the phases and operating modes of flights
- The perspectives with the solutions which might be under study or testing

Prior to this hearing, a document presenting the French Agency ANSES, the objectives of the current work of expertise on air quality in aircraft and the objectives of this hearing was sent to Professor Scholz.

Dieter Scholz is a professor in aircraft design, flight mechanics, and aircraft systems at Hamburg University of Applied Sciences (HAW Hamburg), Germany, Department of Automotive and Aeronautical Engineering, where he is head of the Aircraft Design and Systems Group (AERO).

Henri Bastos, deputy head of the risk assessment department and scientific director of occupational health, began the hearing by introducing Professor Scholz, before initiating a round table presentation of the participants. Then the floor is left to Pr Scholz for 30 minutes presentation followed by an exchange with the experts of the working group.

Presentation

- **Definitions**

Fume Event

In a fume event, the cabin and/or cockpit of an aircraft is filled with fume. Air contamination is due to fluids such as engine oil, hydraulic fluid or anti-icing fluid. A Fume Event includes a Smell Event. Note: Other reasons for fume in the cabin are possible. The term "fume event", however, is generally used as defined here. Definition adapted from (Wikipedia 2019)

Smell Event
A fume event without visible fume or smoke, but with a distinct smell usually described as "dirty socks" from the butyric acid originating from a decomposition of the esters that are the base stock of the synthetic jet engine oil.

Cabin Air Contamination Event (CACE)
In a Cabin Air Contamination Event (CACE) the air in the cabin and/or cockpit of an aircraft is contaminated. Sensation of the contamination can be from vison (fume/smoke), olfaction (smell/odor), a combination of typical symptoms experienced by several passengers and/or or crew or by related measurements of CO, CO2, ozone or other "harmful or hazardous concentrations of gases or vapours" (CS-25.831).

- **Introduction**

Some example of fume events are described: after a fire warning and fume in the cabin, the plane landed. Since, no sign of fire could be observed, it was concluded that it was the failure of seals in the engine. This happened at the altitude corresponding to the top of dissent "TOD", when the thrust levers pulled back which gives not sufficient pressure in the compressor and it's the point where oil can leak. This does not happen on every flight, but when it is combined with a failure of the labyrinth seals.

- **Cabin air contaminated events (CACE)**

There are two kinds of CACE, primary and secondary. Primary when the event is in the engine and secondary when the event is linked to the depot in the ducts, but it is not fully understood yet how secondary contaminations can occur.
Concerning the frequency, there is no scientific consolidated data. The number of 5 events in 100 000 flights is presented, but other numbers are reported. It is difficult to establish this frequency because there is under-reporting. If only 10 % of the events got reported, then it might be 1 flight out of 2 000 that could be affected with fume.

- **Detection of oil in the cabin**
  - Oil traces in bleed air ducts,
  - Oil traces in air conditioning ducts,
  - Oil traces in recirculation filters,
  - Oils traces on cabin surfaces,

Professor Scholz proposed a calculation method for aromatic hydrocarbons concentrations in the cabin, in case of oil leaks, that can be agreed with measurement. But to achieve the calculation, we need to know how much oil is leaking from the seals, which is not known yet. By assuming that 1 % of the oil consumption is due to leaks via the seals, a concentration of 17 $\mu g.m^{-3}$ is calculated.

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

Agence Nationale de Sécurité Sanitaire (ANSES) –
Hearing on the Operation of Air Conditioning in Aircraft Cabins and the Associated Air Quality

Dieter Scholz Hamburg University of Applied Sciences

https://doi.org/10.5281/zenodo.5083057
https://doi.org/10.48441/4427.411

ANSES
Online, 08 July 2021

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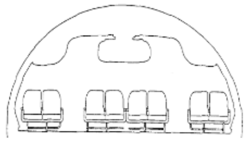

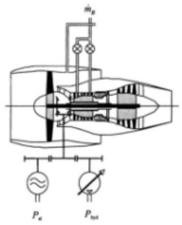

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- **Requirements (certification specifications (CS[25]s) from EASA)**

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Air Conditioning System

Requirements

- **Ventilation**
  - "the ventilation system must be designed to provide a **sufficient amount** of uncontaminated air" "to provide each occupant with an airflow that contains at least **0.25 kg of fresh air** [outside air] **per minute**" CS-25.831(a) "i.e. 10 cubic feet per minute of air at 8000 feet pressure altitude and at a cabin temperature of 24 °C" AMC 25.831(a)(1)
  - "Where the air supply is supplemented by a **recirculating system**, it should be possible to stop the recirculating system and –
    a. Still maintain the fresh air supply prescribed, and
    b. Still achieve 1 [avoid contamination]." AMC 25.831(c)
  - "Each passenger and crew compartment must be ventilated ... to enable crewmembers to perform their duties **without undue discomfort or fatigue**." CS-25.831(a)
  - "Crew and passenger compartment air must be **free from harmful or hazardous concentrations of gases or vapours**." CS-25.831(b)
  - CO, CO2, ozone concentration limits are given, but not for other substances. This does not mean that other substances are allowed in any concentration (BFU 2014) "The BFU is of the opinion that a product [aircraft] 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." (BFU 2014)

Dieter Scholz: Air Conditioning in Aircraft Cabins | ANSES Hearing Online | 08.07.2021, Slide 19 Aircraft Design and Systems Group (AERO)

25 https://www.easa.europa.eu/document-library/certification-specifications/group/cs-25-large-aeroplanes#group-table

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Air Conditioning System

Requirements

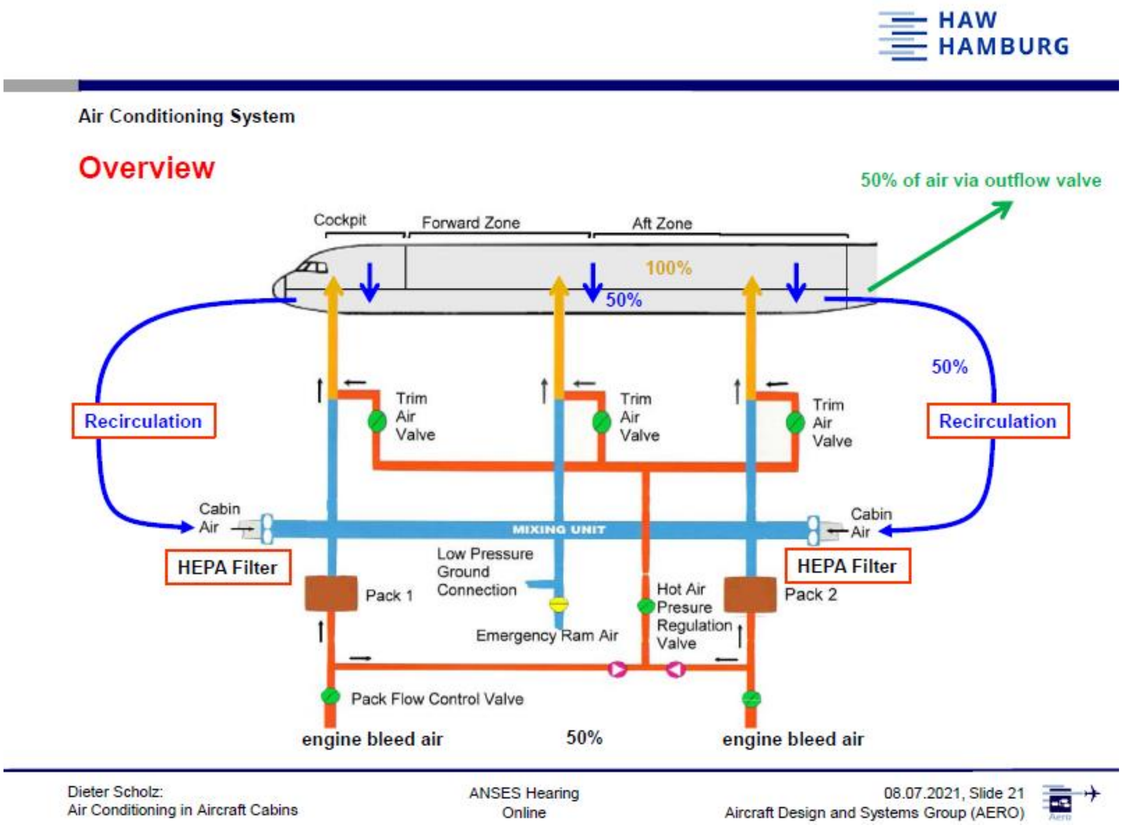
- **Temperature Control**
  - Cabin air temperatures are not defined in CS-25.
  - Temperature control is done by ventilation with (in most cases) cold air.
  - Recirculation allows to use "more air" at temperatures "not as cold" as required with less air.
  - Hence, recirculation
    - allows a more even temperature distribution in the cabin,
    - avoids cold drafts near passengers and increases cabin comfort.
  - "More air" (than required) could also be obtained from outside, but ...
    - outside air needs to be compressed (to cabin pressure), which requires more energy.
    - recirculated air only needs to be pumped (against pressure losses in tubes); it saves engergy.
  - Recirculated air spreads air among all passengers (unlike outside air), hence need of filtration.
- **Pressure Control**
  "provide a cabin pressure altitude of not more than 8000 ft" CS-25.841(a)
- **Moisture Control**
  No requirements

Requirements related to pressure and moisture control are not further detailed.

Dieter Scholz:
Air Conditioning in Aircraft Cabins
ANSES Hearing
Online
08.07.2021, Slide 20
Aircraft Design and Systems Group (AERO)

- **Air conditioning system**

An overview of the air conditioning system based on engine bleed air is done.



The reason for using compressed air from the engine is because it's the cheapest way.

The air is taken from outside, where the conditions are, at cruise altitude :

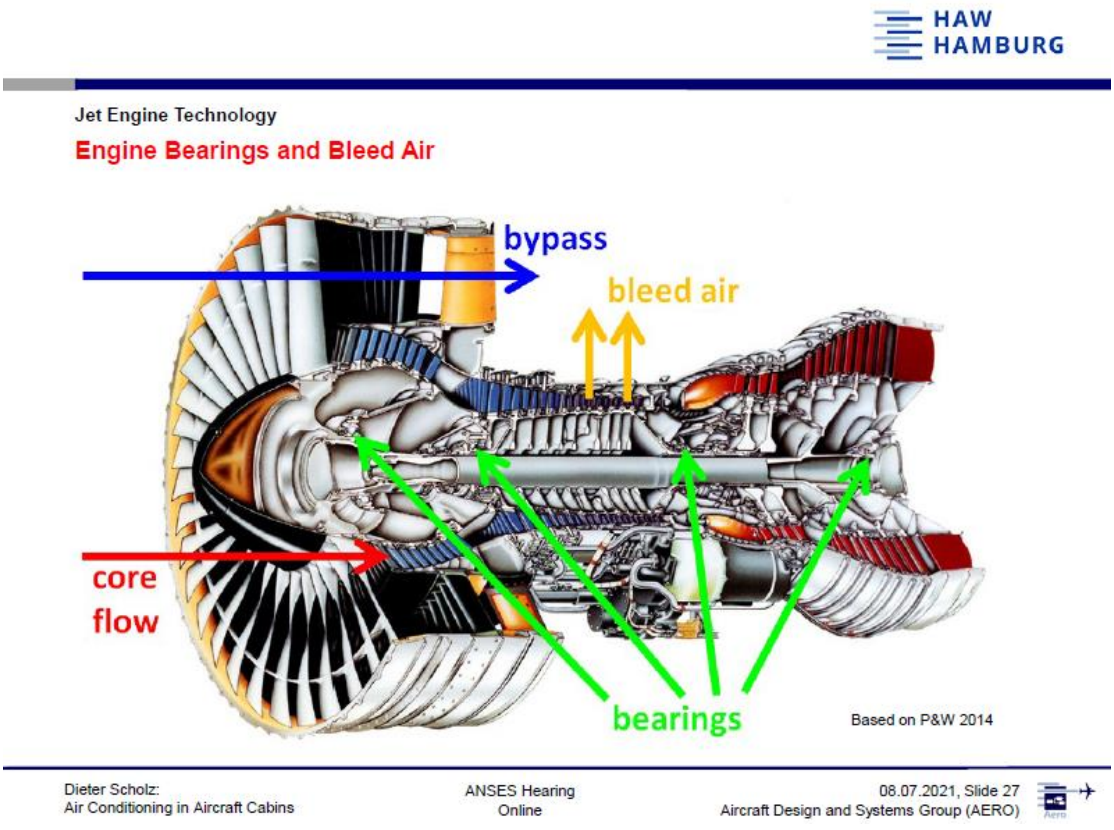
- • 21% of oxygen content,
- • 22% of sea level pressure,
- • -56 °C

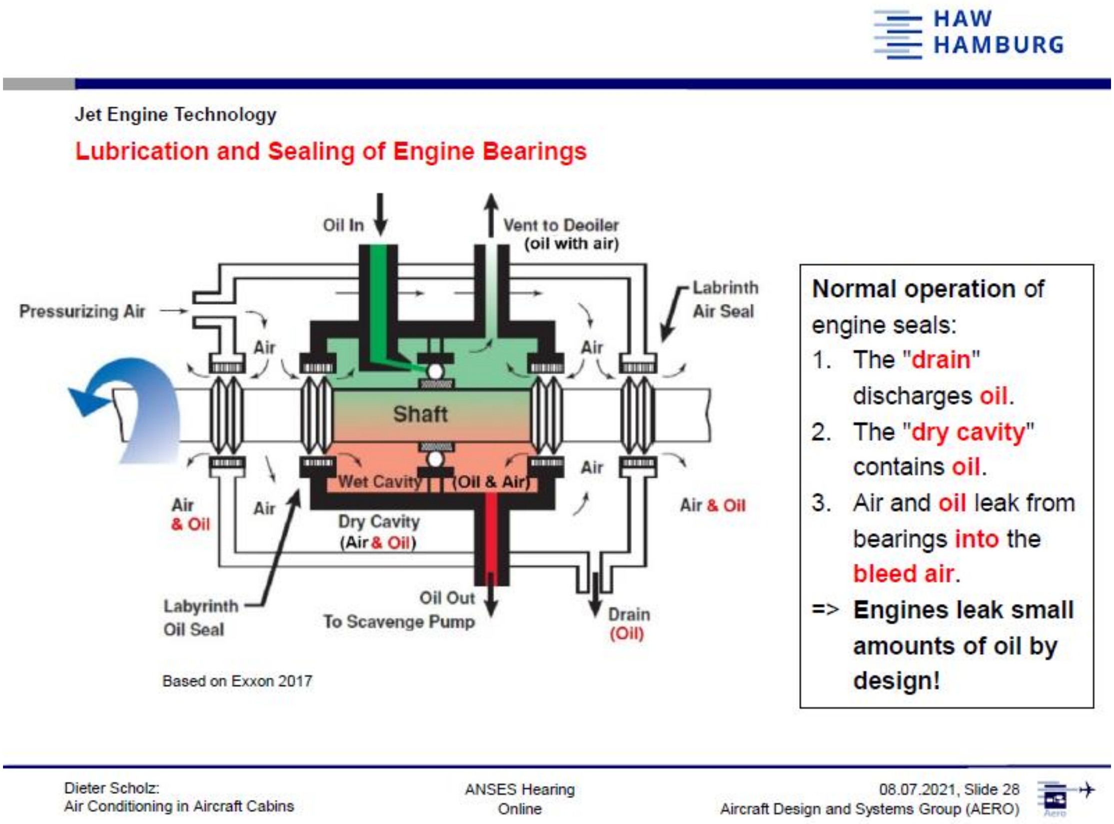
Therefore, the outside fresh air needs to be compressed because the pressure is low, by compression you get very high temperature, so you need to cool the air before it is injected in the cabin.

So the compressed air is taken from the engine, then it is being cooled into the so-called pack before going into the mixing unit. There are two packs for redundancy purposes. The air is heated up a little bit, particularly in the cockpit and the first, less in the economic class, where the seats are close to one another. Then the air goes into the cargo compartment half of the air is going outside and half is recirculated. Before returning to the mixing unit, the air is filtered by HEPA filters.
These filters are in place for health reason, to prevent contamination between passengers. HEPA filters do not filter VOC, but some HEPA filters can be paired with carbon filter to filter, odour/VOC. The incoming concentration of volatile organic compounds (VOC) can be reduced to 58,9% with a filtration rate of 0,7 and a recirculation rate of 0,5. To improve the air quality, filtration unit should be placed after the packs/before the mixing unit.

- **Jet engine technology**

The air from the outside goes in the engine core, then it is compressed and at the end, the bleed air is taken.
In the bearing, the oil is supposed to stay in the wet cavity, but as it shown, in the scheme, oil can also be in the dry cavity, since a drain is foreseen. Engines leak small amounts of oil by design.





- **Metal particles**

Analysis of metal particles in oils identified micro and nano sizes, which can be present into the cabin. In the bearing, several metals are used, including iron, chromium and titanium. There is scientific analysis of the oil and so based on what metals and the size of the particles, it can be determined what are the wear stages of the engine. So having metal particles in the oil is totally normal, but it can go to the bleed air. It was found that these metal particles can be in the human fatty tissue of aviation employee, including chromium.

- **Other contaminants**
  - Deicing fluids,
  - Hydraulics fluids,
  - Fuel,
  - Other aircraft exhaust

The contaminants above can be found on the grounds and in the air of the airport and then enter into the cabins through the bleed air. Deicing fluid and hydraulic fluid leaking on the fuselage can also enter the cabin by the bleed air of the APU.

- **Potable water**

The bleed air is also used to pressurize the potable water, so the bleed air can contaminate the water. The last water extracted from the tank before it is empty is black, probably from engine oil residue.

- **Evidence of contamination of the ducts**

By observing detached parts of planes, collected in junk yards:

  - Brown or black stains (probably from oil) in the bleed air duct vs clean fan air (coming from the engine bypass) duct. The colour depends of the temperature in the duct.

- The inlet of the water extractor is covered with black oily residue
- The inside of air distribution duct in the cabin is black from contaminated bleed air vs "clean" duct which are not fed with bleed air
- Flow limiter clogged from pyrolysed oil in ducts of the air conditioning system,
- Black residues, which is not only dust, in top of overhead bins,
- Oily black soft substance covering the face of the recirculation fan

The access to aircraft junk yard, is rather difficult and expensive.

- **Maintenance**

During a period of 10 years (2004 to 2014) maintenance practice changed such that engines stay on the wing almost twice as long without shop visit and seal replacement and labyrinth-seal clearances naturally increase as engine ages.

In case of fume event, Airbus instructions is to manually clean the affected ducts using rags and appropriate degreasing agent. But, since aircraft are released back into service over night after an CACE, it is not possible:

- Ducts cannot be removed from behind the panels in this short time,
- The inside of ducts is not accessible,
- Most of the deposit cannot be removed.

In conclusion, all these contaminants go in the cabin air, and then in the human body. It is not easy to measure these contaminants in the cabin air notably because the concentrations are low, but this does not mean they are not there. The accumulation on the floor, ducts… are evidences of the presence of substances in the air.

Concerning the EASA studies, it is important to know, that they are done in association with the aviation industry, so the interpretation of the measurement might be biased.

Question and answers

Are Metal nanoparticles always mixed with oil and what form is the chromium found in the oil? Are the nanoparticle detected in the air?

Pr. Scholtz confirm that there always are metallic nanoparticle in the oil. Research are made by Dr Gatti, in Italy, but are not published yet. Dr Gatti also made measurement on pilot clothes. Chromium is in metallic form. There are also other metals.

Nanoparticles were also found in fetus. In the 2017 EASA study, the contamination is confirmed, but it concluded that the concentrations are too low to go through the lung barrier of a healthy person. But are they only healthy persons on board, is it sure that the contaminant do not go through the lung barrier?

Concerning the picture of the human tissues with metallic nanoparticle, they could have come from somewhere else, like car's exhaust?

The point is valid. But this argument is also used when a pilot or a flight attendant shows medical evidence of a contamination: "How do we know that it is from the cabin air?" If several people at the same time in the same place are being affected and they're in an airplane with nanoparticles in the oil that can get into the cabin air, then it is likely that the contamination with nanoparticles came from the airplane.

It is surprising that there is no filter between the pack and the mixing unit. So adding a filter at this place would it be a solution? And why is it not implemented yet?
Yes, placing a filter between the pack and the mixing unit could be a solution. It is not done yet, because there is no industry consensus on the issue of the bleed air contamination. So, if there isn't a problem, why should a filter be added?

Is it possible to analyze the different residues?
Yes, it is possible to analyze the residues. There are publications on analyses of used HEPA filters.

In case of a fume event or CACE, how is it possible to differentiate primary and secondary CACE?
The slide was from the EASA study, and it was a hypothesis. The residues in the ducts could be released with the appropriate humidity and temperature. Ducts from a plane used for decades, were several kilograms heavier than new ones, because of the deposits. Nevertheless, it is not well understood, if it secondary CACEs have already caused a fume event.

The issue of fume event is known since the 1950's but with the smoke from the passengers on board, it was masked. With the ban on smoking in airplanes, the issue became more visible, and some people became concerned of the TCP in the oil, since TCP is known to be responsible of paralysis in 30 000 people in United States. The oil industry achieved to get rid of the TCP ortho isomers, but with the high temperature, other compounds are formed, so the issue is complicated. The issue is not only on TCPs, there are also the hydraulic fluids and deicing fluids, the nanoparticles…

So the solution could be to take the air from outside like the Dreamliner?
To use the air from outside, it needs to be compressed, if you do not use the engine, a compressor must be added, which also has bearings which might be lubricated by oil. From what I've heard from the engineers who manufactured the compressor on the Boeing 787, is that there is absolutely no lubrication on the compressor bearings to pollute the air. They use bearings lubricated by air.

According to the presentation, the fume event or CACE are likely to occur at the beginning of the descent phase, but can they occur at other times?
It seems that many fume events were in that phase of the flight, but they are quite rare and the information is limited because the airline companies do not report all the CACEs. But what is clear is that if we have low RPM (revolutions per minute) in the engine and low thrust then obviously the compressor is producing not much pressure and we rely on the pressure of the air to be pushed through the labyrinth seals to hold the oil back. I understand it's a known problem but then the question is how much money do you want to spend to do something engineering wise to solve the problem.

Concerning the measurement in the air, you do not need to measure TCP, you just need to measure one substance that shouldn't be in the cabin unless something goes wrong with the oil and then take this as an indicator. For example ultrafine particles measured during the cruise were almost zero but when switching between sources APU and engine and then it was kind of 100 fold the concentration.

Portable sensor could be used on board to detect fume events, which are more reliable than the aircrew sense of smell. But to be effective, the sensor should be place in the ducts, so the defective engine could be identify and the air supply from this engine could be switched off.

Is there a specific schedule for the filters maintenance or cleaning the ducts?
The maintenance schedule for plane does not include duct cleaning or even inspecting them, unless there is a problem and then there is maintenance advice for airlines.

Do you think that the physic characteristics of the air into the aircraft (very low humidity, dry air) could add something wrong to the health or pollution?
Temperature, humidity and pressure are regulated and adjusted during the flight. The pressure is a little bit lower than at sea level, but it also true in the mountains. Humidity is also low, that is why passenger and crew are encouraged to drink water. For the effect on chemicals, Pr Scholz does not have the answer as an engineer.

According to the presentation, the bearings are designed to leak. Is the quantity of oil drained of the dry cavity has ever been measured?
Pr Scholz has no answer.

Concerning the water in the plane is it really potable? In the restroom it is indicated that the water in not drinkable?
The water can be used for tea or coffee. It is called potable water system. There also is a problem with bacterial contamination of the water that has been aggravated with the airplanes on the ground because of the pandemic.

Do you know if Boeing intends to implement air sampling technology of the Dreamliner to its future airplanes?
I would just imagine that when they did the step to bleed free airplane with the 787 then they would stay with that decision with new airplanes. When Boeing gave a statement on why they made the airplane bleed free, they never said it was because of cabin air contamination. One thing I learned, as an engineer, is that if you have a good system design for a new airplane, don't tell it to the public, if all the other airplanes are working on the old principle because you would only highlight the problem with your other airplanes. This is the reason why Boeing never advertised any improvement on the cabin air quality with the 787. They mentioned a little bit of energy saving. Just after the Boeing 787, Airbus designed the 350, they had the chance to come up with a new design but they decided otherwise and designed a conventional airplane because they listened to the airlines, which just want working airplanes and not airplanes where engineers build their dream and new configurations.

Question asked after the audition
Could be some contamination of the cabin air generated by the Pack.?
A pack consists (among other parts) of a compressor and a turbine. There is a shaft and there are bearings. If the bearings are lubricated and the seals do not fully seal (seals never fully seal), then the oil can go into the cabin.
The pack can also be contaminated (e.g. from oil from the engine). If it is contaminated the contamination can go into the cabin.

So far, if the air generated by the pack is contaminated, the problem seems to be rather from a contamination of the pack by the air entering the pack (e.g. from oil from the engine) than from the pack itself.

anses

Effets sur la santé liés à la profession de personnels navigants et sur la qualité de l'air dans les cabines d'avions

Avis de l'Anses
Rapport d'expertise collective

Octobre 2023

Connaître, évaluer, protéger

Le directeur général

Maisons-Alfort, le 11 octobre 2023

AVIS
de l'Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail

relatif à l'« Etat des connaissances sur les effets sur la santé liés à la profession de personnels navigants et sur la qualité de l'air dans les cabines d'avion »

L'Anses a été saisie le 17 avril 2019 par la Confédération française démocratique du travail (CFDT) pour la réalisation de l'expertise suivante : "Demande d'avis relatif aux conséquences sanitaires de la pollution de l'air dans les avions de ligne ».

1. CONTEXTE ET OBJET DE LA SAISINE

Depuis plusieurs années, des personnels navigants rapportent des symptômes qu'ils associent à des expositions à des odeurs inhabituelles / émanations ou à des fumées dans les cabines ou dans les cockpits d'avions. Ces symptômes, très variés et aspécifiques, ont été mentionnés dans plusieurs études et regroupés par certains auteurs sous le terme de « syndrome aérotoxique ». Ils ont pu conduire, pour certains travailleurs, à la perte de leur aptitude aéromédicale[1]...

[1] Aptitude aéromédicale : aptitude prononcée pour un personnel navigant par un médecin agréé par la Direction générale de l'aviation civile (DGAC) sur la capacité de ce professionnel à occuper son poste

This file:

https://doi.org/10.5281/zenodo.10675322

https://doi.org/10.48441/4427.1340

The report:

https://www.anses.fr/fr/system/files/AIR2019SA0075Ra.pdf

https://perma.cc/794V-T9P6

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ISBN 979-10-286-0480-6 - Dépôt légal : octobre 2023 - Anses Éditions 2023 - CC BY-NC-ND - Crédit photo : 123RF