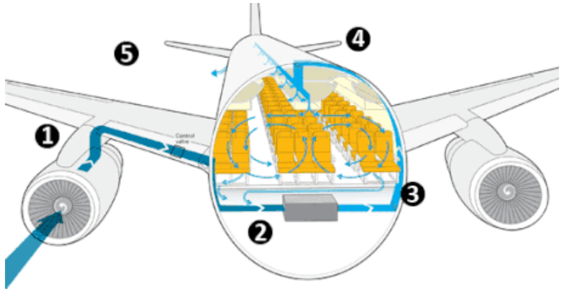
AIR PURIFICATION IN AIRCRAFT CABINS: THE BLEEDAIR

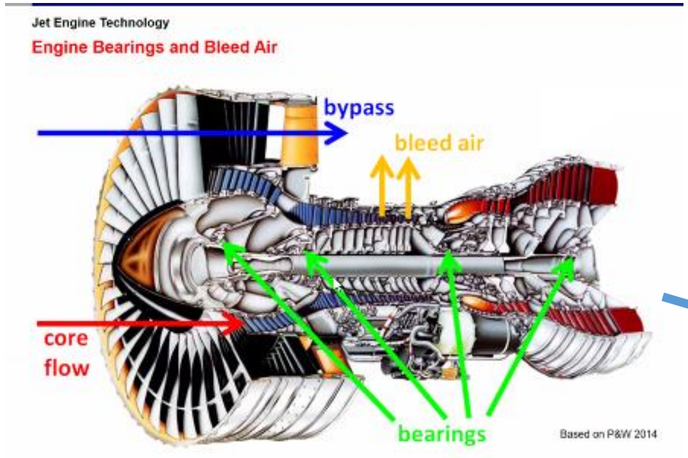
Pascal ALIX, Mickael LEBLANC, Sebastien MAGAND, Guillaume PETAUD, Matthieu TALLEU, Vincent GIUFFRIDA

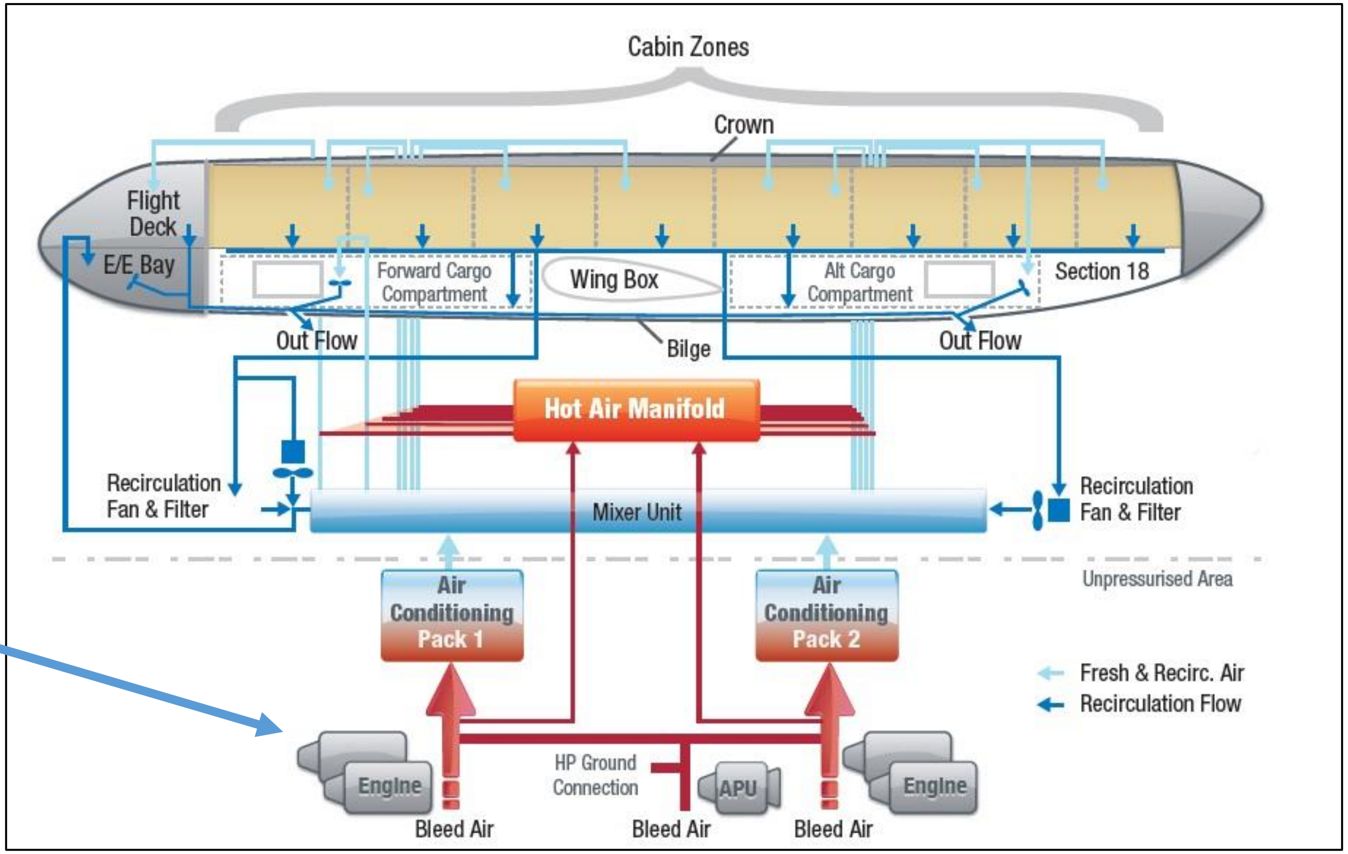
BLEEDAIR : CONTEXT

Climate, environment and circular economy

- Current situation of cabin ventilation:
  - Around 50% of the renewed air flow, recycled through a HEPA filter
  - Fresh air sucked after the compression stage of the turbojet = « **BLEEDAIR** »
  - Fresh and recycled air mixed inside the Mixer Unit and blown into the cabin



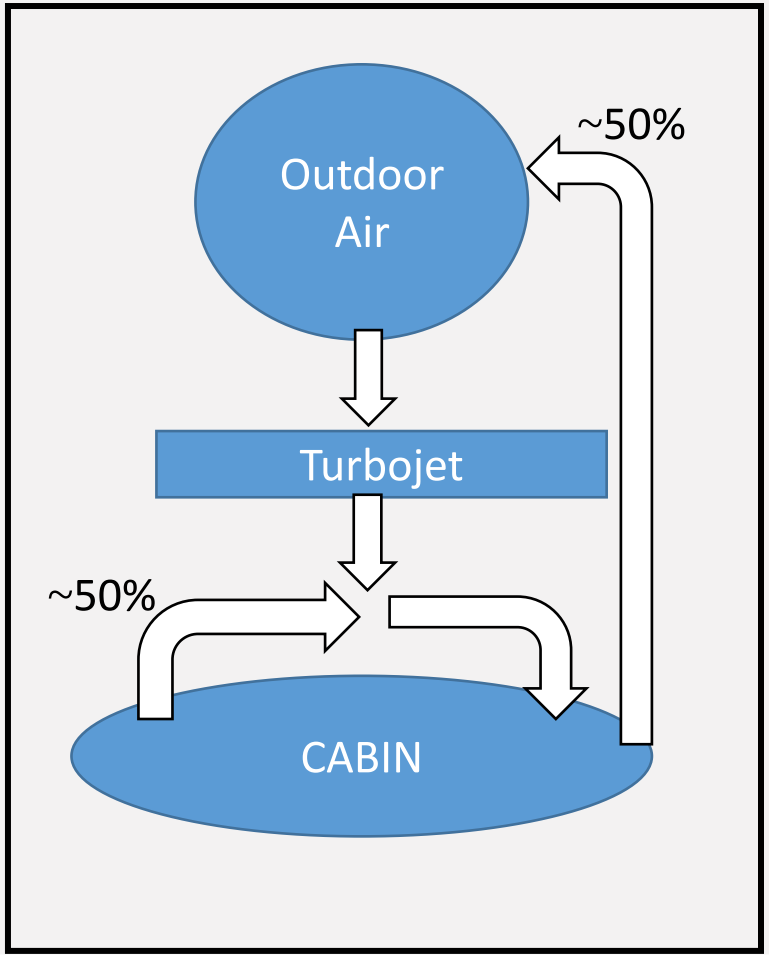




BLEEDAIR : CONTEXT

Climate, environment and circular economy

- An aircraft cabin = enclosure with a high air change rate
- Control agencies (EASA), unions, etc. => *“it must be ensured that no “dangerous substances” may be contained in the breathing air during a flight“*
  - *Standards for aeration rate, ozone, humidity, P, T …* [(1)]
- Different sources of pollution depending on the flight phase:
  - Sucked air outdoor:
    - On the ground: pollutants present around the plane, near the tarmac (HC, NOx,…)
    - High altitude: ozone (O_3)
  - Fluids:
    - On the ground: de-icing (glycol)
    - During flight: engine oil, hydraulic fluids (sucked from the turbojet)
- Emissions from the cabin, whatever the flight phase:
    - furniture, perfumes, cleaning products, etc. => similar to indoor air pollution



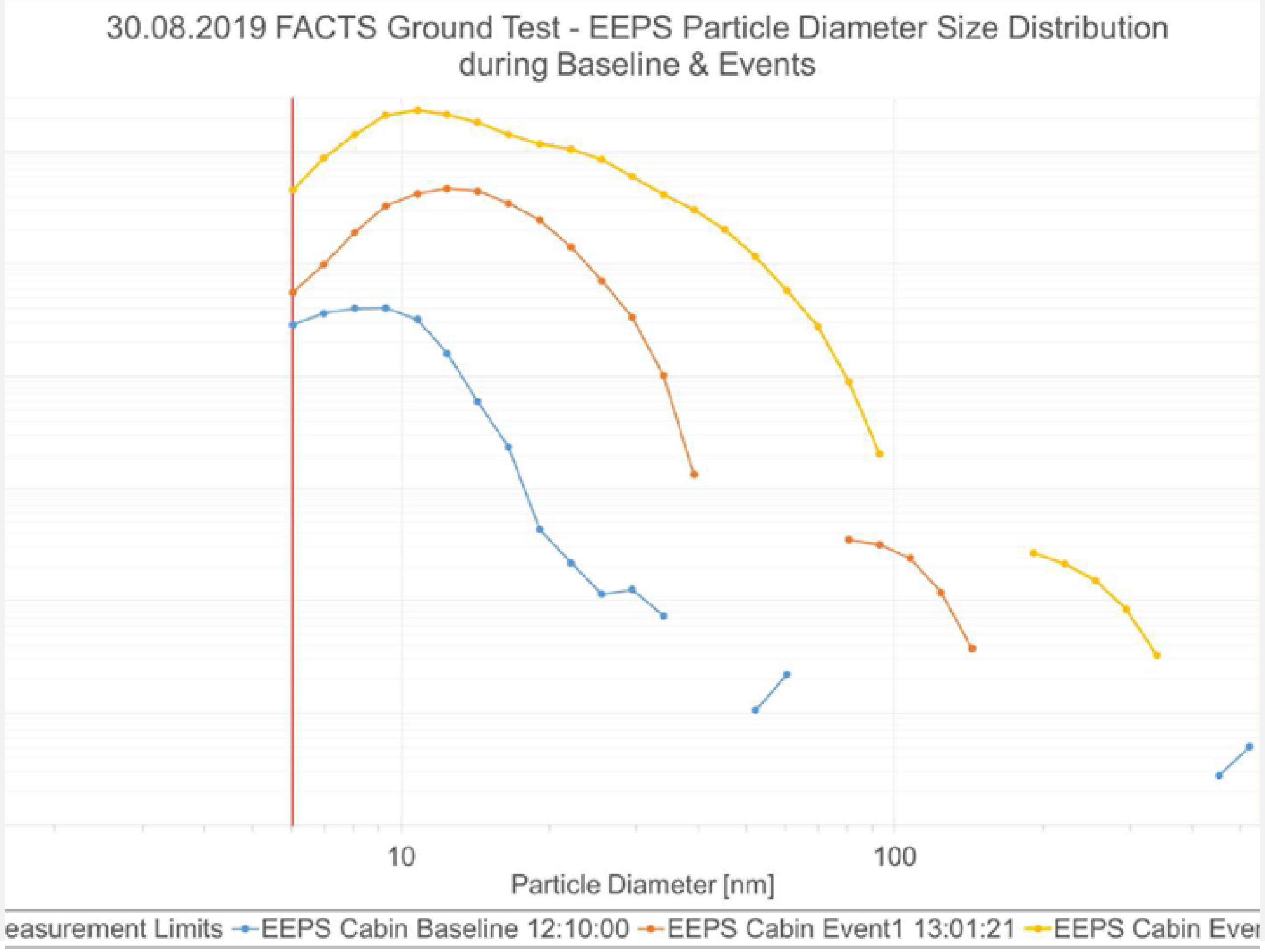
[(1)] https://www.ashrae.org/file%20library/technical%20resources/covid-19/si_a19_ch13.pdf

BLEEDAIR : CONTEXT

Climate, environment and circular economy

- In rear cases, precited sources of pollution are suspected to be responsible of detectable cabin air contamination events (CAC event) => TCP are the main indicators in case of a Bleedair pollution by engine oil *[rapport ANSES, Oct 2023]*
- FACTS Project:
  - Reproduction of an oil leak on a ground device => measurement of pollutants in the cabin
  - Organo-phosphorus compounds including TCP in aerosol form (size range = 5-500 nm)
- The capture of such aerosol would prevent pollutions from different sources including engine oil and would improve cabin air's quality

Houtzager et al. FACTS Deliverable 7.0 , August 2020

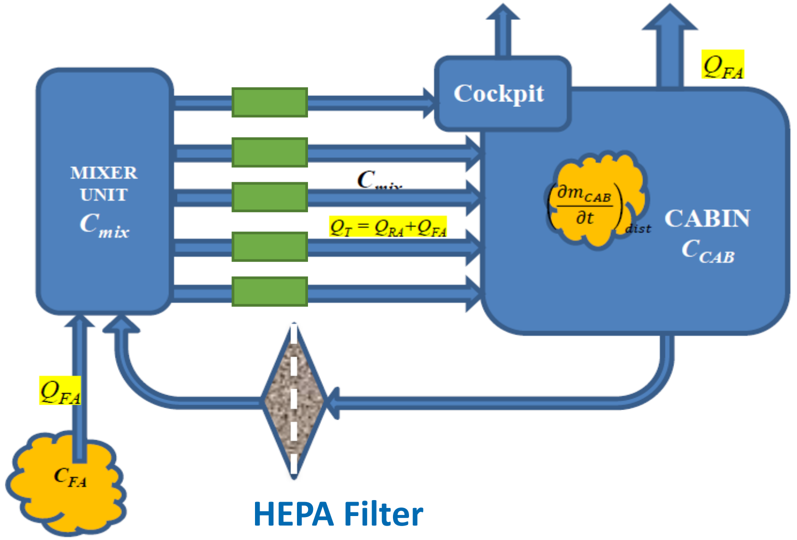


BLEEDAIR : CONTEXT

Climate, environment and circular economy

- System required:
  - which does not modify the architecture of the aircraft
  - Wich could be adapted to existing aircraft

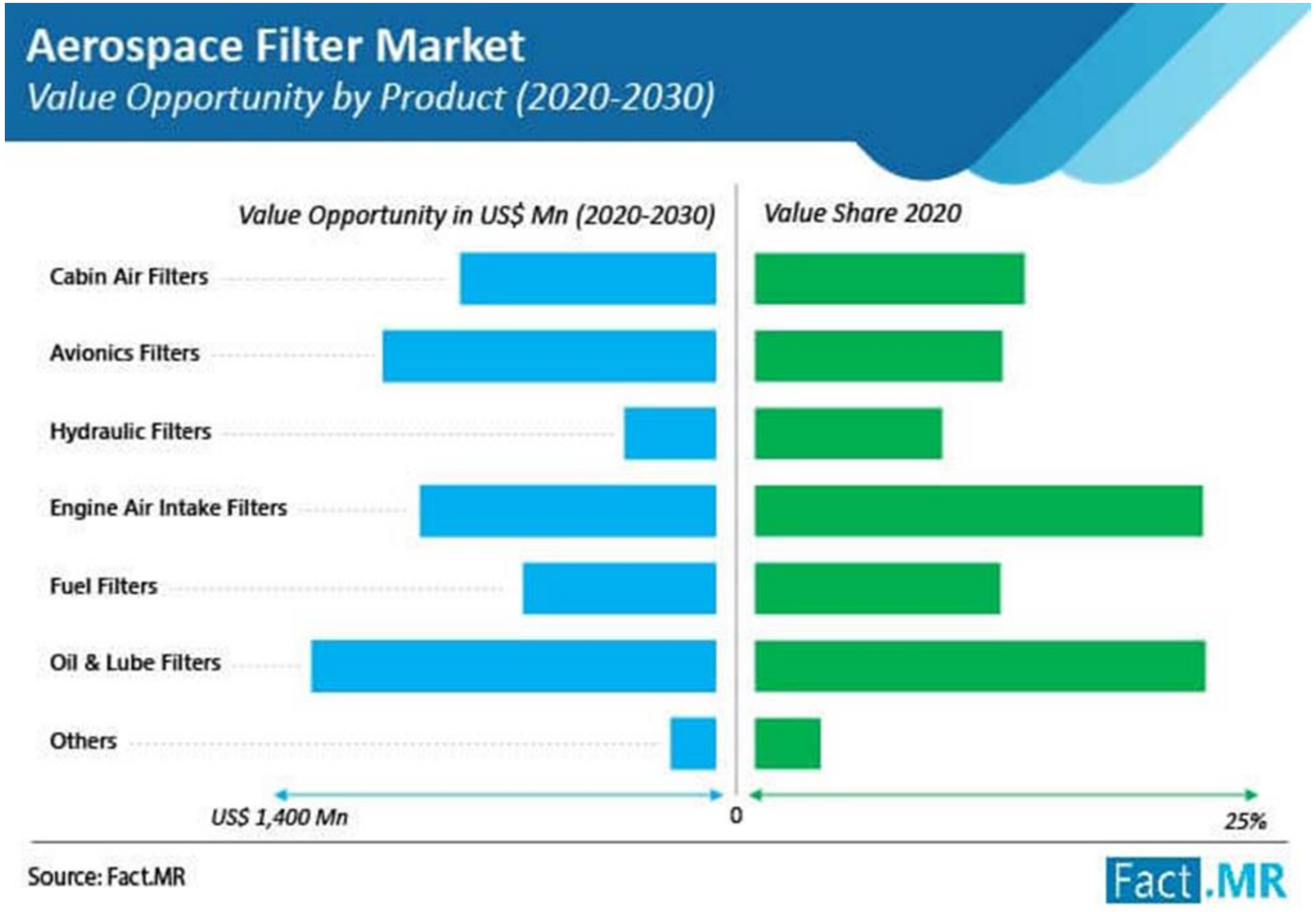
Main features	Target
Function	Bleedair purification
Device's type	Passive system (same architecture)
Target	TCP (ppt)
Location	Downstream the Mixer Unit
Size	Diameter ≤ 150 mm ; Length ≤ 1 m
Pressure Drop	$\Delta P \leq 5$ mbar for U_{air} ~ 10 m/s



BLEEDAIR : MARKET

Climate, environment and circular economy

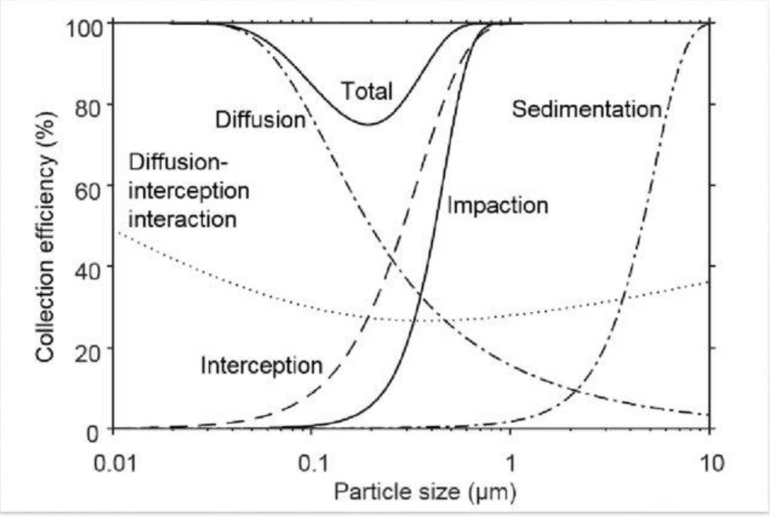
- CAC event cost ~ 40 000 $
  - 5 000 000 $ /year (1)
- Passive System
  - ➔we adress the current and new aircrafts
  - ➔ air cabin management global market
- Filtration (all fluids) ~ 1 Md $
- Air quality ~ 15% of the market
  - 25% short term
- Market ~ hundred Million $ / €
- Annual progression 4-6%



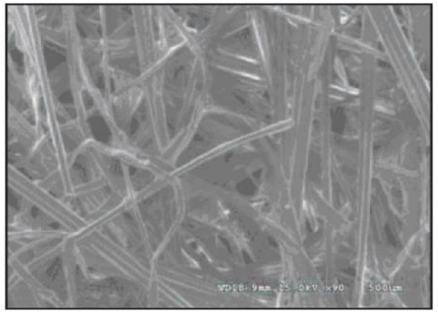
(1) Bleed Air Contamination Financial Related Costs on Board Commercial Flights, Shehadi et al., SAE International Journal of Aerospace · August 2015

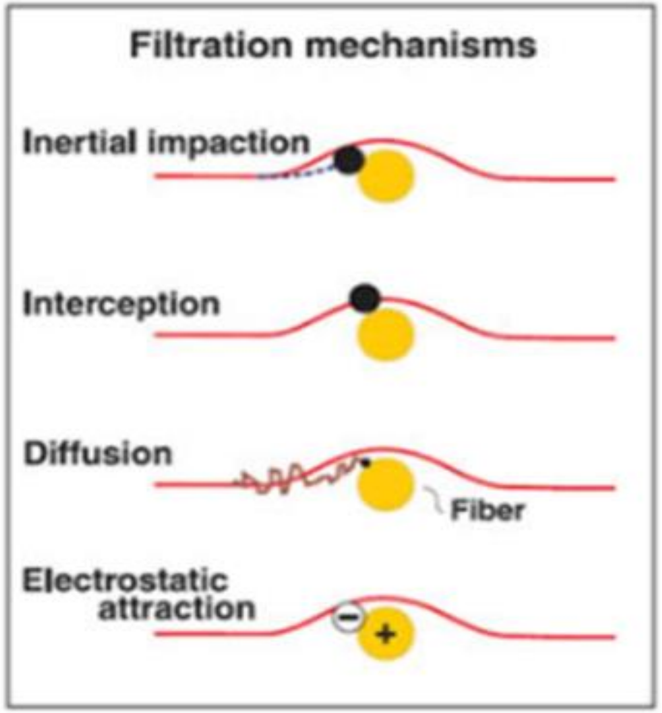
BLEEDAIR : CURRENT TECHNOLOGIES

HEPA filters: fibers based on 3-4 major principles



Filtration efficiency depending on particle's size





- **Superficial velocity = 0.05 – 2.3 m/s**
- **ΔP>100 Pa (H13,…)**

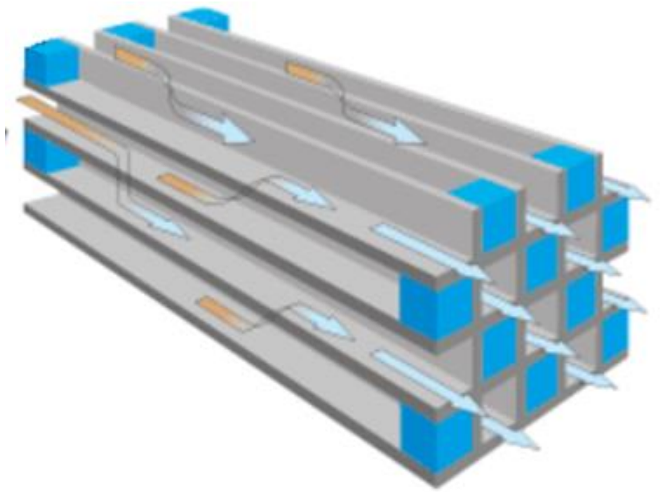
Bleedair :

- **Occupied volume too important**
- **Out of range in terms of gas velocity => High pressure drop, low efficiencies**
- **Risk of clogging => pressure drop ++, freshair flowrate --**

BLEEDAIR : CURRENT TECHNOLOGIES

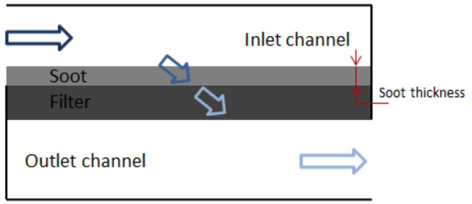
- Particulate Filters:
  - Channels with caps to force the fluid to cross filter media (balls, etc.)
  - Channels density (CPSI) = 300-1200 in the automotive industry to ensure a high efficiency

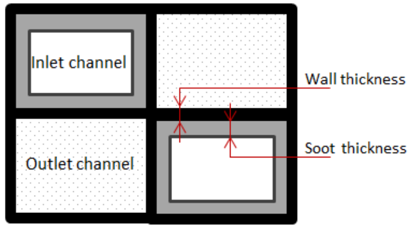
$$cpsi = \frac{N_{mailles}}{A_{max}} \times \frac{1}{1550}$$



  - Examples of hydraulic calculations = AMESIM software

L (mm)	Cells density (CPSI)	ΔP (mbar)
800	50-750	8-76
50-800	500	14-86



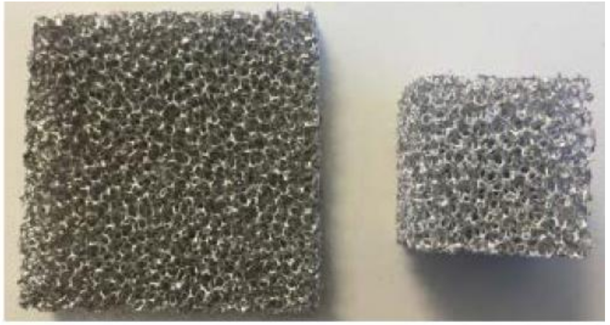


- CPSI < 10 to reach the target of 5 mbar
  - considerable and unpredictable drop in efficiency
  - Higher wall thickness => gain for ΔP not guaranteed

BLEEDAIR : CURRENT TECHNOLOGIES

Climate, environment and circular economy

- Metal Foams:
  - Characteristics:
    - Contact Surfaces of several thousands m^2/m^3
    - Pores Density per « inch »
      - PPI~30-50
  - Calculated Pressure Drop:
    - >> 10 mbar if the thickness of the foam plate L > 1 cm



BLEEDAIR : CURRENT TECHNOLOGIES

- Monolith :
  - Main parameters
    - Channel density (*CPSI*), hydraulic diameter of the channels (D_h) and wall thickness (ε)

$$CPSI = N_{canaux} \times \frac{4}{\pi D^2} \times \frac{1}{1550}$$

  - AMESIM software => *CPSI* < 50 and ε < 0.09 mm required to meet the specified velocity and pressure drop
  - Far from current values for automotive: CPSI = 300-600 ($\varepsilon > 0.12$ mm) => feasibility & efficiency ?
  - Current monoliths not adapted

LOW TRL TECHNOLOGIES SELECTION: ROLE OF CFD

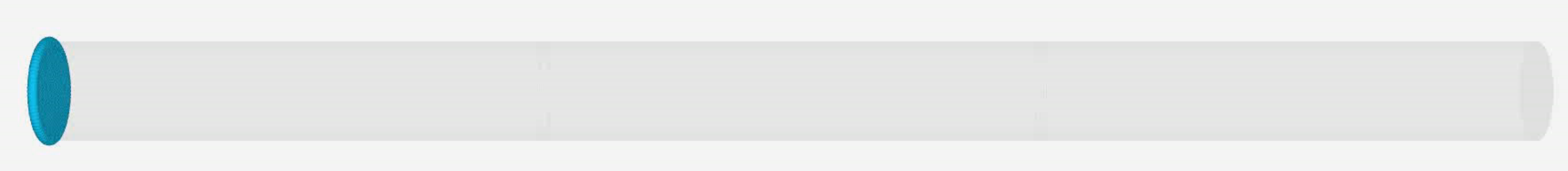
Climate, environment and circular economy

- CFD is relevant to select a technology to meet pressure drop / gas velocity target:
  - Fine and ultrafine particles at very low concentration => gas only
  - Software: Ansys Fluent 2022-R2
  - Gas Reynolds number ~ 100000 => Turbulent flow: SST-kw
- To evaluate a capture rate of particles, one needs:
  - To consider particles => ash (density= 600 kg/m^3) & DPM (Discrete Particle Model)
  - Valid the CFD code with base cases => size of particles which can be modelled ?
    - Impactors, cyclones

LOW TRL TECHNOLOGIES SELECTION: ROLE OF CFD

Climate, environment and circular economy

- Example of an empty pipe:



Particles Size	Escaped	Trapped	Incomplete	Trapped [%]	DeltaP [mbar]
1 µm	894	0	0	0.0	0.05
100 nm	894	0	0	0.0	0.05

BLEEDAIR: DISCUSSION

Climate, environment and circular economy

- The air in aircraft cabins is renewed by around 50% by suction of outside air via turbojets (Bleedair)
- Capturing particles of size range from 10 to 500 nm, would be a real gain in terms of cabin air purification, helping to prevent cabin contamination with substances such as TCP (that may be contained in particles)
- Preserving the current architecture would make it much easier to deploy and access the market
- Constraints in terms of size, gas velocity and pressure drop prevent the use of conventional systems such as HEPA filters, PF, monoliths, cyclones, etc.
- The development of low TRL technologies is required => R&D program
  - Dedicated Experiments, CFD, etc.
- Work in progress at IFPEN

IFP Energies nouvelles

Innovating for energy

Find us on:

www.ifpenergiesnouvelles.com

@IFPENinnovation