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The Capenhurst Ventilation Test House

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

* EA Technology, Capenhurst, Chester CH1 6ES UK

** UMIST/EA Technology Post Graduate Training Ptnership

*** UMIST P O Box 88, Sackville Street, Manchester, M60 1QD, UK

The Capenhurst Ventilation Test House

1.0 Synopsis

A Test House at EA Technology, Capenhurst, has been refurbished to provide a ventilation test facility. The house was required to meet the following requirements:

- A high standard of air tightness
- Insulation to current Building Regulations or better
- Incorporation of several ventilation systems
- Comprehensive instrumentation

The original timber frame front and rear facades of the house were replaced with brick and block construction. All internal floors, ceilings and partitions were replaced and the external walls replastered. Attention was paid to the sealing of junctions between building elements. The result was a house with the low infiltration of $L_{50} = 2.62$ air changes per hour at 50 Pa pressure difference. Mechanical Ventilation with Heat Recovery, Passive Stack Ventilation and extract fans have been fitted. Temperature and humidity sensors are installed in all rooms and temperature and flow sensors are mounted in ventilation ducts. Sampling tubing is fitted to all rooms for tracer gas measurements.

This paper describes the precautions taken to ensure air tightness and illustrates the range of measurements that have been made.

2.0 The Capenhurst Test Houses

EA Technology operates a number of test houses for studies of space heating and ventilation. A matched pair of detached houses has recently been completed, which will enable sensitive comparisons to be made between the performance of different systems operating under identical conditions. Six further houses are in use on a site about 1 km from the main laboratory. The houses were built some 25 years ago and represented a range of constructions, from nine inch solid brick to a contemporary standard of good insulation. Since then, two houses have had major upgrades and are now well insulated, well appointed habitable test houses. A third house, which is the subject of this report, has been upgraded and re-equipped to provide an experimental facility designed for ventilation measurements. The house is a conventional $90m^2$ three bedroom semi-detached house with a space inserted between the two halves to allow access to the loft; the floor plan is shown in Figure 1. The house is designed as a versatile experimental facility. It is not a habitable house, but meets current Building Regulations except where there is an overriding experimental requirement.

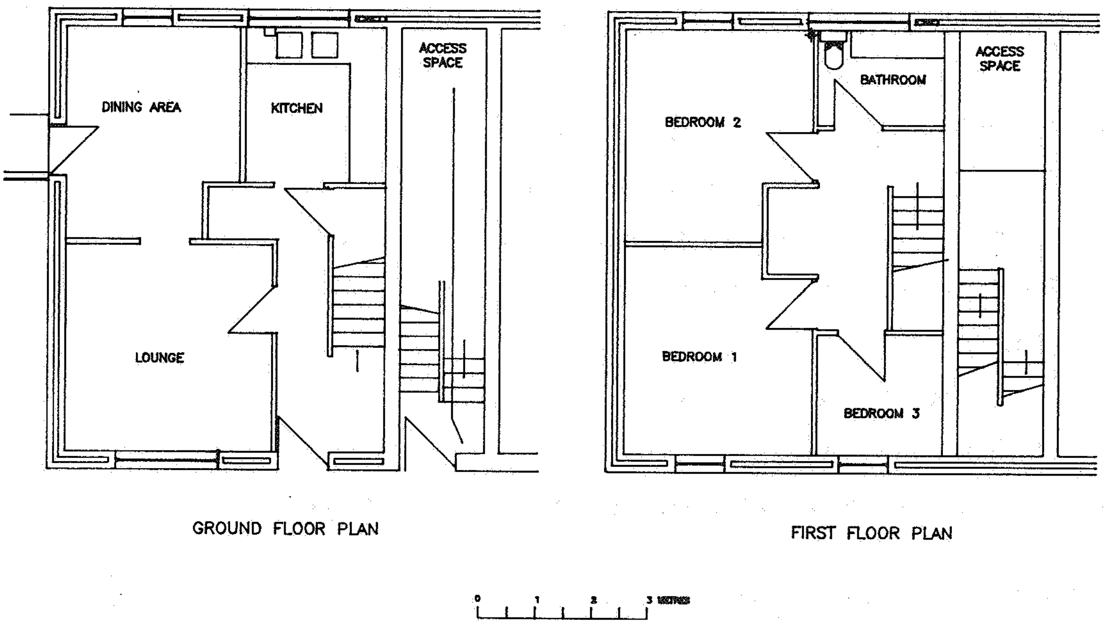


Figure 1. Floor plan of Ventilation Test House

3.0 Construction

3.1 Refurbishment

The pre-existing house was built with brick/cavity/block gable wall. Front and rear walls were lightweight timber frame construction. Renovation of the building involved:

- Removal of all internal fittings and services.
- Removal of internal partitions, internal floorboards and ceiling plasterboard.
- Removal of front and rear walls.
- Removal of plasterboard dry-lining on remaining walls.

The house was then refurbished. The order of construction is important. The aim is to avoid concealing potential leaks before they can be sealed or tested.

1. Build front and rear facades in cavity brick/block insulated with mineral fibre batts.
2. Fit new ground floor in tongue and groove chipboard; seal round edge.
3. Fit new upper storey ceiling plasterboard and seal.
4. Plaster inner blockwork of all walls, including between floor joists. The floor joists are already hung on hangers and do not penetrate the inner leaf.
5. Fit new doors and windows, sealing between frame and wall.
6. It is now possible to carry out a first pressure test. Locate and seal leaks.

7. Install plasterboard ceiling to ground floor.
8. Install internal partitions and skim all plaster work.
9. Fit coving to all wall/ceiling junctions and seal.
10. Seal all wall/floor joints with expanded foam.
11. Carry out a further pressure test and seal leaks as necessary.
12. Fit water and electrical services.
13. Pressure test and seal.
14. Fit ventilation systems.
15. Further pressure test.
16. The house is now ready for final decoration and carpet laying.

The pressure test at Stage 6 is valuable. It takes place with the outer shell of the house complete, all doors and windows fitted and sealed. The interior of the house is empty with virtually complete access to its outer envelope. It is therefore possible to gain access to any leaks and seal with a suitable expanding foam.

3.2 Air tightness

Air tightness is measured using the blower door technique. The pressure test provides a simple way of keeping a check on the air tightness of the house. Table 2 shows that the very low infiltration was maintained during construction and the installation of ventilation equipment. As the house began to dry out during spring and summer, the infiltration increased. The final figure of under 4 air changes per hour is still very much better than the Medallion 2000 standard of $L_{50} = 7$ used by the Electricity Industry as a condition for the installation of full house MVHR. The house will be resealed before commencing a new series of ventilation measurements during the next heating season.

Table 1 Air leakage measurements

Date	L_{50}	Comment
14/09/93	2.35	Outer shell of house complete
13/10/93	2.49	Construction complete
07/01/94	2.62	Ventilation systems installed
28/03/94	3.36	
13/06/94	3.75	After completion of measurements

The U-values of building elements have been calculated using conventional techniques. Table 2 gives a summary of the heat losses.

Table 2 Heat loss summary			
Element	Area	U value	AU
	m^2	$Wm^{-2}K^{-1}$	WK^{-1}
Gable wall	37.49	0.44	16.50
Front & rear walls	43.44	0.46	19.98
Windows	11.48	2.80	32.14
Doors	3.68	2.80	10.30
Ground floor	45.75	0.59	26.99
Roof	45.75	0.28	12.82
Fabric heat loss coefficient			118.7
Internal volume	198 m^3		
Ventilation loss @ 1 ac/h			66.0
Based on thermal dimensions for building elements and internal volume excluding partitions for volume.			

4.0 Equipment

4.1 Heating

The house is heated by direct acting panel heaters, fitted in all rooms except kitchen and bathroom. The integral electronic thermostats can maintain a close temperature control with fluctuations of the order of ± 0.5K. All heaters have are switched via a central time switch operating over a power line carrier system. This controller can be used to switch other equipment, using either hardwired receivers in power outlets or plug in adapters. A total of twelve channels is available, with a minimum switching period of one hour. Under sink water heaters are fitted in kitchen and bathroom. No hot or cold storage tank is fitted and there are no water pipes penetrating into the loft space. No bath is fitted.

4.2 Ventilation

Three independent ventilation systems are fitted in the house. Each may be sealed, to allow independent operation. Transfer grilles have been fitted to all internal doors to give a standard and reproducible leakage between rooms.

4.2.1 Mechanical ventilation

A full house Mechanical Ventilation and Heat Recovery (MVHR) system is fitted. Fresh air is supplied to lounge, dining room and all three bedrooms. Air is extracted from the bathroom and kitchen. The kitchen is fitted with a high level air extract in addition to the cooker hood; in a larger house the second extract would be positioned in a lavatory or utility room. The main unit containing fans and heat exchanger is mounted in the loft space; this allows for replacement or modification if desired. A silencer is fitted in the supply duct to conform with normal practice. The unit was chosen to be capable of providing at least one full air change per hour to the house over a range from 0.5 to 1.0 air changes per hour. All loft duct work is insulated, except for the intake duct, which draws air directly from the loft space. Ductwork inside the house is uninsulated and accessible, to allow for measurement or modifications.

4.2.2 Passive Stack Ventilation

At the time of installing the systems, Passive Stack Ventilation was under consideration for inclusion in the current revision to the Building Regulations for England and Wales. In the absence of the final specification, the PSV system was designed to represent good current practice. Two ducts are installed, extracting from kitchen and bathroom. The kitchen duct travels vertically through the house. In the loft, insulated flexible ducting takes the stacks to ridge mounted terminals for discharge. Trickle ventilators are fitted in all rooms and can be closed when necessary.

4.2.3 Extract fans

Two-speed extract fans are mounted through the wall in kitchen and bathroom and meet the current Building Regulations.

4.3 Instrumentation

Wall mounted temperature and humidity sensors are fitted in each room. Thermocouple sensors are fitted in the ductwork of the ventilation systems. Measuring bends are incorporated in the extract and intake ducts of the MVHR system and hot wire anemometers are installed in the PSV ducts. Measurement values are recorded using a data logger installed in the adjacent cavity.

Four sampling tubes run from the landing to each room in the house, permitting simultaneous sampling and dosing of two tracer gases. Provision is made for the external stowage of gas bottles to avoid any problems of leakage.

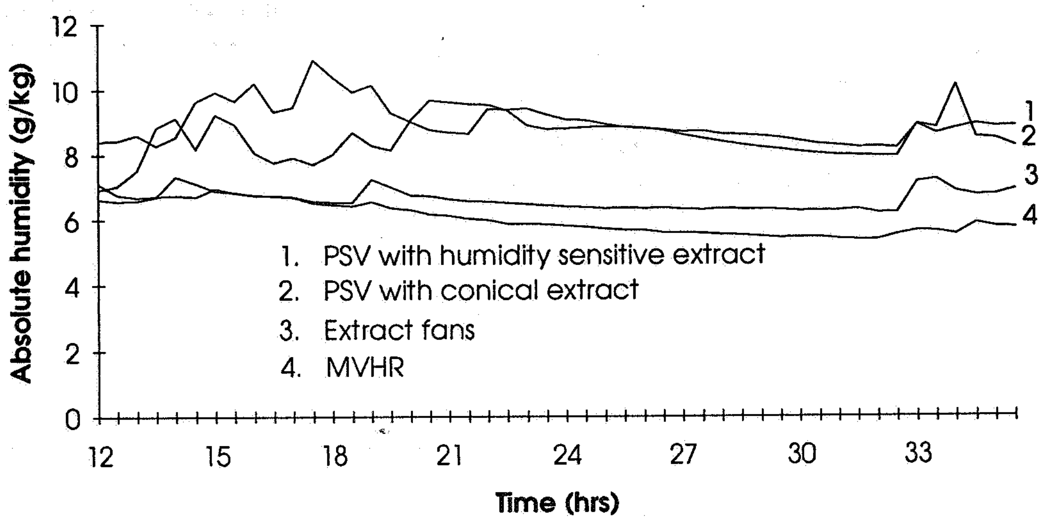
Wind speed and direction, together with insolation on a horizontal surface are measured at roof level on a nearby house. Ambient temperature and humidity are measured in a Stephenson screen in the rear garden of the test house.

5.0 Examples of Measurements

5.1 Humidity Measurements

The Vaisala sensors in each room measure temperature and relative humidity. From these values the logger calculates the absolute humidity in grams per kilogram of dry air. In Figure 2 the results from the kitchen are shown for a twenty-four hour period of operation of each ventilation system, from noon to noon the following day. In each case the kitchen door was closed and the Turmix humidifier was in operation from 12:00 to 14:00, 17:00 to 19:00 and 08:00 to 09:00 to simulate cooking. The moisture generation rate was approximately 0.6 litres per hour of operation in each case. The mean ventilation rates differed between the systems. For the PSV with conical extract the mean extract rate over the day was 12 m^3/h - this is an atypically low value due to a low internal/external temperature difference that day (see Figure 3). The flow rate in the stack with humidity sensitive extract was 16 m^3/h. The total extract rate of the MVHR system was 99 m^3/h, resulting in extraction of approximately 66 m^3/h from the kitchen. The extract fan was operated at the same time as the humidifier at its high speed of 225 m^3/h and was otherwise off.

Figure 2. Humidity Levels in Kitchen



5.2 Stack flows

Figure 3 shows the average daily stack flows for both stacks with conical extract and kitchen stack with humidity sensitive extract. The flows in kitchen and bathroom stacks with conical extract seem to be about equal; it may therefore be assumed that the flow in the bathroom stack with humidity sensitive extract is about equal to the flow in the kitchen stack with humidity sensitive extract. Stack flows with conical extract increase with temperature difference. The humidity sensitive extract throttles the flow back at higher temperature differences; this would be expected since the ventilation requirement for humidity control reduces with colder drier incoming air.

5.3 Energy

Figure 4 shows the gross energy input to the house each day as a function of the internal/external temperature difference. The energy input comprises all electrical energy including heating and an estimate of solar gain. The results have not been corrected for ventilation rate. Measurements are available of power consumption of individual circuits including power used by ventilation systems and will be subjected to detailed analysis.

Figure 3. Average daily stack flows

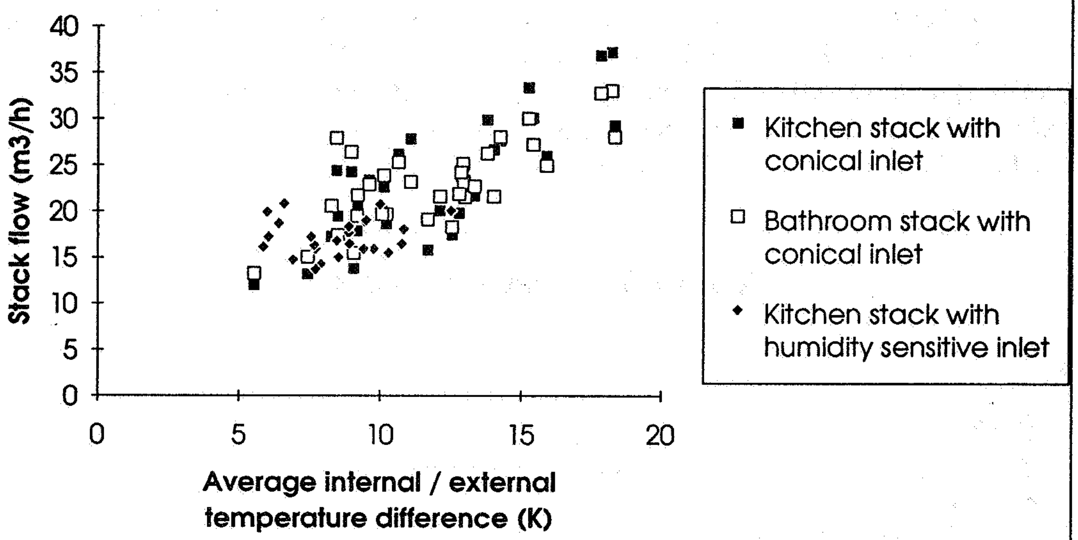
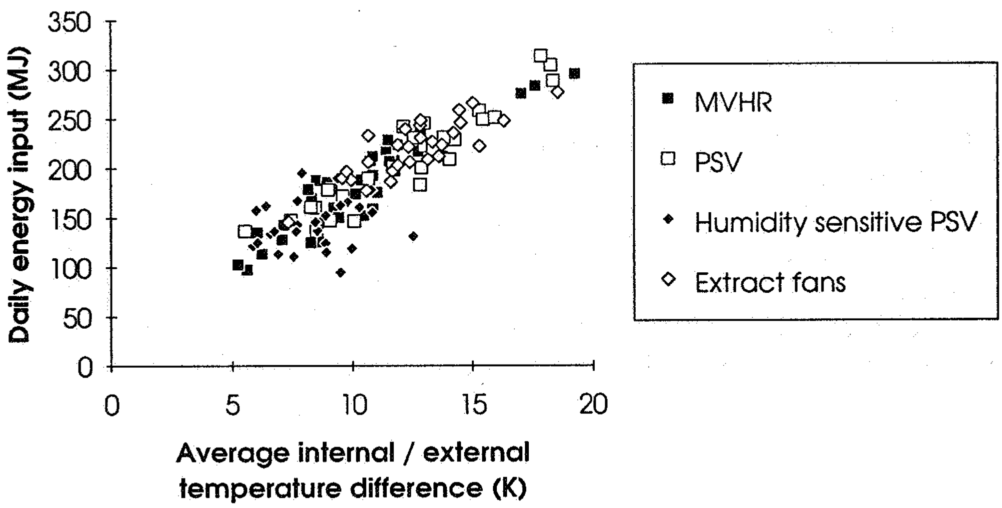


Figure 4. Gross Energy Input



6.0 Discussion

The refurbishment of the test house has produced a test facility enabling practical investigation of the performance of different ventilation systems to be carried out. It is possible to make room by room measurements to investigate the movement of water vapour or other contaminants through the house, as well as measurements of overall ventilation. The house is thus well suited to investigation of Indoor Air Quality as well as the energy performance of ventilation systems.

7.0 Acknowledgements

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