Implementing the Results of Ventilation Research
16th AIVC Conference, Palm Springs, USA
19-22 September, 1995

Trickle Ventilators: Effective Natural Background Ventilation for Offices

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SYNOPSIS

Approved Document (AD Part F1) of the Building Regulations [1] for England and Wales identifies trickle ventilators as an option for providing natural background ventilation in commercial buildings. This paper reports the results of a field measurement study carried out at BRE during the winter of 1994/95 to assess the effectiveness of trickle ventilators. Two occupied office rooms were equipped with trickle ventilators and measurements were carried out for a fortnight period in each office, with the ventilators closed during the first week followed by a week with them open. Internal and external parameters of significance were monitored including level of metabolic CO_2 within the rooms, draught speeds near the ventilators and occupancy.

The study has confirmed results of a previous modelling study [2] which showed that trickle ventilators of sizing given in the AD Part F1 provide adequate background ventilation of about 5l/s per person in typical UK offices. Furthermore, it has also confirmed the results of an earlier laboratory study [3] where it was shown that for average and high occupancy (8-10m^2 per person) trickle ventilators with similar sizing were capable of providing the fresh air required to maintain CO_2 levels at or below 1000ppm (which equated to about 5l/s per person) for average UK external weather conditions.

In conclusion, the present field study *in occupied offices* has shown that trickle ventilators of suitable design and openable area of 400mm^2 per m^2 (of floor area), as advocated in AD Part F1, are effective in providing adequate background fresh air in UK offices during the heating season without creating occupant discomfort.

INTRODUCTION

The new Approved Document Part F1 (Ventilation) of the Building Regulations [1] which have come into force in July 1995 requires that all offices in new build commercial buildings are provided with background ventilation. Guidance is that this is provided via openings having a total area of at least 400mm^2 per m^2 of floor area. Trickle ventilators are a common means of providing this degree of ventilation and the revised Regulations are likely to make the use of these devices more widespread.

Trickle ventilators consist of slot ventilators located either in the window frame or incorporated into the window pane. In the latter, the ventilator has a flange of the same thickness as the glass and lies in the same plane forming a structural part of the glazing. Trickle ventilators are also frequently provided with a damper mechanism which allows user control of the ventilation opening and usually comprises of an adjustable plate mounted in front of the slot. This configuration deflects incoming air vertically upwards or downwards from the ventilator.

This paper describes the third stage of a research project to assess the effectiveness of trickle ventilators to provide adequate and controlled background ventilation in office buildings during the heating season.

Previous Work

In 1992, a study [2] using a multi-zone air flow prediction computer program, BREEZE [4], was carried out to assess whether the inclusion of permanent and controllable background trickle ventilators could provide adequate background ventilation in commercial buildings. The study recommended that 4000 mm^2 open-area ventilators be used in rooms with floor areas less than 10 m^2, or 400 mm^2 per m^2 (of floor area) for those which were larger.

Following on from this, a full scale laboratory study [3] was carried out in the heating season of 1993/94. This was done in two deep-plan office rooms with a depth of 7.5m and an area of approximately 26 m^2. One room was used as a control while the other was fitted with a trickle ventilator, (with opening area of 10 500 mm^2, corresponding to 400 mm^2 per m^2 of floor area) fixed to its main south facing window. Varying levels of occupancy were simulated in both rooms by constant CO_2 injection (to simulate metabolic rate) and heat sources (lamps). Internal measurements included the monitoring of CO_2 levels, air velocity and temperature as well as the ventilation rate using the SF_6 tracer gas decay technique. External measurements included wind velocity, wind direction and temperature.

The study concluded the following:

(a) Trickle ventilators with a minimum openable area of 400 mm^2 per m^2 (floor area) can provide adequate fresh air during winter in a typical office room (located in a suburban site) with maximum occupancy density of 8 m^2 floor area per person.

(b) Cold draughts did not appear to be a problem either at desk or head levels at distances up to 2 m from the ventilators. Measured velocities were well below the accepted threshold of 0.3 m/s for discomfort. However, velocities measured at ankle height were found to be somewhat higher averaging at about 0.5 m/s. While this could cause discomfort, good ventilator design could correct it.

(c) Long term CO_2 monitoring could be used as a marker of indoor air quality in naturally ventilated buildings in the same way it is used for mechanical ventilation systems. No significant variation in CO_2 concentration levels was found with varying heights thus indicating good internal mixing of fresh air.

The above conclusions have indicated that trickle ventilators can be effective in offices. To obtain confirmation of this in the field, measurements were made in two occupied office rooms equipped with trickle ventilators. Monitoring was made during the winter of 1994/95.

EXPERIMENTAL ROOMS AND EQUIPMENT USED

Office A is cellular, with single-sided ventilation and situated on the first floor of a four storey building with a floor area of 12.5 m^2 (3.5 m x 3.6 m). Using the criteria of 400mm^2 per m^2 of floor area, a trickle ventilator with a 5000 mm^2 openable area was fitted to the west facing single glazed window at a height of 2.4 m above floor level. The spinal corridor running outside of this office is 25 m long and 1.8 m wide, is fitted with fire doors at either end and none of the office doors are opposite one another . Ventilation is therefore single-sided and through the windows in each of the offices.

Office B is situated on the ground floor of an one storey building with a floor area of 16 m^2

(4.2 m x 3.8 m). A trickle ventilator with a 7000 mm^2 openable area was fitted using the same criteria as in office A. The ventilator was also placed 2.4 m above floor level and fitted to an east facing single glazed window. The corridor running outside of this room is 12 m long and 1.8 m wide, and, as before, fitted with fire doors at either end. However, unlike that for office A, all of the office doors within this corridor are opposite to one another. During the experiment, occupant in office B kept the corridor door to the corridor open most of the time, while the occupant opposite did the same. Therefore the ventilation flow in office B was generally through cross ventilation.

The following measuring equipment were used in each room:

1) Two ultrasonic anemometers to assess possibility of cold draughts leading to occupant discomfort. One of these was set at desk height (~ 1.5 m above floor level), and the other at ankle height (approximately ~0.25 m above floor level). The anemometer loggers were programmed to measure air velocity in the three x-y-z directions, at intervals of 15 min.
2) Two electrochemical CO_2 sensors to measure the effectiveness of the trickle ventilator to provide the required fresh air. One was placed within the room at approximately 1.75 m above floor level. The second was placed in the corridor and attached to the door frame by a bracket at 2 m above floor level. Data was collected at 15 min intervals.
3) A humidity/temperature sensor: The temperature was measured to assess any discomfort associated with cold air coming through the ventilator. The humidity reading was used as an indicator for calibrating the CO_2 sensors since low humidity were found to affect the range parameters of these instruments.

All equipment used within anyone room were mounted on a stand positioned in each office approximately 1 metre from the window. In addition, a micro-switch was fitted to the door frame and measured when and for how long the door was opened or shut. A questionnaire was provided to the office occupant for completion on a daily basis to note occupancy levels, whether the window was open or shut and whether internal window blinds were either up or down. Outside weather information of wind speed, direction and air temperature were also monitored.

Monitoring was carried out for two weeks in each office; with the ventilator closed during the first week and opened during the second week. A week prior to testing, the equipment stand was placed 2 m from the window (windows shut, ventilators open) in the offices to compare air velocity values. During monitoring the stands were moved to 1 metre from the windows.

RESULTS AND DISCUSSION

Internal air velocity

Air velocity was measured at desk and ankle height at 1 m and 2 m away from the window with the trickle ventilators. Previous laboratory measurements have shown that cold draughts at ankle height could cause discomfort. For this reason, air coming through the ventilators was directed upwards by positioning deflector vanes. All the measurements then made showed

(Figure 1) that the air velocities within the rooms were significantly lower than 0.3m/s, the value usually considered as the upper limit above which discomfort is likely to be felt by draughts during the heating season [5]. A further confirmation was that the occupants did not report any complains concerning cold draughts.

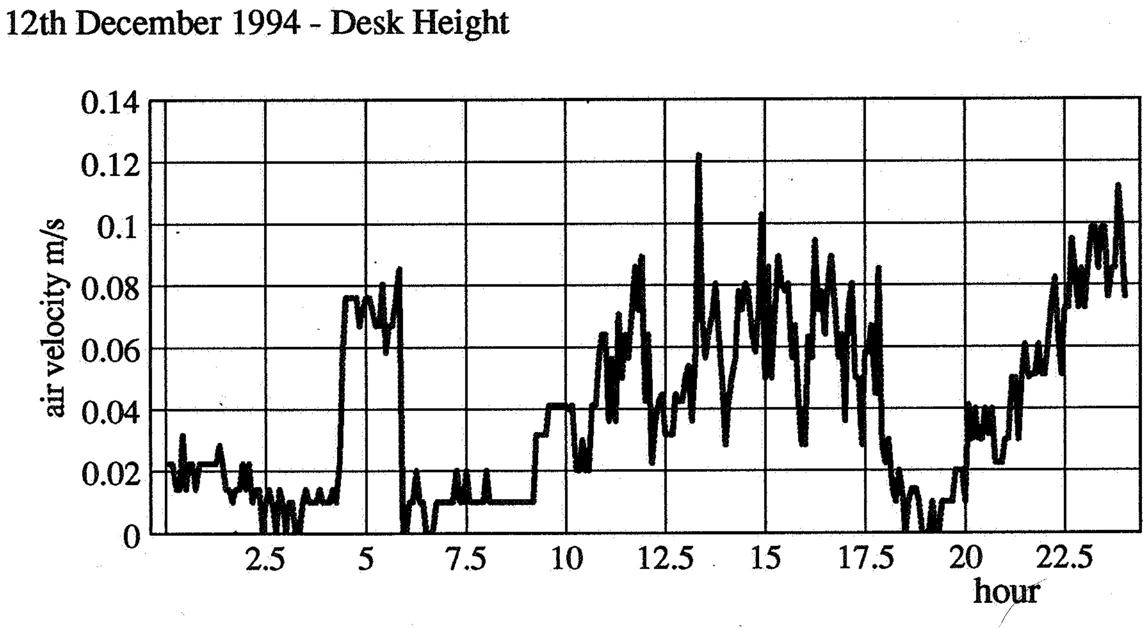

Figure 1A: Internal air velocity at desk height with the trickle ventilator open

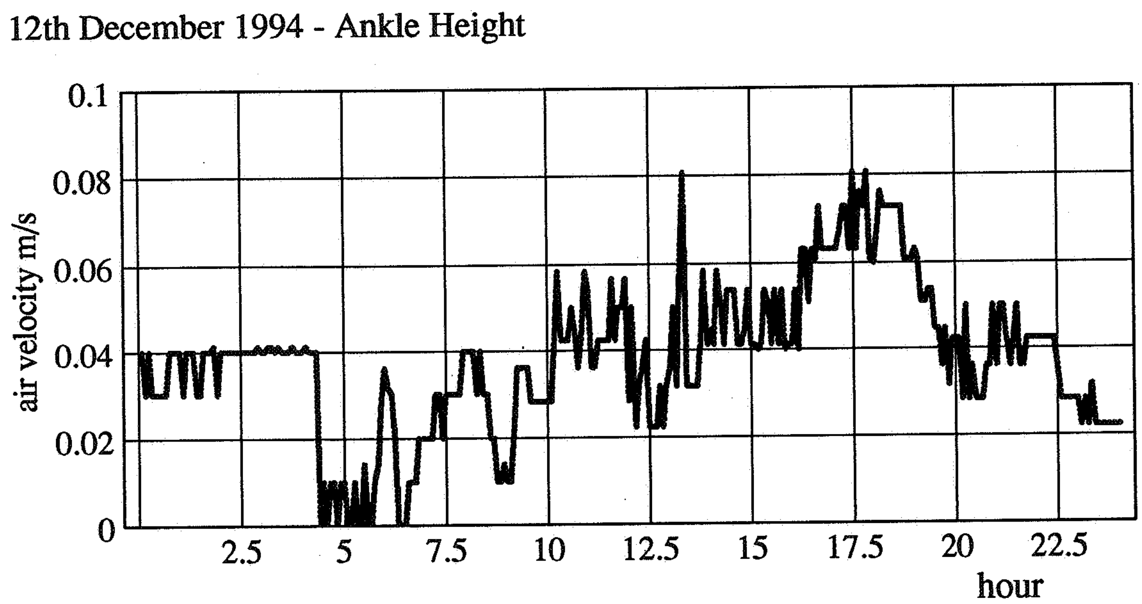

Figure 1B: Internal air velocity at ankle height with the trickle ventilator open

Carbon dioxide

The CO_2 levels recorded in both occupied offices have reconfirmed the findings of the laboratory study which had shown that CO_2 did not exceed 1000ppm when the correct sized ventilator was used for the occupancy of the office. It should be noted that a level below 1000 ppm of CO_2 in an occupied conventional office room indicates a fresh air inflow of about 5 l/s per person [6]. When the ventilators were closed, the CO_2 level was higher and reached that found in the corridors. Figure 2 shows the CO_2 levels recorded for the two monitored weeks in office A and the levels in the corridor outside the office.

It can be seen that during the first week (Fig 2A) the levels in the room and corridor follow each other fairly closely, rising to a peak of approximately 1400 ppm on Thursday. The office was unoccupied on Friday so the room peak level is much lower at about 800 ppm. Apart from the Friday when the room was empty in the afternoon, the CO_2 levels in both corridor and room exceed the 1000 ppm limit. During the weekend, both levels drop to the outside level of about 350-400 ppm. They begin rising again on Monday reaching a peak of ~1100 ppm.

On Tuesday of the second week, the vent was opened about 12 noon, and the room level begins to fall off from a peak of 900 ppm. The corridor level reaches a peak of 1300 ppm. During this second week (Fig 2B), the CO_2 levels within the room were well below the corridor levels. The overall peak recorded for the corridor was in the region of 1600 ppm. During the week when the office was occupied by one person the peak levels did not in any instance exceed 1000 ppm, indicating a fresh air ventilation rate of about 5 l/s per person. However, on the Friday during this phase of the experiment, the peak within the office reached ~1400 ppm arising from increased occupancy (three people) because of a meeting held in that room during the afternoon.

Temperature

Internal air temperatures were very similar in all cases. Figure 3 presents the results for two weeks in office A. It can be seen that although the outside temperatures was much colder during the second week (ventilator open), the internal temperatures were maintained at the same level during both weeks. The following table shows the average temperature inside and outside during both weeks:

	First Week	Second Week
T_{int} (average)	16.8 ^{0}C	15.7 ^{0}C
T_{ext} (average)	10.0 ^{0}C	3.8 ^{0}C

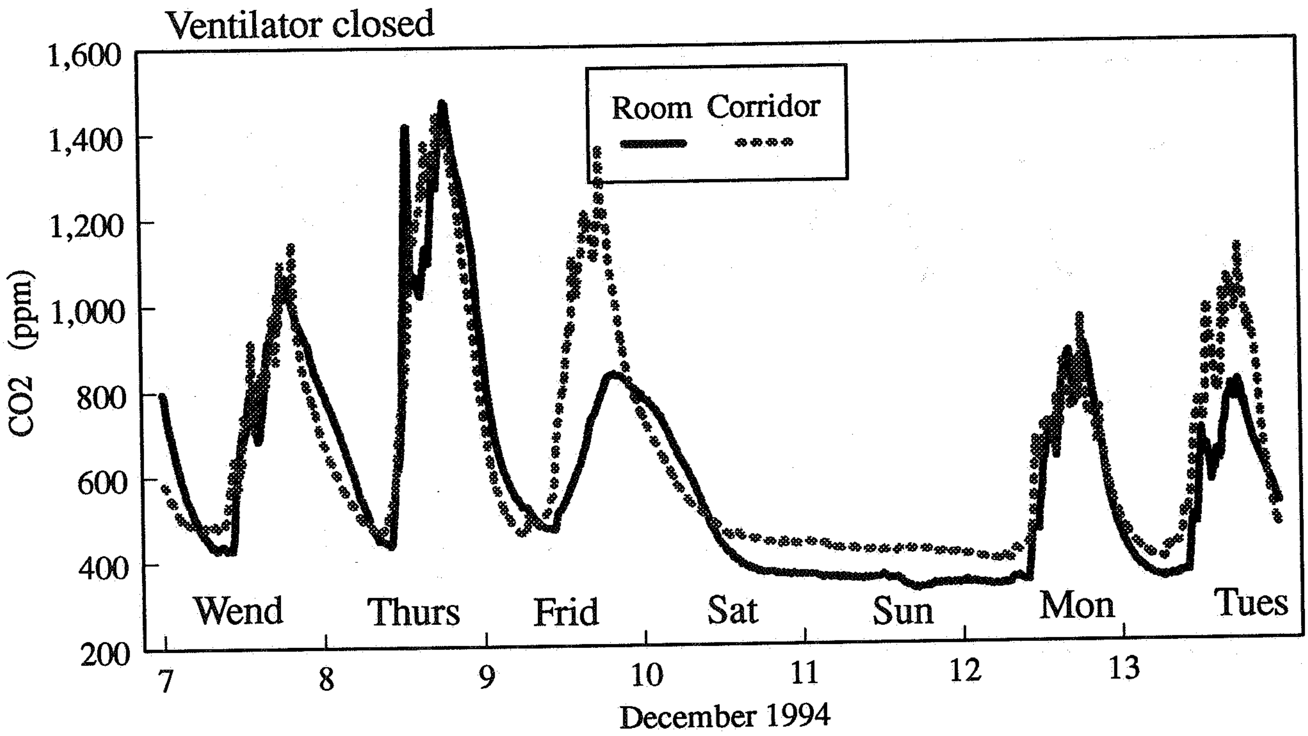

Figure 2A: CO_2 levels in office A and corridor with the trickle ventilator closed

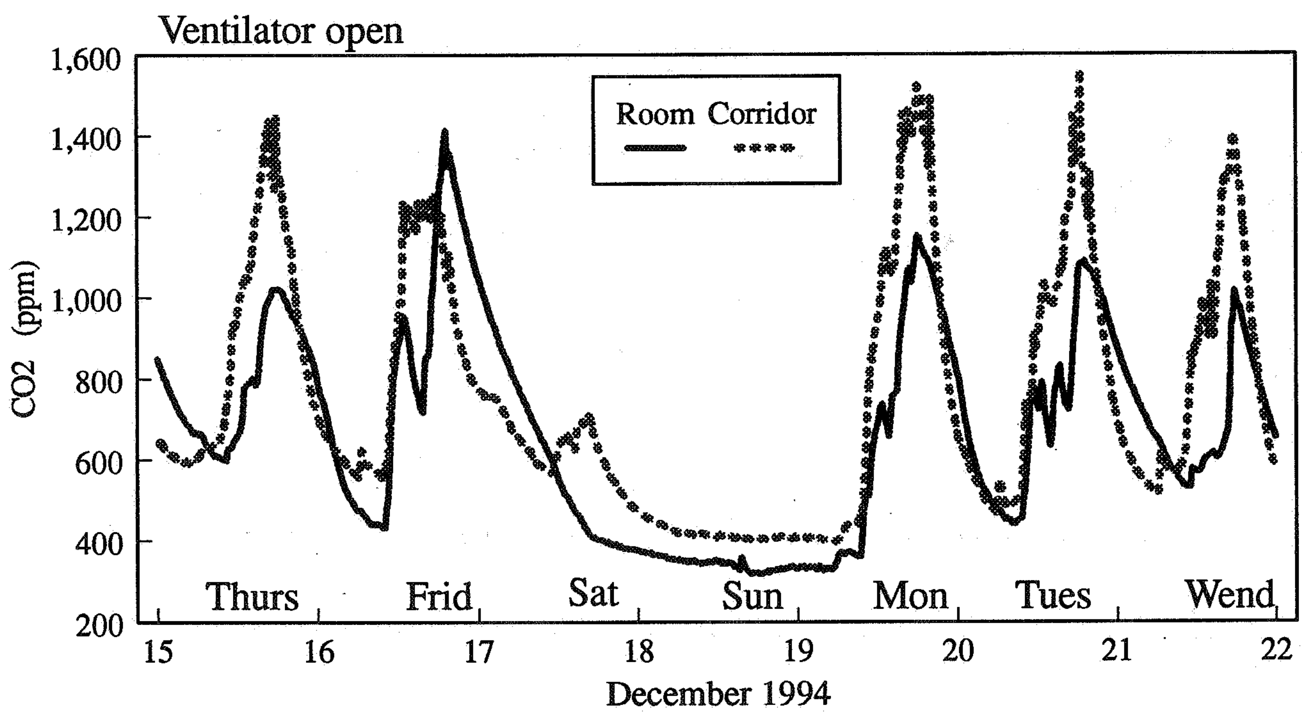

Figure 2B: CO_2 levels in office B and corridor with the trickle ventilator open

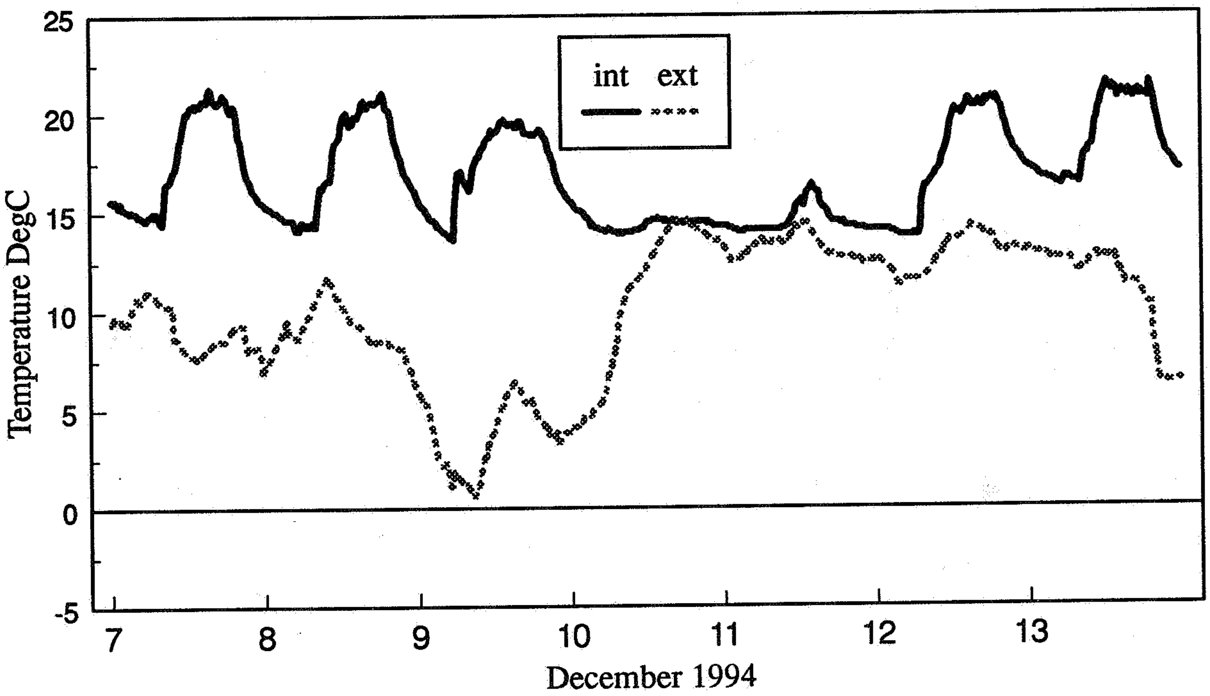

Figure 3A: Internal and external temperature with the trickle ventilator closed

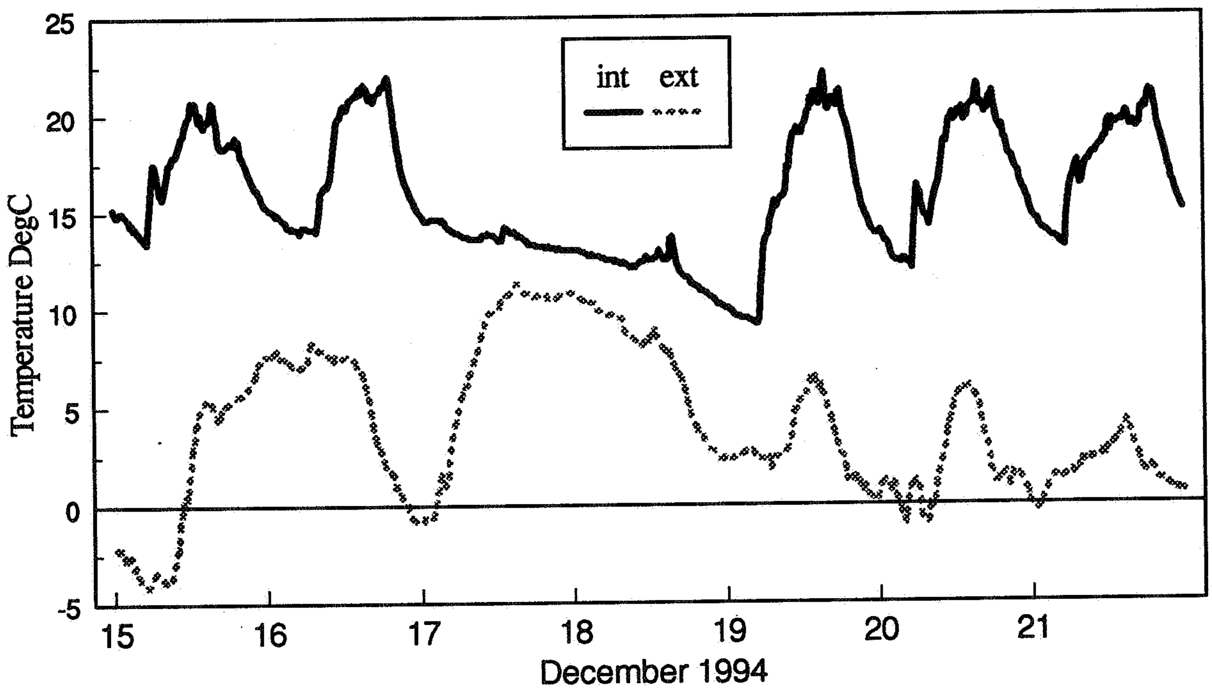

Figure 3B: Internal and external temperature with the trickle ventilator open

CONCLUSIONS

There are four main conclusions:

(a) Trickle ventilators with a minimum openable area of 400mm^2 per m^2 (of office floor area) can provide adequate fresh air during winter and maintain good IAQ (using CO_2 as the surrogate indicator) within a typical office room located in a suburban site.

(b) Maximum metabolic CO_2 levels in Office A were maintained below 1000 ppm when the occupancy of the office was one person with the ventilator open, indicating a fresh air ventilation rate of about 5l/s per person. Transient increased occupancy increased this level but was quickly restored to normal levels when normal occupancy (of one) resumed. It is interesting to note that this level fell rapidly rather than the slower natural decay as is observable when the offices are left for the night. This is most likely due to the increased ventilation (by opening windows and doors) usually undertaken after a space has been occupied at levels higher than normal occupancy.

(c) Ventilators of poor design, positioned incorrectly and with unfavourable external weather conditions may produce cold draughts. However, cold draughts do not appear to present problem either at desk or ankle height during these field tests. This is probably due to the choice of ventilator which projected incoming air upwards. Measured internal velocities were significantly below the accepted draught threshold of 0.3m/s.

(d) Internal temperature was maintained during the week that the ventilator was open even though there was a significant fall in the external temperature.

Therefore, to conclude, ventilators with adequate sizing and correctly positioned, can provide comfortable and sufficient ventilation for occupants.

REFERENCES

1. The Building Regulations 1995, Approved Document F1, "Means of Ventilation", HMSO, 1994

2. Perera M D A E S, Marshall S G and Solomon E W, "Controlled background ventilation for large commercial buildings" Building Serv. Eng. Res. Technol., 14(3) 81-86, 1993

3. Kolokotroni M , Perera M D A E S and Marshall S G, "Effectiveness of trickle ventilators in providing adequate fresh air in commercial buildings during the heating season", Indoor Air Quality, Ventilation and Energy Conservation in Buildings, 2nd International Conference, Montreal, Canada, May 1995

4. Building Research Establishment, BREEZE 6.0, 'User Manual', Garston, BRE, September 1993.

5. Chartered Institute of Building Services Engineers (CIBSE) Guide A1, "Environmental criteria for design", 1978, London, CIBSE, (reprinted 1986)

6. Perera E and Parkins L, "Build Tight - Ventilate Right" Building Services, pp37-38, June 1992.