# A comparison of passive stack ventilation and mechanical extract fans in reducing condensation problems in homes

Claire Aizlewood BEng MSc, David Brown BSc and Nigel Oseland MSc PhD

Building Research Establishment Ltd, Garston, Watford, Herts, WD2 7JR.

## Summary

A study comparing the effectiveness (as reported by occupants) of passive stack ventilation (PSV) and mechanical extract fans (MEFs) was carried out during the winter of 1996. This involved a face-to-face survey of 437 homes in England. More than 50% of the homes in the study had MEFs, 14% had PSV and 8% had humidistat-controlled MEFs (HMEFs). About 25% of the homes had either a kitchen or a bathroom with no ventilation device, and 16% had no ventilation device in the home.

Four measures of condensation problems were analysed: condensation overall in the home, in the kitchen and in the bathroom, and a combined index of condensation and mould. For the measures analysed, the reported effectiveness of PSV and MEFs was not significantly different. The effectiveness of both, however, was reported to be better than HMEFs.

This report concludes that allowing the use of PSV for dwellings is supported by these results. HMEFs may save energy, but are reported by occupants to be less effective. However, this may be due to problems with their acceptance and use by occupants, rather than any technical failing.

## Introduction

One of the reasons for requiring a minimum level of background ventilation in dwellings is to remove excessive moisture from the air. Effects exacerbated by high relative humidity include thermal discomfort, VOC emissions, fungi, mites, and condensation and mould problems in the home. The 1991 English House Condition Survey [1] found that over 22% of householders reported some sort of problem with condensation and mould.

Changes to the Building Regulations Approved Document F [2] have allowed the use of passive stack ventilation (PSV) in spaces with significant moisture generation and low background ventilation. This applies especially to kitchens and windowless bathrooms. Previously, MEFs have normally been used. Previous work has investigated the effectiveness of PSV and other ventilation devices in removing moisture from indoor air (e.g. [3] and [4]). This study investigated the effectiveness of PSV, MEFs and HMEFs, as reported by occupants, by reference to the prevalence of condensation and mould problems in the home.

As a passive means of ventilation, the option of PSV supports the trend towards sustainable construction, and has the additional advantage that it provides background ventilation continually, without being affected by occupant behaviour, power cuts or mechanical breakdown.

## Method

*Fieldwork*

This study involved a face-to-face survey of occupants of 437 homes in England, in March 1996. The sample was based on a previous postal survey of ventilation behaviour in homes. The homes selected were assumed to have had ventilation devices installed as part of the design, or due to the requirements of Building Regulations, rather than because of existing condensation problems.

The questionnaire included questions on: the physical characteristics of the home and immediate environs; ventilation devices present; occupancy patterns and size of household; tenure; ventilation and heating patterns; thermal comfort; symptoms of condensation and mould growth; fuel bills; opening patterns of windows and doors; cooking, bathing and washing. In addition, spot measurements of temperature and humidity were made in the home.

Analysis was conducted on four condensation measures: overall condensation problems in the home, condensation problems in the kitchen, condensation problems in the bathroom, and a combined condensation and mould measure. This last measure was derived by combining the response to ten questions about the occurrence of condensation and mould symptoms in the home, excluding those symptoms that represent permanent damage, which might have been affected by the behaviour of previous occupants. The responses to these ten questions (coded 1 for yes, and 0 for no) were added to get a single value between 0 and 10.

*Control variables*

Some variables have been shown in previous work [1] to have an effect on condensation and mould growth problems. These include tenure, number of dependent children in the home, background temperatures, air change rates and moisture generation. In order to eliminate any effects of these variables when examining the effect of ventilation device, they were used as control variables in the analysis. The air change rates, background temperatures and moisture generation were predicted using the BREDEM-12 model. The calculations included corrections for window and door use, and for differences in construction such as double glazing, insulation and draught-proofing. Tenure and number of dependent children were ascertained from responses to the questionnaire.

The means presented in this paper are adjusted to take into account differences between groups in the control variables.

## Results

*Number of Cases*

Of the 437 questionnaires received, 402 were used in the analysis. The remainder were discounted because of uncertainty about the type of ventilation device present.

*Ventilation type*

The numbers of homes with each ventilation type in the kitchen and bathroom are shown in Table 1. The design set-point for operation of the HMEFs was 70% relative humidity.

Table 1: Ventilation type in bathroom and kitchen

| Ventilation type | Bathroom | Kitchen |
|---|---|---|
| PSV | 57 | 62 |
| MEF | 243 | 209 |
| HMEF | 36 | 31 |
| None | 89 | 124 |

There were 29% of homes with no ventilation device installed in the kitchen, 21% with no ventilation device in the bathroom and 16% with no ventilation device in either room.

Many of the homes did not have the same type of ventilation device in the kitchen and bathroom, so much of the analysis had to be grouped and split by the kitchen and bathroom ventilation types.

## Results

*Thermal comfort*

Spot measurements of temperature and relative humidity were made in the homes. There was no significant difference in these measurements between groups.

Thermal comfort in the home was measured with a 7 point scale, from "too cold" to "too hot". Thermal comfort reported was high, with 88% of the occupant responses being within the comfort range (responses of 3, 4 and 5 – comfortably cool, neutral and comfortably warm). The most frequent response (45%) was "comfortably warm". The mean thermal comfort response and the percentage of occupants satisfied are shown in Tables 2 and 3. A slightly higher percentage of occupants with PSV were satisfied, compared to the other ventilation types, but this difference was not statistically significant. The ventilation type in the kitchen or bathroom may not be expected to have a considerable impact on the thermal comfort in the home overall.

Table 2: Thermal comfort score by kitchen ventilation type

| Ventilation type in kitchen | Mean thermal comfort score | Percentage satisfied with their thermal comfort |
|---|---|---|
| PSV | 3.79 | 92.5 |
| MEF | 3.60 | 86.0 |
| HMEF | 4.00 | 84.2 |
| None | 3.70 | 90.0 |

Table 3: Thermal comfort score by bathroom ventilation type

| Ventilation type in bathroom | Mean thermal comfort score | Percentage satisfied with their thermal comfort |
|---|---|---|
| PSV | 3.70 | 92.5 |
| MEF | 3.60 | 86.0 |
| HMEF | 3.80 | 84.2 |
| None | 3.70 | 93.0 |

*Energy use*

The energy consumption for each home was estimated from a question asking occupants to give the amount per month (£) that they typically spent on fuel bills over the winter. The mean figures for each ventilation type are shown in Table 4. However, data on the breakdown of consumption by fuel type were not available, so the figures should not be interpreted as energy consumption.

Those homes with HMEF had the lowest fuel bills, and those with PSV had the highest fuel bills. This difference was significant by kitchen ventilation type ($F=4.50$, $p<0.05$).

Table 4: Mean fuel bill per month by ventilation type

| | PSV | MEF | HMEF | None |
|---|---|---|---|---|
| Ventilation type in Kitchen | 49.64 | 48.76 | 30.35 | 51.36 |
| Ventilation type in Bathroom | 53.27 | 47.93 | 32.43 | 49.31 |

*Condensation overall in the home*

This measure is the mean response to the question "Overall, would you say that you had a problem with condensation in your home?", where the responses are on a seven point scale, from "not at all" to "severe". The mean responses to the questions are shown in Tables 5 and 6, split by kitchen ventilation type and bathroom ventilation type respectively. There were no significant differences between groups. At least 40% of occupants in each group reported no problems at all.

Table 5: Overall condensation problems by kitchen ventilation type

| Ventilation type | Overall condensation problems in the home |
|---|---|
| PSV | 2.4 |
| MEF | 2.2 |
| HMEF | 2.2 |
| None | 2.1 |

Table 6: Overall condensation problems by bathroom ventilation type

| Ventilation type | Overall condensation problems in the home |
|---|---|
| PSV | 2.1 |
| MEF | 2.2 |
| HMEF | 2.4 |
| None | 2.3 |

*Condensation problems in the kitchen*

This measure is the mean response to the question "Would you describe condensation as a problem in your kitchen during winter?", on a seven point scale from "not at all" to "severe". The mean responses, and the responses adjusted for the control variables, are shown in Table 7. There was a significant difference between ventilation types ($F = 2.49$, $p<0.05$). Those kitchens with HMEFs were reported to have the most problems.

Table 7: Observed and adjusted means for condensation problems in the kitchen

| Ventilation type in the kitchen | Condensation problems in kitchen | |
|---|---|---|
| | Observed Means | Adjusted Means |
| PSV | 2.19 | 2.48 |
| MEF | 2.19 | 1.91 |
| HMEF | 2.94 | 2.82 |

*Condensation problems in the bathroom*

This measure is the mean response to the question "Would you describe condensation as a problem in your bathroom during winter?", on a seven point scale from "not at all" to "severe". The mean responses, and the responses adjusted for the control variables, are shown in Table 8. No significant differences were found.

Table 8: Observed and adjusted mean condensation problems in the bathroom

| Ventilation type in the bathroom | Condensation problems in bathroom | |
|---|---|---|
| | Observed means | Adjusted means |
| PSV | 1.98 | 2.30 |
| MEF | 2.11 | 1.98 |
| HMEF | 2.25 | 2.24 |

*Combined condensation measure*

This measure was derived by combining responses to several of the questions. The observed and adjusted means by ventilation type are shown in Table 9. A significant difference was found ($F =$

3.75, $p<0.05$) between ventilation types. Those homes with HMEF had the highest (worse) responses, in both the observed and the adjusted means, while those with MEFs had the lowest. PSV did not differ significantly from either of the other groups.

Table 9: Observed and adjusted means for the combined condensation measure

| Ventilation type | Combined condensation measure | |
|---|---|---|
| | Observed means | Adjusted means |
| PSV | 4.23 | 5.52 |
| MEF | 3.31 | 3.36 |
| HMEF | 5.89 | 8.84 |

*Tenure*

Tenure differed between ventilation groups and was found to have a large effect on condensation problems reported in the EHCS [1], and this study also found an effect. Problems were significantly worse in homes that were owned by housing associations, compared to owner / occupied and local authority rented homes. The condensation measures, split by tenure, are shown in Table 10.

Table 10: Condensation measures by tenure

| | Owner / occupier | Rented from local authority | Housing Association |
|---|---|---|---|
| Condensation in home overall | 2.0 | 2.1 | 3.0* |
| Condensation in kitchen | 2.0 | 2.0 | 3.5*** |
| Condensation in bathroom | 2.0 | 2.0 | 3.3*** |
| Combined condensation measure | 4.3 | 3.7 | 6.8* |
| Significant differences between Housing Association and other tenures. * = $p<0.05$ *** = $p<0.001$ | | | |

## Conclusions

437 homes were surveyed, of which only 402 were used in the analysis, due to uncertainty about the ventilation type in some cases. Four measures of condensation problems were analysed: condensation in the home overall, condensation in the kitchen, condensation in the bathroom, and a combined condensation measure. In each analysis statistical control variables were used. These included air change rates, background ventilation, moisture generation, tenure and number of dependent children.

No statistically significant differences were found between the ventilation types for condensation problems overall in the home, and in the bathroom. However, significant differererences were found in the number of reported condensation problems in the kitchen and in the combined condensation and mould measure. Those homes with HMEFs had the highest number of reported problems in both of these analyses.

This report concludes that allowing the use of PSV for dwellings is supported by these results. HMEFs may save energy, but are reported by occupants to be less effective. However, this may be due to problems with their acceptance and use by occupants, rather than any technical failing.

## References


1. English House Condition Survey: 1991 *The Energy Report*. London
2. Department of the Environment, 1994. Building Regulations Approved Document F.
3. Parkins L, 1994. Case studies of passive stack ventilation systems in occupied dwellings. Proceedings of the 15th AIVC Conference, Buxton, UK, vol 1, pp13-14.
4. Kolokotroni M and Littler J, 1995. Effectiveness of extractor fans in reducing airborne moisture in homes, Indoor Air, pp69-75.


## Acknowledgements


This work was funded by the Building Regulations Division of the UK Department of the Environment, Transport and the Regions.