DEVELOPMENT OF A LOW ENERGY FAN CONVECTOR

M J Price[1], E M Clancy[2]

[1]Biddle Air Systems Ltd., UK
[2]Coventry University, UK

ABSTRACT

A patented, low energy, fresh air fan convector has been developed by a HVAC equipment manufacturer in conjunction with a leading controls supplier and a local University. It can heat, free cool, provide minimum ventilation air and carry out night cooling strategies in an intelligent self contained package. A number of full-scale tests have been carried out on the unit. These have involved measuring energy consumption and thermal comfort conditions in two modular offices; one fitted with the unit and the other conditioned using more conventional plant.

The test results have shown that the night cooling strategy used has been effective in depressing fabric and internal air temperatures. Computer simulations have indicated that the control algorithms used are producing significant comfort and heating energy savings compared to more conventional plant.

Further development of this product is required, in terms of monitoring the night cooling strategy, improving its control algorithms and further reducing its energy consumption.

1. INTRODUCTION AND UNIT DESIGN

Well designed natural ventilation systems can provide good comfort conditions with minimal operating costs. However, they are perceived by many building owners as lacking control and versatility because of weather effects [1] and requiring high design content. A fan assisted ventilation system consumes more energy, but has the control and versatility to be used in most situations in all weather conditions. The concept of a low energy fan convector that can ventilate in a controlled manner to provide good comfort and indoor air quality (IAQ) was first proposed in June 1995.

The result of a three year research and development programme is a packaged terminal unit designed to control the comfort conditions of a space, such as an office or commercial premises. It can heat, free cool, provide minimum ventilation air in a controlled draught free manner and carry out sophisticated night cooling strategies. The unit consists of a fan, heater battery and filter as found in a conventional fan convector. In addition it has an intelligent controller and a special fresh air damper to provide accurately metered quantities of fresh air. By contrast, a conventional wall mounted fan convector has no fresh air supply and the controls are usually designed to merely switch the heater and fan on or off.

The intelligent controller adjusts the heat output, the fan speed and the operation of the fresh air damper against a room set point temperature and the number of occupants. This enables it to achieve good comfort conditions with accurate levels of ventilation and low energy consumption when compared against traditional heating and ventilation systems. In particular it is a low cost alternative to central ventilation plant. Figure 1 shows the main components of the unit in a typical floor mounted installation on the external wall of an office.

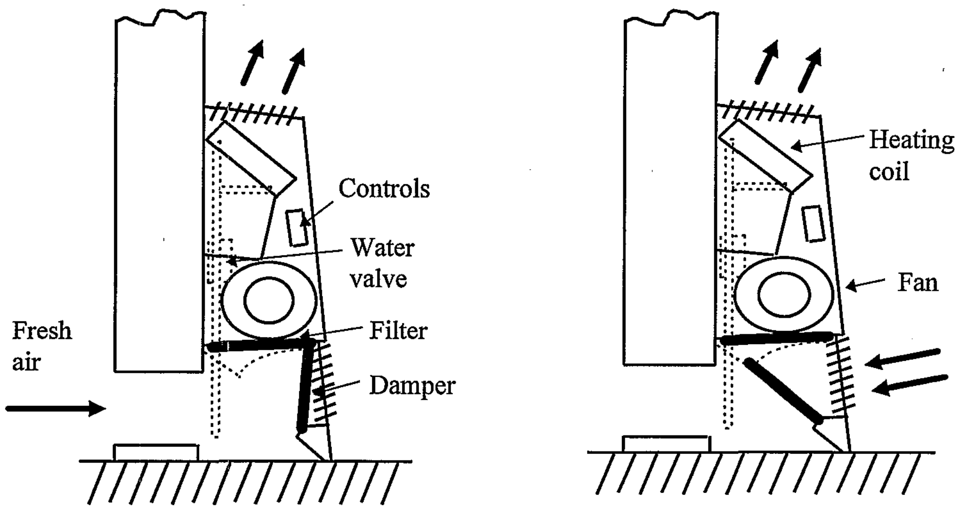

Figure 1 Sectional view of unit installed against external wall (fresh air and recirculation modes)

2. CONTROL STRATEGIES

The control strategy written specifically for the unit is rule based with a conventional P+I (proportional plus integral) loop for heating control of the space. Of particular interest is the incorporation of a rule based night cooling strategy developed by a building services research organisation for natural ventilation [2]. This is shown in the control flow chart, Figure 2.

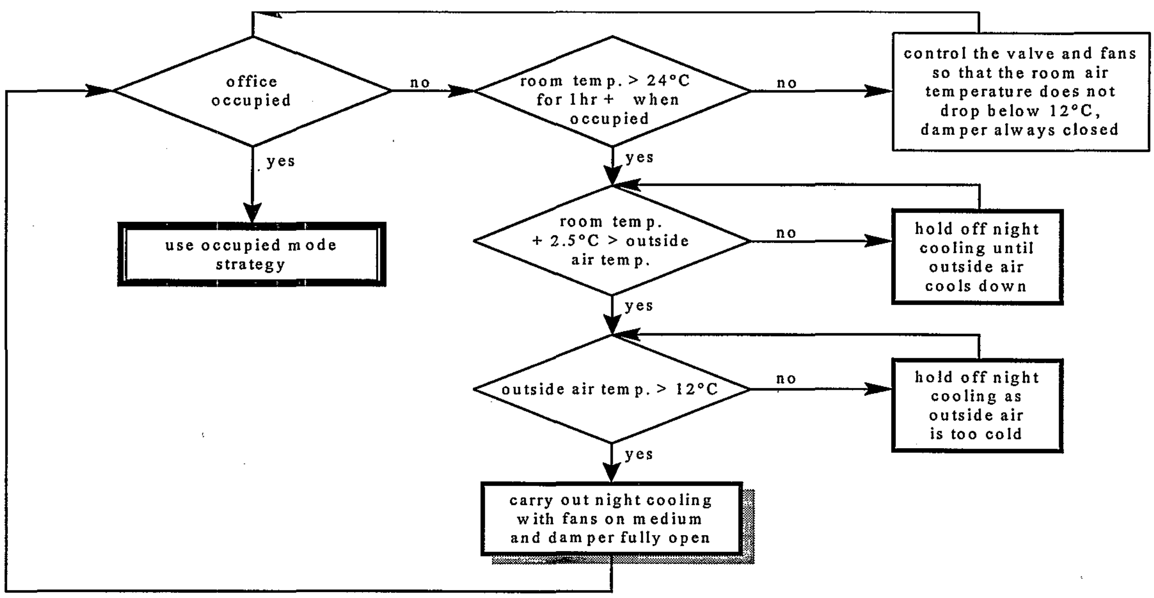

Figure 2 Low energy fan convector night cooling

The primary purpose of the unit is to provide acceptable comfort levels by promoting good indoor air quality (IAQ) with the minimum use of energy. Comfort is a complex issue and only some of the many parameters involved in achieving it can be controlled by HVAC equipment, e.g. air temperature, fresh air ventilation, relative humidity, room air speeds and noise levels. The strategy has been written to control these parameters in one of two basic control modes, "Normal Operating Mode" and "Set Back Mode". Changeover between these two modes of operation is done by manual push button at the wall mounted room control pad or via a timer/ BMS (Building Management System) interface.

There is a manual set point adjuster on the room control pad and dip switches on the controls manufacturer system management board to set the fresh air quantity for different numbers of occupants. There is also a switched interface on the unit to control the operation of an extract fan or extract system so that room air change quantities can be controlled. Several units can also be connected together in a network to form a master/slave system with one wall control and sensor controlling all units simultaneously.

3. THE USE OF COMPUTER SIMULATIONS TO ASSESS AND IMPROVE THE CONTROL STRATEGY

Computer modelling of the control strategy was carried out by a consulting engineering company to investigate the expected performance of the unit and its energy consumption. The control strategy was programmed into dynamic thermal analysis software developed by the company for this and two other HVAC systems. A whole year of operation was then simulated within a Type 2 building (4 storey, heavy weight offices, concrete frame, brick cladding) as per an energy consumption Guide [3]. These simulations produced a number of interesting conclusions resulting in changes being made to the controls strategy to improve unit performance.

Over the past eighteen months the consultancy has been developing computer methods for simulating control strategies [4] in a UK government funded, collaborative research program in which the fan convector manufacturer was a partner. One of the strategies simulated was that from the low energy fan convector and Figure 3 shows the performance of the unit strategy against three other night cooling strategies.

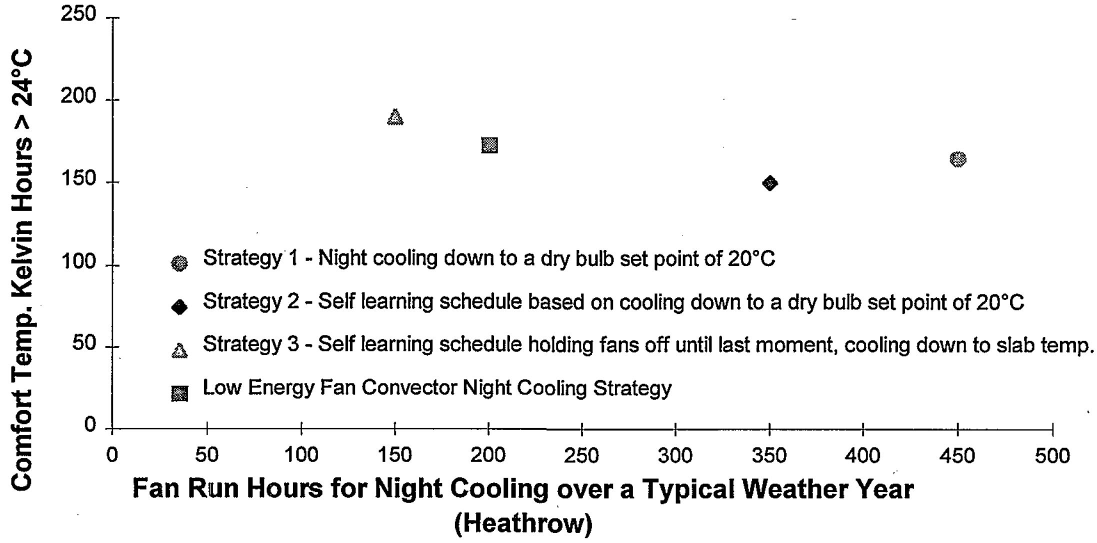

Figure 3. - Dynamic thermal simulation of various night cooling strategy's

NB. The best system is one where "Comfort Temp. Kelvin Hours < 24°C" and "Fan Run Hours for Night Cooling" are both as low as possible. A good compromise has been achieved with the low energy fan convector night cooling strategy.

4. PROGRAM OF TEST WORK TO MONITOR PERFORMANCE

In May 1997 the opportunity arose to construct two test rooms within the manufacturers own building. A low energy fan convector was installed in one of the test rooms and a standard recirculation fan convector was installed in the other. Both test rooms were equipped with data logging equipment, sensors and apparatus for recording the following parameters:

- Room air temperature (°C)
- Globe temperature, to calculate mean radiant temperature (°C)
- Wall and Ceiling Slab surface temperature (°C)
- Outside air temperature (°C)
- Room air speeds (m/s)
- Relative humidity (%)
- Energy consumption of heaters and fans (kWh)

Both rooms each had a volume of 33 m^3 and very similar thermal capacities. They had a southern aspect and equal window area of 1.8 m^2 with fenestration of 21 %. There was a desk and two chairs in each room, short pile carpet and plastered walls. Total internal heat gains were 35 W m^{-2} made up of a personal computer, fluorescent lighting and two 100 W light bulb mannequins to mimic the thermal effects of two persons in sedentary office work. A timer automatically turned on all heat loads and the lights between the occupied hours of 8 a.m. and 5 p.m. together with the low energy fan convector in Room 1 and the recirculation fan convector in Room 2.

The following test work had been carried out:

- Evaluation of air flow patterns throughout the room.
- Determination of the effectiveness of the night cooling strategy (see figure 4).
- Assessment of thermal comfort conditions, using Fanger [5] and Bedford [6] indices (see figure 5).
- Evaluation of the effectiveness of the night cooling routine using different ceiling forms.
- Comparative measurement of external noise ingress as a result of the fresh air intake.

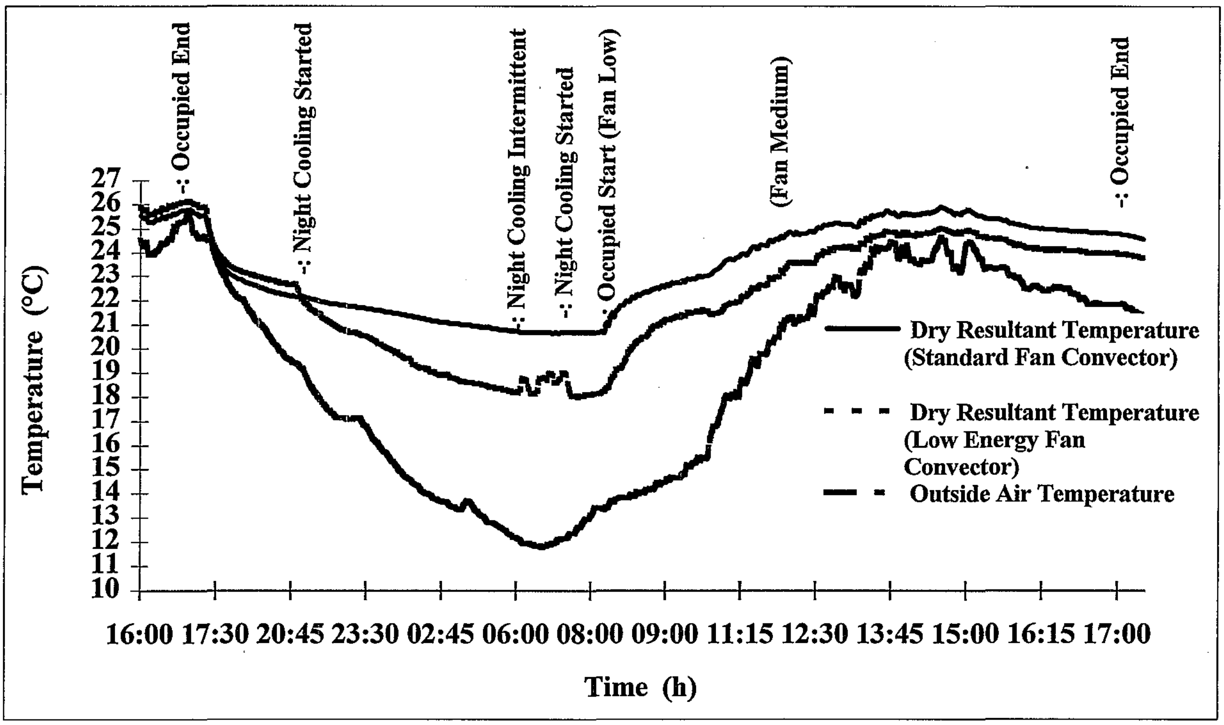

Figure 4: Test results showing control of night cooling during warm period

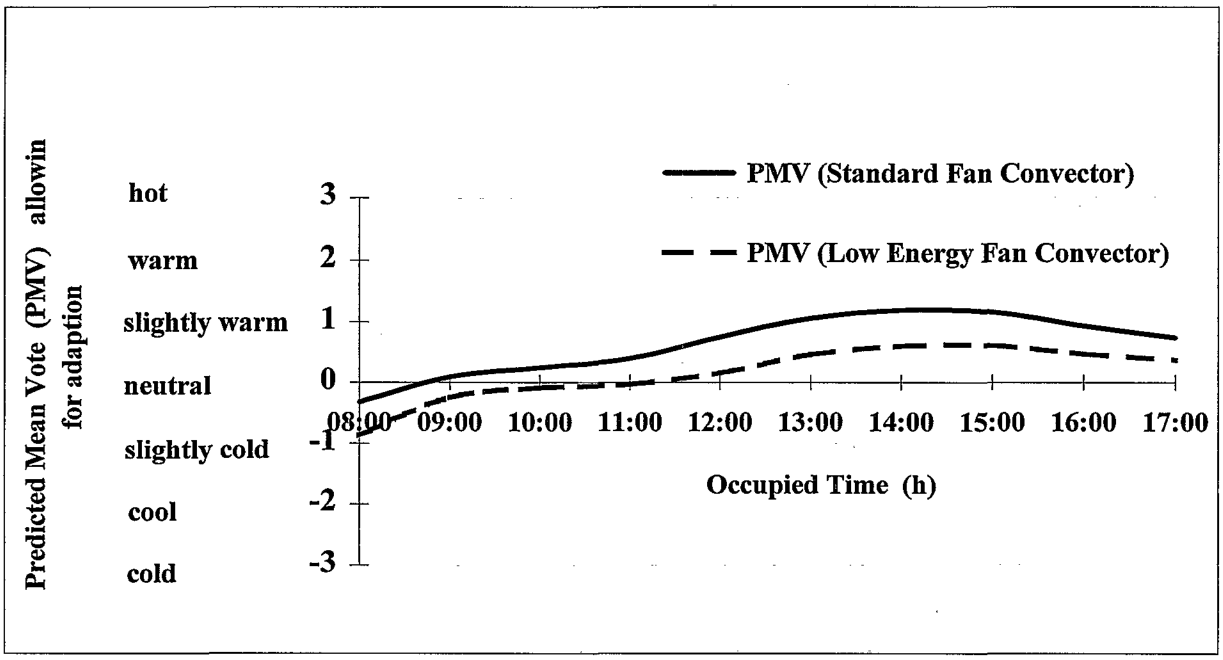

Figure 5 Calculated test results showing effect of night cooling on comfort index

5. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

Comparative tests have been carried out with and without a false ceiling in place in the test rooms. Early indications suggest that for this particular fan assisted ventilation system mounted against an external wall, the degree of fabric cooling of the inside surface of the wall has a greater effect on night cooling than having an exposed ceiling slab. This is at variance with most research findings on natural ventilation systems where an exposed concrete ceiling slab is of greatest significance. This has interesting implications for the retrofit office and refurbishment market where the end user often wants to make as few alterations as possible and retain false ceilings for aesthetic reasons.

Tests were carried out during the 1998 summer which whilst not overly warm did have one week in August when peak outside air temperatures at the test location were consistently between 25 and 35 °C. Further test work is planned for summer 1999.

There is more work to be done in evaluating adaptive techniques for calculating comfort indices in the UK climate. It is well known that ISO 7730 is based on experiments carried out by Professor Fanger in the United States and recent thinking is that PMV's should be modified for adaptation to the climate in question.

Further test work will include :-

- Additional assessments of night cooling effectiveness
- Measuring the effectiveness of the unit in providing good indoor air quality (IAQ)
- Gauging the effect of room extract where the unit is installed.
- An analysis of seasonal energy use and a determination of life cycle costs.
- Development of an air inlet device to filter fresh air and attenuate noise in urban and inner city locations.

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