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Comparative Trials of Ventilation Systems for Humidity Control

D A McIntyre*, S L Palin**, R E Edwards***

*E A Technology, Capenhurst, Chester CH1 6ES, UK
**UMIST/EA Technology Post Graduate Training Partnership
***UMIST, P O Box 88, Sackville Street, Manchester M60 1QD, UK

1 Synopsis

Three ventilation systems were installed in the EA Technology Ventilation Test House: passive stack ventilation (PSV), mechanical ventilation with heat recovery (MVHR) and extract fans. Humidifiers were used to simulate occupancy and the performance of the systems monitored over the winter of 1993/94. The aim was to assess the effectiveness of different ventilation systems in controlling indoor humidity at a level that will inhibit the growth of house dust mites.

The PSV system produced low ventilation rates in typical winter weather; excessive ventilation loss in cold windy weather was prevented by the high standard of air tightness in the house. The MVHR system has the advantage of producing consistent ventilation in all weathers. Total energy consumption of the systems was similar. MVHR was the most effective in reducing indoor humidity and in coping with peaks of moisture production; this is to be expected given its greater ventilation rate. Extract fans dealt well with moisture peaks, but should continue to run after moisture production has finished. Detailed results are presented for the variation in humidity between rooms for each ventilation system.

2 Introduction

Control of humidity in dwellings is necessary for a number of reasons, condensation and mould growth being amongst the most well-known. Mould growth is likely if relative humidity exceeds 70% for a significant period[1]. High indoor humidity also helps ensure the survival of the house dust mite, a major cause of asthma. It is generally accepted that humidity levels below 7 g/kg are detrimental to the house dust mite population[2]. This corresponds to a relative humidity of 48% at 20°C, a more stringent requirement than that for avoidance of mould growth. Ventilation of a dwelling with drier outside air acts to reduce indoor humidity levels. The possibility of maintaining humidity below 7 g/kg during winter by ventilation alone in the UK climate depends on the rate of moisture production in the house, ventilation system design and operation, and on ambient weather conditions. A pilot study[3] found fewer mites in houses where continuous mechanical ventilation with heat recovery (MVHR) was used than in similar houses where it was not used.

This paper describes ventilation and humidity measurements made in a ventilation test house[4], as part of a larger project concerned with the effect of ventilation strategy on asthma. This semi-detached house was refurbished to a high standard of air tightness and equipped with a range of ventilation systems, so that effective comparisons could be made on the selection of a ventilation system and its operation for the effective control of humidity and dust mites. A series of measurements was taken during the 1993/94 winter season, which compared the effect of different ventilation systems on humidity in the house.

3 Experimental

The experiments were carried out at 16 Manorfield Close, Capenhurst, one of a group of six test houses. The house has recently been refurbished with particular attention paid to airtightness in order to monitor ventilation systems effectively. House airtightness was tested periodically by the fan-pressurisation technique. Results were less than 3 ac/h at 50 Pa increasing to 5 ac/h with all trickle ventilators open; both results being considerably lower than the mean value of 11.5 for UK housing[5].

Three ventilation systems have been installed: MVHR, passive stack ventilation (PSV) and extract fans.

The PSV system was installed according to then current good practice and comprised two stacks leading from kitchen and bathroom to separate ridge terminals. Two types of room terminal were used. The standard conical extract provides a smooth entry and minimum resistance to air flow. For some runs, the room terminals were replaced with humidity sensitive extracts, which close progressively at low humidities, thus reducing flow in the stack and reducing excess ventilation when not required.

The MVHR system chosen was a standard loft-mounted heat recovery system incorporating cross-flow heat exchanger unit. This is capable of ventilation rates up to one air change per hour, supplying air to lounge, dining room and bedrooms and extracting from kitchen and bathroom. The MVHR unit was operated at approximately either 0.5 or 1 air changes per hour, i.e. approximately 100 or 200 m^3/h, with a slight excess of extract over supply.

Both kitchen and bathroom two speed extract fans were installed through-the-wall at high level and comply with the building regulations[6]. When under test, both extract fans were switched on and off by the central controller at the same times as the humidifiers. The high speed setting was used for almost all tests; flow rates are quoted by the manufacturer as 225 m^3/h (kitchen) and 102 m^3/h (bathroom).

The three ventilation systems were operated sequentially over a period from January to May 1994. All systems were tested with all internal doors either open or closed; all internal doors contain transfer grilles with an open area of 17,500 mm^2 to give a standard leakage between rooms. Windows were kept permanently closed. Trickle ventilators of 4000 mm^2 are installed in all rooms; these were closed only when the MVHR was operational, except for kitchen and bathroom ventilators that were kept closed at all times. A target temperature of 20°C was maintained throughout the house for most of the time. Lower temperatures were occasionally recorded in the kitchen and bathroom. As these did not contain heaters the temperature depended largely on air transferred from the other rooms. Humidifiers in the kitchen, bathroom and one bedroom were used to simulate occupancy, giving a total daily moisture input of approximately 5 kg. This represents four people living in conditions of 'dry' occupancy[1].

Temperature and humidity measurements in all rooms, at three locations in the stairwell and outside in a Stevenson screen were performed by a transmitter consisting of a platinum resistance thermometer and a capacitative humidity sensor. The humidity sensor measures relative humidity directly and is converted later to give absolute humidity.

Measuring bends were used to monitor flow rate in the intake and extract MVHR ducts. Velocity in each stack was monitored by a hot wire anemometer. The conical inlet gave a uniform velocity profile at the entrance to the stack; the volume flow was therefore calculated by multiplying the velocity measured at the inlet by its cross-sectional area. The humidity sensitive inlet, however, consists of louvers that open and close to regulate the flow; this results in a non-uniform velocity profile and the same method of measurement was therefore not possible. In this case, the centre-line velocity was measured further up the stack, enabling calculation of mean velocity using[7] and hence volume flow. This was not possible in the bathroom stack due to a lack of straight ducting.

Weather data (insolation on a horizontal surface, wind speed and direction) was collected from a weather station above roof level at a neighbouring house. Energy consumption on the following circuits was monitored: ground floor heating, first floor heating, ring main, MVHR and total.

4 Results and Discussion

4.1 Energy consumption

Neglecting energy stored in the mass of the building, the energy balance reduces to electrical energy supplied + solar gain = transmission and ventilation losses. Figure 1 shows the daily energy input to the house against average daily temperature difference. Solar gain was estimated from the measured insolation and detailed estimates of the solar performance of the test house made in[8].

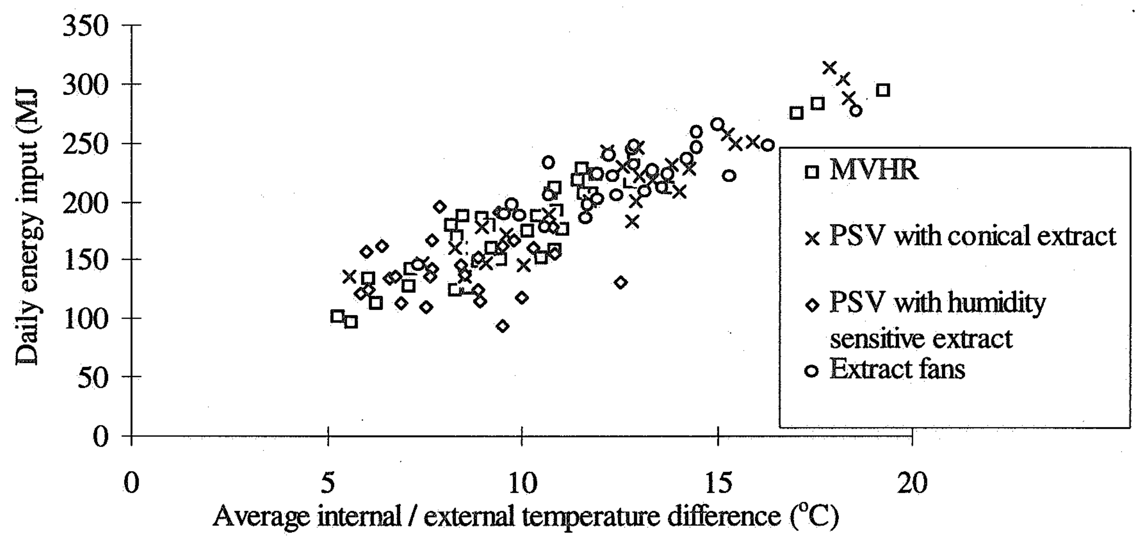


Figure 1. Gross energy input vs. temperature difference (24 hour mean values)

For the ventilation systems used in these trials, there was little difference in gross energy consumption between the systems, i.e. the increased ventilation rate and fan power consumption of the MVHR system was compensated by the heat recovery, to produce an overall energy cost of ventilation similar to the lower ventilation rate produced by the unpowered PSV system. Energy costs due to ventilation would therefore seem to be a less important factor in the choice of a ventilation system than other considerations such as humidity control, capital and installation costs.

4.2 Passive Stack Flow Rates

The flow in a PSV duct is driven by a combination of temperature gradient, resulting from the difference between indoor and outdoor air temperatures, and the pressure resulting from wind speed. Previous research[9] has found that stack flow rates are proportional to square root of internal - external temperature difference at low wind speeds.

The average daily stack flows against square root of temperature difference can be seen in Figure 2. As mentioned earlier, results for flows in the bathroom stack with humidity sensitive extract are unavailable. Stack flows with the conical extract are largely proportional to square root of internal - external temperature difference as expected; the scatter of points would indicate additional variation in flow due to wind speed. The humidity sensitive extract tends to restrict the flow at higher temperature differences; however more measurements at low external temperatures would be desirable.

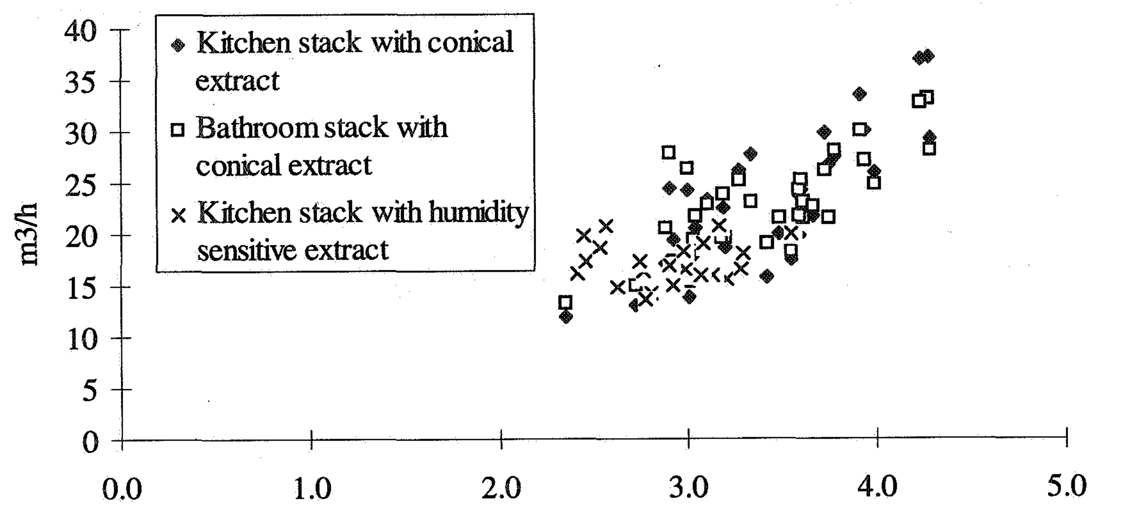


Figure 2. Average Daily Stack Flows

4.3 Humidity

Absolute humidity expressed as the mixing ratio, g, (g/kg) is calculated from the measured relative humidity and air temperature using[10]

$$g = 10\phi \exp\{11.56 - 4030/(T_a + 235)\}$$

where ϕ is the percentage relative humidity and T_a is the air temperature. This is a good approximation within the ranges of temperature and humidity involved.

4.3.1 Whole house

The results for absolute humidity in each room are averaged to give the internal absolute humidity. This and the external absolute humidity are then averaged over each twenty-four hour period. These values for each day are shown in Figure 3. The lowest values of internal humidity tend to be when MVHR is operating, the highest with humidity sensitive PSV. All systems, except humidity sensitive PSV, kept average internal humidity below 7 g/kg for most of the time. External humidity was higher when humidity sensitive PSV was operating, as this was towards the end of the winter, whereas the other systems were tested during the colder, drier months.

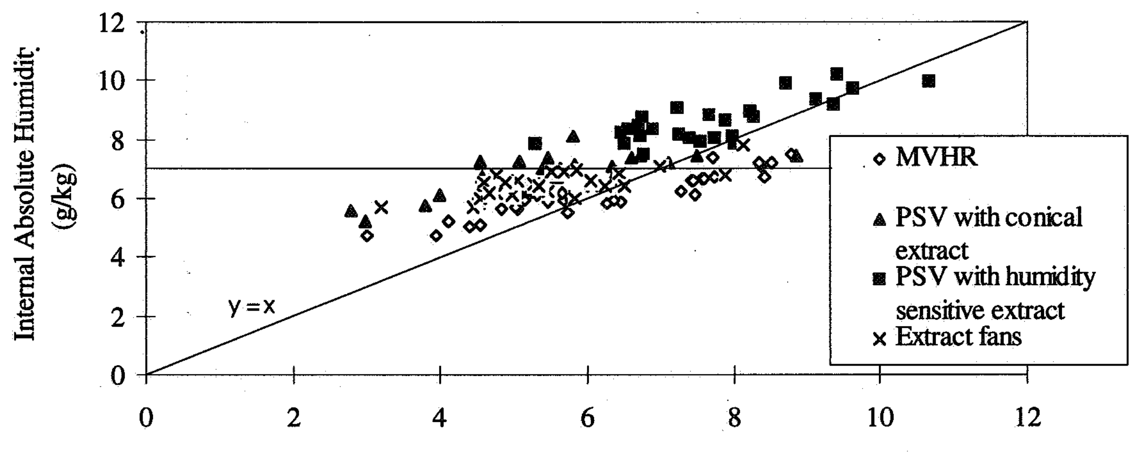
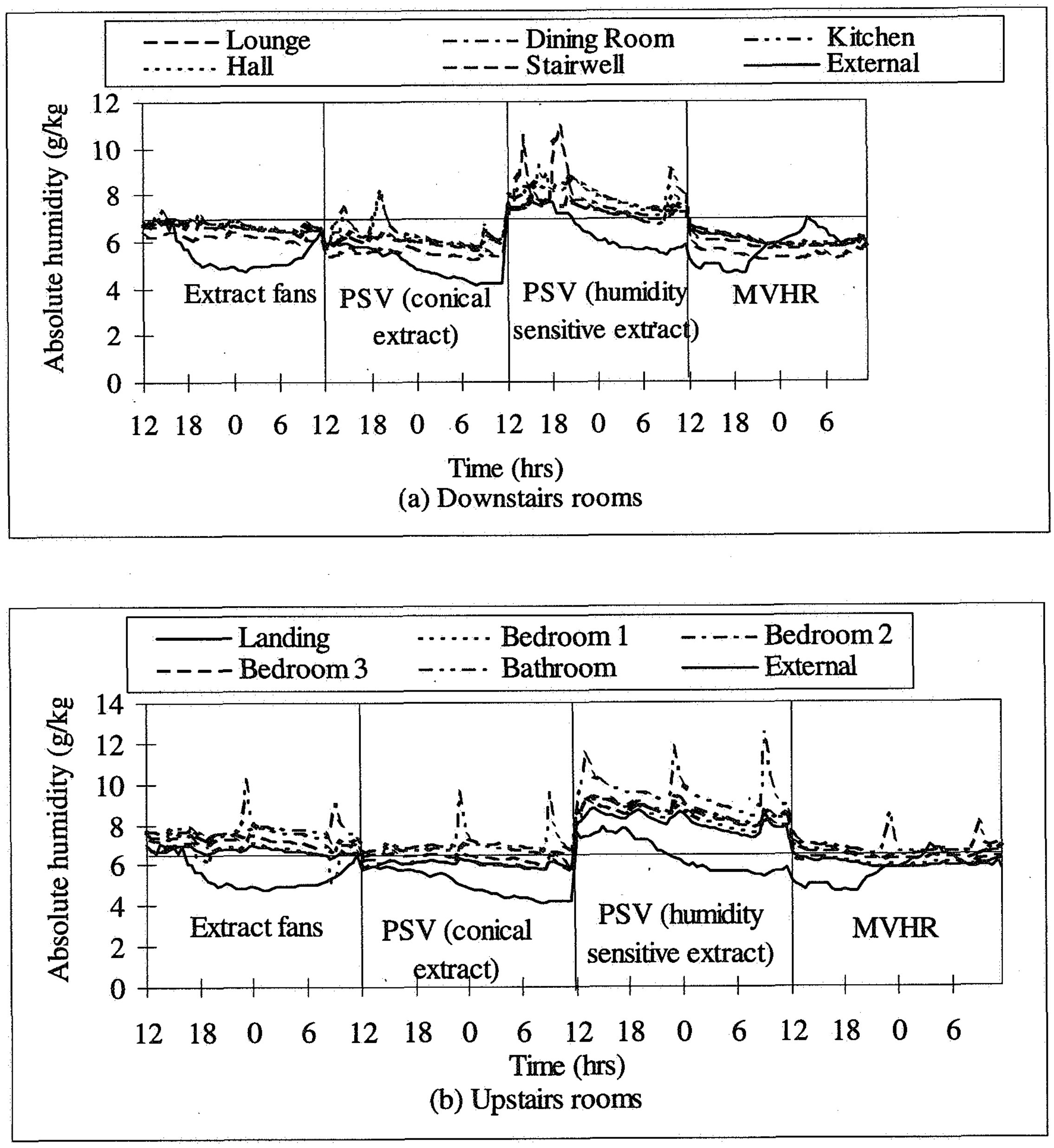


Figure 3. Daily Mean Humidity Levels

Occasionally the internal absolute humidity is less than external absolute humidity. This occurs more often when MVHR is operational than with the other systems, and could be explained by the house and / or MVHR system acting as a buffer, moderating the effect of temporary increases in external humidity by absorption into the building fabric and furnishings.

4.3.2 Room by room

The values of absolute humidity in each room and outside the house are shown in Figures 4(a) and 4(b). A representative twenty-four hour period of operation of each system was taken - these were not consecutive. All internal doors were open in each case. There is considerable humidity transport between rooms, whatever the ventilation system. PSV with conical extract and extract fans exhibit similar performance. MVHR maintains lower humidity than the other systems. Again it can be seen that internal humidity is lower than external humidity for a significant period of MVHR operation. PSV with humidity sensitive extract would seem to have the poorest performance; however the external humidity was higher in this case.



(a) Downstairs rooms

(b) Upstairs rooms

Figure 4. Room by Room Variation of Humidity with Internal Doors Open

5 Conclusions

Energy consumption of the systems tested was similar. An important factor in the comparison of ventilation systems is house airtightness, which is essential for the benefits of MVHR to be realised, and also desirable for other systems. The test house construction ensured a relatively high level of airtightness, which was maintained throughout these tests.

The mechanical ventilation system performed well. The passive stack system showed the expected variation of stack flow with temperature and wind speed. Total house ventilation with a PSV system is affected by general infiltration. For the test house fitted with 4000 mm^2 trickle ventilators, the house under ventilated in typical winter weather. The use of humidity sensitive extracts reduced stack flow in cold weather and would act to prevent over ventilation. The low driving force of passive stack ventilation makes the system sensitive to variation in design, installation and the geometry of house and surroundings.

Total energy consumption for the MVHR and PSV systems was very similar, reflecting the lower ventilation rate of PSV against the higher ventilation and heat recovery of the MVHR system.

MVHR proved the most effective of the systems in reducing indoor humidity levels. This was primarily because of the higher ventilation rate compared with PSV. Opening doors of moisture producing rooms promotes the spread of moisture to the rest of the house, regardless of choice of ventilation system. The fresh air supply to the bedrooms provided by a MVHR system was effective in reducing humidity in occupied bedrooms.

There were strong indications that the dynamic effects of moisture absorption and desorption in the house structure and ventilation system may play an effect in modifying the internal humidity. The effects may be diurnal or seasonal.

7 Acknowledgements

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8 References

[1] "British Standard Code of Practice for Control of Condensation in Buildings"
BS 5250 British Standards Institution, 1989.

[2] PLATTS-MILLS, T A E AND DE WECK, A L
"Dust mite allergens and asthma -A world wide problem"
J Allergy Clin Immunol 83 1989, pp416 - 427.

[3] MCINTYRE, D A
"The control of house dust mites by ventilation: a pilot study"
13th AIVC Conference, Nice. Coventry, UK. 1992, pp497 - 507.

[4] MCINTYRE, D A, PALIN, S L, AND EDWARDS, R E
"The Capenhurst ventilation test house"
15th AIVC Conference, Buxton. Coventry, UK. 1994, pp343 - 351.

[5] "Domestic draughtproofing: ventilation considerations"
Digest 306 Building Research Establishment, 1986.

[6] "Building Regulations 1985 (1990 Edition) Approved Documents F1, F2"
HMSO, 1991.

[7] MILLER, D S
"Internal Flow Systems"
British Hydromechanics Research Association, The Fluid Engineering Centre, 1986.

[8] SIVIOUR, J B
"Theoretical and experimental heat losses of a well-insulated house"
ECRC/N1537 EA Technology, 1982.

[9] PARKINS, L M
"Experimental Passive Stack Systems for Controlled Natural Ventilation"
CIBSE National Conference. University of Kent, Canterbury. 1991, pp508 - 518.

[10] MCINTYRE, D A
"Indoor Climate"
Applied Science, London, 1980.