MOISTURE PERFORMANCE CRITERIA FOR UK DWELLINGS

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Abstract
The new ventilation regulations in England and Wales have introduced performance criteria for the control of mould. The UK Government's Building Regulations Research Programme has funded University College London (UCL) to investigate the extent to which these are the most appropriate criteria for the control of mould in UK dwellings. This paper reports on the plans for this study which involve both field and laboratory related work. Some initial early work has already been undertaken and the paper summarises the progress to date. This initial work is based on analysis of data from a national study of England's Home Energy Efficiency scheme (Warm Front). Surveys were undertaken of dwellings and households participating in the scheme in five urban areas. Half-hourly living room and main bedroom temperatures and relative humidity measurements were recorded for two to four weeks (in the heating season) in approximately 1600 dwellings. This data is being analysed to investigate the typical relative humidities that exist in UK dwellings and also any relationship that exists between these levels and the mould growth that was recorded.

Introduction
A revised version of Approved Document F1 – 'Means of Ventilation' (ODPM 2006), which relates to the Building Regulations for England and Wales, is due to come into effect in April 2006. The performance criterion for moisture in dwellings, as stated in the Approved Document, is as follows:

> *"there should be no visible mould on external walls in a properly heated dwelling with typical moisture generation."*

For the purposes of this Approved Document, the moisture criterion is stated to be met if:

> *"the relative humidity in a room does not exceed 70% for more than two hours in any twelve hour period, and does not exceed 90% for more than one hour in any twelve hour period, during the heating season".*

The UK Government's Building Regulations Research Programme has now funded University College London (UCL) to investigate the extent to which the above is the most appropriate standard for the control of mould in UK dwellings. This paper reports on the plans for this study which will involve both field and laboratory related work. Some initial early work has already been undertaken and the paper also summarises the progress to date.

Plans for the study
The overall aim of this project is to investigate the conditions that are required for mould growth to occur in UK dwellings, and if necessary, amend the relevant performance standard and make recommendations for whole dwelling ventilation rates. The methods proposed are firstly to review the existing scientific literature, laboratory data and mould growth field data to determine the extent to which the current Approved Document F performance standard for relative humidity (RH), is the is the most appropriate standard for the control of mould in UK dwellings. A starting point for this review will be the documentation of the expert opinion which was utilised to develop the current performance criteria.

While the review of the literature and existing data is carried out, a number of small pilot studies are being undertaken to test potential methods of substantiating the existing assumptions behind the current performance standard for room RH. For example, a small number of mould samples will be exposed to transient RH conditions and a methodology will be developed to investigate typical UK moisture production rates.

The current performance standard for RH is based on laboratory data relating to mould growth. This requires hygrothermal simulation to relate laboratory RHs (which will equate to the wall RH) to room RHs and a suitable methodology will thus be developed. At this stage a review will be undertaken and a decision will be taken as to whether the existing standard is considered appropriate or whether a new approach/standard, which is more scientifically credible, is to be developed. Based on this review, the second phase of work will be an in-depth scientific evaluation of the critical factors which are required to substantiate the current performance standard or, if necessary, develop a new approach.

Initial work
One of the very early phases of the work is based on analysis of data from a national study of England's Home Energy Efficiency scheme (Warm Front). This project was undertaken in 2001-2003 to evaluate one of the Government's programmes to help eradicate fuel poverty. Funded by the Department of the Environment, Food and Rural Affairs, and managed by the Energy Saving Trust, Warm Front is one of the most comprehensive health and building environment studies ever conducted in the UK. The scheme provides a comprehensive study of occupant behaviour, energy use, and moisture production, the occurrence of mould and damp as well as HDM allergen levels in dwellings occupied by families on low income and pensioners. Temperature and RH was monitored in living rooms and bedrooms for an approximately 3 week period during the heating season. Measurements of external temperatures and RH were also recorded in central locations in each of the survey areas. Subsets of 222 cases have also been pressure tested to evaluate air tightness. Although the occupant profile of the dwellings is heavily skewed towards the over 60's and those on low income, the properties they occupied are fairly typical of UK dwellings and were located in five areas across England. The study included 3,099 dwellings undergoing *Warm Front* improvements over the winters of 2001-02 and 2002-03 in five urban areas of England: Birmingham, Liverpool, Manchester, Newcastle and Southampton. These dwellings underwent a property survey, and had detailed measurements of temperature and relative humidity (n=1,604). In 2,917 households, a computer assisted personal interview was undertaken with a household member.

Work by UCL and the original Warm Front team (Oreszczyn *et al* 2006) presented a first analysis of the hygrothermal measurements from this evaluation and assessed the impact of Warm Front interventions on moisture-related parameters. Some additional initial analysis is presented below:

 (i) RH levels, Occurrence of Mould and Excess Vapour Pressure
The mean measured (un-standardised) RH for living rooms in the Warm Front study was 50.3% and for bedrooms 55.3%. To provide an objective assessment of the severity of mould growth in the houses, a mould severity index (MSI) was used. The MSI ranks the seriousness of condensation mould growth on a simple scale. If mould is reported in any room it simply scores 1. The severity of the mould growth is judged based on three photographs. An additional point is added if the middle "moderate" mould photograph was chosen and 2 additional points if the "severe" mould growth was chosen. Finally, if mould growth was found in any living room one additional point was added.

Data from a total of 1,388 properties in the Warm Front study have been analysed and referred to in this paper. Overall, 19.5% of the surveyed dwellings had a Mould Severity Index (MSI) greater than 0 (i.e. mould in at least one room). Of these 19.5%, 72.0% had an MSI score of 1 or 2, 18.5% had an MSI score of 3 or 4 and 9.5% had an MSI score of 5 and over. In comparison, the English House Condition Survey (DETR 1996), which is the last large survey that collected mould or condensation data, reports 14.6% of the total English stock to have mould growth of any MSI range.

Previous work by UCL has investigated the vapour pressure excess of the dwellings. The standardised vapour pressure excess at an outside temperature of 5 $^{\circ}$C was calculated in a total of 969 Warm Front living rooms and 681 bedrooms. The average normalised vapour pressure excess was calculated to be 316 Pa in living rooms and 329 Pa in bedrooms. The highest 5% of the vapour pressure excess distribution may be considered to represent extreme occupant behaviour. The highest 5% of bedrooms have a vapour pressure excess greater than 700 Pa. The highest 5% of living rooms have vapour pressures greater than 625 Pa. There is no evidence to suggest that the houses with extremes of vapour pressure excess had high occupant density or air tightness. For comparison, BS5250 (BSI 2005) characterises occupancy under three categories, dry, moist and wet. The wet category corresponds to a vapour pressure excess greater than 600 Pa. The following two figures (1 and 2) show the distribution of the Warm Front standardised vapour pressure excess and how they relate to the 5 Humidity Classes specified in BS5250 at 5 $^{\circ}$C outside. Note, these humidity classes have been defined to examine a range of different building types; dwellings are predominately meant to fall into class 3 and 4. Under a third of Warm Front dwellings fall into these two categories.

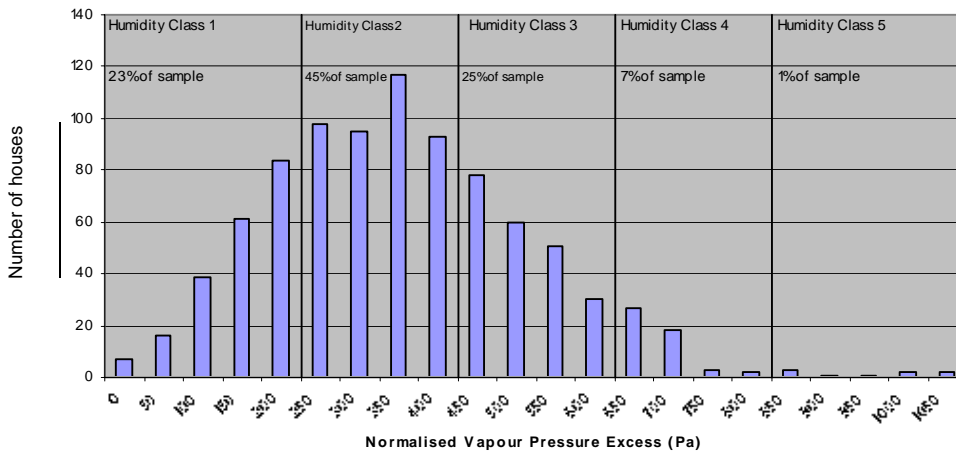**Frequency Distribution of Normalised VPX in Bedrooms**

Humidity Class 1	Humidity Class2	Humidity Class 3	Humidity Class 4	Humidity Class 5
23%of sample	45%of sample	25%of sample	7%of sample	1%of sample

Number of houses

Normalised Vapour Pressure Excess (Pa)

Figure 1.

Frequency Distribution of Normalised VPX in Living Rooms

Humidity Class 1	Humidity Class 2	Humidity Class 3	Humidity Class 4	Humidity Class 5
23%of sample	49%of sample	24%of sample	3%of sample	0.5%of sample

Number of houses
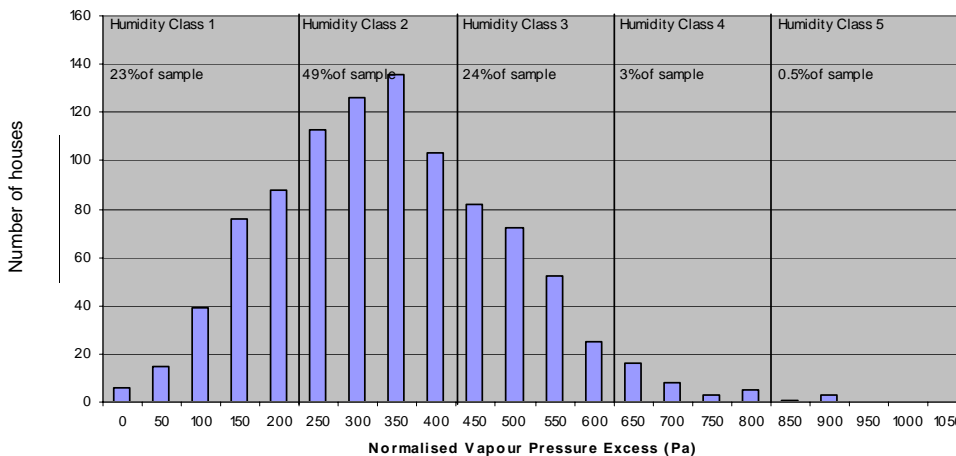
Normalised Vapour Pressure Excess (Pa)

Figure 2.

(ii) Percentage of properties meeting the ADF 1995 and ADF 2006 criteria for mould growth
The data referred to above has been further examined and analysed to determine the percentage of time that the RH exceeds the current performance criteria and correlated with the reported mould growth. Additionally the percentage of time that the RH exceeds the previous ADF 1995 (ODPM 1995) guidelines is reported. The 1995 ADF refers to BS5250 and in that document can be found guidance relating to mould growth. Although the term 'criteria' is used in this report ADF2006 simply requires there to be no mould growth and so strictly speaking any property that had mould growth could be seen to be not meeting the criteria. Conversely any that does not have mould will be meeting the performance criteria. Some interpretation of the current criteria and the previous guidelines is required. For the purposes of this report, the following has been assumed:

- ***Current 2006 ADF:*** for each dwelling the number of hours with RH above 70% during the entire period (2 - 4 weeks) was determined and the percentage of time with RH above 70% thus calculated. It was thus possible to record those houses that presented 70% of RH for more than 2 hours in a period of 12 hours (where 2 hours represents 17% of the time). Note that if one uses the criteria that relates to having more than two hours with an RH above 70%, in **any** 12 hour period there will be significantly more properties that fail this criteria
- ***Previous 1995 ADF:*** the period of data collection for the Warm Front database varies between 2-4 weeks. The average RH was calculated for the entire period.

The initial results are given in table1 below.

Regulation	Requirement		Total number of properties failing the criteria	% of properties failing criteria
BS 5250: 1989 British Standard Code of Practice for Control of condensation in buildings	" as a guide, if the average relative humidity within a room stays about 70% for a long period of time the localized relative humifdity at external wall surfaces will be higher and is likely to support the germination and growth of moulds"		124	8.9
Approved Document F performand standard for relative humidity / edition 2006	"the relative humidity in a room should not exceed 70% for more than two hours in any twelve hour period, and should not exceed 90%, for more than one hour in any twelve hour period, during the heating season"	70%	258	18.5
		90%	16	1.2

Table 1.

(iii) Mould vs. number of hours above 70% RH – all properties
ADF 2005 has as one of its criteria for mould, 2 hours in 12 above 70%. i.e. 17% of the time above 70%. Table 2 reports the sensitivity of mould growth to the percentage of time above 70%.

%of time RH greater than 70%	no mould (MSI =0)	mould (MSI > 0)	Total	% of properties with mould in the category
0	793	131	924	14.2
1-10	125	34	159	21.4
10-20	51	21	72	29.2
20-30	29	19	48	40.0
30-40	18	10	28	35.7
40-50	16	8	24	33.3
50-60	10	6	16	37.5
60-70	12	3	15	20.0
70-80	16	8	24	33.3
80-90	16	11	27	40.7
90-100	31	20	51	39.2
Total	1117	271	1388	

Table 2.

Figure 3 shows a plot of the percentage of time the RH is above 70% versus the percentage of properties with mould (MSI > 0). It appears that for room RH, as the percentage of time above 70% increases the number of properties with mould increases up to roughly 30% of the time after which the occurrence of mould does not appear to depend on the percentage of time above 70% RH.
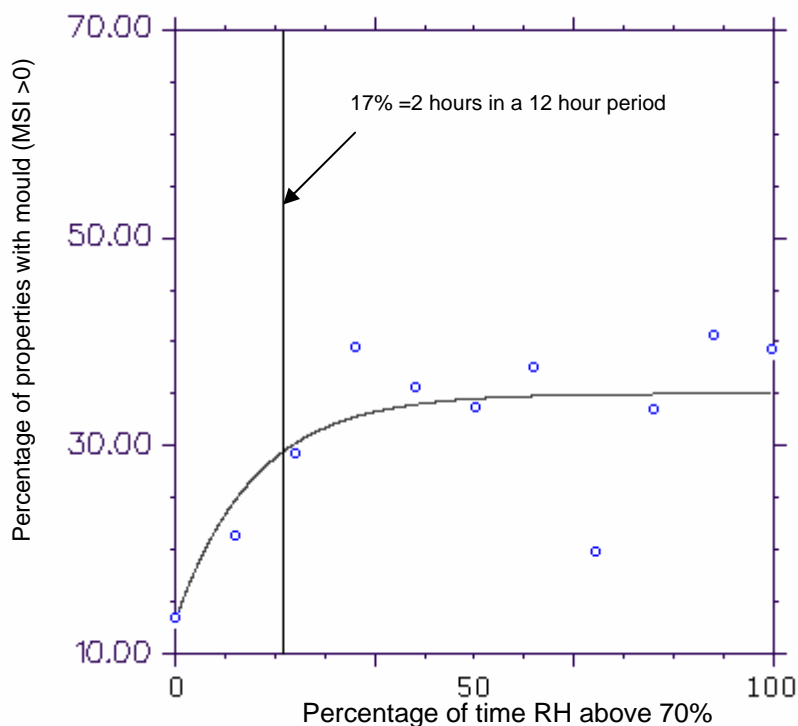
Figure 3.

Note that this work is still at a very early stage and further statistical analysis needs to be undertaken to determine the best fit and confidence intervals.

(iv) Occurrence of mould in those properties that do and do not meet the ADF 1995 and 2006 criteria

Since there are a significant number of properties that do and do not meet both sets of criteria it is interesting to see if there is a greater incidence of mould in those that do not meet the criteria and which set of regulations better defines the occurrence of mould. This analysis was thus also undertaken. 16.1% of Warm Front properties that met the ADF 2006 had mould whereas 35.5% had mould if they did not meet the ADF2006 assumptions. This compares with 17.8% having mould if they met the 1995 ADF requirement of RH below 70% whereas 37.1% had mould if the had not met this requirement.

Preliminary Conclusions

It is far too early in the project to reach any detailed conclusions. The following is however indicative of the sorts of conclusions that may be provided at the end of the field data analysis:

- The Warm Front data set had roughly one in five properties with mould growth which is greater than that found in the last English House Condition Survey which recorded mould (DETR 1996). The Warm Front dwellings also contain a wide range of excess vapour pressures with slightly over 5% of properties/occupants falling in the wet category of BS5250:2005

- Preliminary analysis has been undertaken to determine the number of properties that exceed the new Part F criteria (ADF2006) and the old criteria (ADF1995 as specified in BS5250). Approximately 20% of the Warm Front properties fail the new criteria whereas only half this number (10%) fails the older criteria.

- There appears to be a base level of mould growth in about 15% of dwellings regardless of the internal RH – probably attributable to thermal bridges and other localised effects. If you do not meet the ADF requirements, either old or new, the chances of mould growth at least double. Given that the new criteria are much more difficult to achieve (certainly for the Warm front sample), at this stage in our data analysis it is not clear that the new criteria are significantly more appropriate. However much more wok is required to support this view.

Acknowledgements

References

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