The Effect of Heat Source Elevation on Ventilation Effectiveness

Hautalampi T[1], Sandberg E [2], Koskela H [1]
[1]Finnish Institute of Occupational Health, Turku, Finland
[2]Satakunta Polytechnic, Technology, Pori, Finland

Introduction

This study is a part of a research project called 'Convective Flows and Vertical Temperature Gradient within Active Displacement Air Distribution'. The project and the two zone model developed have been introduced by Sandberg (1). The aim of this study was to examine the ventilation effectiveness with different elevations and horizontal positions of the heat sources within active displacement air distribution. This was studied by carrying out experiments using convective heaters and ordinary fluorescent tube lamps at several elevations as heat sources.

The influence of the lamps is an important factor, because in most of the practical installations their effect is considerable. The measurements were carried out by varying the level of the lights and the subtemperature of the supply air. Two types of air distribution were used, the air distribution upwards (=nozzles in a 240° sector on the surface of the device) and the all around (=nozzles in a 360° sector).

The effect of the placement and the number of the convective heaters were examined with the air distribution upwards and the constant air flow rate. The air flow rate of the undisturbed convector plume was measured and modelled earlier (4).

Methods

Measurements were done in a test room built for this project. Two supply air units were located symmetrically in the room at the height of 3 m. The exhaust air was taken through a perforated plate located in the middle of the ceiling. Both the supply and exhaust air temperatures and the temperature gradient in the room were measured with thermistors. Tracer gas experiments (2) were carried out with convective heaters in all the cases tested. The temperature effectiveness and the local ventilation index in the lower zone were calculated from the measurement data using basic formulas (3).

The plan view of the placement of the lamps and supply air devices can be seen in Figure 1. The lamps were tested at the levels of 2.5, 3.0 and 4.0 m using 240° and 360° nozzle sectors and two supply air flow rates (10 Pa and 40 Pa static pressure).

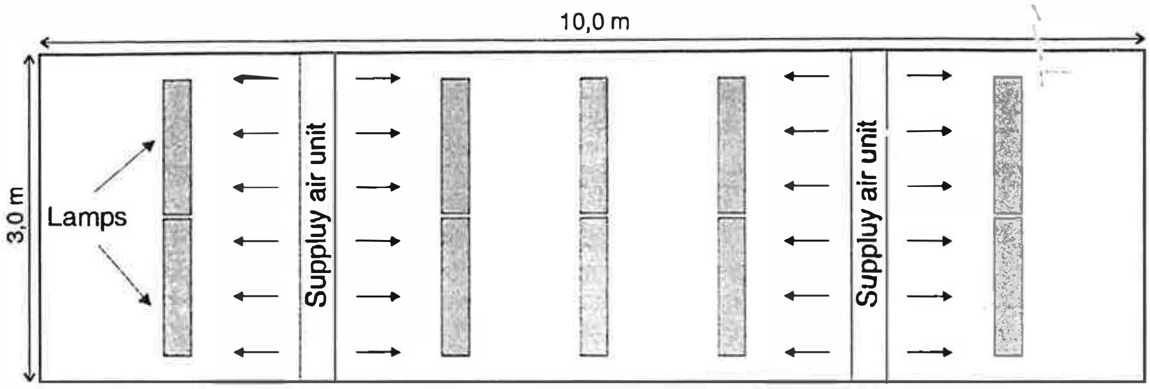

Figure 1. Plan view of the placement of the lamps

The side projection of the placement of the convective heaters in different test cases can be seen in Figure 2. Heaters were placed in the middle plane of the test room. In cases a, b, c and e the total heating power was 900 W. In case d the test was run using a total power of both 900 W and 1800 W. The subtemperature of supply air varied between 2 and 7 °C. All the tests of the convective heaters were carried out with the supply air flow rate of 240 l/s and using a nozzle sector of 360°.

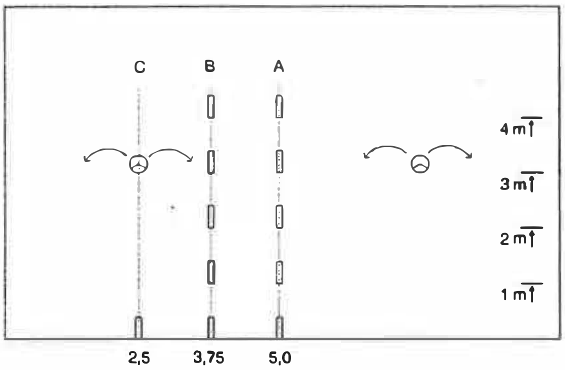

Figure 2a. The placement of the convector in test cases a, b and c (1 heater)

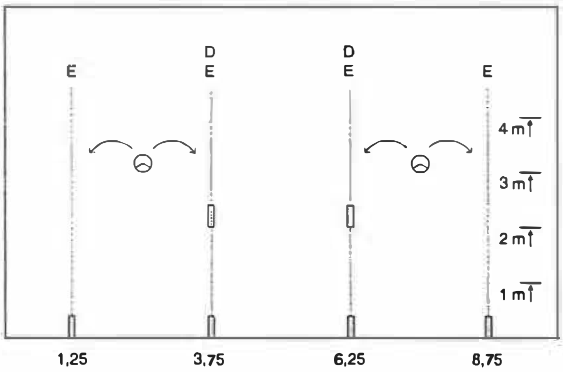

Figure 2b. The placement of the convectors in test cases d (2 heaters) and e (4 heaters).

The model for the air flow rate of the convector plume without temperature stratification was determined in earlier studies (4) with a convector placed on the floor. The plume air flow rate in a case without any disturbances can be calculated according to Equation 1. $q(z) = 5.6 \sqrt[3]{P_c}\,(z + z_{virt})^{5/3}$ (1)

where z_{virt} is the location of the virtual origin and P_c is the convective power. If a heater is replaced by two heaters and the same total convective power is used, the total air flow rate of the plumes increases almost 60 %. If the heater is moved to a higher position the total plume air flow rate is strongly reduced. The plume air flow rates are in actual cases affected by the supply air flow patterns. Therefore, the plume air flow rates and ventilation efficiencies can not be estimated by using formulas developed for undisturbed plumes.

Results

The results of the lamp tests are presented in Figure 3. The temperature effectiveness increases when the lamps are mounted in the upper part of the room above the supply air devices. The effectiveness was also better with 360° than with 240° nozzle sector units. A low supply air flow rate generates good effectiveness values.

The values of measured efficiencies with convectors are presented in Figure 4. The temperature effectiveness increases when the convectors are mounted on a higher level due to smaller plume air flow rates.

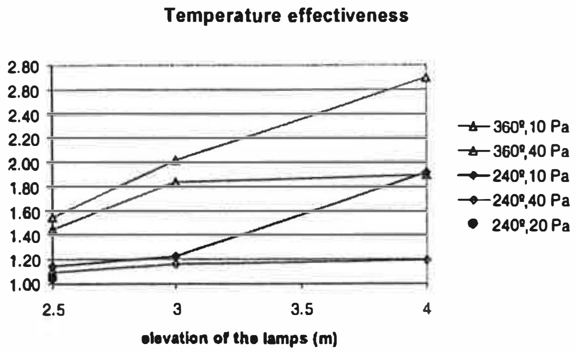

Figure 3. The temperature effectiveness vs. elevation of lamps

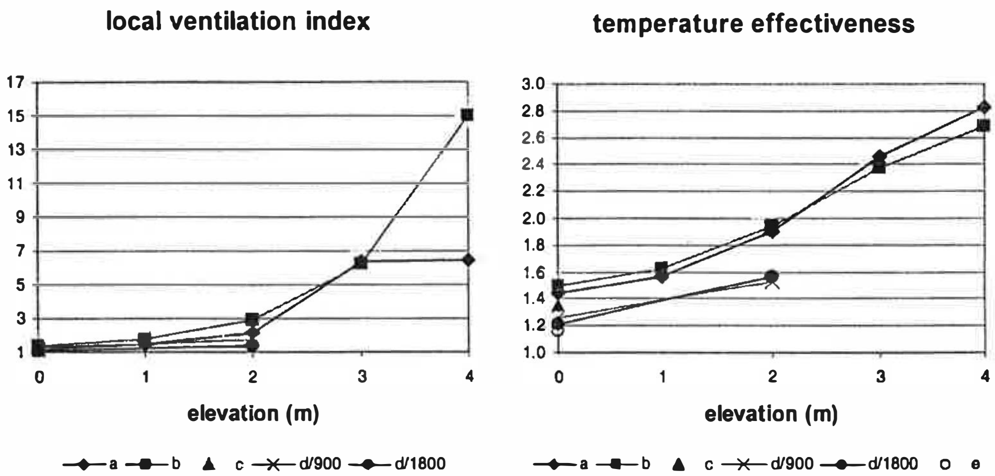

Figure 4. Measured temperature effectiveness and local ventilation index in the lower zone with convective heater.

The smallest values of temperature effectiveness were measured when they were placed under the supply air unit, where the effect of the supply air flow pattern on the plume is strongest. When the total heating power was divided among two or four convectors, the temperature effectiveness values were reduced. This was caused by an enlarged total plume air flow rate, when the return air flow across the boundary level back from the upper zone to the lower zone is increased.

The temperature effectiveness values were smaller than the local ventilation index values because of the influence of the radiation of the surfaces. The index values in the cases a, b and c were larger than in other cases. The largest values were found in case b. In case d the index was better with a smaller power of the heater.

Discussion

The ventilation efficiencies were increased when the heat loads were moved to a higher position and decreased when the same total convective power was divided among several heaters. Also, the effect of the supply air flow pattern to the ventilation efficiencies was significant. When the lamps were placed 1,0 m above the supply air units, the values of the temperature effectiveness increased considerably with low supply air flow rates. For example, with a 240° nozzle sector and a 10 Pa static pressure raising of one meter increased the effectiveness by 55 %. With larger air flow rates the impact on effectiveness was rather insignificant. With the same 240° duct unit and a 40 Pa static pressure, the effect was only 3 %. The supply air flow still effected the plumes of the lamps and the values would have improved if the lamps had been mounted higher above the supply air devices. To accomplish good effectiveness values, it is recommendable to mount the lamps above the supply air flow pattern.

If the convective heat sources are placed in the upper part of the room, a good ventilation effectiveness can be achieved. In practice, heat sources are often mounted on the floor level. However, it is essential to know the impact of the the horizontal location of the heat sources. Dividing the same total power among several heat sources weakens the temperature efficiency. This is due to the increased total plume air flow rate.

Acknowledgements

The financial support of the Technology Development Centre Finland is greatly appreciated.

References

1. Sandberg, E., Koskela, H. and Hautalampi, T. (1998) Convective Flows and Vertical Temperature Gradient with the Active Displacement Air Distribution, Proceedings of Roomvent '98. Stockholm, Sweden
2. Koskela, H., Hautalampi, T., Sandberg, E. and Lindgren, M. (1998), Test Room and Measurement System for Active Displacement Air Distribution, submitted to Proceedings of Roomvent '98. Stockholm, Sweden
3. Ethridge, D. and Sandberg, M. (1996) Building Ventilation: Theory and Measurement. John Wiley & Sons, Chichester.
4. Hautalampi, T., Sandberg, E. and Koskela, H. (1998) Behaviour of Convective Plumes with Active Displacement Air Flow Patterns, Proceedings of Roomvent '98. Stockholm, Sweden