# Different Air Distribution Principles in an Aircraft Cabin
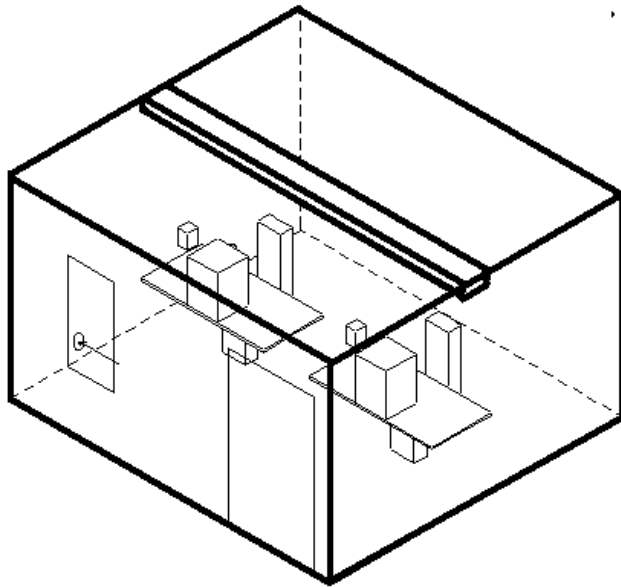
Peter V. Nielsen
Aalborg University

pvn@civil.aau.dk

1

# Different Air Distribution Principles in an Aircraft Cabin

- **Introduction**

- Mixing ventilation

- Displacement ventilation

- Vertical Ventilation

- Personalized ventilation

# Ealier 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

# 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 (*PDgrad*)

• Percentage of dissatisfied due to asymmetric radiation (*PDrad*)
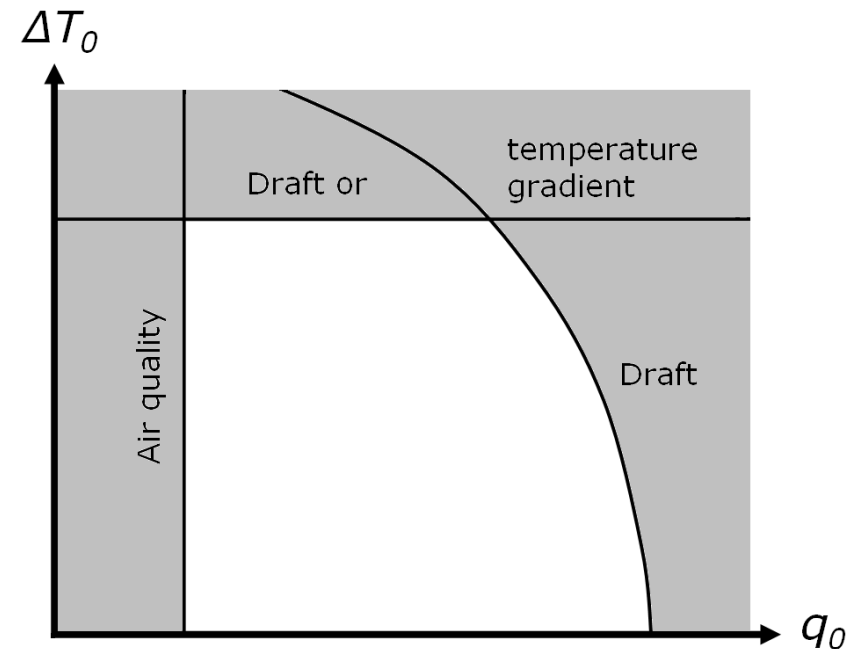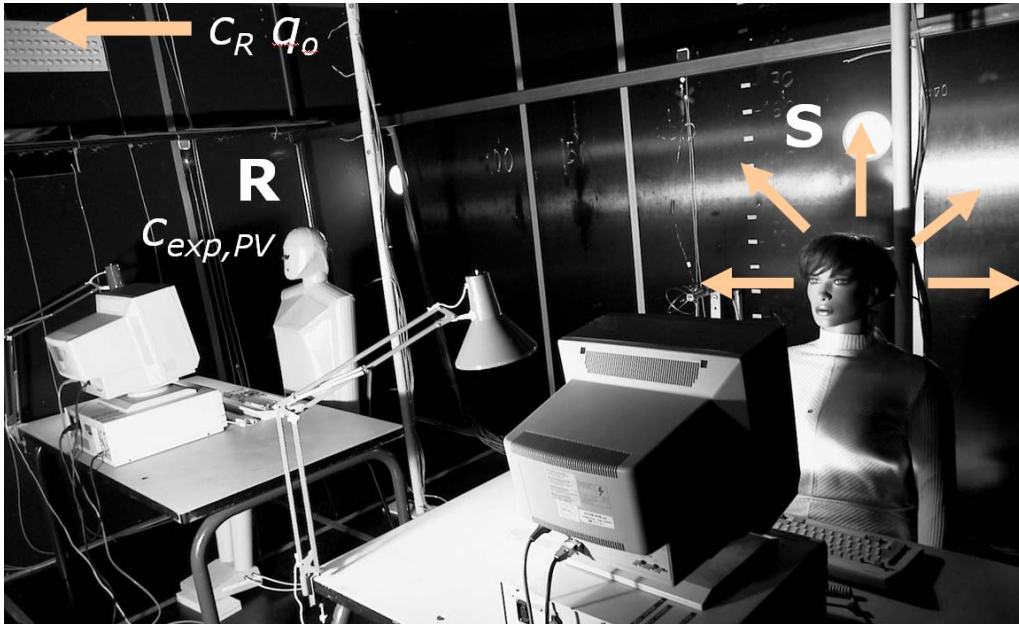
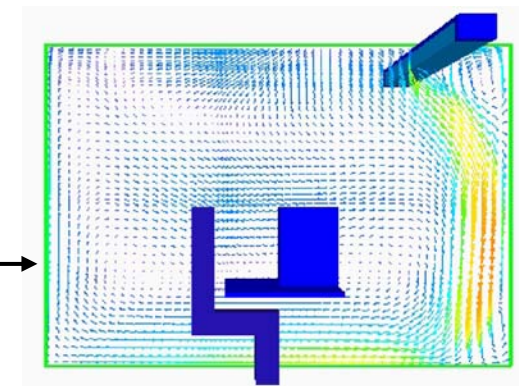# Design Chart for an Office Room
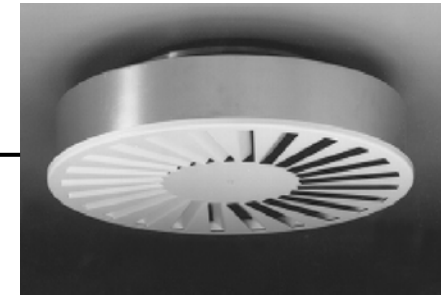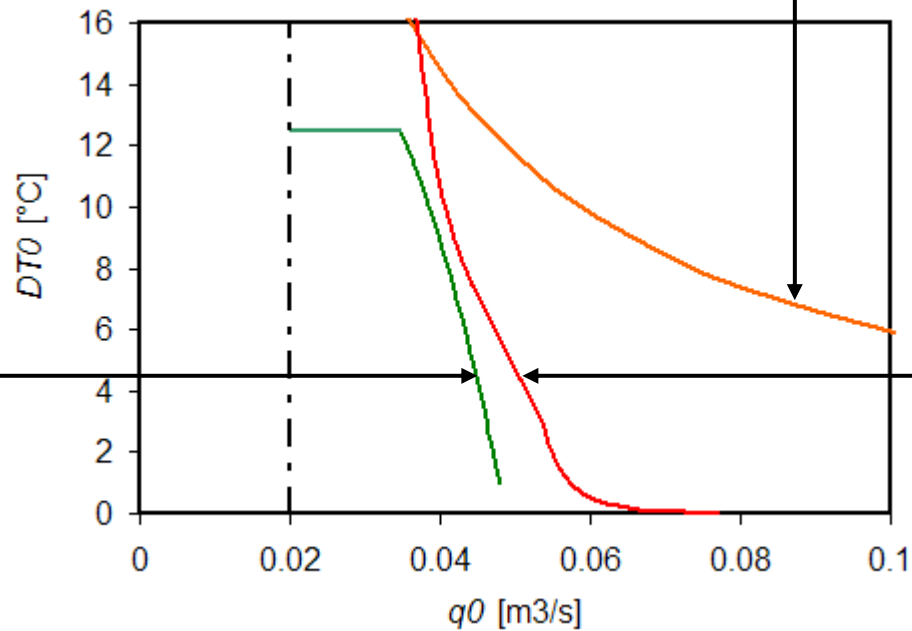


This experience with different systems **will be tested in an aircraft cabin**

# Airborne Cross Infection



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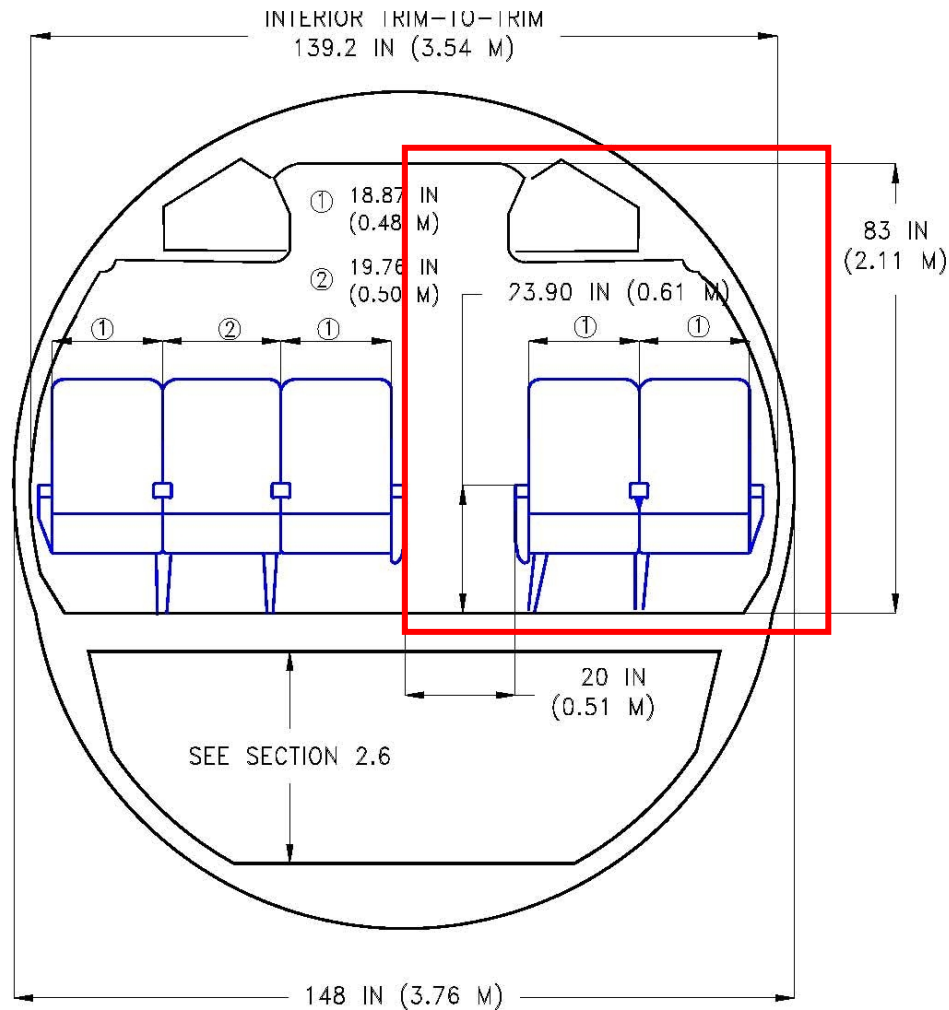
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- Introduction

- **Mixing ventilation**

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# The Aircraft Cabin



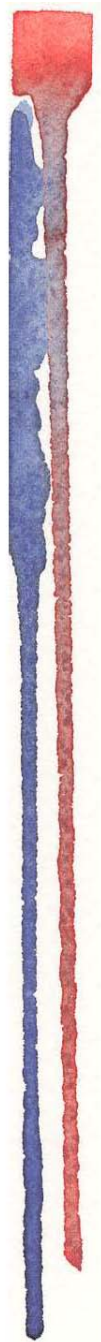Four seats from a Boeing 737 cabin equipped with seated thermal manikins

# 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.
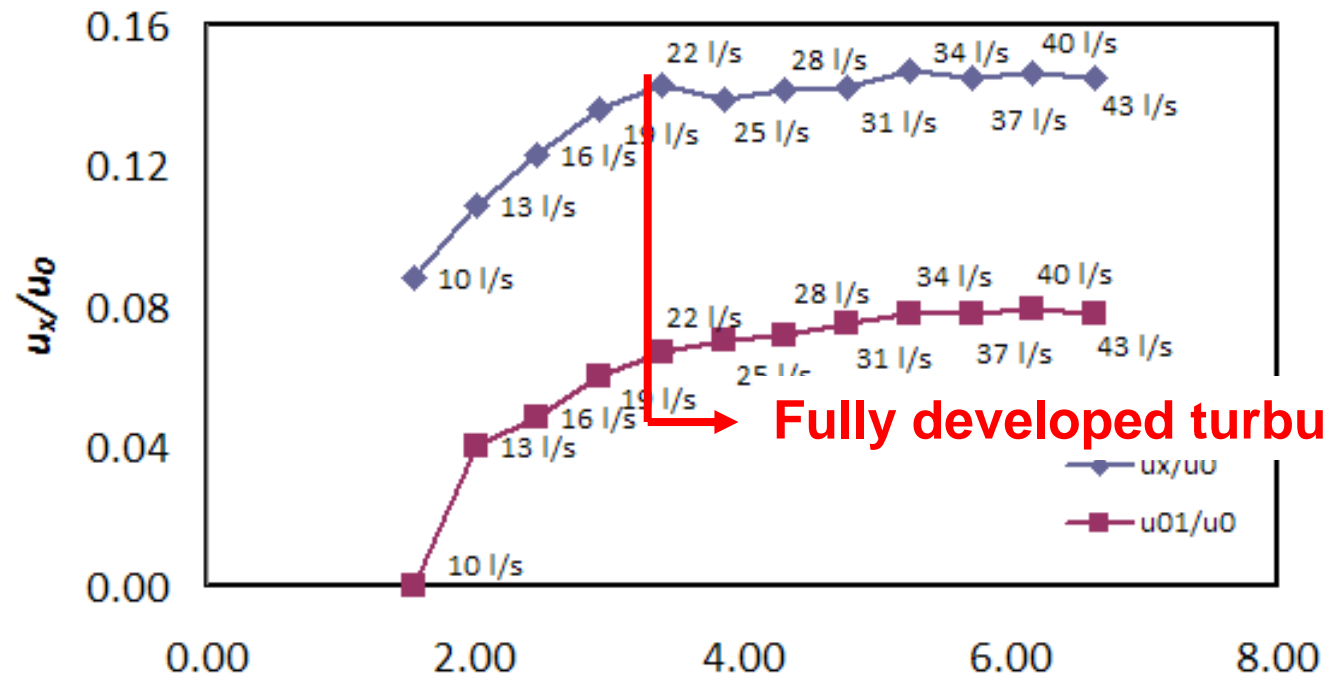
**Flow rate:** 3.5 l/s per person. 50% recirculation, giving a flow rate of 28 l/s. ($n = 22.4$ h$^{-1}$)
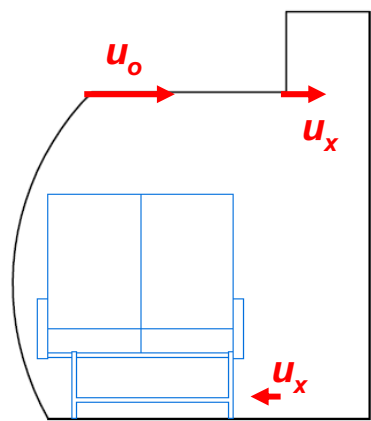
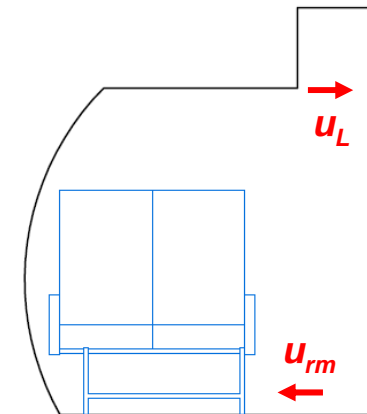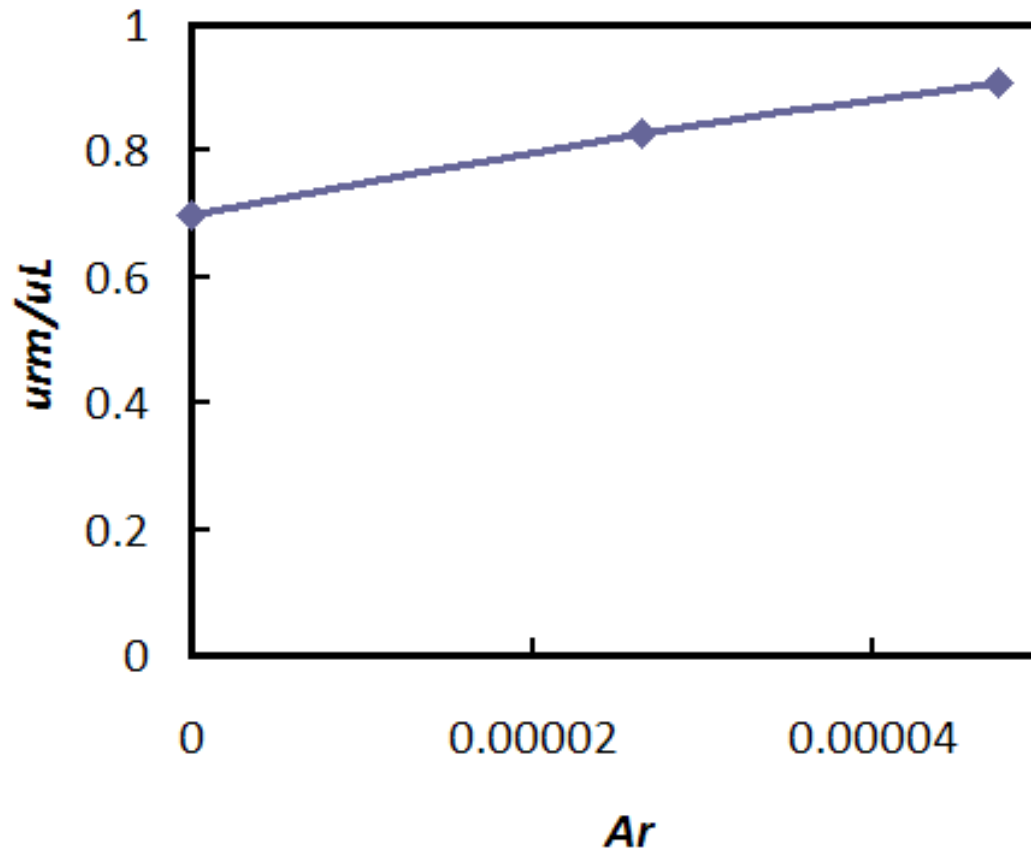**Supply slot:** In full length. $h_o = 4$ mm

# Turbulence Level in the Cabin
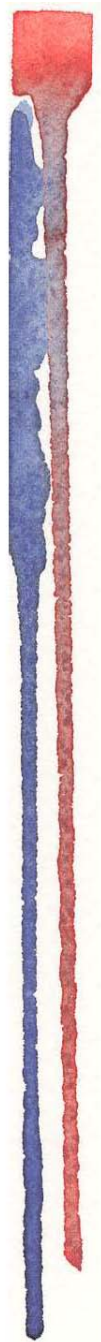


Fully developed flow is important
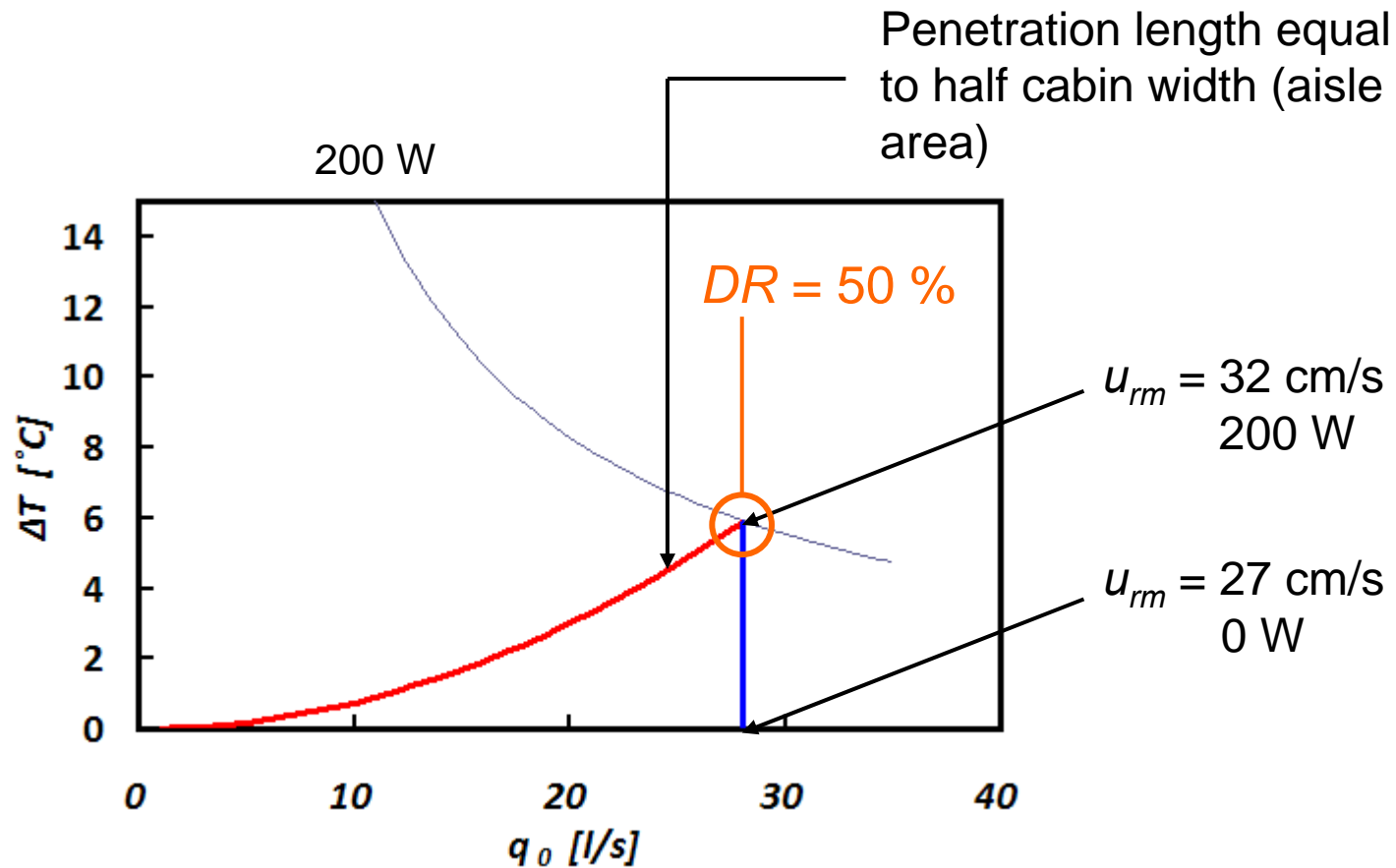for the use of the flow element theory
in the following design procedure.

# 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)

200 W

*DR* = 50 %

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

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

(graph: vertical axis $\Delta T$ [°C] from 0 to 14; horizontal axis $q_0$ [l/s] from 0 to 40)

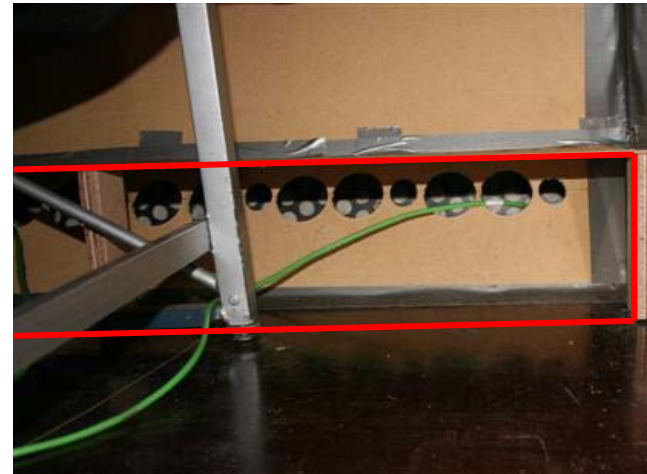# Different Air Distribution Principles in an Aircraft Cabin

- Introduction

- Mixing ventilation

- **Displacement ventilation**

- Vertical Ventilation

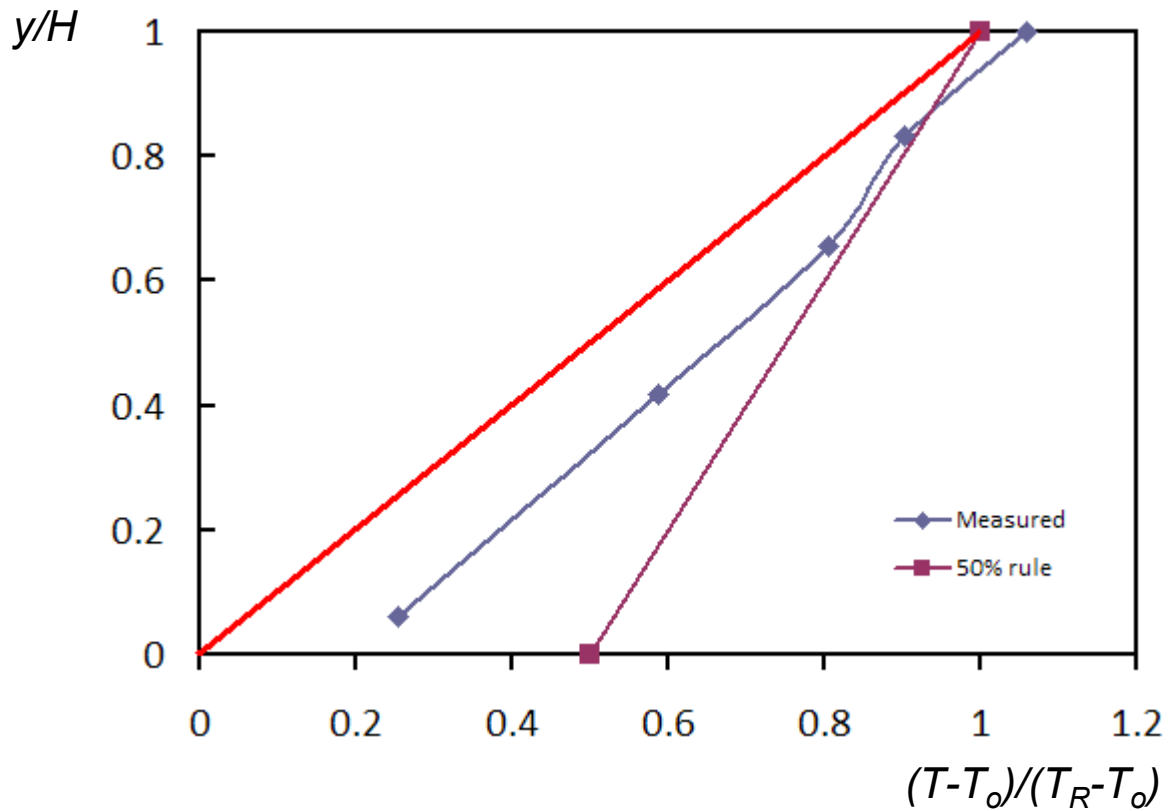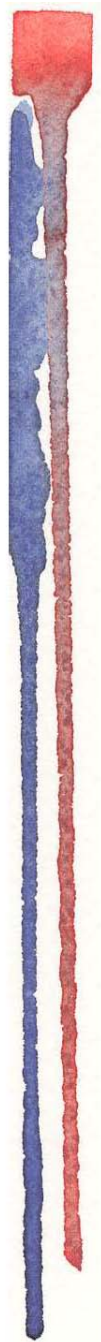- Personalized ventilation

# 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.

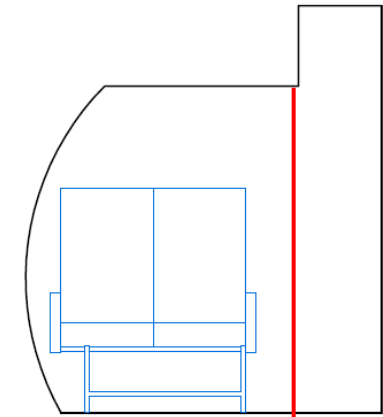**Flow rate:** 3.5 l/s per person. 50% recirculation, giving a flow rate of 28 l/s. ($n$ = 22.4 h$^{-1}$)

**Supply opening:** $a_o$ = 0.24 m$^2$

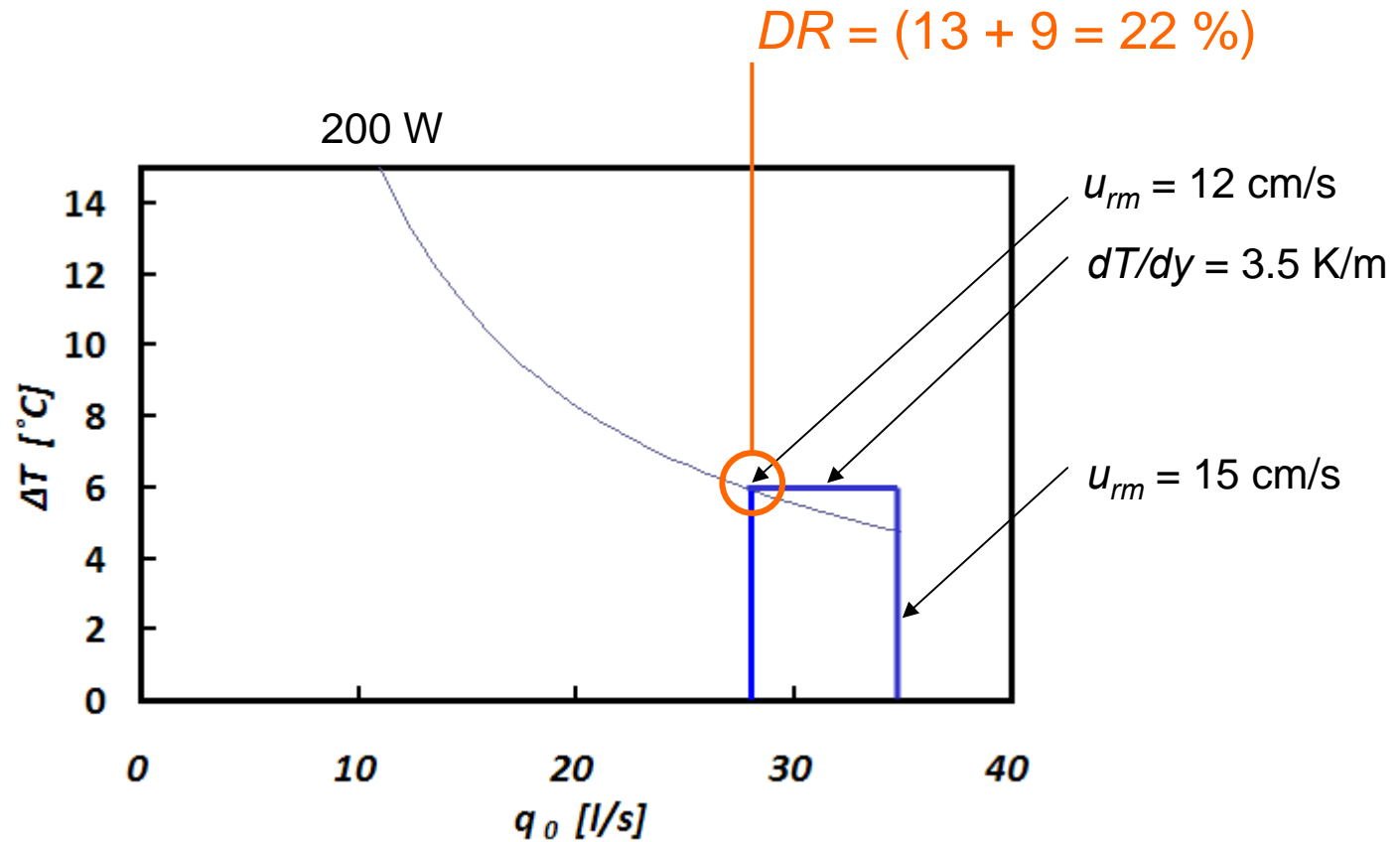# Vertical Temperature Gradient



$dT/dy = 3.5$ K/m

# Design Chart for Displacement Ventilation



DR = (13 + 9 = 22 %)

200 W

$u_{rm}$ = 12 cm/s

$dT/dy$ = 3.5 K/m

$u_{rm}$ = 15 cm/s

Axes: $\Delta T \ [°C]$ (vertical), $q_0 \ [l/s]$ (horizontal)

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- Personalized ventilation

# 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.

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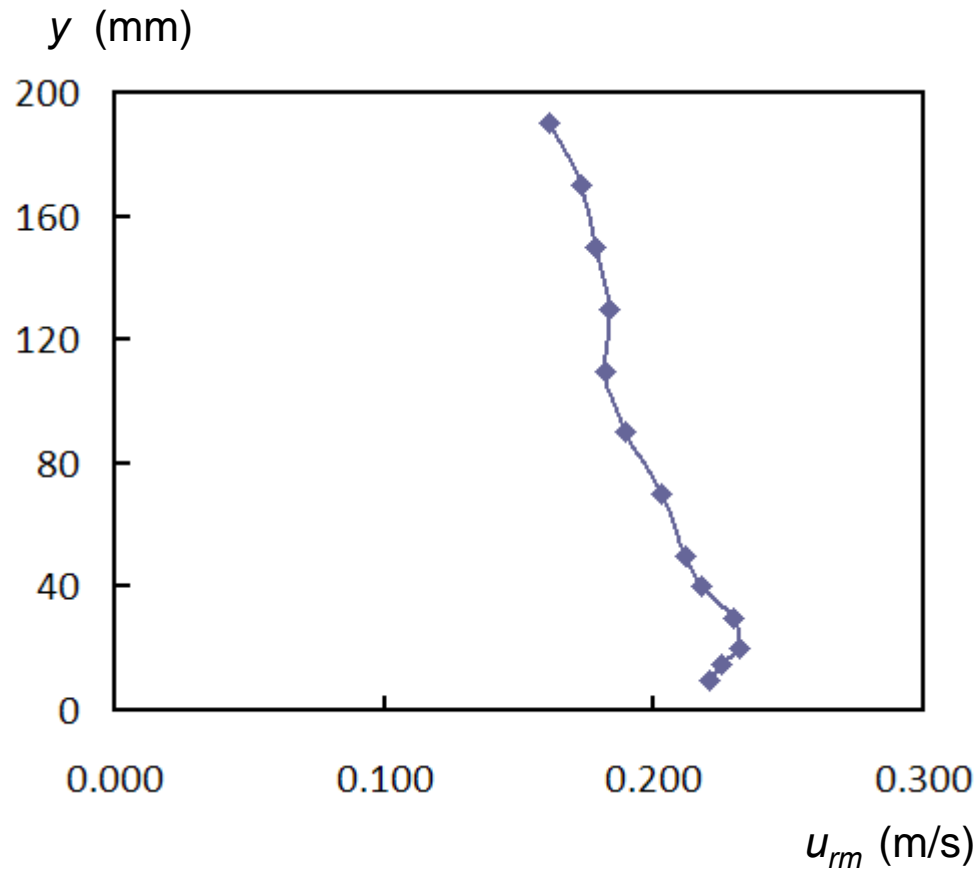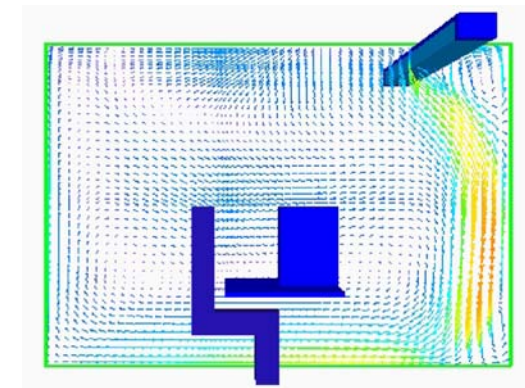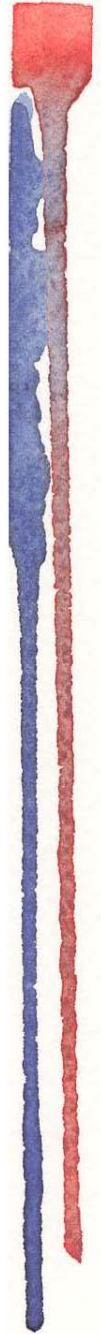
**Supply opening:** $a_o$ = 0.7 m$^2$

# Vertical Temperature Gradient



y/H

dT/dy = 2.6 K/m

$(T-T_o)/(T_R-T_o)$
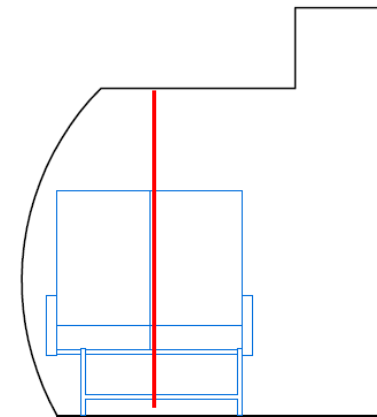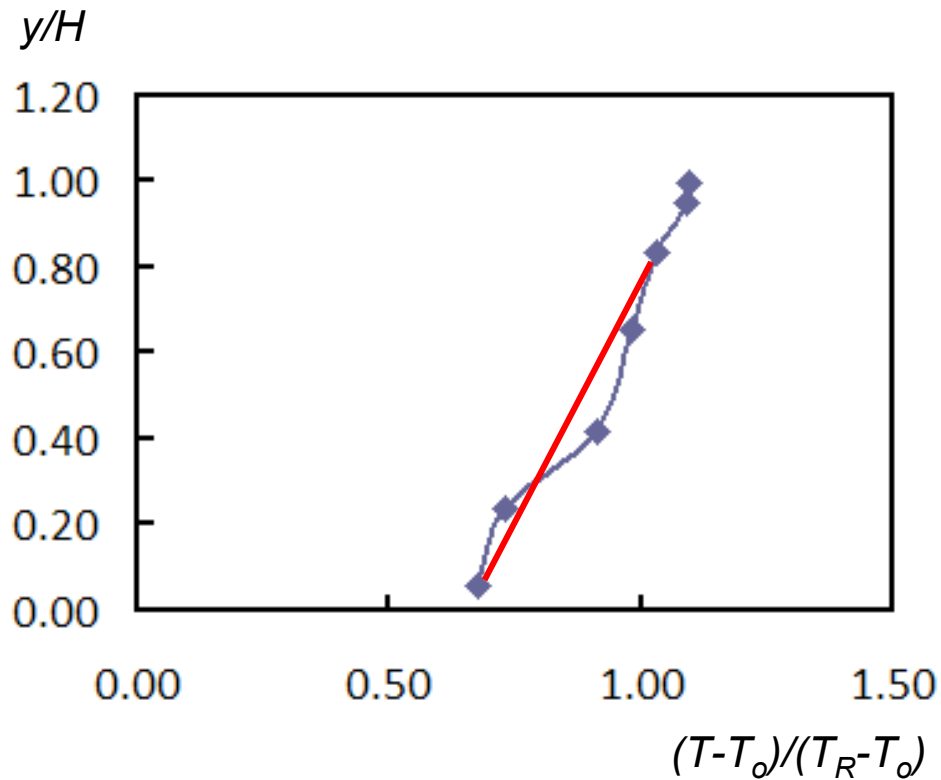
# Maximum Velocity in the Occupied Zone of the Cabin
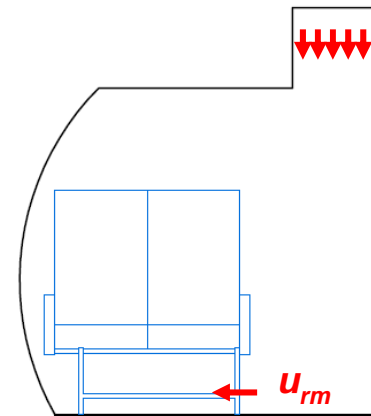
# Design Chart for Vertical Ventilation
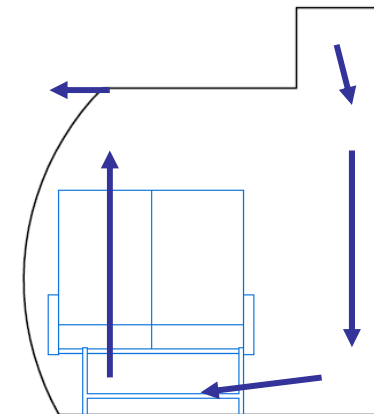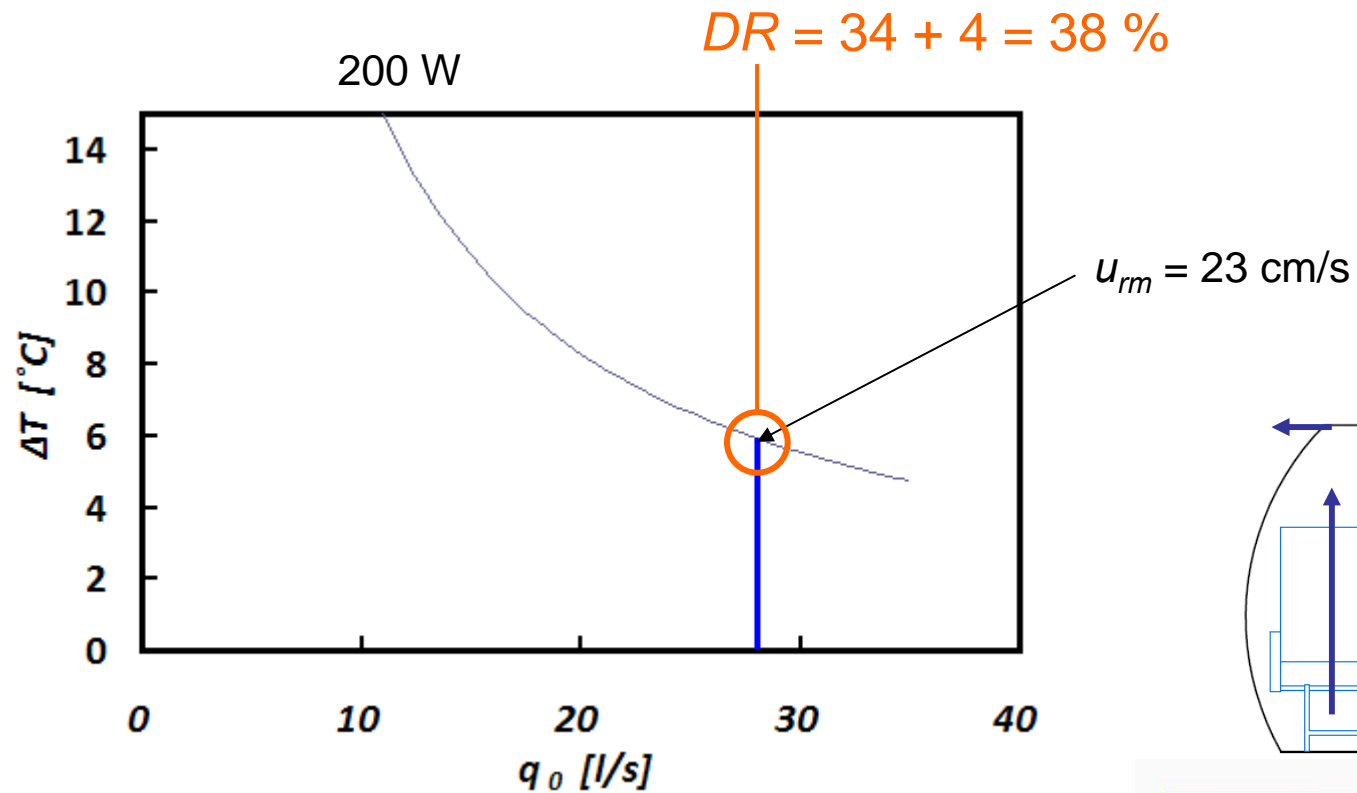
$DR = 34 + 4 = 38\ \%$

200 W

$u_{rm} = 23$ cm/s



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# Different Air Distribution Principles in an Aircraft Cabin

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- **Personalized ventilation**

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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.
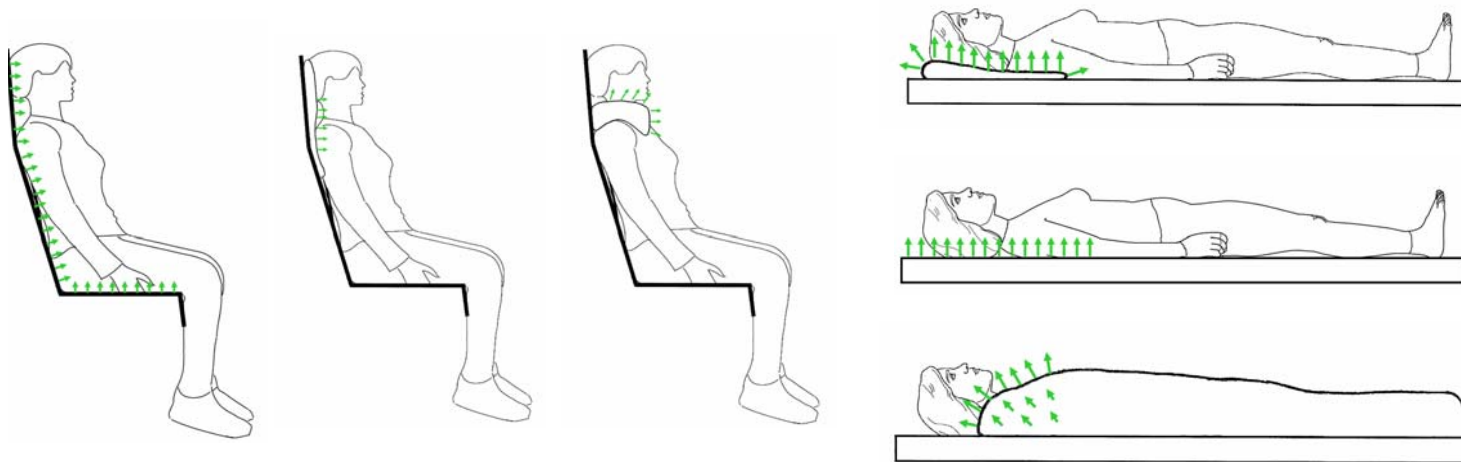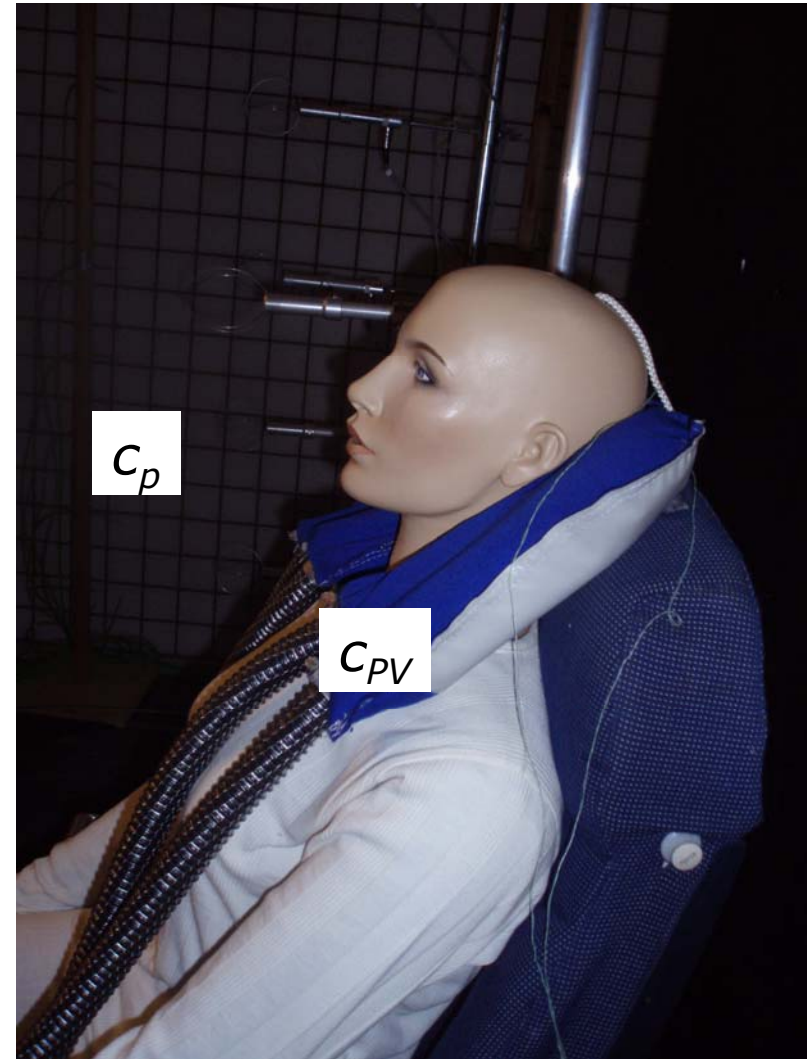
# Effectiveness

The effectiveness of personalized ventilation

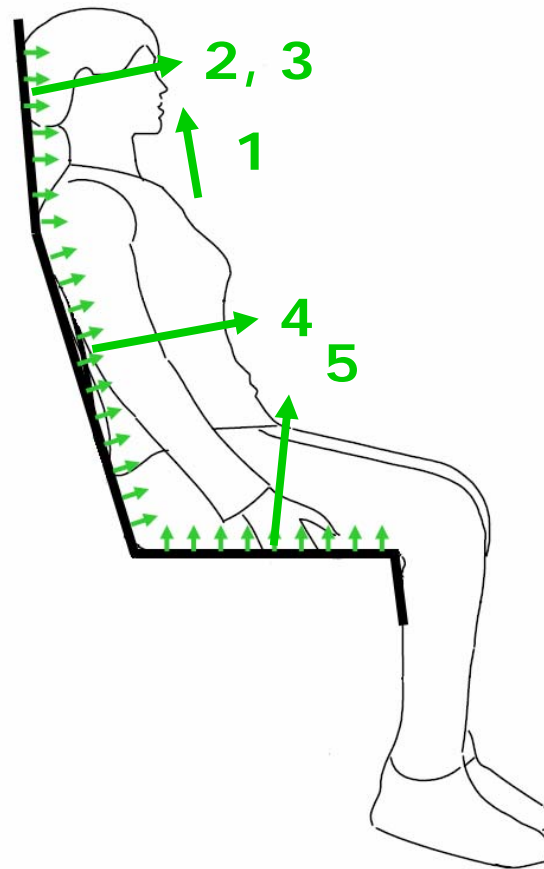If the concentration in the inhalation is $c_{PV}$

$\varepsilon_{PV} = 1.0$

If the concentration in the inhalation is $c_p$

$\varepsilon_{PV} = 0.0$
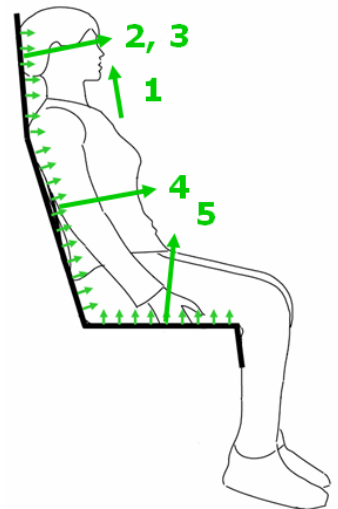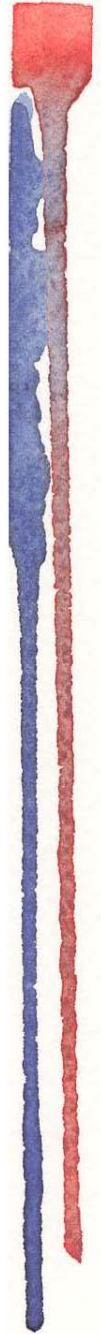


$c_p$

$c_{PV}$

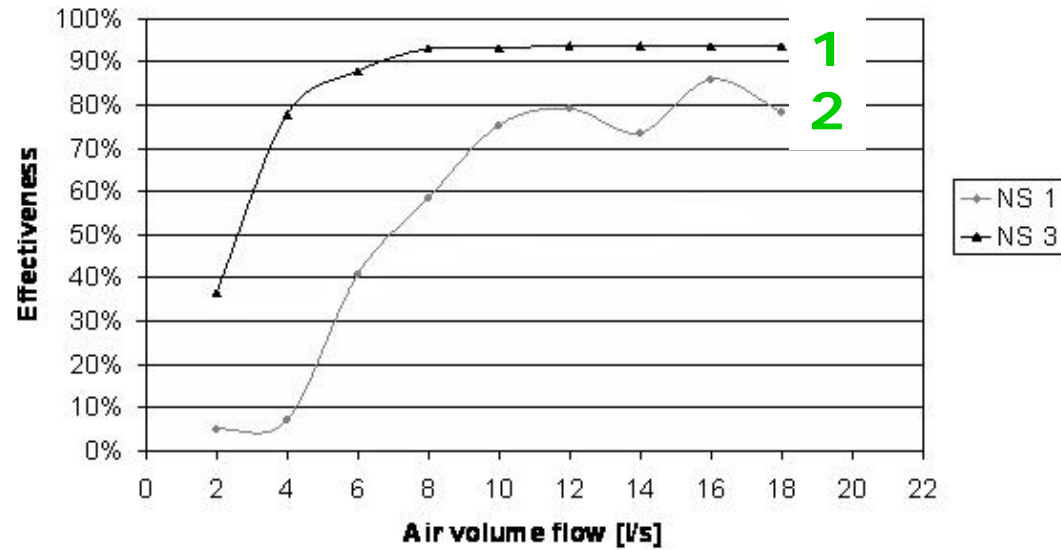# Air Supplied Direct to the Boundary Layer

Five different paths into the boundary layer.

# Neck Support Pillows
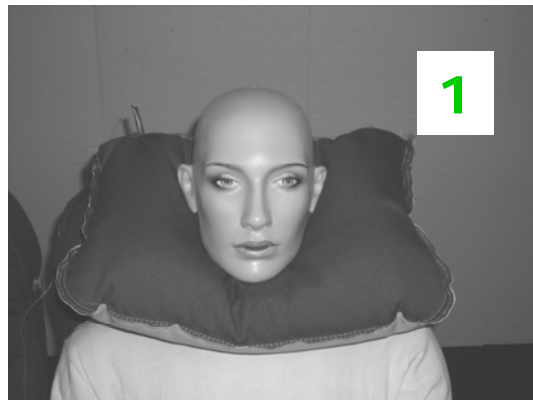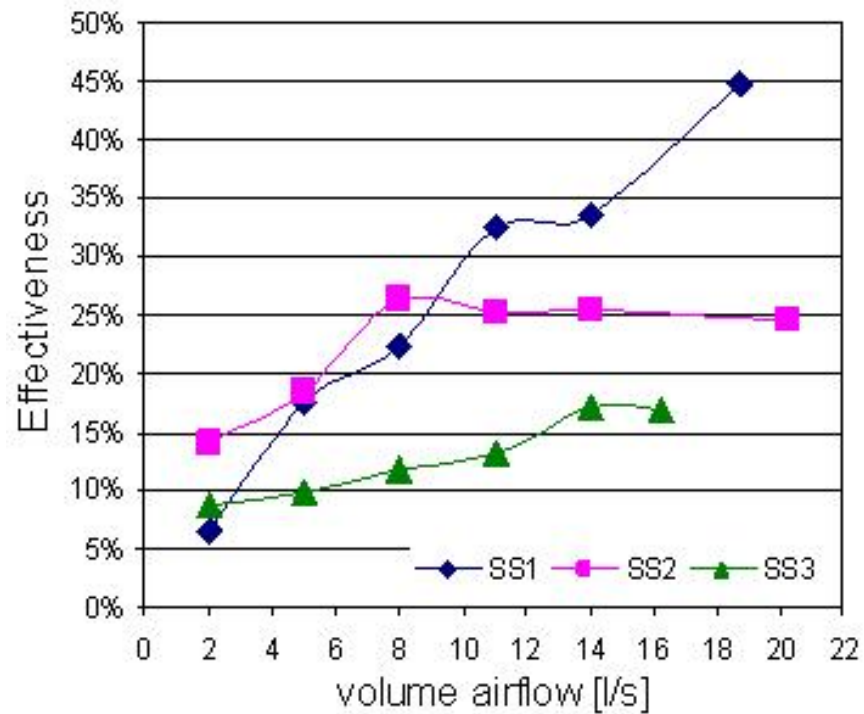
The neck support



NS 3
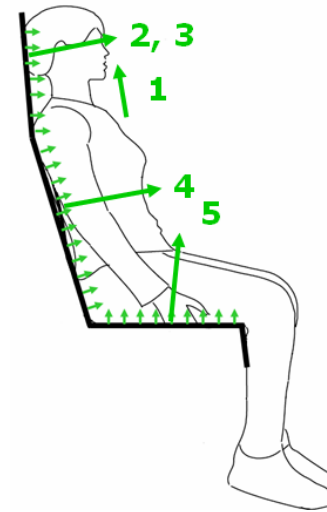
NS 1

# Seat as Diffuser



Supply areas are white

# Draught from the Right-Hand Side



$q_{PV}$ = 10 l/s
$u$ = 10 cm/s

**EFFECTIVENESS - BREATHING FUNCTION 90°**



Legend:
- 20 cm/s
- 15 cm/s
- 10 cm/s
- 5 cm/s

X-axis: Flow rate [l/s]
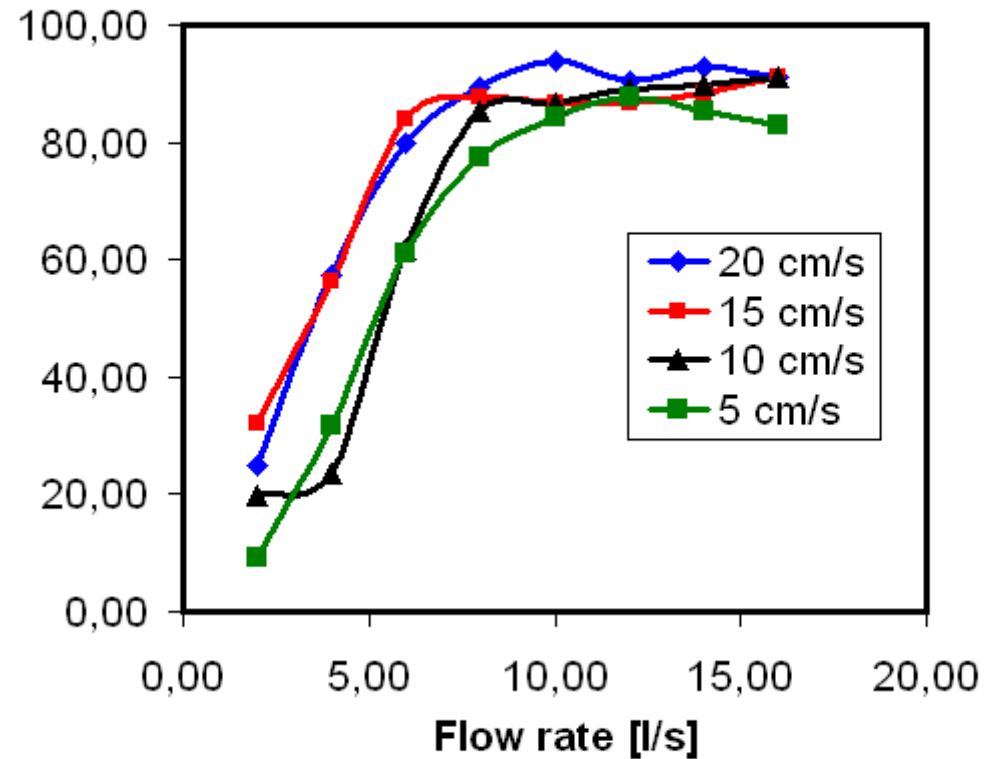
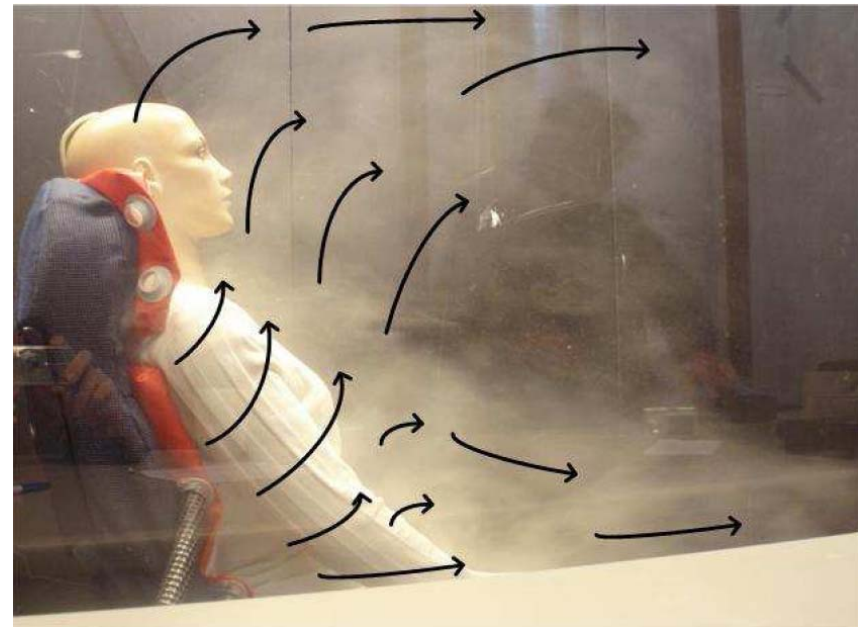# Chair with Diffuse Surface

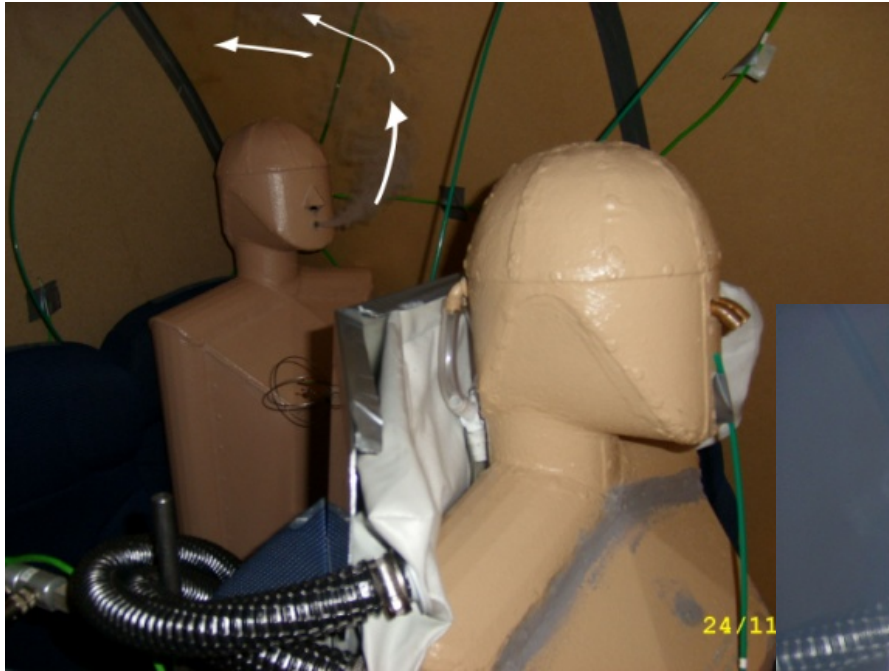Results with flow from behind, $q_{PV}$ = 8 l/s
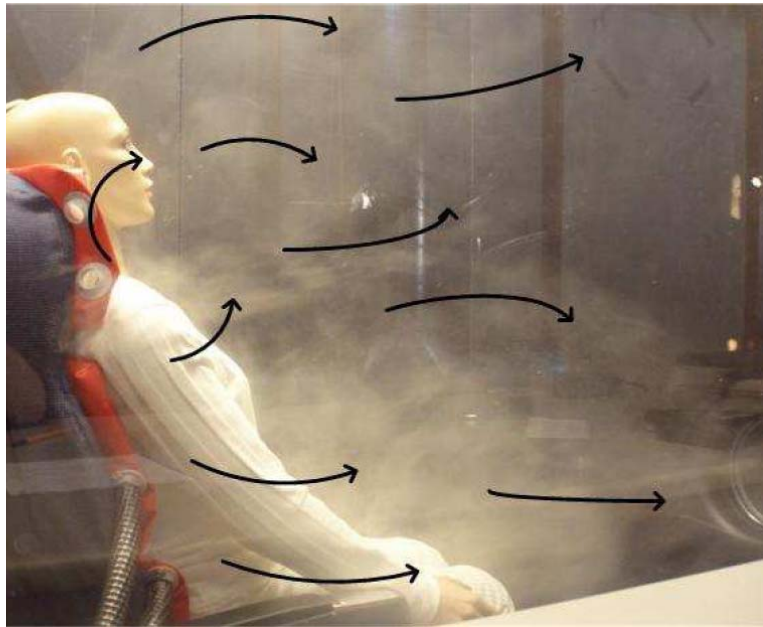


= 0.05 m/s

$u$ = 0.20 m/s

# Personalized Ventilation Combined with Mixing Ventilation



# Thank you!