Different Air Distribution Principles in an Aircraft Cabin

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Different Air Distribution Principles in an Aircraft Cabin

• Introduction
  • Mixing ventilation
  • Displacement ventilation
  • Vertical Ventilation
  • Personalized ventilation
Earlier Experience with Air Distribution Systems in e.g. offices

A number of different air distribution systems have been tested in the same room with the same heat load. In this way it is possible to compare the performance of the different systems.

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Design Chart for the Air Distribution System

- Sufficient air supply
- CO$_2$ concentration
- Draught
  - Draught ratio (DR)
- Vertical temperature gradient
  - Percentage of dissatisfied due to temperature gradient ($PD_{grad}$)
  - Percentage of dissatisfied due to asymmetric radiation ($P_{Rad}$)

\[
\Delta T_0
\]

Draft or
temperature
gradient

Air quality

Draft
This experience with different systems will be tested in an aircraft cabin.
Airborne Cross Infection

- **Mixing ventilation** $\varepsilon = 1.0$
- **Displacement ventilation**
  - $\varepsilon$ larger and smaller than 1.0
- **Vertical ventilation**
  - $\varepsilon$ larger than 1.0

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The Aircraft Cabin

Four seats from a Boeing 737 cabin equipped with seated thermal manikins
Conditions

Heat load: Four persons corresponding to 400 W. It is assumed that 200 W is removed by radiation/conduction, and 200 W by the air distribution system.

Flow rate: 3.5 l/s per person. 50% recirculation, giving a flow rate of 28 l/s. \((n = 22.4 \text{ h}^{-1})\)

Supply slot: In full length. \(h_o = 4\text{ mm}\)
Turbulence Level in the Cabin

Fully developed turbulent flow

Fully developed flow is important for the use of the flow element theory in the following design procedure.
Maximum Velocity in the Occupied Zone of the Cabin
Design Chart for Mixing Ventilation

Supply slot in full length. $h_o = 9.46$ mm

Penetration length equal to half cabin width (aisle area)

$u_{rm} = 32$ cm/s
200 W

$u_{rm} = 27$ cm/s
0 W

$DR = 50\%$
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**Flow rate:** 3.5 l/s per person. 50% recirculation, giving a flow rate of 28 l/s. \( n = 22.4 \text{ h}^{-1} \)

**Supply opening:** \( a_o = 0.24 \text{ m}^2 \)
Vertical Temperature Gradient

\[ \frac{dT}{dy} = 3.5 \text{ K/m} \]
Design Chart for Displacement Ventilation

\[ DR = (13 + 9 = 22 \%) \]

- \( u_{rm} = 12 \text{ cm/s} \)
- \( dT/dy = 3.5 \text{ K/m} \)
- \( u_{rm} = 15 \text{ cm/s} \)
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**Supply opening:** \(a_o = 0.7 \text{ m}^2\)
Vertical Temperature Gradient

\[ \frac{dT}{dy} = 2.6 \text{ K/m} \]
Maximum Velocity in the Occupied Zone of the Cabin

![Graph showing the maximum velocity (v (m/s)) in the occupied zone of the cabin as a function of the vertical position (y (mm)).]
Design Chart for Vertical Ventilation

$200 \text{ W}$

$DR = 34 + 4 = 38\%$

$u_m = 23 \text{ cm/s}$
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Low Velocity PV System

The personalized ventilation system (PV) utilizes the situations where the head or the body is in natural contact with surfaces as: *chairs, beds, pillows, clothing, headrests, blankets, mattresses, walls, etc.*

The surfaces are designed to be *supply openings of fresh air*, for example by the use of fabric as a diffuser.
Effectiveness

The effectiveness of personalized ventilation

If the concentration in the inhalation is $c_{PV}$

$\varepsilon_{PV} = 1.0$

If the concentration in the inhalation is $c_p$

$\varepsilon_{PV} = 0.0$
Air Supplied Direct to the Boundary Layer

Five different paths into the boundary layer.
Neck Support Pillows

The neck support

Air volume flow [l/s]

Effectiveness

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

NS 3

NS 1

1

2
Seat as Diffuser

Supply areas are white
Draught from the Right-Hand Side

\[ q_{PV} = 10 \, \text{l/s} \]
\[ u = 10 \, \text{cm/s} \]
Chair with Diffuse Surface

Results with flow from behind, $q_{PV} = 8 \text{ l/s}$

$u = 0.05 \text{ m/s}$

$u = 0.20 \text{ m/s}$
Personalized Ventilation Combined with Mixing Ventilation

Thank you!

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