Night cooling is a viable technique in the UK, but there is no suitable commercially available equipment. The BRE has been testing prototype ventilators and concludes that they work although weather, security and acoustics issues need to be addressed.

BY BRIAN WEBB AND PETER CONCANNON

In the cool of the night

BRE publications are available from CRC Ltd, 151 Rosebery Avenue, London EC1R ODA. Telephone: 0171-505 6622. Up-to-date details about BRE events and publications are also available from the World Wide Web on URL http:// www.bre.co.uk

References

[1]Blyth A, "Refurbishment: curtain walling provides for natural cooling", *The Architects' Journal*, 10 August 1995.

[2]Webb B C and Kolokotroni M, "Night cooling a 1950's office", *The Architects' Journal*, 13 June 1996.

[3]OFAR, "Ongoing UK activities", IEA Annex 28: Low energy cooling system, Newsletter 02, January 1995.

Brian Webb is with the Building Research Establishment. Peter Concannon is with Oscar Faber Applied Research.

Building professionals and developers in the UK are showing an increased interest in the use of night-time natural ventilation for cooling as part of the current trend towards low energy buildings.

Providing the required and controlled night-time natural ventilation requires ventilators designed for this purpose, something which doesn't exist in the UK at present.

A DoE Partners In Technology project should overcome this. The BRE, Oscar Faber Applied Research and Willan Building Services have combined field measurements with thermal and air flow modelling of a "typical" office to determine the possible level of cooling available using a range of strategies and ventilator configurations.

Naturally ventilated offices

The effectiveness of a night cooling strategy in a refurbished 1950s four storey office building[1,2] was examined over a four week period during the summer of 1995.

Large open-plan offices on the first and third floors were chosen for the study. The main source of ventilation in these offices was from 850 mm by 600 mm bottom-hung ventilators installed around the perimeter of the building.

During each week, Monday to Friday, between 18.00 and 08.00, the ventilators were kept closed on one floor and open on the other. At weekends, the ventilators on both floors were either closed or open. For subsequent weeks, and weekends, the conditions were reversed.

During the four week monitoring period daytime temperatures were generally high, with 30°C being exceeded on several occasions.

The internal dry resultant temperatures in the offices at the start of the working day can indicate how effective night cooling was during the previous night, and can affect the occupants' comfort level.

Figure 1 shows the internal dry resultant temperature at the start of the working day (08.00) against external air temperature (at 05.15, ie sunrise, usually the coolest time of the night).

It highlights a linear trend of these parameters for both floors. The vertical difference between the two lines shows the night cooling benefit, while the variation in slope illustrates the degree to which this diminishes at higher dawn temperatures.

For example, at 15°C external night air temperature, the dry resultant temperature difference between the two floors is 3°C, while at 19°C the difference is halved. The internal dry resultant temperatures on the floor with the ventilators open overnight remained lower than on the third floor without night cooling for most of the following working day, though on a few occasions the difference was small towards midday.

The study showed that the office managers and staff appreciated the benefits offered when they were introduced to night cooling. In fact, the strategy was continued beyond the period of the study and well into November, because both October and November were relatively mild months.

However, security was a concern, and the office managers initially had to be convinced that the ventilators provided adequate security and weather protection.

Thermal and air flow modelling

Thermal and air flow modelling was carried out to determine achievable air flow rates for a range of UK weather data and a combination of openable areas.

The magnitude of the external driving forces – eg wind speed and air temperature – are important parameters in determining the degree of night cooling possible with natural ventilation, so a range of weather conditions must be examined in the study.

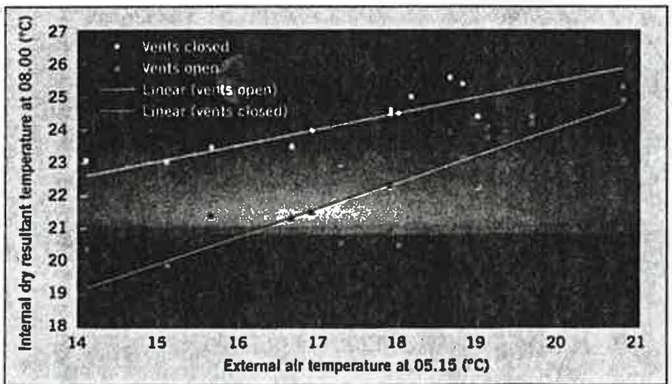

FIGURE 1: Internal dry resultant temperature at 08.00 against external air temperature at 05.15 in a night cooled office.

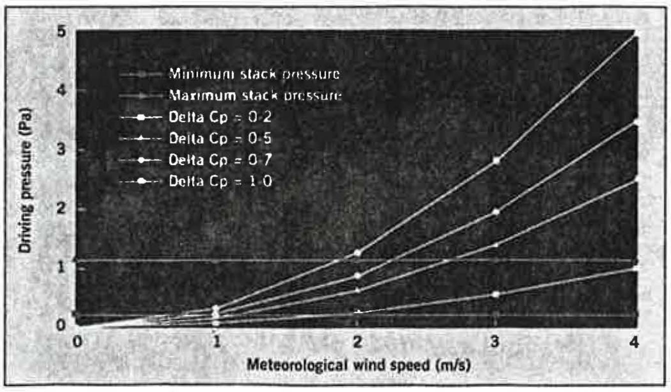

FIGURE 2: Wind speed measured against stack pressure for natural ventilation.

First, the CIBSE Example Weather Year for Kew (1964-65) has been used, specifically 12 August and the preceding week. This day has conditions which correspond closely with a design risk of conditions being exceeded for 50 days over a ten year period.

The preceding week is used so that the building thermal mass is preconditioned. As the average wind speed for this week is high (4·2 m/s) two further wind conditions have been investigated – 50% value and no wind.

In addition, the week ending 5 June from the CIBSE Example Year for Heathrow has been used to provide a period with a peak temperature close to the summer design temperature for the south east of England of 29°C and with lower wind speeds than at Kew.

Previous work[3] on night cooling has identified a "typical" office (6 m deep by 10 m long, with an internal floor-to-ceiling height of 3 m), favourable to a night ventilation strategy.

There is one external wall, insulated to current *Building Regulations* standards. Windows cover 40% of the external wall area and are double glazed units with clear float glass plus internal blinds, but no external shading. The ceiling is exposed heavyweight concrete, the floor raised above a services void. Internal walls are lightweight plasterboard partitions.

Experience shows that naturally ventilated buildings can deal with internal gains of 20-30 W/m² and therefore this is the level of gain used in the model. These gains occur only during the occupied period, taken as 09.00 to 17.00, Monday to Friday. Two levels of solar gain have been considered by looking at two different orientations: south west and north.

Both stack and cross-flow ventilation have been considered. The total air flow rate can be calculated by combining the stack and wind driven flow in quadrature. By substituting inlet to outlet stack and wind pressure differences it is possible to derive a simplified equation, relating air change rate to equivalent opening area, inlet to outlet height difference, temperatures and wind speeds.

Temperatures and wind speeds can be read directly from the weather data, while the equivalent area and height difference must be fixed for each ventilator configuration. Four values of equivalent opening area have been used, based on previous work. Stack-driven ventilation has been modelled with four stack heights, while a stack height of zero has been used to model cross-flow ventilation.

Modelling results

Results have been normalised so they can be applied to a range of buildings. Flow rates are measured in air changes per hour (ac/h), opening areas in square millimetres of opening area per square metre of floor area (mm²/m²).

The effect of increasing the stack height varies with wind pressure for a given equivalent opening area. With no wind, or with the lower wind speeds for Heathrow, the ventilation rate can be increased by increasing the stack height. With the high wind pressures for Kew there is very little difference for a similar increase in stack.

Figure 2 illustrates that, even for low wind speeds and pressure coefficients, wind pressure rapidly dominates stack pressure.

Figure 3 shows the air flow rates for a range of opening configurations under the Kew weather conditions. As expected from the air flow equation, the ventilation flow rate is directly proportional to the equivalent opening area – doubling the area doubles the flow rate. The absolute magnitude of the change is dependent on the wind pressure.

For the no wind case with a stack equivalent to one floor, flow rates of between 4 and 5 ac/h can be achieved with an inlet area of about 8300 mm²/m² for most practical outlet sizes. This represents an area of around 20 times the minimum required for background ventilation by the current *Building Regulations*. To maintain the same flow rate on each floor of a building, the opening area must increase with decreasing stack height.

For high wind pressures, very high ventilation rates can be achieved, up to 48 ac/h for the cases investigated in this work. These are excessive, especially in the light of the small differences in temperature achieved, and therefore some form of control is necessary to ensure that this does not occur.

Despite the large variations in ventilation rate achieved, there is a relatively small variation in peak comfort temperatures (figure 4). As the ventilation rate increases beyond 5 ac/h the reduction in temperature achieved decreases.

It is important to consider temperatures at the start of the occupied day. If these are too low then occupants are likely to either require heating or feel uncomfortable.

If no control is placed on the night ventilators, an analysis of comfort temperatures during occupied hours indicates that the office will be too cold, below a comfort temperature of 18°C, for around 21% of the time at Kew and around 17% of the time at Heathrow.

Conclusions

Measurements in an occupied naturally ventilated office have shown that night ventilation reduces daytime dry resultant temperatures by up to 4°C at the start of occupation compared with an office without night ventilation.

Occupants were keen on the implementation of this ventilation strategy once they experienced it.

Modelling has shown that the following controls are needed in relation to achieved internal comfort:

- control to prevent excessive ventilation rates when driving forces are high (high wind speeds) during the day;
- provide control during the night to prevent over-cooling during the day;
- control to reduce ventilation rates to background levels when external air temperature exceeds internal temperature during the day.

Weather (wind and rain) and security concerns also need to be addressed for the night period.

Natural night ventilation would provide maximum cooling benefit if integrated as part of an overall low energy strategy to minimise internal and solar gains.

The above requirements must be combined with the possible need to provide noise and pollution control as well as aesthetic appeal in a specification for a purpose built night ventilator. The project is continuing with the design, prototype construction and field trials of a suitable ventilator.

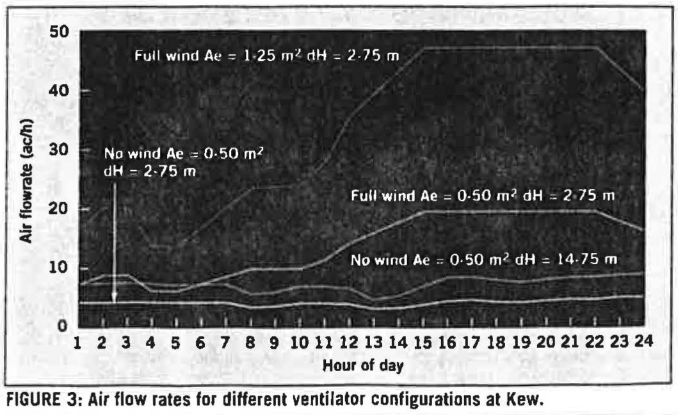

FIGURE 3: Air flow rates for different ventilator configurations at Kew.

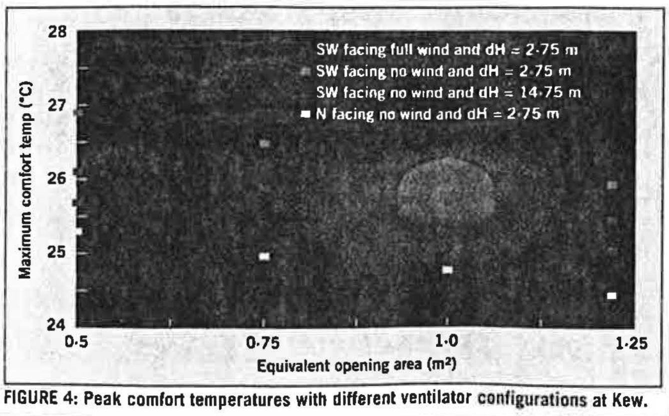

FIGURE 4: Peak comfort temperatures with different ventilator configurations at Kew.