Passenger Aircraft Indoor Air Quality Challenges and Solutions II

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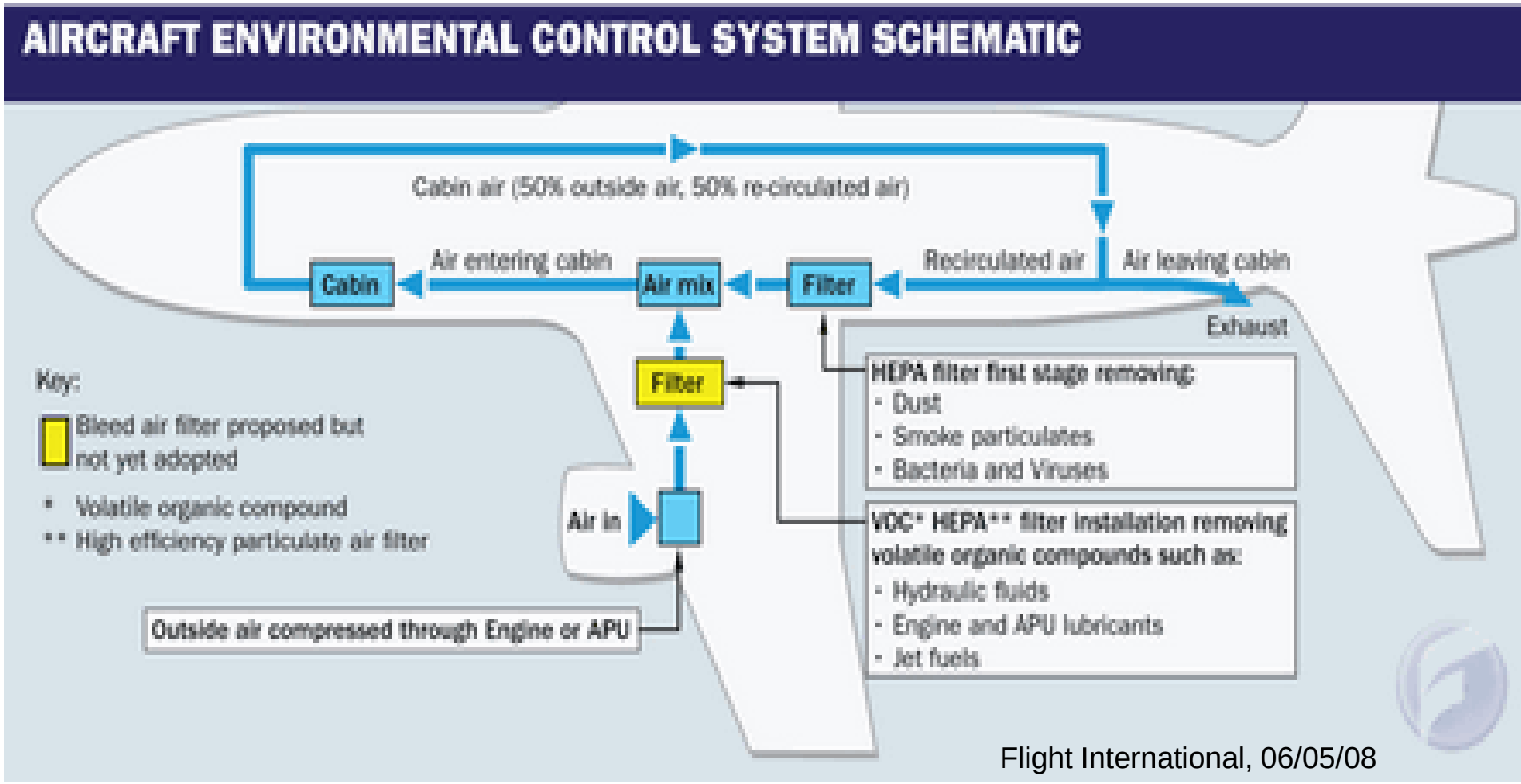
Cabin Air Health, Safety & Comfort Challenges

1. Respiratory system infections.
2. Low humidity health and comfort effects.
3. Impacts of toxic bleed & cabin air gases & particles on flight crew.
4. Envelope fires.

Passenger Aircraft Environmental Control System (ECS) Design Challenges

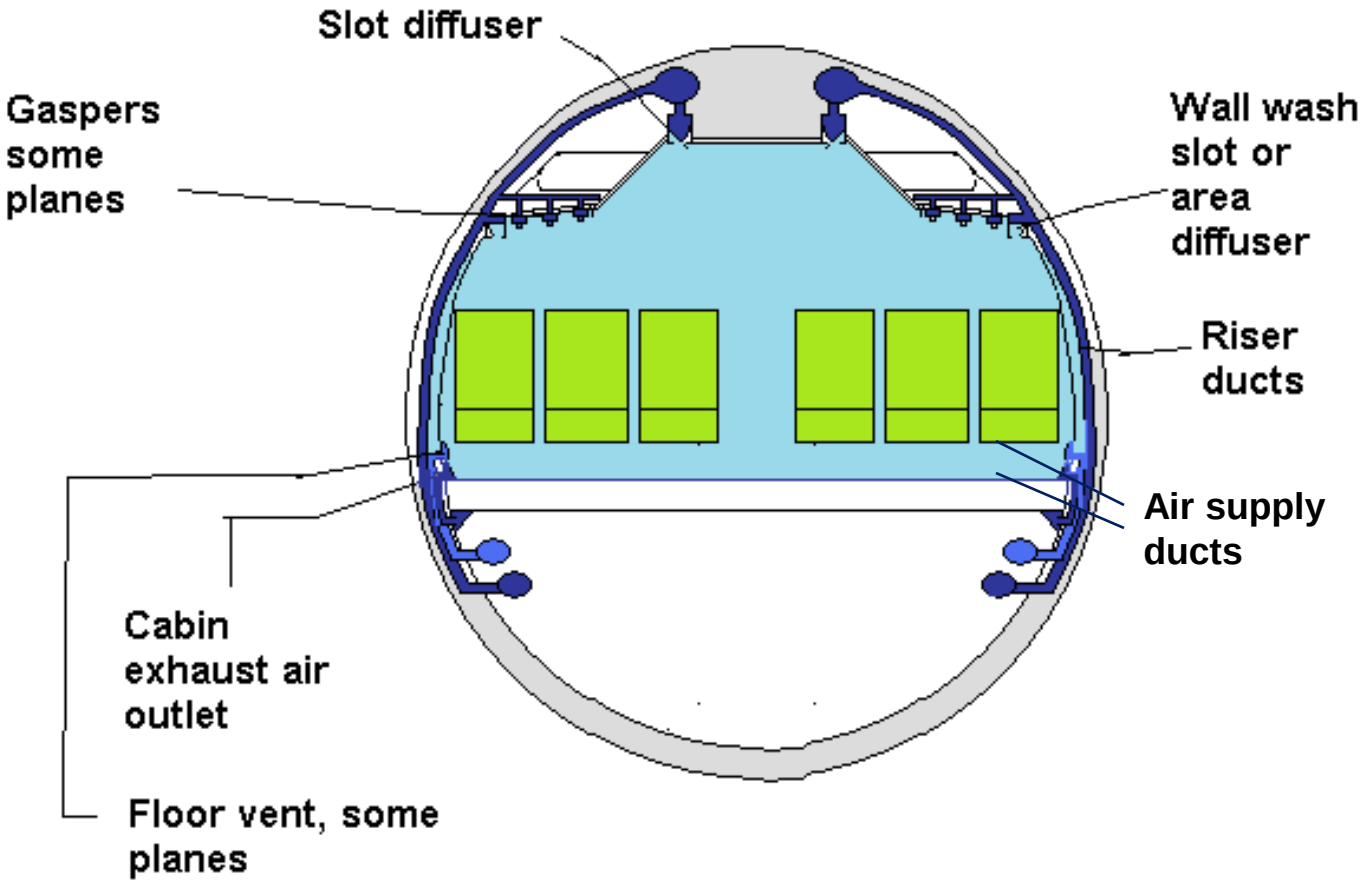
High occupancy density. Wide range of occupant ages, health conditions, activities, & pathogen strains. Unique air contaminant & fire challenges.

THE AIRCRAFT ECS (HVAC) SYSTEM



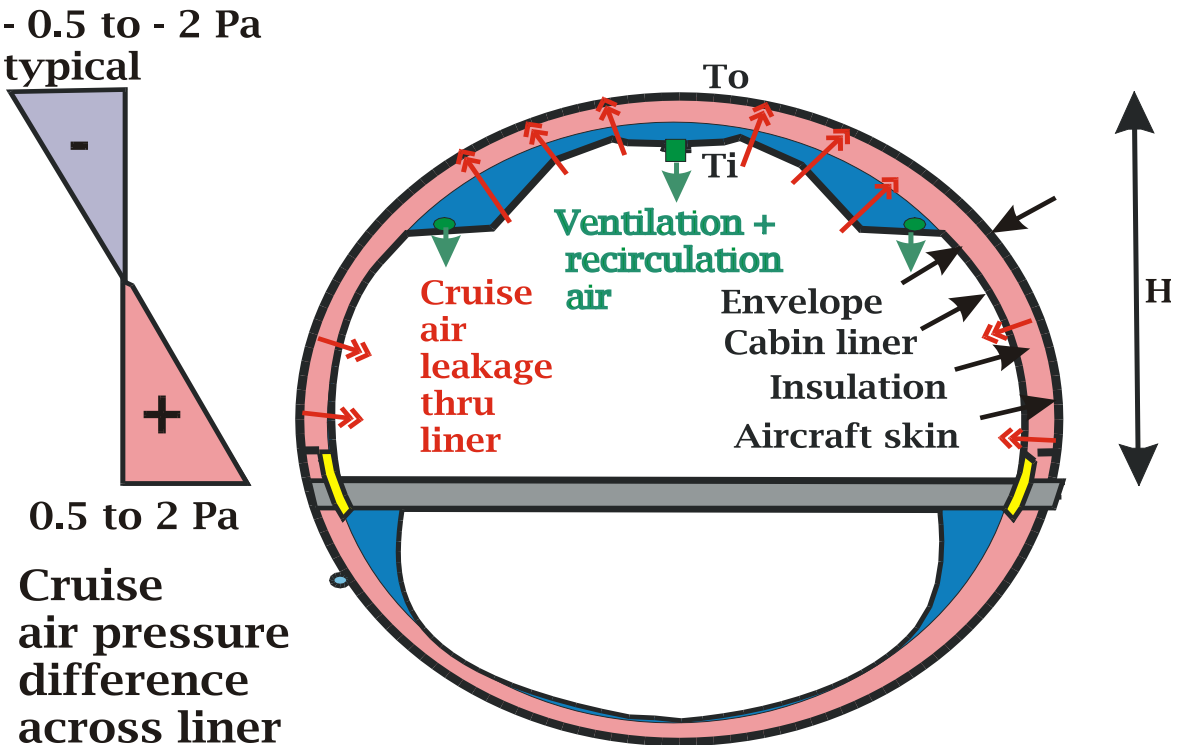
Flight International, 06/05/08

ECS ventilation air outlets



Envelope Ventilation

Stack Pressure = Air density * (Ti-To) * H/2



Cabin air circulates thru the envelope unintentionally, with a number of adverse effects: condensation, corrosion, microbials, VOCs, fire safety issues.

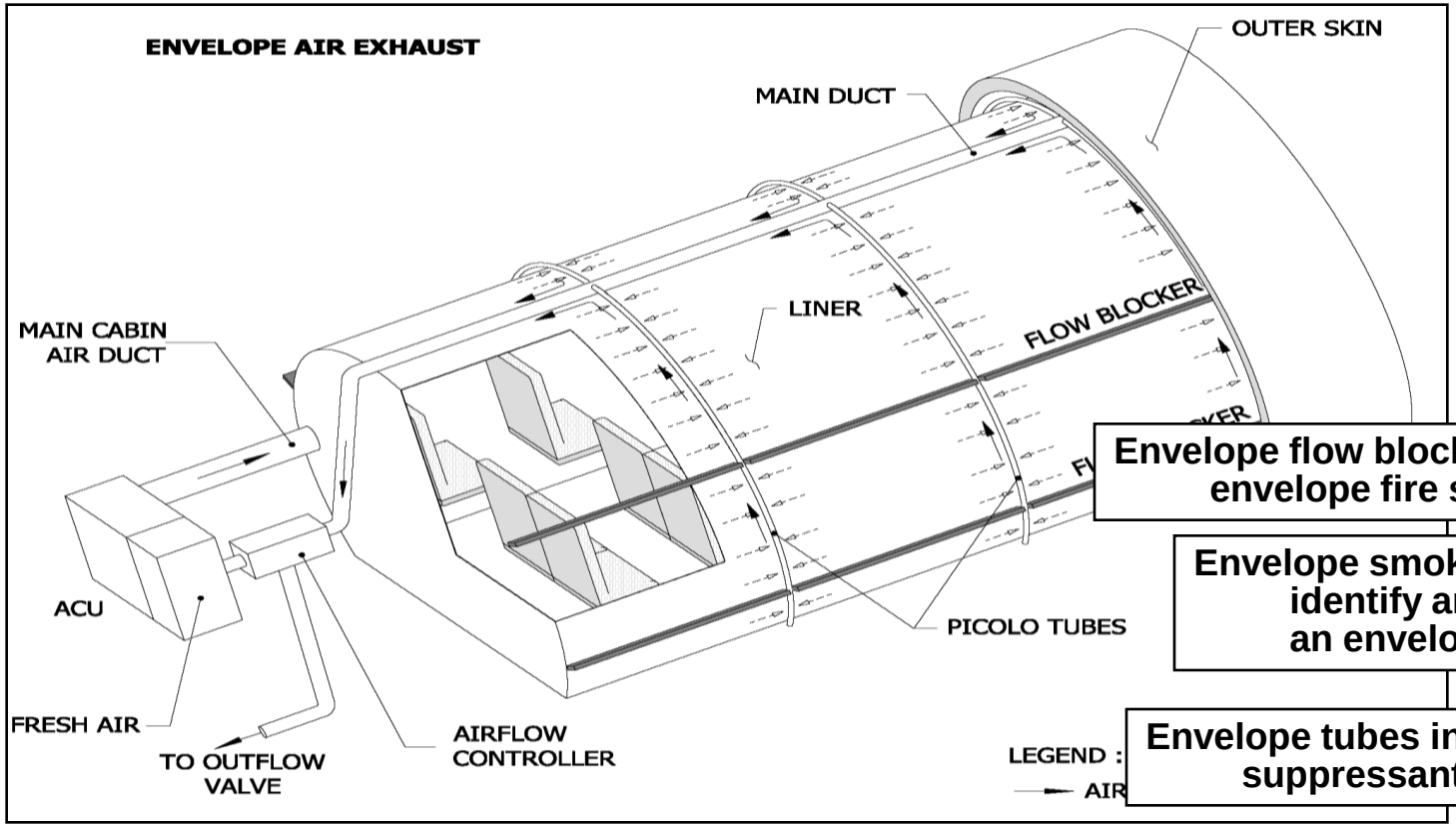
CHALLENGE #4: Envelope fire

- Electrical wire vibrations potentially lead to arcing if not maintained.
- Envelope fire hidden & inaccessible.
- Cockpits in some passenger aircraft have recirculation air which could include envelop toxic fire gases.
- Oxygen mask does not protect against ambient air contaminants.

Example of envelope fire Swissair Flight 111, Sept. 2, 1998

- Fire caused plane to crash into the Atlantic Ocean near Peggy's Cove, southwest of Halifax, killing all 229 people on board.
- Crew smelt smoke in cockpit. Thought to be coming thru ECS (no recirc. in DC10-MD11).
- Transport Canada investigation
  - Fire was in envelope ceiling straddling cockpit bulkhead.
  - Arcing of wiring + flammable insulation.

Solution to Envelope Fire & Smoke Events: Depressurize & Exhaust Outdoors



Drawing courtesy of Air Data Inc., Canada.

CHALLENGE # 3
Toxic Gases & Particles (SVOCs)

- 1,800 bleed air oil mist events reported to UK Civil Aviation Authority' between1985 and 2006. T0CP the main concern.

- Most involved BAE 146s or Boeing 757s, followed by Airbus A320s, Boeing 737s and Embraer ERJ-145s.

VOC/SVOC knowledge base

•None of 53 VOCs/SVOCs identified by industry contractor were ToCP found in engine oil.

• Two of the top 5 VOCs reported appear to be measurement artifacts.

•“Toxic fumes in airliner cabins are ignored by authorities” Flight International (UK), May 6, 2008.

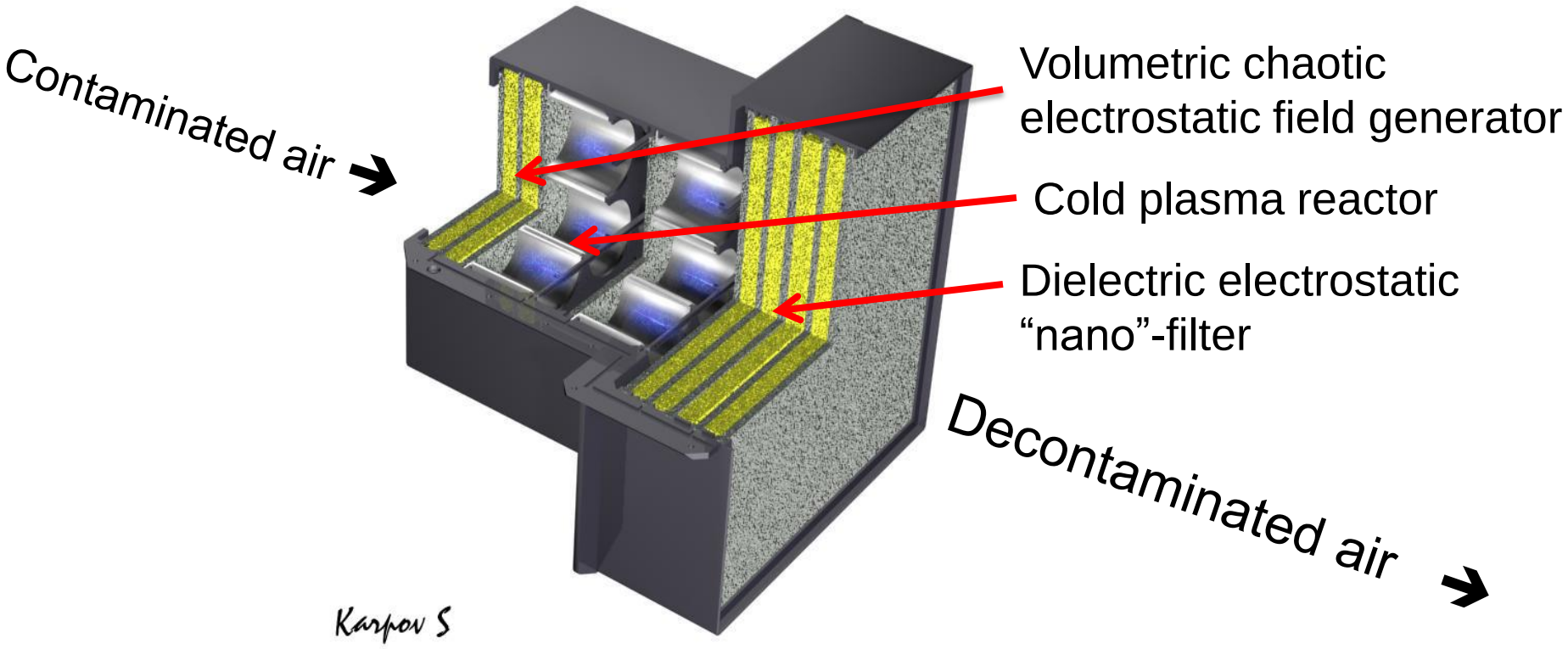
Top 5 Cabin VOCs as reported by industry contractor

Rank	VOCs	Some possible sources	Cabin air	Office air
1	Isopropanol (Propan-2-ol)	**Possible artifact** from ultra fine particle counter used in contractor measurements. Low cost industrial solvent, rubbing alcohol. In humans, bio-transformed to acetone.	339	6.5
2	Ethanol	Human metabolism, beverages, microbials.	174	75
3	Propylene glycol	Deodorants, cosmetics, de-icers.	60	13
4	Acetone	Human metabolism, jet fuel, cleaners, industrial solvent.	45	25
5	Acetonitrile (methyl cyanide)	**Possible artifact** from aldehyde sorbent sampling cartridges used in contractor measurements. Solvent, nail polish remover, HPLC, engine exhaust.	367	0

Measures for Eliminating Toxic Bleed air Aerosols

- Separate air bearing compressor for cabin air supply.
- Bleed air filter.
- Cabin air entrainment and filtration right at gaspers and slot diffusers.
- Bleed air filtration via injecting into envelope to filter into cabin.

Plasma ionization and oxidation eliminates CO, NOx, some VOCs, all microbials



Drawing courtesy of Air Data Inc., Canada.

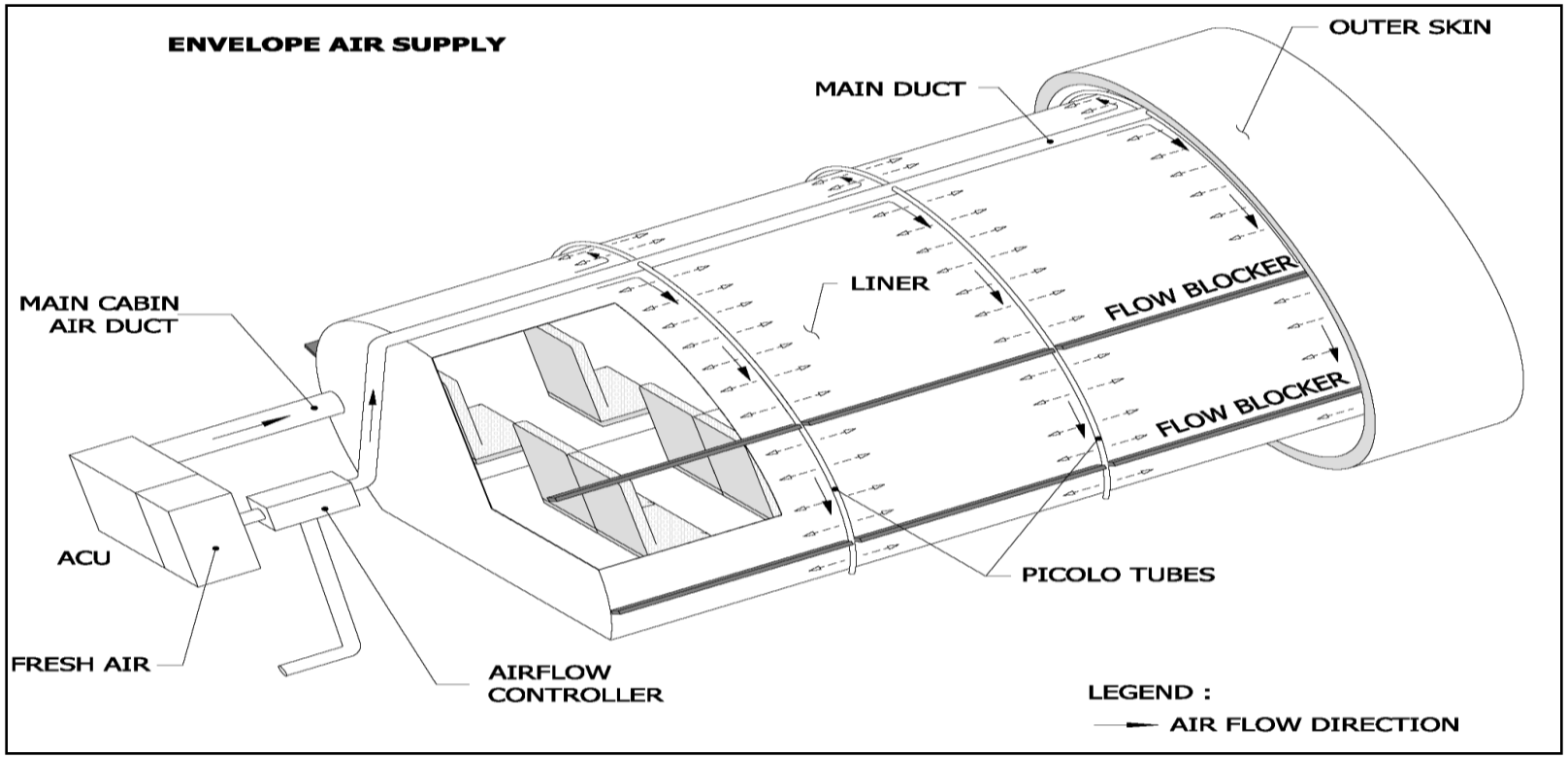
CHALLENGE #2: Low Humidity Health Effects

- Mucosal membrane irritation of eyes and respiratory system.
- Asthma attacks.
- Influenza transmission favored (Lowen et al, 2007).

LOW HUMIDITY

- Flights : 35,000 ft, > 1/2 hour: 10-25%, depending on occupancy.
- Flights > 3 hours can be < 10%, depending on OD.
- Reducing ventilation rate increases cabin humidity but also cabin pathogen levels.
- Humidifying the cabin would increase envelope condensation and add water weight fuel penalty – latter partially offset by reduced beverage consumption.

Envelope pressurized with dry bleed air enables condensation-free cabin humidification



Drawing courtesy of Air Data Inc., Canada.

Envelope bleed air pressurization benefits

- Humidification enabled.
- Reduced wet envelope microbial growth.
- Corrosion and wet insulation cost savings.
- Radiant heating and cooling enabled.
- Same piccolo tube system can be used for fire fighting envelope depressurization.
- Filters bleed air before entering cabin.

CHALLENGE # 1 Respiratory system infections

This challenge includes air travel during pandemics and during the cold weather flu, cold and sore throat season.

Who has not suffered a sore throat or worse a few days after a flying?

The flu season

- 20% of passengers reported upper respiratory infections (URI) within 5 to 7 days of flying, representing an infection rate over 5 times the norm. (Nutik-Zitter, 2003. Hocking, Foster, 2003).

- Higher than previously predicted microbial/viral airborne concentrations were recently measured in aircraft cabins (La Duc, 2006).

Remember SARS?

Headline: Air Canada Grounds Planes As 'ruinous' SARS and War Hit Home, May 15, 2003.

•“Canada's cash-strapped national airline is to ground 40 aircraft due to a "terrible" slump in passenger numbers caused by fears about the deadly SARS virus at its busiest hub, Toronto. Air Canada - which filed for bankruptcy protection last month - yesterday revealed that SARS had cost it C$125m (£55m) in April.”

•“Another carrier hit by SARS, Singapore Airlines, yesterday said it was dropping 60 weekly services. The airline has cut its route network by some 31.5% since March.”

• “Hong Kong's airport authority said its passenger numbers had collapsed by 68% during April; flights fell by 27.9% and the short-term outlook remains uncertain.”

SARS Statistics

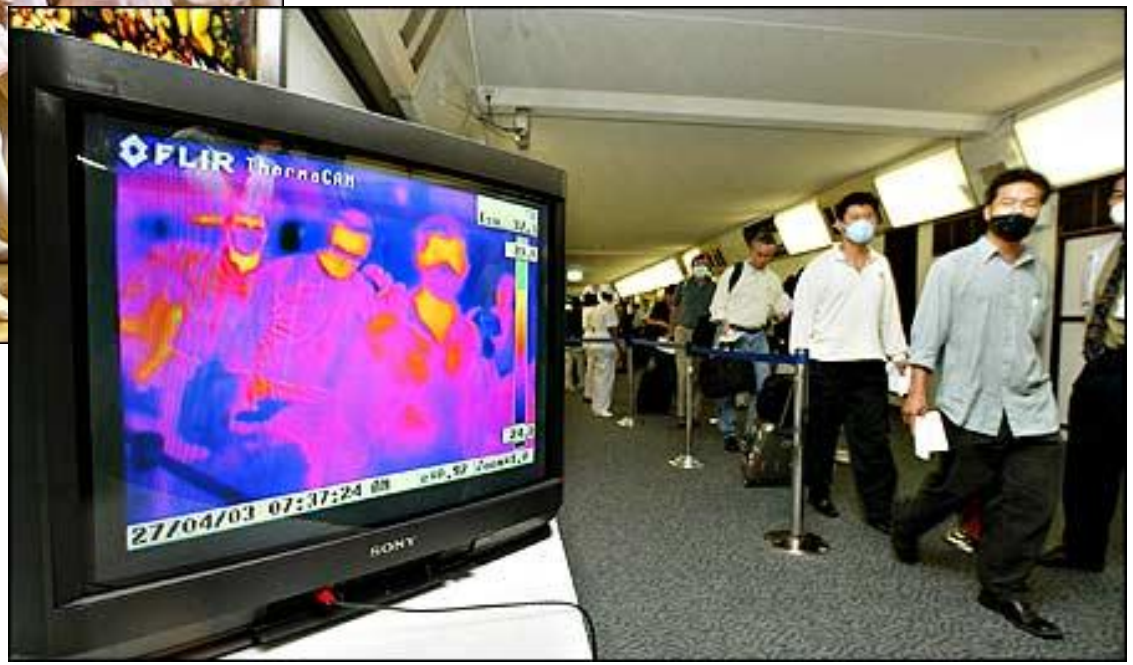
- Severe acute respiratory syndrome (SARS) is a respiratory disease in humans which is caused by the SARS coronavirus.

- Mortality rate was 70% for the primary viral pneumonia and 9.6% for all infections. Compares with 0.6% mortality rate for influenza.

- Mortality by age group: below 1 percent for people aged 24 or younger, 6 percent for those 25 to 44, 15 percent in those 45 to 64 and more than 50 percent for those over 65.

SARS Vignettes

Children learning ballet lessons in Hong Kong wear masks to protect themselves from SARS.



A screen shows the results from a thermal imaging camera used to detect potential SARS carriers at Bangkok's airport, April 27, 2003.

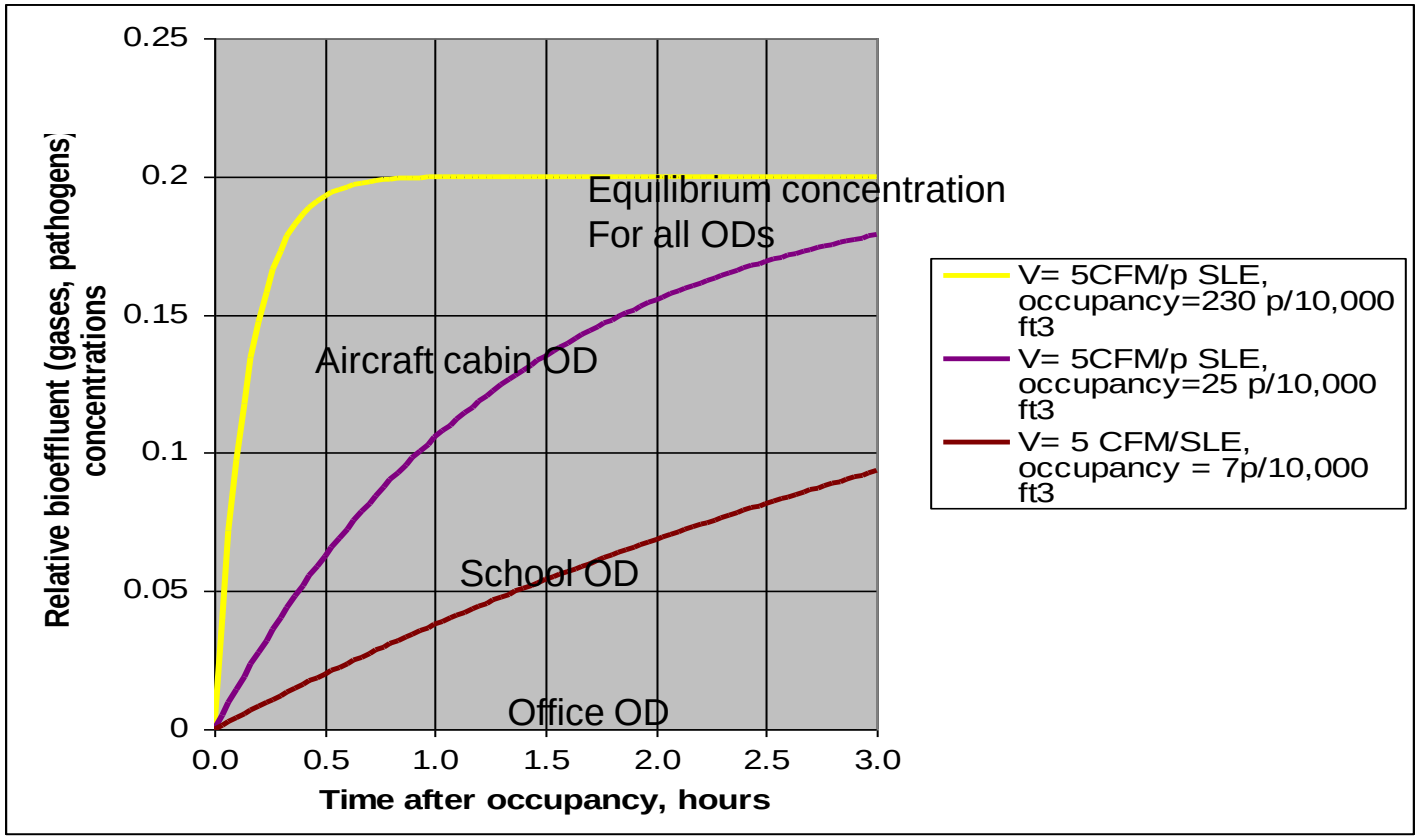
Factors in the spread of respiratory infections in passenger aircraft

- Air circulation patterns and close seating proximity spreads pathogens between people in the same & several nearby rows.
- Multi-city & international travel increase risk.
- High cabin OD, low ventilation rate increase risk.
- Low humidity increases risk.

The role of Occupancy Density (OD)

The volume of air surrounding an office worker is typically 30 times that surrounding the occupant of a passenger aircraft. Classroom OD typically is 10 times lower than in aircraft

OD Effect at V= 5 CFM/p



Aircraft occupancy density is 30 times that of an office occupancy and 10 times that of a classroom.

Role of Recirculation on Pathogen Risk

A passenger survey showed HEPA filters are working as there were no effect of cabin air recirculation on the incidence of post flight URI, runny noses or colds. (Nutik-Zitter, 2003).

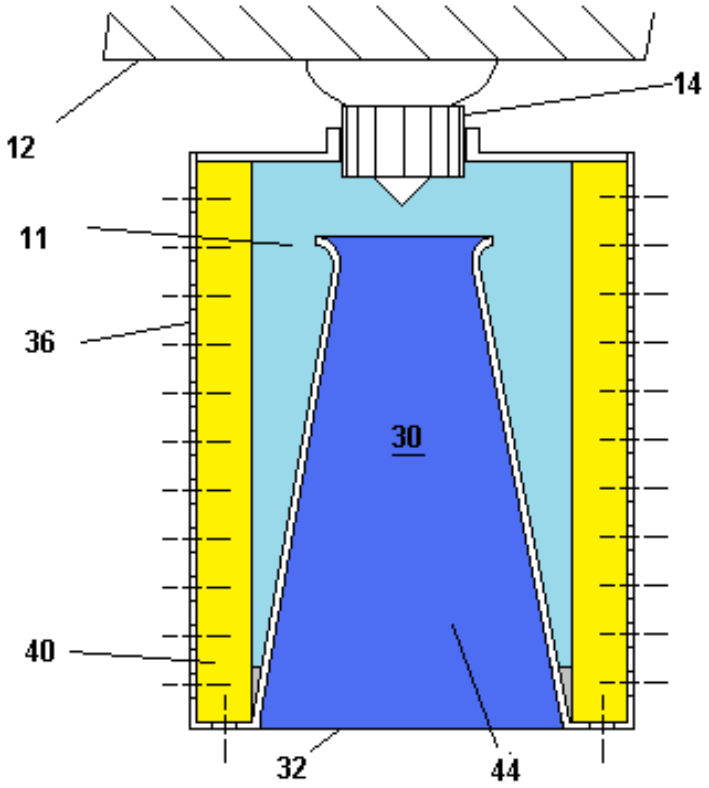
Role of local air circulation

• ECS air delivery circulation flows cause air to circulate between occupants in the same row and in nearby rows.

•This circulation, plus low humidity, may be the main factors in the higher than ‘normal’ URIs.

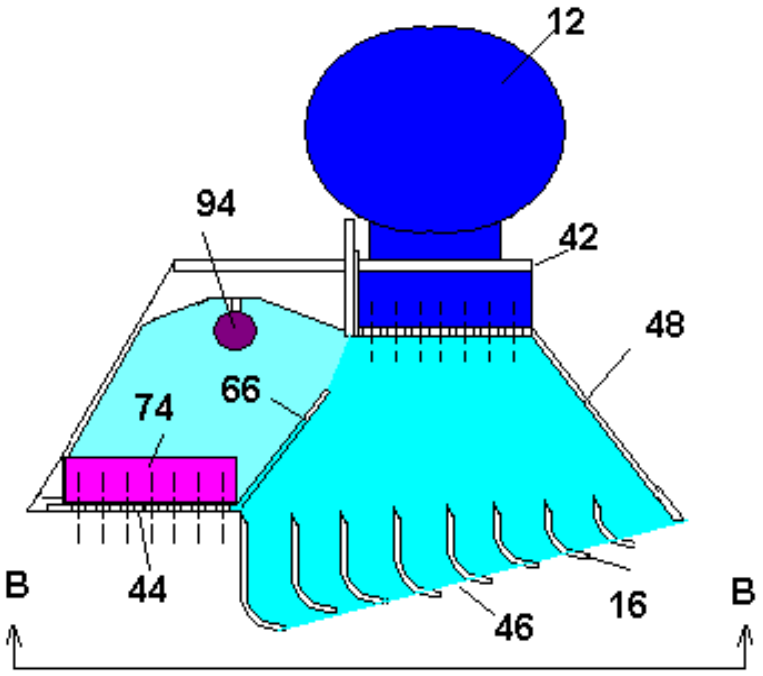
Using outlet air momentum to entrain air (Bernoulli effect) & filter it right at cabin air outlets

PATHOGEN removal with Gasper Entrainment Filtration



PEACE (personal environment airflow controller) diffusers use high velocity gasper air stream from the pressurized ECS supply system to entrain, filter and supply 2 or more times the air now being supplied by gaspers.

PATHOGEN removal with Slot Diffuser Entrainment Filtration



These devices run the length of the cabin. They also use high velocity diffuser air stream from the pressurized ECS supply system to entrain, filter and supply 5 or more times the air now being supplied to occupants.

Benefits of Diffuser Entrainment Filtration

- Dilution and elimination of occupant-generated pathogens.
- Dilution and elimination of bleed air aerosol toxins.
- Elimination of cold drafts.
- Improved air circulation and ventilation efficiency.
- Reduction in bleed air requirements for ventilation giving energy savings.

IAQ Challenges & Solutions

1. Respiratory system infections - entrainment filtration at outlets.
2. Low humidity - cabin humidifiers & envelope pressurization.
3. Bleed air and cabin air toxins
   - Separate supply air bearing compressor.
   - Bleed air filter.
   - Entrainment filtration at cabin air outlets.
   - Envelope filtration.
   - Ionization oxidation.
4. Fire safety - Envelope exhaust, smoke sensors and fire suppressant injection.

The End