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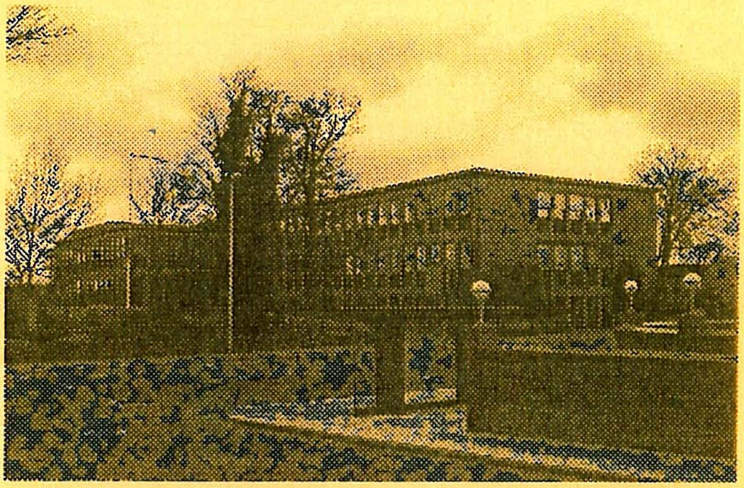

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PAPER NO. 75

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DETECTION AND SOLUTION OF INDOOR AIR QUALITY PROBLEMS IN A DANISH TOWN HALL.

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ABSTRACT

In connection with the research programme "Healthy Buildings", a building with indoor air quality problems was selected for further investigations. A Danish town hall was chosen because of many complaints over several years. A full-scale mock-up of a typical town hall office was built in the climate laboratory. A new heating and ventilating system and a new control strategy were chosen and implemented into the town hall. It was found that air supply upwards along a window may make it nearly impossible to achieve comfort and a good air quality the year round without full-scale measurements.

INTRODUCTION

In spite of considerable investments, a Danish town hall had many complaints about the indoor climate. Therefore, it was selected within the research programme "Healthy Buildings" as a case study. Measurements in the field should point out the problems and full-scale measurements in the laboratory should give a solution. This solution should be implemented into the building and measurements in the field a year later than the first one at almost similar outdoor conditions, should verify the solution.

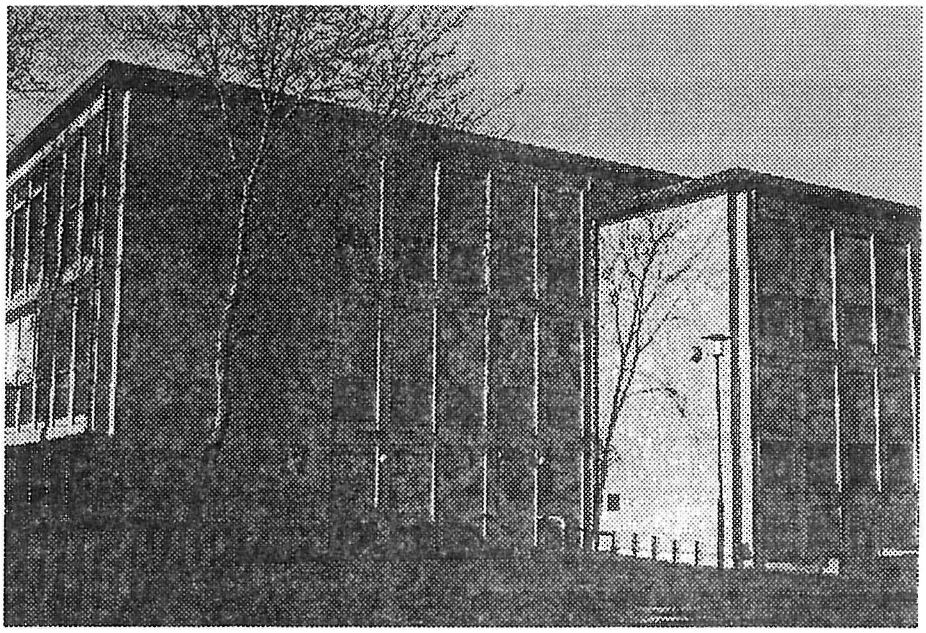

Figure 1 The town hall

This paper is about the solution of the problems within the area of temperature and air velocity distribution in a typical office. The solution also includes an improvement of the acoustic conditions.

METHODS

Field measurements

At the field measurements in the town hall during a week in March 1996 a typical single office was selected for intensive investigations. Since the complaints were about poor indoor air quality and cold draught in winter, an office with northwards windows was chosen. In Figure 2 is seen a photo of the interior of the office. The room has three windows and air supply upwards along the central window. The heating and ventilation of the room is done by a dual duct system with a wall thermostat regulated mixing box. The outlet passes through two fluorescent tube fixtures placed in the ceiling.

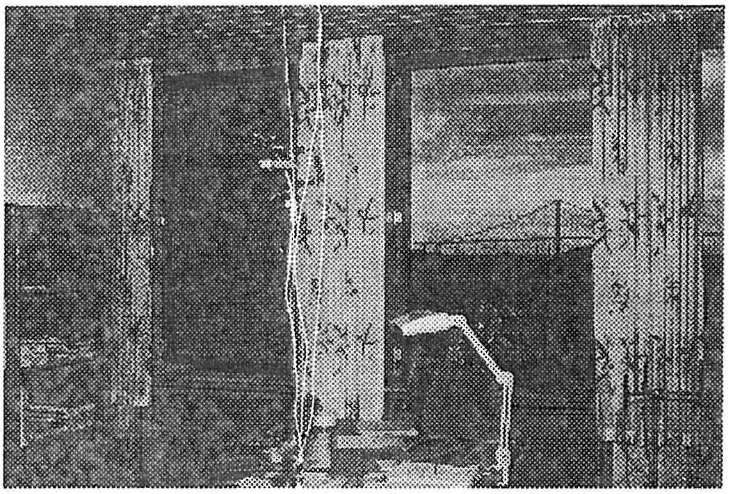

Figure 2 Interior from the town hall office

The room temperatures were measured at three measuring columns at the heights 0.1 m, 1.1 m and 1.8 m. Furthermore the inlet temperature, the outlet temperature, the inner surface temperature on the windows, the temperatures just below and on the ceiling and the outside temperature were measured. The sampling interval was one minute. Air movements in the room were investigated by means of smoke visualisation and by anemometers. Besides temperature and velocity measurements, tracer gas measurements were carried out as described in (1).

Full-scale mock-up

By means of the field measurements a full-scale mock-up of the office was built in the laboratory. In Figure 3 is seen the interior of this. The mock-up was established with dummy furniture with the same geometry and position as in the town hall and a breathing thermal manikin was placed at the writing table. The room was equipped for measuring temperatures, air velocities and tracer gas concentrations. To simulate windows, plane radiators were installed in order to control the surface temperature as wanted. The air supply vertically along the central window was worked out similar to the inlet in the real office. The outlets were, as in reality, the fluorescent tube fixtures in the quarter points of the ceiling opposite the central window. As the ceiling covering in the town hall had a rather rough profile a similar covering was mounted in the mock-up. The air supply was equipped with an orifice plate to measure the air flow rate.

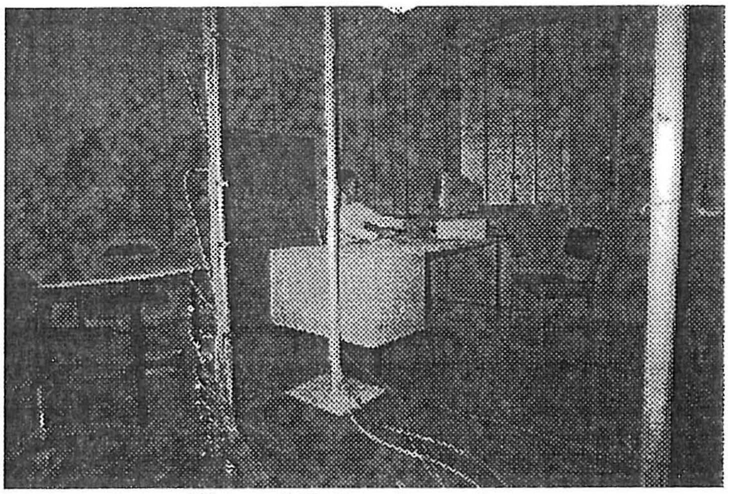

Figure 3 Full-scale mock-up

The room temperatures were measured at three measuring columns at the same heights as in the field measurements. Furthermore surface temperatures on the "windows", on the walls, the ceiling and the floor were measured. In Figure 3 is seen a column with 24 probes for measuring air velocity. In the mock-up tracer gas measurements were also carried out as described in (1).

RESULTS

Field measurements, March, 1996

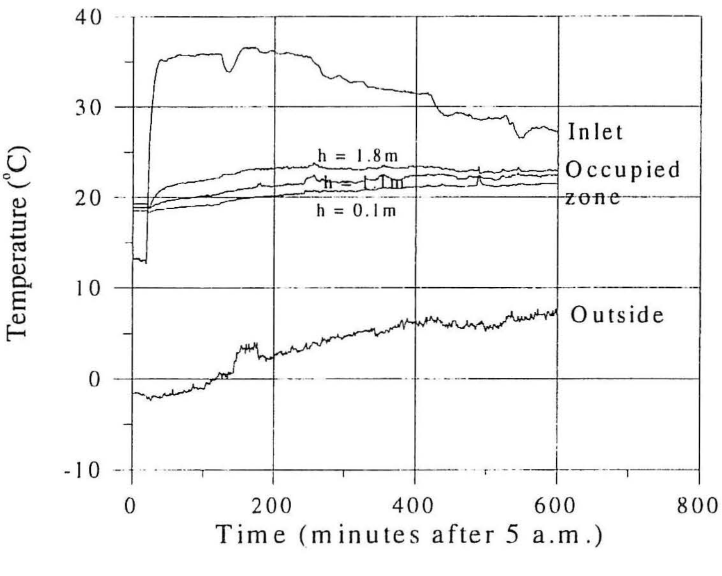

Figure 4 Field measurements, March, 1996

In Figure 4 the most important temperatures measured in the office the 27. of March, 1996 can be seen. It appears that the ventilation is started a little later than 5 a.m. and that the supply air temperature reaches a maximum at about 36 °C. On the measuring column located in the centre of the room the three temperatures designated "occupied zone" are measured. They show a temperature gradient of approximately 1 °C/m which clearly reveals that the mixing of the room air is insufficient in spite of a relatively high air change rate and a noisy air inlet. Smoke tests and tracer gas measurements (1) confirm the insufficient mixing.

Laboratory measurements

Like in the field
With the air supply and the temperatures similar to those which were measured in the field, conditions in the room analogous to those in the town hall were found. A varying of the outside temperature and the heat loads in the room showed that the air distribution during a great part of the year would be insufficient, and that cold down-draught from the two windows without air supply would be a problem. So it was impossible to adjust the existing system to an acceptable indoor climate and air quality.

After modification
Now a radiator was placed below each window. A dynamic temperature calculation programme was used for calculations of temperatures over a year for the real office with different air change rates. A new air change rate was chosen so that too high temperatures in summer could be avoided without installing a refrigerating plant. Measurements in the full-scale mock-up determined the choice of a new inlet device and the choice of a new control strategy. It was found that an air change rate of 5 h^{-1} and a constant inlet temperature of 20 °C, could give acceptable conditions throughout the year. By keeping the supply temperature (20 °C) a little lower than the room air temperature (22-25 °C) it was ensured that the ascending air flow from the radiators could prevent cold down-draughts from the windows.

The temperature gradient in the mock-up was reduced to be nearly zero in summer as well as in winter. Air velocities in the worst case, 1 m from the end wall in the winter case is presented in Figure 5.

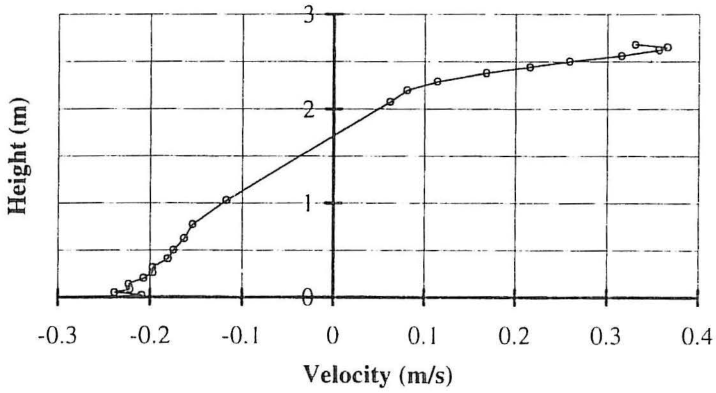

Figure 5 Air velocities measured in the mock-up, worst case.

The figure shows that the maximum air velocity locally near the floor were relatively high. This had to be accepted if reasonable conditions should be achieved elsewhere in the room. Velocity measurements, smoke tests, tracer gas measurements (1) and measurements by means of a breathing thermal manikin placed at the writing table showed acceptable conditions. At the same time the noise from the air inlet was reduced to an acceptable level.

The investigations in the laboratory showed that the supply air temperature had to be controlled rather precisely to be 20 °C. If this temperature was too low the supply jet would drop down into the occupied zone. If the supply air temperature was too high the heat loads of the radiators were too low to prevent cold down-draughts from the windows. The air flow rate could not be increased without causing too high air velocities in the occupied zone and it could not be decreased if too high temperatures in summer should be avoided. It was only possible to find the solution by means of a combination of dynamic temperature calculations and full-scale measurements. In Figure 6 is seen the air movements in the mock-up when smoke is added to the air supply.

Figure 6 Smoke visualisation. To the left acceptable conditions, to the right the supply jet drops down because of too low supply air temperature.

Field measurements, March, 1997

To verify that the dynamic calculations and the laboratory measurements were covering the loads in reality and to verify that the solution would give a satisfying indoor climate, test measurements in the field were carried out after the proposed modifications were applied. Fortunately the outdoor climate during the field study was nearly identical with that one a year before. In Figure 7 the most important temperatures during a typical day are presented.

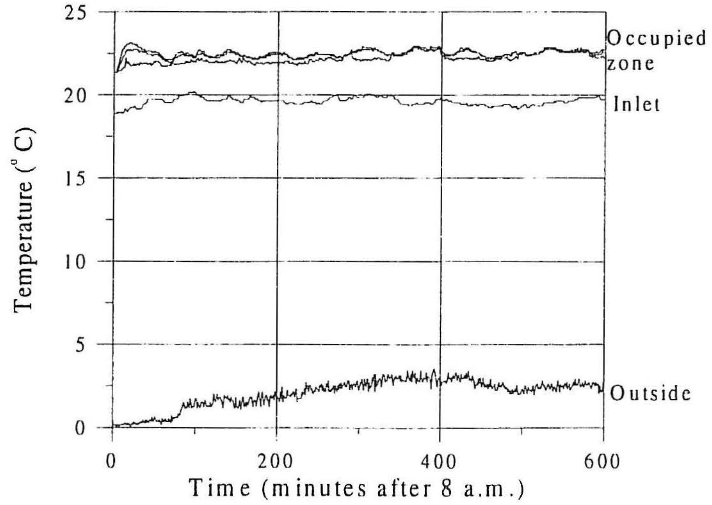

Figure 7 Field measurements, March, 1997

Figure 7 in comparison with Figure 4 shows a significant reduction of the temperature gradient in the occupied zone. Yet it is not reduced to be approximately zero as in the mock-up because the air flow was only 80% of the prescribed value. Still, the temperature distribution, the tracer gas measurements (1) and the air velocities in the room, were satisfactory. When the air flow is increased to 100% the supply jet will not drop down into the occupied zone in the summer case.

DISCUSSION

Both the field measurements and the laboratory measurements clearly shoved that an air supply upwards along one out of more windows can not give acceptable indoor conditions without radiators mounted below each window. Even with radiators below each window this type of air supply may be problematic with the actual heat loads in a typical office. It is necessary to choose a reduced air supply temperature to assure a sufficient heat flow from the radiators at lower outdoor temperatures to prevent down-draught from the windows. Then, however, the supply jet may drop down into the occupied zone. Especially at lower surface temperatures on the inside of the window the supply air jet is cooled and will drop down in many cases where an isothermal window would not cause any problems. Therefore this kind of air supply can not be recommended without full-scale measurements.

ACKNOWLEDGEMENTS

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