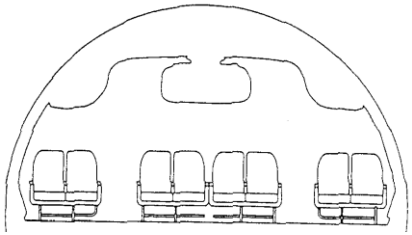
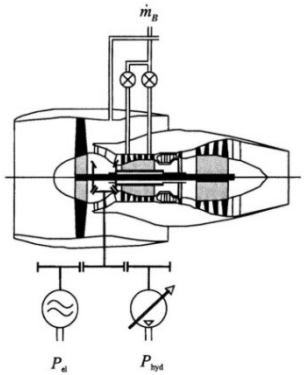
Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

AIRCRAFT DESIGN AND SYSTEMS GROUP (AERO)

Contaminated Aircraft Cabin Air – A Short Engineering Explanation

Dieter Scholz Hamburg University of Applied Sciences





Press Meeting

10 Years German Wings "Cabin Air Contamination Event" (CACE): 2010-12-19

Online, HAW Hamburg, 2020-12-18

https://doi.org/10.5281/zenodo.18072295

Contents

Introduction

Fume Event on US Airways Flight 432 Phoenix to Maui in 2010
Video on: https://youtu.be/AZqeA32Em2s

Note:

- Smell events (without fumes) are much more frequent than fume events.
- Health effects have been reported from smell events alone (where patients never encountered a fume event) .

Definition: Cabin Air Contamination Event (CACE)

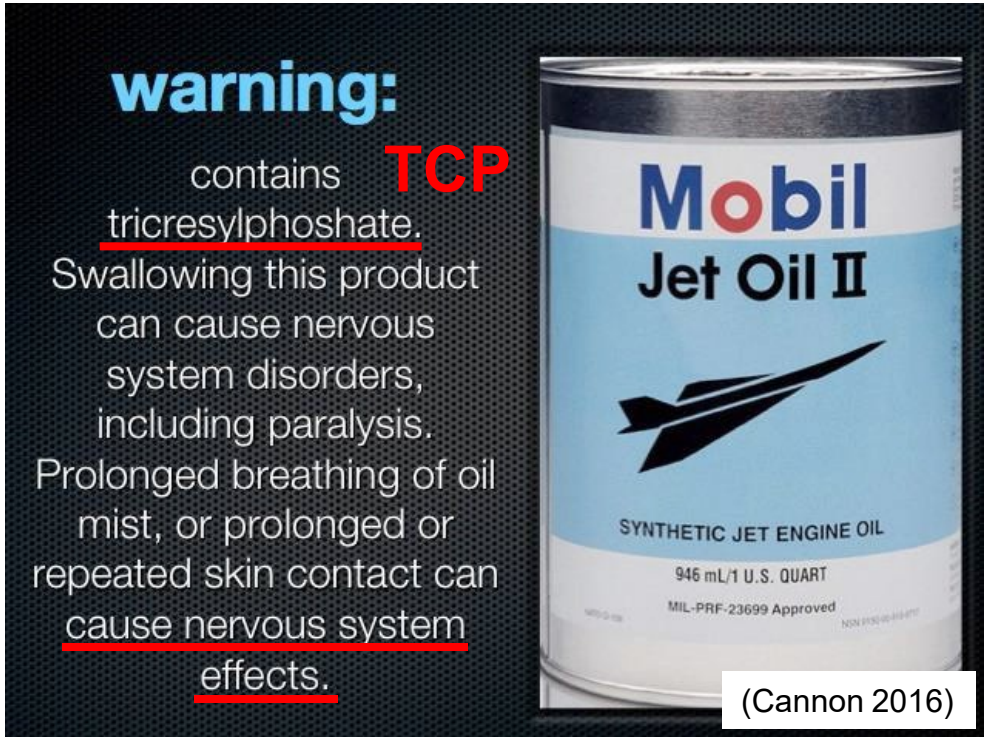
In a Cabin Air Contamination Event (CACE) the air in the cabin and/or cockpit of an aircraft is contaminated. Sensation of the contamination can be from vison (fume/smoke), olfaction (smell/odor), a combination of typical symptoms experienced by several passengers and/or or crew or by related measurements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

Headache	Drowsiness
Dizziness	Impaired vision
Nausea	Vomiting
Tingling (e.g. hands, feet, etc.)	Trembling
Numbness	Irritated eyes/throat/nose
Difficulty speaking and finding words	Memory problems
Muscle incoordination	
Breathing difficulties	Coughing

Typical symptoms following a CACE (ECA 2017)

Detach the definition from merely human sensation.
Allow also drastic health degradation to define the event.
Objective measurements would certainly be best, but are usually not available.

Jet Engine Oil - Ingredients



(Cannon 2016)

This warning was changed in 2004 (Michaelis 2012) to:

"This product is not expected to produce adverse health effects under normal conditions of use ... Product may decompose at elevated temperatures ... and give off irritating and/or harmful ... gases/vapours/fumes. Symptoms from acute exposure to these decomposition products in confined spaces [*aircraft cabin*] may include headache, nausea, eye, nose, and throat irritation."

(Exxon 2016a)

Judging Jet Engine Oil Based on Warnings Given by Manufacturer

ExxonMobil

Material Safety Data Sheet (MSDS)

FIRST AID MEASURES, INHALATION
Remove from further exposure [*in a fume event?*]... Use adequate respiratory protection [*not available for passengers!*]. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

(Exxon 2016a)

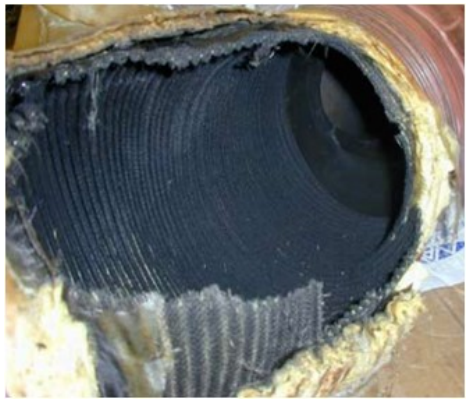
How Do We Know about Oil in the Cabin?

Oil has left traces on its way from the engine to the cabin interior:

1. Oil traces in bleed duct
2. Oil traces in air conditioning ducts
3. Oil traces in recirculation filters
4. Oil traces on cabin surfaces (wall panels, seats, ...)

Evidence collected in: Scholz 2017

1.



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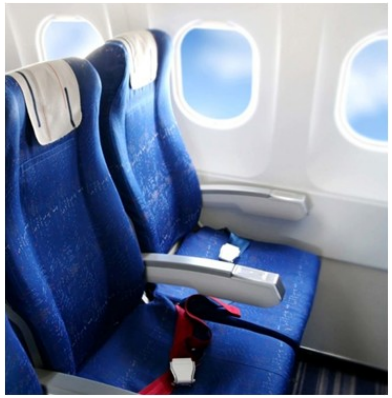
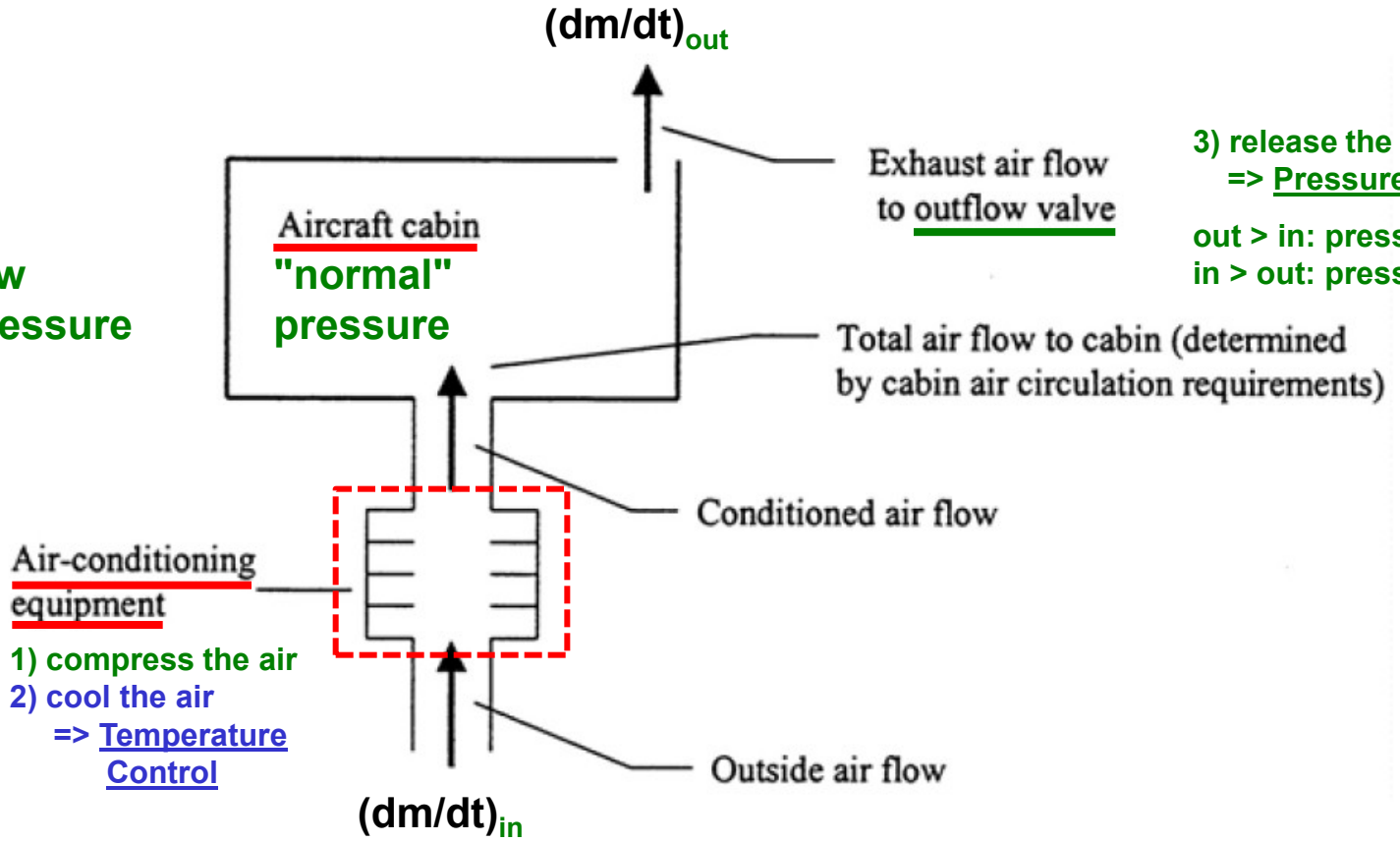
3.



4.

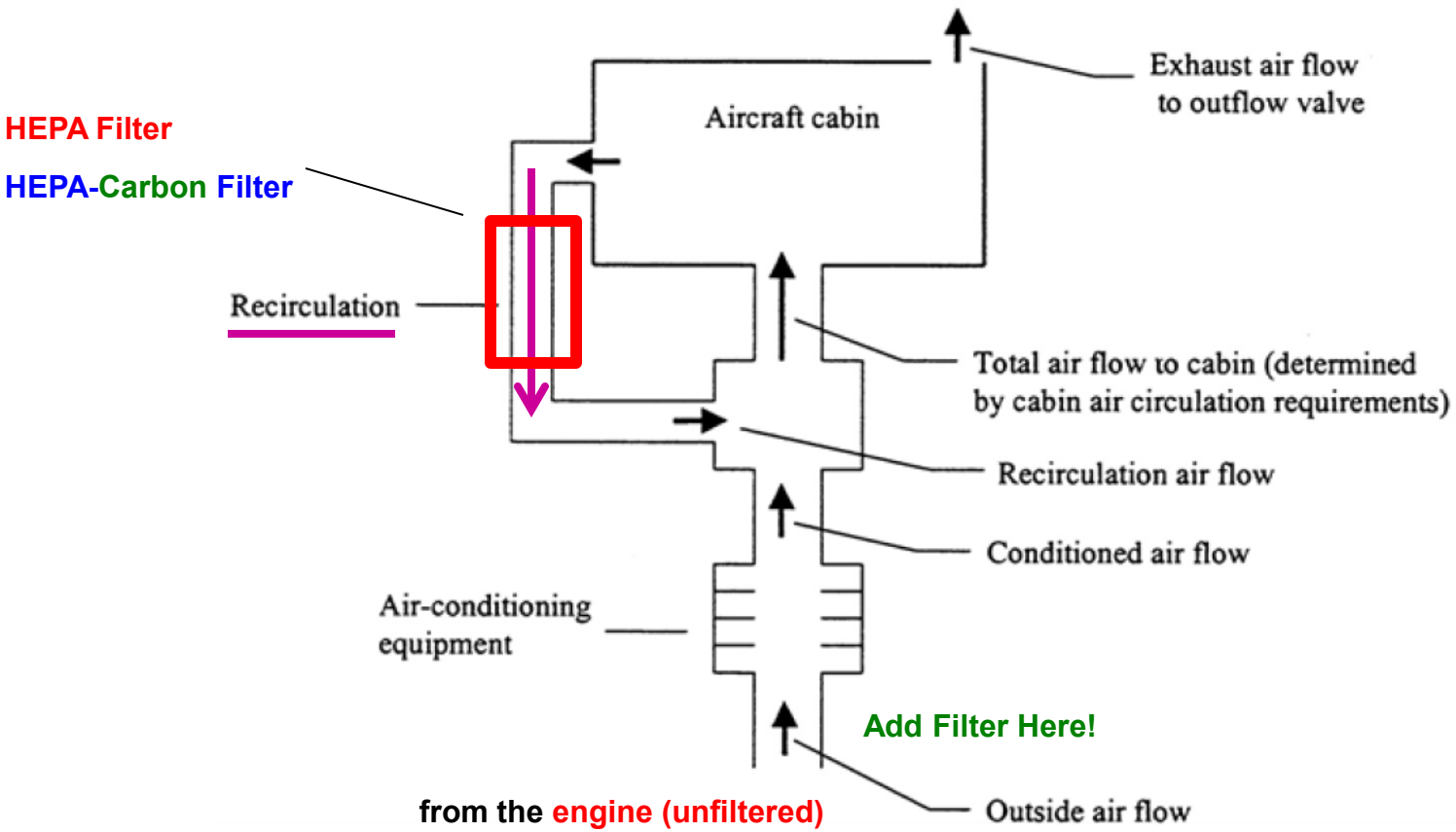
Air Conditioning Basics

Temperature Control, Pressure Control, Ventilation



Adapted from (NRC 2002)

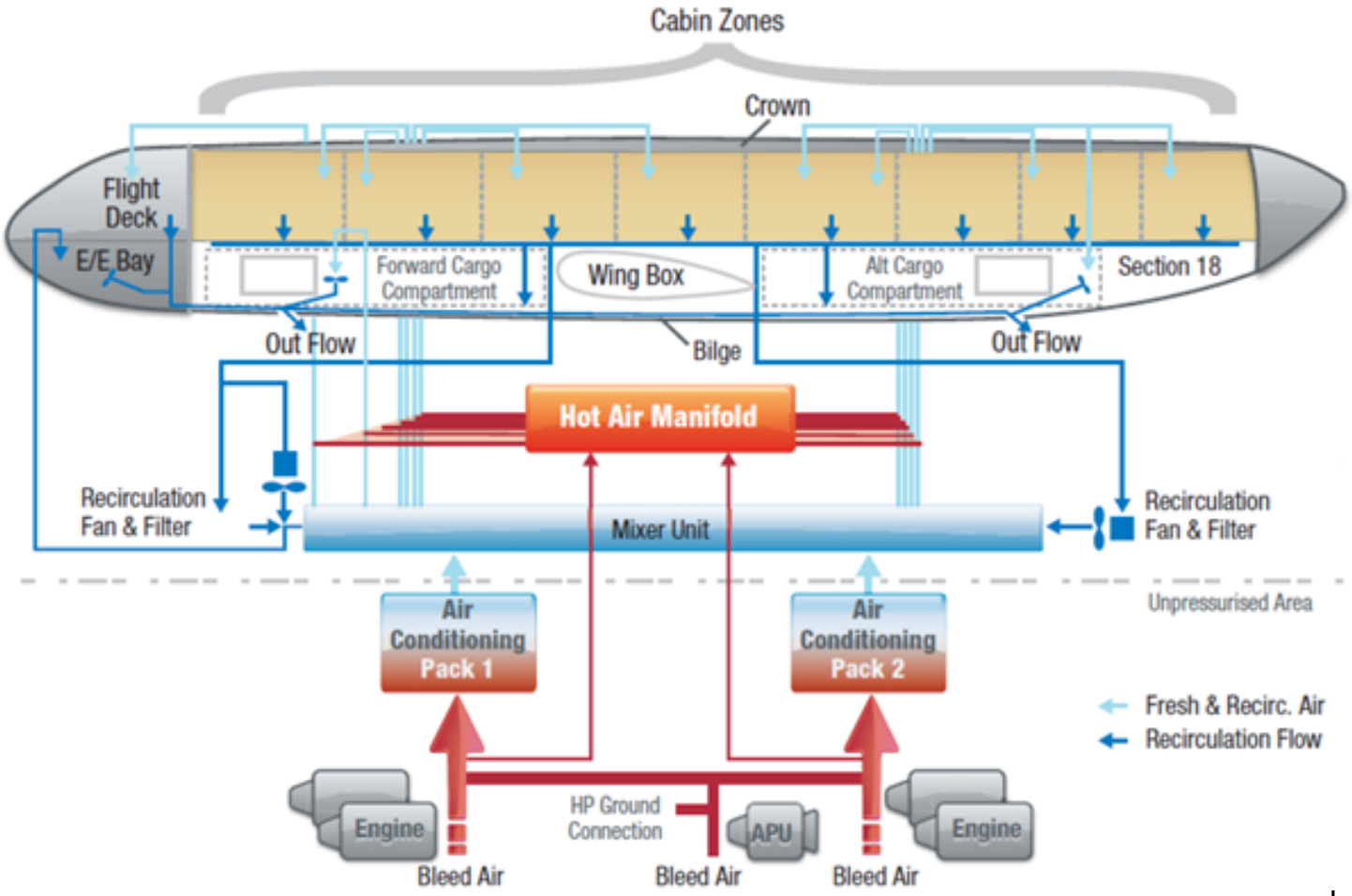
Air Conditioning with Recirculation



Adapted from (NRC 2002)

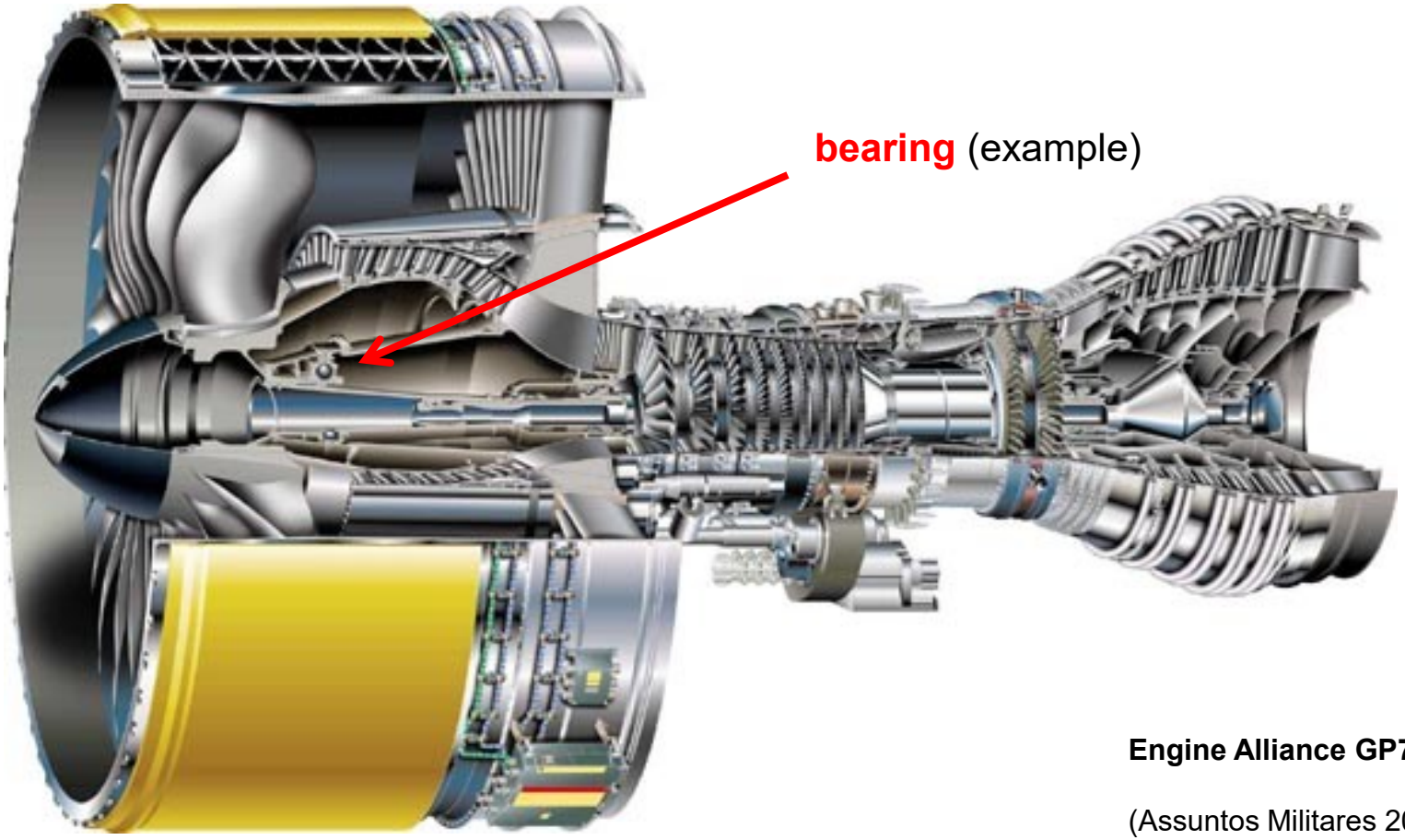
Air Conditioning Technology

Complete Air Conditioning System



Lufthansa 2015

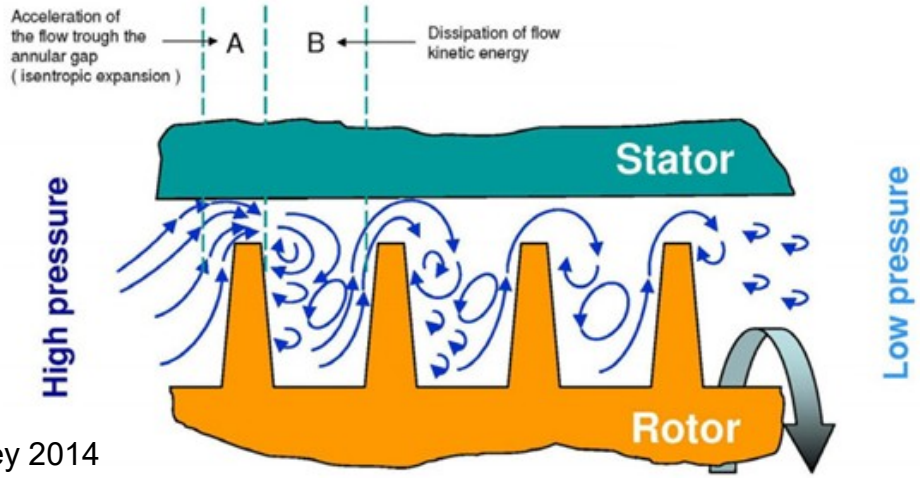
Engine Overview



Engine Alliance GP7000

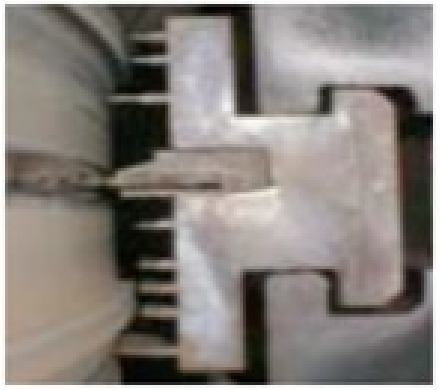
(Assuntos Militares 2013)

Labyrinth Seals / Brush Seals – All Seals Leak by Design

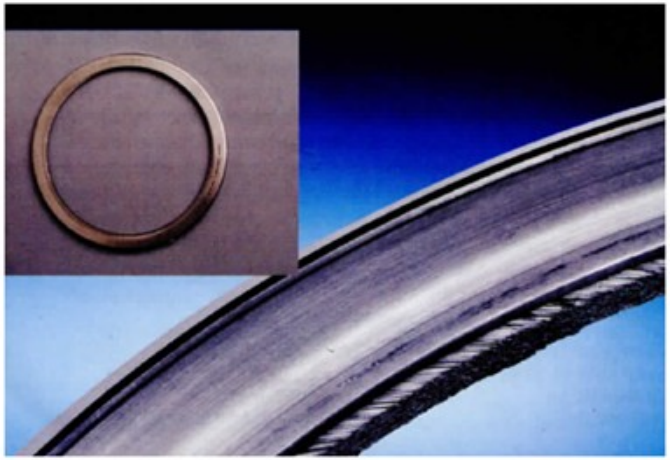


Flitney 2014

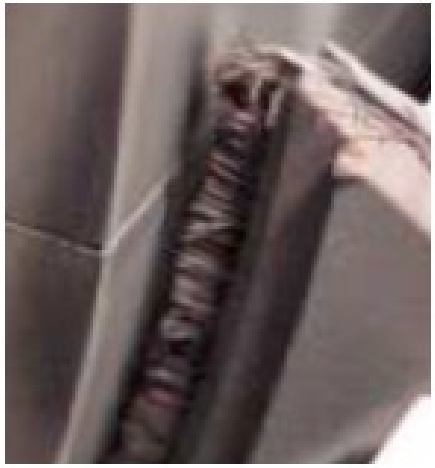
Childs 2017



labyrinth seal

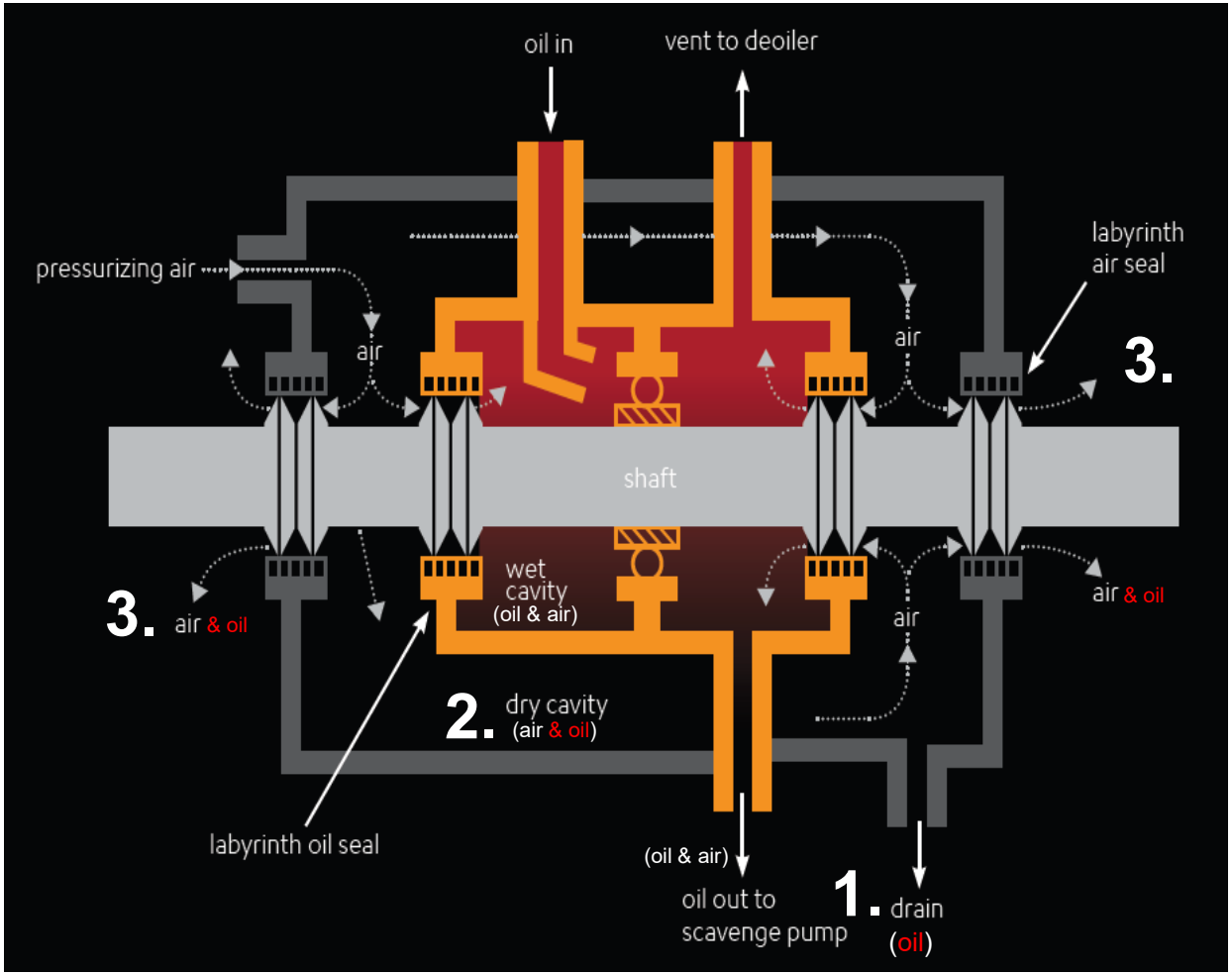


DGLR 2014



brush seal

Engine Air and Oil System



Normal operation of engine seals:

1. The "**drain**" discharges **oil**.
2. The "**dry cavity**" contains **oil**.
3. Air and **oil** leak from bearings **into** the **bleed air**.

=> **Engines leak small amounts of oil by design!**

based on (Exxon 2016b)

Engineering Design Principles for Air Conditioning from SAE

SAE AIR 1168-7: Aerospace Pressurization System Design
(first edition: 1991, A in 2011)

"Compressor bleed from turbine engines is attractive because of the mechanical simplicity of the system." However, "**oil contamination ... can occur in using compressor bleed air from the main engines**." "Popular opinion regarding the risk of obtaining contaminated air from the engine **may preclude its use for transport aircraft, regardless of other reasons**."

Where Are the Legal Problems?

1.) Missing sensors for air quality on board

EASA CS-25.1309 (c) Information concerning unsafe system operating conditions must be provided to the crew to enable them to take appropriate corrective action

EASA AMC-25.1309 c. Compliance with CS 25.1309(c).
(5) Even if operation or performance is unaffected or insignificantly affected at the time of failure, information to the crew is required if it is considered necessary for the crew to take any action or observe any precautions.

2.) Fail-Safe Design Concept violated with bleed air used for the cabin

EASA AMC-25.1309 b. Fail-Safe Design Concept.
(2) The fail-safe design concept uses the following design principles:
(xi) Error-Tolerance that considers adverse effects of foreseeable errors during the aeroplane's design, test, manufacture, operation, and maintenance.

Known deficiencies (here: oil contamination of bleed air) are not allowed. The system has to be error-tolerant to yet UNKNOWN design errors that have to be envisaged because it is a known fact in life that errors do occur. The system's error-tolerance is compromized, if it has to cope with already known design errors that are not rectified out of negligence relying on the systems error-tolerance. This means: The fail-safe design concept is not applied here.

Where Are the Legal Problems?

3.) Cabin air must be free from contamination

EASA 2017: CS 25.831 Ventilation

(a) Each passenger and crew compartment must be ventilated ... to enable crewmembers to perform their duties without undue discomfort or fatigue.

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

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)

4.) Bleed air is not tested to be fit for use in the cabin as stated:

EASA 2018: CS-E 690 (b)

(b) Contamination Tests of Bleed Air for Cabin Pressurisation or Ventilation. The specifications of this paragraph (b) are applicable where it is desired to declare that compressor bleed air is suitable for direct use in an aircraft cabin pressurisation or ventilation system.

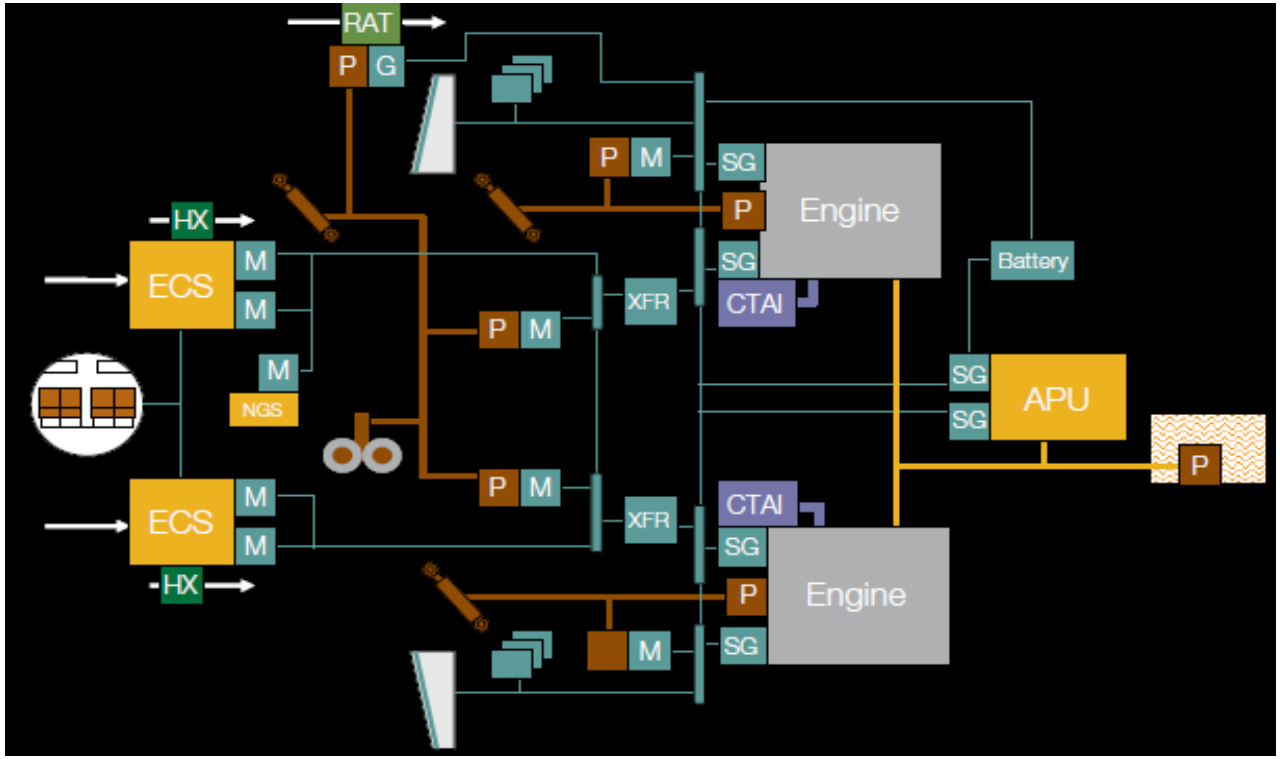
(1) Tests to determine the purity of the air supply must be made.

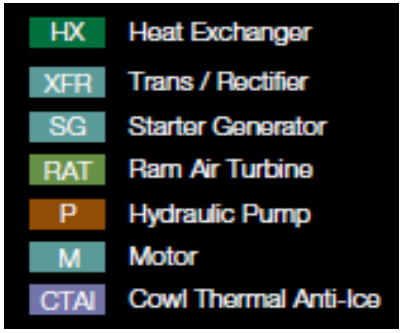
(2) An analysis of defects which could affect the purity of the bleed air must be prepared and where necessary the defects must be simulated and tests, as agreed by the Agency, must be made to establish the degree of contamination which is likely to occur.

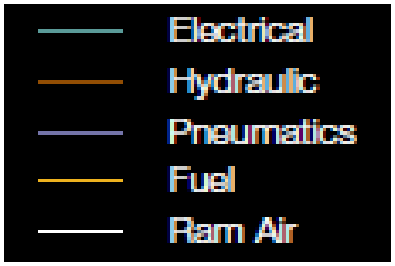
Solution: Compress Outside Air – Bleed Free Design

Solution Boeing 787

(Boeing 2007)



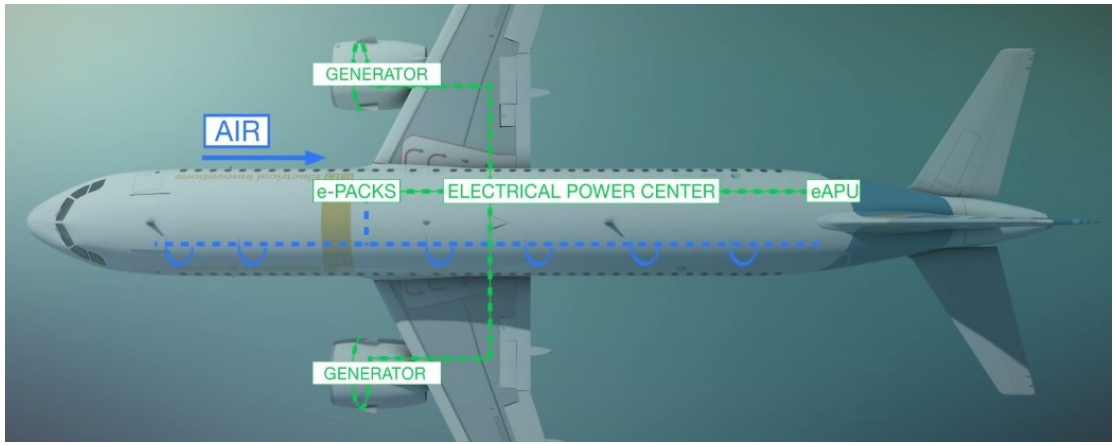


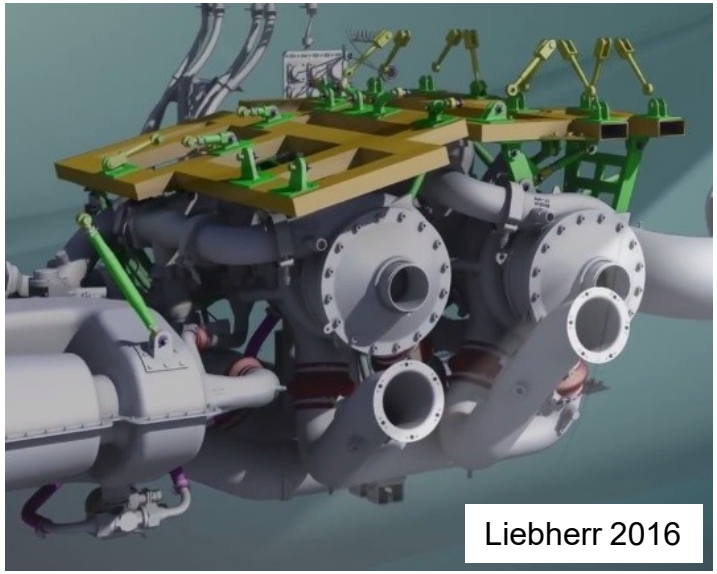


The "Pack" of the B787's Environmental Control System (ECS) is powered by electric motors (M) to compress ambient air up to cabin pressure and to push the air through the heat exchangers (HX) for cooling. The power for the electric motors is produced by generators (SG) connected to the aircraft's engine and APU. After compression and cooling the air is delivered to the cabin.

Solution: Compress Outside Air – Bleed Free Design

Airbus – A Solution Exists, but Is Not Applied!





Summary

- Frequent Cabin Air Contamination Events (CACEs) show: There is a real problem:
  - **engines leak oil by design,**
  - **oil can be traced on its way from the engine into the cabin, ...**

- **There is a legal problem / Democracy corrupted?**

- **Technical solution: Bleed-free architecture with direct air intake and dedicated compressor**

- **Short term partial technical solution: Carbon filter:**
  a) in the duct to the cabin and
  b) attached to the recirculation filter
  suitable for **retrofit**

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