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PARTICLES AND DISPLACEMENT VENTILATION

E. Mundt

Department of Building Services Engineering, KTH,
100 44 Stockholm, Sweden

ABSTRACT

In displacement ventilation the airflow pattern in a room is mainly guided by the convection flows from the heat sources present in the room. This implies that the air in the breathing zone mostly comes from the lower parts of the room, where the air often is less polluted by pollutants originating from persons or electrical appliances present in the room. In earlier investigations by the author the transportation of tracer gas from thermally active and thermally passive sources into the convection flows has been studied.

A resuspension of floor deposited particles caused by the influence of the supply air or people moving around may increase the number of particles in the convection flows rising around the heat sources. This transportation of particles, by the convection flows, from the floor level of the room up to the breathing zone has not yet been reported.

In this paper will be presented some results from laboratory measurements of particle concentrations at different positions under steady state and transient conditions. Transient conditions in this case means that a person walking around has initiated a resuspension of particles and the decay of particles is then measured.

The results indicate that there seem to be little risk of resuspension of particles, in the measured size interval, by the influence of the supply air. With a forced resuspension the particle concentrations in the convection current differs from concentration outside the convection current.

KEYWORDS

Particles, displacement ventilation

INTRODUCTION

The resuspension and dispersion of particles from the floor in a displacement ventilated room is a matter of great concern as the particles may then enter into the convection flows and reach the breathing zone. There has been little research in this area which often is a non steady-state process caused by people moving around in the room. Holmberg and Li (1998) has reported a numerical study on non-passive particle dispersion in a displacement ventilated room. Particles of 0.3 and 20 μm were supplied in an airstream with a velocity of 0.1 m/s. The smaller particles were entrained in the vertical plumes and gave a breathing zone concentration above the exhaust air concentration. The larger particles settled to a great extent and were then reentrained into the thermal plume of the manikin positioned close to the settling area.

The parameters influencing deposition and resuspension of particles from a surface was investigated by Lengweiler et al (1998). Based on experiments with air velocities above 0.1 m/s and different turbulence levels they concluded that the air velocity, turbulence level and surface orientation play a major roll. They also conclude that the deposition and resuspension need to be studied separately.
In this paper a small study on the particle concentration variations in a displacement ventilated room is reported with focus on what happens when a person walks around in order to resuspend particles from the floor area into the thermal plumes.

METHODS

Measurements were made in a test-room 4.6 x 3.6 x 2.64 m (L x W x H) equipped with displacement ventilation. The test-room is situated in a laboratory where the surroundings can be kept at a relatively constant temperature. The lay out of the room is shown in Figure 1. In the room were three person simulators each consisting of 1 m painted vertical ventilation duct covered at the top and with a diameter of 0.4 m. Inside each simulator were light bulbs of altogether 100 W. Two of the person simulators were heated by the bulbs and no other heat sources were present in the room. The air flow rate was either 87 or 175 m^3/h, which equals 2 or 4 ach/h and the supply air temperature set so that all heat emitted within the room was evacuated by the ventilation air flow.

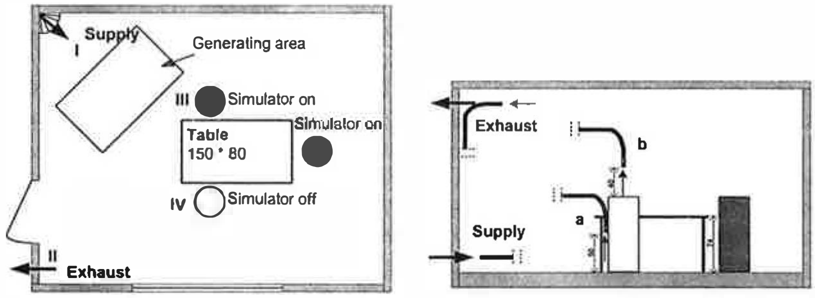

Figure 1: Plan and elevation of the test room for particle measurements

Particle concentrations are measured in position I-IV, see Figure 1. The tubes for measurements close to the simulators are positioned either in position a or b, i.e. in the convection flow along the cylinder or in the flow above the cylinder in case of the heated cylinder. Between each measurement in position II-IV a measurement in position I is taken as a reference. Particle concentrations were measured by a Hiac/Royco Particle Counter Model 245A, situated outside the test room, which classifies particles greater than 0.5, 5, 10 and 25 μm. The sampling flow-rate of the particle counter is 1 ft^3/min and the concentrations presented in number/ft^3. Pre-filtered supply air to the room is taken from the laboratory and measurements of steady state conditions with no extra particle loads in the room are first made. A person then enters the room and walks around in the area (dotted in Figure 1) between the supply air device and the table, after the person left the room measurements were made during the decay period.
To increase the particle concentration in the room talcum powder was used, the powder was spread on the floor in front of the air supply device, the dotted area in Figure 1, and similar measurements as described above were performed.

RESULTS

In Table 1 the different cases presented in this paper are summarised. The results obtained are shown in Figure 2-5, where the concentration variation in the measurement positions are shown for three of the particle sizes, there were as expected almost no particles larger than 25 µm in any of cases measured. The unit on the Y-axes is number of particles/ft^3. In the figures the shaded areas represent the time when a person is in the room and walks around in front of the supply air device.

TABLE 1
AIRFLOW RATE, TUBE POSITION AND PARTICLE SOURCE FOR THE CASES PRESENTED

Case no	Airflow rate (m^3/h)	n (1/h)	τ_n (h)	Tube position	Particle source
1	87	2	0.5	a	Supply air
2	175	4	0.25	a	Supply air
3	175	4	0.25	b	Supply air + talcum powder (vigorous walking)
4	175	4	0.25	b	Supply air + talcum powder

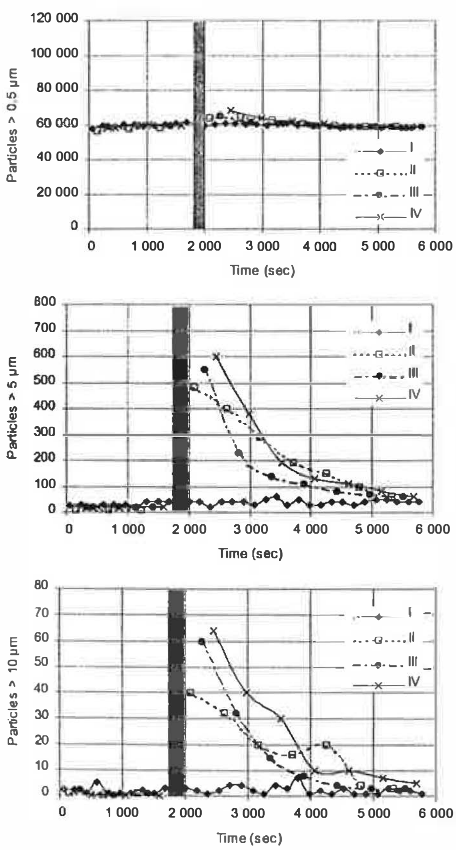

Figure 2: Case 1 (Y-axis number of particles/ft^3)

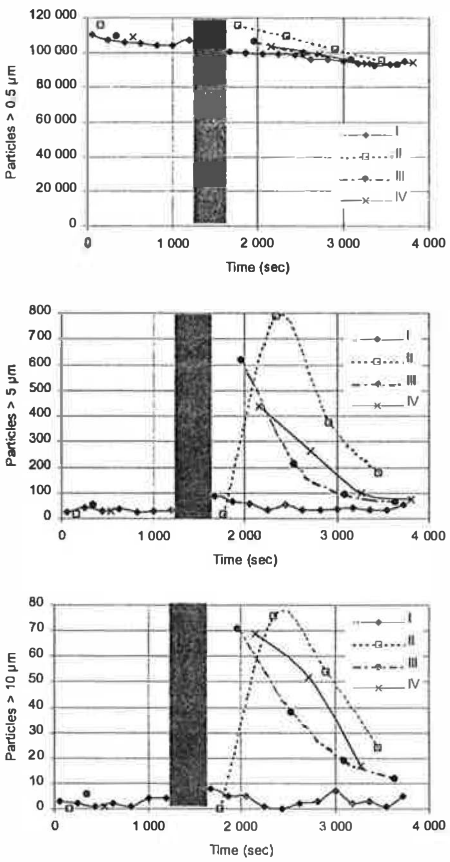

Figure 3: Case 2 (Y-axis number of particles/ft^3)

From the graphs in Figure 2 and 3 can be seen that the particle concentrations in all three classes are almost the same in all positions when measured before a person enters the room. (In Figure 3 measurements in pos. III and IV were only made once before the disturbance.) In case 3 and 4 when talcum powder was spread in the room, two decay periods can be seen in the graphs. In case 3 the person moved vigorously and the concentrations after the disturbance was outside the measuring range of the instrument, this explains the long time before resuming the measurements.

The results show that there seem to be little risk of an increased amount of particles in the convection flows due to resuspension of floor dust into the supply air. When a person has been walking around, the number of particles increased in the exhaust air and in the two measuring points in the room. After the person has left the room the concentration decays in all points. It can further be noted that the concentration of particles of all sizes is decreasing faster close to the warm simulator than close to the simulator off.

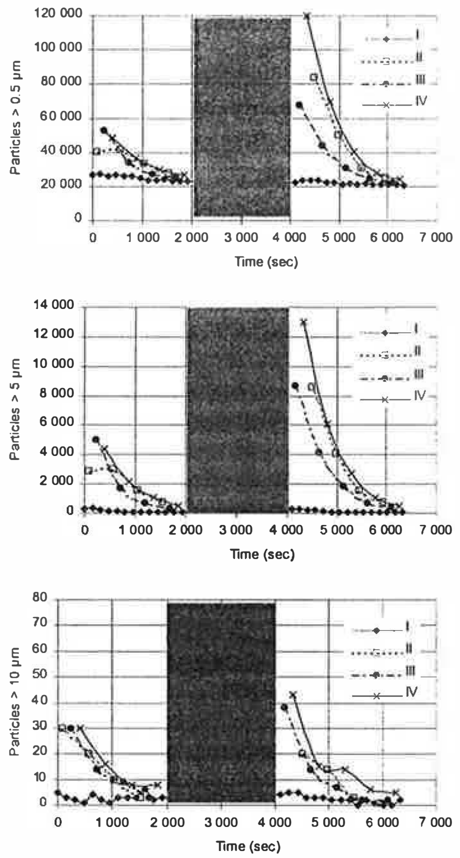

Figure 4: Case 3 (Y-axis number of particles/ft^3)

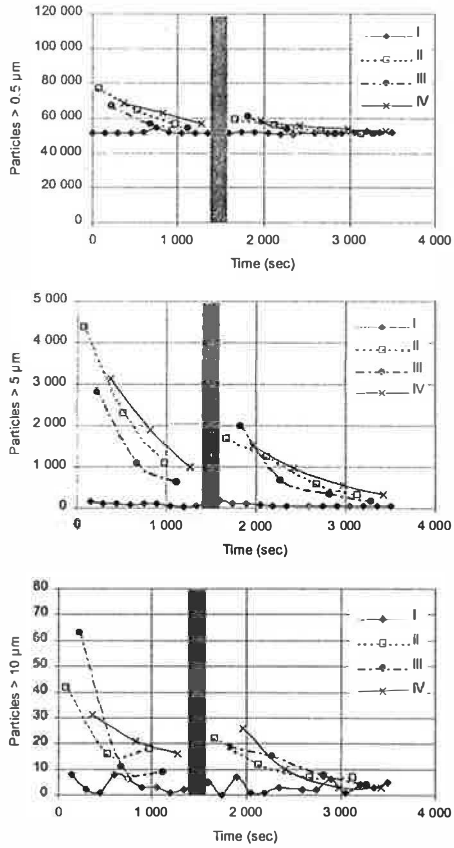

Figure 5: Case 4 (Y-axis number of particles/ft^3)

From the curves can be seen that the decay has an almost exponential form and by plotting the concentration minus the supply concentration, a relative comparison with particle decrease caused by ventilation and particle settling can be made. The small particles can be expected to follow the airflow and in case of fully mixed ventilation the decay of particles should then be according to Eqn. 1.

$$N(t) = N_o \exp^{-t/\tau_n} \tag{1}$$

In a room without any ventilation and an even distributed concentration of particles, the decay should be according to Eqn. 2, Hinds (1982).

$$N(t) = N_o \exp^{-v_s t/H} \tag{2}$$

where H the room height and v_s is the settling velocity which can be calculated by Eqn. 3, Hinds (1982).

$$v_s = \frac{(\rho_p - \rho_a)\cdot d^2 g}{18\eta} \tag{3}$$

where ρ_p, ρ_a are the densities of the particle and air, d the diameter and η the dynamic viscosity. The particles in the talcum powder have a density of 2.7 g/cm^3 and the particles in the supply air are supposed to have a unit density of 1 g/cm^3.

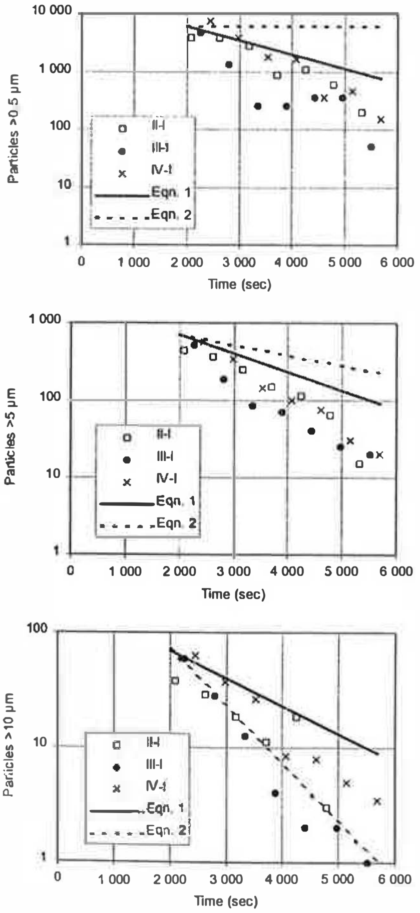

Figure 6: Case 1 (Y-axis number of particles/ft^3)

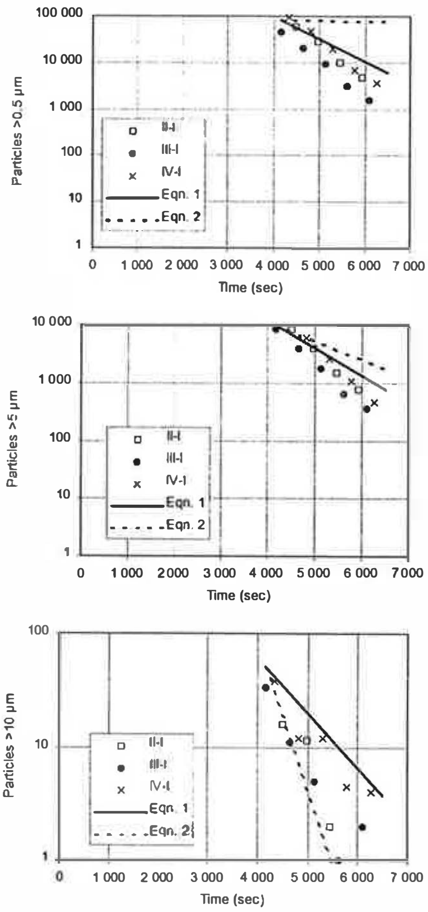

Figure 7: Case 3 (Y-axis number of particles/ft^3)

Eqn. 3 gives for talcum powder a settling velocity of. 0.002 cm/s for the 0.5 μm particles, 0.2 cm/s for the 5 μm particles and 0.8 cm/s for the 10 μm particles. For the unit density particles the corresponding velocities are 0.0008, 0.08 and 0.3 cm/s.

Figure 6 and 7 shows the decrease in particles concentration minus the concentration in the supply air in two of the measured cases. In the figures are also shown the decrease that could be expected in case of fully mixed ventilation with no particle settling, Eqn. 1, and the decrease caused only by particle settling, Eqn. 2. It can be seen that the decrease for particles >10 μm is close to the decrease caused by settling, but the smaller particles seem to follow the airflow. The decay is however faster than what could be expected in fully mixed ventilation, this is natural in a displacement ventilated room. The same test room and lay-out was also used to measure air change efficiency and contaminant removal effectiveness with a non-buoyant pollutant source see Mundt (2000) and the air change efficiency with 2 and 4 ach/h was 76-79 %.

DISCUSSION

The measurements presented here indicate little risk of an increased concentration of particles caused by resuspension by the supply airflow in a displacement ventilated room. With a forced resuspension caused by a person walking around, the particle concentration increased both in the convection flows and in a place outside the convection flow. As the measurements were only made after the forced resuspension was finished, the concentration variations during the disturbance were not measured.

During the decay period the concentrations in the convection flows were always lower than the concentrations outside the convection flows. This is also an indication that the supply air does not cause a resuspension of particles from the floor.

The decay of particles >10 μm indicate that they settle in all measured positions and do not follow the convection flows. More research is needed to clarify what happens in the convection flows during a forced resuspension.

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