# Medical Issues in Aviation

## Cabin Air Quality

Lima, Peru, April 2009

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CABIN AIR QUALITY

# Normal Operation

vs

# Incident

(Episodic contamination)


DISCOMFORT
≠
HEALTH RISK

## ***COMFORT***

- **Temperature**

  **Winter: 68 - 74.5º F Summer: 73 - 79º F**

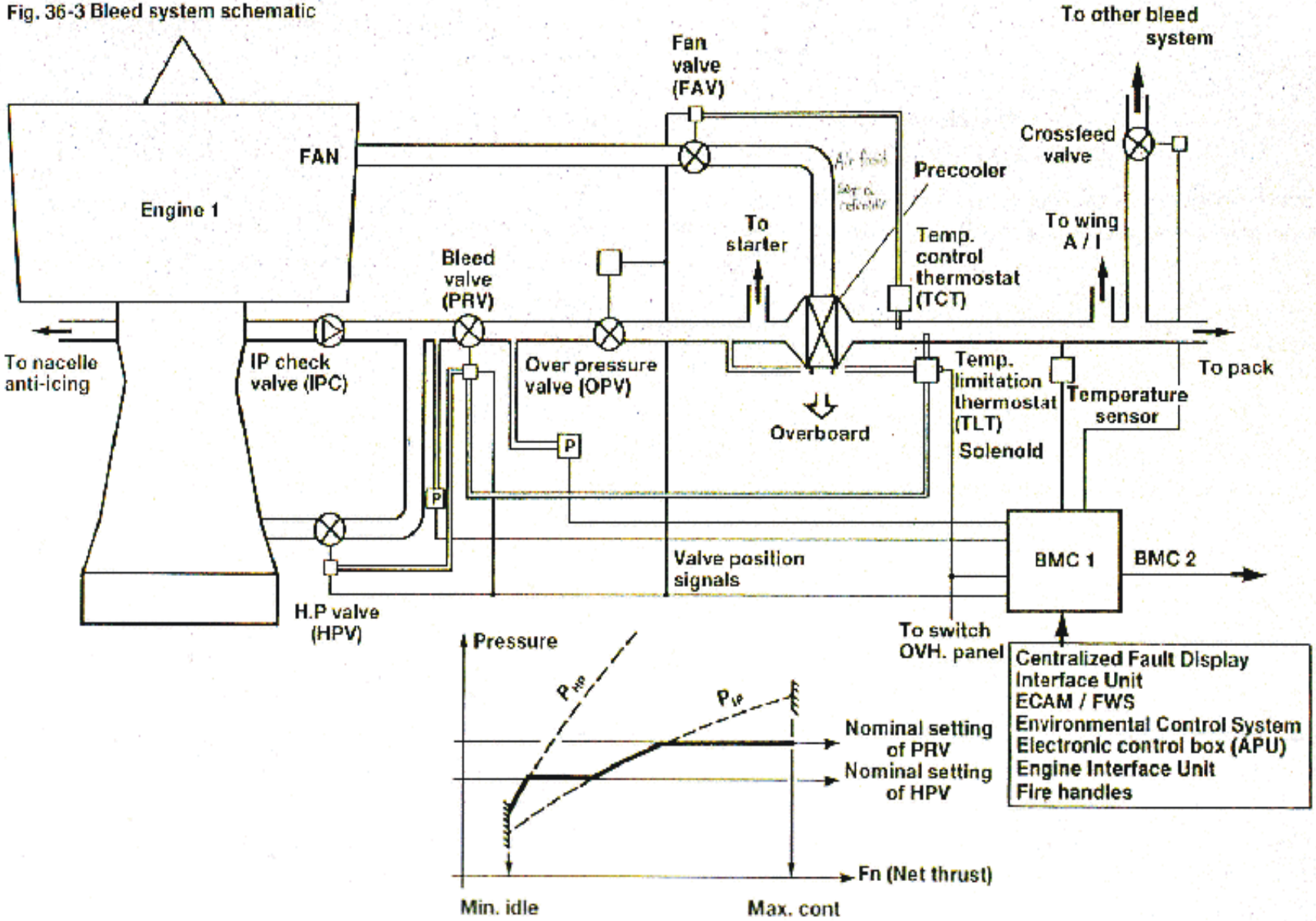
  **20 - 23º C 22 - 26º C**

- **Relative humidity 30 - 50 %**
- **No odor**
- **No draft**
- **No stale air**

## ***Cabin Air Quality***

- **Pressurization**
- **Ventilation**
  - **Recirculation**
  - **No recirculation**
- **Air Contaminants**
  - **Chemical**
  - **Biological**
- **Air Filtration**
- **Relative Humidity**
- **Temperature**

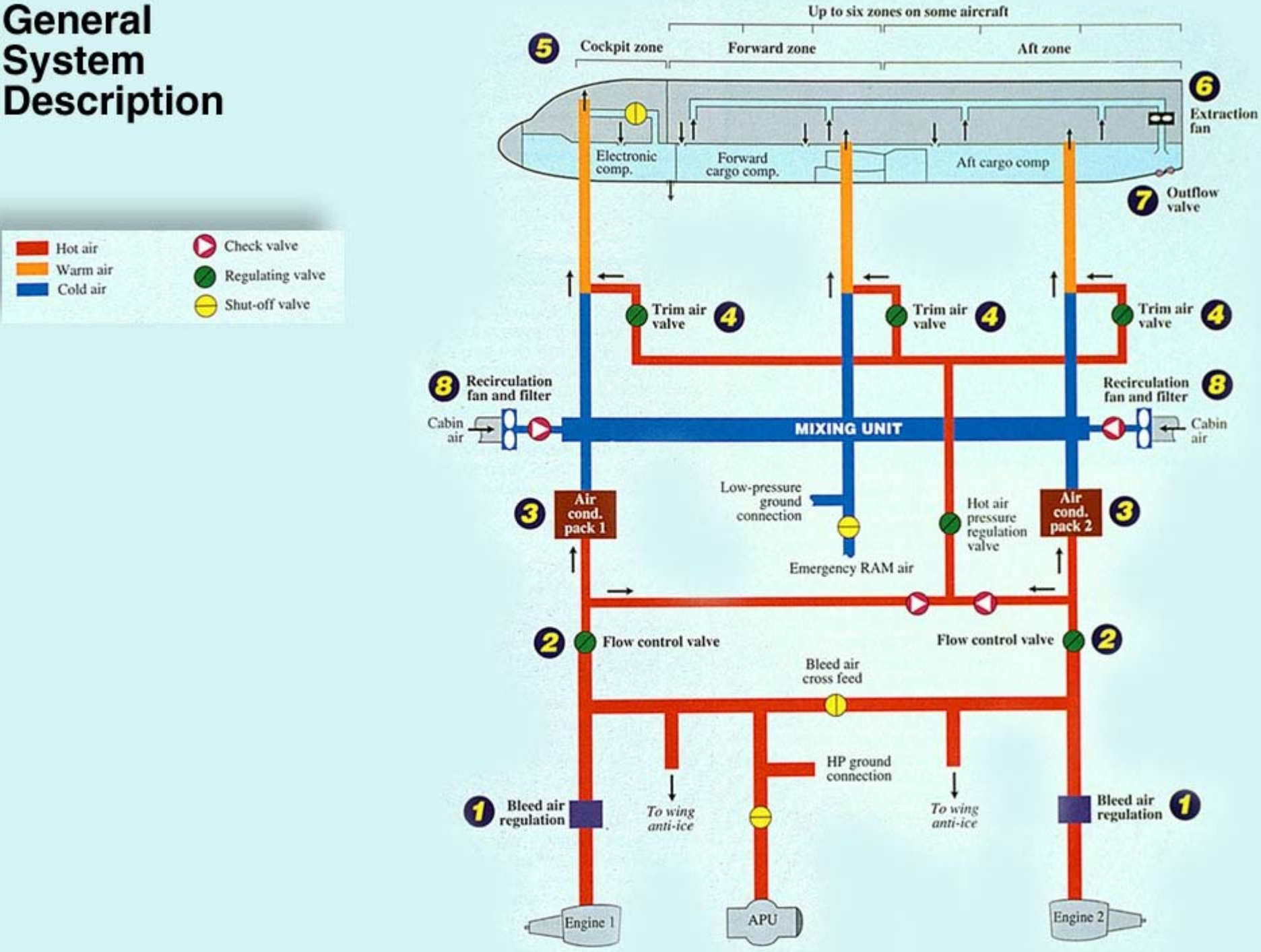
Fig. 36-3 Bleed system schematic

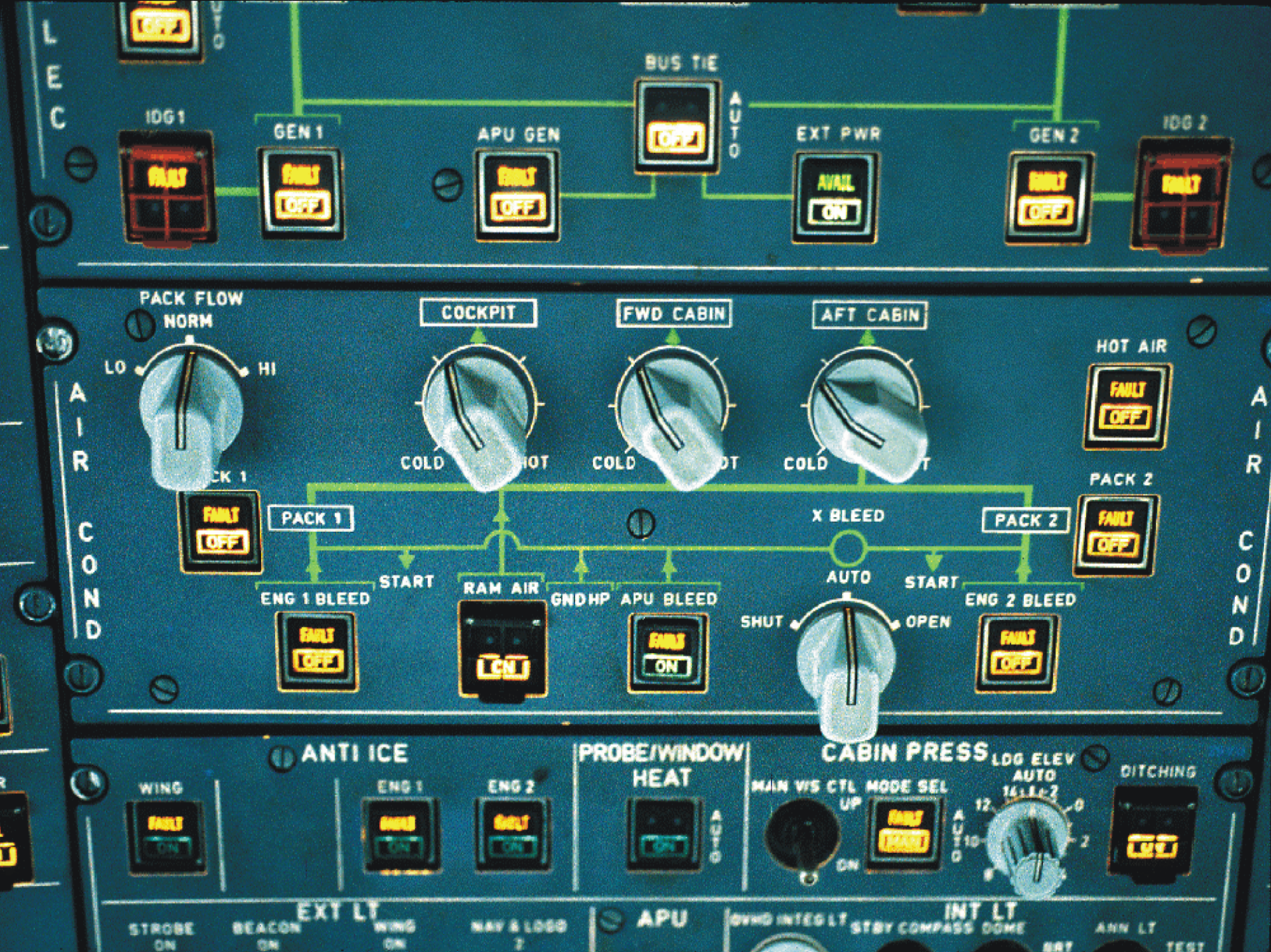



787
DREAMLINER
BOEING

# VENTILATION

# General System Description




L E C
IDG 1
FAULT
GEN 1
FAULT OFF
APU GEN
FAULT OFF
BUS TIE
OFF
AUTO
EXT PWR
AVAIL ON
GEN 2
FAULT OFF
IDG 2
FAULT
AIR COND
PACK FLOW
NORM
LO
HI
COCKPIT
COLD
HOT
FWD CABIN
COLD
HOT
AFT CABIN
COLD
HOT
HOT AIR
FAULT OFF
PACK 1
FAULT OFF
PACK 1
X BLEED
PACK 2
PACK 2
FAULT OFF
ENG 1 BLEED
START
FAULT OFF
RAM AIR
GND HP
APU BLEED
FAULT ON
AUTO
SHUT
OPEN
START
ENG 2 BLEED
FAULT OFF
ANTI ICE
WING
FAULT ON
ENG 1
FAULT ON
ENG 2
FAULT ON
PROBE/WINDOW HEAT
ON
AUTO
CABIN PRESS
MAIN VIS CTL MODE SEL
UP
ON
FAULT MAINT
AUTO
LDG ELEV
AUTO
DITCHING
EXT LT
STROBE ON
BEACON ON
WING ON
NAV & LOGO
APU
INT LT
OVHD INTEG LT
STBY COMPASS
DOME
ANN LT
TEST

# PROCEDURE (EXAMPLE)

## A-320

- 2 Air Conditioning Packs on at all times
- Flow control:

| | |
|---|---|
| Low | - Passengers < 85 |
| Normal | - Passengers > 85 |
| High | - Excessive ground temperature<br>- Request from F/A or passengers |


AIR
CONTAMINANTS

# Chemical Contaminants

## Carbon dioxide $CO_2$

| Study | Year | # Flights | Aircraft type | $CO_2$ range (ppm) | $CO_2$ avg (ppm) |
|---|---|---|---|---|---|
| Nagda, et al. | 1989 | 92 | 11 | 765 -3157 | 1756 |
| O'Donnell, et al. | 1991 | 45 | F-100 | 330 -2170 | 719 |
| CSS | 1994 | 35 | DC9, B727, MD80, B757 | 749 -1395 | 1162 |
| Consumers Union | 1994 | 158 | 44 | 464 -1552 | NR |
| AC/Airbus | 1994 | 4 | A-320 | 900 -2300 | 1314 |
| Spengler, et al. | 1997 | 6 | B777 | 1200 -1800 | 1400 |
| CSS | 1998 | 8 | B777 | 942 -1959 | 1509 |
| NIOSH | 1999 | 17 | 11 | 707 -2750 | NR |
| CABINAIR (economy cruise) | 2003 | 50 | 4 | 679 -1788 | 1136 |

# Chemical Contaminants

## ICE

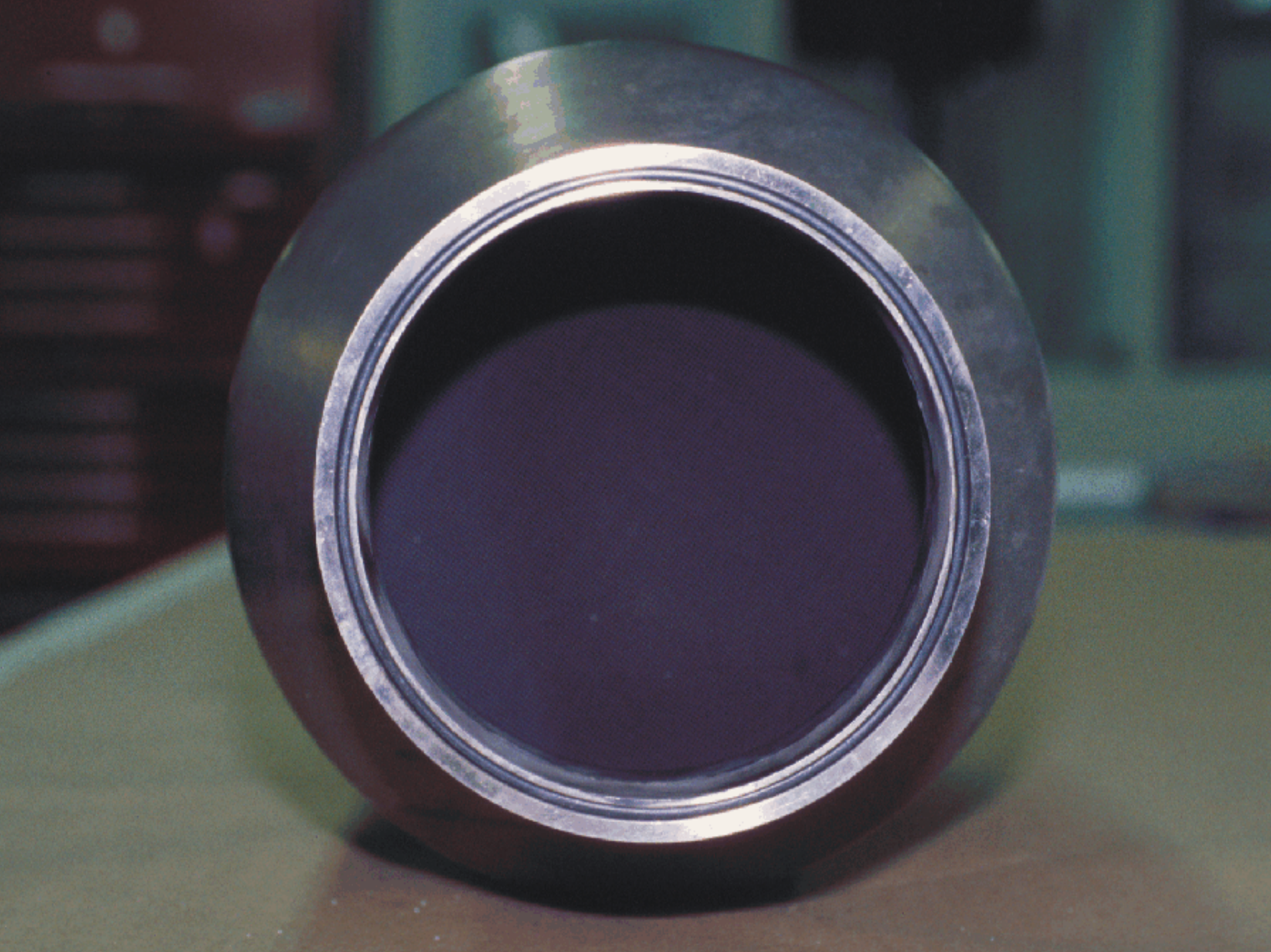
## Idea Cabin Environment

## Carbon monoxide CO

| Study | Year | # Flights | Aircraft type | CO range ppm | CO avg ppm |
|---|---|---|---|---|---|
| Nagda, et al | 1989 | 92 | 11 | ND -1.3 | 0.6 |
| O'Donnell, et al. | 1991 | 45 | F-100 | 1.0 - 40 | 1.6 |
| AC/Airbus | 1994 | 4 | A-320 | < 2 | _ |
| Spengler, et al. | 1997 | 6 | B777 | 0.8 -1.3 | 0.7 |
| CSS | 1998 | 8 | B777 | <0.1 - 7 | NR |
| NIOSH | 1999 | 17 | 11 | <1.0 – 2.41 | NR |
| CABINAIR | 2003 | 50 | 4 | < 10 | NR |

## Ozone $O_3$

| Study | Year | # Flights | Aircraft type | $O_3$ range ppb | $O_3$ avg ppb |
|---|---|---|---|---|---|
| Nagda, et al | 1989 | 92 | 11 | NR - 78 | 22 |
| AC/Airbus | 1994 | 4 | A-320 | < 50 | - |
| Spengler, et al. | 1997 | 6 | B777 | 2 – 10 | NR |
| CSS | 1998 | 8 | B777 | < 20 -122 | 50 |
| De Ree, et al. | 1998 | 19 | B747- 400 | NR – 158.6 | 39 |
| De Ree, et al. | 1998 | 12 | B747 - 400 | NR – 383.5 | 177.4 |
| NIOSH | 1999 | 17 | 11 | < 100 - 200 | NR |
| CABINAIR | 2003 | 50 | 4 | < 20 | _ |



# Chemical Contaminants

- Volatile organic compounds (VOC)
- Semi-Volatile Organic compounds (SVOC)

## Formaldahyde $CH_2O$

| Study | Year | # Flights | Aircraft type | range ppm | avg ppm |
|---|---|---|---|---|---|
| O'Donnell, et al. | 1991 | 45 | F-100 | 0.01 – 0.07 | 0.02 |
| Dechow | 1996 | NR | A310, A340 | 0.003 – 0.026 | 0.007 |
| CSS | 1998 | 8 | B777 | < 0.001 – 0.005 | 0.003 |
| NIOSH | 1999 | 17 | 11 | ND | _ |
| CABINAIR | 2003 | 50 | 4 | < 0.004 | _ |

# Volatile organic hydrocarbons (NIOSH)

## quantitative (ppb)

| | |
|---|---|
| toluene | <3-130 |
| limonene | <3-12 |
| ethanol (ppm) | <0.8-2.4 |
| heptane | nd |
| hexane | <0.004 |
| ethyl acetate | <0.02 |
| formaldehyde | <0.07 |
| acetaldehyde | nd |
| acrolein | <0.2 |
| hexanal | nd |
| heptanal | nd |
| butyraldehye | nd |
| proprionaldehyde | nd |
| valeraldehyde | nd |

## semi-quantitative (mg/m3)

| | |
|---|---|
| PGMEA | tr - 0.007 |
| siloxane | <0.04 - 0.18 |
| tributyl phosphate | <0.003 - 0.5 |
| perchloroethylene | <0.002 - 0.05 |
| butyl cellosolve | <0.004 - 0.2 |
| methyl pyrollidine | < 0.004 |
| benzene | <0.003 - 0.02 |
| 1-methoxy-2-propanol | <0.005 |
| | |
| | |
| | |
| | |
| | |
| | |

# Chemical Contaminants

## Other VOCs

- Acetone

- Tricresyl phosphate (TCP)

# Chemical Contaminants

## Cranfield Study

# Cabin Air Quality

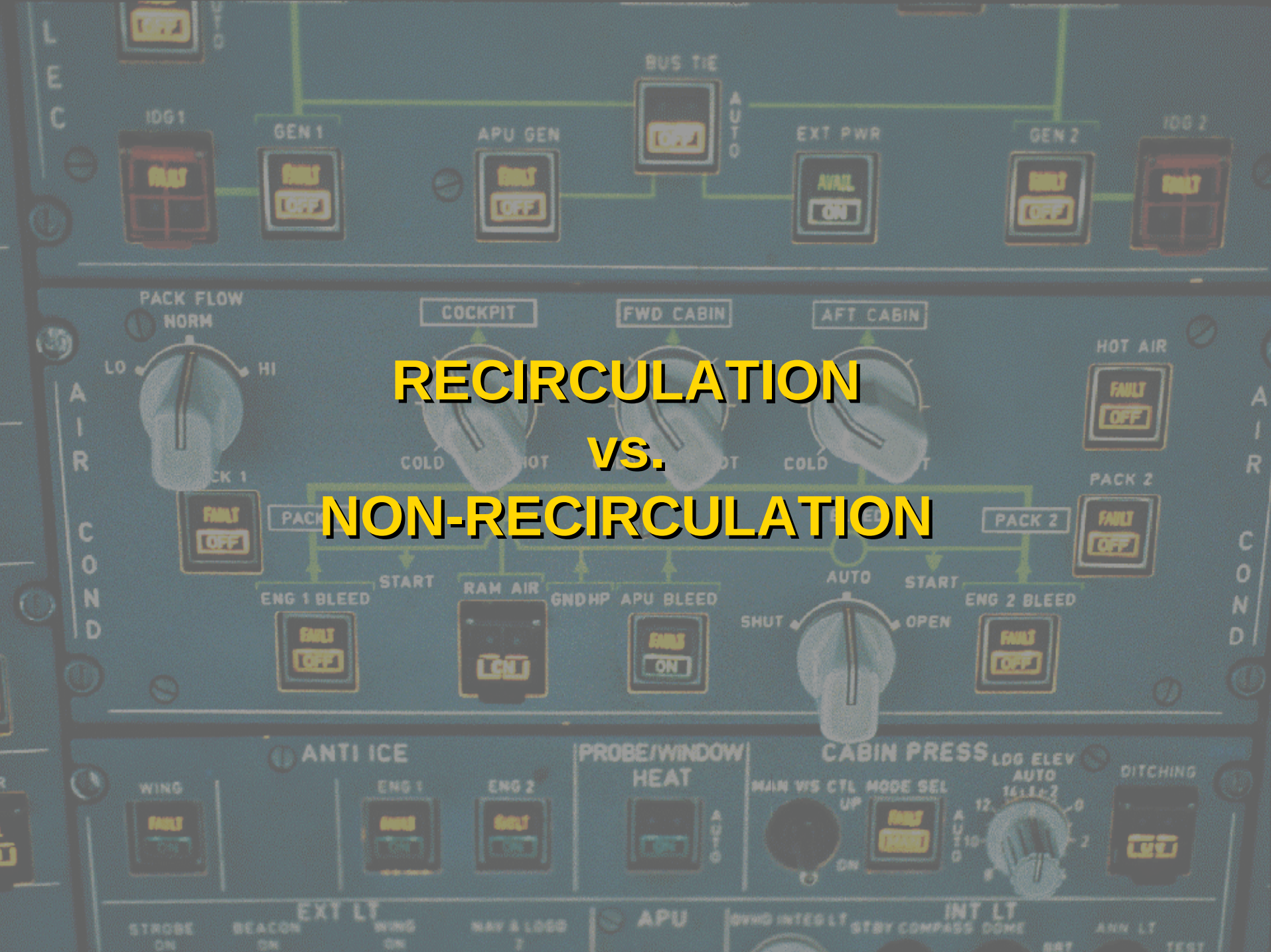
**ASHRAE** (American Society of Heating, Refrigerating and Air Conditioning Engineers)

Recommendations:

- Temperature 65-75°F (18.3-23.9°C)
- Cabin ventilation
  - outside air supply 7.5 CFM/person (minimum)
  - total air supply 15 CFM/person (minimum)
- Recirculated air requires HEPA filter 99.97% efficiency at 0.3 micron

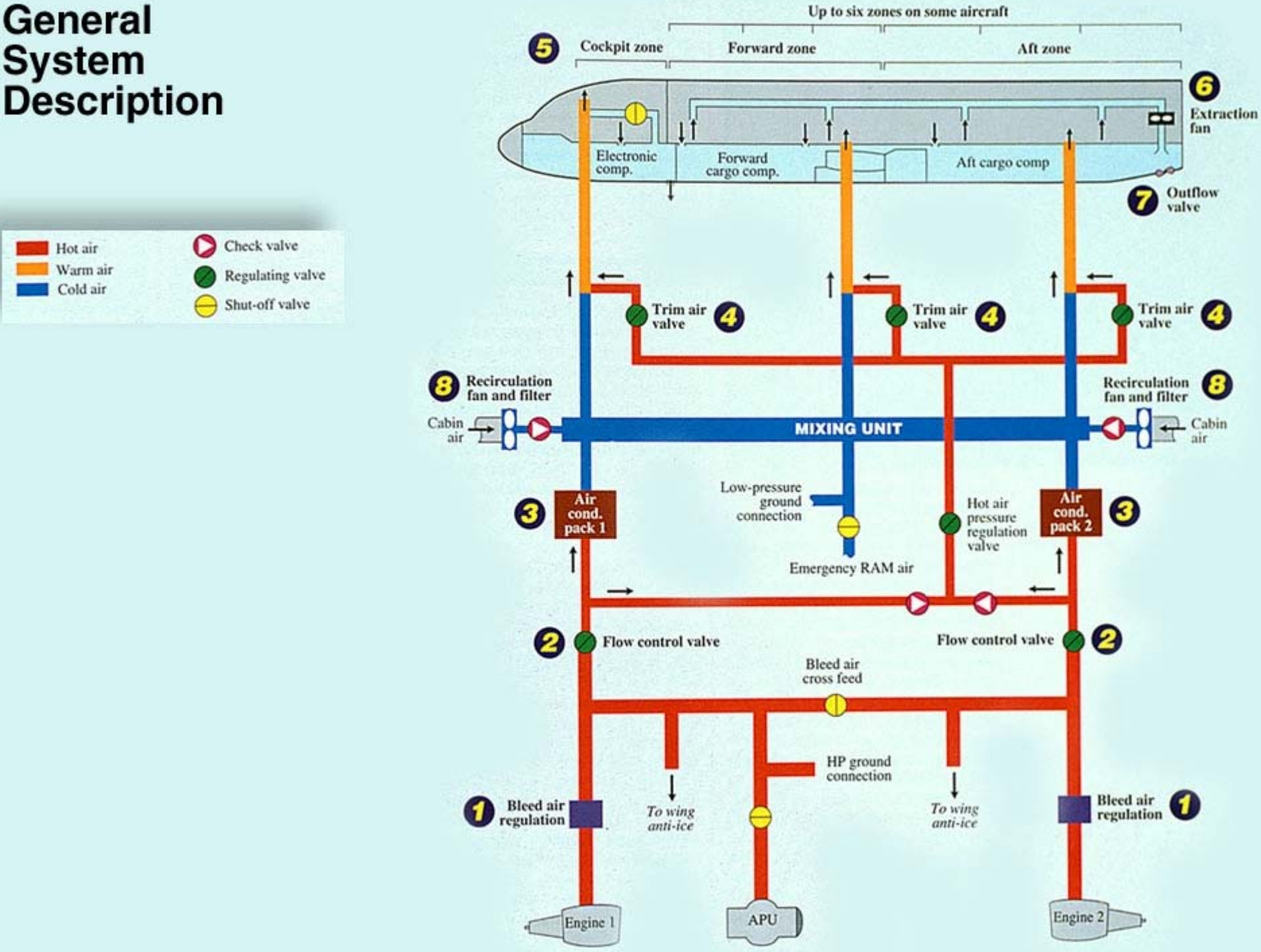

22248
U.S. AIR FORCE

# Biological Contaminants

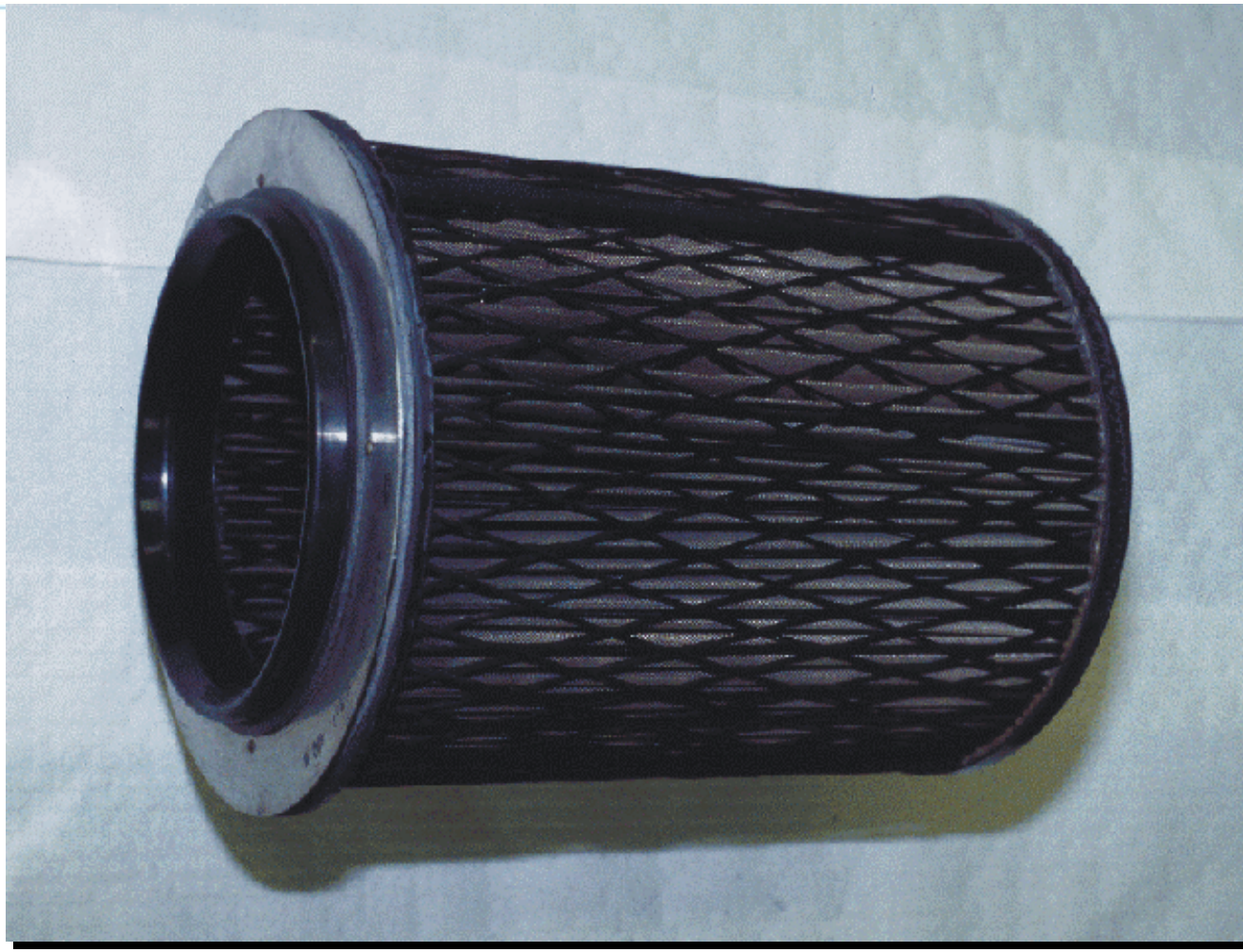


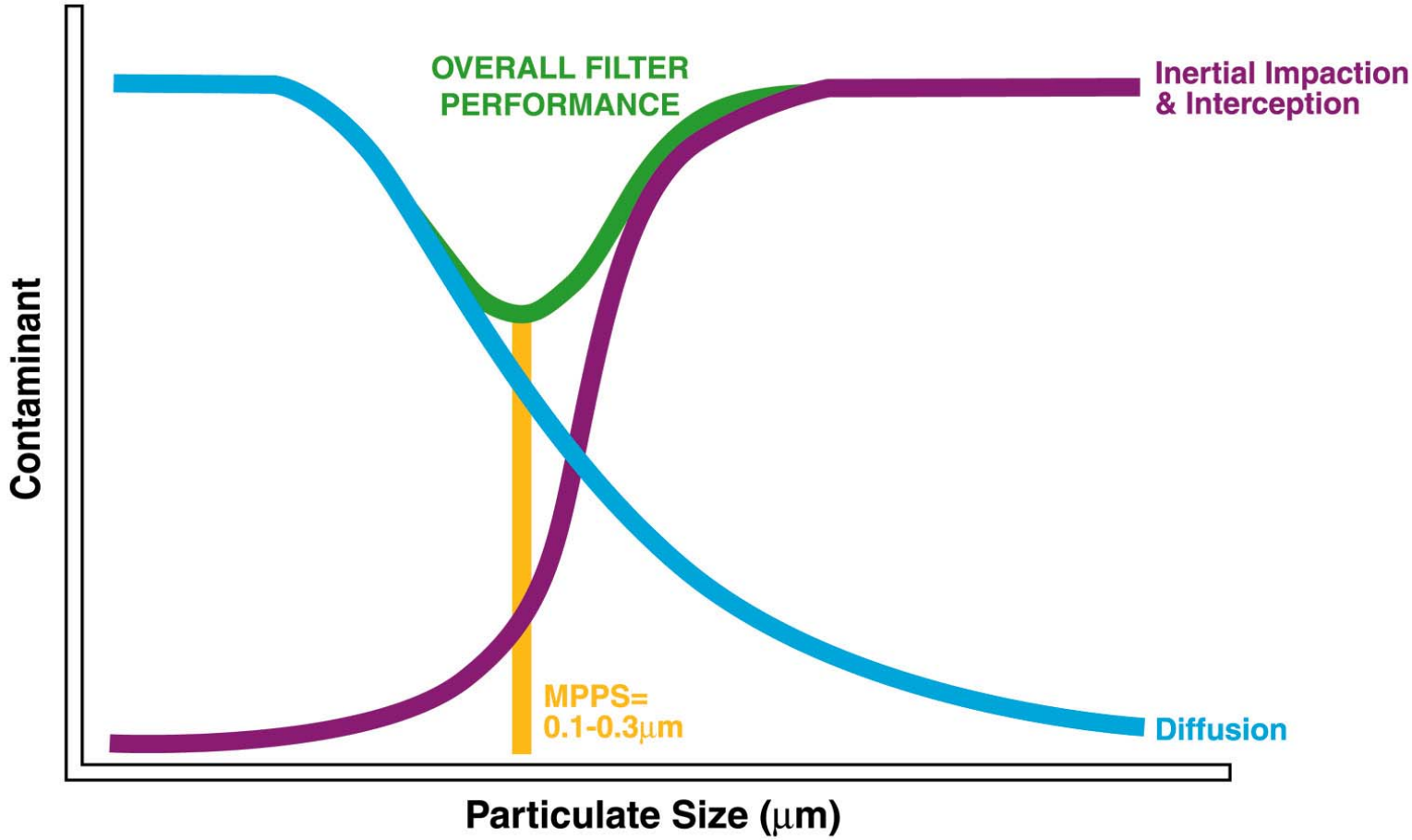

# RECIRCULATION
# vs.
# NON-RECIRCULATION

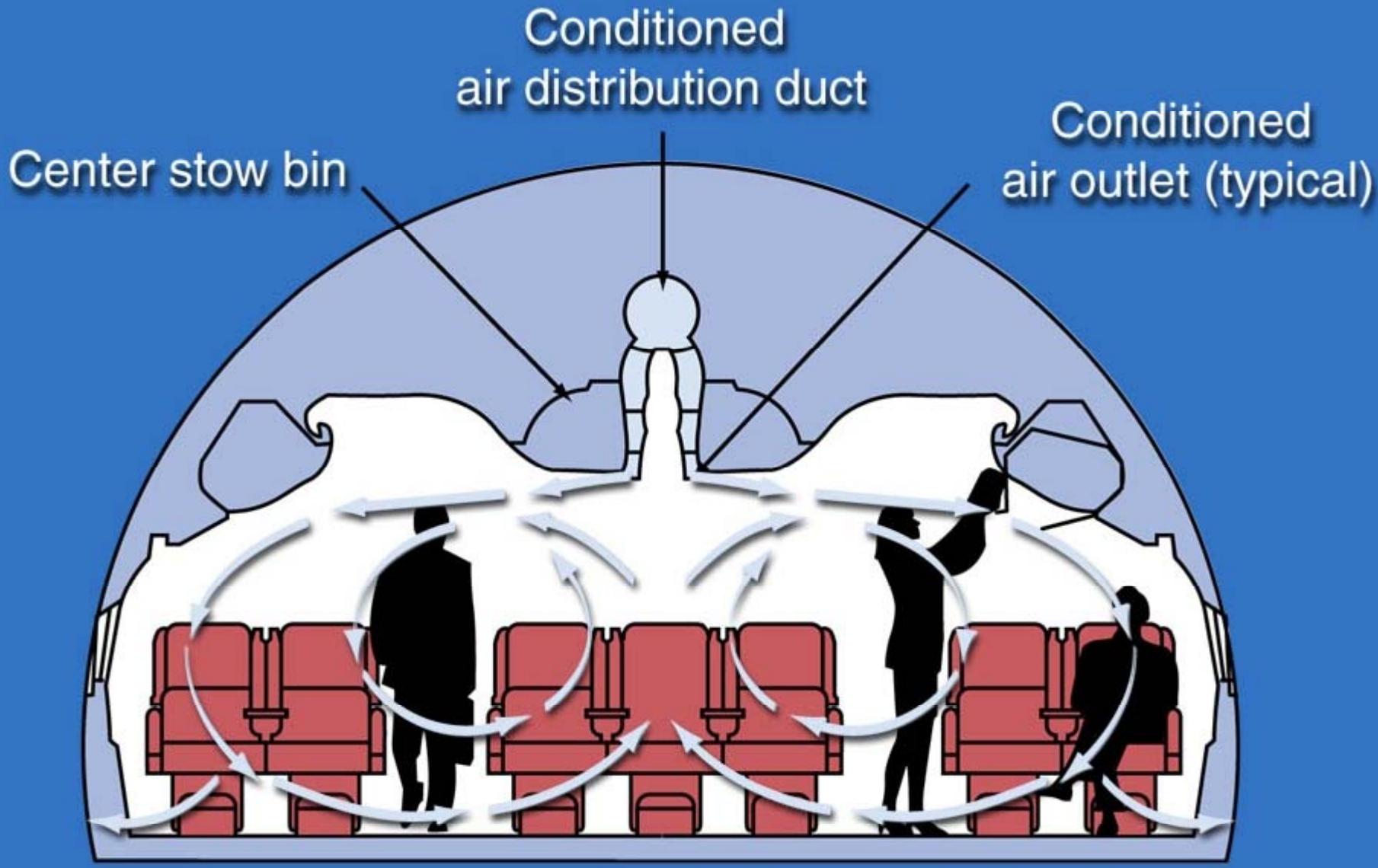
# General System Description



# Air Filtration
# HEPA




OVERALL FILTER PERFORMANCE
Inertial Impaction & Interception
Diffusion
MPPS= 0.1-0.3μm
Contaminant
Particulate Size (μm)


Conditioned
air distribution duct
Center stow bin
Conditioned
air outlet (typical)

## Microbiological

| Study | Year | # Flights | Aircraft type | Bacteria CFU/m$^3$ Range | Bacteria CFU/m$^3$ Avg | Fungi CFU/m$^3$ Range | Fungi CFU/m$^3$ Avg |
|---|---|---|---|---|---|---|---|
| Nagda, et al | 1989 | 92 | 11 | NR – 642 | 131 | NR – 61 | 9 |
| CSS | 1994 | 35 | DC9, B727, MD80,B757 | 0 – 360 | NR | 0 – 110 | NR |
| Wick & Irwin | 1995 | 45 | 7 | 56 -1763 | NR | 0 – 450 | NR |
| DeChow | 1996 | NR | A310,A340 | 20 -1700 | NR | _ | _ |
| Spengler, et al. | 1997 | 6 | B777 | 0 – 681 | 201 | _ | _ |
| CSS | 1998 | 8 | B777 | 39 – 244 | NR | <1 – 37 | NR |
| CABINAIR | 2003 | 50 | 4 | 200 – 400 | NR | 10 - 100 | NR |

# Microbiological

## Wick et Irwin (1995)

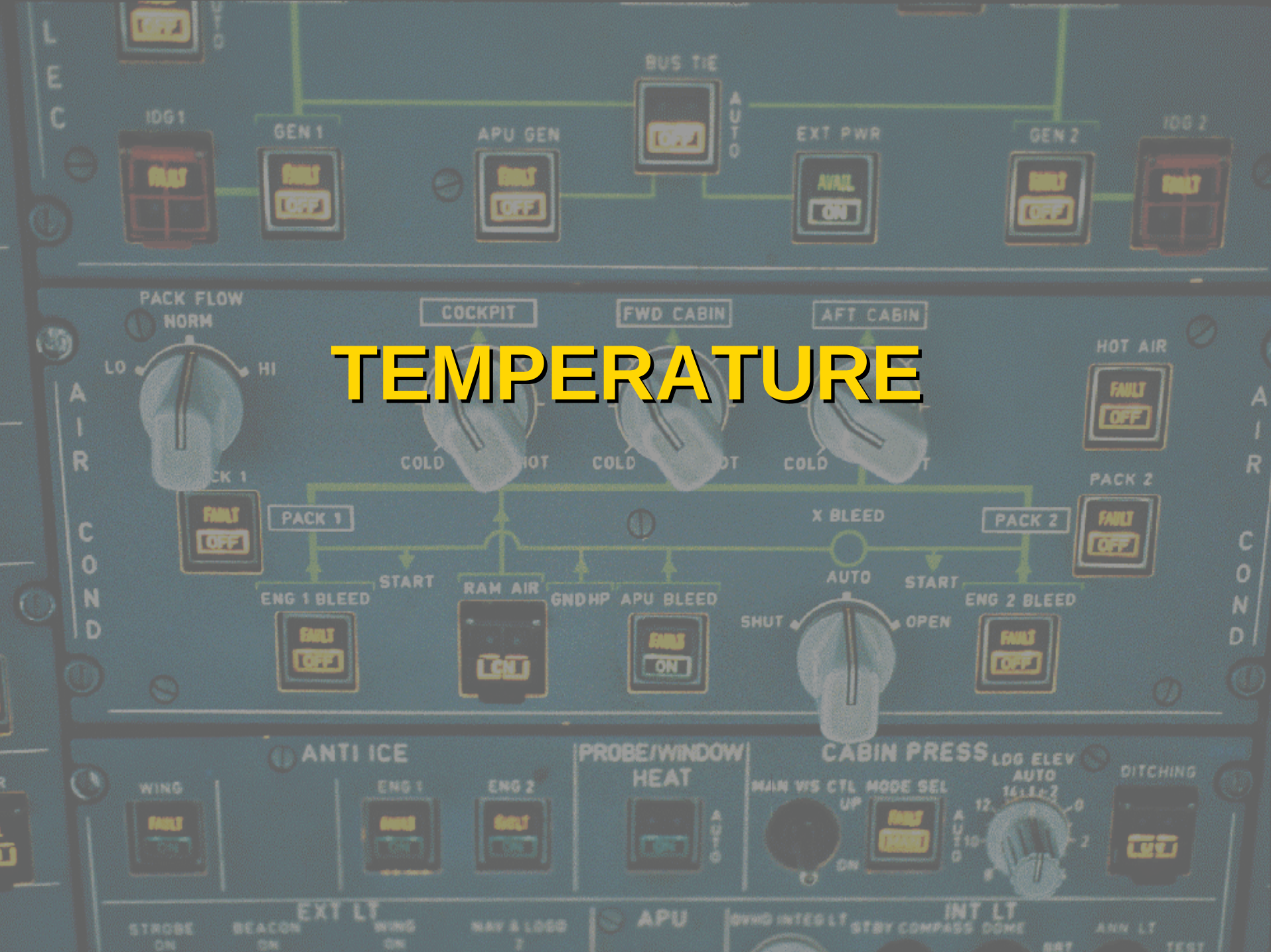
CFU (bacteria & fungi) in aircraft **<**

- Buses
- Shopping centers
- Street corners

## Spengler et al. (1997) (J. Hopkins)

CFU (bacteria & fungi) in aircraft **<**

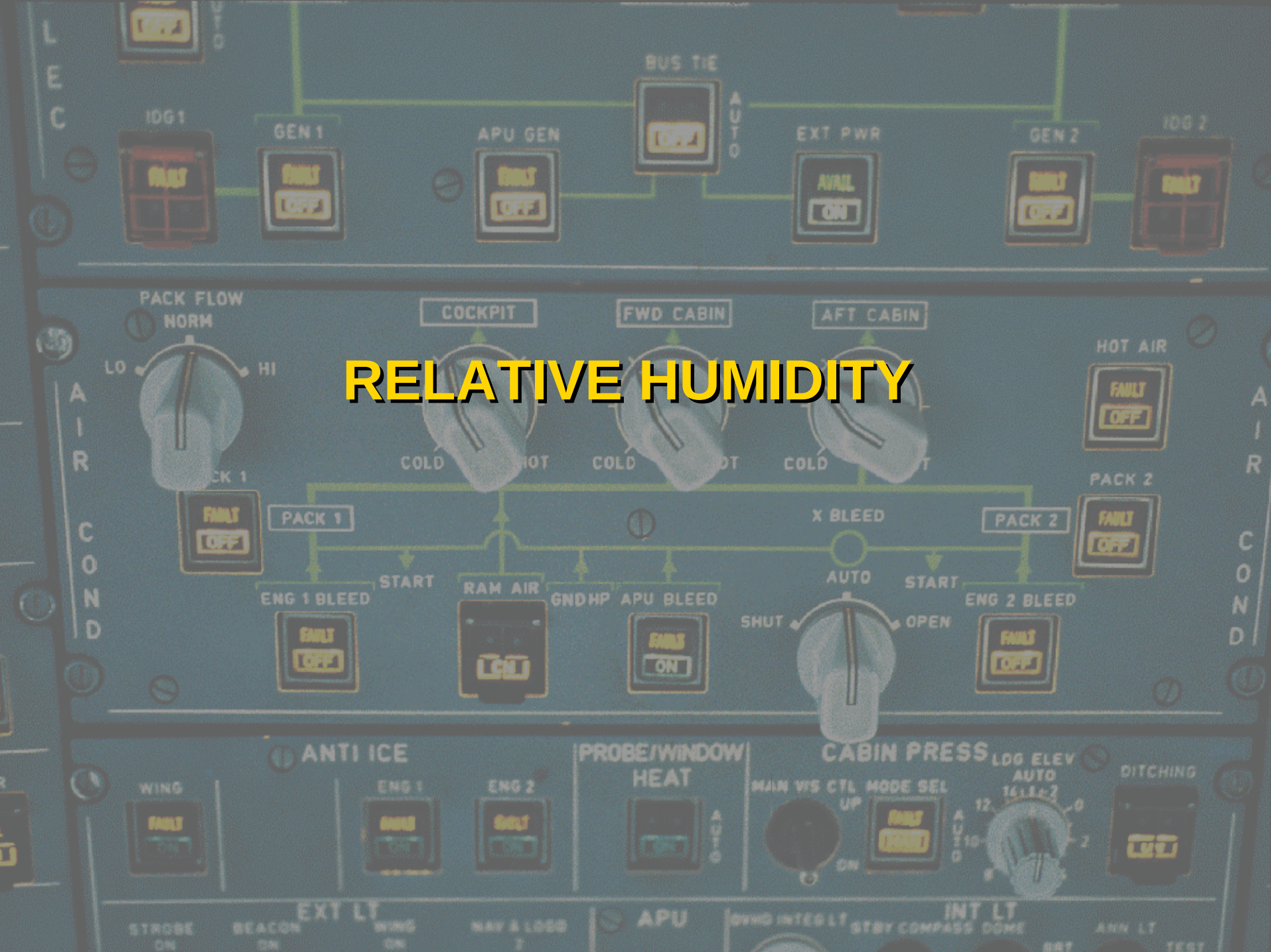
- Buses
- Trains
- Subways




# TEMPERATURE

# Temperature

| Study | Year | # Flights | Aircraft type | T° range ( C ) | T° avg ( C ) |
|---|---|---|---|---|---|
| Nagda, et al. | 1989 | 92 | 11 | 21.0 – 27.3 | 24.2 |
| O'Donnell, et al. | 1991 | 45 | F-100 | 13.2 – 35.1 | 23.4 |
| CSS | 1994 | 35 | DC9, B727, MD80, B757 | NR | 24.4 |
| Spengler, et al. | 1997 | 6 | B777 | 22.2 – 25.6 | 23.8 |
| CSS | 1998 | 8 | B777 | 17.8 – 26.1 | 23.0 |
| CABINAIR | 2003 | 50 | 4 | 22.3 – 27.5 | 23.6 |


RELATIVE HUMIDITY
BUS TIE
IDG 1
GEN 1
APU GEN
EXT PWR
GEN 2
IDG 2
PACK FLOW
NORM
LO
HI
COCKPIT
FWD CABIN
AFT CABIN
HOT AIR
PACK 1
X BLEED
PACK 2
ENG 1 BLEED
START
RAM AIR
GND HP
APU BLEED
AUTO
START
ENG 2 BLEED
SHUT
OPEN
ANTI ICE
WING
ENG 1
ENG 2
PROBE/WINDOW HEAT
CABIN PRESS
MAIN VIS CTL
MODE SEL
LDG ELEV
AUTO
DITCHING
EXT LT
APU
INT LT

# Relative Humidity

| Study | Year | # Flights | Aircraft type | RH range (%) | RH avg (%) |
|---|---|---|---|---|---|
| Nagda, et al. | 1989 | 92 | 11 | 4.7 – 38.1 | 17.0 |
| O'Donnell, et al. | 1991 | 45 | F-100 | 4.6 – 48.5 | 18.5 |
| CSS | 1994 | 35 | DC9, B727, MD80, B757 | _ | 16.8 |
| Spengler, et al. | 1997 | 6 | B777 | 17.0 – 19.0 | 18.0 |
| CSS | 1998 | 8 | B777 | 8.8 – 27.8 | 14.7 |
| CABINAIR | 2003 | 50 | 4 | < 30% for 97% of time | < 10% on long haul |

# Summary of results

- Low relative humidity
- Temperature variations
- High air velocity in some areas of some cabins

# Other Factors Related to Air Travel

- Stress of travel
- Crowded airport
- Fear of flying
- Turbulence
- Noise
- Inactivity
- Mild hypoxia
- Jet lag

# What it means for aircraft occupants

- As stated by several bodies which looked extensively into CAQ: **Air travel presents no significant risk to the health of the vast majority of occupants**
- There is evidence that thermal comfort is sometimes deficient
- The future resides in innovative technology and concepts of operation that foster win-win solutions i.e. better comfort and better operation efficiency

Thank you for your attention

to represent, lead and serve the airline industry