#4473

ROOM AIR DISTRIBUTION AND VENTILATION EFFECTIVENESS IN AIR CONDITIONED OFFICES

P.J.Jones
Welsh School of Architecture (R&D)
University of Wales College of Cardiff
P.O.Box 25
Cardiff
CF1 3XE

This paper describes some problems associated with room air distribution in offices and discusses the use of computational fluid dynamics (CFD) techniques as a means to improve this aspect of environmental design.

INTRODUCTION

Recent sick building syndrome (sbs) surveys carried out in air conditioned offices in the UK [1] have indicated that ventilation effectiveness is often unsatisfactory with fresh air ventilation rates below recommended levels. Ventilation effectiveness is an indication of the efficiency with which fresh air is supplied to the occupied region of a space, and it is dependent on room air distribution which in turn is sensitive to varying heating/cooling loads, type and positioning of diffusers and office scenery. There is a need to understand the effect of these variables on room air distribution in order to successfully engineer satisfactory office environments.

This paper first summarises the results from a number of sbs surveys relating to room air distribution and ventilation effectiveness. It then discusses the use of computational fluid dynamics (cfd) techniques to simulate the room air distribution in an air conditioned office taking account of variations in heating/cooling loads and Furniture layout.

ROOM AIR DISTRIBUTION IN OFFICES

The air in the occupied zone of an office should be comfortable in terms of its physical parameters (ie. Temperature, velocity and relative humidity), and be of good quality in terms of pollutants being kept below recommended levels.

Room air distribution in air conditioned offices is determined by a number of factors:

(i) temperature and velocity of the supply air
(ii) type of air conditioning system
(iii) position and type of supply diffusers and extracts
(iv) room geometry, office Furniture and scenery
(v) heat gains and losses of the space

The aim of air-conditioning is to dilute or displace the air in the space with supply air which contains a proportion of fresh air. The temperature and velocity of the supply air should be controlled to produce air in the occupied zone to be within a comfortable temperature (and sometimes humidity) range without causing draughts.

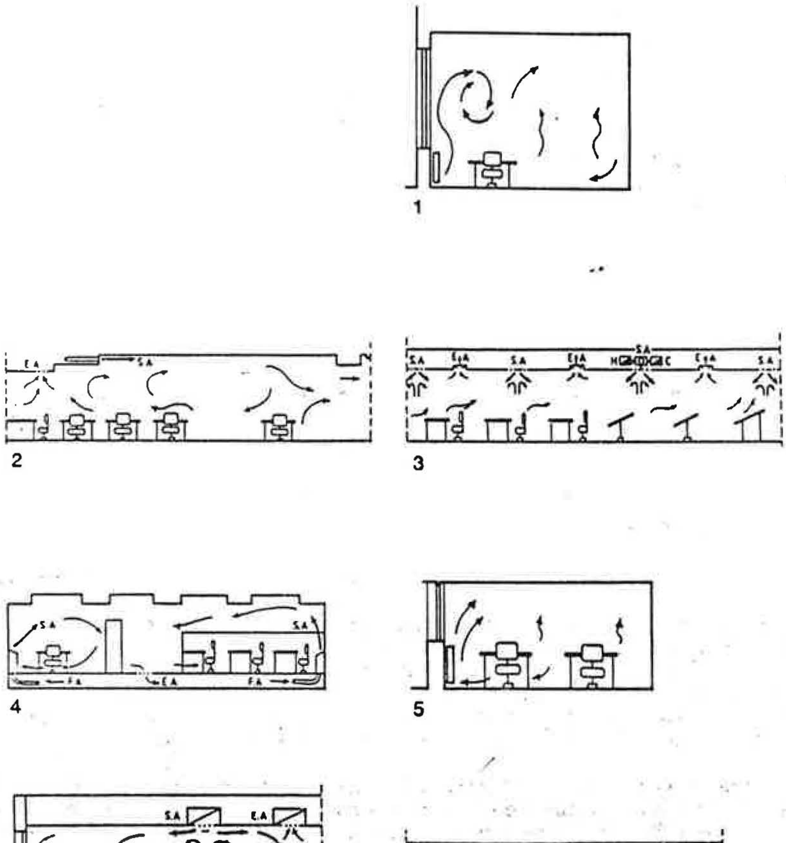


Figure 1 : Room air distribution for 9 case studies

The most common form of air conditioning in the UK is the dilution type of system, which supplies air to the space at an appropriate temperature and velocity, and to entrain air from the space thus providing satisfactory conditions in the occupied zone. Typical problems arise with a VAV (variable air volume) system in a summer cooling situation when the supply air speed is too high resulting in draughts. Conversely, in a winter heating situation, problems arise when the supply air is controlled such that it has a low velocity and is almost isothermal in relation to the room air temperature. This can give rise to short circuiting between the supply and ceiling extract.

Because the room air distribution is dependant on factors (i) to (v) above it is likely to be quite different from building to building, even if similar systems are used. This point was well illustrated by the 9 case studies [1] presented in Figure 1 (1 and 6 being naturally ventilated). The figure

illustrates schematically the main airflow characteristics of each space through a typical vertical section based on air speed measurements and smoke flow visualisation. The physical parameters that affect thermal comfort were measured in each office over a two week winter period. The average air temperatures and speeds recorded at seated head height positions, together with the estimated fresh air ventilation rates, calculated from (Carbon Dioxide) are presented in Table 1. These results show a general trend in air conditioned offices to be warm, often with low air speeds (sometimes with localised draughts), and low ventilation rates especially for spaces where smoking is permitted.

Table 1 : Summary of results from 9 Case Studies.

Type of system	Air temperature (degC)	Air Velocity (range -m/s)	CO2 Level (ppm)	Ventilation Rate (ac/hr)
1 NV	19.9	0.10-0.14	1134	0.6
2 VAV	21.6	0.06-0.16	693	2.4
3 MV	22.2	0.11-0.42	601	2.7
4 FCU	23.4	0.04-0.14	613	2.5
5 NV	22.6	0.11-0.22	1152	0.9
6 CAV	21.7	0.11-0.36	375	4.0
7 VAV	21.6	0.11-0.43	687	1.4
8 PHP	22.3	0.12-0.56	639	2.7
9 IU	21.9	0.06-0.09	501	2.5

NV - Natural ventilation ; VAV - Variable air volume ; FCU - Fan coil units
CAV - Constant air volume ; PHP - Perimeter heat pumps ; IU - Induction Units
MV - Mechanical ventilation

A recent case study on an office building where there were complaints concerning the thermal environment identified short circuiting between supply and extract as a cause of poor ventilation effectiveness. Figure 2 presents carbon dioxide levels for an office space where air was supplied from ceiling fan coil units and extracted via the plenum a proportion being recirculated. The plot shows that the carbon dioxide levels in the extract are significantly lower than in the space, indicating short circuiting between the supply and extract. Levels in the occupied space are high for an air conditioning system in comparison with the case study levels presented Table 1.

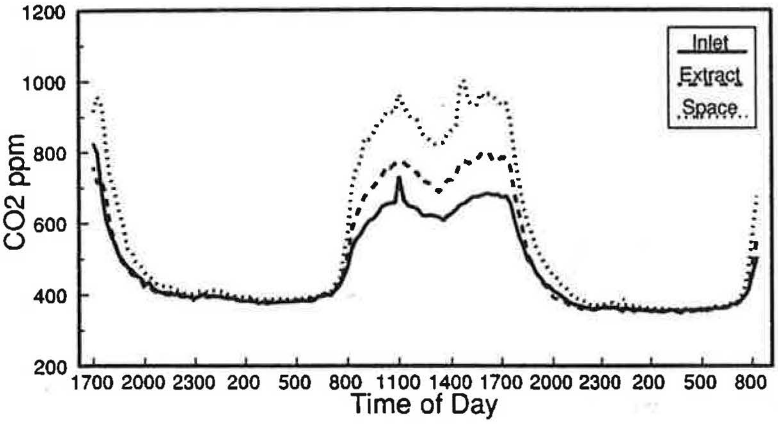


Figure 2 : Carbon dioxide levels in an office indicating short circuiting between supply and extract.

CASE STUDY SIMULATIONS

CFD techniques can be used during design to predict airflow and temperature distribution in 3-dimensional space and there are a range of commercial codes available based on solving the Naviar Stokes equations on a grid of cells that define the room geometry and the space contained [2]. Furniture and other objects can be represented on the grid by blocking the relevant cells. Heat gains and losses and sources of momentum, eg. air from diffusers, can be simulated.

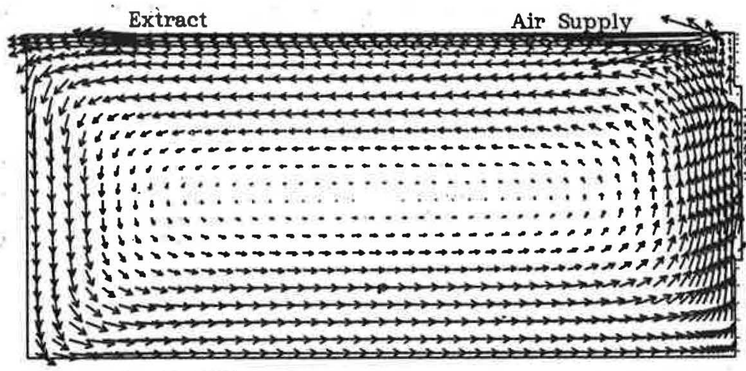
Two case studies are presented below to illustrate how the techniques are being used to investigate room air distribution in relation to the type of problems outlined above.

(i) Summer/winter room air distribution

Room air distribution can be sensitive to the heat load in the space, which will differ from summer to winter. Figure 3 presents the summer and winter airflow patterns for an office with a VAV system. The office is a small cellular office situated in what is largely an open plan development. Figure 3(a) indicates that during summer cooling the supply jet may cause draught problems when it hits the opposite wall. Figure 3(b) presents a typical low speed isothermal situation in winter, with the danger of short circuiting between the supply and extract and also some cold downdraught at the window which could give rise to thermal discomfort. This example illustrates the sort of problems that can arise for a space which has a variable heat load over time.

(ii) Perimeter heat pump

Figure 4 presents a simulation based on the Case Study 5 in Figure 1. It contains a vector plot of velocities in a vertical plane containing a perimeter heat pump and a ventilation from a ceiling bulkhead supply. Furniture is included in the simulation by blocking off cells in the solution domain. This type of prediction illustrates the relatively high velocities obtained in the space as a result of the interaction of the two opposing flows. It also shows the effect of Furniture blocking air flows at lower levels and creating stagnant areas, eg. to the right of the cupboard.



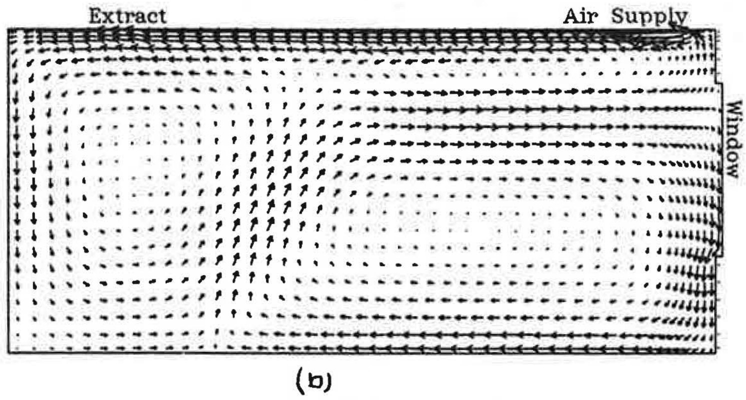


Figure 3 : Room air distribution, (a) summer (b) winter.

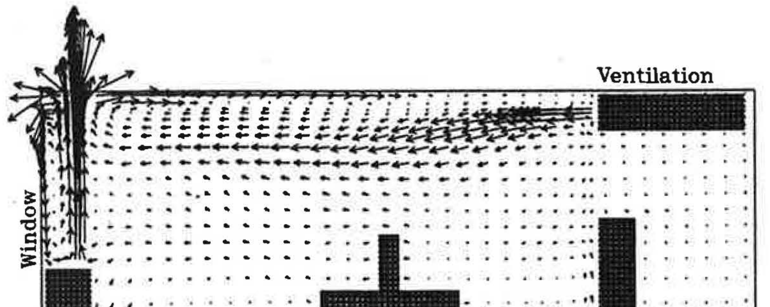


Figure 4 : Perimeter heat pump with separate ventilation.

CONCLUSION

Room air distribution is probably one of the least understood aspect of environmental design, and poor air distribution is often associated with offices that suffer from high levels of sbs and complaints of thermal discomfort..

The main problems that arise in air conditioned offices due to poor room air distribution include low fresh air ventilation rates, complaints of draughts, complaints of lack of freshness and inefficient heat distribution.

CFD techniques provide a useful tool for the design of room air distribution. They can be used to predict room air distribution, taking account of variable heat loads, Furniture, room geometry and type of system. They can also be used predict concentrations of pollutant such as CARBON DIOXIDE and current work is underway in this area.

ACKNOWLEDGEMENTS

The cfd code used for the simulations is the property of Design Flow Solutions, 4 Church End, Arrington, Herts, UK.

REFERENCES

1. Wilson S, O'Sullivan PE, Jones PJ and Hedge A (1988) Sick Building and Environmental Conditions: Case studies of nine buildings, Building Use Studies, London.

2 Whittle GE (1990) A Review of Airflow Models for Application to Buildings, Report to DEn (ETSU).