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Effectiveness of Various Means of Extract Ventilation at Removing Moisture from a Kitchen

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Effectiveness of various means of extract ventilation at removing moisture from a kitchen

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Synopsis

A kitchen is one of the major moisture producing areas in a dwelling. In order to prevent condensation and mould growth the relative humidity should not be too high. This paper describes a set of experiments comparing methods of kitchen ventilation and their effectiveness at moisture removal.

The three methods of extract ventilation were:

1. A mechanical extract fan of extract rate 60 ls^{-1}
2. A passive stack ventilation system
3. An open-flued gas boiler

The extract fan was only activated during moisture production, whereas the other (passive) methods of extract ventilation were permanently operational. Parameters were varied to assess their influence on both the ventilation rate of the kitchen and on the distribution of moisture about the dwelling. The effect of the kitchen door being either open or closed was investigated as well as the effect of an air-brick and trickle vent.

The three types of extract ventilation operated at differing rates throughout the test cycle. High ventilation rate for a short period, slow continuous ventilation, or an intermittent heat driven cycle all gave similar average kitchen ventilation rates. All three methods of extract ventilation can provide a satisfactory solution to moisture control in kitchens in a temperate climate. Closing the door while cooking is as important as providing extract ventilation because it prevents a large proportion of the moisture from migrating upstairs.

1. Introduction

The kitchen is one of the major moisture producing rooms of a house. In order to prevent problems of mould growth the level of relative humidity should not exceed 70% for prolonged periods [1]. Extract ventilation reduces the humidity level and is therefore desirable; it is included in Approved Document F to the Building Regulations [2]

The Approved Document F coming into force on 1 July 1995 provides for both mechanical extract ventilation and passive stack ventilation or appropriate open-flued combustion appliances.

Open-flued combustion appliances and passive stack ventilation systems (PSV) are similar in that they both have a permanent passage for airflow from inside to outside via a vertical duct. They both maintain their flow because of the temperature difference between outside and inside, and the effect of the wind blowing on the roof terminal. The combustion appliance also provides a heat input which increases the flow rate up the flue. A PSV has the advantage that its opening is at ceiling height, meaning that warmer moist air near the ceiling can be ventilated away more easily.

Work by BRE on the flow rates in PSV systems and their potential for ventilation of kitchens and bathrooms has previously been presented [3].

This paper describes some experiments in which three types of kitchen extract ventilation were compared with the case of no purpose provided ventilation. The three ventilation types were: mechanical extract fan; PSV; open-flued gas boiler. Additional variables tested were the kitchen door and an air vent, which both had two conditions: open and closed.

2. Experimental Design and Set-up

Similar houses at either end of a terrace were used for the experiments. The kitchen of House One had a PSV system (diameter 150 mm) and an extract fan (flow 60 l/s). House Two had an open-flued gas boiler with a 125 mm diameter twin walled stainless steel flue.

The experiment was designed to measure the ventilation rate of the kitchen and the change in moisture content of the kitchen and other rooms under different ventilation regimes. To ensure the data collected was not dominated by the weather, the six different experiments were repeated at least six times. Each test lasted for around 24 hours. During an experiment in which the fan was being tested, the PSV was sealed and vice versa.

At the start of each test 4 to 5 litres of water was boiled off into the kitchen in the space of two hours. This level of moisture production is a severe case and represents a heavy two hour cooking and washing session in the kitchen. The six ventilation cases were:

Condition	House One	House Two
1	No Purpose Provided Ventilation	No Purpose Provided Ventilation
2	PSV open	Flue open, boiler off
3	Fan on during moisture input	Flue open, boiler on
4	Door open, (no other ventilation)	Door open, (no other ventilation)
5	Door open, PSV open	Door open, flue open
6	Door open fan on for moisture input	Door open, boiler on

Table 1: The six ventilation conditions

Conditions were matched so that similar experiments went on at the same time in the two houses. 'Flue open, boiler off' was considered analogous to 'PSV open' (passive ventilation); 'flue open, boiler on' was the equivalent of 'fan on' (forced ventilation). The extract fan was only activated for the two hour period of moisture input, whereas the other ventilation measures were unchanged over a 24 hour test period. This assumes that people operate extract fans during the period of moisture generation, and turn them off as soon as the cooking or washing is finished. The reality may be that fans are used less than this [4].

The ventilation rate of the two kitchens was monitored continuously using a constant concentration of the tracer gas sulphur hexaflouride, SF_6. The tracer gas concentration in the hall and one bedroom was also monitored, to give the rate of air flow to each of those rooms. The relative humidity and temperature in these rooms and at two other locations in the house as well as outside were monitored every 10 minutes. Wind speed and direction were also logged.

3. Example results

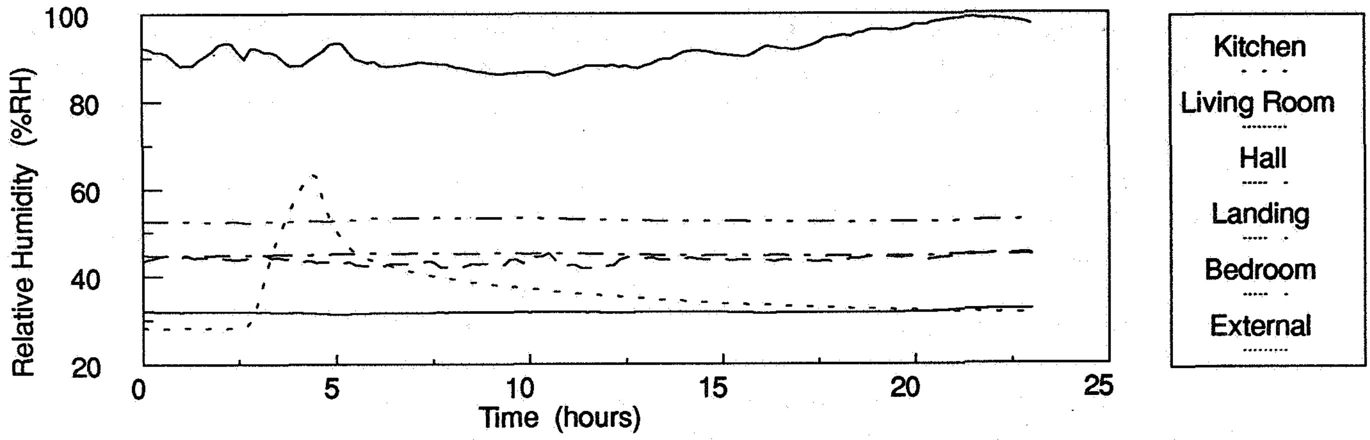

Figure 1: Plot of relative humidity vs time in House Two with the kitchen door closed

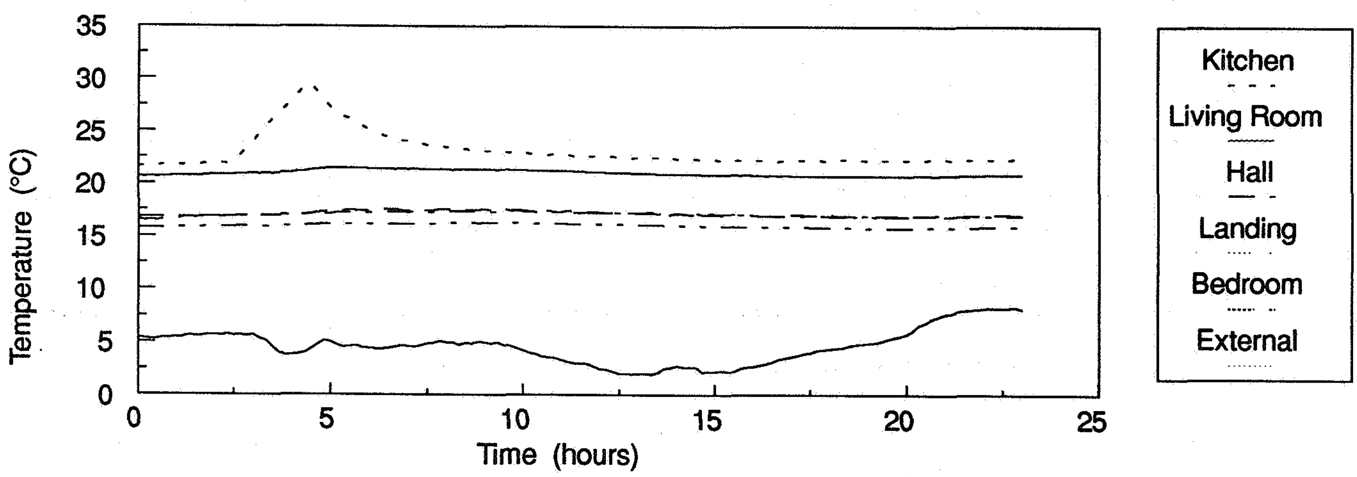

Figure 2: Plot of temperature against time in House Two with the kitchen door closed

Figure 1 shows a typical development of the relative humidities (RH) over time for a condition 2 test in House Two (kitchen door closed, flue open). Figure 2 shows the temperatures for the same test. These both show the experiment progressing, with both RH and temperature rising as the water is boiled on the cooker, reaching a peak as the two hour heat input is finished. From this time on the RH and temperature then decrease as hot moist air is replaced by cooler, dryer air from outside.

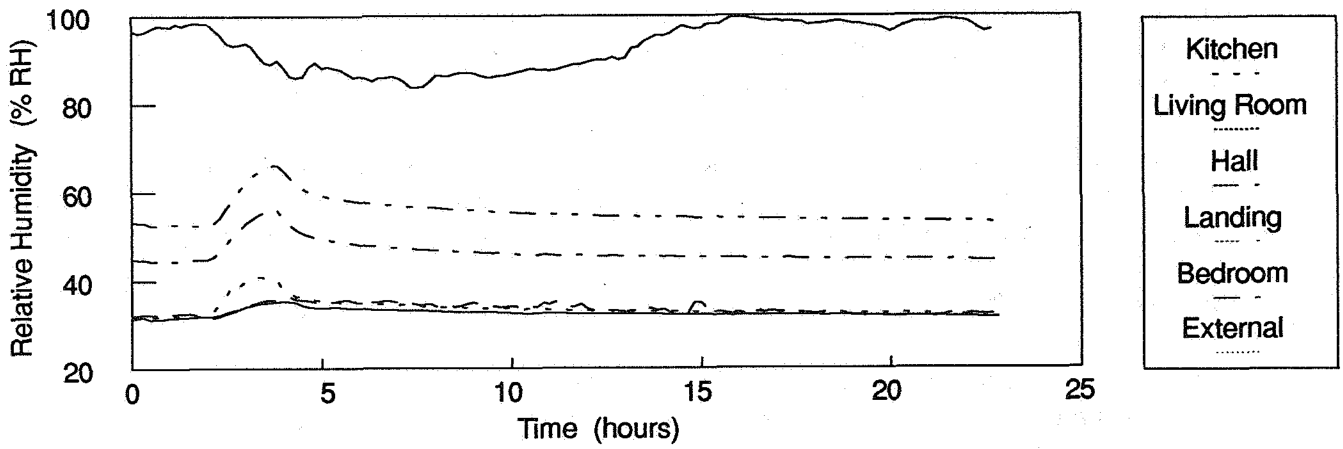

Figure 3: Plot of relative humidities vs time in House Two with the kitchen door open

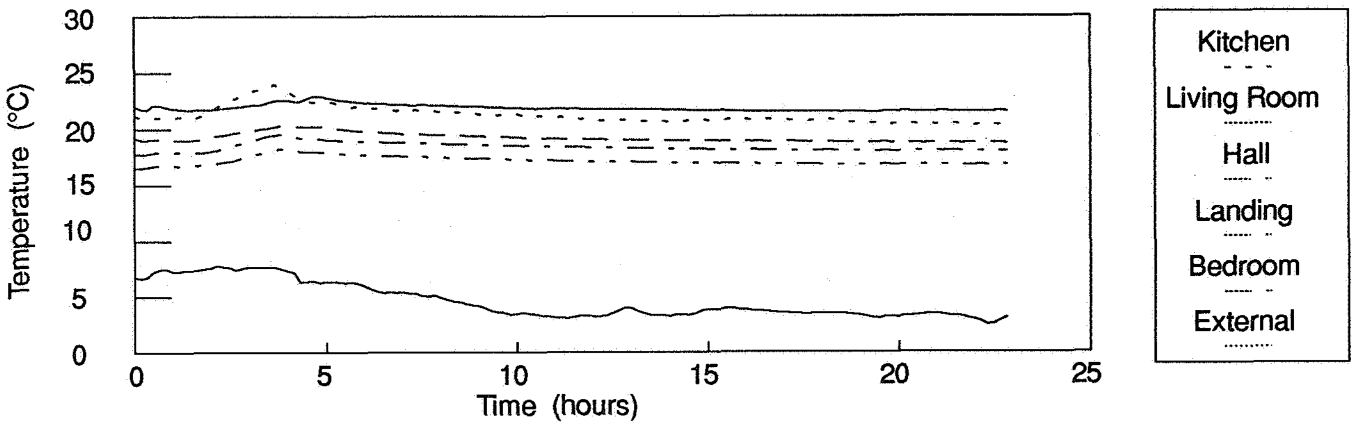

Figure 4: Plot of temperatures against time in House Two with the kitchen door open

Figure 3 shows the impact that opening the kitchen door has on the relative humidity levels in the house. Compared to figure 1 it shows that much more moisture reaches upstairs with the door open, which results in high relative humidities in the bedroom. Figure 4 shows that opening the kitchen door raises the temperatures throughout the house, but lowers that in the kitchen. Because the temperature is lower upstairs than downstairs in the house the RH is actually higher in the bedroom than in the kitchen, meaning that in this case the greatest risk of mould growth is not in the moisture producing room.

Buffer effect

When moisture is produced, the relative humidity of the atmosphere increases. When the relative humidity in a room exceeds the surface relative humidity of the walls, furnishings and fabric of the room, moisture begins to be absorbed into these surfaces, and this restrains the rate of increase of the RH of the air. After moisture production stops, the relative humidity of the room air will fall as the high moisture content air is ventilated away and dryer air replaces it. When the RH falls below the surface RH of the fabric of the room then moisture is desorbed out of the surfaces and into the air. Hence the fabric of the room acts as a buffer, reducing the rate of change of the humidity of the room air.

Because of this an extract method which is switched off when cooking finishes will not reduce the moisture levels by as much as one which continues afterwards. An extra period of extraction would remove water given off by the room fabric as the air RH decreases.

4. Analysis

In a paper to be presented elsewhere [5] the data are analyzed using analysis of variance. This method shows which changes have the greatest effect on the ventilation rate and moisture levels, using statistics. It shows that while an extract fan clearly gives the highest ventilation rate when it is running, over a 24 hour period there is little difference between a fan, a passive stack or an open flue in terms of mean air change rate or effective removal of moisture. The open or closed state of the kitchen door emerges as the key variable. In this paper we have chosen to look at the same data using transfer indices.

4.1 Transfer indices

A transfer index is a measure of the amount of contaminant released at one point found at another. The higher the concentration and/or the longer it stays in the atmosphere at that point, the higher the transfer index. Generally, the further from the source that a sample is taken the lower the transfer index for any contaminant because it is found in lower concentrations. Because of the different methods used to introduce water and SF_6 the transfer indices T_{pn} for the point p due to a source at n are defined differently [6].

For the introduction of a set volume of pollutant V_{cn}(water) it is the integral of the concentration C_p at the sample point n over time, divided by the input volume:

$$T_{Pn} = \frac{\int C_p(t) \,.\, dt}{V_{cn}}$$

The units of T_{Pn} are s/m^3.

When a constant concentration of tracer gas is maintained in one room there is no need for the integral, so the transfer index is defined by:

$$T_{Pn} = \frac{C_p(\infty)}{q_n}$$

q_n is the input rate of pollutant
C_p is the equilibrium concentration at point p

SF_6 was used as a tracer gas to measure the ventilation rate of the kitchen. Unlike water vapour, SF_6 does not get absorbed into the fabric of the room, and therefore the levels of SF_6 in a room give the amount of air that has come from the source room. The transfer index for SF_6 is a measure of this, for a given experimental set up.

Comparing the transfer indices of SF_6 and water vapour gives information about the absorption of water by the building. If no water was absorbed by the building the transfer indices would be the same. In the following tables the average transfer indices for tests under different conditions are given. They were calculated by taking the average of all the transfer indices for all of the tests for the same condition.

House 1	Door	Kitchen	Living	Landing	Bedroom	Hall
SF_6 TI	closed open	218.9 52.0	not measured	not measured	41.1 45.2	44.9 41.9
Water TI	closed open	77.5 16.9	8.9 12.8	not measured	6.2 15.3	7.2 12.6
House 2						
SF_6 TI	closed open	245.3 70.7	not measured	not measured	65.9 61.6	65.7 57.6
Water TI	closed open	69.0 10.3	2.9 7.5	2.9 14.1	2.7 15.9	2.0 8.1

Table 2: Average transfer indices when no additional ventilation was provided

Looking first at the Transfer indices (TI) for the kitchen, the ratio of the door closed value to the door open case shows that the kitchen ventilation rate increases just over 4 times in House One, and by 3½ times in House Two, when the door is open.

Despite the greater ventilation rate of kitchen One, more moisture is detected in that room's atmosphere than in kitchen Two. This is probably due to the difference in the internal surfaces of the two kitchens with more moisture being absorbed into the surfaces in House Two's kitchen. The walls in house Two were only plasterboard and had not been painted, whereas those in House One had been painted. House One had lino on the kitchen floor which absorbs less moisture than the carpet in House Two's kitchen.

In both houses the transfer index for SF_6 in the hall and bedroom is approximately the same when the door is open and when it is closed. When the kitchen door is closed less SF_6 is released to keep the kitchen at a concentration of 10 ppm than when it is open. Because the kitchen ventilation rate is lower less SF_6 leaves the kitchen and the SF_6 concentration in other rooms is low (generally between 1 and 2 ppm). However as a proportion of the SF_6 released into the kitchen that found in the other rooms is the same.

The amount of water vapour which reaches other rooms is far greater when the kitchen door is open. This is because any moisture which leaves the room while the door is closed has to leave via small cracks in the fabric. With small cracks there is more chance of the water vapour coming into contact with a surface and being absorbed. When the door is open there is the possibility of bulk air movement, meaning that moist air will pass through the doorway without coming into contact with any surfaces.

Comparing methods of ventilation: kitchen door closed

House 1	Ventilation	Kitchen	Living	Landing	Bedroom	Hall
SF_6 TI	none psv open fan on	218.9 84.1 68.0	not measured	not measured	41.1 5.4 14.6	44.9 6.3 15.5
Water TI	none psv open fan on	77.5 41.4 37.2	8.9 1.4 3.2	not measured	6.2 2.2 2.6	7.2 1.8 2.4

Table 3: Comparing ventilation measures, kitchen door closed, House One Transfer Indices

The kitchen ventilation rate increases when both the psv and the fan are used meaning that the SF_6 transfer indices go down. There is also a large drop in the moisture measured in the kitchen and other rooms when extract ventilation is provided. The SF_6 transfer index for the bedroom and hall when the fan is used is larger than when the psv is used. This is because the fan only changes the kitchen conditions for its two hour period of operation.

The fan and PSV both reduce the amount of moisture in the atmosphere. That in the kitchen is reduced by about half and in the other rooms by even more. The extract fan and PSV reduce the water vapour transfer indices by similar amounts. This is because the extract fan is operating at the time when the moisture is being produced. For a fan operating for two hours, and a contaminant being produced continuously (as modelled by the SF_6) then the PSV would have removed a greater quantity of it than the fan.

House 2	Flue	Kitchen	Living	Landing	Bedroom	Hall
SF6 TI	none flue open boiler on	245.3 75.9 68.3	not measured	not measured	65.9 6.3 6.9	65.7 6.6 7.0
Water TI	none flue open boiler on	68.9 37.2 37.2	2.9 1.0 1.2	2.9 1.2 1.8	2.7 1.2 1.8	2.0 0.9 1.1

Table 4: Comparing ventilation measures, kitchen door closed, House Two Transfer Indices

The open-flued gas boiler behaves in a similar way to the psv. Turning the boiler on whichshould increase the draught up the flue does not seem to have a significant effect on the amount of contaminant in the rooms. The effect from this could be masked by weather and experimental error, but these data suggest it is not a significant factor.

Comparing methods of ventilation: kitchen door open

In the door open case the transfer indices for the fan and the PSV are almost exactly the same, for both SF_6 and moisture. This suggests they have equal effect on the average ventilation rate over the test period. It is also significant that the SF_6 TI is reduced by both the fan and PSV compared to no ventilation, but that the water vapour TI is not. This probably results from the heat input of the moisture source, causing the moisture to leave via a plume near the ceiling making it less affected by changes in the room ventilation.

House 1: Door open	Ventilation	Kitchen	Bedroom	Hall
SF_6 TI	none	52.0	45.2	41.9
	psv open	40.0	31.4	29.4
	fan on	40.7	31.8	31.6
Water TI	none	16.9	15.3	12.6
	psv open	17.5	15.6	12.0
	fan on	17.5	15.5	12.6

5. Conclusions

Experimental studies, and analysis of their results using transfer indices has shown that:

Each of an extract fan, passive stack ventilation and open flue are equally effective means of ventilating a kitchen to reduce the build up of excess levels of moisture.

Whether the kitchen door is open or closed makes the largest difference to the movement of moisture within the house. It is more important than the choice of ventilation system and none of the ventilation methods is able to prevent the movement of moisture with the door open. As a result kitchen doors should be kept closed while large amounts of moisture are being produced in the kitchen to prevent the migration of moisture upstairs where it will condense on cold surfaces.

Future work could investigate the optimum time for fan use, the impact of open windows, and the effectiveness of humidity controlled fans and passive stack devices.

6. Acknowledgements

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