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Energy Implications of Domestic Ventilation Strategy

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

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

Synopsis

Mechanical ventilation with heat recovery (MVHR) and passive stack ventilation (PSV) systems are both proposed as methods of ensuring satisfactory ventilation rates in UK housing. MVHR provides controlled ventilation in all rooms together with heat recovery, while the cheaper PSV system offers lower running costs, but without heat recovery and without a controlled air supply to all rooms. The relative energy consumption of the two systems depends on a number of factors that are difficult to predict.

To provide a direct comparison, a test house at EA Technology was fitted with both MVHR and PSV systems. In a pilot study, the systems were operated alternately during the winter of 1993, with controlled internal air temperature and humidity. Both systems provided satisfactory humidity control; the use of humidity sensitive extract with PSV was found to be effective. Overall energy consumption of the PSV system was similar to MVHR.

1 Introduction

In older houses, especially in the UK, there has usually been adequate ventilation provision due to natural infiltration through leaks in the building envelope. However, in recent years there has been a trend towards more airtight buildings, due to improved building practices and concerns about energy efficiency. In such cases, it is necessary to introduce some form of purpose-provided ventilation system. However, it is important to ensure that a balance is achieved between energy efficiency and acceptable indoor air quality.

In some countries, such as Sweden and Canada, where the level of air-tightness in houses is very high in comparison to the UK, the law requires that mechanical ventilation with heat recovery (MVHR) be installed in new premises [1,2]. This ensures sufficient ventilation and also warms the incoming cold fresh air with heat from the exhaust stale air. In such countries, where the climate is severe, this system provides considerable energy savings.

Other countries make use of purpose-provided natural ventilation, an example of which is passive stack ventilation (PSV). This system consists of stacks, usually one each from the kitchen and bathroom to the roof, relying on the chimney principle and wind speed to extract the stale air. Passive stack systems have a low unit cost, and have been demonstrated to give satisfactory condensation control [3-5]; however, the extraction rates are not controlled, and there is a risk that over ventilation may take place, thus resulting in the wasting of energy [6]. If current proposals are accepted, PSV will be specifically sanctioned within the Building Regulations, subject to restrictions on system design.

2 The Test House

The test house [7] is one of a row of six semi-detached three-bedroom houses (No. 16) near the EA Technology site at Capenhurst, on a flat, moderately exposed site. The house has suspended floors, a pitched roof and timber and plasterboard internal partitions. Double glazing has been installed and the exterior walls are well insulated to give a calculated design day heat loss of 4.2 kW. The gable and party walls are of brick and block construction, whilst the front and rear walls are timber framed with tile cladding.

Prior to the monitoring program the airtightness of the test house was measured using the fan pressurisation procedure described in [8]. Initially, the fan pressurisation technique was carried out before any sealing work was done. The result was approximately 13 air changes per hour (ac/h): that is not unusual for a British house of this type, but not good enough for the installation of a ventilation system. It was therefore necessary to seal leak paths prior to the installation of the ventilation systems. This gave a result of approximately 7 ac/h, which is acceptable.

However, several weeks later after the installation of the systems and the house being fully heated, the fan pressurisation test gave a result of over 9 ac/h. All detectable leaks were sealed but it was impossible to achieve the desired result, the final result being over 7 ac/h. This appears to be due to the fact that heating the house has dried it out considerably, increasing the infiltration. It was therefore necessary to measure airtightness at periodic intervals. The final fan pressurisation test, on 20 April 1993, gave a result of 8.55 ac/h.

3 Ventilation Equipment

3.1 PSV Description and Installation

Each stack comprises a ceiling extract connected to 150 mm diameter ducting to the loft where it was connected to flexible ducting that was connected via an adapter to a ridge terminal. Initially the extract terminals used were the standard circular type. These were used with the centre-piece removed. Also used were humidity sensitive terminals that are designed to give a high rate of ventilation when the humidity in the room is high then close down when humidity is low; also a constant volume flow terminal, which provides a flow of 30 m^3/h when the pressure difference across the terminal is 50-150 Pa. Fresh air is brought into the house by a combination of natural infiltration and trickle ventilators that are fitted to all the windows except in the kitchen and bathroom.

3.2 MVHR Description and Installation

The MVHR unit was a commercially available unit with fans and heat exchanger mounted over a cooker hood. Stale air was extracted from the kitchen and bathroom and fresh air was supplied to the other rooms by 100 mm ducting. In a new house, ductwork is normally concealed in the ceiling space, with the diffusers flush to the ceiling. In the experimental house, the ducts and diffusers have been installed as close to the ceiling as possible.

The supply terminals used were the standard circular type. The cooker hood has three user-controlled levels of operation (level two was used) and also a pullout section that doubles the surface area whilst halving the resistance to flow caused by the filters, hence greatly increasing the extract rate in the kitchen. This section was kept closed during measurement in order to increase the extraction from the bathroom.

4 Experimental Procedure

The systems were operated alternately from February to April 1993, several variables being monitored using a programmable data logger. Individual room heater controls were each set to maintain 20°C over twenty-four hours. Reasonable uniformity was achieved but a tendency for upstairs rooms to overheat slightly was evident. Downstairs room temperatures settled within a band of 20°C±1.5°C while upstairs the range was 22°C±1.5°C. Water vapour was produced by humidifiers in the kitchen and bathroom in order to simulate occupancy and enable comparison of the systems in terms of moisture control. Therefore the humidity and air temperature in each room, and at three points in the stairwell were monitored. Other variables monitored include the wet and dry bulb temperatures outside the house (enabling the outside humidity to be calculated), wind velocity and the energy consumption of the eight heaters in the house. The insolation on a horizontal solarimeter (Wm^{-2}) was also measured by another logger. The velocity of air exhausted via the stacks was measured using hot wire anemometers, which were calibrated against an orifice plate using [9].

5 Results

5.1 Ventilation Rates

Several tracer gas decay measurements were carried out. The kitchen and bathroom were tested simultaneously using different tracer gases and hence ventilation in both rooms can be compared under identical conditions. One result shown by tracer gas decay measurements was that, with PSV, air change rate in the bathroom was usually higher than in the kitchen. Values between 1 and 4 ac/h were recorded in the bathroom (equivalent to 10-38 m^3/h) and 0.25 to 2.15 ac/h in the kitchen (equivalent to 4-32 m^3/h). Figure 2 gives an example of some stack flows and their correlation with the weather conditions, where P_S is pressure difference due to the stack effect (proportional to the interior/exterior temperature difference) and P_W pressure difference due to wind (proportional to the square of wind speed); this is based on an expression derived in [10]. The values used are within the range 3.8-15.8K temperature difference and 0.1-3.1 m/s wind speed. Measurements carried out with MVHR running on fan setting 2 gave results of 3.1 to 3.6 ac/h for the kitchen (45-53 m^3/h) and 4.5 to 5.2 ac/h for the bathroom (42-49 m^3/h), which is in good agreement with extract flows of 42 m^3/h and 47 m^3/h measured during commissioning.

5.2 Humidity Control

The performance of both systems (MVHR and PSV with circular terminals) was similar with regard to moisture extraction in the kitchen and bathroom, the only significant difference being that the MVHR gave a lower mean background humidity level in the moisture producing rooms (30% as opposed to 50% for PSV). Both systems allowed some spread of moisture to other rooms; however this was not excessive. The humidity sensitive terminal also performed well, giving an enhanced rate of extraction at times of high moisture production coupled with a low background rate at other times. The constant volume flow terminal under-ventilated due to the low driving forces of PSV; it is therefore unsuitable for this application.

5.3 Energy Efficiency

Over a period when there is no change in the heat stored in the house, the energy input over that period must equal the energy loss:
electric heating + solar heating + fan heating (from MVHR) = transmission and ventilation heat losses.
The electric heating and fan heating were measured directly and solar gain estimated from the measured insolation using [11]. Dividing each side by the mean internal/external temperature difference gives an estimate of the heat loss coefficient in W/K, enabling comparison of the two systems independent of variations in temperature difference. Values of the left-hand side were plotted for a typical period of operation for each system, see figure 1 (PSV with circular terminals). This shows that the heat loss coefficients for the two systems are very similar. The ventilation heat loss for both systems was estimated from the discharge flow rate and the discharge air temperature; this does not include heat loss due to background infiltration. The heat recovery of the MVHR led to a lower discharge air temperature than for PSV. However this was compensated by the rather higher discharge flow rate, and led to a similar ventilation heat loss of around 35 W/K for both systems.

5.4 Back-flow in PSV system

Reverse flow in stacks has been known as a potential problem [12] therefore this possibility was monitored. It was found that this did not occur, however it is more likely where the dwelling is sheltered by tall buildings.

6 Discussion

Various problems were encountered in the work, the most significant being the level of airtightness of the test house, which, despite much draught-sealing, did not match up to the electricity industry's "Medallion 2000" specification [13], which requires a result of 7 ac/h from the fan pressurisation test before installation of MVHR. The concept of "build tight - ventilate right" as advocated by the Building Research Establishment [14] is most important. Problems were also encountered with the operation of the MVHR with regard to heat recovery and the balance of supply and extract flows. These results show that MVHR has similar performance to PSV in this type of dwelling, although it is more suitable than PSV in other types of dwellings such as flats, dwellings that are sheltered by tall buildings, or where the outdoor air quality is poor. PSV, although dependent on weather conditions, is likely to provide adequate ventilation for this type of dwelling during the winter season and will not over-ventilate in a reasonably airtight UK house.

7 Conclusions

This is a pilot study that has shown that PSV is a viable alternative to MVHR in this type of dwelling in terms of energy efficiency. PSV with humidity sensitive extract offers increased potential for energy saving but should only be used where humidity is the main pollutant.

Further work is necessary, and will be carried out over the next heating season in a refurbished, more airtight test house, with the elimination of the problems mentioned above. In particular, the ventilation rates in individual rooms need to be considered.

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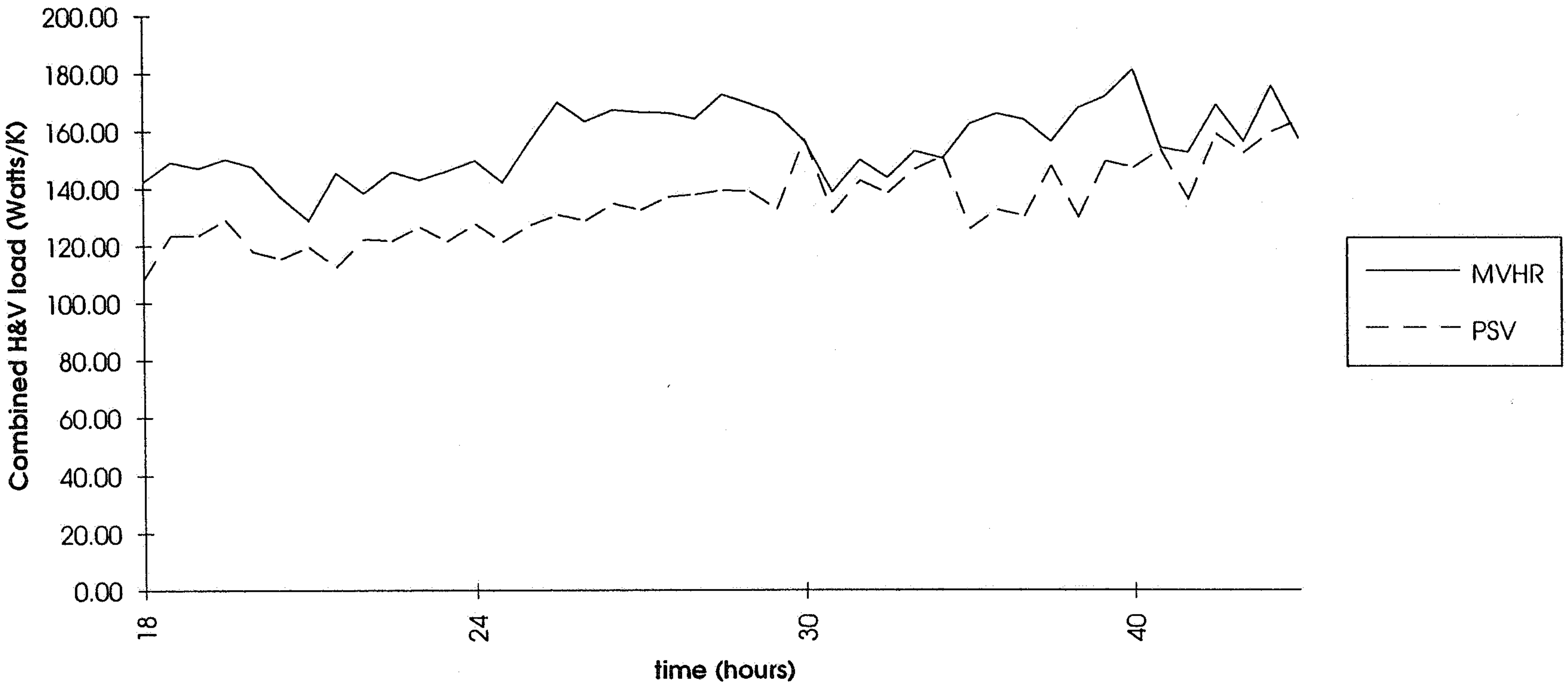

Figure 1. Comparison of heating and ventilation load: 12-13 Feb (MVHR) and 19-20 Feb (PSV)

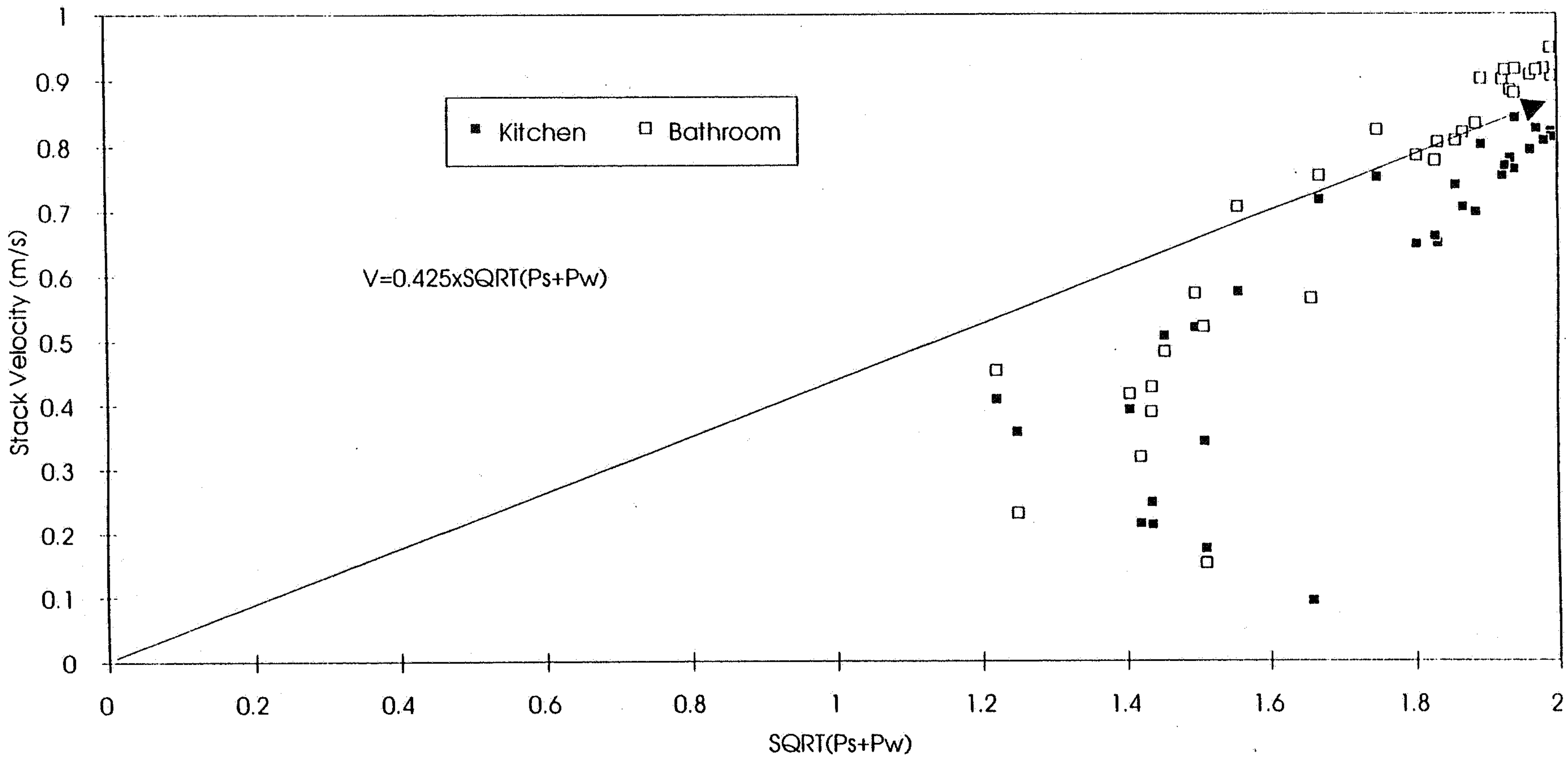

Figure 2. Correlation of Stack flows with Weather Data