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Displacement Ventilation in Non-industrial Premises

an old principle with new technology
Rehva Guidebook on Displacement Ventilation

Aimed at:
- the practising engineer

Discussing:
- what is displacement ventilation?
- what are the benefits
- what are the limitations?
- where should it be used (and not used)?

The theory is illustrated by case studies showing how displacement ventilation can be utilised in practice.
Contents of the book

- Disp.vent in a nutshell
1. Terminology, symbols and units
2. Basic knowledge about displacement ventilation
3. Air diffusers
4. Design procedures
5. Energy aspects
6. Automation and control
7. Case studies
   • Restaurant
   • Cell office
   • Auditorium
   • Meeting room
   • Class room
8. References
The basic idea

Warm air rises due to buoyancy, and carries the pollutants from people up towards the ceiling.

In industry....

....and non-industrial premises
Man = heat source – in theory

The air rises because of the heat release of the human body

80 – 90 W
Man = heat source – in practice

- Warm, polluted air rises due to buoyancy.

Cigar smoke visualises the rising air, but it is the heat from the body that drives the flow.
Air supply

The air floats along the floor like water and fills the room from below.
Air is extracted at ceiling level

The extract opening can be located anywhere in the highest part of the room

The extract air flows along the ceiling
Air supply

The air is supplied from wall panels with low velocity.

The supply air is colder than the room air.
Air supply can be arranged in many ways

- Plane, wall-mounted
- Circular, free-standing
- Semi-circular, corner-mounted
- Floor-mounted
Be aware of cold draught along the floor!

- When the supply air is colder than the room air, it will fall to the floor, and may cause cold draught.

- This may avoided by choosing the right diffuser.

- Remember:
  - Choose a diffuser that is suited for the purpose
  - Make sure that the adjacent zone (the “draught zone”) does reach places where people are located permanently.
Diffuser types - Casino

Air diffusers behind columns
Diffuser types - Atrium

Air diffuser
Diffuser types - Restaurant

Air diffuser
Diffuser types - Department store

Air diffuser
Basic principles – Convection currents

The air that rises in the convection current must be replaced by new air. This makes a two-layer flow, where the polluted, “used” air stratifies in the upper layer.

Less supply air lower the interface between the two layers.
Basic principles – Thermal stratification

In practice, the air will stratify in many layers, making the temperature rise from floor to ceiling.
Basic principles – Thermal stratification

- Occupied zone
  - 50 - 90%
  - 90% - 100%
- Supply 0%
- Extract 100%
- Contaminants
  - Breathing zone
    - < 100%

Temperature:
- 18 °C
- 26 °C
Temperature distribution - normal rooms

Less cooling is needed to obtain the desired temperature in the occupied space.

Mixing

Displacement
Temperature distribution - Tall rooms

The cooling advantage is most pronounced for tall rooms.
Contaminant distribution in normal rooms

For the same ventilation rate, we may get better air quality with displacement ventilation.
Little air - less benefit

- Supply 0%
- Occupied zone 50 - 90%
- Extract 100%
- Height above floor, \( z \) [m]
- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5

- Contaminants
- Breathing zone < 100%

- Supply 0%
- Occupied zone 90% - 100%
- Extract 100%
- Height above floor, \( z \) [m]
- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5

- Contaminants
- Breathing zone < 100%

- Supply 0%
- Occupied zone 50 - 90%
- Extract 100%
- Height above floor, \( z \) [m]
- 0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5

- Contaminants
- Breathing zone < 100%

- 20 l/s per person = very good
- 10 l/s per person = acceptable
- < 10 l/s per person = insufficient
Contamination in inhaled air

The rising flow around a person brings fresh air to the breathing zone

Concentration ratios measured at a manikin

Source: Mats Sandberg, Sweden
Better air quality: Yes – and No?

When there are many people, and insufficient air, the contaminants stratify at lower levels

![Diagram showing CO₂ concentration with different number of people in the room.](image-url)
Passive smoking in crowded rooms with Displacement Ventilation

A standing person’s exposure may be greater, but people are still protected by the rising air current around themselves.

Source: Peter V-Nielsen, Denmark
For protection against tobacco smoke, see REHVA Guidebook no 4: “Ventilation and Smoking”.
Contaminant distribution in tall rooms

**Perfect mixing**

**Displacement**
Auditoria – air supply

- Air supply in front of the room
- Air supply under the seats
Auditoria – air flow pattern

Thermal and contaminant stratification
Auditoria – air flow pattern

Supply air is contained between the rows.

Supply air is floating down the stairways.
Auditoria – temperature distribution

- Extract air temperature \( \theta_e = 26^\circ C \)
- Supply air temperature \( \theta_s = 16^\circ C \)
- Air temperature at floor level, \( \theta_{oz} = 21^\circ C \)

Temperature [°C]

Height above floor [m]

0 1 2 3 4 5 6

Supply air temperature \( \theta_s = 16^\circ C \)

Air temperature at floor level, \( \theta_{oz} = 21^\circ C \)

Extract air temperature \( \theta_e = 26^\circ C \)

appr. 6K
Auditoria – Recirculation

Supply air  \( q_s = 10 \text{ l/s per pers} \)
\( c_s = 750 \text{ ppm} \)

Outdoor air
\( q_p = 6 \text{ l/s per pers} \)
\( c_p = 350 \text{ ppm} \)

Extract air
\( q_e = 10 \text{ l/s per pers} \)
\( c_e = 1350 \text{ ppm} \)

Recirculation air
\( q_r = 4 \text{ l/s per pers} \)
\( c_r = 1350 \text{ ppm} \)

\( q_{CO2} = 0.006 \text{ l/s per pers.} \)

Displacement ventilation gives benefits to recirculation in tall rooms – for details, see the book
Cooled ceiling - high temperature cooling

Cooled ceiling is ok when the cooling output of the ceiling is less than 40% of the total cooling.

Cooled ceilings, or cooling convectors, decrease the air quality benefit.

Mixing ventilation should be considered as an alternative.
Room heating

When the room is occupied:
• Don't heat the room by the ventilation air!

At night:
• Some people recommend heating by the ventilation air….
Heating by radiator/convector

Warm air from radiator balances meets the cold air from window/wall
Floor heating is ok as long as the floor temperature is moderate (i.e. less than appr. 25° C)
Useful or useless?

Best suited for:

- Restaurants,
- Meeting rooms,
- Classrooms
- Tall rooms:
  - Conference rooms,
  - Theatres,
  - Supermarkets, etc

Advantages:

- Improved air quality
- Most efficient in tall room
- 1°C – 3°C lower temperature in the occupied space for a given supply temperature

Less suited for:

- Where surplus heat is the main problem, and not air quality.
- Where ceiling heights are lower than approximately 2.3 metres.
- When the problem is cooling in low rooms (in offices, consider mixing and cooling panels)
- Where disturbances to room air flow is strong.
- Where the contaminants are colder/denser than the ambient air.
Displacement Ventilation is no miracle, and should not be used everywhere.

It has lost much of its reputation in several countries due to incompetent or over-optimistic use.

Problems:
- draught along the floor
- diffusers require much wall space

..but used with skill in the right places, it has definite advantages.
Thank you for your attention

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