DISTRIBUTION OF WATER VAPOUR IN A ROOM; EXPERIMENTAL RESEARCH IN A CLIMATE ROOM

ir. A.M.S. Weersink
DGMR Raadgevende Ingenieurs bv (Advisory Engineers)
The Hague, The Netherlands

INTRODUCTION

In building practice the water vapour pressure in every point in one room is often considered to be the same. One of the premises in the present moisture models is the ideal mixture of the air-vapour compound.

In order to verify this, indicative measurements are taken of the water vapour distribution in a room. One needs to gain an insight into water vapour distribution in order to interpret measurement data in problem situations and to study mould problems in building practice.

The research is executed by the FAGO Department (Physical Aspects of the Urban Environment) of the Faculty of Building Science and Architecture of Eindhoven University of Technology in the scope of the research "Damp Economy of Buildings".

EXPERIMENTS

During half an hour water vapour was produced in a climate room (LxBxH = 10x5x3.5 m^3) by boiling water on an electric cooker. The development of the vapour pressure (p) was determined by recording the relative humidity and temperature at various distances from this vapour source and at various heights.
In the measurement set up the position of the vapour source and the surface temperature of space boundaries, among other things, were varied.

RESULTS

In this abstract the results of one of the measurement-series are discussed.

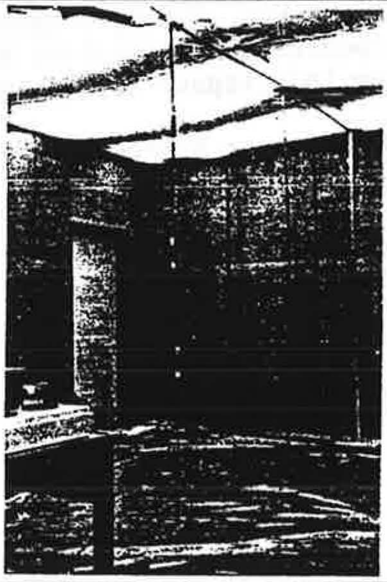
Measurement set up of the main-serie, which will be discussed:
- the vapour source is placed in the middle of the climate room, at a height of 0.8 m above the floor;
- surface temperature of the walls: 293 K;
- surface temperature of the floor: 293 K.
- several positions of 4 temperature/humidity sensors and 4 air-velocity sensors. The sensors are all projected in a straight line (horizontal or vertical), see figures 1 and 2. The positions of the sensors are given by co-ordinates (x,y,x)
  x = horizontal distance from the vapour source to the probes (facing the short axis) [m];
  y = horizontal distance from the vapour source to the probes (facing the long axis) [m];
  z = vertical distance from the probe to the floor [m].
  Also, the position of the vapour source, in the experiment described below, can be given as (x;y;z)=(0;0;0.8);

Serie A1

Measurement set up: The horizontal distance from the vapour source to the points of measurement is 1m. Distances from the floor to the points of measurement (z-values) vary.

Right from the start of the water vapour production the vapour pressure near the ceiling (z=3m - z=3.5m) increases dramatically. The increase of vapour pressure is a lot less at z=0.05 and z=0.8m.
Vapour pressure gradients were built up over the vertical section during the vapour production ($\Delta p = p_{z=0.8m} - p_{z=2.9m} \approx 750$ Pa).

At t=30 min, when the vapour production is stopped, the vapour pressure against the surface of the ceiling first drops by leaps and bounds and then exponentially. At 30 cm below the ceiling the vapour pressure decreases more gradually. In contrast with these points, the local vapour pressure still continues to rise for some time at z=0.8 and z=1.6m.



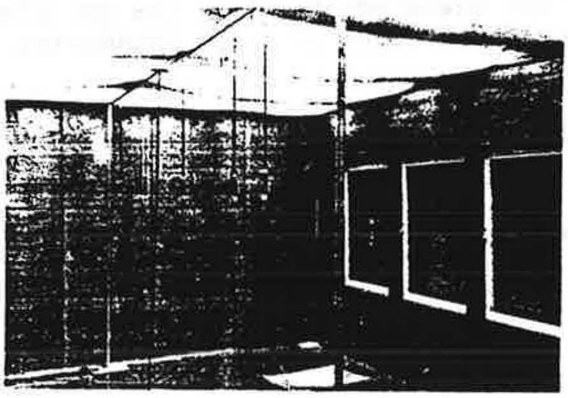


FIGURE 1: Vertical projection of the sensors

FIGURE 2: Horizontal projection of the sensors

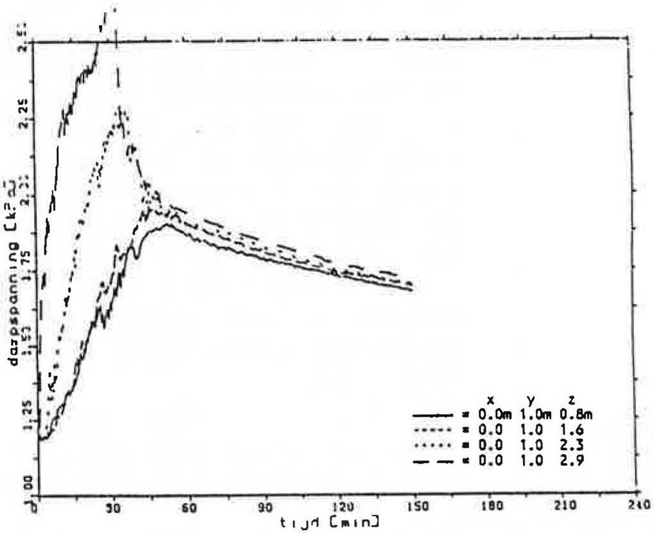


FIGURE 3: Results serie A1

About 20 minutes after removing the vapour source, the vapour pressure over the section is equal (see figure 3). This is called the "vapour pressure balancing period".

Serie A2

Measurement set up: The horizontal distance from the vapour source to the points of measurement is 2m. The distance from the floor to the points of measurement vary (see co-ordinates in figure 4).

At a height of z=1.6m, p_{max} is reached at t=45 min. After t=45 min, the pressure increases gradually. When z=0.8m and y=2m, the vapour pressure rises gradually from t=0 up to t≈60 min. The vapour pressure remains at a lower level in comparison to the other points of measurement. At t=90 minutes, the vapour pressures at the points of measurement in the vertical section are equal (i.e. the balancing period lastst about 60 minutes!).
At a height of z=2.9m, the maximum vapour pressure (p_{max}) at t=30 minutes is at y=2m much <u>lower</u> compared to p_{max} at t=30 minutes at y=1m. In contrast with this, at the hight of z=2.3m, p_{max} at t=30 minutes is <u>higher</u> at a distance of y=2m than p_{max} at a distance of y=1m;

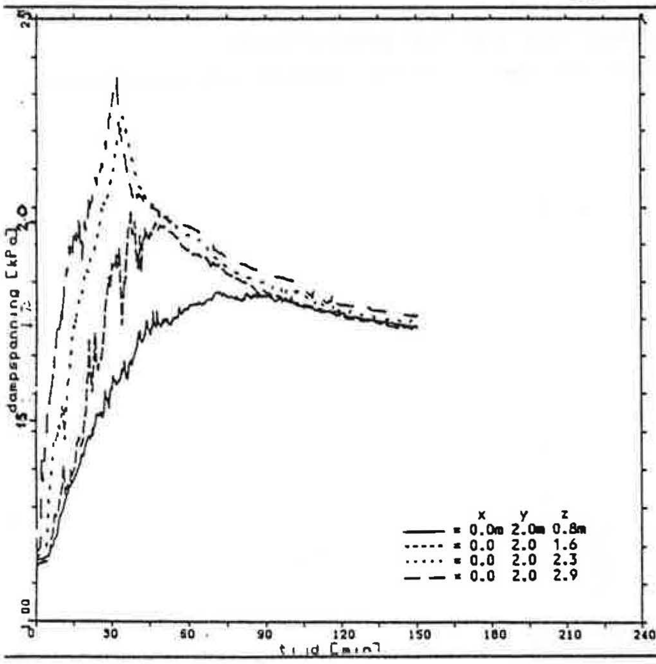


FIGURE 4: Results serie A2

Serie A3
Set up: y=4m, z-values vary.

There is hardly any difference in the course of the vapour pressure at y=3m and y=4m. However, at y=4m distance from the vapour source, the vapour pressure gradients that are built up in the period lasting from t=0 to t=30 minutes are not as big. The balancing period lasts about 10 minutes.
Near the wall (y=5m), the vapour pressure gradients are smaller than at a distance of y=4m.
The balancing period for both the distances y=4m and y=5m counts just a few minutes.

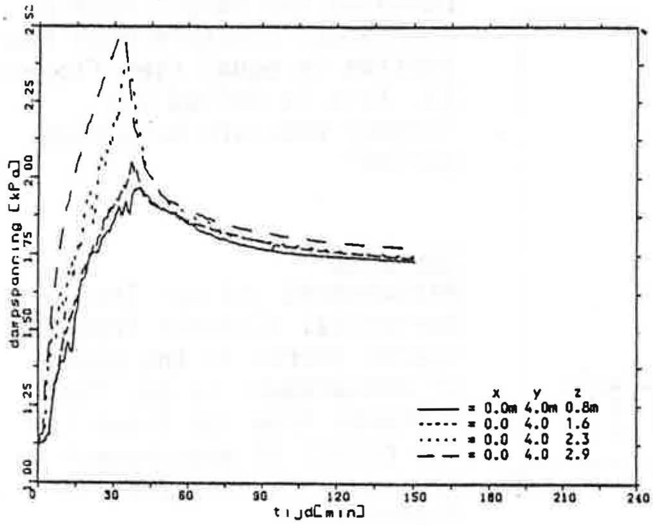


FIGURE 5: Results serie A3

Serie A4
Measurement set up: Sensors are positioned at a height of z=2.9m. Y-values vary.

The gradients of the vapour pressures in horizontal sections is a lot less in comparison to the vapour pressure gradients that were built up in vertical sections.
It appears that after starting the vapour production the excess of the water vapour pressure is enormously at z=2.9m (i.e. near the surface of the ceiling) at all points of measurement varying from y=0.5 to y=5m (see figure 6). The shorter the horizontal distance to the vapour source the higher the vapour pressure during the vapour production.

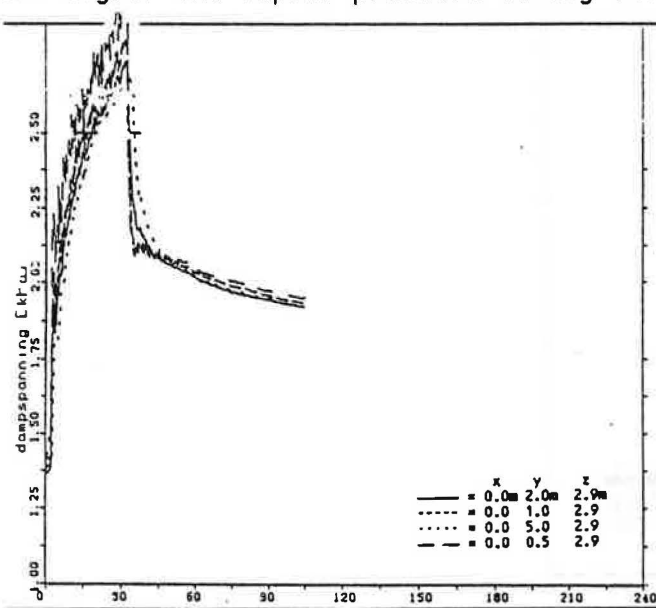


FIGURE 6: Results serie A4

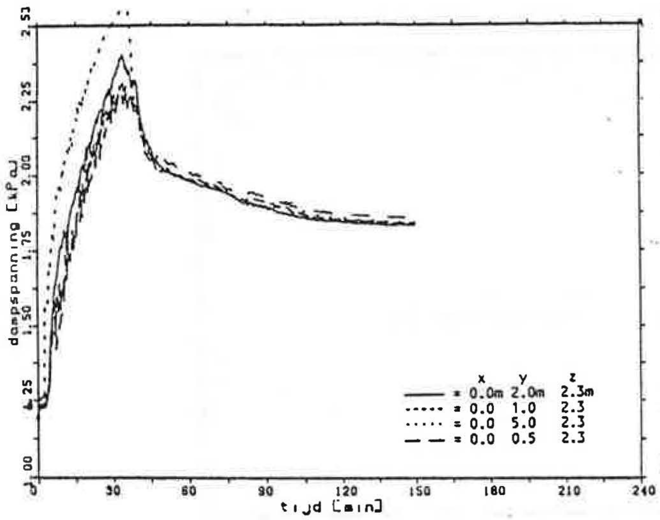


FIGURE 7: Results serie A5

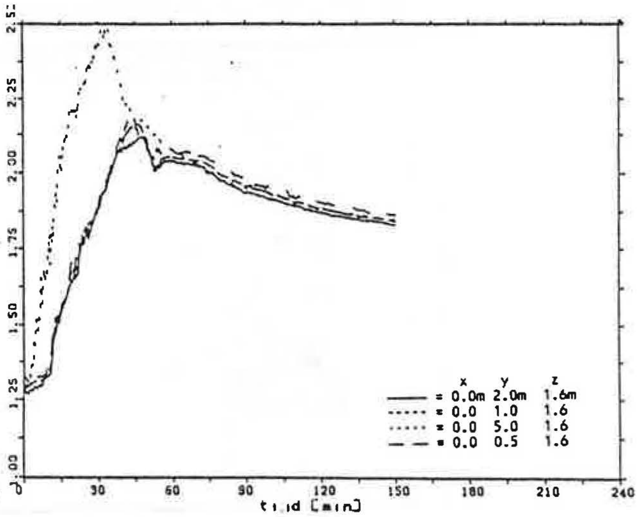


FIGURE 8: Results serie A6

The vapour pressure decreases during the vapour production when the horizontal distance to the vapour source is increased. The vapour presure gradient at location (x;y;z)=(0;0.5;2.9) and (x;y;z)=(0;5;2.9) is about 250 Pa.

After the vapour source is removed, the vapour pressure drops by leaps and bounds. There remains no significant vapour pressure gradient after t=30min.

<u>Series A5 and A6</u>
Set up: z=2.3m (serie A5)/z=1.6 (serie A6); y-values vary.

At horizontal distances of y=0.5, 1, 2 and 5m, and at the heigths of z=0.8, 1.6 and 2.3m, the course of the vapour pressures are more or less the same (see figure 7 and 8).

However, it is remarkable that the vapour pressure near the wall (y=5m) is much higher compared to the other points of measurement. This is caused by the air flow patterns.

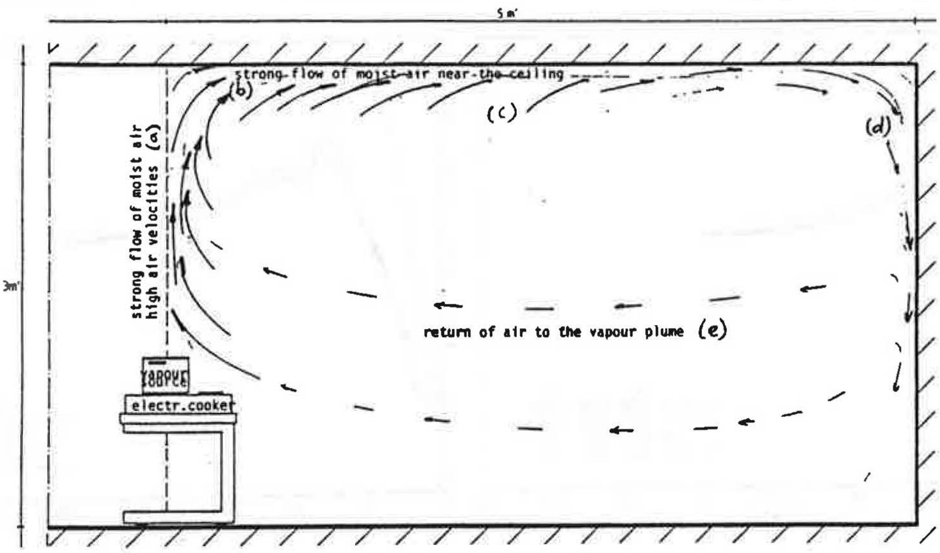


FIGURE 9: Pattern of air movements in the climate room during vapour production (cross section)

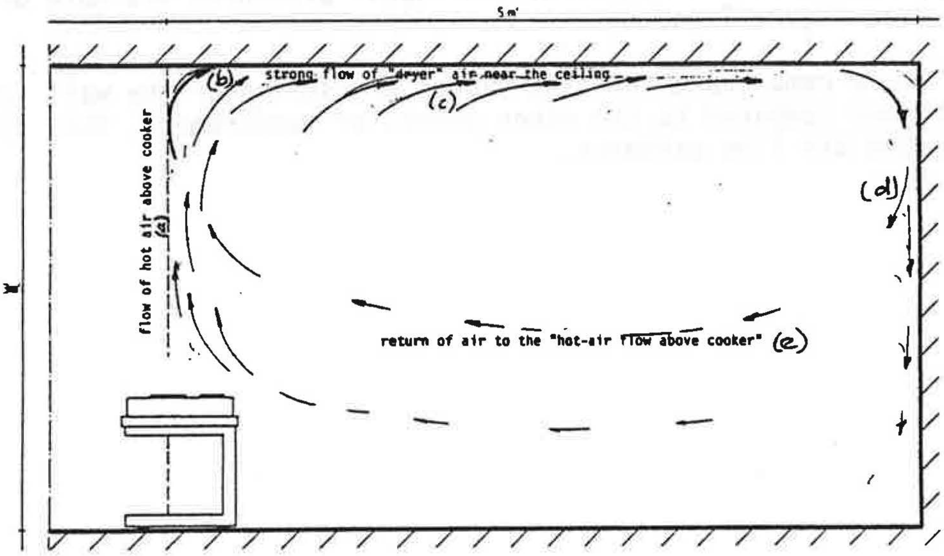


FIGURE 10: Pattern of air movements in the climate room immediately after stopping the vapour production (cross section)

Figures 9 and 10 show that the air flows and the air velocities determine both the development of the local vapour pressures and the balancing period:

During water vapour production (1):
1a- a strong flow of moist air rises from the vapour source to the ceiling, which causes exponential increase of the vapour pressure;
1b- moist air flows near the surface of the ceiling. The airvelocity is high. This causes a strong increase of the vapour pressure;
1c- mixture of moist air (near the ceiling) and "dry air" (in lower layers, the increase of the vapour pressure is less);
1d- moistened air bends near the walls;
1e- return of moistened air to the "vapour plume" above the vapour source (air velocities <5 cm/s). Mixing of air continues. Also, the vapour pressure in these lower laying areas rise gradually.

After stopping the water vapour production (2):
2a- a flow of hot air, mixed up with "dry air", rises from the electric cooker in the direction of the ceiling. The air velocities are high. This causes exponential decrease of the vapour pressure;
2b- flow of relatively dry air flows against the surface of the ceiling (high air velocities). This causes a strong drop of the local vapour pressure near the whole ceiling, because of the high air velocities at its surface;
2c- the aircirculation causes equalisation of the vapour pressure in the room, i.e. decrease of the vapour pressure in higher areas ($z > 1m$), increase of the vapour presser in lower areas ($z < 1m$);
2d- air with lower humidity bends near the walls (drop of water vapour pressure near the wall);
2e- return of the air to the "hot-air flow" above the electric coker ("recirculation").

CONCLUSIONS

During the production of water vapour, large vapour pressure gradients are built up, especially in vertical direction. These vapour pressure gradients can be explained by analysis of air flow patterns in the climate room.
The vapour pressure balancing period in the climate room in areas with $z \geq 0.8m$ lasts about 60 minutes.

LITERATURE

Weersink A.M.S., Verspreiding van waterdamp binnen een ruimte; klimaatkameronderzoek, Afstudeerverslag Technische Universiteit Eindhoven, Faculteit der Bouwkunde, FAGO rapport 88.33.K.