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AIR QUALITY IMPROVEMENT USING A DISPLACEMENT VENTILATION SYSTEM

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SUMMARY

Displacement ventilation systems become more and more popular in Germany at present.
The system guarantees no draught and a better air quality is expected.
In an experimental study the air quality was measured using a combined particle/heat source in a ventilated room. Particulate concentrations were measured at different locations in a room with several heat sources representing persons.
In the vicinity of persons in the breathing zone a better air quality was recorded than at other locations of the room at the same height.
Temperature differences between the room air and the surrounding surfaces affects the room air movement and influences the results.

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INTRODUCTION

Displacement ventilation, in Germany often called "Quellüftung" (source flow), is becoming more and more popular within the recent years and is acknowledged to be the most effective ventilation system in respect to thermal comfort. The major advantage of displacement ventilation is the avoidance of draught if designed and performed properly. In the future research and development work in ventilation systems will focus on air quality improvements. Displacement ventilation systems also provide advantages if compared with conventional mixing flow systems.

DISPLACEMENT VENTILATION AND AIR QUALITY IN ROOMS

Displacement ventilation is ensured by supplying air into the room at a temperature that is lower than the room air temperature. Beside the displacement flow from the floor to the ceiling, heat sources cause an additional air flow through buoyancy effects. This air flow is greater than the displacement flow and therefore a downward convection flow takes place and there is a mixing zone between the clean zone near the floor and a contaminated zone near the ceiling. Air flow rate, type and location of the heat sources in the room influence the height of the clean lower zone.

Significant for displacement ventilation system is a very low air velocity, which has its maximum near the supply air terminal device. Reduction of thermal comfort will not occur if this velocity is always smaller than 0.2 m/s and the temperature difference between the supply air and the room air smaller than 4.5 K where the vertical temperture gradient in the occupation zone is limited to 2 K/m.
Displacement ventilation from the floor to the ceiling has always an increase of temperature and contamination with height. Room air quality investigations of displacement ventilation systems were carried out by Fitzner (1981) and Heiselberg and Sandberg (1990). But in these investigations the influence of the location of the heat sources on the vertical gradients of the contamination was neglected.
They found a better air quality in the occupation zone and the decrease of contamination with increasing distance from the particle source. In the lower zone near the floor there are very low concentrations and in the upper zone the concentration is like that of the exhaust air. In some experiments a worse air quality was found in the occupation zone than that of the exhaust air with no advantages for displacement ventilation if compared with conventional mixing ventilation. This makes obvious that the

interactions of the transport phenomena are very complex and need a detailed investigation.

The acceptance of the room air is determined by the air quality in the breathing zone. Each person is also a heat source and causes a convective air flow upwards by buoyancy. Under ideal conditions this will cause a continous air flow upwards from the clean lower zone providing a better air quality in the breathing zone than at other locations in the room at the same height. Investigations on this subject were carried out by Holmberg et al. (1990) and Nickel (1990). Holmberg recorded an improvement of the air quality in the head height of seated persons which becomes unlikely with decreasing the air flow. Nickel compares in his investigation the displacement and the mixing ventilation, blowing cigarette smoke in the occupation zone and measuring the Co-concentration. He also found a gas quality improvement, which was reduced during the movements of people.

EXPERIMENTAL INVESTIGATION

In this investigation air quality was measured in a room ventilated with a displacement ventilation system. A continous particle source was placed in the room. Measuring the particulate concentration at different locations in the room, the room air quality can be determined. The influence of type and location of heat sources shall be found out.

TEST ROOM

The experimental investigation was carried out in a test room (figure 1) with the shown test assembly.

Supply air is introduced into the room from one front side. The following table shows the parameters.

Air flow volume	m^3/m^2h	8.75
Supply air temperature	°C	20
Thermal load	W/m^2	22

The supply air is filtered by a series connection of two HEPA filters and contains nearly no particles. The exhaust air is taken from the ceiling and the concentration is used as a reference measurement. In the room a particle source is placed with a continous particle production. The advantage of this technique is the simultaneous measurement at different locations in the room. The local particulate contamination was normalized with the contamination of the exhaust air.

$$\mu = (C_p - C_s)/(C_e - C_s)$$

where μ in the degree of contamination and C the particulate concentration. The indices state the location of measurement; p is the point of measurement, e is the exhaust air and s the supply air. An important prerequisite for the experiments is the overpressure in the test room and a comprehensive sealing of the room.

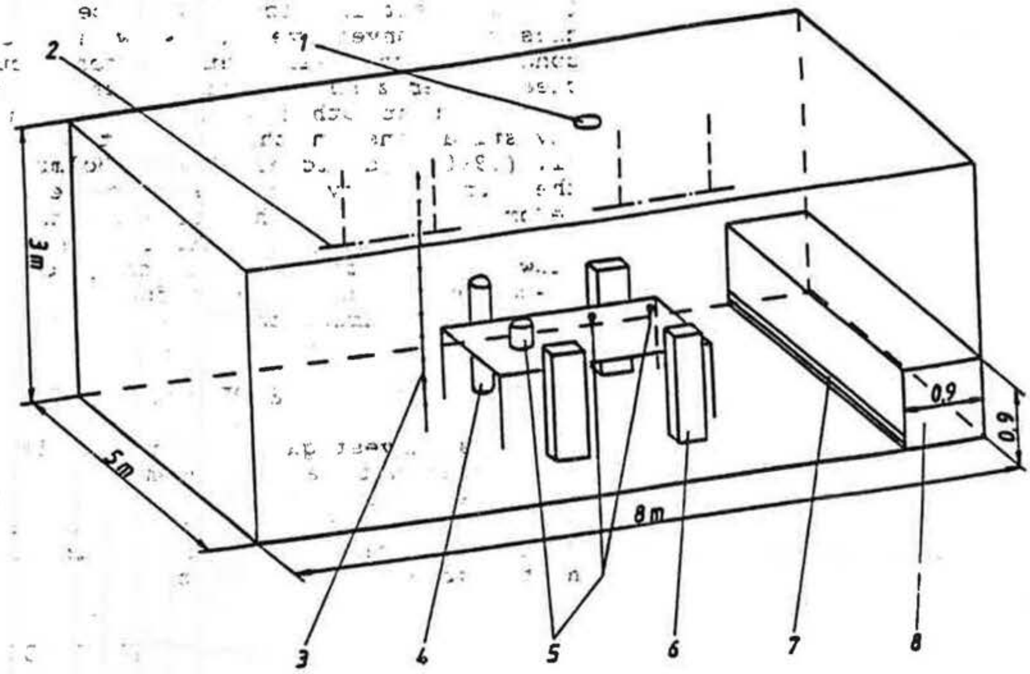

Fig. 1 Test room with test facilities

1. Exhaust air
2. Luminaries
3. Movable measurement device
4. Combined particle heat source
5. Heat source
6. Person simulator
7. Supply air terminal device
8. Perimeter zone

PARTICLE SOURCE

For the generation of the particles a combined heat and particle source was developped (fig. 2). In the height of 0.9 m the particle source is placed. Particle production is provided by blowing air into water and causing the formation of very small bubbles. By this procedure and aerosol was produced with a maximum particle size of 0.2 µm.

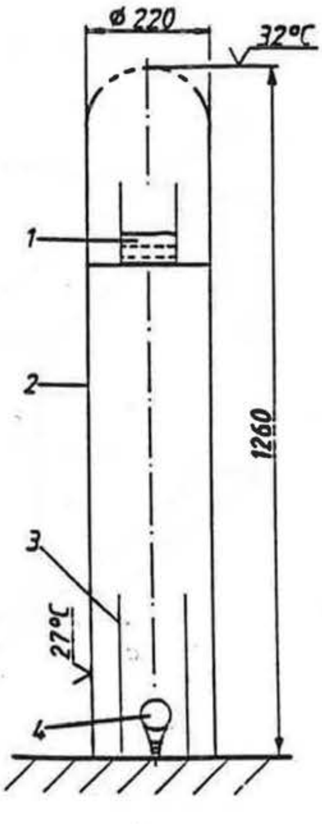

Fig. 2 Combined heat and particle source

1. Particle source
2. Black painted surface
3. Screen to reduce direct radiation
4. 75 W heat source

EXPERIMENTAL SETUP

The experimental setup was designed that there is no need to enter the room during measurement. This was necessary because with people entering the room lots of particles are entrained and it takes a long time till the particle concentration is at base line again.

Particulate concentration was measured with a removable measuring stand (fig. 3). For the measuring procedure a selector switch was used. A laser light scattering instrument was used for particle counting. The location of the measuring point in the room is shown in fig. 4.

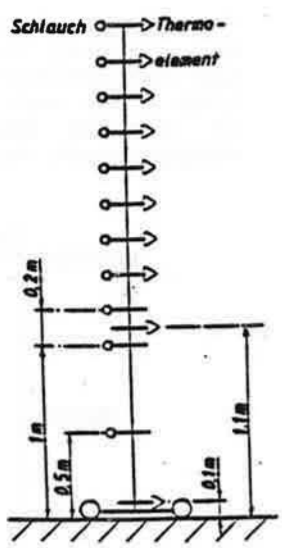

Fig. 3 Arrangement of the measuring stand with thermocouples and probes for air sampling.

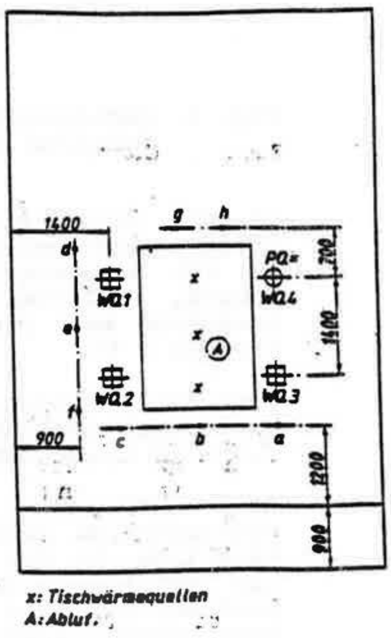

Fig. 4 Location of the measuring points (a-h)

EXPERIMENTS AND RESULTS

The investigation was started with testing the particle source and checking the system boundaries of the test room. Fig. 5 shows the particulate concentration of the exhaust air as a function of time after switching on the particle source.
It can be seen that the particles are removed quicker by displacement ventilation, if compared with a mixing ventilation.

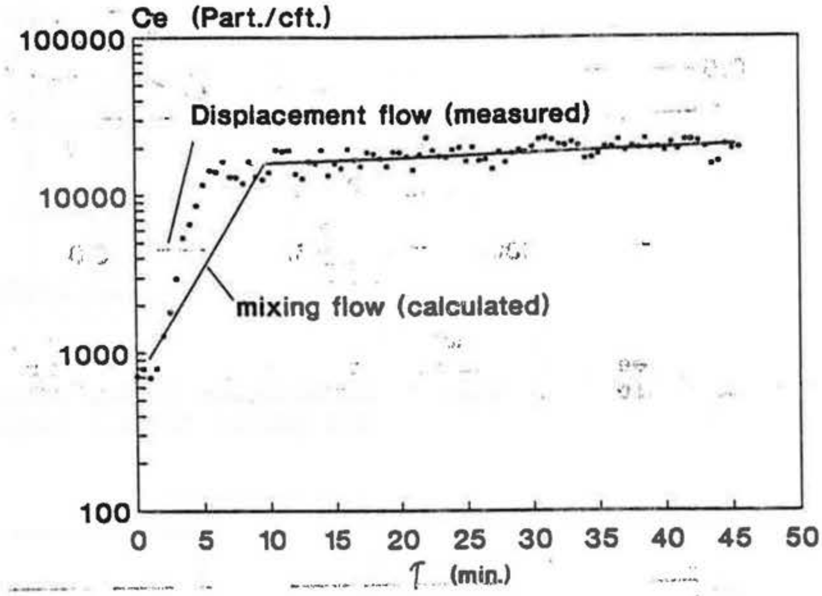

Fig. 5 Particulate Concentration of the exhaust air as a function of time after starting particle production.

In the first set of experiments the vertical concentration profiles were measured in the room (fig. 6).
At all measuring points, except very close to the particle source, a better air quality ($\mu < 1$) was recorded in the breathing zone (height: 1.1 m - 1.4 m), if compared with mixing flow ($\mu = 1$).

From the measured vertical particle concentration profiles also horizontal profiles can be derived. For two heights 1.0 m and 1.4 m in these horizontal profiles are shown in figure 7.

At a distance of 1.5 m from the particle source the degree of contamination falls down and reaches at a distance of 2.5 the base line. In the vicinity of the particle source fluctuations of the particulate concentration are recorded. Additionally to the vertical profiles another profile was measured directly above a heat source. Figure 8 shows the results of this measurement. It becomes obvious that there is a very good air quality up to a height of 1.8 m. Above this height a considerable rise of the contamination was recorded.

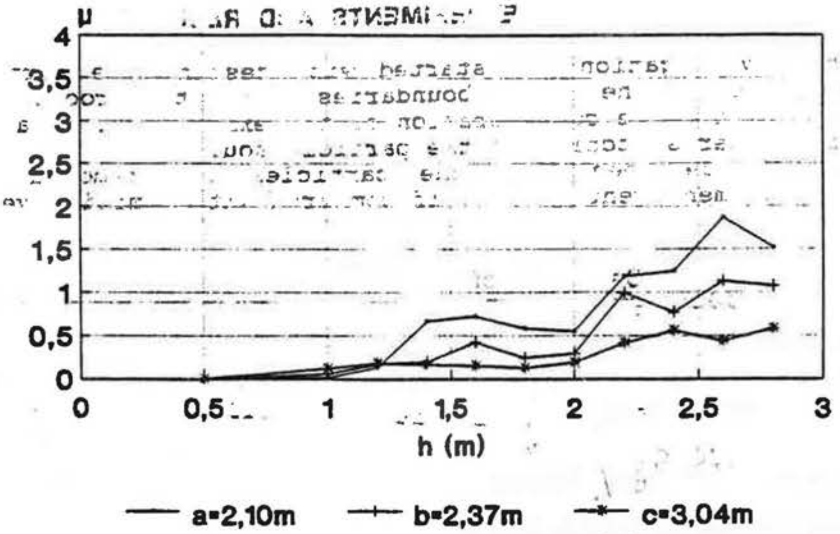

Fig. 6 Degree of contamination μ as a function of room height at three locations with the given distance from the particle source.

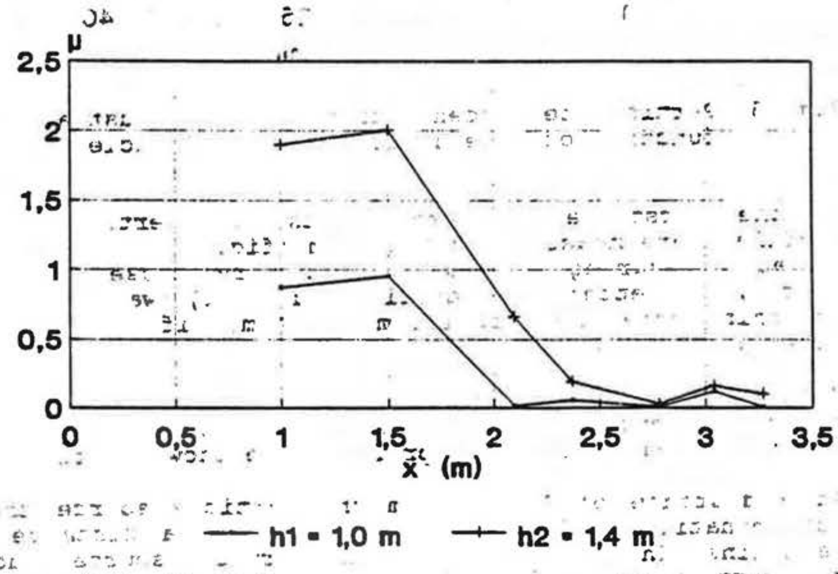

Fig. 7 Degree of contamination as a function of the distance from the particle source at two heights.

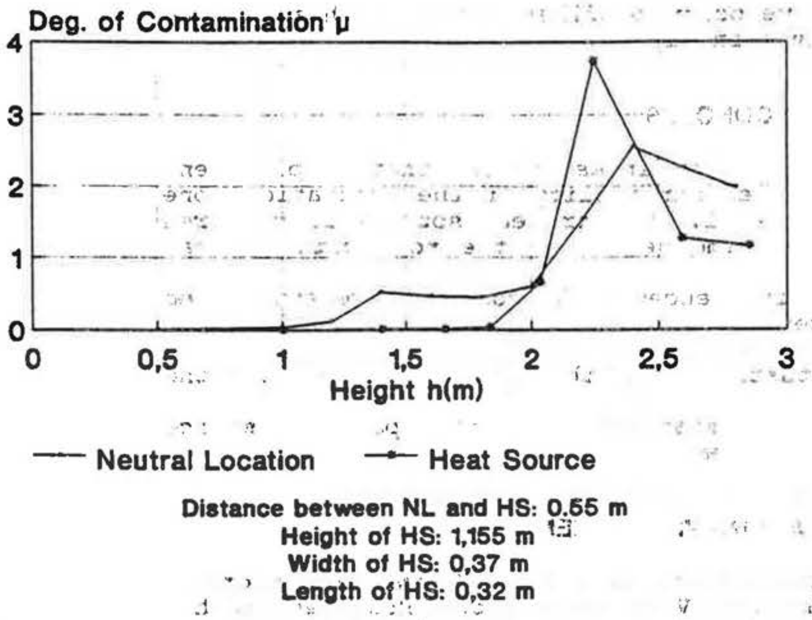

Fig. 8 Comparison of the degree of contamination above a heat source and at a neutral location in the room.

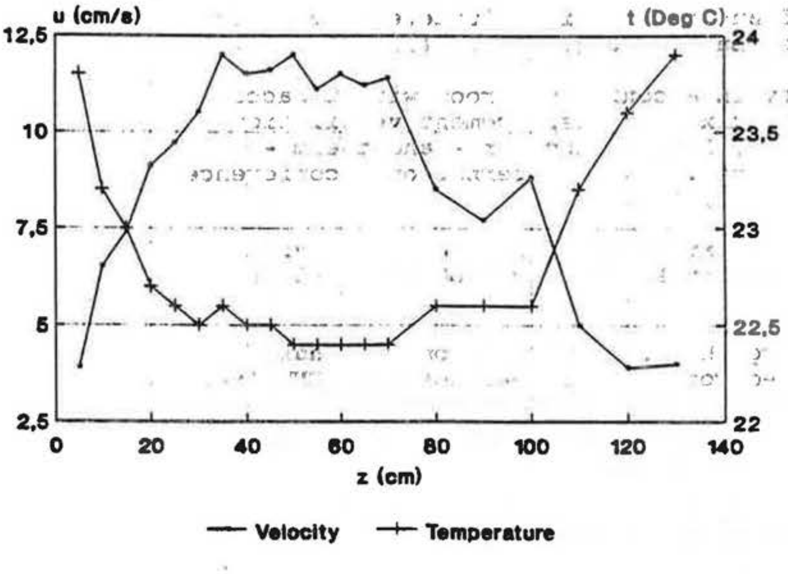

Fig. 9 Air velocity and temperature profiles above a heat source (person simulator 100 W).

The temperature and air velocity profiles above the heat source (person simulator) is given ~~in fig. 9.~~

CONCLUSIONS

It could be demonstrated in this investigation that displacement ventilation provides a better air quality in the occupation zone at a height of 1.0 m through 1.4 m near heat sources if compared with the locations of the same height in the room with no heat sources.
Room air quality is also influenced by a room air movement caused by temperature differnces between the room and the surrounding surfaces.
This also causes fluctuations in the concentrations of the exhaust air.
For future measurements a constant and continous particle source will be used as a reference measurement.

ACKNOWLEDGEMENT

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